ESO

European Organisation
for Astronomical
Research in the
Southern Hemisphere

Annual Report

2024

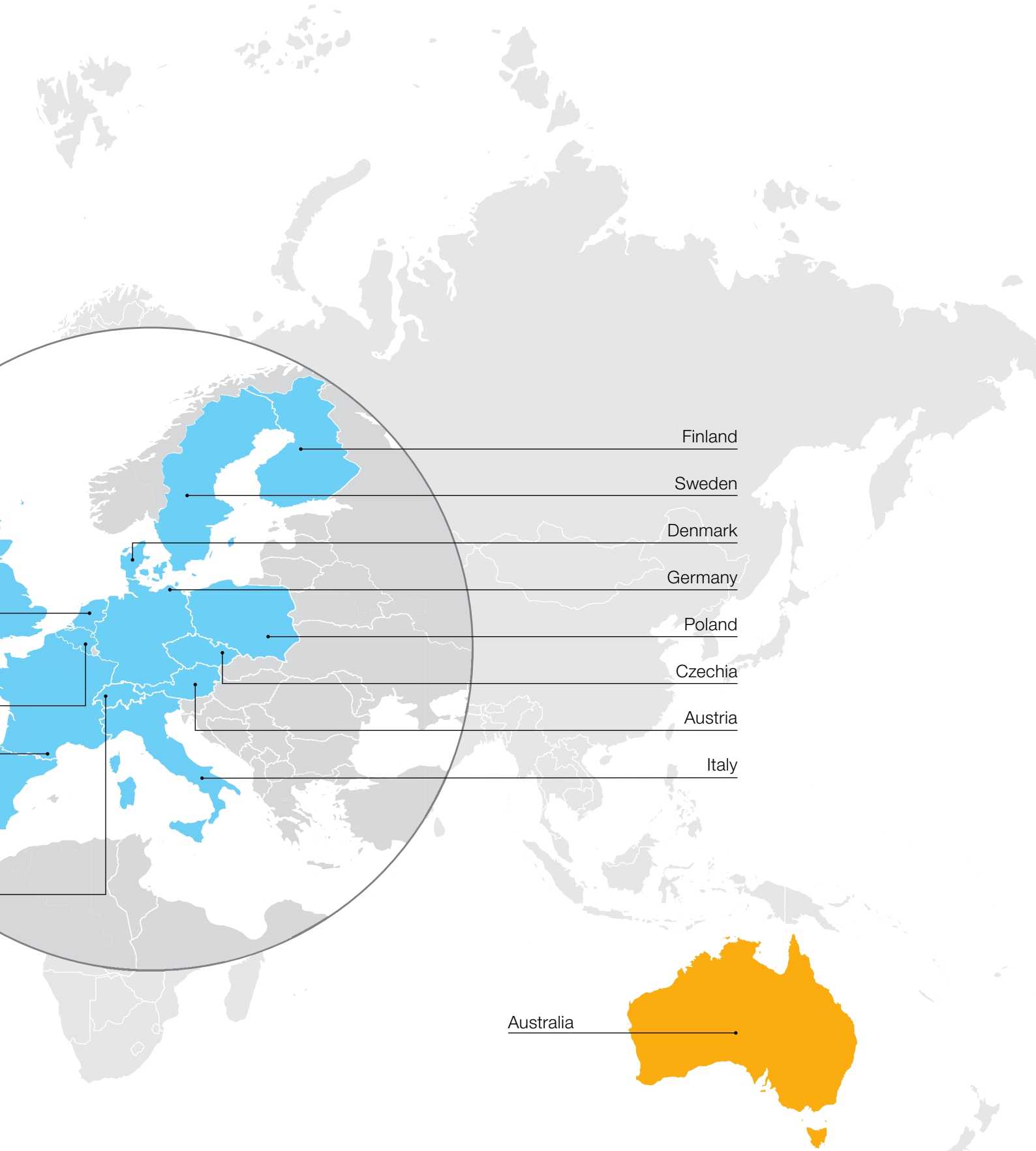
What is ESO?

The European Southern Observatory (ESO) enables scientists worldwide to discover the secrets of the Universe for the benefit of all. We design, build and operate world-class observatories on the ground — which astronomers use to tackle exciting questions and spread the fascination of astronomy — and promote international collaboration for astronomy. Established as an intergovernmental organisation in 1962, today ESO is supported by 16 Member States (Austria, Belgium, Czechia, Denmark, France, Finland, Germany, Ireland, Italy, the Netherlands, Poland, Portugal, Spain, Sweden, Switzerland and the United Kingdom), along with Chile as the Host State of our observatories and Australia as a Strategic Partner.

ESO's Organisational Locations

Garching near Munich, Germany — is where ESO has its Headquarters, where most telescope design and development takes place, and the ESO Supernova. From here, ESO staff also manage data from ESO's observatories, including archiving and user support.

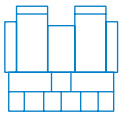
Vitacura, Santiago, Chile — the site of ESO's organisational hub in the Host State of our observatories.


Finland
Sweden
Denmark
Germany
Poland
Czechia
Austria
Italy
Australia

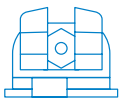
Our Telescopes in Chile

All our current observatories are in Chile's Atacama Desert, a special place with unique conditions to observe the sky. Our most advanced telescope yet is under construction: ESO's Extremely Large Telescope (ELT) will dramatically change what we know about our Universe and make us rethink our place in the cosmos.

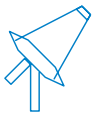
Paranal



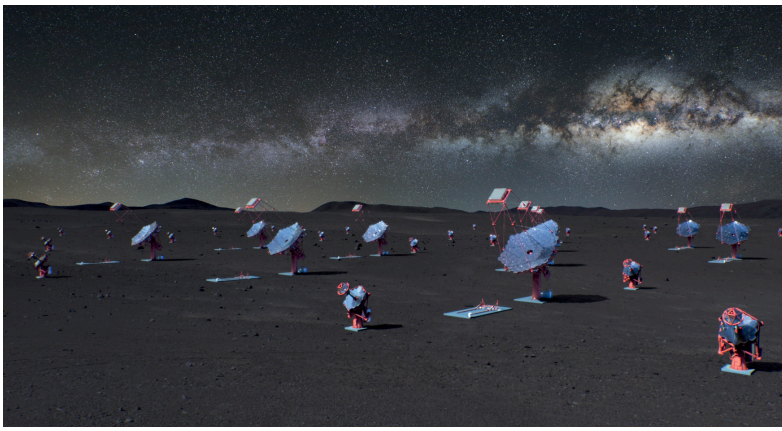
VLT/VLTI — the Very Large Telescope is the world's most advanced optical and near-infrared observatory. Its telescopes work individually or together to form the Very Large Telescope Interferometer, which can pick up much finer details of the cosmos. The nearby Visible and Infrared Survey Telescope for Astronomy (VISTA) complements the VLT/VLTI by surveying the night sky.



ELT (under construction) — the Extremely Large Telescope is a revolutionary 39-metre optical and near-infrared telescope that will explore the Universe in unprecedented depth and detail.



CTAO-South (starting construction) — the future Cherenkov Telescope Array Observatory will explore the Universe at the highest energies. ESO is a fully participating member of the CTAO organisation and will host and operate the southern array.



Chajnantor

ALMA — together with international partners, ESO operates the Atacama Large Millimeter/submillimeter Array, the most powerful telescope for observing the cold Universe.

La Silla

ESO 3.6-metre telescope

NTT

Telescopes at La Silla — ESO's first observatory hosts pioneering telescopes, such as the ESO 3.6-metre Telescope and the New Technology Telescope, along with various hosted telescope projects.

ESO's Mission

is to design, build and operate advanced ground-based observatories, and to foster international collaboration for astronomy.

ESO's Vision

is to advance humanity's understanding of the Universe by working with and for the astronomy community, providing it with world-leading facilities.

ESO's Organisational Values

ESO strives for **excellence**. It achieves this through **innovation**. ESO provides outstanding **services to its communities**. ESO fosters **diversity & inclusion**. ESO believes in the key role of **sustainability** for its future. These values of the organisation are realised and maintained by the people working at ESO.

ESO's Personal Values

Our efforts to achieve ESO's values are only possible on the basis of personal values and attitudes: **respect, integrity, accountability, commitment, collaboration, clear and open communication**.

Foreword

Stepping into the role of ESO Council President at the beginning of 2024 has been an exciting experience. These are extraordinary times for astronomy, with ESO at the forefront of shaping its future.

The progress of the Extremely Large Telescope has been truly remarkable. It remains on track to begin scientific operations around the end of the decade and will be the first telescope of its kind on the sky.

At the same time, launching the Expanding Horizons initiative has demonstrated the strength of ESO's collaborative spirit. Driven by scientific curiosity and community needs, this exercise highlights the power of international cooperation in creating facilities beyond what is achievable with national efforts alone. ESO continues to be the place where such bold visions become reality.

Looking ahead, ESO's leadership is also evolving. The Council has begun the search for the next Director General, who will take over in the second half of 2026.

I am confident that ESO's long history, combined with fresh perspectives, will provide a fruitful mix of continuity and inspiration for the years ahead.

Tom Ray, ESO Council President

Introduction

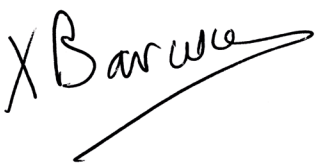
2024 has been another extraordinary year of progress and discovery for ESO.

The Extremely Large Telescope continues to take shape at an impressive pace. Meanwhile, ESO's existing facilities — the VLT, VLTI, ALMA and La Silla — continue to push the boundaries of knowledge, contributing to a record 1200 scientific publications in 2024. These achievements are only possible thanks to the unwavering support of our Member States, the dedication of our staff and the engagement of our community.

Beyond our current projects, we have our sights set on the future. The Expanding Horizons initiative, launched in 2024, invites the scientific community to shape ESO's next major endeavour, which will transform astronomy beyond the 2040s.

We must also work to safeguard the few remaining truly dark and quiet sites for astronomy. Paranal is a unique and irreplaceable such site, being one of the darkest locations on Earth, and hosting what will remain the most powerful optical telescopes for many years to come.

Preserving these windows on the Universe is not just a commitment to science — it is an investment in humanity's ability to explore, understand, and marvel at the cosmos.



Xavier Barcons, ESO Director General

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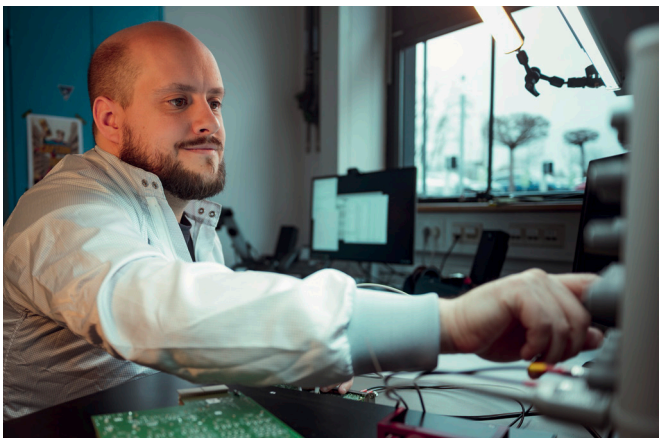


122

NGCII — a unified detector controller

90

GRAVITY+ — natural guide star mode commissioned

56

ELT primary mirror — first segments coated and installation-ready

ESO's year in numbers

Over

1200

papers published using data from ESO facilities[1]

Over

21 800

total papers published since 1996

Over

2200

observing proposals submitted[2]

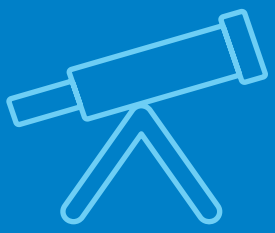
[1] See publication digest on page 116 for more details.

[2] La Silla Paranal Observatory plus ESO's share of the ALMA partnership.

Over

30 000

mentions of ESO in print and online media



Approximately

19 000

hours of scientific observations[2]

About

750

staff drawn from more than **40 different nationalities**

€234 million

financial contributions from ESO Member States

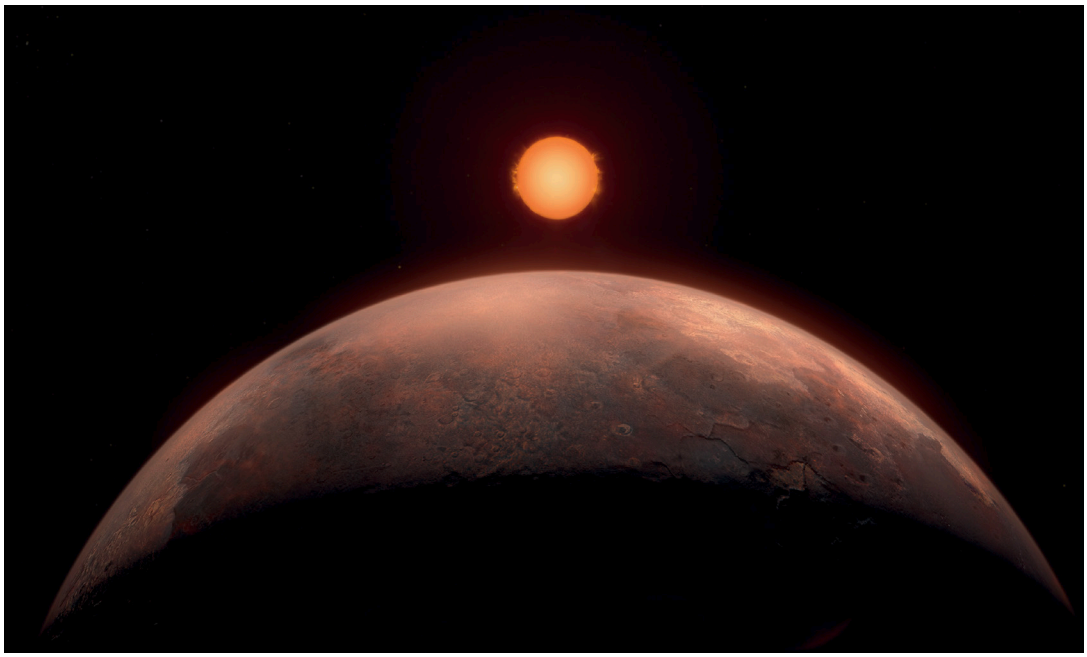
Science highlights

The flow of high-impact scientific publications using observations from ESO facilities is testimony to the talent of a world-leading community of astronomers, the productivity and quality of ESO's observatories, and the remarkable data obtained there. The highlights presented here represent a small sample of the many fascinating results published during 2024.

ESO/VPHAS+ team. Acknowledgement: CASU

The Gum 3 nebula, an interstellar cloud of gas and dust located about 3600 light-years from Earth, observed with the OmegaCAM instrument on the VLT Survey Telescope, hosted at ESO's Paranal Observatory.

VLT reveals exoplanet orbiting Barnard's Star



ESO/M. Kornmesser

Artist's impression of the sub-Earth-mass planet that was discovered orbiting Barnard's star, six light-years away. Five years of observations with the VLT's highly precise ESPRESSO instrument confirmed its presence.

Using ESO's Very Large Telescope (VLT), an international team of astronomers discovered an exoplanet orbiting Barnard's star which, at a distance of six light-years, is the closest single star to our Sun. Barnard b, as the exoplanet is called, is twenty times closer to Barnard's star than Mercury is to the Sun, has at least half the mass of Venus, and orbits its star in 3.15 Earth days.

The discovery is the result of observations made over five years with the VLT's highly precise ESPRESSO instrument, and it has been confirmed by data from other specialised exoplanet-hunting instruments, including HARPS on the ESO 3.6-metre telescope at La Silla. ESPRESSO detected the planet using the radial velocity method, which measures the wobble of a star caused by the gravitational pull of an orbiting planet.

The international team, led by Jonay González Hernández (Instituto de Astrofísica de Canarias, Spain), was looking for signals from exoplanets within the temperate, or habitable, zone of Barnard's star — the range where liquid water can exist on the planet's surface. But with a surface temperature of around 125 °C, the planet is too hot for that. The team also found hints of three more exoplanet candidates in various orbits around the star, but these detections will require additional observations before they can be confirmed. Together with previous planet discoveries around Proxima Centauri, it is now clear that our cosmic neighbourhood is full of low-mass exoplanets, ready to be discovered.

González Hernández, J. I. et al., *A sub-Earth-mass planet orbiting Barnard's star*, Astronomy & Astrophysics 685, A54 (2024), https://doi.org/10.1051/0004-6361/202451311

Astronomers reveal a new link between water and planet formation

Researchers have found water vapour in the disc of gas and dust around a young star, exactly where planets may be forming. The observations reveal at least three times as much water as in all of Earth's oceans, all of it in the inner disc around the young Sun-like star HL Tauri, which is located 450 light-years away from Earth in the constellation Taurus. A key ingredient for life on Earth, water is also thought to play a significant role in planet formation.

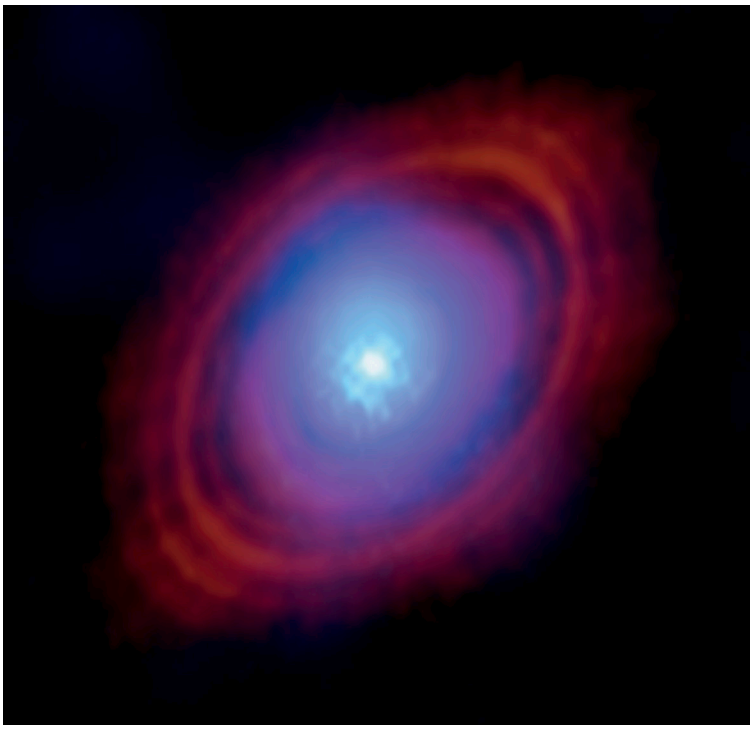
Using ALMA, a team of astronomers led by Stefano Facchini (University of Milan, Italy), managed not only to detect water vapour but also to map for the first time its distribution across the different regions of the disc.

A significant amount of water was found in the region where there is a gap in the HL Tauri disc. Ring-shaped gaps are carved out in gas- and dust-rich discs by orbiting young planet-like bodies as they gather up material and grow.

Inside the disc, dust grains become the seeds of planet formation, colliding and clumping into ever larger bodies. Astronomers believe that where it is cold enough for water to freeze onto dust particles, things stick together more efficiently — an ideal spot for planet formation.

With upgrades happening at ALMA, and the ELT coming online later this decade, planet formation and the role water plays in it will become clearer than ever. In particular, the ELT's METIS instrument will give astronomers unrivalled views of the inner regions of planet-forming discs, where planets like Earth form.

Facchini, S. et al., *Resolved ALMA observations of water in the inner astronomical units of the HL Tau disk*, Nature Astronomy 8, 587 (2024), https://doi.org/10.1038/s41550-024-02207-w



ALMA (ESO/NAOJ/NRAO)/S. Facchini et al.

The disc around HL Tauri, as seen by ALMA. Water vapour is depicted in shades of blue, and dust in red. The observations revealed the importance of water in the formation of planets.

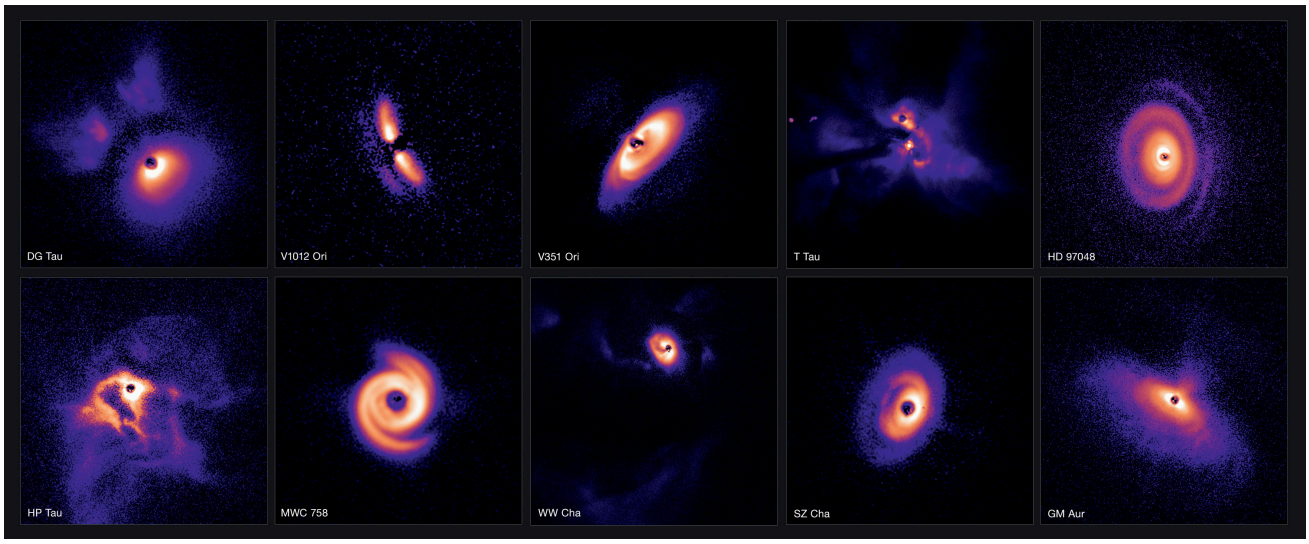
Groundbreaking survey reveals secrets of planet birth around dozens of stars

Using the SPHERE instrument on the VLT, scientists conducted one of the largest ever surveys of planet-forming discs, revealing their extraordinary diversity. Planet-forming discs can have huge spiral arms, and their interiors may be smooth or show rings and cavities where planets were formed. In a series of studies, observations of 86 young stars provided unique insights into how planets arise in different regions of our galaxy, the Milky Way. The VLT's X-shooter instrument allowed the astronomers to determine how young and how massive the stars are.

The survey covered three star-forming clouds of our galaxy: Orion — located about 1600 light-years away — and Taurus and Chamaeleon I, both around 600 light-years from Earth. The observations were gathered by a large international team of scientists from more than 10 countries, led by Christian Ginski (University of Galway, Ireland).

Their research shows that stars in groups of two or more were less likely to have large planet-forming discs. This is a significant result, given that most stars in the Milky Way have companions. The uneven appearance of the discs in Orion also suggests massive planets might be embedded within them, which could be causing the discs to become misaligned.

Ginski C. et al., *The SPHERE view of the Chamaeleon I star-forming region: The full census of planet-forming disks with GTO and DESTINYS programs*, Astronomy & Astrophysics 685, A52 (2024), https://doi.org/10.1051/0004-6361/202244005
Garufi, A. et al., *The SPHERE view of the Taurus star-forming region. The full census of planet-forming disks with GTO and DESTINYS programs*, Astronomy & Astrophysics 685, A53 (2024), https://doi.org/10.1051/0004-6361/202347586
Valegård, P.-G. et al., *Disk Evolution Study Through Imaging of Nearby Young Stars (DESTINYS): The SPHERE view of the Orion star-forming region*, Astronomy & Astrophysics 685, A54 (2024), https://doi.org/10.1051/0004-6361/202347452

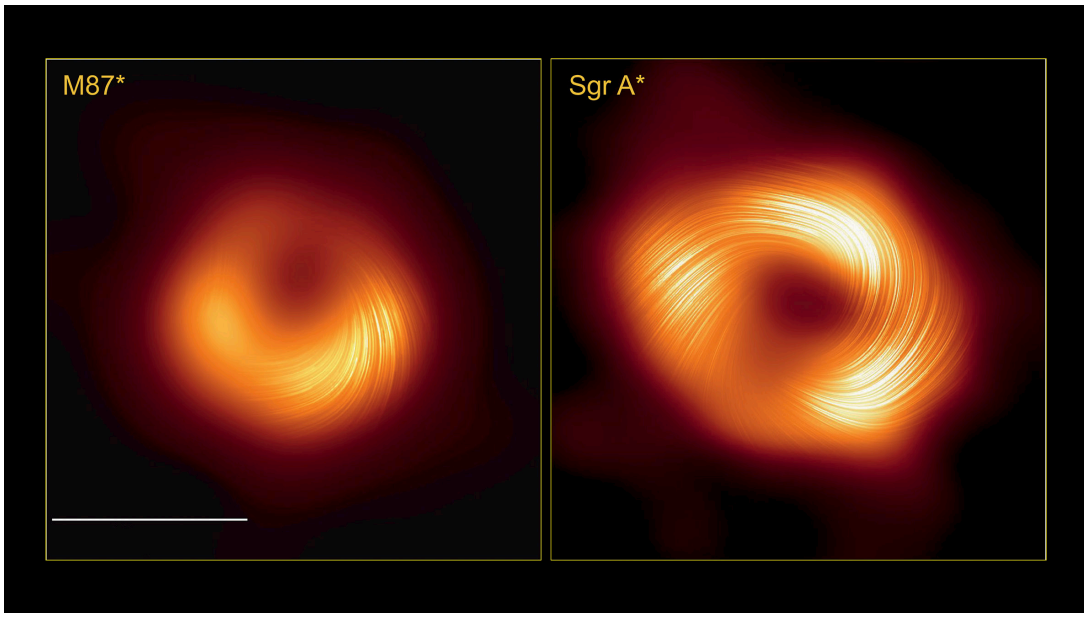


ESO/C. Ginski, A. Garufi, P.-G. Valegård et al.

Direct images by the VLT reveal the planet-forming discs around 86 young stars in three regions of the Milky Way, showing a variety of shapes. The survey found that stars in groups of two or more are less likely to have large discs.

Event Horizon Telescope reveals strong magnetic fields spiralling around Sagittarius A*

EHT Collaboration



This image of the supermassive black hole Sagittarius A*, made in polarised light by the Event Horizon Telescope, shows strong spiralling magnetic fields. Similarities to a previous image of M87* suggest that black holes might all have similar magnetic field structures and hint at a hidden jet in Sagittarius A*.

Astronomers have succeeded in imaging Sagittarius A* — the supermassive black hole at the heart of the Milky Way — in polarised light. The Event Horizon Telescope (EHT) collaboration linked eight telescopes around the world, including ALMA, to create a virtual Earth-sized telescope. As the largest and most powerful of the telescopes in the EHT, ALMA played a key role in making the observations possible.

When light oscillates in a preferred direction rather than randomly, we call it polarised. This happens in the plasma around the black hole, where the particles whirling around magnetic field lines align, allowing the astronomers to map the black hole's magnetic fields by measuring the polarisation of the light. They uncovered strong, twisted and organised magnetic fields spiralling from the edge of the black hole. Interestingly, the image shows a field structure very similar to that of the black hole M87*, despite the two black holes' having very different masses and very different host galaxies. This suggests that such magnetic fields might be a common feature of all black holes — maybe even a fundamental one — critical to how they interact with the gas and matter around them.

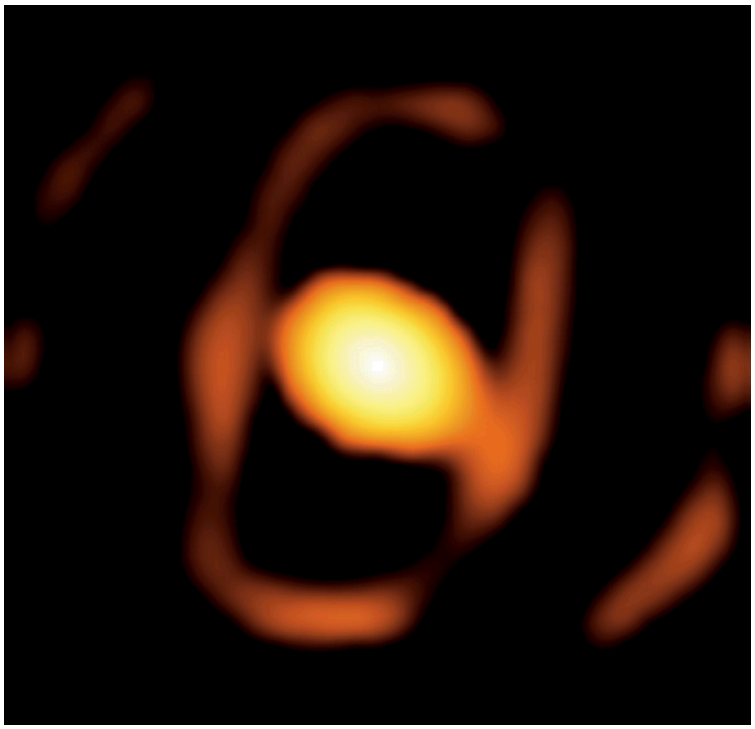
The EHT project involves more than 300 scientists from Africa, Asia, Europe, and North and South America.

Planned expansions of the EHT in the next decade should enable high-fidelity movies of black holes, revealing whether Sagittarius A* — like M87* — also has a jet launching material out into its surroundings.

The Event Horizon Telescope Collaboration, *First Sagittarius A* Event Horizon Telescope Results. VII. Polarization of the Ring*, Astrophysical Journal Letters 964, L25 (2024), https://doi.org/10.3847/2041-8213/ad2df0
The Event Horizon Telescope Collaboration, *First Sagittarius A* Event Horizon Telescope Results. VIII.: Physical interpretation of the polarized ring*, Astrophysical Journal Letters 964, L26 (2024), https://doi.org/10.3847/2041-8213/ad2df1

First close-up picture ever of a star outside our galaxy

ESO/K. Ohnaka et al.



This is the first close-up picture of a star outside the Milky Way: the star WOH G64, taken by GRAVITY. The bright oval at the centre of this image is a dusty cocoon that enshrouds the star, while the fainter elliptical ring around it could be the inner rim of a dusty torus.

This is the first zoomed-in image of a star in a galaxy outside our own Milky Way: WOH G64. Located in the Large Magellanic Cloud, a staggering 160 000 light-years from us, the star was imaged thanks to the impressive sharpness offered by the VLTI. The observations reveal a star puffing out gas and dust, in the last stages before it becomes a supernova.

While astronomers have taken about two dozen zoomed-in images of stars in our galaxy, unveiling their properties, countless other stars dwell within other galaxies, so far away that observing even one of them in detail has been extremely challenging. Until now.

A team of astronomers led by Keiichi Ohnaka (Universidad Andrés Bello, Chile) had been interested in this star for decades, and given that its size is roughly 2000 times that of our Sun, had appropriately dubbed it the ‘behemoth star’.

To image this red supergiant, the team had to wait for the development of one of the VLTI’s second-generation instruments, GRAVITY. And surprisingly, the star had become dimmer over only a decade, a rare opportunity to witness a change in a star’s life in real time. In their final life stages, red supergiants like WOH G64 shed their outer layers of gas and dust in a process that can last thousands of years and which could be responsible for the dimming of the star.

The new image also shows that the star is surrounded by a dust cocoon that is unexpectedly egg-shaped, different from what previous observations and computer models predicted. The team believes that this shape could be explained by either the star’s shedding material or the influence of a yet-undiscovered companion star.

As the star becomes fainter, taking other close-up pictures of it is becoming increasingly difficult, even for the VLTI. Nonetheless, planned updates to the telescope’s instrumentation, such as the future GRAVITY+, promise to change this soon.

Ohnaka, K. et al., *Imaging the innermost circumstellar environment of the red supergiant WOH G64 in the Large Magellanic Cloud*, Astronomy & Astrophysics 691, L15 (2024), https://doi.org/10.1051/0004-6361/202451820

VLT and ALMA team up to study the life-cycle of galaxies

Galaxies are surrounded by vast haloes of gas extending far beyond their visible stars. Gas from these haloes feeds into the galaxies, and is the stuff from which new stars are formed. In turn, material formed in stars and supernovae is expelled from the galaxies back out into the haloes. The haloes therefore play a key role in the life-cycle of galaxies.

The MUSE–ALMA Haloes survey is an ongoing project using multiple ESO observatories and other telescopes to study these haloes. It is an excellent example of how it is often necessary to use more than one telescope, each observing the Universe in a different way, to answer scientific questions.

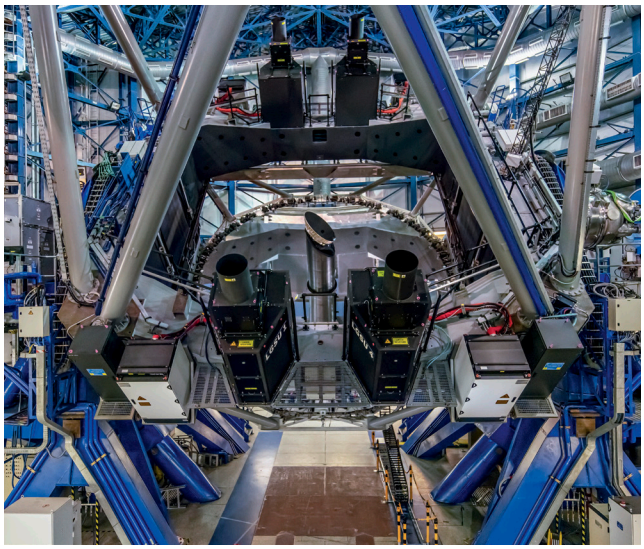
Observations with the VLT's MUSE enable the study of atomic and ionised gas in the haloes by detecting how this gas absorbs light from distant quasars. Observations with ALMA trace colder and denser molecular gas around the galaxies. Combining the observations gives an unprecedented view of the properties and movement of these different components of the haloes.

A paper published in 2024 as part of this study added to the mix observations of starlight — a measure of the total mass of stars in the galaxies — made with the Hubble Space Telescope. The researchers confirmed that galaxies with more stars tended to have less atomic hydrogen gas around them. This inverse relationship seems counter-intuitive, but perhaps galaxies with more stars use up their gas supply in forming them, or the higher temperature produced by more stars prevents the survival of the cooler gas clouds of atomic hydrogen.

The researchers are continuing their investigations, but — whatever the cause of this relationship — it is another demonstration of the complex interplay of factors in the life-cycle of galaxies.

Augustin, R. et al., *MUSE–ALMA Haloes X: the stellar masses of gas-rich absorbing galaxies*, Monthly Notices of the Royal Astronomical Society 528, 6159 (2024), https://doi.org/10.1093/mnras/stae387

Zdeněk Bardon/ESO



S. Otarola/ESO

The MUSE–ALMA Haloes survey combines observations from MUSE on the VLT (left), ALMA (right), and other facilities to study the gaseous haloes of galaxies.

The brightest and fastest-growing: astronomers identify record-breaking quasar

Using the VLT, astronomers have characterised the most luminous object ever observed: a quasar called J0529-4351, located 12 billion light-years from Earth. Quasars are the bright cores of distant galaxies, and are powered by supermassive black holes. This quasar's black hole is growing in mass by the equivalent of one Sun per day, making it the fastest-growing black hole recorded to date.

Black holes collect matter from their surroundings, powering their quasars in a process so energetic that they emit vast amounts of light. The disc of matter falling into the black hole is seven light-years in diameter and is over 500 trillion times more luminous than the Sun.

Despite these incredible numbers, this record-breaking quasar was hiding in plain sight. The object appeared in ESO's Schmidt Southern Sky Survey back in 1980, but was not recognised as a quasar until decades later. A team of astronomers led by Christian Wolf (Australian National University, Australia) had identified it as a quasar in 2023 and their newer observations, with the VLT's X-shooter spectrograph, confirmed that this is the most luminous quasar ever observed.

Purpose-designed machine-learning models are often used to find quasars by searching through vast observational datasets from large areas of the sky. However, the models used in this case were trained on existing data, and were not optimised to find quasars very different from those already known. The quasar J0529-4351 was so bright that until the team identified it, these automated analyses suggested it was a star not too distant from Earth.

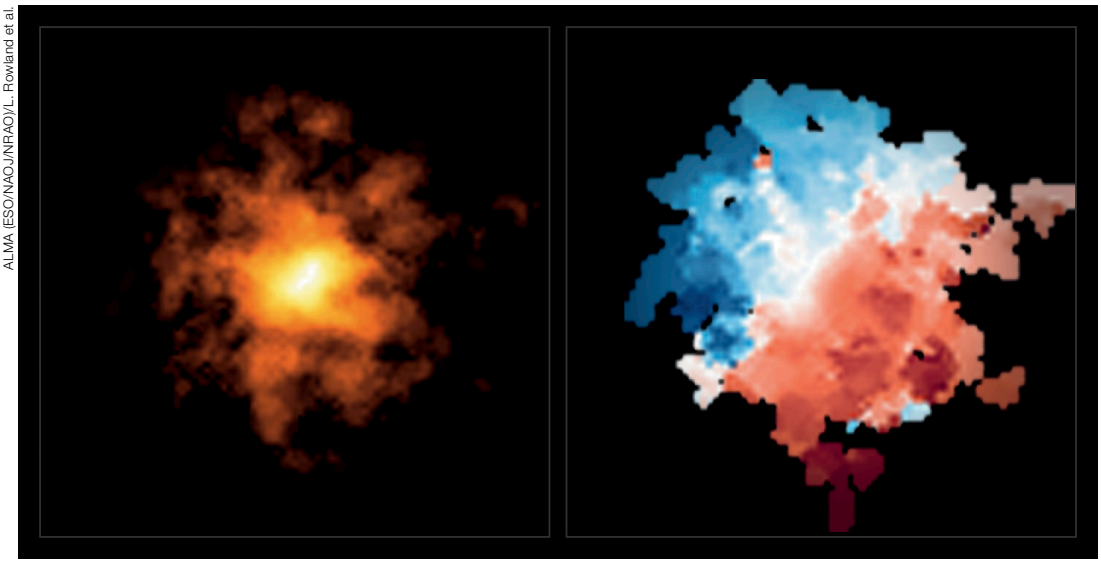
Studying quasars and their supermassive black holes could shed light on some of the mysteries of the early Universe, revealing how their host galaxies formed and evolved.

Wolf, C. et al., *The accretion of a solar mass per day by a 17-billion solar mass black hole.* Nature Astronomy 8, 520–529 (2024), https://doi.org/10.1038/s41550-024-02195-x

ESO/M. Kornmesser

Artist's impression of the record-breaking quasar J0529-4351, the most luminous object known in the Universe to date. The supermassive black hole is seen here pulling in surrounding matter, growing in mass at speeds never seen before.

ALMA finds most distant Milky-Way-like galaxy yet



ALMA (ESO/NAOJ/NRAO)/L. Rowland et al.

These ALMA images show the galaxy REBELS-25. The left panel shows how cold gas is distributed in the galaxy. The right panel shows the motion of the gas, blue indicating movement towards Earth and red indicating movement away from Earth, with darker shades representing faster movement. The red-blue divide shows clearly that the galaxy is rotating.

Using ALMA, researchers have discovered REBELS-25, the most distant strongly rotating disc galaxy ever observed. It is so distant that we see it as it was when the Universe was only 700 million years old, just five percent of its current age.

Surprisingly, REBELS-25 rotates in a similar way to present-day rotating galaxies, which challenges our understanding of how quickly galaxies in the early Universe evolve into the orderly galaxies of today's cosmos. Our current understanding of galaxy formation is that the chaotic conditions in the early Universe mean that galaxies at that time have more turbulent and disordered motions, having undergone mergers with each other. Galaxies should then need billions of years to develop a form like our Milky Way — a rotating disc with well-ordered structures like spiral arms. But it seems we might have to adjust that timescale.

The team, led by Lucie Rowland (Leiden University, the Netherlands), had already detected REBELS-25 in previous observations with ALMA, but the resolution of the data was not fine enough to properly discern its structure and motion. Follow-up observations at a higher resolution confirmed the unexpectedly strong and clear rotation of this young galaxy. Surprisingly, the data also hinted at more developed features similar to those of the Milky Way, including a central elongated bar, and even spiral arms, but more observations will be needed to confirm this. Future observations of REBELS-25, alongside other potential discoveries of similar galaxies, might transform our understanding of early galaxy formation, and the evolution of the Universe as a whole.

Rowland, L. E. et al., *REBELS-25: Discovery of a dynamically cold disc galaxy at z = 7.31*, Monthly Notices of the Royal Astronomical Society 535 (2024), https://doi.org/10.1093/mnras/stae2217

ESO in society and our communities

Providing outstanding services to our communities is one of ESO's Values as an organisation. Our passion for research, innovation, and collaboration leads to far-reaching and invaluable impacts in our Member States, Chile as the Host State of our observatories, our Strategic Partner Australia, and beyond. The benefits are seen not only in science and engineering, but in talent development, education and outreach, the economy and innovation, and international collaboration and policy.

In this section, we share some highlights from the year of how ESO has contributed to and engaged with our many communities and society as a whole.

ESO/M. Kornmesser

Infrared photography at the ESO Garching Open House Day on 3 October 2024.

Serving scientists and engineers in Member States, Chile, and worldwide

It is no surprise that ESO's most significant benefits to society are in the areas of science and engineering — many of which are showcased throughout the rest of this report.

We serve a growing user community of astronomers in our Member States, Chile, our Strategic Partner Australia, and around the world, who make use of the telescopes and data archives of the La Silla Paranal Observatory and of the ALMA partnership.

In addition to designing, building, and operating advanced ground-based observatories, ESO fosters international collaboration by promoting and contributing to the development — by consortia of universities and research institutes — of state-of-the-art astronomical instruments and technologies. Over 50 institutes from more than 20 countries are involved in instrument development for the ELT, Paranal, and La Silla. This investment has a direct economic impact, as well as developing technology expertise and industrial collaborations.

Expanding Horizons: crowdsourcing to shape the next ESO programme

With the ELT just a few years away from completion, ESO is already looking to the future. What breakthroughs in astronomy will scientists make in the 2040s and beyond, and what facility is best suited to make them?

In 2024 ESO launched Expanding Horizons, the process to identify ESO's next transformational ground-based facility. It will address scientific challenges that cannot be tackled with ESO's facilities, both the current telescopes and those under construction or planned, and — in line with ESO's Vision — advance humanity's understanding of the Universe whilst fostering international collaboration.

ESO is inviting the community to think about scientific challenges for the 2040s and later, that will be beyond the reach of current and planned facilities worldwide, as well as innovative and potentially paradigm-shifting technologies, all to be discussed in a series of workshops. Proposals for a new facility will then be invited in a call for ideas.

July 2024–July 2026

Preparatory phase
Workshops for astronomical community to encourage dialogue and debate

Q3 2026–June 2027

Call for ideas
Letters of Intent before 1 December 2026, call open until 1 June 2027

June 2027–September 2028

Assessment phase
Assessment by ESO Executive and Senior Science Committee

October–December 2028

Final decision
by the ESO Council

The goal of reaching out to the entire astronomical community is to collect a broad range of original ideas, and ESO guarantees a transparent and fair assessment of all proposals. With this open and inclusive process, ESO also intends to anchor its mission of serving the community even deeper into its way of working.

ESO's Executive and a specially appointed Senior Science Committee of internationally recognised experts will assess the proposals, and ESO will host dedicated community workshops to transparently share the most promising ideas. The final selection of the concept for the new programme will be made by the ESO Council, with a decision expected at the end of 2028.

Find out more about Expanding Horizons at https://next.eso.org/

Training and inspiring the next generation of scientists and engineers

ESO develops unique expertise which we spread back into our communities to educate the next generation of scientists and engineers, and to trigger the next generation of instruments and telescopes.

Students and postdoctoral researchers at ESO

Having active staff who also conduct front-line research in science and engineering is critical to enabling us to achieve our mission by keeping on top of the latest developments and pushing ideas and facilities to their limits. The scientific and engineering community at ESO in Garching and Chile is enriched by postdoctoral researchers, as well as postgraduate students who spend part or all of their project work at ESO.

At any one time we have at ESO about 45 PhD students, who spend between six months and three years with us, depending on the studentship. We additionally have about 45 ESO Fellows and other postdoctoral researchers, who spend three to four years with us.

The students and postdoctoral researchers at ESO are hosted through various schemes, including ESO Studentships and Fellowships and other ESO funding, the International Max Planck Research Schools, the Irish Research Council–ESO Studentship Programme, the ESO–Czechia training programme, European Research Council grants held by staff at ESO, and other grants from national funding organisations.


Julia Seidel/ESO

Participants in the ESO Chile Fellows' retreat in August 2024 visiting ALMA's 5000-metre-altitude Array Operations Site.

In August 2024 the ESO Fellows in Chile took part in a retreat, held at the ALMA Operations Support Facility. They were joined by management from the Office for Science and Paranal Science Operations, as well as Human Resources. The retreat — the first such event in over a decade — offered a valuable opportunity amidst busy schedules to bring all these groups together for an extended period, for in-depth discussions, presentations and feedback about the fellowship programme. The venue was chosen because the majority of the fellows perform their observatory duties at Paranal and therefore do not normally have the chance to visit ALMA.

Training the next generation of researchers at the La Silla Observing School

The 2024 La Silla Observing School was held in February at the ESO premises in Vitacura and at the La Silla Observatory, offering a series of training workshops on the use of telescopes and astronomical instruments for students and early-career researchers in astronomy.

The school was open to applicants worldwide. The 20 participants selected, from 140 applicants, were based at institutes in South America, Europe and Australia. During two weeks of intense work the participants, with the help of experienced tutors, got hands-on real-life experience of the full cycle, from observation planning, observing with professional 2–4-metre-class telescopes, and the data reduction and analysis afterwards.

ESO gratefully acknowledges support from the Max Planck Institute for Astronomy for providing three nights of ESO/MPG 2.2-metre telescope time to the summer school.

ESO/Rodrigo Soruco

Participants at the 2024 La Silla Observing School.

A decade of discoveries with MUSE and beyond

Workshops and conferences are another vital way in which ESO fosters collaborations within the scientific community. Each year, we support and fund meetings for the community which can take place at the ESO Headquarters in Garching, the ESO offices in Vitacura, or in ESO Member States or our strategic partner Australia. Organising these events is also a valuable way to encourage collaboration between community astronomers and people at ESO.

Among the many such events organised in 2024 was an event celebrating ten years since the first light of MUSE, the Multi Unit Spectroscopic Explorer, on the VLT's Unit Telescope 4. MUSE is an integral-field spectrograph, which means it captures a full spectrum of light at each pixel of its images, generating a wealth of information for astronomers to study. Among the VLT instruments, it is regularly the one in the highest demand, with data from it contributing to the most papers.

The event, held at the ESO Headquarters in November, not only showcased a decade of groundbreaking scientific results, but brought the user community together to share insights, to highlight synergies with other current and future facilities such as ALMA, the JWST, and the ELT, and to discuss challenges and prospects for science using integral-field spectroscopy.

ESO/A. Tsaousis

Participants at the workshop 'A decade of discoveries with MUSE and beyond'.

ESO exhibitions around the world

Michael Hilker/ESO

2024 was a particularly busy year for ESO as an exhibitor at conferences in Europe and around the world, giving us a valuable opportunity to meet face-to-face and engage with scientists, engineers, industrial partners, decision-makers and other stakeholders.

At the SPIE Astronomical Telescopes + Instrumentation conference in Yokohama, Japan in June we ran a dedicated recruitment initiative to encourage engineers to consider careers at ESO. We also had our regular exhibits at the European Astronomical Society's annual meeting in Padova, Italy in July and at the International Astronomical Union's three-yearly General Assembly in Cape Town, South Africa in August.

ESO was one of the organisers of the Big Science Business Forum in Trieste, Italy in October. The event is a meeting place for research infrastructures and industry in Europe. Our Director General and other ESO speakers gave presentations, and many representatives from companies across the continent visited the ESO booth in the exhibition to learn about our big-science ground-based astronomy projects and business opportunities, including future Calls for Tender.

Visitors to the ESO exhibit at the International Astronomical Union's General Assembly in August 2024.

Leading the field in international collaboration

As an intergovernmental organisation, ESO brings countries together to create a scientific and political capacity for development that is beyond the reach of its individual Member States. ESO therefore stands out as a role model, offering a platform for international research and development, collaboration and science diplomacy that actively encourages political and cultural understanding between nations.

ESO is a founding member of EIROforum, the partnership of European research infrastructures, and also maintains formal cooperation agreements with the European Space Agency, CERN, and the SKA Observatory. ESO has a seat on the United Nations Committee on the Peaceful Uses of Outer Space, and is a member of the UN-mandated International Asteroid Warning Network, which monitors the skies for potentially threatening asteroids.

ESO's mission to protect our dark and quiet skies

Astronomy is humanity's oldest science and for thousands of years humans have looked up at the stars, used them as our guides and time keepers, and been inspired by the cosmos. Over the past few decades, however, the quality of the night sky around the world has been diminished as a result of human activity.

ESO has been actively involved in the campaign for the preservation of dark and quiet skies for many years, and participates in many projects supporting the reduction of pollution resulting from errant light, satellite constellations and aeroplanes.

ESO also uses its position as a permanent observer at the UN Committee on the Peaceful Uses of Outer Space (COPUOS) to advocate for dark and quiet skies. Early in 2024, following a substantial engagement campaign coordinated by ESO, the SKA Observatory, the European Astronomical Society and the International Astronomical Union, COPUOS approved a five-year agenda item on this topic from 2025 to 2030.

"Chile's dark skies are a natural heritage that transcends its borders and benefits all humanity."

Itziar de Gregorio-Monsalvo
ESO Representative in Chile[1]

[1] as of 1 January 2025; formerly Deputy Representative, October–December 2024

World’s darkest and clearest skies at risk from industrial megaproject

The pristine skies above Paranal are the darkest and clearest of any astronomical observatory in the world, but this unique location is now under threat.

In August 2024 AES Andes, a subsidiary of the US power company AES Corporation, publicly presented plans for a massive industrial complex, planned to be located just five to 11 kilometres from the telescopes at Paranal. The megaproject would cause irreparable damage to astronomical observations, in particular resulting from light pollution emitted throughout the project’s operational life.

ESO established a dedicated task force, supported by external advisors, which began analysing the likely impact of the project on the operations and observations at Paranal, Armazones and the future CTAO-South site.

In response to a *note verbale* sent by ESO to the Chilean Ministry of Foreign Affairs (MINREL), an interministerial working group was established, including the Ministry of Science, Energy, Economy, Environment, and MINREL. ESO held meetings with all these ministries and the entire working group, as well as with the Environmental Evaluation Service, to raise awareness about the impact this project would have on the sites’ dark skies.

As part of a broader communication campaign to raise awareness of the need to protect the night sky, a visit to Paranal and Armazones of journalists from important Chilean media outlets was organised in October (see page 41).

In November ambassadors from ESO’s Member States to Chile gathered at the ESO premises in Vitacura to discuss the importance and value of Chile’s dark skies, how to protect and preserve them, and the challenges threatening them, in particular from light pollution.

Despite having been alerted by ESO to the irreparable damage that would occur to the capabilities of the telescopes at the Paranal Observatory, AES Andes formally submitted the project for environmental impact assessment in late December.

Ambassadors from ESO’s Member States to Chile meet at the ESO premises in Vitacura in November 2024.

High-level visits to ESO Headquarters

During the year ESO was honoured by several high-level visits to the ESO Headquarters in Garching. ESO always welcomes opportunities to share the latest developments and news from our programme with stakeholders from our Member States, Chile as the Host State of our observatories, our Strategic Partner Australia, or elsewhere.

In June Chilean President Gabriel Boric visited, accompanied by a high-level delegation of over 60 people, including four ministers. The visit was hosted by the Director General and ESO's top-level management. It provided an opportunity for ESO and Chile to review the close relationship they have developed over 60 years of collaboration — which has generated unique opportunities for Chilean academia, companies and society — and to discuss ways of strengthening it.

The delegation saw the development of telescope and instrument components, including some for ESO's upcoming ELT, visited the ESO Supernova Planetarium & Visitor Centre, and met Chilean staff working at the Headquarters.

One of the ministers on this visit was Aisén Etcheverry, the Minister of Science, Technology, Knowledge and Innovation, who had made an earlier visit to the ESO Headquarters in April, accompanied by her delegation.

Left to right: Xavier Barcons, ESO Director General; Gabriel Boric, Chilean President; and Aisén Etcheverry, Chilean Minister of Science, Technology, Knowledge and Innovation visiting the ESO Supernova exhibition at the ESO Headquarters in June 2024.

Aisén Etcheverry, Chilean Minister of Science, Technology, Knowledge and Innovation sees the Large Integration Hall during her visit to ESO Headquarters in April 2024.

In November Antonio Tajani, Deputy Prime Minister and Minister of Foreign Affairs and International Cooperation of the Republic of Italy, visited the Headquarters with his delegation.

The ELT Programme is one of the ESO activities in which Italian companies and institutions are particularly strongly involved: a consortium of Italian companies is constructing the dome and telescope structure, under what was the most expensive ground-based astronomy contract ever awarded.

Antonio Tajani, Italian Deputy Prime Minister and Minister of Foreign Affairs and International Cooperation, visiting the ESO Headquarters in November 2024.

ESO takes over the presidency of EIROforum

On 1 July 2024 ESO assumed the presidency of EIROforum, a position which rotates annually among the partnership's members. In this role, ESO will help to steer EIROforum's activities, to foster international collaboration in science, establish and exchange best practices among Europe's leading research organisations, and to ensure that basic science and research infrastructures have a strong voice in European policy-making. ESO will hold the presidency until 30 June 2025. The eight EIROforum organisations are: CERN, the European Organisation for Nuclear Research; the European Molecular Biology Laboratory; the European Space Agency; ESO; the European Synchrotron Radiation Facility; EUROfusion, the European Consortium for the Development of Fusion Energy; the European X-ray Free-Electron Laser Facility; and the Institut Laue-Langevin.

Fostering public interest in astronomy, science and engineering

Astronomy has a strong popular appeal, and its discoveries generate excitement and interest. ESO harnesses the public excitement for astronomy to increase society's understanding of and engagement with science and technology, and to inspire more children and young people to pursue science, technology, engineering and mathematics (STEM) fields.

We share ESO's achievements and challenges in research, technology development and engineering with the world, highlighting also the people behind them. We tell our stories through many channels, including traditional and social media, public visit programmes at our observatory sites, conferences and outreach events and the ESO Supernova Planetarium & Visitor Centre, situated at the Garching Headquarters.

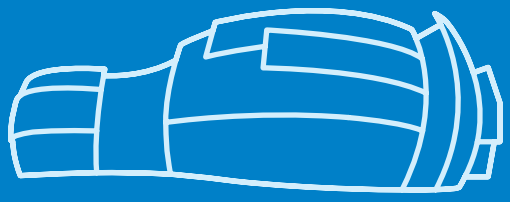
During 2024

Mentions of ESO in print and online media: over

30 000

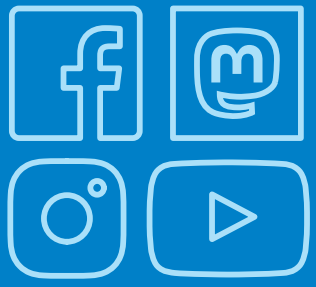
Members of the public, school students and teachers visiting our observatory sites: more than

7000



Visitors to the ESO Supernova Planetarium & Visitor Centre: more than

64 000



Followers of ESO social media channels: over

900 000

Sharing the ELT with the world

Chepox/Fernando Carrasco

Filming an interview with ESO staff in the ELT Technical Facility at the Paranal Observatory.

The ELT is ESO's flagship programme and — as the largest visible-light and infrared telescope in the world — its construction is drawing significant public interest. ESO shares this exciting story with the world directly through our communication channels, and through media outlets worldwide. This led to over 4300 mentions of the ELT in online and print media during 2024.

ESO hosted 10 ELT media visits, mostly at Paranal and Cerro Armazones, including a group visit of six national and regional Chilean media outlets in October (see page 41), as well as a group of five high-profile European broadcast media outlets and newspapers from Germany, Austria, and Portugal at the Garching Headquarters in November. These visits let journalists see activities first-hand and interview experts.

We also continued producing our own audiovisual material documenting ELT construction in Chile and in Europe. We make this freely available, to media and content creators who are unable to visit Cerro Armazones or the other sites, and as ELT updates through our own channels. We also make available material for planetariums, giving audiences the experience of being at Armazones without having to travel, and we plan to produce an ESO documentary about the ELT for its First Light.

ESO Garching Open House Day 2024

The Open House Day at ESO Garching on 3 October 2024, part of the campus-wide *Tag der Offenen Tür*, was a great success. We welcomed an estimated 6000 people to the Headquarters and the ESO Supernova, making our first Garching Open House Day since 2018 very well attended.

Visitors enjoyed activities for kids and adults, including public talks, exhibitions and demonstrations, and the opportunities to "ask an engineer" and "ask an astronomer" their questions. There was great interest in the ELT, with many activities for people to explore. Visitors could see prototype components, admire a new scale model of the whole telescope, and explore a virtual ELT. Our younger guests could also build their own mini LEGO ELT to take home. Meanwhile, at the ESO Supernova, the dedicated Open House Day activities on offer included exhibition tours and planetarium shows aimed at children.

ESO/M. Kornmesser

Hands-on electronics: kids learning to solder at the ESO Garching Open House Day 2024.

ESO–ALMA Vitacura Open House Day 2024

On 22 March over 600 members of the public and school children visited the ESO premises in Vitacura to enjoy the ESO-ALMA Open House Day. This long-running public outreach activity was coordinated jointly by ESO and ALMA as part of the celebrations of Chilean astronomy week. In the morning, school groups toured the many stands and took part in activities. In the afternoon, members of the public engaged in a mix of creative workshops, public talks and live connections with the Paranal Observatory.

The television and radio stations NTV and Cooperativa Ciencia attended the event, streaming and reporting on their channels. Several content creators also attended and shared the activities on their social media channels. The day closed with astronomical talks from staff astronomers and an astronomy-themed concert by a quartet from the Fundación de Orquestas Juveniles e Infantiles (FOJI) — a non-profit foundation that involves students from disadvantaged backgrounds in classical music across the country.

ALMA (ESO/NAOJ/NRAO)

Luis Chavarria, ESO Representative in Chile until 31 December 2024, gives a talk at the ESO–ALMA Vitacura Open House Day.

Accessible astronomy at the Open House Days

Among the new activities at this year's Open House Day at the ESO Headquarters was an interactive experience allowing blind people and those with visual impairments to explore star and planet formation through touch.

In one activity, an interactive 3D-printed model allowed people to learn about star and planet formation, with individual pieces that could be removed in sequence to demonstrate the stages of the process.

Another activity was a tactile model of the Solar System, with different textures for the Sun and the planets, presented on two different scales, one for the sizes of the objects and one for the distances between them.

At the ESO–ALMA Open House Day in Vitacura, a dedicated tour with sign-language interpreters was offered for deaf students and those with hearing impairments, during the morning session. In addition, the activity stations during the day included material about the Sun and the Solar System for blind people and those with visual impairments.

Supporting STEM education

Children are naturally curious about the world around them, and early childhood scientific learning engenders a thirst for knowledge and a drive for lifelong learning. ESO supports science, technology, engineering and mathematics (STEM) education through the activities of the ESO Supernova Planetarium & Visitor Centre at our Headquarters, and through programmes in Chile, including our observatory tours for schools (see page 39 for more about these).

Early-years STEM at the ESO Supernova

Visitors to a one-day conference on early-years STEM education, held at the ESO Supernova in October 2024.

Bildungswerk der Bayerischen Wirtschaft e.V.

The ESO Supernova Planetarium & Visitor Centre is an astronomy outreach centre for the public and schools, located on the site of ESO's Headquarters in Garching, Germany. At its heart is a 109-seat planetarium with state-of-the-art projection technology, offering a range of shows suitable for all ages, each of which contains a live presentation component. The ESO Supernova also offers a free-of-charge 2200-square-metre exhibition area, introducing the science and technology behind modern astronomy and our place in the Universe.

Among the more than 64 000 visitors to the ESO Supernova Planetarium & Visitor Centre in 2024 were over 2200 children in more than 100 primary school and kindergarten groups, and we offered planetarium shows, interactive workshops and guided tours aimed specifically at young children.

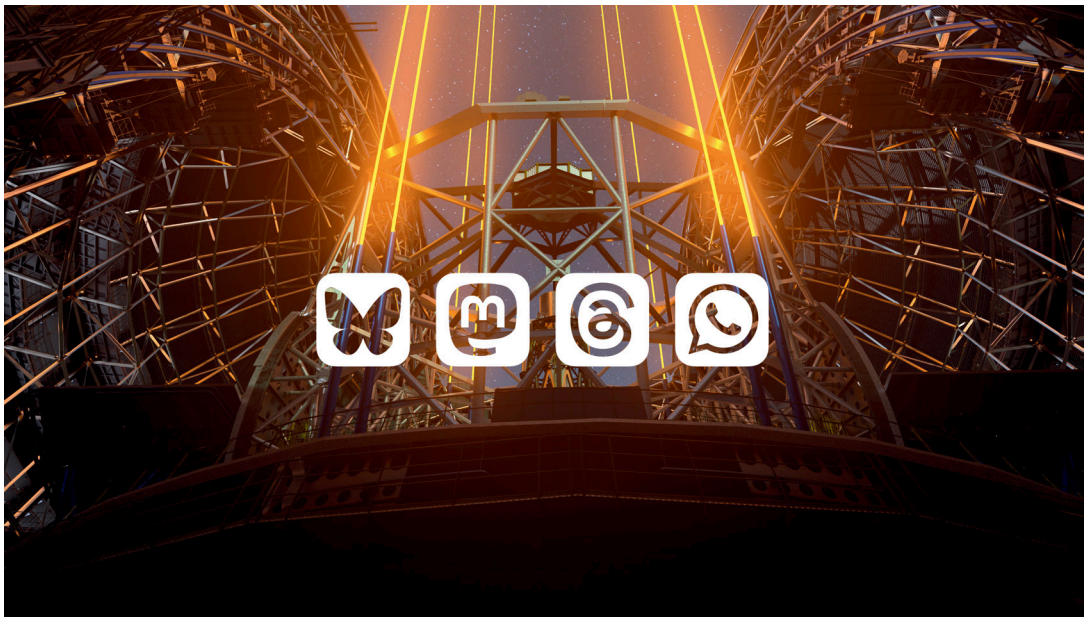
The vital role of educational specialists and teachers in early-years STEM education was a key focus throughout a year of collaborations at the ESO Supernova, working with local and international organisations.

Among the many collaborations was an ongoing one with the Forscherstation Heidelberg, which focuses on supporting and training educators of children in kindergartens and primary schools. A new aspect of this collaboration was a Materials Library at the ESO Supernova, which was officially opened in March with an event for about 50 educators. The library offers boxes for educators to borrow, containing science experiments related to astronomy and everyday natural phenomena, specially designed for younger children.

In October the ESO Supernova ran a one-day conference on early-years (kindergarten and primary school) STEM education in collaboration with the Bildungswerk der Bayerischen Wirtschaft (Educational Institution of Bavarian Industry). The event, attended by about 30 educators, offered inspiring ideas, varied workshops, and many opportunities for exchange and networking.

New social media channels at ESO

ESO established several new social media channels, joining Mastodon, BlueSky, and Threads, and setting up an Instagram Broadcast channel and LinkedIn Newsletter. These changes reflect adaptations to our audiences' interests and how we can best engage with them, and are part of our ongoing monitoring and evaluation of the social media landscape.



ESO in Chile

In 1963 ESO and Chile signed a visionary agreement which paved the way for the construction of the La Silla Observatory, ESO's first observatory site. The ongoing spirit of trust and cooperation stemming from this agreement, and the successes that began with La Silla, have led ESO to build and operate some of the most powerful observatories on the planet in Chile, building a unique and deeply valued relationship with the country.

Engaging with the public in Chile

ESO engages with members of the public throughout Chile, in particular in the Antofagasta, Coquimbo and Metropolitan regions. This encompasses a wide range of science outreach activities and events, including visits to the observatories, and ESO also engages with local and national media to share the latest news and results from the telescopes and the excitement of scientific discovery.

ALMA (ESO/NAOJ/NRAO)

A quartet from the Chilean Fundación de Orquestas Juveniles e Infantiles (FOJI) plays an astronomy-themed concert at the ESO–ALMA Vitacura Open House Day 2024.

Bringing schools and the public to ESO observatories

SERNATUR Antofagasta

A special tour to Paranal organised with the Chilean National Service of Tourism (SERNATUR) for Heritage Day in May 2024.

ESO updated its programme of visits to the observatories in 2024, with particular emphasis on tours for school groups. The updated programme provides more visit options, strengthening our commitment to our local communities in Chile.

The programme of free educational visits to La Silla and Paranal for public schools in the Coquimbo and Antofagasta regions, which was launched in 2023, continued in 2024. A total of 560 school students and teachers took part. New for 2024, for certain municipalities in these regions, a shuttle bus was offered between schools and the observatories.

A free virtual tour programme for schools brought the La Silla, Paranal and ALMA observatories into classrooms through a live guided tour and Q&A, supported by videos, photographs and 360º images.

In 2024 we also started offering special tours on the Heritage Day weekend in May, in collaboration with the Chilean National Service of Tourism (SERNATUR). These tours, to La Silla and Paranal with shuttle buses from La Serena and Antofagasta respectively, were for audiences who cannot easily access visits such as seniors, on holiday tours organised by SERNATUR, and minors in state care. In addition, the free public visit programme at Paranal and La Silla continued, with weekend visits throughout the year.

Ten years of the Day of Astronomy in Chile

2024 marked a decade of the Day of Astronomy in Chile, celebrated each year on 20 March in an event coordinated by the Public Science programme of the Ministry of Science and Technology, Planetarium Chile and the Chilean Astronomy Society. To celebrate this milestone, ESO, in collaboration with the La Moneda Cultural Center, organised a series of free activities during the month of March. The ESO's Astounding Universe exhibition showcased the most outstanding images of the cosmos from ESO's telescopes. Talks and discussions covered topics that included astronomical discoveries, geological, astronomical and human scales and our place in the Universe, and the contributions of women in science. The centrepiece of the activities was the ESO–ALMA Open House Day at the Vitacura premises on 22 March (see page 35).

Activities at the ESO–ALMA Open House Day 2024 in Vitacura.

all images: ESO/J. Bianchi

Celebrating science at Puerto de Ideas in Antofagasta

ESO took part in the Puerto de Ideas festival in Antofagasta in April 2024, an event that drew more than 16 000 people to a celebration of science, knowledge and culture. On offer were engaging talks on topics ranging from exoplanets to the construction of the ELT, as well as an astronomical gallery and models of our telescopes and their mirrors.

Chilean media visit to Paranal and Armazones

Six national and regional Chilean media outlets visited Paranal and the ELT construction site on Cerro Armazones in October as part of a communication campaign to raise awareness of the advances and milestones of the ELT, and the importance of dark sky preservation. The journalists interviewed staff at ESO as well as experts on light pollution from the Fundación Cielos de Chile (Skies of Chile Foundation).

The visit led to extensive coverage on television, radio and the web and in newspapers. The online coverage included a dedicated hour-long video by a well-known Chilean digital content creator on “The largest telescope in the world”, which received more than 113 000 views, bringing the ELT to a broader audience, who might not previously have been aware of ESO.

El Mercurio

A 8 vct@mercurio.cl @VCT_ElMercurio VIDA • CIENCIA • TECNOLOGÍA @vctelmercurio EL MERCURIO DOMINGO 3 DE NOVIEMBRE DE 2024

Los cielos prístinos y despejados del desierto de Atacama son ideales para la observación astronómica. En la foto, el observatorio Paranal de noche.

ALEXIS IBARRA
Desde Cerro Paranal, Región de Antofagasta

Una riqueza única en el mundo podría estar en peligro en el norte de Chile. Sus prístinos cielos, hogar de los principales observatorios del mundo, podrían verse amenazados por su peor enemigo: la contaminación lumínica.

El 19 de octubre entró en vigor en Chile una nueva norma de ley que regula la contaminación lumínica principalmente en ciudades y que, entre otras medidas, establece límites de luminosidad, horarios para el funcionamiento de pantallas publicitarias y de los focos de recintos deportivos y, además, promueve el uso de luz cálida.

Si bien existía una normativa en regiones relacionadas con la astronomía (Antofagasta, Atacama y Coquimbo), esta se hace extensiva a todo el país y se preocupa, además, de la protección de la biodiversidad y la salud humana. Además, en las áreas consideradas de Protección Especial, como las ya mencionadas, la normativa es más rigurosa y comenzó a regir de inmediato.

Sin embargo, para los astrónomos esto es solo un primer paso —que es bien recibido—, pero claman por una solución que proteja aún más los cielos de lugares donde se desarrolla la astronomía de más alto nivel del mundo.

Para ellos, tan importante como controlar las luces en ciudades y proyectos industriales es clave proteger la calidad de los cielos de la contaminación lumínica acumulada. En definitiva, lo que quieren es que el cielo de lugares de interés astronómico esté protegido con un rango mínimo de contaminación, por ejemplo, que no se sobrepase el 1%. Esto, pensando

Son los mejores cielos del mundo, pero de su cuidado depende el futuro de la astronomía en el país:

La contaminación lumínica podría “apagar” los grandes observatorios de Chile

Hace unos días comenzó a regir una nueva norma sobre el tema, pero los astrónomos piden ir un paso más allá: que, además de regular proyectos y luminarias por separado, se garantice la calidad del cielo en ciertos sectores, viéndola como un todo. Así, se pueden conservar zonas de alto interés con menos de 1% de polución debido a la luz.

que ciudades y proyectos industriales que pueden cumplir la norma por separado podrían tener un efecto acumulativo en zonas cercanas a los telescopios.

El astrónomo Eduardo Unda-Sanzana, director del Centro Astronomía en la U. de Antofagasta, dice que Chile concentrará más del 50% de la capacidad astronómica del mundo para 2030. “Y si tomamos solo la Región de Antofagasta —donde se encuentran Paranal, ALMA y próximamente el ELT, el telescopio más grande del mundo—, concentrará esta por sí sola prácticamente el 40% de la capacidad astronómica del mundo (...). La responsabilidad y las oportunidades que tenemos sobre nuestros hombros son gigantes”, añade.

Pero advierte: “Desde 1990, hemos podido ver que la contaminación lumínica en nuestra región ha ido aumentando (...). Las ciudades crecieron, aparecieron muchas empresas mineras que vienen acompañadas con proyectos fotovoltaicos”.

Muestra un mapa donde se puede ver la contaminación lumínica de faenas industriales a 30 o 70 kilómetros de distancia y de ciudades como Calama, a 300 km. En la norma que ya rige, se regula con mayor rigurosidad a las ciudades a menos de 100 km de un área de interés científico. “Esto no es un fenómeno local, abarca grandes distancias, de manera que hay que tener una visión bien panorámica de los efectos de nuestras acciones”, dice.

“¿Por qué si somos una organización europea tenemos todos nuestros telescopios en Chile?”, se pregunta, en tanto, la astrónoma Itziar de Gregorio-Monsalvo, jefa de la Oficina de Ciencia del Observatorio Europeo Austral (ESO) y su vicerrepresentante en Chile. Y responde: “Solo por las condiciones excepcionales del desierto de Atacama (...). Eso se consigue en muy pocas partes del mundo, y en especial en el observatorio Paranal”.

“Este es un lugar único en el mundo. No existe uno mejor para la observación astronómica”, dice, desde Paranal, Luis Chavarría, representante de ESO en Chile. “La estabilidad atmosférica, una humedad ambiental que no sobrepasa el 5%, con unos cielos despejados gran parte del año y con menos de un 1% de contaminación lumínica”, agrega.

Pero hay preocupación. “Alrededor de la zona otorgada a la ESO para construir telescopios hay focos de contaminación lumínica. Unos vienen de la ciudad de Antofagasta, otros de mineras, pero cada vez más están llegando proyectos nuevos vinculados a energía y minería que se están comenzando a acercar”, dice De Gregorio-Monsalvo.

Y otra inquietud que tiene es que “los proyectos industriales pueden instalarse en el borde de nuestra área de protección”, añade.

“En el mundo, la contaminación lumínica avanza a una tasa de casi el 10% anual y más del 80% de las personas viven bajo cielos contaminados”, dice Juan Pablo Valenzano, coordinador de proyectos en la Fundación Cielos de Chile, ONG cuyo objetivo “es promocionar, proteger y preservar los cielos de Chile”, agrega.

Para él, la contaminación lumínica se define como “todo ese exceso de luz artificial que se desperdicia”. Y eso implica las luminarias que no apuntan hacia el lugar que necesitan iluminar, las que están prendidas cuando no se necesitan o que emiten luces en el espectro que no es visible por el ojo humano, entre otras.

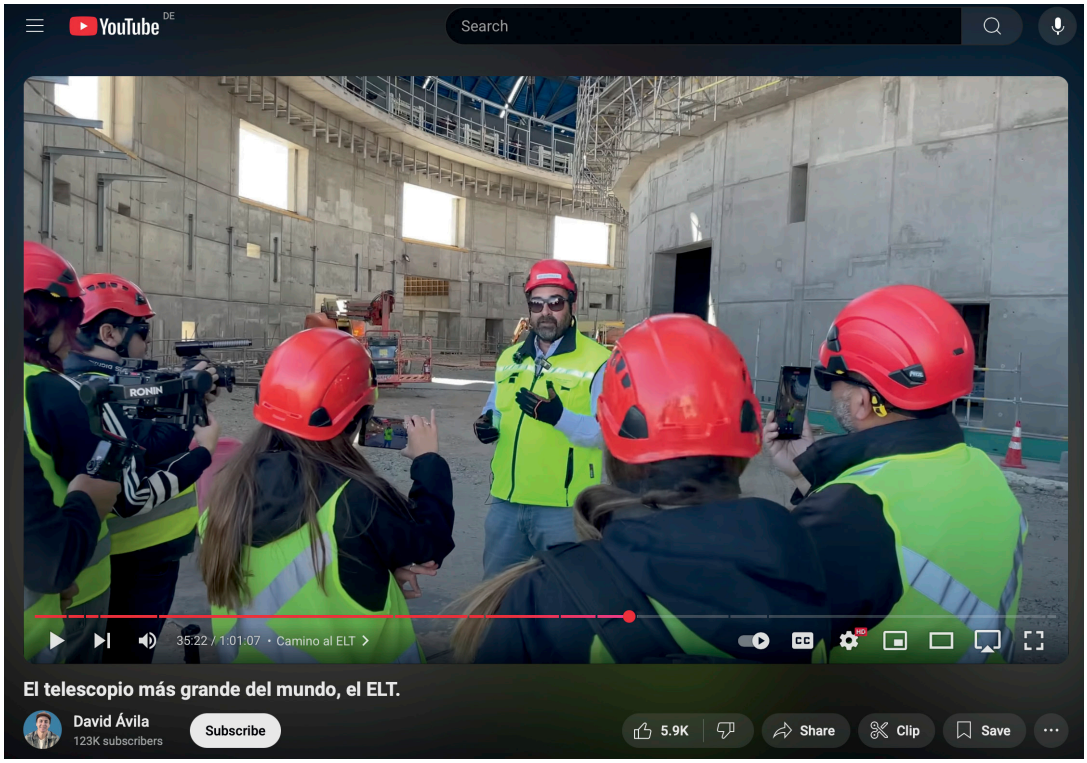
Sus repercusiones, dice Valenzano, van más allá de la astronomía: “Tiene que ver con la pérdida de la biodiversidad, ya que altera los patrones de vida de las especies nocturnas, ya sea su hábito de migración, de reproducción o de alimentación”. Y también con el cambio climático, ya que hay un desperdicio energético que contribuye al calentamiento global.

La nueva normativa, dice Valenzano, tiene normas simples, pero que sí generan un impacto. “En tres regiones, Coquimbo, Atacama y Antofagasta, se establecieron áreas protegidas por ser de interés astronómico: 29 de sus 33 comunas se establecen como áreas especiales de protección”, añade.

El sitio del Ministerio del Medio Ambiente dice que la actualización de

Above: An article in El Mercurio, part of the newspaper coverage resulting from the Chilean media visit to Paranal and Armazones.

David Ávila/YouTube



Video on “The largest telescope in the world” by digital content creator David Ávila, resulting from the Chilean media visit to Paranal and Armazones.

ESO–Chile Joint Committee funded projects

The Joint Committee of ESO and the Government of Chile provides funds to promote cooperation with Chile, the Host State of our observatories, in areas related to astronomy, technology and scientific culture in the country. Every year delegates from ESO together with Chilean authorities jointly evaluate and select a number of eligible programmes to be supported by this fund.

In 2024 20 projects from all over the country were funded by the Joint Committee, distributing a total of 625 million Chilean pesos (approximately 600 000 euros). Of the awards, seven will support science and technology research and development, while four will be allocated to projects for the dissemination and education of astronomy in Chile. This includes support for Chilean students to travel to the 2025 Latin American Astronomy and Astronautics Olympiad, and projects aimed at preserving Chile's dark and pristine skies.

A total of 186 million Chilean pesos (approximately 180 000 euros) was also awarded to 11 projects in a regional call for the Antofagasta and Coquimbo regions, home to the ESO observatories. The projects covered areas including STEM initiatives for young schoolgirls and the protection of the skies in the Coquimbo region. In the Antofagasta region, the projects aim to preserve astronomical heritage and to disseminate ancient and modern astronomy among local communities.

ESO/P. Horálek

Breathtaking dark skies and the arc of the Milky Way above the VLT on Cerro Paranal.

Chilean Senate committee visits Paranal and the ELT site

The Chilean Senate Committee on Challenges of the Future, Science, Technology and Innovation held one of their formal sessions, on technology transfer, at Paranal in August 2024. The committee, composed of senators Alfonso de Urresti, Juan Antonio Coloma, Luciano Cruz-Coke and Rojo Edwards, was joined by the Minister of Science, Technology, Knowledge and Innovation, Aisén Etcheverry.

Welcoming them to Paranal, the ESO Director General gave a presentation on the benefits and opportunities of ESO's activities for astronomy and technology in Chile, as well as the importance of preserving the pristine quality of the night sky at Paranal. During their visit, the committee members toured the ELT construction site and saw for themselves the progress being made with the huge telescope and its dome — another example of the advanced scientific and technological development, and international collaboration, fostered in Chile by ESO.

The visit to Paranal followed an invitation from the senate committee for the ESO Representative in Chile to discuss proposals for technology transfer legislation earlier in the year. This discussion, as well as the subsequent visit, underlines ESO's increasingly important role in Chile as both a responsible leader and respected expert in matters of science and technology policy.

ESO/ J. Bianchi

The Chilean Senate Committee on Challenges of the Future, Science, Technology and Innovation, with the Minister of Science, Technology, Knowledge and Innovation, Aisén Etcheverry, visiting Paranal in August 2024.

Taltal students get hands-on technical experience at Paranal

Four students majoring in electromechanics at the technical high school Liceo Politécnico José Miguel Quiroz in Taltal — the closest town to Paranal — took part in a new technical internship initiative at the observatory. The students spent ten weeks learning about and gaining first-hand experience of the fundamentals of Paranal's operations under the direct supervision of the facility management services company LINKES.

Valentin Santander/ESO

Some of the Taltal students taking part in a new technical internship initiative at the Paranal Observatory.

The programme emphasised fostering curiosity in a safe learning environment. It involved not only the time at Paranal but also school visits and engagement with teachers and parents as well as the students.

The project was a way not only to connect more closely with our neighbours in Taltal, but also to highlight the novel job opportunities associated with the work of astronomical observatories, and to build technical skills and knowledge in the young people of the area.

This initiative was a collaborative effort between ESO, the company LINKES, and UN Women, a United Nations entity charged with working for gender equality and the empowerment of women. It followed the renewal earlier in the year of a memorandum of understanding between ESO and UN Women that was originally signed in 2020, which had already led to a programme giving Chile-based women professional technical training and job opportunities in astronomical telescope maintenance.

ESO and University of Antofagasta sign collaboration agreement

CITEVA

Members of the University of Antofagasta's Center for Research, Technology, Education and Astronomical Outreach (CITEVA) in 2024.

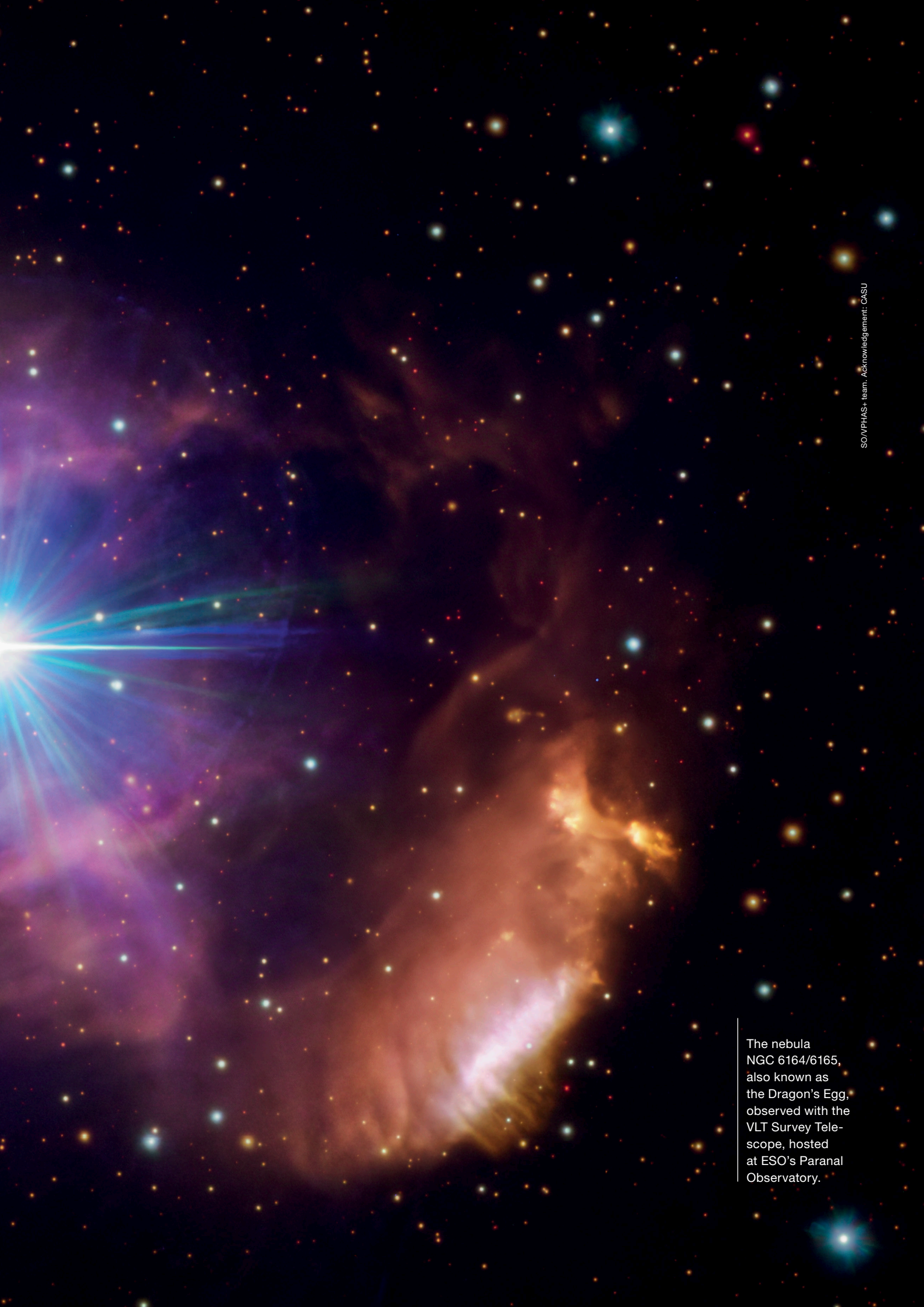
In 2024 ESO and the University of Antofagasta (UA), through its Center for Research, Technology, Education and Astronomical Outreach (CITEVA), signed a cooperation agreement to foster collaboration and strengthen the development of astronomy and related sciences in the Antofagasta Region.

An annual Universidad de Antofagasta Day at ESO's offices in Santiago will offer students, academics, and researchers involved in CITEVA projects a dedicated day to present their research to ESO's scientific staff, as well as student visits to ESO's Office for Science in Vitacura and open access to ESO's scientific colloquia for UA's academic community.

In engineering, the partnership promotes collaboration and knowledge transfer. Once a year, ESO will host UA engineering and astronomy students and faculty at Paranal. These visits will include technical meetings between ESO and CITEVA personnel to explore project challenges and solutions. A framework for donations of decommissioned ESO hardware for use in selected UA projects will also reinforce the university's capabilities in astronomical engineering.

Allocation of telescope time

Observing time is among ESO's most precious resources, and access to ESO's telescopes is highly sought after by a world-leading community of astronomers. Researchers submit proposals for observing projects to address specific scientific objectives, and each year many times more observing time is requested than is available. Projects are therefore selected through a competitive process in which the proposals are peer-reviewed by experts from the community.



ESO/VPHAS+ team. Acknowledgement: CASU

The nebula NGC 6164/6165, also known as the Dragon's Egg, observed with the VLT Survey Telescope, hosted at ESO's Paranal Observatory.

La Silla Paranal Observatory

The number of proposals submitted to ESO in 2024 for observations to be executed at the La Silla Paranal Observatory in Periods 114 (1 October 2024 to 31 March 2025) and 115 (1 April to 30 September 2025) was 860 and 763, respectively. Large Programmes (LPs) were offered only in Period 114.

The upper table on the right shows the requested and scheduled observing time (in units of nights) in the two observing periods combined. Ongoing LPs approved in previous periods, Director's Discretionary Time, Guaranteed Time Observations Programmes and Public Surveys are not included in the scheduled time column. The pressure is computed as the ratio of the requested and the scheduled time. The last two columns show the total telescope time allocations (including current LPs approved in previous periods etc.) and the fractions per instrument.

Some columns may not sum exactly to the total shown, owing to rounding effects. The Incoherent Combined Coudé Focus (ICCF) is listed separately and presents the statistics for ESPRESSO in the 4-Unit-Telescope (UT) mode. The time fractions are computed relative to the total allocated time on the four VLT UTs. In the request, the ESPRESSO-1UT proposals are randomly distributed across the four UTs, while the allocated time reflects the final schedule, which is constructed considering the loads on the different UTs.

ALMA

The ALMA Cycle 11 Call for Proposals (covering the period from October 2024 to September 2025) resulted in 1712 proposals, including 42 LPs, worldwide. Of the 1670 non-LP proposals, 615 had Principal Investigators (PIs) from an ESO Member State. Of the 42 LPs, 41 had a PI or co-PI from an ESO Member State. The proposal review process used Distributed Peer Review for all proposals except LPs. Dual-anonymous reviewing was employed, independent of proposal type.

The lower table on the right shows the total number of proposals submitted and the total requested time per array type (12-metre, 7-metre and Total Power). For the 12-metre Array, the requested and scheduled (priority A and B) time is also shown per ALMA frequency band, and separately for the community in the ESO Member States and the rest of the world. The statistics for the number of proposals per band are not given since one proposal may request more than one band. The pressure is defined as the number of hours requested divided by the number of hours scheduled in priority A and B.

Note that the sum of the per-band requested hours for the 12-metre Array shown in the table is approximately 3.5 hours more than the actual total hours requested for the 12-metre Array, also shown in the table, owing to rounding effects.

Allocation of telescope time for the La Silla Paranal Observatory

Telescope	Instrument	Requested time (hours)	%	Scheduled time (hours)	%	Pressure	Total allocation (hours)	%
UT1	FORS2	293	57.4%	111	59.1%	2.64	117	47.5%
	KMOS	108	21.1%	22	11.2%	4.87	22	9.0%
	ESPRESSO1	110	21.5%	55	29.2%	2.00	107	43.5%
Total		**511**	**100.0%**	**188**	**100.0%**	**2.71**	**246**	**100.0%**
UT2	FLAMES	101	16.5%	49	22.1%	2.06	56	22.7%
	UVES	295	48.4%	109	49.0%	2.72	116	47.5%
	VISIR	75	12.2%	22	9.8%	3.43	23	9.4%
	ESPRESSO2	139	22.8%	42	19.1%	3.28	50	20.4%
Total		**610**	**100.0%**	**222**	**100.0%**	**2.75**	**244**	**100.0%**
UT3	CRIRES	187	22.0%	47	23.8%	3.94	56	25.8%
	SPHERE	120	14.2%	26	12.8%	4.70	26	11.7%
	X-SHOOTER	440	51.8%	127	63.4%	3.48	136	62.5%
	ESPRESSO3	102	12.0%	0	0.0%	–	0	0.0%
Total		**849**	**100.0%**	**200**	**100.0%**	**4.25**	**218**	**100.0%**
UT4	ERIS	226	21.7%	49	32.6%	4.65	85	41.2%
	HAWK-I	78	7.5%	13	8.6%	6.07	15	7.0%
	MUSE	640	61.4%	88	58.7%	7.31	107	51.8%
	ESPRESSO4	97	9.3%	0	0.0%	–	0	0.0%
Total		**1042**	**100.0%**	**149**	**100.0%**	**6.99**	**206**	**100.0%**
ICCF	ESPRESSO-4UT	11	1.4%	1	0.3%		1	0.3%
VLTI	GRAVITY	190	58.5%	61	60.3%	3.10	78	60.4%
	MATISSE	86	26.6%	19	19.0%	4.48	30	23.4%
	PIONIER	48	14.8%	21	20.7%	2.29	21	16.2%
Total		**324**	**100.0%**	**102**	**100.0%**	**3.19**	**130**	**100.0%**
3.6-metre	HARPS	275	63.2%	84	60.9%	3.27	135	39.8%
	NIRPS	160	36.8%	54	39.1%	2.96	203	60.2%
Total		**436**	**100.0%**	**138**	**100.0%**	**3.15**	**338**	**100.0%**
NTT	EFOSC2	190	81.1%	113	79.5%	1.67	203	79.3%
	ULTRACAM	44	18.9%	29	20.5%	1.52	53	20.7%
Total		**234**	**100.0%**	**143**	**100.0%**	**1.64**	**256**	**100.0%**

Allocation of telescope time for ALMA

	Number of proposals	Requested time (hours)			Band	Requested 12-metre time (hours)		Scheduled 12-metre time (hours)		Pressure	
		12-m	7-m	Total power		All	ESO	All	ESO	All	ESO
ALMA	1712	31 608	12 994	8928	1	2336.4	867.0	524.5	158.0	4.45	5.49
					3	4793.3	2139.7	386.3	215.1	12.41	9.95
					4	2012.6	729.6	331.3	158.6	6.07	4.60
					5	1368.0	517.7	174.8	100.1	7.83	5.17
					6	9768.4	3317.2	1217.0	317.6	8.03	10.44
					7	8315.1	2999.6	1159.3	367.0	7.17	8.17
					8	1667.1	838.2	202.2	40.1	8.22	20.90
					9	974.5	401.1	76.2	15.3	12.79	26.22
					10	376.1	138.8	35.0	3.3	10.75	42.06
Total						**31 611.5**	**11 949.0**	**4107.1**	**1375.0**	**7.70**	**8.69**

The Extremely Large Telescope

ESO's Extremely Large Telescope, or ELT for short, is a revolutionary ground-based telescope that will be the largest visible- and infrared-light telescope in the world. The ELT is situated on Cerro Armazones, at an altitude of 3046 metres in Chile's Atacama Desert. It is currently under construction and will become operational later this decade.

Comet C/2023 A3 (Tsuchinshan-ATLAS) is visible near the horizon, to the left of the dome of the ELT, in September 2024.

ESO/Apical

The ELT's pioneering five-mirror optical design will allow it to unveil the Universe in unprecedented detail. The five mirrors have different shapes, sizes and roles but will work together seamlessly.

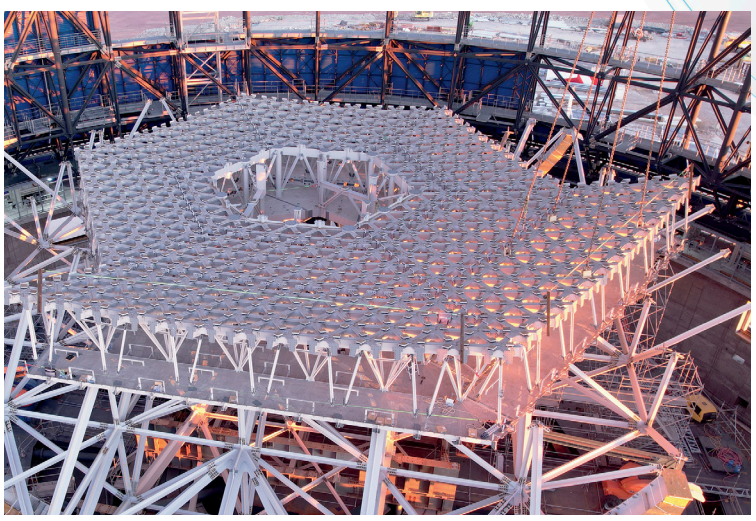
The primary mirror, M1, is the most spectacular: a giant 39-metre concave mirror composed of 798 hexagonal segments. It will collect light from the night sky — tens of millions of times as much light as the human eye — and reflect it to the secondary mirror, M2.

The convex M2, the largest secondary mirror ever employed on a telescope, will hang above M1 and reflect light back down to the tertiary mirror M3.

M3 in turn will relay it to an adaptive flat mirror (M4) above it.

M4 will adjust its shape a thousand times a second to correct for distortions caused by atmospheric turbulence, before sending the light to M5.

M5 is a flat tiltable mirror that will stabilise the image and send it to the ELT instruments.



ESO/G. Vecchia

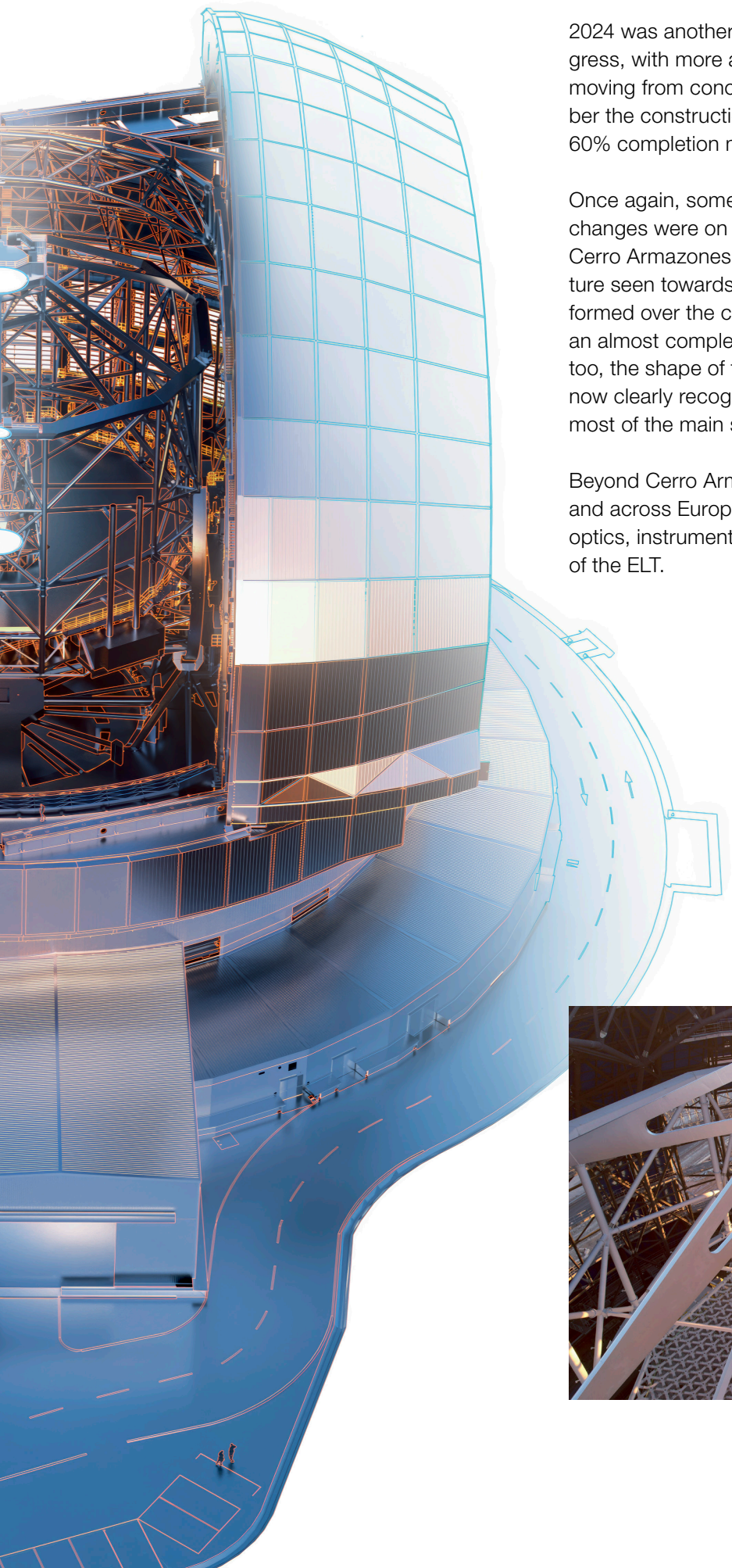
The M1 cell, which will hold and support the ELT's primary mirror, being assembled in July 2024.

2024 was another year of impressive progress, with more and more parts of the ELT moving from concept to reality. In September the construction programme passed its 60% completion mark.

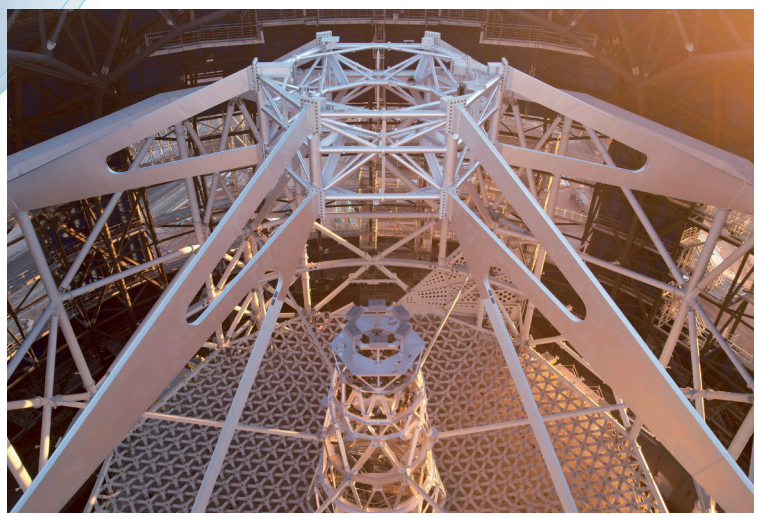
Once again, some of the most visible changes were on the summit of Cerro Armazones, where the skeletal structure seen towards the end of 2023 transformed over the course of the year into an almost complete dome. Inside the dome, too, the shape of the telescope itself is now clearly recognisable, with assembly of most of the main structure completed.

Beyond Cerro Armazones, teams in Chile and across Europe made good progress on optics, instrumentation, and other systems of the ELT.

A list of industrial and institutional partners working on ELT construction can be found at https://elt.eso.org/about/industrial/



By the end of 2024, the metal skeleton of the ELT, with the exception of the Nasmyth instrument platforms, was complete.



ESO/G. Vecchia

Telescope dome and main structure

The giant dome, approximately 93 metres across and 80 metres high, will house the telescope, providing protection from the extreme environment of the Atacama Desert.

In 2024 Cerro Armazones saw the completion of the steel structure of the dome, as well as major progress on its cladding. This cladding includes a first layer of large panels, mostly completed; a second layer of aluminium panels, more than half of them now installed; and additional louvres, half of which have already been preassembled at base camp.

The dome passed one of its first tests with flying colours at the start of the year, when it was rotated for the first time. Engineers moved the 2500-tonne frame of the dome 10 metres in each direction. This was done ‘manually’, using special hydraulic devices, at a speed of just 1 cm per second. When the dome is completed, it will weigh about 6100 tonnes, and will be rotated by motors over one hundred times faster at 5 km per hour, approximately walking pace.

The vast metal skeleton of the telescope is now complete, with the exception of the Nasmyth platforms on which the instruments will sit. These have been deliberately held back for now, to make it easier to install the various telescope mechanisms — the ‘muscles’ that will move the skeleton.

ESO/G. Vecchia

Aerial view of the ELT construction site.

The crown — which will hold the M2 mirror almost 30 metres above the primary mirror — was installed in mid-December.

The M1 cell, which will hold and support the primary mirror, was completed in late August.

The Adaptive Relay Tower, the 10-metre-tall central tower which will hold the M3, M4 and M5 mirrors, was completed in late November

ESO/F. Carrasco (Chepox)

As the dome took shape, the 360-degree internal webcam installed in 2023 had half of its view blocked by the dome walls. The unit contained two cameras, so it was split into two separate inward-facing cameras, one at the top and one at the bottom of the dome: elt.eso.org/about/webcams/#dome

M1 primary mirror

The ELT's primary mirror has a diameter of 39 metres. Too large to be made from a single piece of glass, it is composed of 798 hexagonal segments, each 1.45 metres across and 5 centimetres thick. Each segment assembly, including support structure, weighs 250 kg.

To achieve the required scientific performance, the mirror needs to be maintained in position and in shape to an accuracy of tens of nanometres — 10000 times thinner than a human hair — across its entire 39-metre diameter. Edge sensors on each side of every segment measure the position relative to its neighbours, while positioning actuators (PACTs) maintain perfect alignment of all the segments.

The last of the M1 mirror segment blanks was produced in June, making a total of 949 including spares. All of the M1 segment supports (936 including spares) have been produced. The polishing of the blanks and their integration with the supports to make the final M1 segment assemblies is ongoing.

All of the PACTs (2418 including spares) have been produced, with all except for the batch of spares already delivered to Chile. All the edge sensors (4566 pairs) have also been produced and delivered to Chile.

By the end of the year, a total of 180 segment assemblies had made the 10 000-kilometre journey from Europe to Chile, where they are being stored at the ELT Technical Facility at Paranal, and 162 had received their reflective coating.

This is the first time that ESO has done series manufacturing like this for optical telescopes, where the precise accuracy needed for optics at visible-light wavelengths must not only be achieved for an individual mirror but also be maintained throughout the production of hundreds of units.

ESO/F. Carrasco (Chepox)

The first delivery of 18 ELT primary mirror segments arrives at Paranal from Europe in January 2024.

Once they are installed, all 798 segments will be kept in the ideal shape to act as one single mirror — a process called phasing — by a phasing and diagnostic station (PDS) that will test the telescope before and during operation. The PDS was designed and is being manufactured internally at ESO. Its optics are being produced and delivered, and a mock-up of the welded mechanical structure has been produced for evaluation.

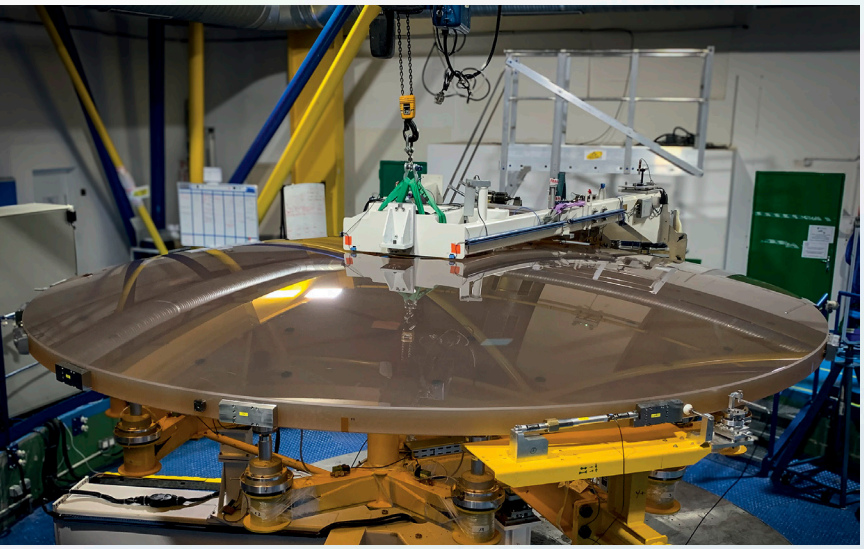
G. Hüdepohl (atacamaphoto.com)/ESO

Working on an ELT M1 segment assembly before mirror coating.

ESO/F. Carrasco (Chepox)

The reflectivity of a newly coated ELT mirror segment is checked.

M2 mirror and M3 mirror



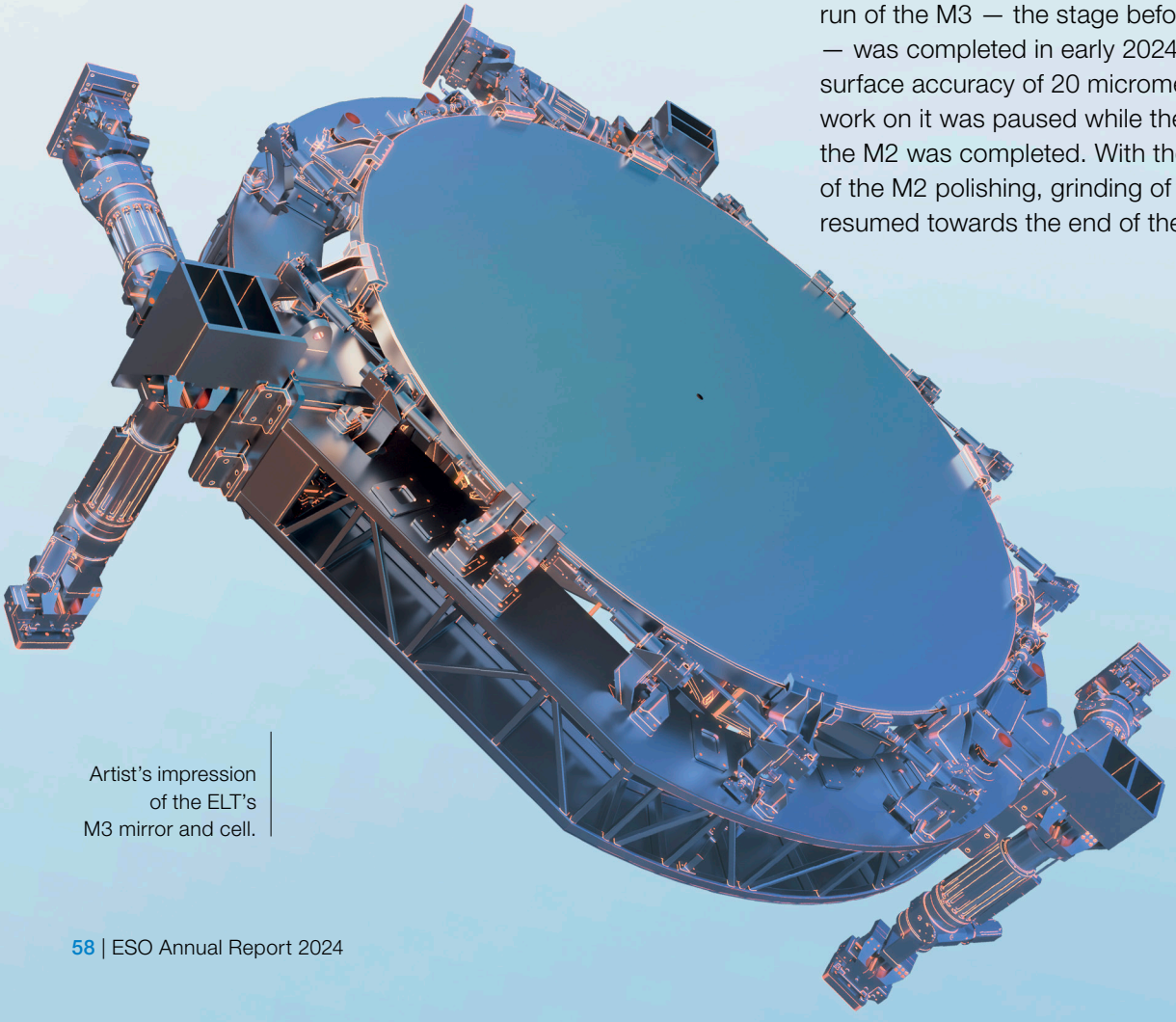
Safran

Testing the polished ELT M2 mirror.

The ELT's secondary mirror is the largest convex mirror ever produced. It will reflect light collected by M1 to the tertiary mirror M3, a concave mirror similar in size to M2. The three curved mirrors will allow the ELT to deliver a better image quality over a larger field of view than would be possible otherwise.

The polishing of the M2 mirror was completed in July 2024, reaching an impressive surface accuracy of just a few tens of nanometres. The mirror shows excellent optical performance, even exceeding most of the requirements. For such a challenging mirror design, this is an outstanding result.

The M3 mirror is being produced in the same facility as the M2. The second grinding run of the M3 — the stage before polishing — was completed in early 2024, reaching a surface accuracy of 20 micrometres, before work on it was paused while the polishing of the M2 was completed. With the completion of the M2 polishing, grinding of the M3 resumed towards the end of the year.



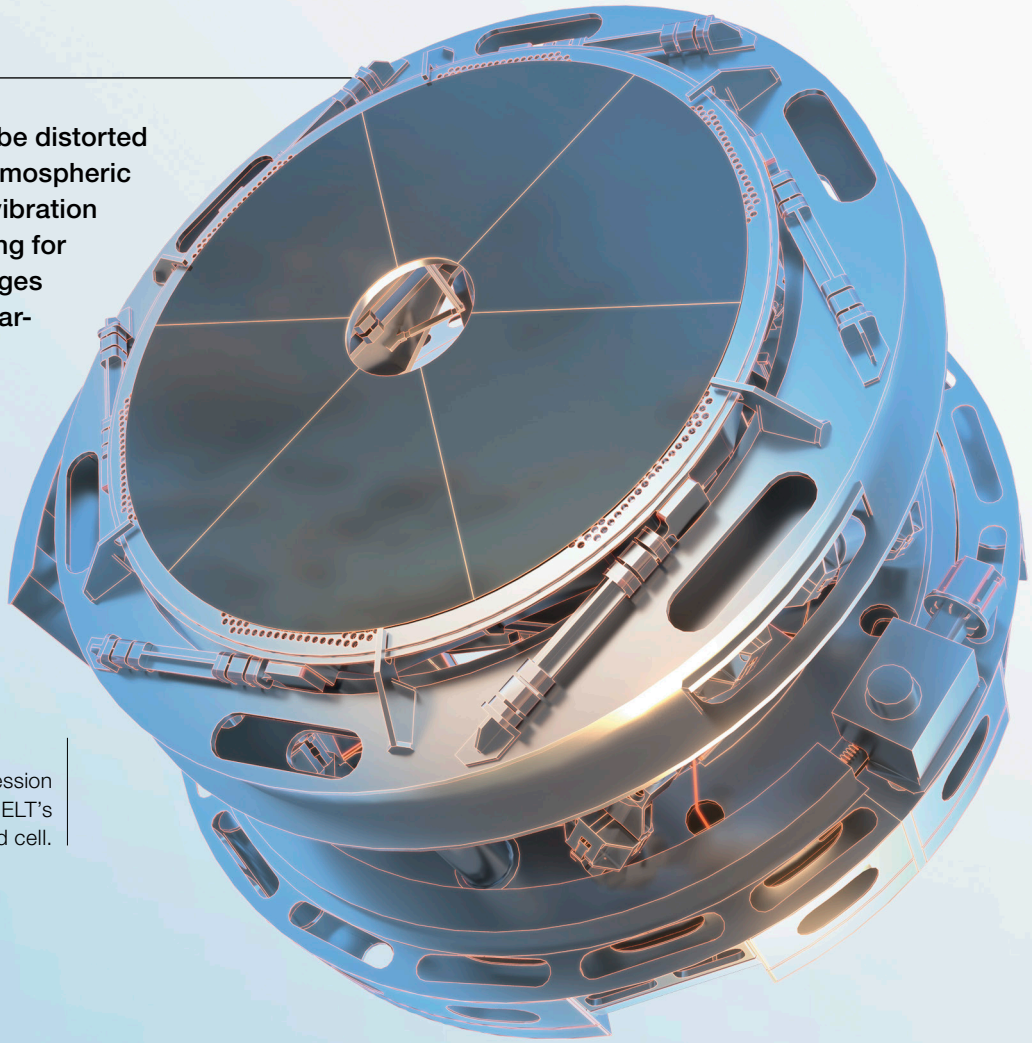
Artist's impression of the ELT's M3 mirror and cell.

Sener

Integration of the dummy ELT M2 mirror on the M2 support cell.

M4 mirror

The M4 mirror's surface can be distorted and adapted to correct for atmospheric turbulence and the residual vibration of the telescope itself, allowing for the delivery of the sharp images needed for science. It is the largest deformable mirror ever made.

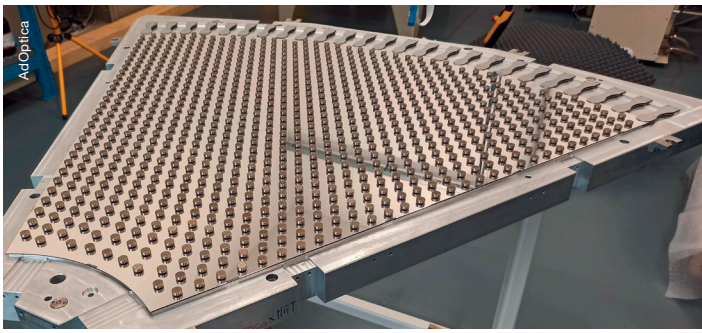


Artist's impression of the ELT's M4 mirror and cell.

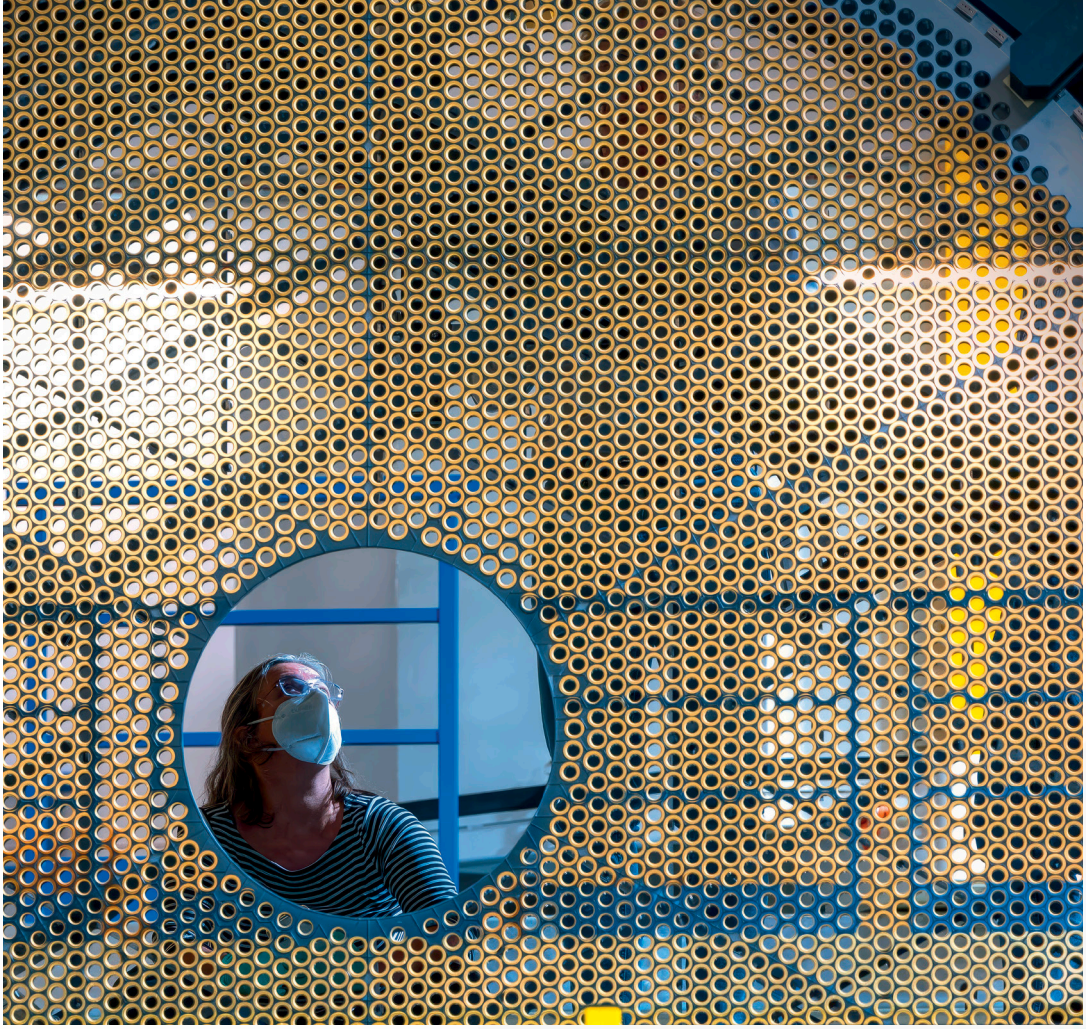
The mirror is an assembly of six thin shells, or petals, made of the low-expansion glass-ceramic ZERODUR®. Each shell is only 1.95 mm thick, allowing about 5000 voice-coil actuators to push and pull the entire mirror like the surface of a loudspeaker, adjusting its shape up to 1000 times per second.

Inspecting one of the ELT M4 mirror shells.

A reference body made of silicon carbide, a material with exceptional mechanical and thermal stability, provides a rigid and accurate flat surface onto which the actuators are mounted. To control the actuators, capacitive sensors track the mirror's position relative to the reference body, to an accuracy of a few tens of nanometres, 70 000 times per second. Part of each sensor is a conductive tile, made of borosilicate glass, bonded to the reference body. In 2024 the bonding of these tiles — about 5000 of them, one for each actuator — was completed. The rest of the M4 mirror support, including the mirror cell, was also integrated during the year, making it ready for initial tests without the mirror petals, which are currently in storage.



An ELT M4 mirror shell, after integration of the magnets which form part of the voice-coil actuators that will adjust its shape.

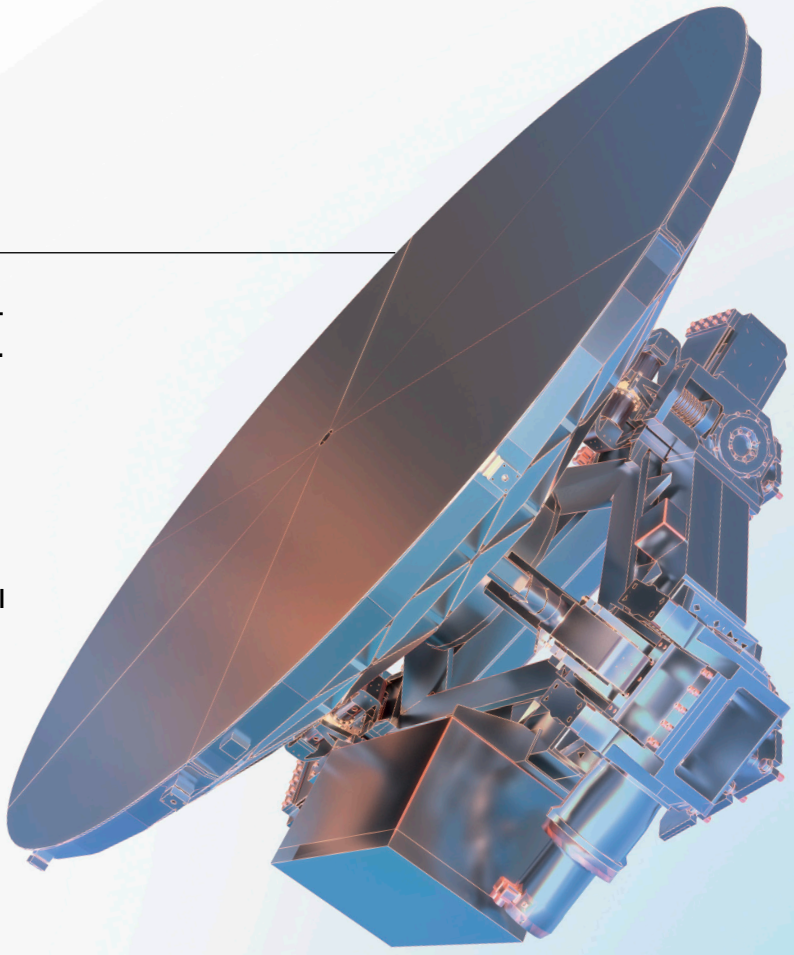


Sandro Rizzetto, AdOptica

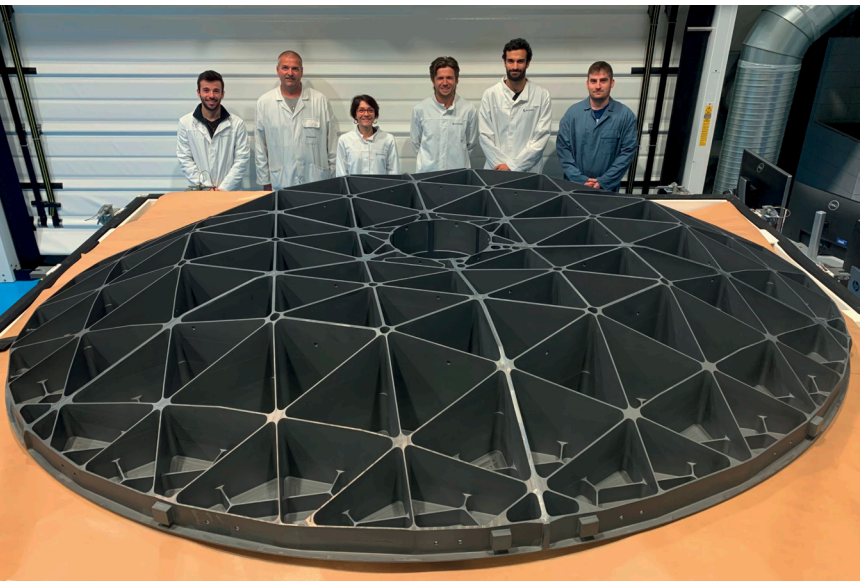
The ELT M4 mirror reference body.

M5 mirror

Together with M4, M5 is a crucial component of the ELT's adaptive optics system. Its precise tip and tilt movements will ensure images are stabilised before they reach the ELT instruments. The mirror therefore must be very light and very rigid, and will be made of silicon carbide, a material with exceptional mechanical and thermal stability. M5 will be a flat, elliptical mirror measuring 2.7 by 2.2 metres, constructed from six lightweight 'petal' segments brazed together. It will be the biggest tip-tilt mirror ever employed in a telescope.



Artist's impression of the ELT's M5 mirror.



Safran Reosc

The ELT M5 mirror blank, comprising six ‘petals’ brazed together, is seen here from the reverse side.

2024 saw multiple milestones in the development of M5. The M5 blank — the shaped piece of material that will be polished to become the mirror — was accepted from the subcontractor and delivered to the polisher.

Next, it will be polished to an accuracy of less than a hundredth of the width of a human hair.

Such a large silicon-carbide mirror, with such strict polishing requirements, has never been produced before, and several risks remain during the process.

To mitigate these risks and avoid potential delays, a smaller, backup mirror will be made from glass-ceramic, a material that has been used in astronomical telescopes for decades. This ‘M5 commissioning mirror’ will not demonstrate all the adaptive optics capabilities of the ELT, but it can be used to start commissioning the telescope if the silicon carbide M5 is not yet ready.

The manufacture of this mirror blank was completed at the end of 2024. The first call for tender for polishing, held in 2023, was unsuccessful but a second call for tender

Laser guide stars

The ELT is designed to use up to eight laser guide stars for its adaptive optics systems, with an initial complement of six.

The laser guide star units are being manufactured in a combined procurement with the GRAVITY+ project: six for the ELT and three for GRAVITY+. The final two of the nine laser light sources were delivered to ESO in 2024.

Each laser source will be combined with a projection subunit, which expands the laser beam to a diameter of 30 cm and directs it into the sky through a launch telescope. The first of the nine projection subunits has been assembled and was undergoing testing at the ESO headquarters at the end of 2024.

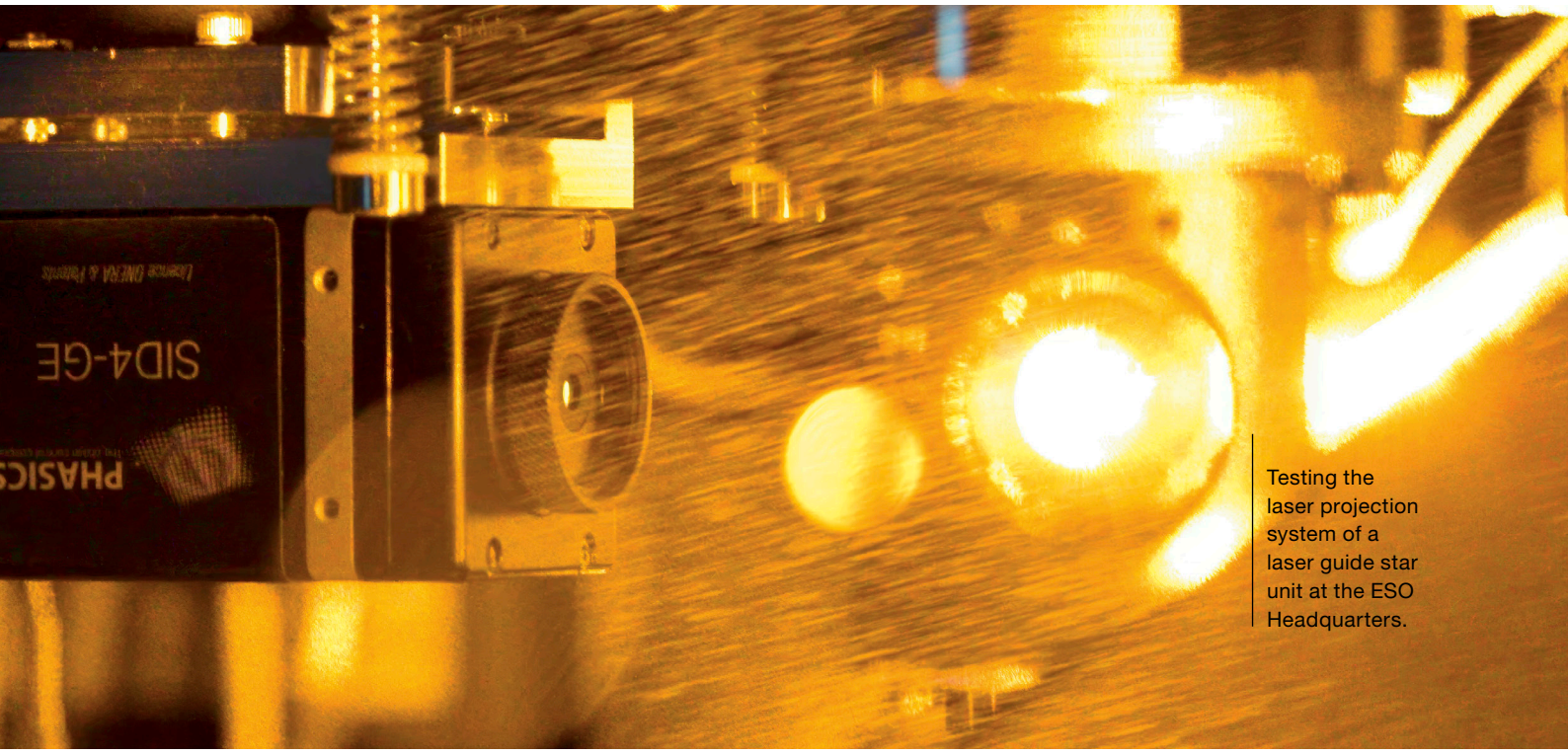
led to a successful contract signature in June 2024 for this next step.

A further risk mitigation is the production of a spare silicon-carbide M5 blank. The final, sixth, petal for this spare was manufactured during 2024.

Another milestone from 2024 was the completion of the M5 mirror support cell, following successful testing. The cell's tip-tilt mechanism will adjust the angle of the mirror with very high accuracy (a few tens of milliarcseconds), up to ten times per second.

The completed cell was transported to ESO Garching, where it was integrated with the telescope control system, for further testing and tuning with a dummy mirror.

The ELT M5 mirror support cell, with a dummy mirror, ready for testing and tuning at ESO Garching.



Testing the laser projection system of a laser guide star unit at the ESO Headquarters.

Instruments for the ELT

MICADO

MICADO, the Multi-AO Imaging Camera for Deep Observations, is a near-infrared camera that will take high-resolution images of the Universe, making it ideal for identifying exoplanets, and also for resolving individual stars in other galaxies and investigating the centre of the Milky Way.

Artist's impression of the ELT instrument MICADO.

The multi-stage Final Design Review process for MICADO was successfully completed, with a final review meeting in July 2024, followed by a series of splinter meetings, and formal announcement of this major milestone in September 2024.

Approval to go ahead with many major components of MICADO had already been given, allowing manufacture and procurement of these to proceed while the rest of the review was completed. For example, the instrument's vacuum vessel was accepted from the manufacturer in May 2024 and is now being fitted with its cryogenic hardware. This vessel will keep MICADO's optics and detectors cold so they can work effectively at near-infrared wavelengths.

With the formal completion of the review, the MICADO team is now fully focused on manufacturing and testing the instrument.

Read more about MICADO, including consortium members, at https://elt.eso.org/instrument/MICADO/

MICADO Consortium

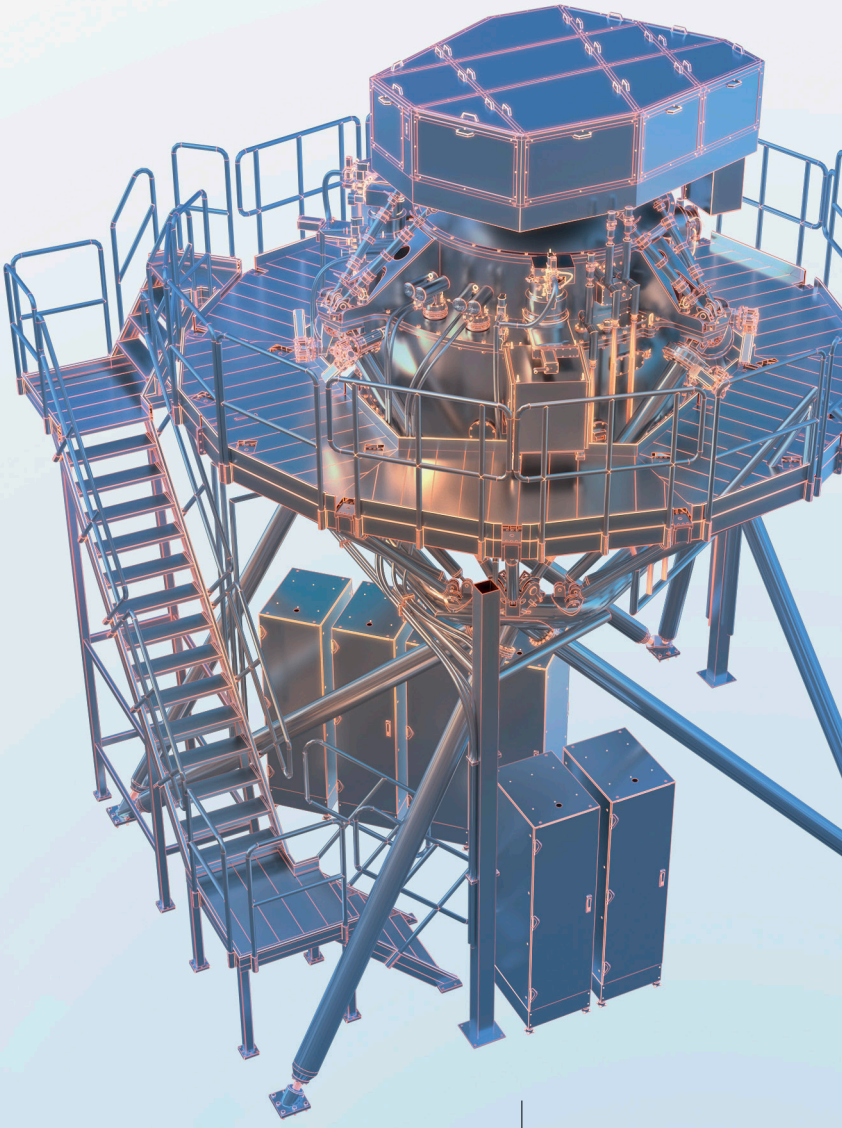
METIS

METIS — the Mid-infrared ELT Imager and Spectrograph — combines a powerful spectrograph and a high-contrast imager, both operating in the infrared. This two-in-one instrument will allow astronomers to study a wide range of science topics, from objects in our Solar System to distant active galaxies.

After the Final Design Review meetings, which took place between November 2022 and November 2023, the completion of the critical actions — including successful prototyping — allowed the formal closure of the review in May 2024. While some key parts of METIS had already been procured and tested, such as the cryostat, this major milestone clears the way for the instrument to move fully into the manufacturing phase.

An engineering model of ESO's NGCII detector controller was made available and used successfully for adaptive-optics testing. A new GeoSnap detector was ordered for the longer wavelength range of METIS's imager, because the previous one was not fulfilling the science requirements. It is currently being manufactured.

Read more about METIS, including consortium members, at https://elt.eso.org/instrument/METIS/

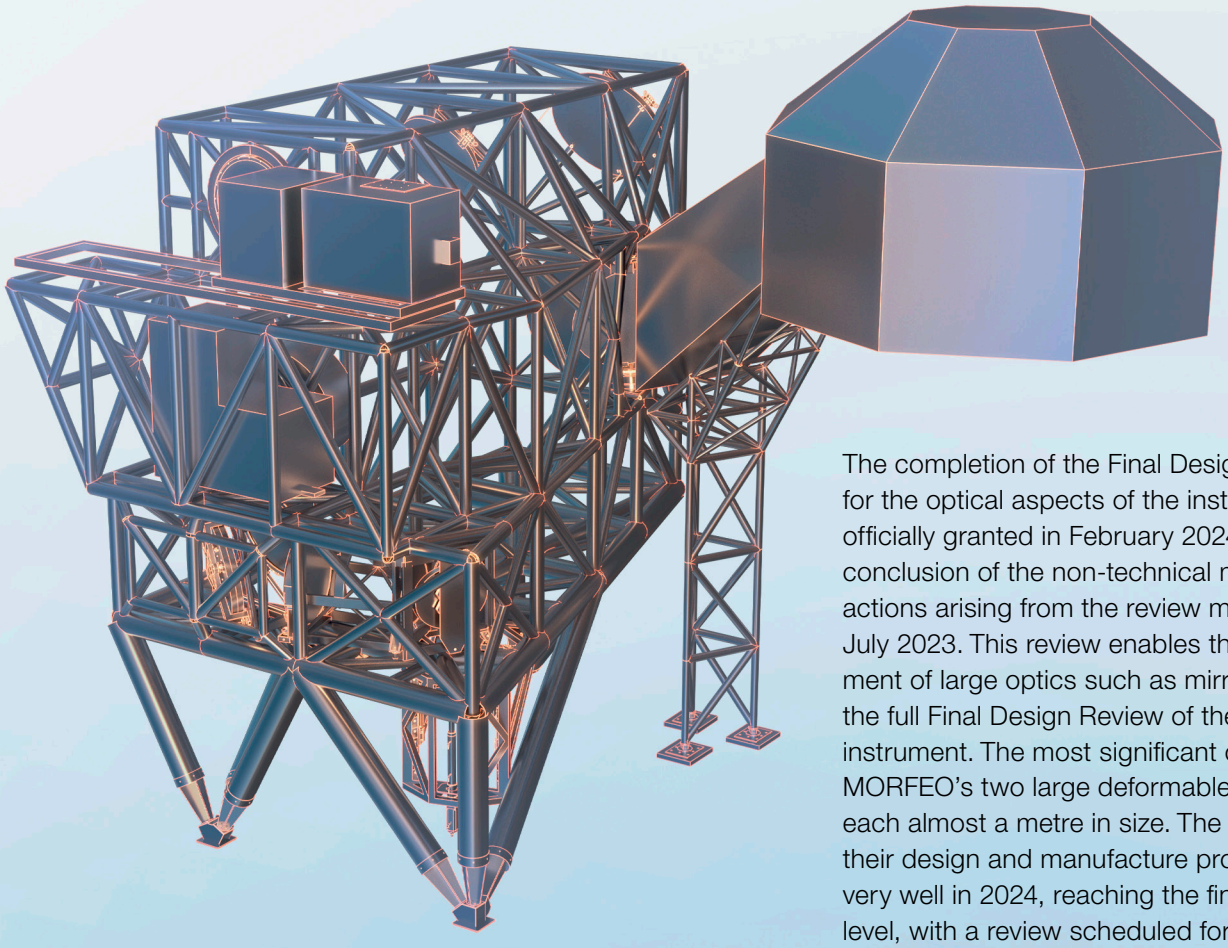


Artist's impression of the ELT instrument METIS.

Facing page: Vacuum testing of the MICADO cryostat.

MORFEO

MORFEO, the Multiconjugate adaptive Optics Relay For ELT Observations, is a unique instrument that will not make observations itself. Instead, it is an adaptive-optics module which, by further correcting for the blurring effect of Earth's atmosphere, will enable other instruments to take exceptional images and spectra.



Artist's impression of the ELT instrument MORFEO.

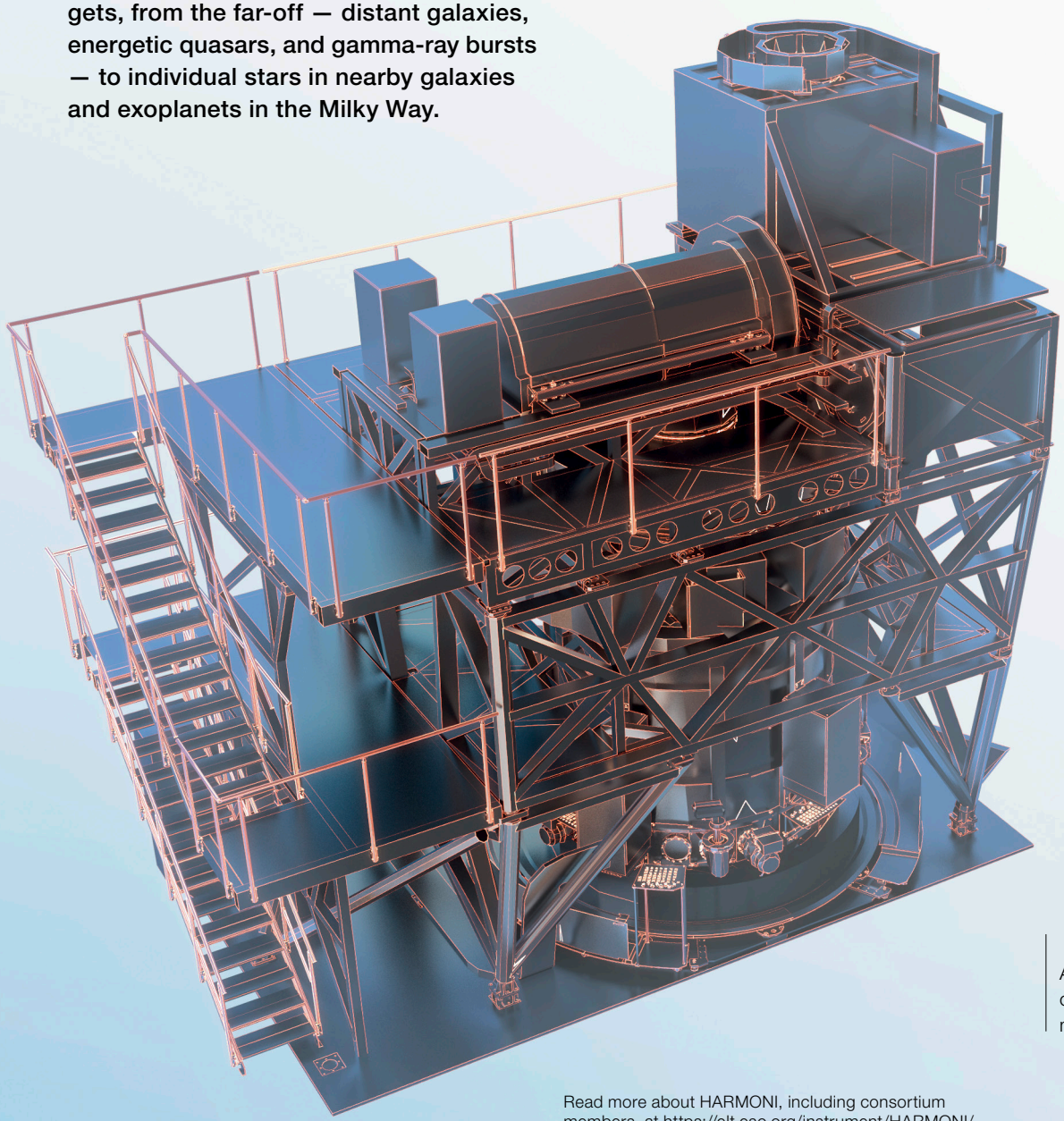
The completion of the Final Design Review for the optical aspects of the instrument was officially granted in February 2024, after the conclusion of the non-technical managerial actions arising from the review meeting in July 2023. This review enables the procurement of large optics such as mirrors, before the full Final Design Review of the entire instrument. The most significant of these are MORFEO's two large deformable mirrors, each almost a metre in size. The contract for their design and manufacture progressed very well in 2024, reaching the final design level, with a review scheduled for early 2025.

Read more about MORFEO, including consortium members, at https://elt.eso.org/instrument/MORFEO/

HARMONI

HARMONI, the High Angular Resolution Monolithic Optical and Near-infrared Integral field spectrograph, is a work-horse 3D-spectrograph that will disperse the visible and near-infrared light from astronomical objects into its component wavelengths, allowing astronomers to study many different astronomical targets, from the far-off — distant galaxies, energetic quasars, and gamma-ray bursts — to individual stars in nearby galaxies and exoplanets in the Milky Way.

Following the lifting of the red flag for the HARMONI project at the end of 2023, further restructuring, both technical and managerial, took place throughout 2024, and was ongoing at the end of the year, to reduce risks and to ensure a viable way forward for the construction of the instrument.



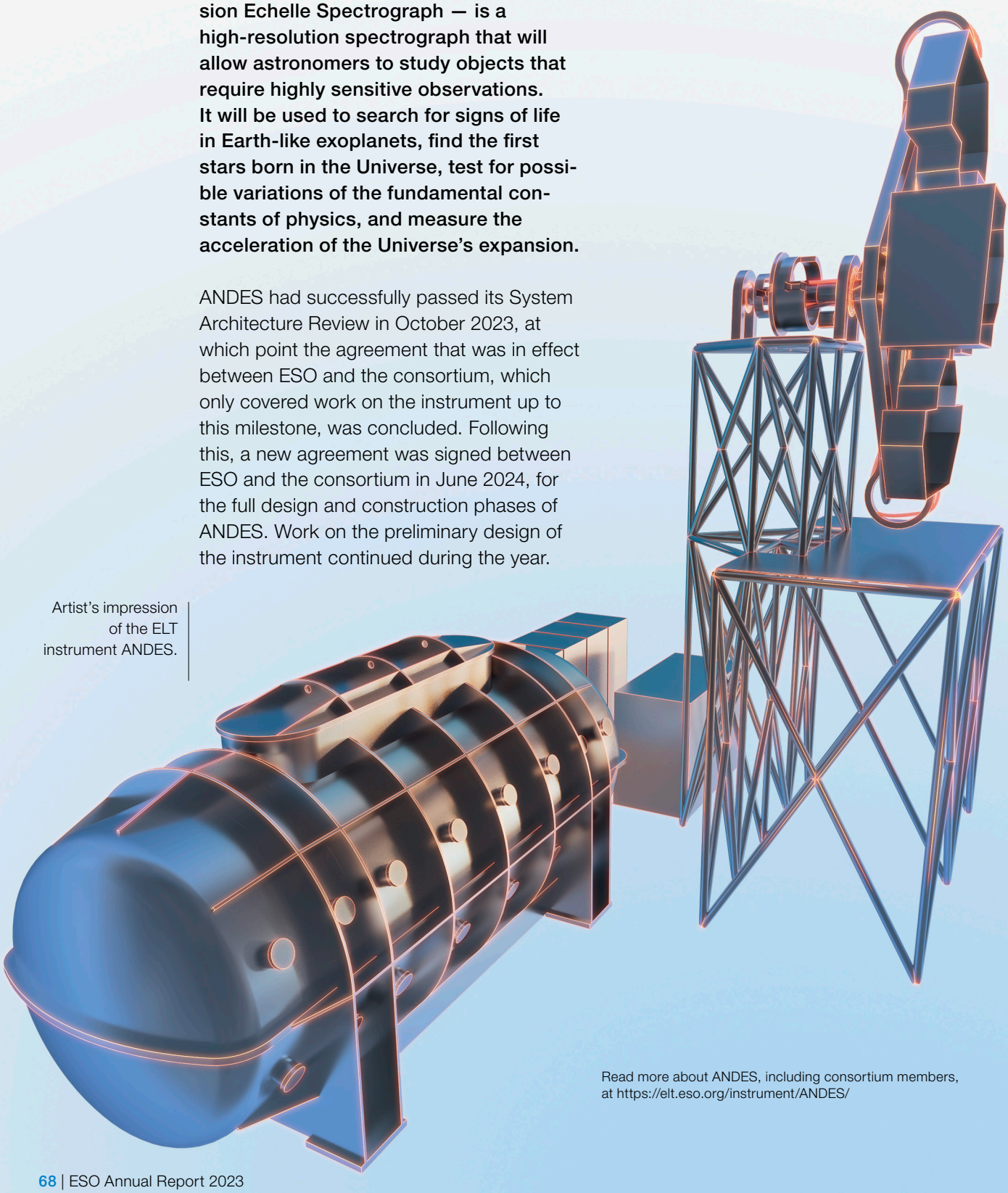
Artist's impression of the ELT instrument HARMONI.

Read more about HARMONI, including consortium members, at https://elt.eso.org/instrument/HARMONI/

ANDES

ANDES — the ArmazoNes high Dispersion Echelle Spectrograph — is a high-resolution spectrograph that will allow astronomers to study objects that require highly sensitive observations. It will be used to search for signs of life in Earth-like exoplanets, find the first stars born in the Universe, test for possible variations of the fundamental constants of physics, and measure the acceleration of the Universe's expansion.

ANDES had successfully passed its System Architecture Review in October 2023, at which point the agreement that was in effect between ESO and the consortium, which only covered work on the instrument up to this milestone, was concluded. Following this, a new agreement was signed between ESO and the consortium in June 2024, for the full design and construction phases of ANDES. Work on the preliminary design of the instrument continued during the year.



Artist's impression of the ELT instrument ANDES.

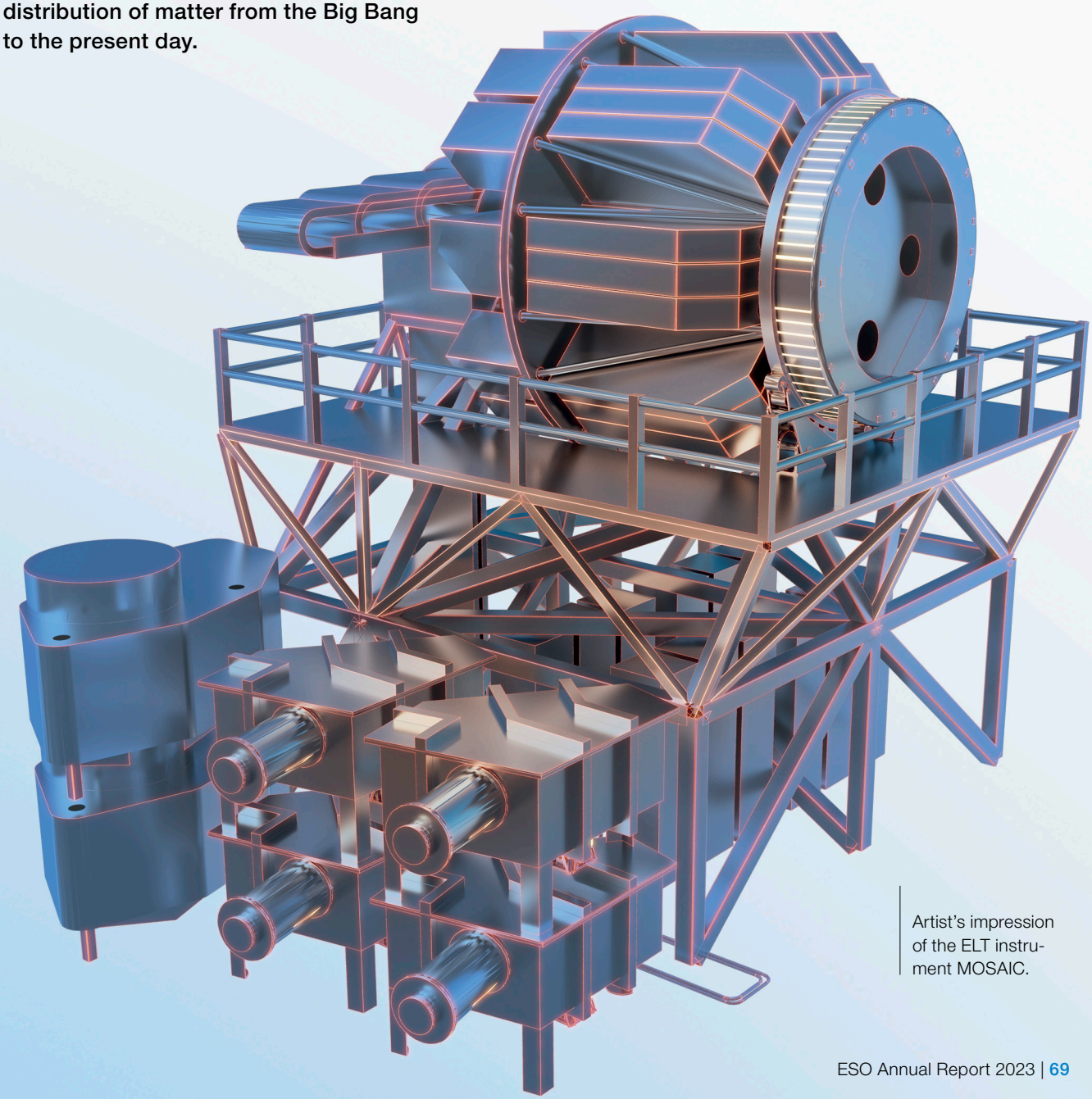
Read more about ANDES, including consortium members, at https://elt.eso.org/instrument/ANDES/

MOSAIC

MOSAIC is a multi-object spectrograph, operating at visible and infrared wavelengths, that will allow astronomers to observe more than one hundred targets simultaneously. By studying the light of objects from stars at the heart of the Milky Way to the most distant galaxies at the very edge of the observable Universe, MOSAIC will enable astronomers to trace the growth of galaxies and the distribution of matter from the Big Bang to the present day.

During 2024 the MOSAIC team made good progress on the definition of the instrument architecture, focusing on the consolidation of the requirements and the conceptual design, in preparation for the future System Architecture Review.

Read more about MOSAIC, including consortium members, at https://elt.eso.org/instrument/MOSAIC/



Artist's impression of the ELT instrument MOSAIC.

La Silla Paranal Observatory

La Silla Paranal is the unified observatory through which ESO operates telescopes at three sites in northern Chile.

The flagship Paranal site is the home of ESO's VLT, VLTI, and the VISTA survey telescope. La Silla, ESO's first observatory site, is the home of ESO's 3.6-metre telescope and the New Technology Telescope. ESO also supports a number of hosted telescopes at both Paranal and La Silla, and hosts and operates the APEX telescope at Chajnantor.

Paranal will also be responsible for the operation of the ELT on the nearby Cerro Armazones, and the southern array of the Cherenkov Telescope Array Observatory (CTAO), on the Paranal site.

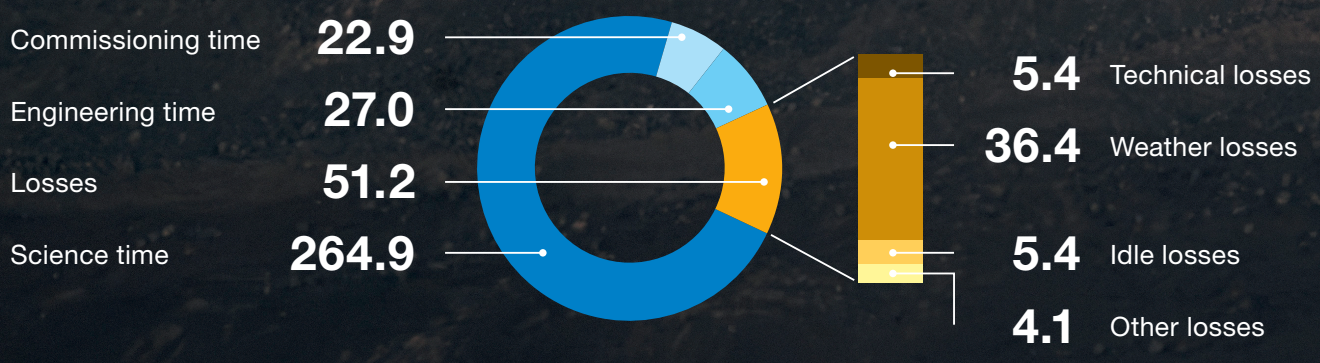
ESO/VPHAS+ team. Acknowlegement: CASU

The Gum 41 nebula, seen here in observations made with the VLT Survey Telescope at Paranal, is a shell of hydrogen gas atoms made to glow by the radiation of the central star HD 100099.

Operational statistics

Telescope time usage and losses in nights – Paranal

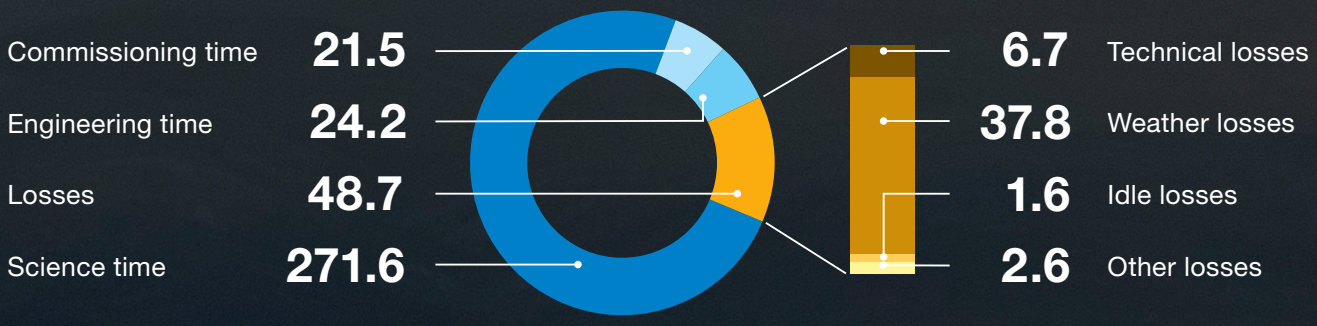
UT1



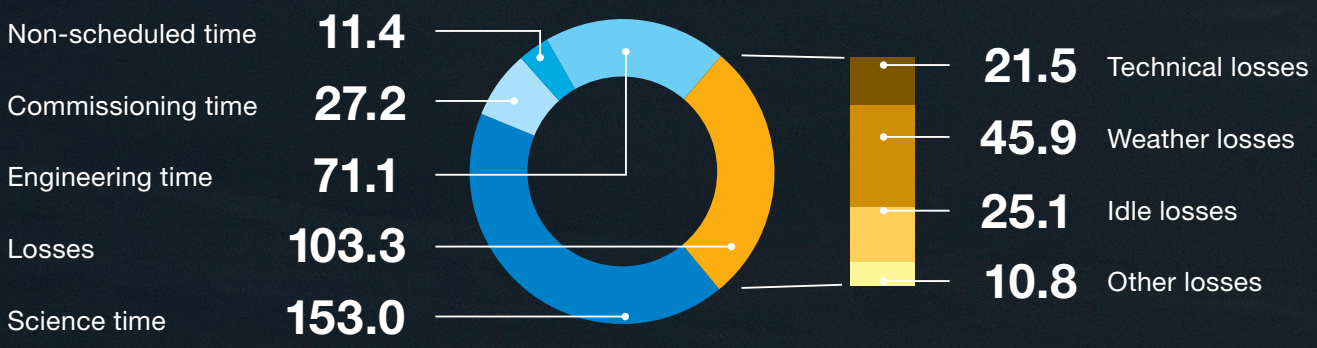
Y. Beletsky (LCO)/ESO

UT2

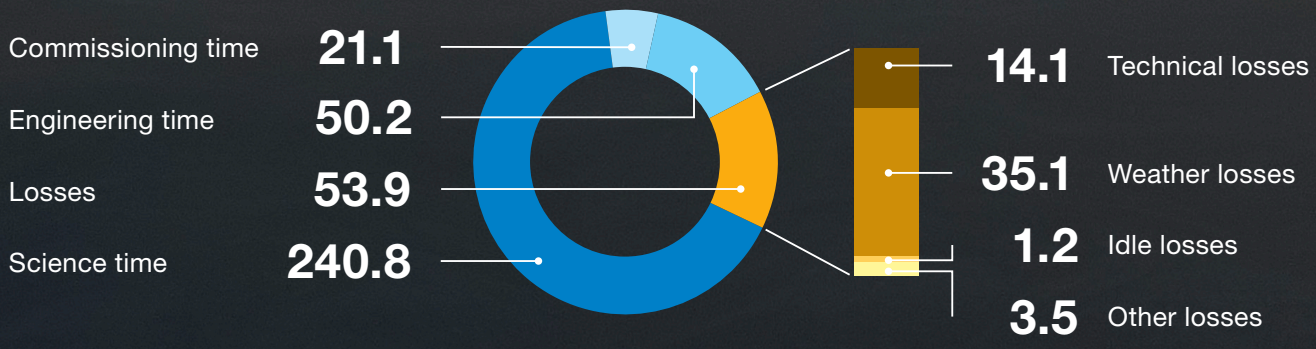
UT3


Commissioning time 21.5
Engineering time 24.2
Losses 48.7
Science time 271.6
6.7 Technical losses
37.8 Weather losses
1.6 Idle losses
2.6 Other losses

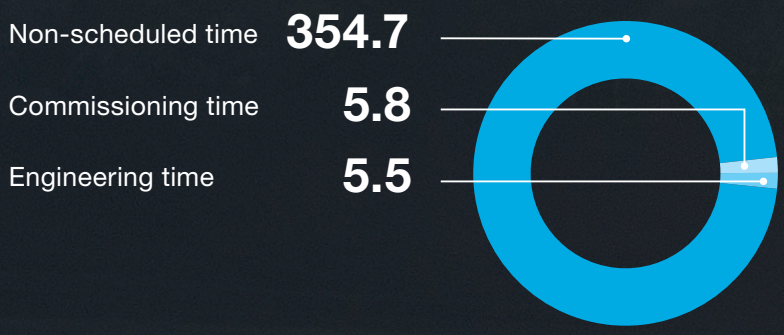
VLTI


Non-scheduled time 11.4
Commissioning time 27.2
Engineering time 71.1
Losses 103.3
Science time 153.0
21.5 Technical losses
45.9 Weather losses
25.1 Idle losses
10.8 Other losses

UT4

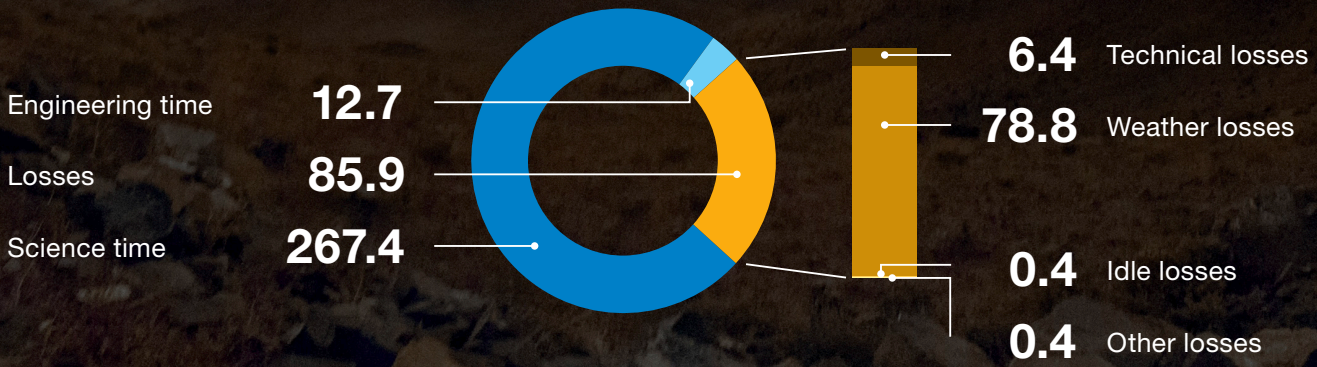

Commissioning time
21.1
Engineering time
50.2
Losses
53.9
Science time
240.8
14.1
Technical losses
35.1
Weather losses
1.2
Idle losses
3.5
Other losses

VISTA


Non-scheduled time
354.7
Commissioning time
5.8
Engineering time
5.5

Telescope time usage and losses in nights – La Silla

3.6-metre telescope



ESO/P. Horálek

Paranal

At 2600 metres above sea level in Chile's Atacama Desert, ESO's Paranal Observatory is one of the very best astronomical observing sites in the world. It is home to several world-class telescopes: ESO's VLT, VLTI, and VISTA survey telescope, as well as several telescopes hosted by ESO. There are also observatory support facilities, including the Paranal Residencia.

ESO's ELT will be operated from Paranal, and the ELT Technical Facility is located here. The southern array of the Cherenkov Telescope Array Observatory (CTAO) will also be located on ESO's Paranal site and operated by ESO.

About VLT and VLTI

ESO's Very Large Telescope (VLT) consists of four Unit Telescopes (UTs) with main mirrors of 8.2 metres diameter and four movable 1.8-metre-diameter Auxiliary Telescopes (ATs). The Unit Telescopes can observe individually, with a suite of advanced instruments capable of a wide range of scientific applications at visible and infrared wavelengths.

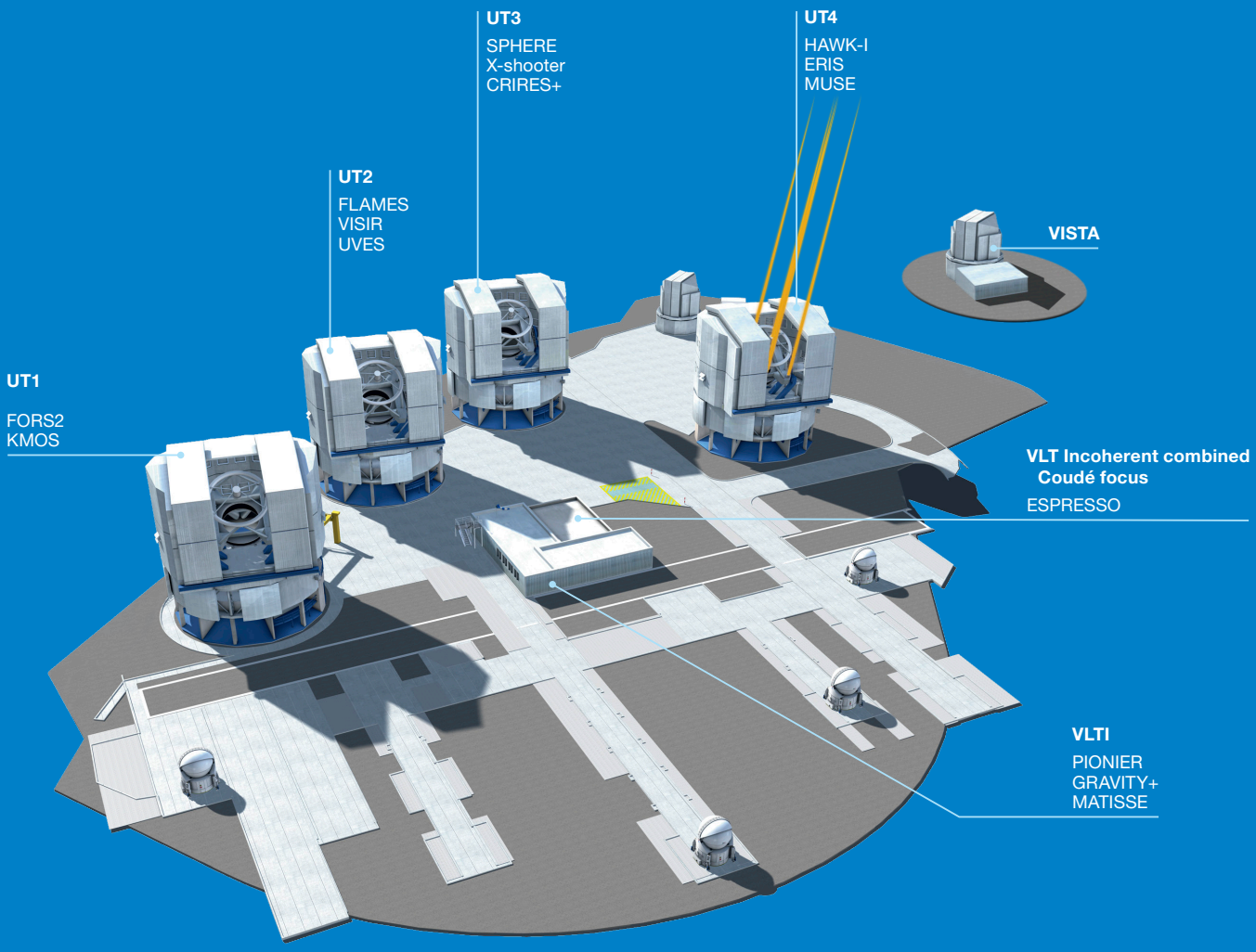
UT4 is an adaptive optics telescope, with four laser guide stars and a deformable secondary mirror, allowing it to correct for the distortions caused by the Earth's atmosphere.

The VLTI (VLT Interferometer) combines the light from either the four UTs or the four ATs using a technique called interferometry, allowing the combined telescopes to act like a single telescope as large as the distance between them.

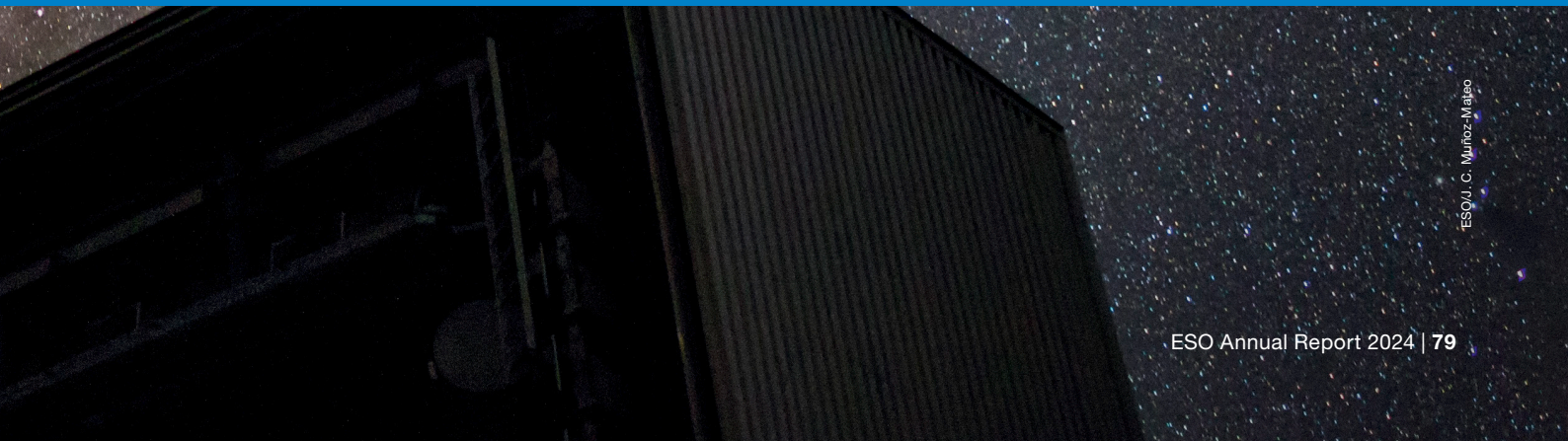
This lets astronomers make observations, using dedicated interferometric instruments, with much finer resolution than would be possible with a single UT.

About VISTA

The Visible and Infrared Survey Telescope for Astronomy (VISTA) is a survey telescope, whose 4.1-metre-diameter mirror and wide field of view allow it to map wide areas of the sky quickly, creating atlases and catalogues of objects that can be further studied with telescopes such as the VLT and VLTI.



Instruments in operation on the VLT, VLTI, and VISTA, as of the end of 2024.



ESO/J. C. Muñoz-Mateo

Operations, infrastructure, upgrades

Periscope fix boosts ERIS performance

The Enhanced Resolution Imager and Spectrograph (ERIS) is a near-infrared instrument on UT4 that provides diffraction-limited observations via the telescope's adaptive optics facility. After ERIS started operations in 2023 several technical issues were identified, but thanks to the joint effort of ESO staff and the ERIS consortium the performance and stability of the instrument, which was already working well and producing excellent adaptive optics observations in 2023, continued to improve in 2024.

ERIS is equipped with a periscope that moves around the field of view to select a natural guide star, which is tracked during the observations as part of the adaptive optics correction. The periscope had suffered from intermittent failures, which were very disruptive for nighttime operations, wasting valuable telescope time recovering and resuming the interrupted observations. After an unsuccessful attempt to fix this early in 2024, a change to the periscope's control parameters in October 2024 eliminated failures during the night.

Thanks to this and other improvements, the completion rate of ERIS observing programmes was close to 100% in Period 113 (April–September 2024), a notable increase from less than 80% a year before.

ERIS AO Periscope Failures

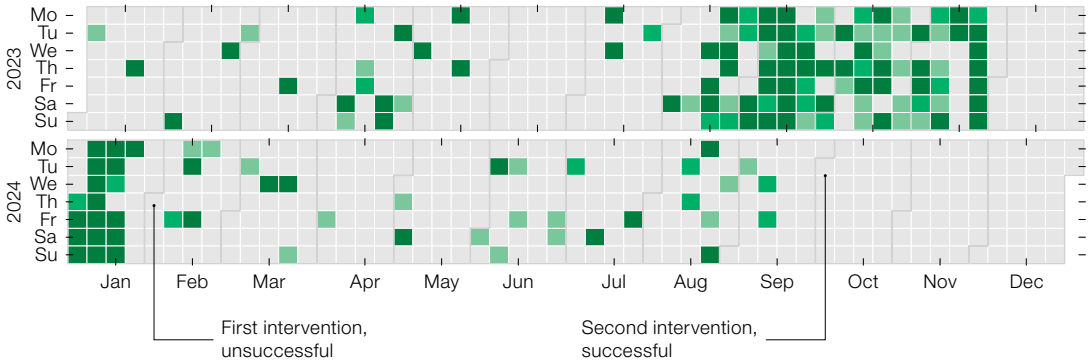
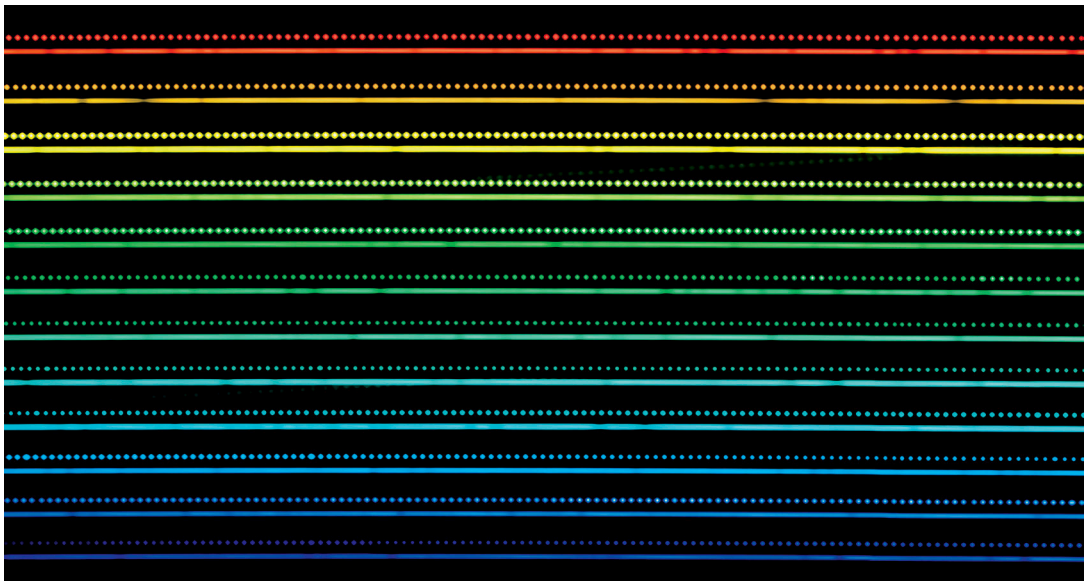


Chart showing the occurrence of ERIS periscope failures in 2023 and 2024 (darker shades of green indicate more failures). The attempted fix in early 2024 and the successful fix in October are marked.

ESPRESSO Laser Frequency Comb available for science observations



A laser frequency comb (LFC) is used for highly accurate wavelength calibration. The continuous lines are a scientific spectrum, here of a star. The LFC produces the adjacent spots, at regularly spaced and very well-defined wavelengths, which are used for comparison.

ESPRESSO, the Echelle SPectrograph for Rocky Exoplanets and Stable Spectroscopic Observations, is an ultra-stable, high-resolution spectrograph at the VLT. One of its key science goals is investigating whether certain fundamental constants, such as the charge on the electron or the speed of light, change with cosmic time. This requires an extremely accurate wavelength calibration that isn't possible with classical methods.

Traditional calibration lamps produce light at specific wavelengths, also known as emission lines, which can be used as a reference. However, they produce only a few emission lines, which are widely separated in wavelength. Moreover, the exact wavelengths of these lines cannot be fully anchored to fundamental physics. To allow more accurate wavelength calibrations, ESPRESSO is equipped with a Laser Frequency Comb (LFC) that creates an array of regularly spaced emission lines with very well-defined wavelengths — a highly accurate spectral ruler.

The performance of ESPRESSO's LFC has unfortunately been unstable since the instrument began operations in 2022. In 2024 this instability was traced to a damaged optical fibre in the unit that ensures the light from the LFC evenly illuminates the spectrograph in ESPRESSO. This faulty fibre was replaced by ESO staff and the manufacturer of the LFC. The brightness of the LFC emission lines has increased by about an order of magnitude, and the LFC was brought back to regular science operations in December 2024.

Progress with the Integrated Operations Programme

The Integrated Operations (IOP) Programme aims to make Paranal Observatory fit for the future joint operations of the VLT and the ELT. Its goal is to deliver an operations model that is lean, efficient and sustainable in the 2030s and beyond. The programme is currently in its consolidation phase, following a successful Phase A review in 2023.

In 2024 the IOP Programme developed a first version of the '24-hours operation plan', to plan the staffing levels and roles in different sites under the future operations model. There was also progress with the definition of maintenance processes for the ELT's dome and main structure and the ELT Technical Facility, where the mirrors are recoated.

All maintenance activities at Paranal are handled by a Computerised Maintenance Management System (CMMS), and in December 2024 the IOP Programme finalised the first version of the future data model for this system, which describes the data elements and how they relate to each other. A viewer tool for the ELT's Building Information Model, which contains a digital representation of every component of the ELT, has already been integrated into the CMMS.

Upgrades for GRAVITY+

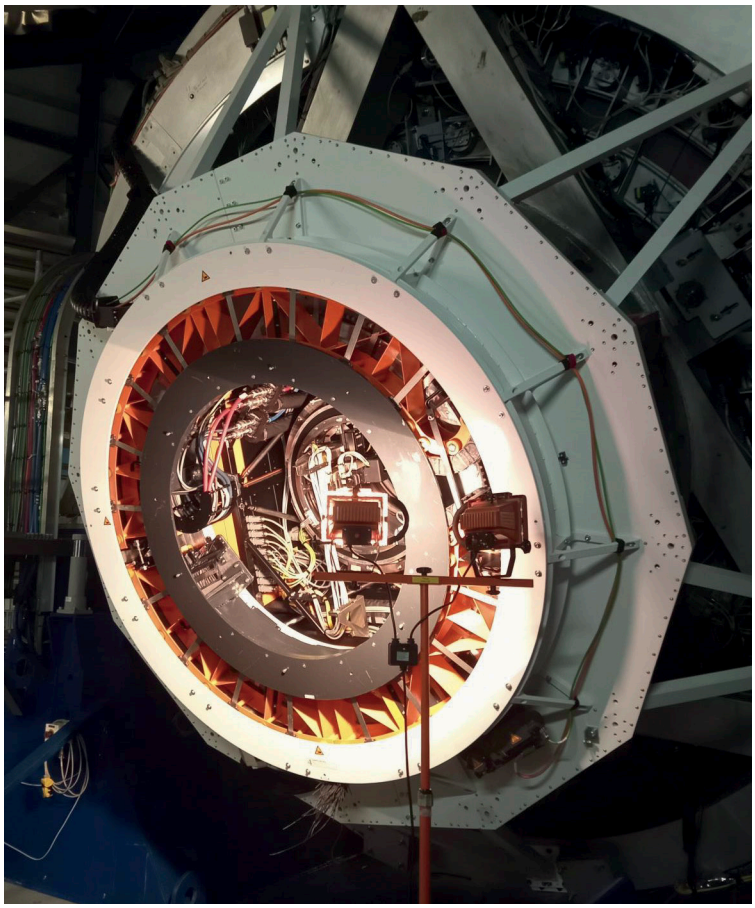
The GRAVITY+ project consists of a series of upgrades that enhance the capabilities of the GRAVITY instrument at the VLTI. GRAVITY uses bright reference stars close to the science target for 'fringe tracking' — stabilising the optical path lengths to each of the VLTI telescopes. GRAVITY+ will be able to use reference stars further away from the target, enabling observations across more of the sky. Thanks to improved adaptive optics technology it will also be able to observe fainter targets.

In 2024 staff from Garching and Paranal installed and commissioned the Beam Compressor Differential Delay Lines, which perform additional fine corrections to the optical paths of the light coming from the telescopes and compress the beams of light before they enter the instrument. The new GRAVITY+ natural guide star adaptive optics mode was commissioned; ESO engineers provided extensive support in areas including software, optics, instrumentation and mechanics. Finally, we also decommissioned the old MACAO adaptive optics system.

Getting VISTA ready for 4MOST

4MOST is a visible-light multi-object spectrograph that will be installed at VISTA. Using thousands of optical fibres, it will be able to obtain the spectra of about 2400 objects simultaneously within a field of view of 4.2 square degrees. Unlike most other instruments at Paranal, installing 4MOST at VISTA requires a significant upgrade of the telescope itself, and 2024 has seen significant progress on this front, with Paranal and Garching staff providing mechanical, control and optical engineering support throughout.

The platform that will be used to install the instrument's spectrographs has been fabricated, and it was temporarily installed on the telescope for testing. Two components were also installed that are key to ensuring optimal image quality across the field of view: the wide-field and atmospheric dispersion corrector, and the acquisition and guiding wavefront sensors. The Focal Surface Test Tool, used to verify the telescope's pointing accuracy and optical quality, and the M2 baffle, that will prevent background light from entering the fibres, were also put in place. After these upgrades the recommissioning of the telescope began in late November 2024.



The new cable wrap and adapter-rotator for 4MOST, installed on VISTA.

UT4's deformable secondary mirror exchanged for the first time

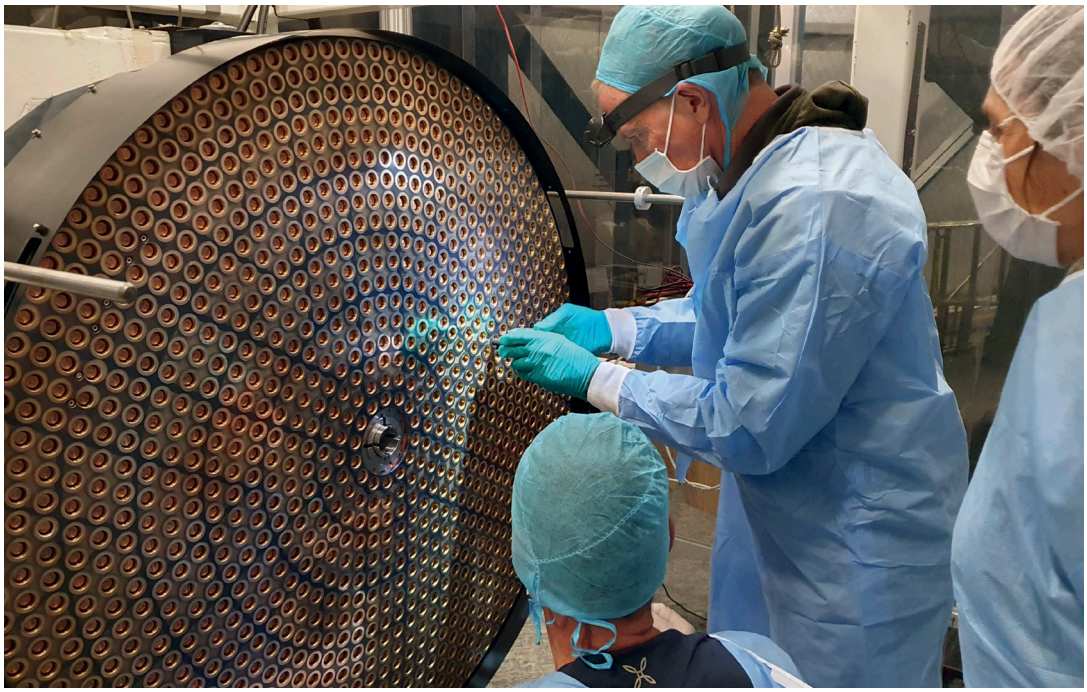
UT4 has a deformable secondary mirror that provides adaptive optics capabilities to the telescope's instruments. It has undergone a few maintenance cycles since it was installed in 2016, but the reflective shell of the mirror had never been exchanged.

The shell is a flexible membrane of ZERODUR®, 1.12 m across but just 2 mm thick, mounted on a reference body. The shell's shape is adjusted by 1170 voice-coil actuators on the reference body, each controlling a magnet attached to the back of the shell. Capacitive sensors accurately measure the separation between the shell and the reference body.

The performance of these sensors was reduced after an incident with condensation and small coolant leaks in 2023 that contaminated the back of the shell.

The shell is also so delicate that during regular operation it can only be cleaned gently with CO_2 'snow', despite which dust slowly accumulates, reducing the mirror's reflectivity.

To address these reductions in performance, the shell was replaced with a spare, which had never been used and had a clean coating. The replacement was also an opportunity for general maintenance of the electromechanics and software. The old shell will be recoated to become a fresh spare, but it is hoped that it will not be needed for at least another decade.



Working on the exchange of the deformable secondary mirror of the VLT's Unit Telescope 4.

Forthcoming instruments

The ESO community, in close collaboration with teams of engineers, scientists and other staff at ESO, is deeply involved in the Paranal Instrumentation Programme, which develops and delivers new instruments for the telescopes. Most projects are delivered by collaborations between research institutes in the Member States and ESO in return for Guaranteed Time Observations.

In 2024 the new combined Instrumentation Programme was put in place. It is responsible for the delivery of all the new optical and infrared instruments for Paranal and La Silla (formerly under the Paranal Instrumentation Programme), and for the ELT (formerly under either the ELT Construction Programme or the Armazones Instrumentation Programme).

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

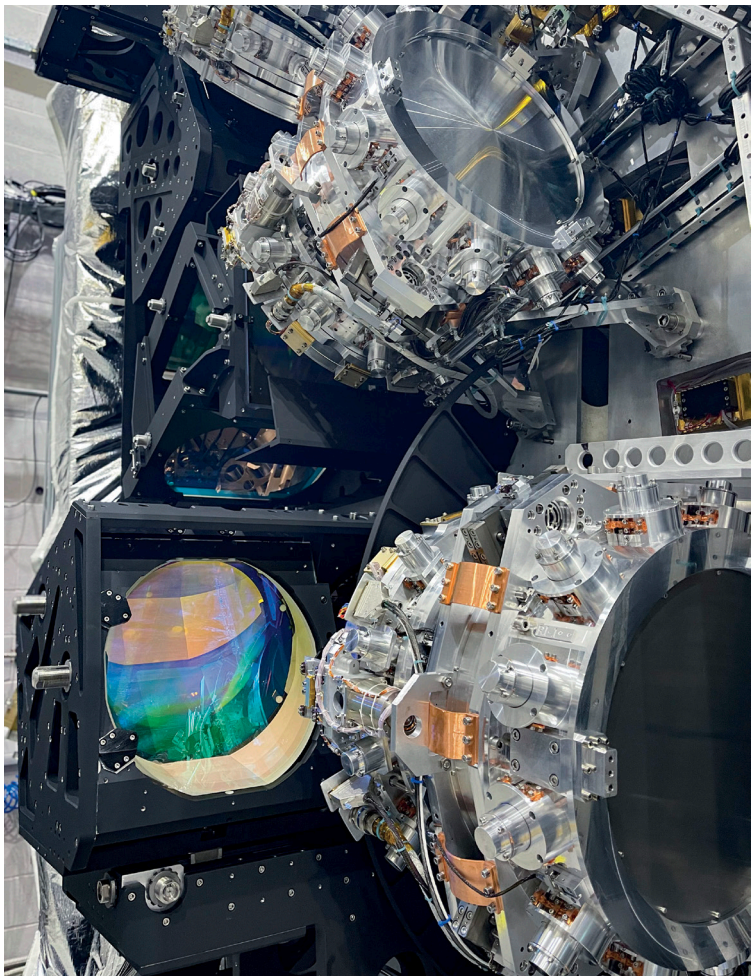
The beam of a laser guide star on the VLT's Unit Telescope 4 at Paranal passes in front of the Moon.

MOONS

MOONS (Multi Object Optical and Near-infrared Spectrograph) is a 0.8–1.8-µm multi-object spectrometer designed to work at the Nasmyth focus of the VLT's UT1. It will have 1000 optical fibres patrolling a field the size of the full Moon. MOONS can be used with a spectroscopic resolving power *R* ~ 4000 spanning the full near-infrared wavelength range, or with *R* ~ 9000 in the *I* band and *R* ~ 20 000 in the *H* band. MOONS has two main sub-components, the rotating front end (which is at the focal plane and houses the fibre positioners, the acquisition system and the metrology system for the fibres) and the cryogenic spectrographs, which will be on the telescope's Nasmyth platform.

The integration and testing of MOONS continued during 2024. The pending issues, in areas such as some of the motors and the realignment of optical elements, were resolved during the year. End-to-end tests of the hardware and software were successfully completed, and the instrument is meeting its specifications. A successful Preliminary Acceptance Europe close-out meeting was held in December 2024.

MOONS Consortium



One half of the MOONS cryostat, showing three of the six cameras in the foreground, facing the dispersive optics housed in black cryogenic mounts, which were installed in 2024.

Science with MOONS is expected to include:

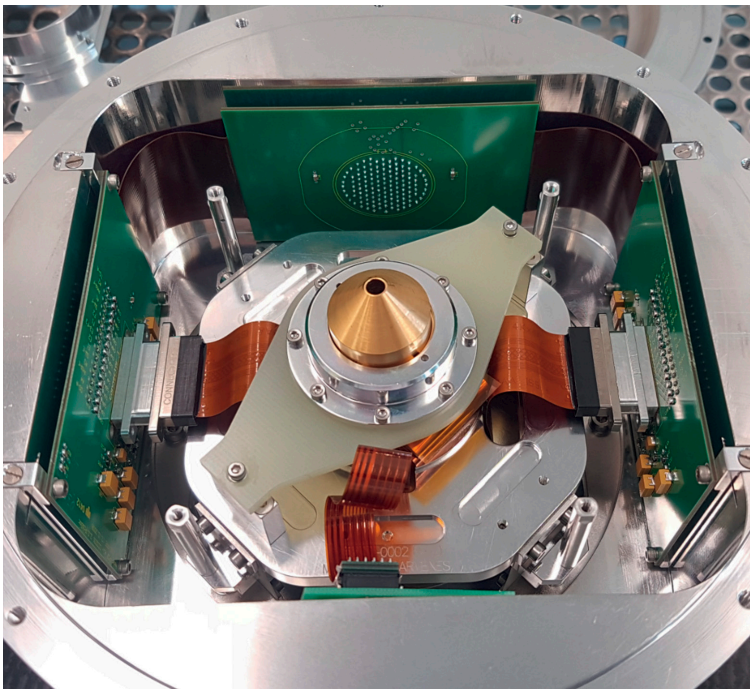
Probing the structure of the Milky Way; studying galaxy formation and evolution over most of the history of the Universe; spectroscopic follow-up for ground- and space-based optical and near-infrared surveys, as well as for facilities operating at other wavelengths.

Read more about MOONS, including consortium members, at https://www.eso.org/public/teles-instr/paranal-observatory/vlt/vlt-instr/moons/

FORS upgrade project

FORS (Focal Reducer and low-dispersion Spectrograph) can not only take images of astronomical targets but also capture spectra from multiple objects, and even measure the polarisation of light, making it an extremely versatile tool. Twin instruments were made: FORS1, decommissioned in 2009, and FORS2, currently operating on UT1. However, FORS needs an update to make it ready for the next decade of operations. The project will refurbish FORS with a new detector, calibration unit, and filters and grisms, plus new software, making it a test-bench for the ELT standard technologies that will come to all instruments at the VLT and ELT. To minimise downtime, the upgrade is being performed on the previously decommissioned FORS1 while FORS2 remains in operation.

Extensive work on the design of all aspects of the instrument throughout the year brought the project to readiness for its Final Design Review, which is scheduled for early 2025. The order was placed for the new grisms and filters during the year, as these are long-lead items.



Javier Reyes/ESO

Electronics inside the cryostat of the upgraded FORS instrument, prior to the integration of the detector.

Science with the upgraded FORS is expected to include:

A very wide range of astronomical investigations, from studying very distant galaxies and galaxy clusters, to individual and binary stars, and from the explosions of supernovae and the atmospheres of exoplanets, to asteroids and other objects within our Solar System.

Read more about the FORS upgrade project, including consortium members, at https://www.eso.org/public/teles-instr/paranal-observatory/vlt/vlt-instr/fors-up/

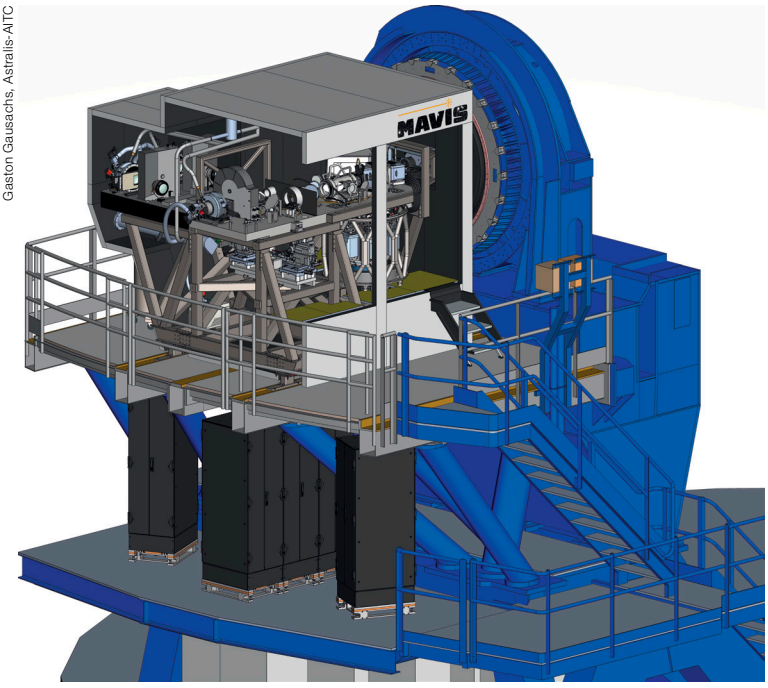
MAVIS

MAVIS (MCAO-Assisted Visible Imager and Spectrograph) will be an imager and an integral-field-unit spectrograph operating at visible wavelengths on the VLT, using adaptive optics to compensate for the blurring effects of atmospheric turbulence. MAVIS will take advantage of UT4's powerful laser guide stars and deformable secondary mirror, and extend its capabilities with a technique called multi-conjugate adaptive optics (MCAO). This will deliver diffraction-limited science observations at visible wavelengths — offering comparable spatial resolution to near-infrared observations with the ELT — with an unprecedentedly wide 30-arcsecond field of view.

To do this MAVIS will add two additional deformable mirrors to correct for turbulence at different heights in the atmosphere, and will split each of the four UT4 lasers into two beams, producing eight laser guide stars, in addition to which it will also use three natural guide stars.

Having passed its Preliminary Design Review in 2023, MAVIS is now well into its final design phase and working towards its Final Design Review.

In parallel, during 2024 the first of the two deformable mirrors for MAVIS was produced, as part of an ESO technology development project. This compact mirror features over 3000 electromagnetic actuators that rapidly adjust the mirror shape. Testing of the system started in September, revealing very good performance, and was ongoing at the end of the year. For more information see page 124.



Gaston Gausachs, Astralis-AITC

Computer rendering of the MAVIS instrument on the Nasmyth platform of the VLT's UT4.

Science with MAVIS is expected to include:

A wide variety of research questions, ranging from how the first stars formed 13 billion years ago to how weather changes on the planets and moons of the Solar System.

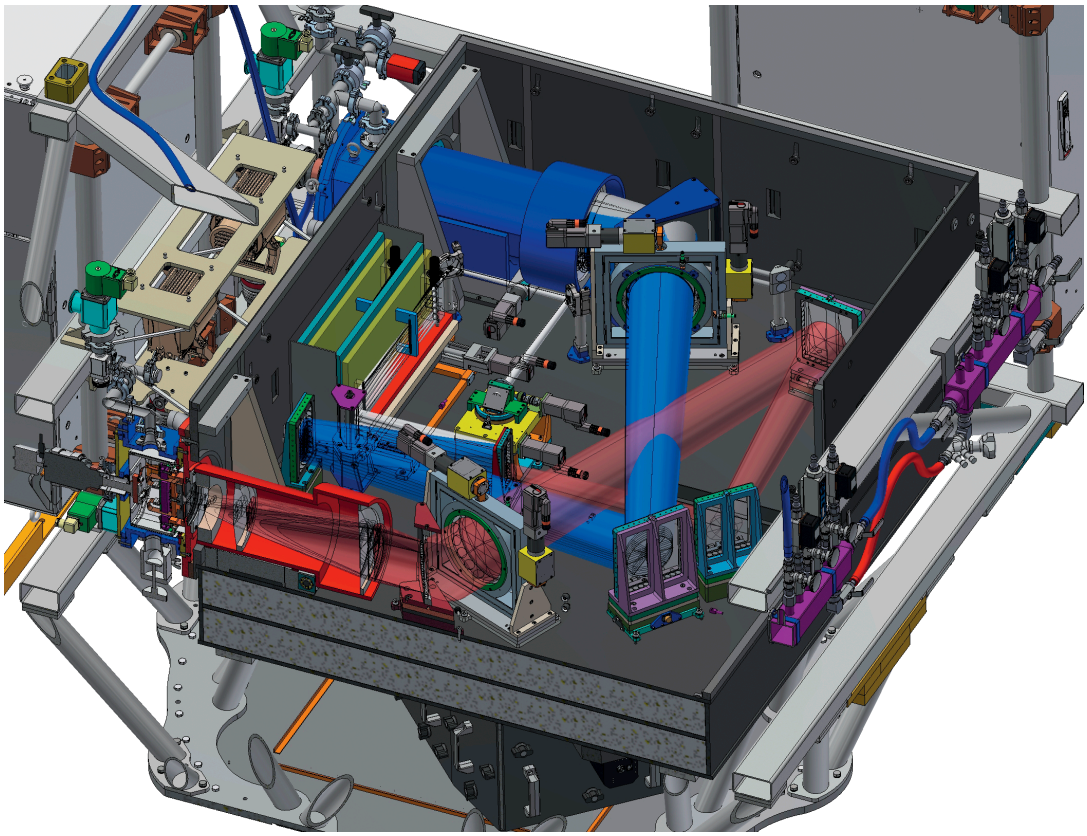
Read more about MAVIS, including consortium members, at https://www.eso.org/public/teles-instr/paranal-observatory/vlt/vlt-instr/mavis/

CUBES

CUBES (Cassegrain U-Band Efficient Spectrograph) will bring a unique capability to the VLT: a high-efficiency ultraviolet spectrograph in the wavelength range 300–405 nm with two spectral resolution modes of 20 000 and 7000.

CUBES had a successful Final Design Review meeting in October 2024, with only a few remaining actions needing to be closed. In addition to ongoing procurement of long-lead items, general procurement of the components for the instrument has started.

CUBES Consortium



Computer rendering of part of the CUBES instrument.

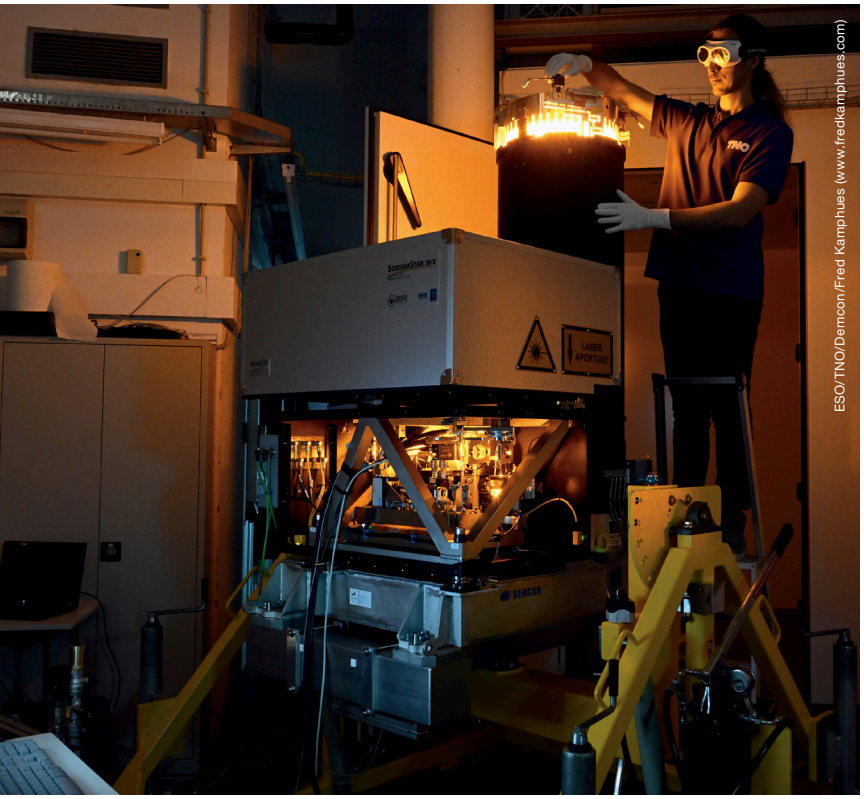
Science with CUBES is expected to include:

New windows on distant galaxies and the gas in and around them, elements and molecules in the spectra of stars, and targets in our Solar System including comets and the surfaces of icy moons.

Read more about CUBES, including consortium members, at https://www.eso.org/public/teles-instr/paranal-observatory/vlt/vlt-instr/cubes/

GRAVITY+

GRAVITY+ is a very demanding project to upgrade the GRAVITY instrument and the VLTI infrastructure, enabling the imaging of fainter and more distant astronomical objects than previously possible, while also improving the high contrast precision on bright objects.



ESO/TNO/Demcon/Fred Kamphues (www.fredkamphues.com)

Laboratory testing of a laser guide star unit at the ESO Headquarters.

GRAVITY+ will install one laser guide star on each of Unit Telescopes 1, 2 and 3, and will make use of one of the lasers currently installed on Unit Telescope 4. The project will also upgrade the VLTI's fringe-tracking capabilities, allowing for further correction of atmospheric turbulence, to image targets in unprecedented detail. The new features will benefit all present and future VLTI instruments.

During the year, parts of the GRAVITY+ adaptive optics system, including four new deformable mirrors, were shipped from Europe to Paranal, where they were installed and commissioned on the four UTs. This allowed the improved GRAVITY+ natural guide star mode to be successfully commissioned and offered for science observations, delivering excellent adaptive optics performance. It significantly improves the sensitivity and signal-to-noise ratio, greatly extending GRAVITY's capabilities.

Preparations also began for the laser guide star mode of the GRAVITY+ adaptive optics. The laser guide star units are being manufactured in a combined procurement with the ELT project: three for GRAVITY+ and six for the ELT. For more information on these units, see page 62.

Science with GRAVITY+ is expected to include:

The discovery and characterisation of exoplanets, the imaging of young stars and their protoplanetary discs, the study of active galactic nuclei, and the search for intermediate-mass black holes. It will also take us deeper and closer to Sagittarius A*, the black hole at the centre of the Milky Way, providing us with a better understanding of the heart of our galaxy.

Read more about GRAVITY+, including consortium members, at https://www.eso.org/public/teles-instr/paranal-observatory/vlt/vlt-instr/gravity+/

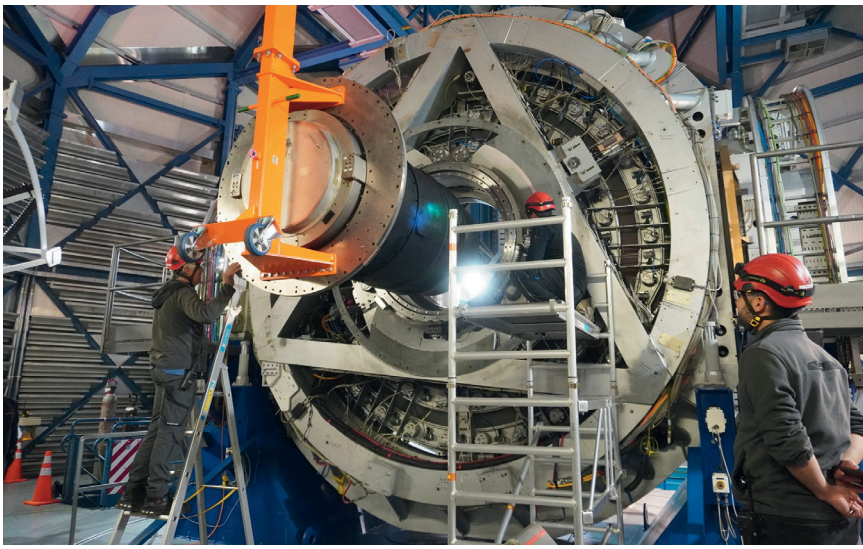
4MOST

The 4MOST (4-metre Multi-Object Spectrograph Telescope) facility will give VISTA the ability to perform large visible-light spectroscopic surveys, capturing the spectra of 2400 objects simultaneously by feeding their light through independently positionable optical fibres, over an area on the sky equivalent to 20 full Moons. Its unique capabilities result from the combination of a large field of view, very high multiplex, and simultaneous observations at medium and high spectral resolution for both Galactic and extragalactic astrophysics. 2436 fibres are available simultaneously — 1624 dedicated to low-resolution and 812 to high-resolution spectroscopy.

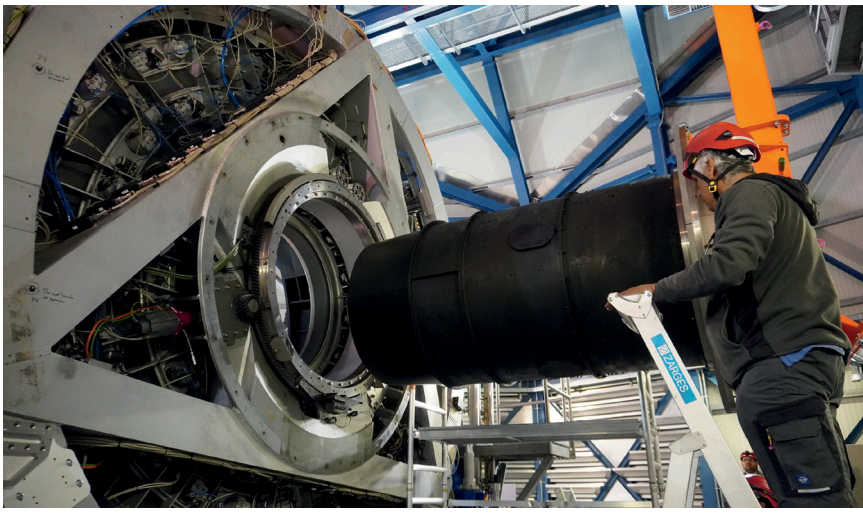
Following upgrades to the VISTA telescope to prepare it for 4MOST (see page 83) the recommissioning of the telescope began in late November 2024. This progressed well, including a VISTA recommissioning 'first technical light' image taken with the new 4MOST autoguider camera. Image quality is very good, giving confidence in the performance of the VISTA telescope in the new 4MOST configuration.

The full 4MOST instrument is now in its final verification stages, working towards the Preliminary Acceptance Europe milestone. Software for management of the surveys that 4MOST will perform is also under development.

Allar Saviauk



Allar Saviauk



Top and above: The 4MOST Wide Field Corrector being installed on the VISTA telescope.

Science with 4MOST is expected to include:

Studying the dynamics and chemical evolution of the Milky Way, analysing large numbers of active galaxies and galaxy clusters, and helping to constrain models of the accelerating Universe. It will also complement space-based and ground-based all-sky survey projects.

Read more about 4MOST, including consortium members, at https://www.eso.org/public/teles-instr/paranal-observatory/surveytelescopes/vista/4most/

Phase A studies

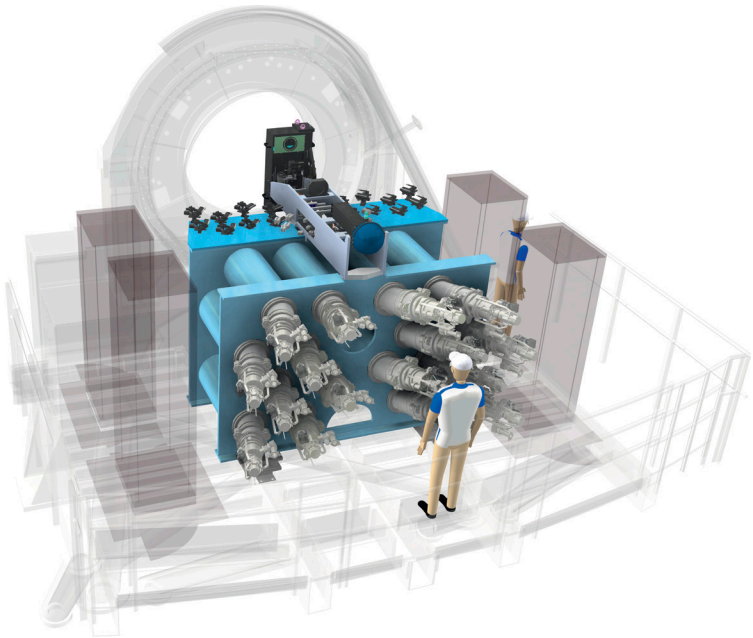
Future instrumentation projects for ESO telescopes are identified and selected in a careful process, undertaken in collaboration with ESO's community of astronomers and instrument builders and ESO's governing bodies. The earliest major project stage is a 'Phase A study', a conceptual design phase which defines the project, consolidates science cases, and develops top-level requirements. Depending on the outcome, the Phase A study may lead to an agreement between ESO and a consortium to develop the project.

BlueMUSE

BlueMUSE is a proposed integral-field spectrograph with a wide field of view, to be installed at the VLT, which is an evolution of the technology used on the VLT's MUSE instrument. It has a similar architecture, but is optimised for blue and near-ultraviolet light, covering shorter wavelengths than MUSE.

Computer rendering of the BlueMUSE instrument.

BlueMUSE Consortium

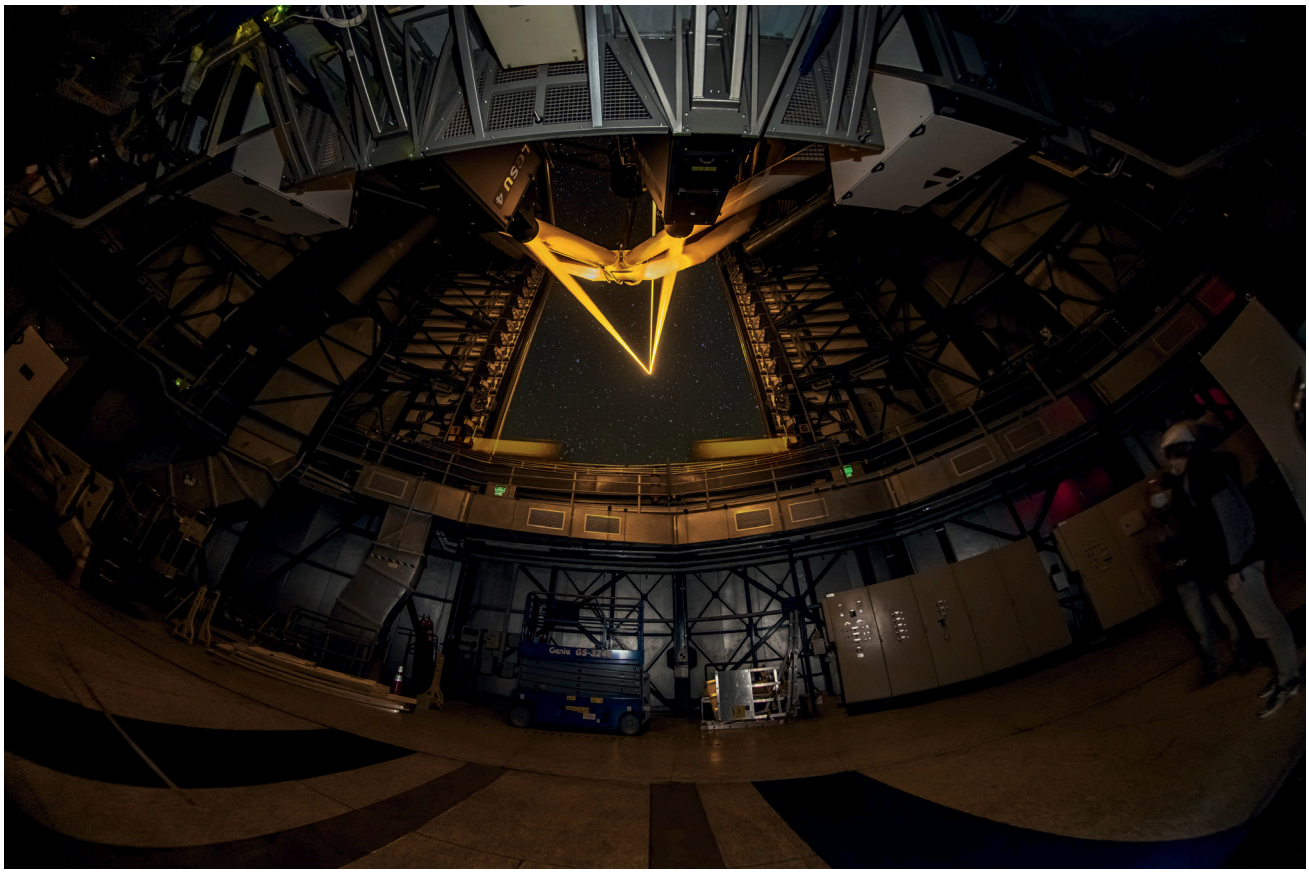


BlueMUSE would offer new and unique science opportunities in many fields of astrophysics. These are expected to include surveying large samples of massive stars in our galaxy and the Local Group, studying ionised nebulae, starburst and low-surface-brightness galaxies. At high redshift, BlueMUSE would allow astronomers to detect unambiguously for the first time the intergalactic medium in emission, as well as to study the evolution of the properties of the circumgalactic medium near the peak of the cosmic star formation history.

ESO has approved the Phase A study for the project, and the kick-off meeting for this phase was held with ESO and the consortium institutes in June 2024. This phase, expected to last about 10 months, will be used to validate the scientific goals, develop a first design concept, and build a development plan for the project.

A second-generation deformable secondary mirror for the VLT

Zdeněk Bardon/ESO



UT4's deformable secondary mirror is part of the telescope's Adaptive Optics Facility, whose laser guide star beams are seen here.

The Adaptive Optics Facility (AOF) on the VLT's UT4, including the deformable secondary mirror and 4-Laser Guide Star Facility, has significantly enhanced the observational capabilities of UT4. As a result, UT4 is significantly oversubscribed compared to the other UTs, with even extremely good scientific observing proposals being rejected because there is insufficient capacity.

Relocating any of the UT4 instruments to another UT is currently not possible, as their performance is closely linked to the availability of the AOF. However, installing a new deformable secondary mirror on one of the other UTs, and taking advantage of the single laser guide star unit that will also be installed on the UT as part of the GRAVITY+ project, would enable a more balanced distribution of instruments, improving the scientific performance of the VLT overall.

In April 2024 a Phase A study was approved to investigate the possibility of installing such a second-generation deformable secondary mirror on UT1, UT2, or UT3. In addition to providing a full cost and feasibility estimate, the study will evaluate the best location for the new mirror, by investigating the technical and scientific impact of possible distributions of instruments.

La Silla

La Silla was ESO's first observatory site, at an altitude of 2400 metres on the outskirts of the Chilean Atacama Desert. Here, ESO's 3.6-metre telescope and NTT (New Technology Telescope) are in operation. The La Silla site further supports several hosted telescope projects, among them the Max-Planck-Gesellschaft/ESO 2.2-metre telescope, the Swiss 1.2-metre Leonhard Euler Telescope, and the Danish 1.54-metre telescope.

A. Ghizzi Panizza/ESO

ESO's La Silla Observatory at the start of the night. The sunset is visible on the horizon, and the glow rising in the centre is zodiacal light.

Operations, infrastructure, upgrades

Dutch Minister of Science visits La Silla for BlackGEM inauguration

The Dutch Minister of Education, Culture and Science, Robbert Dijkgraaf, visited La Silla with his delegation in January 2024 for the official inauguration ceremony of BlackGEM, a Dutch-Belgian project hosted by ESO at La Silla.

BlackGEM, which started operations in 2023, is a wide-field array of remotely controlled visible-light robotic telescopes, initially comprising three telescopes, each 0.65 metres in diameter.

The telescopes will rapidly scan large areas of the southern sky in visible light to precisely hunt down the cosmic events that produce gravitational waves, such as the mergers between neutron stars and black holes.

BlackGEM will also perform surveys of the southern sky. Its operations are fully automated, meaning the array can quickly find and observe ‘transient’ astronomical events, which appear suddenly and quickly fade out of view. This will give astronomers deeper insights into short-lived astronomical phenomena such as supernovae, the huge explosions that mark the end of a massive star’s life.

Minister Dijkgraaf took the opportunity of being in Chile to tour all of ESO’s observing sites, including Paranal and Chajnantor. At Paranal, he was also able to visit the nearby ELT construction site at Cerro Armazones.

Zdeněk Bardon (bardon.cz)/ESO

The three telescopes of the BlackGEM array at La Silla.

High-pressure washing of the NTT mirror shows promise

Guillaume Blanchard/ESO

Testing high-pressure washing of the NTT mirror.

A telescope's mirror must capture and reflect the light it collects as efficiently as possible. The mirror is first polished until it approaches perfection, and is then coated with a very thin, highly reflective layer of aluminium or silver — 10 000 times thinner than a human hair.

Over time, dust inevitably accumulates on this delicate reflective surface, absorbing and diffusing some of the light, so mirrors need periodic cleaning and recoating. At the NTT, the 3.58-metre-diameter primary mirror is cleaned weekly with frozen flakes of CO_2 'snow', and washed by hand about twice a year with soft natural sponges, delicate soap and distilled water. Even with this cleaning regime, the mirror needs a new reflective coating — a complex technical process — every three years.

In August 2024 a new way of washing the NTT's primary mirror was tested, using high-pressure water. Results of the test were promising, demonstrating that the technique gives good results on large mirrors without degrading the coating. The improved cleaning should make it possible to extend the time between recoatings, saving on maintenance work and downtime. The technique, and the knowledge gained from this test, may also be relevant for cleaning mirrors on the VLT and ELT.

Forthcoming instruments

An earlier call for proposals for new instruments for the ESO 3.6-metre telescope and the New Technology Telescope at La Silla led to the selection of two instruments for development — originally within the framework of the Paranal Instrumentation Programme and now the newly combined Instrumentation Programme (see page 85) — by consortia in close collaboration with ESO, in exchange for Guaranteed Time Observations. The first of these instruments, NIRPS (Near Infra Red Planet Searcher) on the ESO 3.6-metre telescope, entered operations and was offered to the community in 2023.

SOXS

SOXS (Son Of X-Shooter) is a new instrument to be installed on the New Technology Telescope (NTT). This instrument, inspired by X-shooter on the VLT, will be a unique spectroscopic facility for following-up transient and variable astronomical events identified in imaging surveys. It has two spectrographs, optimised for the ultraviolet–visible and near-infrared wavelength ranges, respectively.

Assembly and testing of the SOXS instrument in Europe were successfully completed during 2024. The Provisional Acceptance Europe milestone was passed in November, after which the instrument was packed and shipped to Chile, with arrival at La Silla expected early in the new year.

Kalyan Radhakrishnan/INAF

SOXS during Assembly, Integration and Verification.

Science with SOXS is expected to include:

Following up transient events encompassing all distance scales and branches of astronomy, including fast alerts such as gamma-ray bursts and gravitational waves, mid-term alerts such as supernovae and X-ray transients, and fixed-time events such as the close passage of a minor planet or asteroid. It will also observe exoplanet transits, active galactic nuclei and blazars, tidal disruption events, fast radio bursts, and more.

Read more about SOXS, including consortium members, at https://www.eso.org/public/teles-instr/lasilla/ntt/soxs/

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

The Magellanic Clouds, neighbour galaxies of the Milky Way, seen at La Silla above one of the BlackGEM telescopes.

CTAO

The Cherenkov Telescope Array Observatory (CTAO) will be the world's most powerful ground-based gamma-ray observatory. It will consist of two arrays of telescopes: CTAO-North in La Palma, Spain, and CTAO-South at ESO's Paranal site in Chile. In addition to hosting CTAO-South, ESO is a fully participating member of the CTAO organisation.

In its planned configuration, the CTAO will comprise 64 telescopes of different sizes, 13 in the northern site and 51 in the southern one. They will detect the faint and ephemeral radiation produced when gamma rays from deep space hit our atmosphere, thus probing the most powerful and extreme objects in the Universe, such as supermassive black holes and supernovae, with unprecedented sensitivity. CTAO's high-energy capabilities constitute a perfect match to ESO's current roster of telescopes, which observe all the way from visible/infrared light to sub-millimetre wavelengths, a synergy that will allow astronomers to study the Universe in brand new ways.

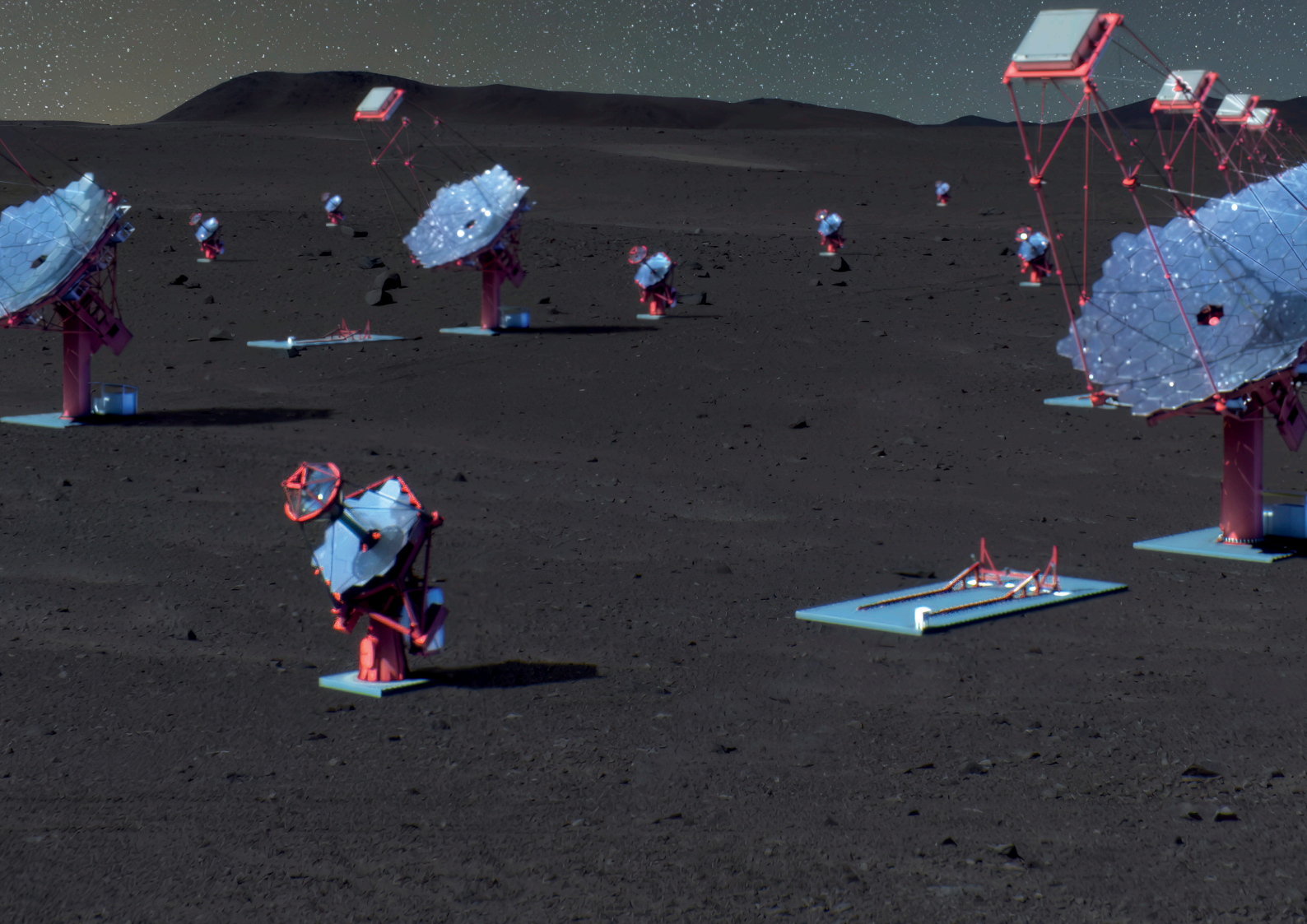
In April the CTAO marked the end of its design phase and entered a new phase of major infrastructure development and growth. This included the definition of a new 'intermediate array' configuration of telescopes. At the CTAO-South site, this will comprise seven telescopes, which are expected to be delivered to the site in

Artist's impression of the CTAO-South site, near ESO's Paranal Observatory.

2026. As a waypoint on the path to the full configuration, the intermediate array will already provide performance two to three times better than the current generation of ground-based gamma-ray instruments, enabling scientists to detect fainter sources and capture variations in gamma-ray signals on timescales of minutes. Construction of CTAO-South at the Paranal site continued during the year. In preparation for further infrastructure development and construction, various Calls for Tender were issued, and the on-site team was expanded with the addition of a site system engineer, responsible for planning, supporting, and executing systems engineering and quality assurance activities at the site.

A programme scientist at ESO was also appointed, who will liaise with the CTAO users — of both CTAO-North and CTAO-South — among the ESO community.

Discussions continued with the European Commission with a view to changing the operating structure of the CTAO from the current gGmbH — a non-profit, limited-liability entity under German law — to a European Research Infrastructure Consortium (ERIC), under European law, with ESO as a founding member of the ERIC. By the end of the year, good progress had been made, with the hope of a successful conclusion in early 2025.

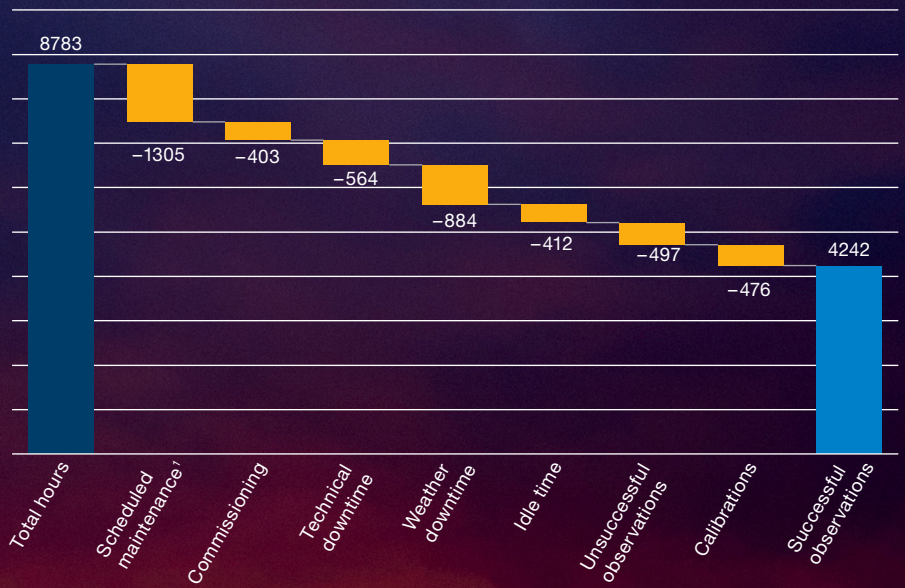


ALMA

ALMA is a large interferometer operating at millimetre and submillimetre wavelengths, operated jointly through an international collaboration involving Europe, 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 antennas, which have diameters of 12 metres and 7 metres, can be placed in various configurations, with separations ranging from 15 metres to 16 kilometres. They are moved between foundation pads using two custom-built transporter vehicles, named Otto and Lore.

Operational statistics

ALMA observing cycle 10 (October 2023–September 2024)



[1] During the 'Altiplanic winter' period of January–March, seasonal atmospheric conditions can limit observations at submillimetre wavelengths. Scheduled maintenance therefore also includes the month of February, routinely used as an extended maintenance and upgrade period, during which no science observations are planned.

C. Duran/ESO

The rare sight of clouds over the Chajnantor plateau, a typically arid region, creates a dramatic display of reds and blues, as well as a sun pillar — an optical phenomenon caused by ice crystals in the atmosphere — above one of the ALMA antennas.

Operations and infrastructure

Record number of successful observation hours in Cycle 10

ALMA's observing cycle 10, from October 2023 to September 2024, produced a record of approximately 4250 hours of successful observations. This is a significant increase over previous years, and marks the first cycle to get so close to the figure of 4300 hours which is used when planning the observing queue.

This achievement demonstrates that ALMA is now operating very efficiently. The improvement is the result of many factors, including the experience and practice gained in previous years. Scheduling has become more flexible, with better planning to make the most of changing weather conditions.

More engineering tasks are being performed in parallel with science operations, without interrupting observations. The Hardware-in-the-Loop Simulation Environment, which allows engineering and computing tests to be performed using a small number of antennas rather than occupying the whole array, helped a lot with this.

Telescope time continues to be extremely sought after, reflecting ALMA's position as a unique astronomy facility worldwide. Oversubscription rates are highest for ESO's share of ALMA time, demonstrating the ongoing strong demand and competition for ALMA time from the ESO community.

Alex Pérez

ALMA antennas on the Chajnantor plateau.

Otto and Lore both back in action

Mark Gallilee (ESO ALMA)

Repairs to the hydraulic units of the ALMA antenna transporters, Otto and Lore, were performed during 2024, addressing faults that had occurred in the previous year. As the transporters were part of ESO's contribution to the ALMA partnership, ESO staff were able to provide specialised support and technical advice to the Joint ALMA Observatory, while a consultant from the vehicles' manufacturer ensured that the contractor selected for the repairs had the necessary knowledge and skills to perform them. The maintenance brought both Otto and Lore back to full operational capability by early August 2024.

The final testing phase of the ALMA antenna transporter Lore after repairs to its hydraulic units. Lore is carrying a dummy antenna weight to simulate the load of a real antenna.

Lightning-protection systems retrofitted to avoid antenna collisions

P. Horálek/ESO

ESO-delivered ALMA antennas on the Chajnantor plateau. The locations where the lightning protection system was rerouted are marked with white circles on the foremost antenna.

ALMA's antennas can be placed in various configurations by moving them between different foundation pads, with separations ranging from 15 metres to 16 kilometres. Widely-spaced array configurations deliver observations at higher resolution, while more compact configurations optimise observations of the extended structure of astronomical objects.

One of ESO's major contributions to the construction of ALMA was 25 of the telescope's array of 50 12-metre antennas. In late 2023 an inspection revealed damage on two of these antennas to the carbon-fibre 'legs' which support the secondary reflector above the 12-metre primary dish. It was discovered that the antennas could in rare circumstances collide when on close-together foundation pads and pointing in certain directions.

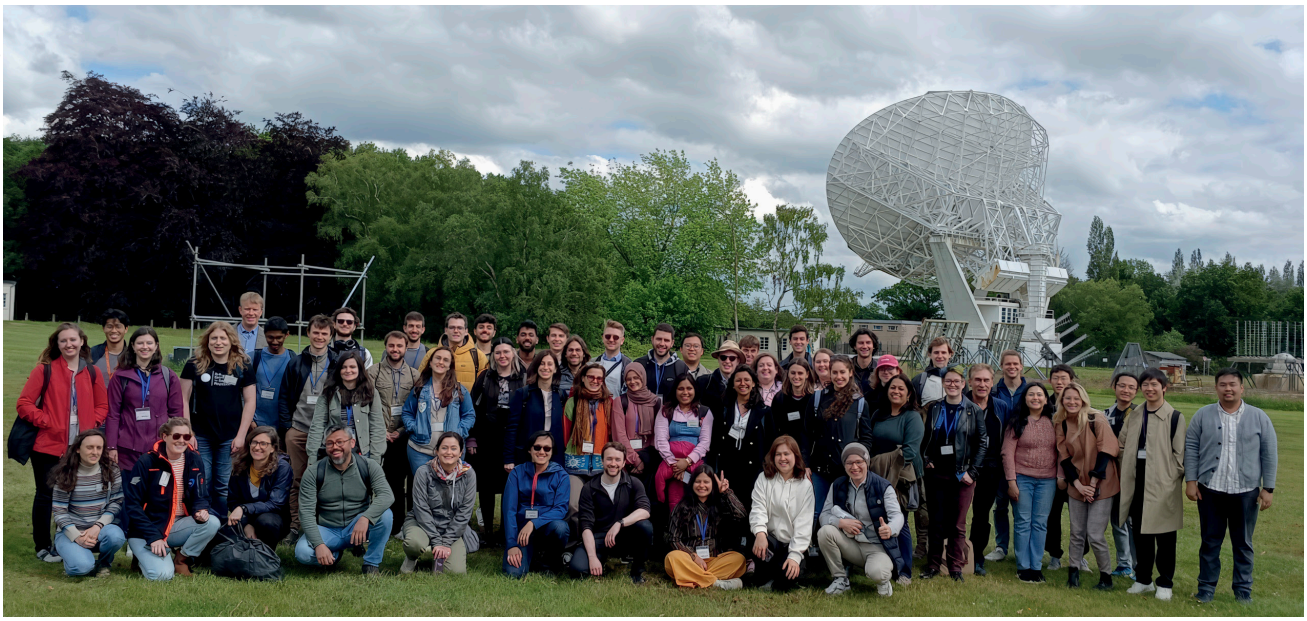
During the first quarter of 2024, work was performed on all 25 ESO-delivered antennas to mitigate the risk of collisions, by re-routing copper rods which are mounted on these 'legs' and which form part of the lightning protection system that protects the exposed antennas during thunderstorms on the plateau.

European ALMA School

The first dedicated European ALMA School was organised in June 2024 by the European ALMA Regional Centre (ARC) network, with support from all the ARC nodes and ESO, and hosted at the University of Manchester by the United Kingdom ARC node. The five-day school was aimed at novice ALMA users, with 41 of the 50 participants being either novice users or completely new to ALMA, and about three quarters of them being PhD students. Participants came mostly from ESO Member States.

The school was designed to provide training on a broad range of aspects related to ALMA, with participants learning about: interferometry basics; data calibration, visualisation and analysis; the ALMA Science Archive; observing proposal preparation; current ALMA science; and future ALMA developments. The school was funded partially through the OPTICON-RadioNet Pilot project.

Emmanuel Bempong-Manful



Attendees at the first dedicated European ALMA School, held at the University of Manchester in June 2024, visiting Jodrell Bank Observatory.

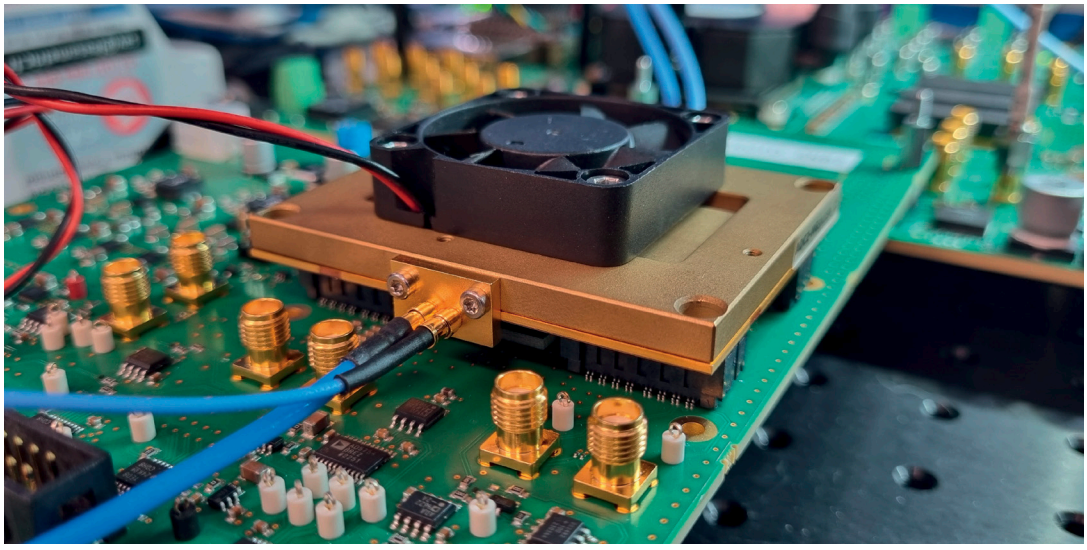
ALMA Wideband Sensitivity Upgrade

The Wideband Sensitivity Upgrade (WSU) is, despite its prosaic name, the most ambitious upgrade to ALMA since its conception. As the top priority of the ALMA 2030 roadmap, the WSU will deliver what is in effect a 'brand new ALMA' with dramatically increased speed and sensitivity. This will be done by increasing ALMA's bandwidth by up to a factor of four, while also upgrading the entire signal chain, starting with the receivers and digitisers, and including a second-generation correlator — the specialised supercomputer that combines the signals from the antennas to transform them into a single vast telescope.

The Wideband Intermediate Frequency Processor project

ALMA observes the Universe in light with wavelengths in the millimetre and submillimetre range, equivalent to a frequency range from tens of gigahertz to one terahertz. These very high frequencies captured by the antennas are downconverted to lower 'intermediate frequencies' (IF) that can be more easily processed. As the WSU will increase ALMA's IF bandwidth by a factor of four, the entire signal path — in which the receiver output is digitised and transferred to the second-generation correlator — must also be upgraded.

The Wideband Intermediate Frequency Processor (WIFP) project is a critical component of the WSU. Its objective is to design, develop and deliver the equipment responsible for digitising the analogue IF signals from the receivers and to prepare them for transportation to the new correlator.



An analogue-to-digital converter mounted on a custom-designed board, part of the work done on the preliminary design of the Wideband Intermediate Frequency Processor project for ALMA.

The goal is to be able to digitise the incoming IF signal over a broad bandwidth from approximately 2 GHz to 20 GHz. Compared to the existing system, the signal will be sampled at a rate — 40 billion samples per second — that is ten times higher, with a 10% increase in sensitivity thanks to a change from 3-bit to 6-bit sampling. This will produce a raw data rate of 960 gigabits per second — also ten times higher — which will be handled using commercial off-the-shelf 400-gigabit ethernet hardware, instead of the current custom system. The upgrade will also involve a major change in the ALMA system architecture from the current synchronous data transmission between the antennas and the correlator, to asynchronous transmission.

Phase 1 of this project focuses on the preliminary design. An important part of this is to demonstrate asynchronous data transmission in the laboratory as a proof of principle. During the year different design options were explored and simulated, hardware was tested, and manufacturing options were evaluated. In November the Preliminary Design Review was held, with some specific actions identified as needing to be closed before the review is formally passed.

Read more about ESO contributions to the WSU, including projects, partners and consortium members, at https://www.eso.org/sci/facilities/alma/wsu.html

S. Otarola/ESO

A group of vicuñas, relatives of the llama, walk past ALMA antennas and an antenna transporter on the Chajnantor plateau.

Data flow and science archives

Observations with ESO's telescopes are made as an integral part of an end-to-end 'data-flow system', from the initial submission and selection of proposals for observing time, through the scheduling and execution of the observations themselves, including quality control and processing, to delivery of the final data products. The researchers who proposed the observations typically have exclusive access for the first year, after which the data are made publicly accessible worldwide.

All science data collected at La Silla and Paranal, as well as data collected at APEX until mid-2023, are made available online through the ESO Science Archive, physically located at the ESO Headquarters in Garching. Data from ALMA are also directly accessible from the ESO archive and can be queried together with data from other ESO observatories. ESO also hosts and operates the European instance of the dedicated ALMA Science Archive.

Fostering open access to data and ensuring they are findable, accessible, interoperable and reusable (the FAIR principles) lets the wider community do even more science with the same observations. The number of papers that use partly or exclusively archival data has increased steadily during recent years, demonstrating the important legacy value of the archives.

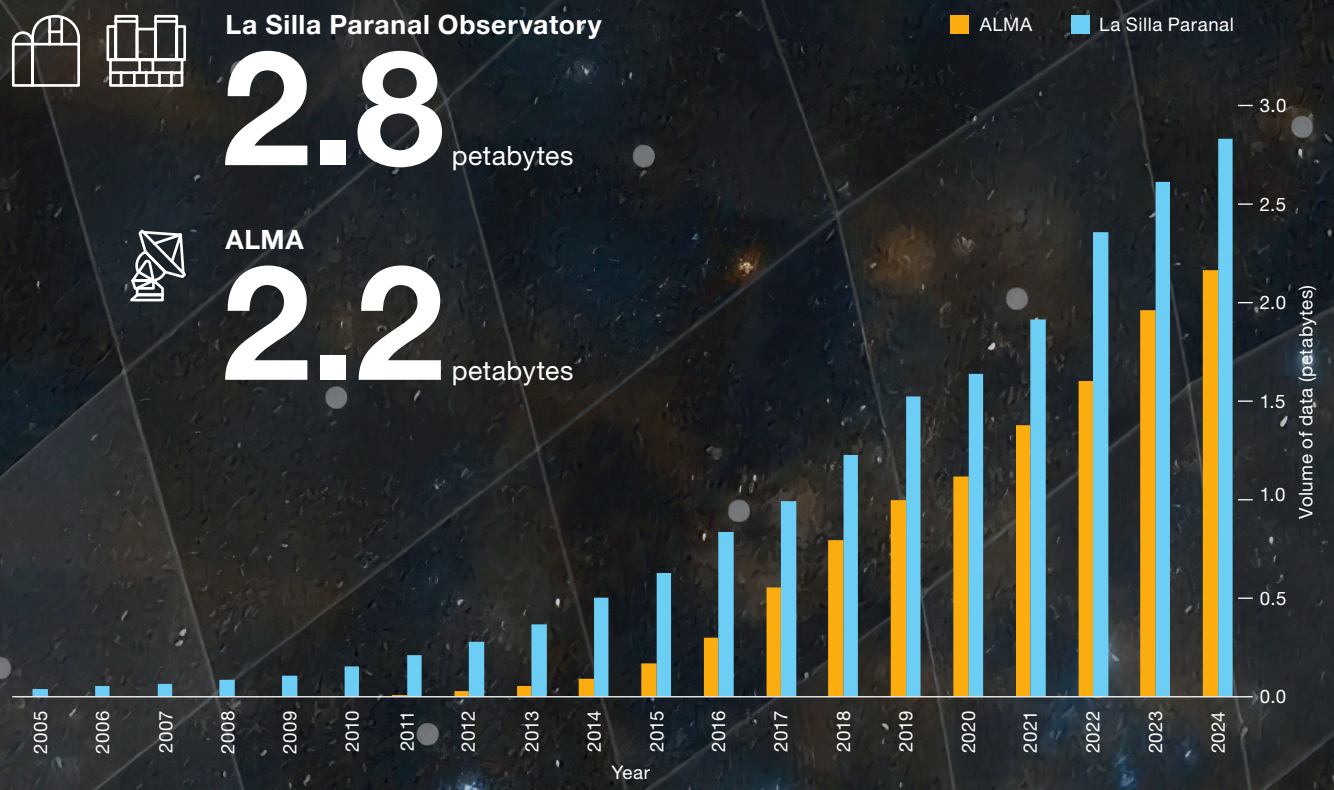
Total volume of data stored in the ESO archives

La Silla Paranal Observatory

2.8 petabytes

ALMA

2.2 petabytes



Building data-processing recipes from a single cookbook

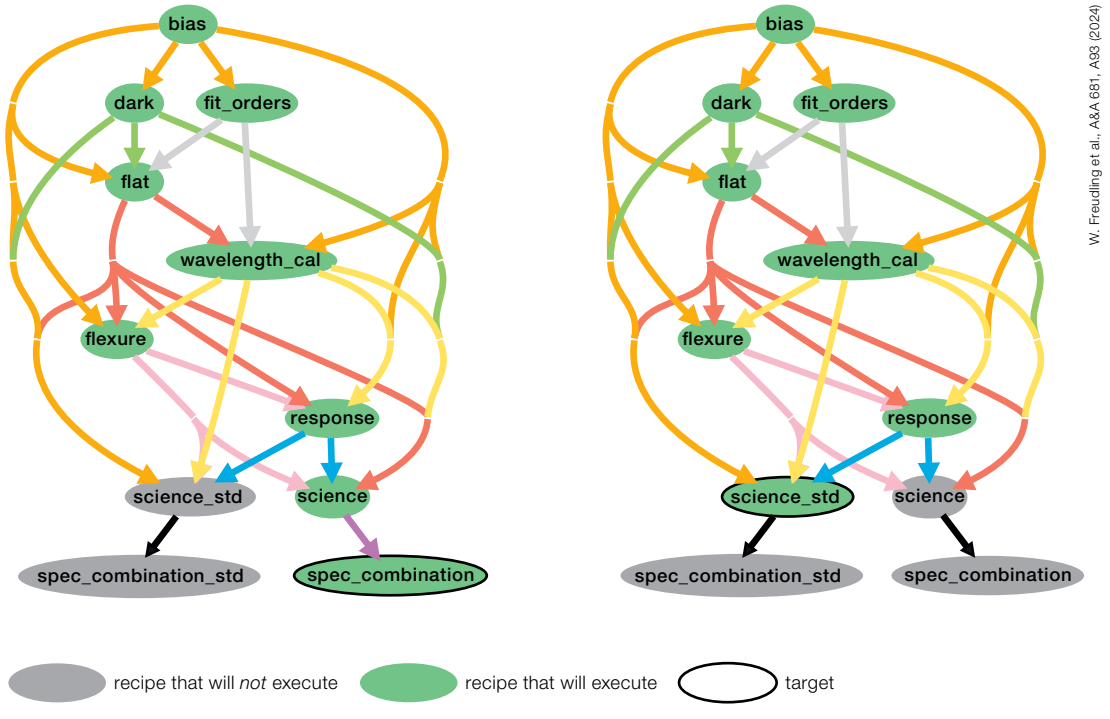
The first non-beta release of the new ESO Data Processing System (EDPS) was published in the first quarter of 2024. Raw data from telescopes must be processed in various ways before use — to serve the specific research goals of a scientist, or to produce science and calibration products for an archive, or for quality control.

This processing, known as ‘data reduction’, is done by combining individual processing steps into a pipeline or workflow, like a recipe. Different workflows are needed depending on the goal, and must be updated when systems and plans change, so creating and maintaining these workflows is a complex and resource-intensive task.

The new EDPS can automatically derive the workflows for different goals, all from a single specification of all the available processing steps. It provides a common unified framework that can be used for quality control, archival products, or specialised science data, both internally at ESO and externally by our user community.

The modern, futureproof implementation uses formalised descriptions of data processing pipelines, which allow the system to select the data sources and processing steps needed to reach a desired goal.

The new EDPS will eventually replace the several different workflow systems currently maintained by ESO for VLT and VLTI, including various quality-control and archive-processing systems used internally, as well as the ESO Reflex system offered to science users.



W. Freudling et al., A&A 681, A93 (2024)

Depending on the goal, the ESO Data Processing System builds different workflows from the same set of available steps. On the left, the goal is a combination of spectra for a science observation (“spec_combination”). On the right, it is a spectrum of a standard star for calibration (“science_std”). In each case, steps that are executed are in green, while steps that are not executed are in grey.

First full year of ALMA automatic data delivery

2024 was the first full year of automatic data delivery for ALMA, in which a fraction of the datasets, consisting of the best quality data, pass through a quality-assurance ‘fast lane’ and are delivered to astronomers automatically without human review. These datasets have been shown to be comparable in quality to those that have been reviewed manually.

For data to be eligible for automatic delivery, they must pass stringent quality-assurance criteria, including excellent weather conditions and system stability. The fraction of observations for which this applies varies depending on the configuration of ALMA’s array of antennas, and the weather. Over the year, a total of 27% of the observations — a proportion in line with expectations — were automatically delivered.

Optimising operations with automatic delivery saves resources, allowing us to invest time and effort into other projects. This is particularly important as we work towards the major Wideband Sensitivity Upgrade for ALMA over the coming years.

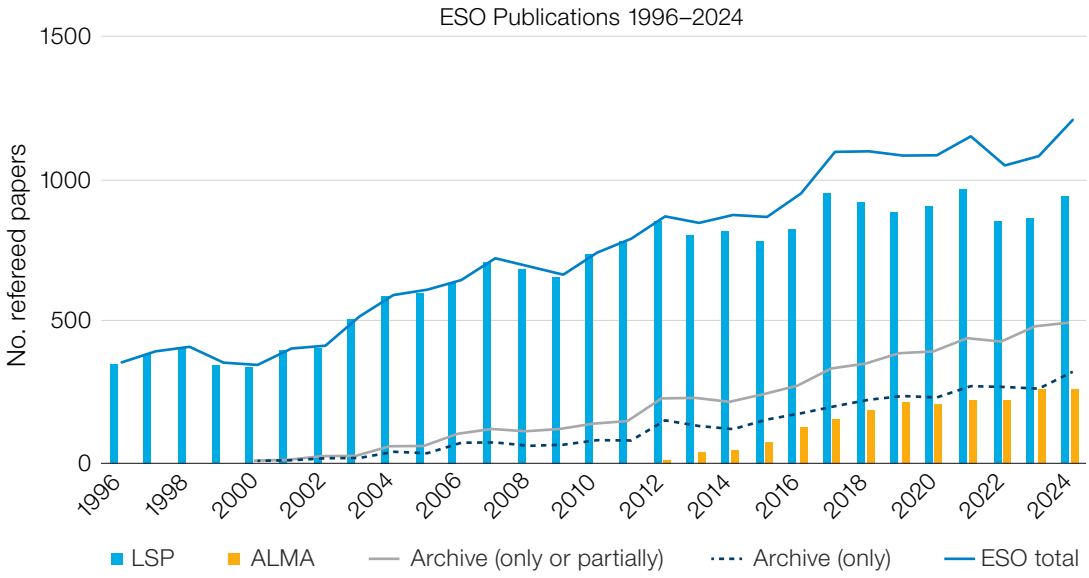
Sergio Otarola – ALMA(ESO/NAOJ/NRAO

ALMA antennas lit by moonlight under the central region of the Milky Way.

Publication digest

In 2024 more than 1200 refereed papers were published using data from ESO telescopes, continuing the flow of scientific publications from the community who use our facilities. The total number of data papers included in the ESO Telescope Bibliography (telbib) published between 1996 and 2024 has risen to more than 21 800.

L. Calçada/ESO



The chart gives an overview of refereed papers using ESO data, by year of publication. Only data taken in ESO observing time are counted, that is, time recommended by the ESO Observing Programmes Committee (OPC), or ESO's share of observing time for ALMA.

La Silla Paranal: papers that use data taken in ESO observing time at the La Silla Paranal Observatory, including the VLT and VLTI, the La Silla facilities, the VISTA and VST survey telescopes, and APEX. Papers are shown by publication year, so may appear after the end of ESO observations on telescopes which have since become hosted facilities, such as VST and APEX.

ALMA: papers that use data taken in ESO observing time at ALMA.

ESO total: these are all papers that use data taken in ESO observing time at La Silla Paranal or ALMA. Papers may use data from both facilities, so this total cannot be calculated by adding the separate La Silla Paranal and ALMA statistics.


J. Pérez/ESO

Archival papers

An archival paper uses ESO data (from La Silla Paranal or ALMA) but none of the original observers are among the authors of the paper. These data are accessed via the ESO Science Archive. The number of such papers has increased steadily in recent years, demonstrating the important legacy value of the archive.

Archive (only) means that the paper uses ESO archival data but no ESO data obtained directly by the authors as original observers.

Archive (only or partially) means that the paper uses ESO archival data and may also make use of ESO data obtained by the authors as original observers.

About these statistics

These statistics are derived from telbib, a database curated and developed by ESO to link publications with data in the ESO Science Archive and help evaluate ESO's productivity and impact. Whilst text-mining scripts are applied to screen the literature for papers using ESO data, papers are carefully examined by human curators to ensure that telbib only includes papers that are refereed, which make direct use of data (as opposed to in review articles or in citations), and that these data were obtained in ESO observing time.

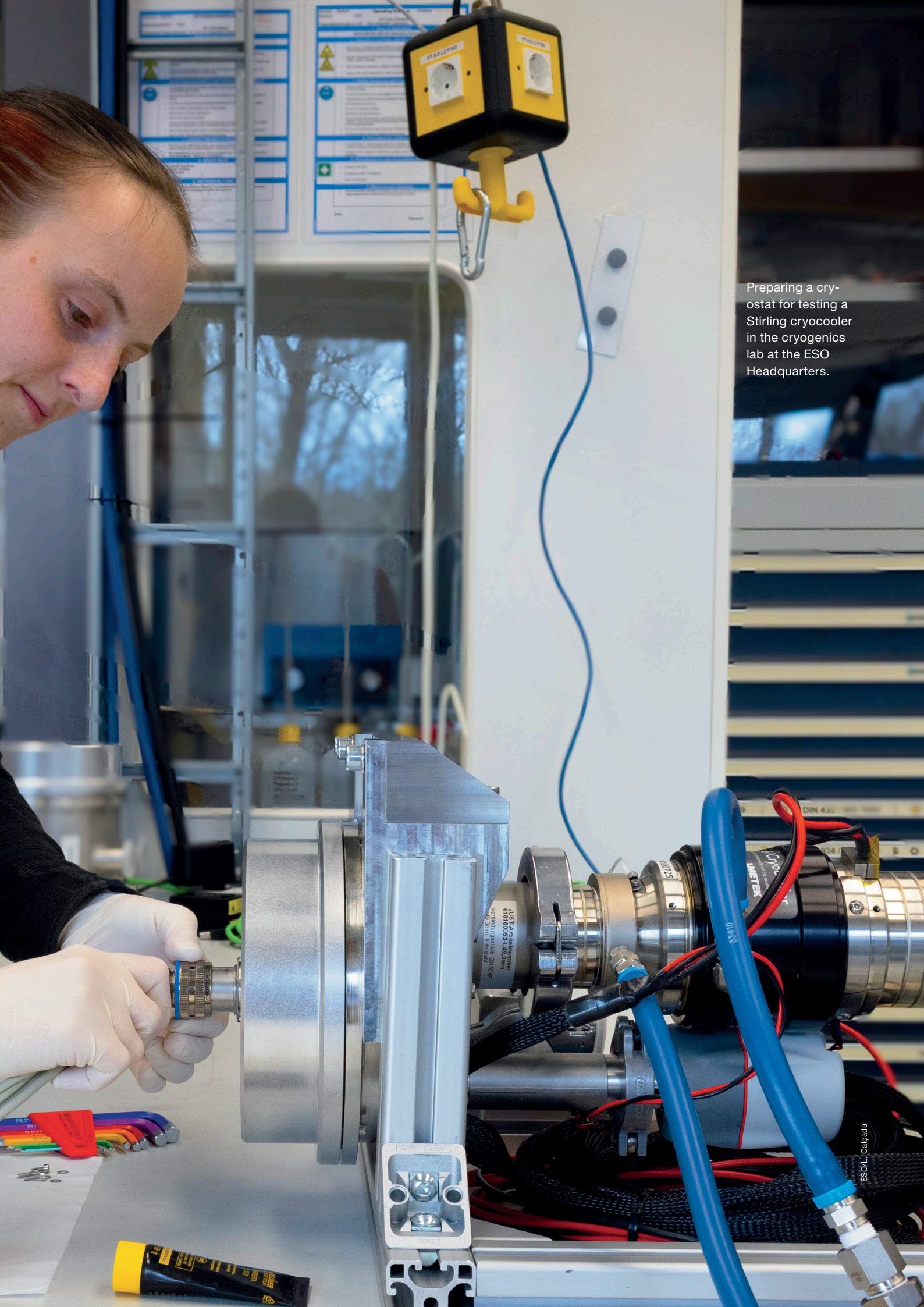
The telbib website, at telbib.eso.org, offers visualisations of search results including on-the-fly graphs and predefined charts, as well as details of the methodology used to screen and classify papers.

Records of all 2024 data papers written by the ESO user community can be accessed at https://telbib.eso.org/ESODataPapers2024.php.

Long-exposure panorama at La Silla. The faint green light is airglow, produced when air molecules split by sunlight recombine at night.

Technology development and R&D

Technology development and R&D are activities at ESO that are vital to making our vision and mission possible. We aim to develop and secure key technologies which will keep our facilities at the forefront of astronomy, by taking technologies that are at low levels of technological readiness and developing them to a level sufficient to be incorporated in new projects.



Preparing a cryostat for testing a Stirling cryocooler in the cryogenics lab at the ESO Headquarters.

Keeping ESO facilities at the forefront of astronomy

Technology development projects are funded by ESO through its Technology Development Programme and its ALMA Development Programme. In the case of ALMA, the North American and East Asian ALMA partners also run similar programmes.

A full list of ESO's currently running technology development projects can be seen in the tables below, and selected highlights from the year are presented.

ESO's Technology Development projects running during 2024

Project	Description
Astrocomb design study	Development of a next-generation laser frequency comb calibration system for ESO's high resolution spectrographs
ATTRACT Phase 2 & 1B	ESO's activity as a consortium partner in ATTRACT, a Horizon 2020 research and innovation project funded by the European Union
Curved CCD Project	Investigating potential curved CCD detectors for future astronomical instruments
Curved CMOS design study and prototyping	Investigating potential curved CMOS detectors for future astronomical instruments
Deformable Mirror Development	Development of deformable mirrors for adaptive optics instruments for both the VLT and the ELT
Laser Guide Star Systems R&D	Development of the CaNaPy laser guide star adaptive optics facility and the Wendelstein Laser Guide Star System
Large Saphira Development	Development of a large-format 512×512-pixel Saphira electron avalanche photodiode array detector with applications for the ELT
Next Generation Controller II	Development of NGCII, a customisable controller platform for all infrared and optical detectors for all VLT and ELT instruments in construction
PCS Technology Development (Phase 2)	Technology development for the Planetary Camera and Spectrograph, a future planet-finding instrument for ELT
PLANETES	Developing technologies for PLANETES, a system for high-contrast planet detection with the VLTI. Part of a European Research Council funded project.
SAXO+ demonstrator on SPHERE	Developing a second-stage adaptive optics system for high-contrast imaging, which will be a technology demonstrator for the ELT's Planetary Camera and Spectrograph
GPU Technology for Correlators	Investigating potential use of Graphics Processing Units for radio and (sub)millimetre interferometry correlators
Cryogenic Amplifiers for advanced ALMA Receivers	Developing prototype cryogenic low-noise broadband IF and RF amplifiers for ALMA receivers

A list of partner institutes for ESO's Technology Development projects can be found at https://www.eso.org/sci/future/techdev.html

ESO's ALMA Development studies running during 2024

Study	Description
Development of InP MMIC based Wideband Low-Noise Amplifiers for the Next Generation ALMA Receivers	Developing monolithic microwave integrated circuits (MMICs) for cryogenic low-noise broadband IF amplifiers for ALMA receivers
TASER: Towards ALMA System on Chip European Receivers	Extending MMIC technology to further integrate higher-frequency RF amplifiers and other ALMA receiver components
Towards a Producible ALMA2030-Ready Band 9 CCA	Producing a refurbished ALMA Band 9 cold cartridge receiver compatible with the Wideband Sensitivity Upgrade requirements
Streaming visibility processing for ALMA	Investigating a streaming approach to the initial processing of raw ALMA data from the correlator
Advanced waveguide component technologies	Developing a new low-loss microfabrication technique for waveguide components to improve the sensitivity of ALMA receivers
SIS Process Development to serve next generation receivers for ALMA	Developing new processes to make smaller Superconductor Insulator Superconductor (SIS) junctions for ALMA receivers
ALMA Band 6 and 7 Cold Cartridge Demonstrator	Investigating the additional upgrade requirements, on all the ALMA Band 6 and 7 receiver components, of a significant increase in IF bandwidth
Towards High-resolution Solar ALMA Images Overcoming current ObsMode limitations	Verifying if ALMA observations of the Sun can be made in more extended antenna configurations, increasing both spatial resolution and available observing time
Improved and tested atmospheric model beyond 300 GHz	Verifying ALMA's atmospheric transmission model at more than 1000 times improved spectral resolution, using data from an APEX calibration programme
Scientific opportunities and technical considerations for the development of ALMA focal plane arrays	Defining transformative yet technically attainable science cases for potential focal-plane arrays for ALMA.
Prototype for ALMA Spectral Line Advanced Data Product Pipeline	Optimising an automated spectral line detection method on ALMA data cubes and developing an imaging pipeline to derive scientifically relevant information from them

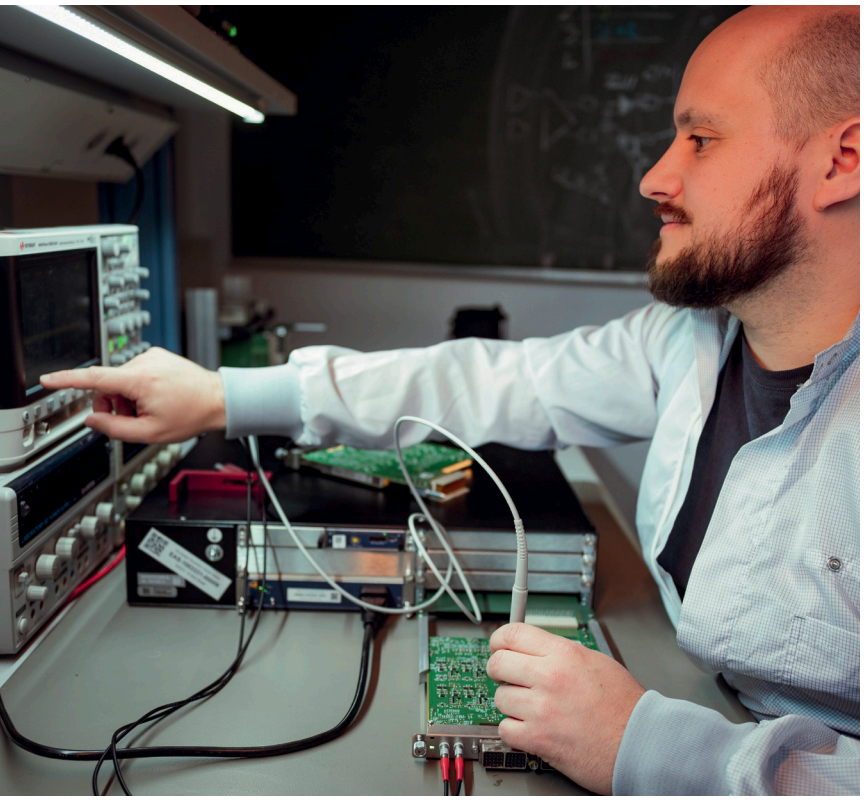
A list of partner institutes for ESO's ALMA Development studies can be found at https://www.eso.org/sci/facilities/alma/development-studies.html

NGCII — a unified way to control any infrared and optical detectors for ground-based astronomy

Astronomical telescopes gather light and direct it to instruments, in which sensitive detectors measure the light, converting it to a signal that can be further processed. These detectors need electronics to control them and read out their data. At visible and infrared wavelengths, two main types of detectors are CCD (charge-coupled device) and CMOS (complementary metal-oxide-semiconductor) arrays. CCDs are classic astronomical workhorse detectors, while CMOS devices are a more modern technology.

The "Next Generation Controller II" (NGCII) is a new controller platform being developed by ESO for the infrared and optical detectors of all forthcoming instruments for the VLT and ELT. Having a common controller platform simplifies operation and maintenance, as it allows different types of detectors, in various instruments, to be controlled in a uniform way.

NGCII is a modular controller designed to control any scientific or wavefront-sensor detector used in infrared or visible-light ground-based astronomy. It is the successor to NGC, an ESO controller successfully used by most of the science detectors at the VLT, but which needs to be updated to work with the newer network infrastructure of the ELT, and because the older components used in NGC are becoming obsolete. The initial configurations of NGCII will fall into three major families, for CCD, analogue CMOS, and Geosnap-type detectors (which are also CMOS but with on-chip electronics for fast, fully digital readout).



ESO/L. Calçada

Testing hardware modules for the NGCII detector controller in the electronics lab at ESO headquarters.

After the laboratory first light of NGCII systems for analogue CMOS (first in 2022 for a SAPHIRA detector, and then in 2023 for a HAWAII-2RG detector), extensive testing and characterisation work took place during 2024. An overview of the project and its current status was presented in the Journal of Astronomical Telescopes, Instruments, and Systems in October.

In December the first NGCII system for CCD detectors was delivered to ESO, where in-house detector engineers integrated it with a detector and began testing.

Also in December, following the successful tests of the NGCII CMOS systems, ESO placed an order for pre-series production by an external supplier. This will be a small batch, made to the standards of a production series, allowing ESO to test the handover of production to the supplier.

Sharpening the ELT's vision to search for Earth-like exoplanets

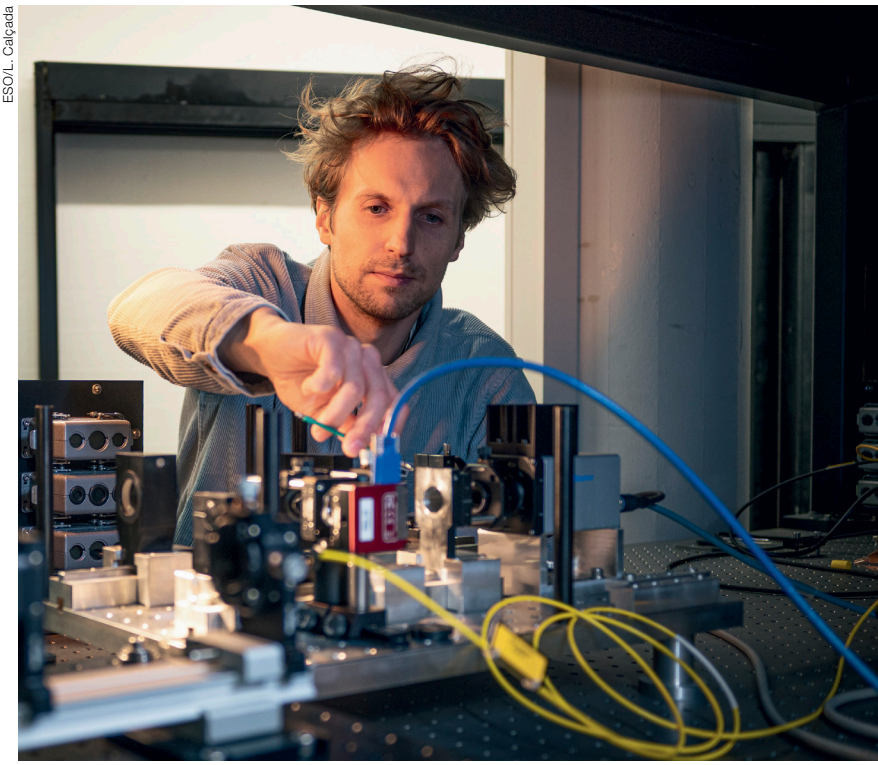
One of the highest scientific priorities for the ELT is to take images of Earth-like exoplanets. This is enormously challenging, as planets, which are extremely faint, are very close to their stars, which are a million to a billion times brighter. Multiple cutting-edge technologies must work together to make this high-contrast imaging possible: extreme adaptive optics to reduce blurring due to atmospheric turbulence, wavefront control, coronagraphy to block out the bright light of the star, and high-resolution spectroscopy.

An ambitious and powerful planetary camera and spectrograph (PCS) is included in the ELT instrumentation plan. PCS is currently in a preparatory phase, in which ESO is working with the community to develop the dedicated technologies required to build it.

One of the main challenges in high-contrast imaging is that delays in the adaptive optics (AO) system make it harder to correct for rapidly changing atmospheric turbulence. The resultant blurring of observations reduces the contrast between the star and the planet.

There are two ways to mitigate this: predicting the turbulence to anticipate what correction will be needed even after a delay, and increasing the frequency at which the AO system operates. ESO is collaborating with groups of partner institutes to develop both approaches.

The 'predictive control' approach of anticipating the turbulence is being tested with a type of machine learning algorithm called reinforcement learning. During 2024 the algorithm was optimised in simulations and verified on the GPU-based High-order adaptive Optics Testbench (GHOST) at ESO Garching. The tests successfully demonstrated raw contrast gains of factors of three to five compared to conventional AO control systems.

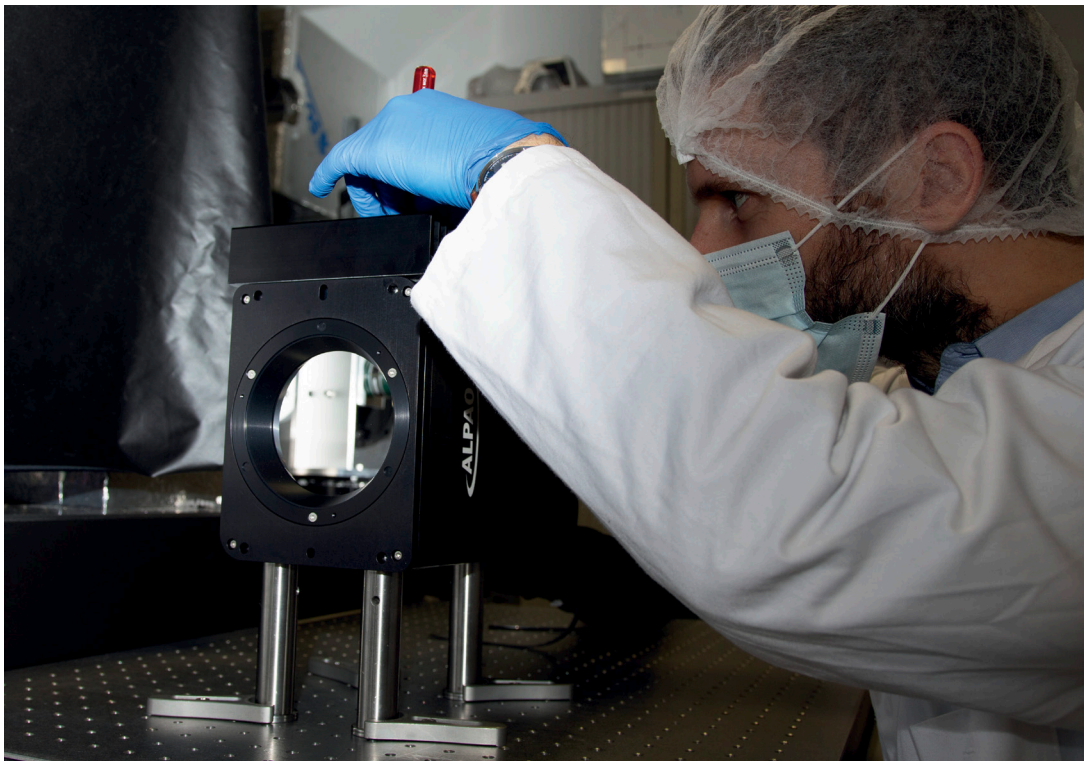


ESO/L. Calçada

Testing a machine-learning algorithm to predict atmospheric turbulence, on the GHOST testbench at ESO.

In addition to predictive control, increasing the AO system frequency is also being investigated with SAXO+, a second-stage AO system to be installed on the VLT instrument SPHERE, downstream of its existing AO system, SAXO. It will provide additional extremely fast AO to remove residual blurring around the star and aims to improve the image contrast by at least an order of magnitude. After a consolidation phase, the construction of SAXO+ was approved in mid-2024, and it is currently in its final design phase, with work being done on design, analysis, and simulations.

Building advanced deformable mirrors for MAVIS



Working on the first of two deformable mirrors being developed for adaptive optics on the MAVIS instrument on the VLT. The mirror is the circular reflective surface visible at the front of the unit.

Bertin ALPAO

Adaptive optics systems improve telescope observations by compensating for turbulence in Earth's atmosphere. Deformable mirrors, which adjust their shape precisely and rapidly, apply corrections to the wavefront of the collected light in real time, cancelling out the effect of the turbulence.

During 2024 the first of two deformable mirrors for the MAVIS instrument was produced. This compact mirror features over 3000 electromagnetic actuators that rapidly adjust the mirror shape.

The mirror was challenging to produce not only because of the large number of actuators but also because the advanced adaptive optics techniques used by MAVIS require particularly high thermal-mechanical stability. To achieve this, the springs in the actuators had to be manufactured using a specially developed technology — the first time this technology had been deployed at this scale. The spring elements were manufactured in early 2024, achieving an excellent yield, with only three out of the 3228 actuators having defects.

Testing of the fully assembled deformable mirror system started in September 2024, revealing very good performance. The mirror can be made perfectly flat using only 5% of the movement of the actuators, meaning that the remaining 95% is still available to correct for atmospheric turbulence. At the end of the year, further extensive tests were ongoing under the simulated environmental conditions of Paranal.

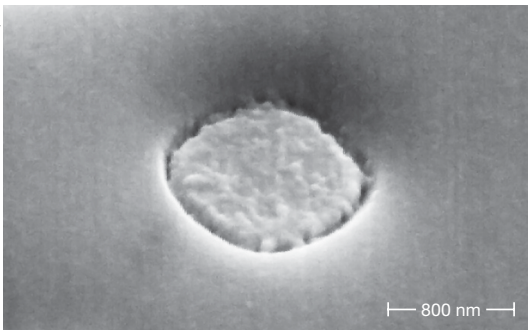
Improving the tiny superconducting cores of ALMA receivers

The ALMA telescope observes the Universe in light with wavelengths in the millimetre and submillimetre range, equivalent to a frequency range from tens of gigahertz to one terahertz. Most of the receivers for ALMA have at their core an electronic device known as a superconductor-insulator-superconductor (SIS) junction, in which the very high radio frequency (RF) of the astronomical signal captured by the antenna is mixed with a 'local oscillator' signal to down-convert it to a lower intermediate frequency (IF) that can be more easily processed. The SIS junction comprises two superconductors separated by an insulating barrier

To enable the planned Wideband Sensitivity Upgrade for ALMA, the frequency coverage of the receivers must be expanded, and upgrading these junctions is critical to achieving this.

The study "SIS Process Development to serve next generation receivers for ALMA" was successfully completed in 2024. It developed new fabrication technology using 'direct laser writing' to make sub-micrometre-size SIS junctions with aluminium nitride (AlN) as the insulating barrier.

Vincent Desmaris, Cristian Lopez



Scanning electron microscope image of the top layer of a superconductor-insulator-superconductor (SIS) junction with an area of just 0.8 μm^2, using aluminium nitride as the insulator. It was made using new fabrication technology developed in an ALMA development study.

The study successfully produced AlN SIS junctions with sizes of just 0.8 μm^2 — about half that of previous junctions — as part of a demonstrator chip for ALMA's Band 9 frequency range. Reducing the size and using AlN instead of the standard aluminium oxide material, are ways to reduce the capacitance of the junctions, which increases the frequency coverage.

The first few junctions already show performance comparable to or better than the best Band 9 receivers currently installed at ALMA, successfully demonstrating the potential of the new fabrication process for future ALMA receiver upgrades.

Jan Olov Yxell

Samples are inserted into a vacuum chamber in a cleanroom, during the manufacture of superconductor-insulator-superconductor (SIS) junctions using new fabrication technology in an ALMA development study.

R&D activities

In addition to the ongoing technology development projects, our engineers are engaged in a wide range of further research and development activities, which come from across the engineering disciplines at ESO, using our laboratory infrastructure and funding from the Directorate of Engineering. An example activity from the year is presented below.

Shrinking spectrographs with photonic chips

Astronomers use spectrographs to disperse the light from astronomical objects into its component wavelengths, giving them an important tool to study the objects' properties.

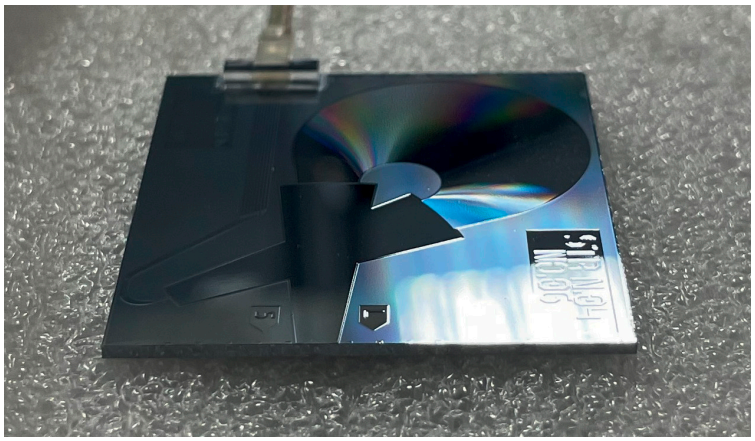
Conventional spectrographs use discrete optical elements such as gratings, lenses, and mirrors. As telescopes get larger, these components also need to be scaled up, making them increasingly complex, bulky, and expensive. For the 8.2-metre-diameter VLT, the optics in an instrument approach 1 metre in size.

A possible alternative to these components is photonic devices, which manipulate light in monolithic chips, similar to microchips for electronics. Not only are photonic chips very compact (just centimetres in size), stable, and relatively cheap and easy to reproduce, but there is also no need to scale them up for bigger telescopes — a huge advantage in the era of the 39-metre ELT. However, while photonic technology is widely used in fibre-optic communications, applications in astronomy have so far remained limited.

ESO engineers, with external partners, designed and fabricated a prototype photonic spectrograph using an arrayed waveguide grating (AWG). The work was presented at the 2024 SPIE Astronomical Telescopes + Instrumentation meeting.

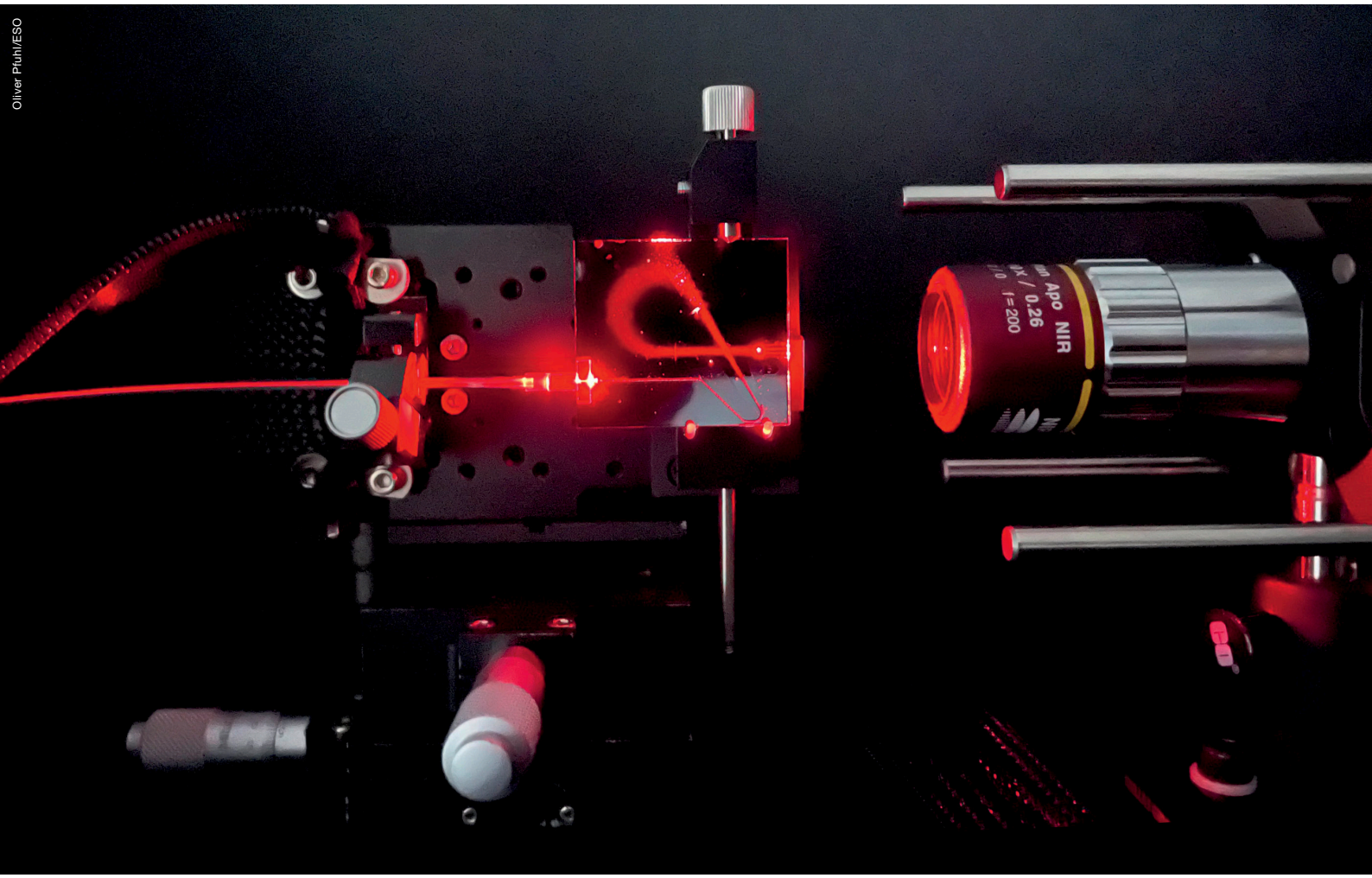
AWGs are photonic chips containing a set of many waveguides — channels that guide light — of incrementing length, running next to each other. The optical effect of the varying lengths is that light entering the waveguides is separated into its component wavelengths at the output: exactly what's needed to make a spectrograph.

The potential of AWGs in astronomy has been studied mainly at infrared wavelengths of 1500–1700 nm, because most commercial AWGs are designed for the standard 1550 nm wavelength used in fibre-optic communications.



An arrayed waveguide grating fabricated on a photonic chip, just 4 cm across.

Oliver Pfuhl/ESO



Oliver Pfuhl/ESO

In this ESO research and development project, the custom AWG was developed for shorter infrared wavelengths of 1100–1500 nm, expanding the available wavelength range for astronomical applications.

The prototype system outperformed its specifications and achieved spectral resolution and transmission values comparable to those of conventional spectrographs. The successful results demonstrate that AWGs are a promising technology for future astronomical spectrographs.

The arrayed waveguide grating being tested. Light enters on the left via an optical fibre, follows the curved loop around the waveguides, and emerges on the right separated into its component wavelengths. The chip operates at infrared wavelengths; the red light visible is a laser used for alignment.

Organisational matters

Delivering ESO's wide-ranging and ambitious programme is only possible thanks to the work of all areas of the organisation, from our engineers and scientists, to our administrators and support staff.

Running an international organisation with sites in two Host States, Germany and Chile, and multiple collaborations with partners around the world, requires complex administration, in areas including human resources, contracts and procurement, facilities management, and logistics and transport activities, including shipments of hardware between Europe and Chile, and domestic and international travel for staff and visitors.

ESO was established as an intergovernmental organisation by its Member States in order to ensure that it could function independently and effectively. Accordingly, some aspects of how ESO operates reflect this intergovernmental status, such as the implementation of internal rules and regulations that take into account international recommendations, standards and best practices.

Whether our work is directly visible to our communities in our facilities, activities and publications, or is in the equally essential internal tasks that allow the organisation to operate, all parts of ESO act together to ensure that we can fulfil our mission, successfully, efficiently, and safely, throughout the year.

S. Lowery/ESO

ESO's Sustainability Strategy approved

ESO believes in the key role of sustainability for its future, taking a long-term environmental, social, and economic perspective, and actively pursuing the responsible management of natural, human and monetary resources.

As part of this long-term perspective, the organisation is putting in place extensive measures to prepare for the coming decades. A key development in 2024 was ESO's Sustainability Strategy, which was approved by the Directors Team in September 2024 and presented to the ESO Council at the Committee of Council meeting, and to staff, in October.

The strategy sets organisational targets grouped into three pillars: 'Healthy planet and healthy space'; 'Thriving communities'; and 'Safe, inclusive and happy workforce'. The ten targets are in areas ranging from reducing greenhouse gas emissions and dark and quiet sky stewardship, through investing in the talent pipeline at ESO and contributing to the socio-economic development of our local communities, to improving staff health and well-being and promoting diversity, equity and inclusion.

With the strategic framework approved, work has begun to implement the strategy, starting with defining the necessary policies, guidelines, and site-specific local action plans.

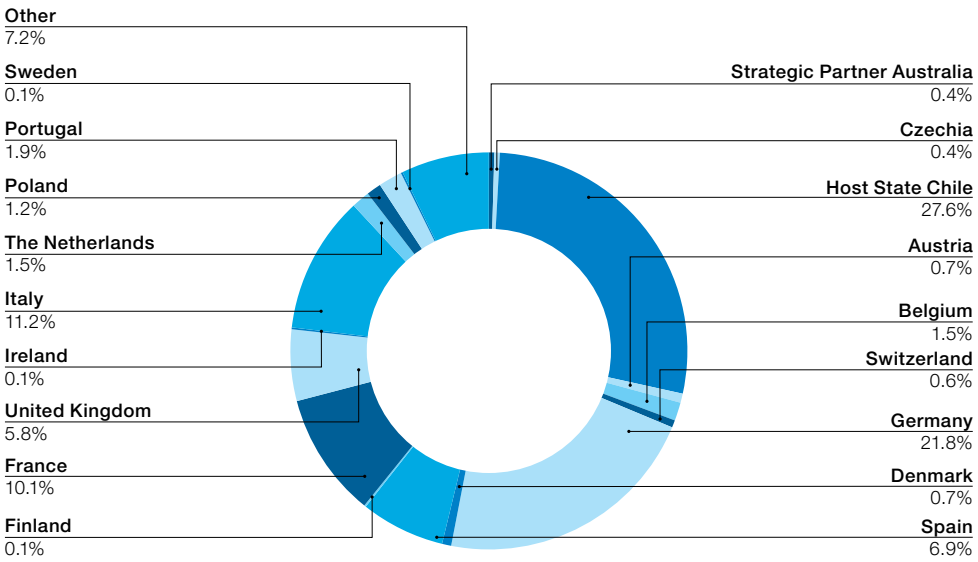
Among other initiatives preparing ESO for the future is the Integrated Operations (IOP) Programme, which will deliver an operations model for the Paranal Observatory that is lean, efficient and sustainable in the 2030s and beyond. More information about this programme is on page 82.

People at ESO

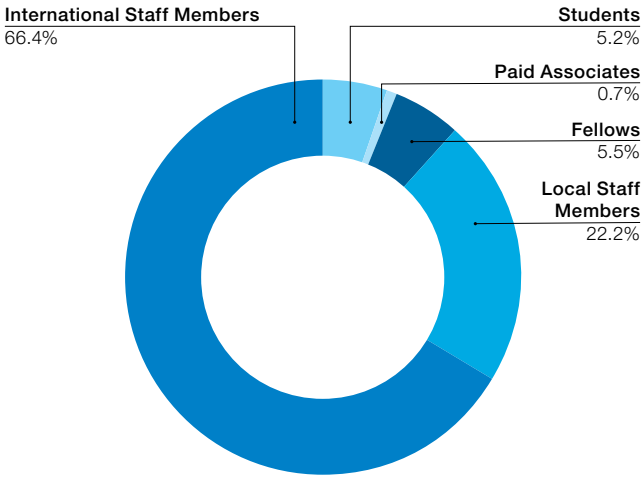
An essential ingredient of ESO's continued success is our highly talented, committed and hard-working staff.

We employ around 750 people, drawn from more than 30 different nationalities.

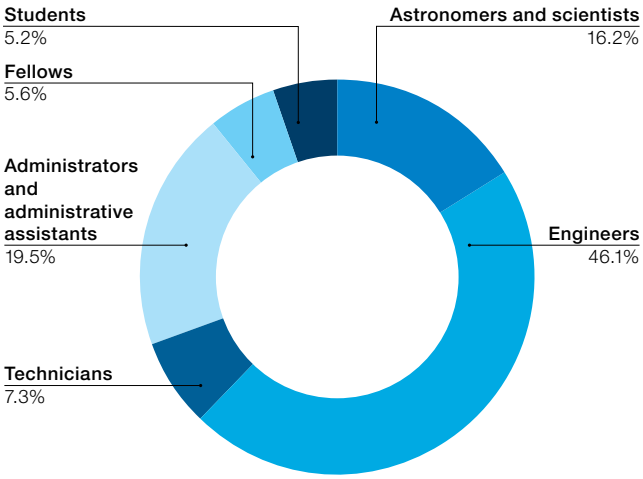
Distribution of International Staff Members and Local Staff Members by nationality (December 2024)



Distribution of ESO personnel by staff category (December 2024)

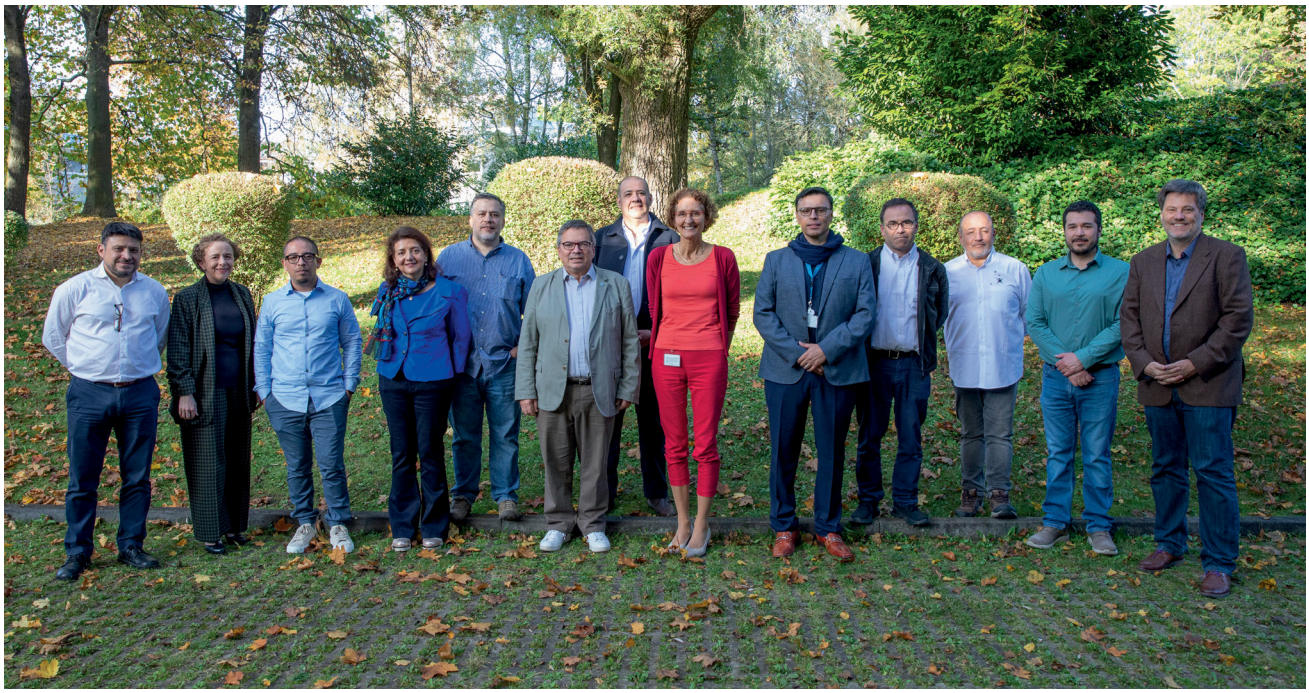


Distribution of ESO personnel by job category (December 2024)



New collective contracts for Local Staff Members in Chile

In October new Collective Contracts for the Local Staff in Chile were signed, valid for three years from November 2024 to October 2027, a welcome extension to the normal two years. The agreement was reached between the Paranal Union, the La Silla Union, the Group of Non-Unionized Local Staff Members, and the ESO Management, following several weeks of constructive and meaningful discussions and without the need for a formal Collective Bargaining process. ESO places great value on positive labour relations, and therefore sincerely thanks the bargaining commissions and everyone else who contributed to this process.



ESO/L. Calçada

Members of the bargaining commissions for the new Collective Contracts for the Local Staff in Chile, with members of ESO Management.

Fostering a learning culture and investing in people

A comprehensive new policy for staff learning and professional development was introduced in April. The goal is to foster a positive learning culture, invest in staff members' professional growth, and ensure we have a fully skilled and effective complement of people to deliver our mission.

Among various measures was the adoption of a more strategic approach through a new Corporate Development Plan. This is a prioritised, high-level overview of the technical and behavioural skills and competencies, including management & leadership skills, which are considered crucial for ESO's mission, goals and objectives, and which will therefore receive targeted investment and support.

The plan complements the existing individual development plans for staff, in addition to which ESO introduced voluntary career coaching for staff who wish to develop a greater awareness of their strengths, values and preferences, and to think about how to advance in their professional goals.

Nicolas Schafer/ESO

During 2024 the gardens of the ESO premises in Vitacura were relandscaped, to reduce water consumption and to replant trees and vegetation with indigenous species.

ESO’s new Ombuds starts work

ESO was very happy to welcome a new Ombuds in July 2024. The Ombuds is a designated neutral person who can provide independent, impartial and confidential assistance to people working at ESO for informal resolution of work-related disputes. With the arrival of the new Ombuds, access was expanded to include all colleagues at the Joint ALMA Observatory. The position, first established in 2019, is part of our commitment to creating a diverse and inclusive work environment that is safe, professional and of mutual trust where everyone is treated with courtesy and respect. In accordance with the standards of the International Ombuds Association, the Ombuds works independently, with unrestricted access to the ESO Council President.

Raising awareness of, and building support for, disabilities at ESO

ESO's Diversity, Equity and Inclusion plan identifies disability as one of the key areas to be addressed, in order that people with disabilities should experience full equity in the workplace.

To raise awareness of disability matters within ESO, experts were invited to give talks for staff, on how to enable blind people and those with visual impairments to learn about and work in astronomy and astrophysics, which have traditionally been considered as visual sciences, and on the inclusion of people with invisible disabilities in the workplace, with a focus on neurodiversity, mental health, and the barriers, stigma, and workplace conditions that can impact employees.

One of the projects presented, an interactive experience allowing blind people and those with visual impairments to explore star and planet formation through touch, was also used at the ESO Garching Open House Day (see page 35).

A key element in creating awareness of, and understanding and support for, people with disabilities at ESO will be a new network of Disability Contact Persons. These are staff who have volunteered to provide information and guidance to colleagues with disabilities, and act as an interface with those parts of the organisation — such as human resources, facilities and logistics, or IT — that can provide assistance or reasonable accommodations where suitable. They will also provide advance and guidance to managers and colleagues of staff with disabilities, and contribute to raising awareness and promoting inclusive practices in the organisation. During 2024 twenty one staff in Garching and Chile received training as Disability Contact Persons, preparing them to take up their roles formally from the start of 2025.

Supporting staff preparing for retirement

The demographics of ESO's personnel means that over 50% of International Staff Member colleagues will retire in the coming 15 years. As a further aspect of our commitment to supporting staff, we reintroduced workshops on preparing for retirement, initially on a trial basis and with the intention to offer them more widely. They offer time and space for staff to think through the next phase of their lives, and help them prepare for the changes, opportunities and challenges that retirement brings.

Finance and budget

The External Auditors, from the Spanish Court of Audit, have expressed their opinion that the financial statements for 2024 give a true and fair view of ESO's affairs.

The accounting statements for 2024 show a net surplus of 48.8 million euros. The operating revenue declined by 118.5 million euros, mainly as a result of a reduced value in 2024 for the conversion into income of previously received advances for the ELT. This conversion, and the subsequent increase in assets, which are mostly in the form of work in progress, depends on the spending on the programme. By the end of 2024 all advances received for the ELT programme had been converted into income.

The surplus from operating activities was 36.8 million euros. From financial activities a net surplus of 6.4 million euros was generated, mainly from increased investment activity, where ESO obtained considerable interest income from deposits. There was a surplus of 5.6 million euros from non-periodic and extraordinary revenues and expenditures. The revenues are mainly generated from the release of a provision created in 2023 related to an arbitration case. Since the decision was in favour of ESO, the compensation due from the other party is also recorded as extraordinary income. The extraordinary expenses are related to the legal fees payable in the above-mentioned arbitration case.

ESO's net assets have decreased by 101.5 million euros. This was mainly caused by the actuarial losses of the Pension Fund. The total cash flow turned negative by 30.3 million euros in 2024. A high operating cash flow was used up by increased investment activity. The operational cash flow was 128.8 million euros. The closing cash position on 31 December 2024 stood at 149.7 million euros.

ESO Council approved the budget for 2025 in December 2024. The approved 2025 expenditure budget amounts to 381.2 million euros, remaining at a considerably high level, with a large fraction dedicated to the ELT programme.

The 2025 approved income budget amounts to 268.0 million euros. It comprises the regular contributions from the ESO Member States including their additional contributions for the ELT, income from third parties and partners, and other income.

Financial Statements 2024

Accounting Statements 2024
(in €1000)

Statement of Financial Position	31.12.2024	31.12.2023
Assets		
Cash and cash equivalents	149 724	179 999
Inventories, receivables, advances and other current assets	99 502	73 716
Non-current assets	1 525 013	1 423 658
Total Assets	**1 774 239**	**1 677 373**
Liabilities		
Payables, advances received and other current liabilities	64 427	81 118
Non-current liabilities	1 050 886	835 852
Total Liabilities	**1 115 313**	**916 970**
Accumulated surpluses/deficits	760 403	793 477
Other changes in net assets	– 150 246	– 215 425
Net surplus/deficit for the year	48 769	182 351
Total Net Assets	658 926	760 403
Total Liabilities and Net Assets	**1 774 239**	**1 677 373**

Assets

- Cash and cash equivalents
- Inventories, receivables, advances and other current assets
- Non-current assets

Liabilities

- Payables, advances received and other current liabilities
- Non-current assets
- Accumulated surpluses/deficits incl. other net changes
- Net surplus/deficit for the year

Cash Flow Statement	2024	2023
Cash Flow		
Net surplus for the year	48 769	182 351
Non cash relevant transactions	90 775	78 318
Changes in current assets and liabilities	– 10 715	– 9 280
Net Cash Flow from Operating Activities	**128 829**	**251 389**
Net Cash Flow from Investment Activities	**– 162 573**	**– 277 802**
Net Cash Flow from Financing Activities	**3 469**	**1511**
Net Cash Flow = Net Increase/Decrease in Cash and Cash Equivalents	**– 30 275**	**– 24 902**

External auditors, Spanish Court of Audit

Enriqueta Chicano Jávega (External Auditor, President of the Spanish Court of Audit)
Santiago Martinez Arguelles (Director General)
Guadalupe Fernández Espinosa (Director International Relations and Coordinator)
Alvaro Garrido-Lestache (Audit Manager)
Beatriz Sanchez Almendros (Deputy Audit Manager)
Aranzazu Piñeiro Hernaiz (Deputy Audit Manager, Contracts and Compliance)
Paloma de Carlos Lardíes (Senior Auditor)
Alberto Sánchez Chaves (Senior Auditor)
Paloma Pardo Oláguez (Auditor)

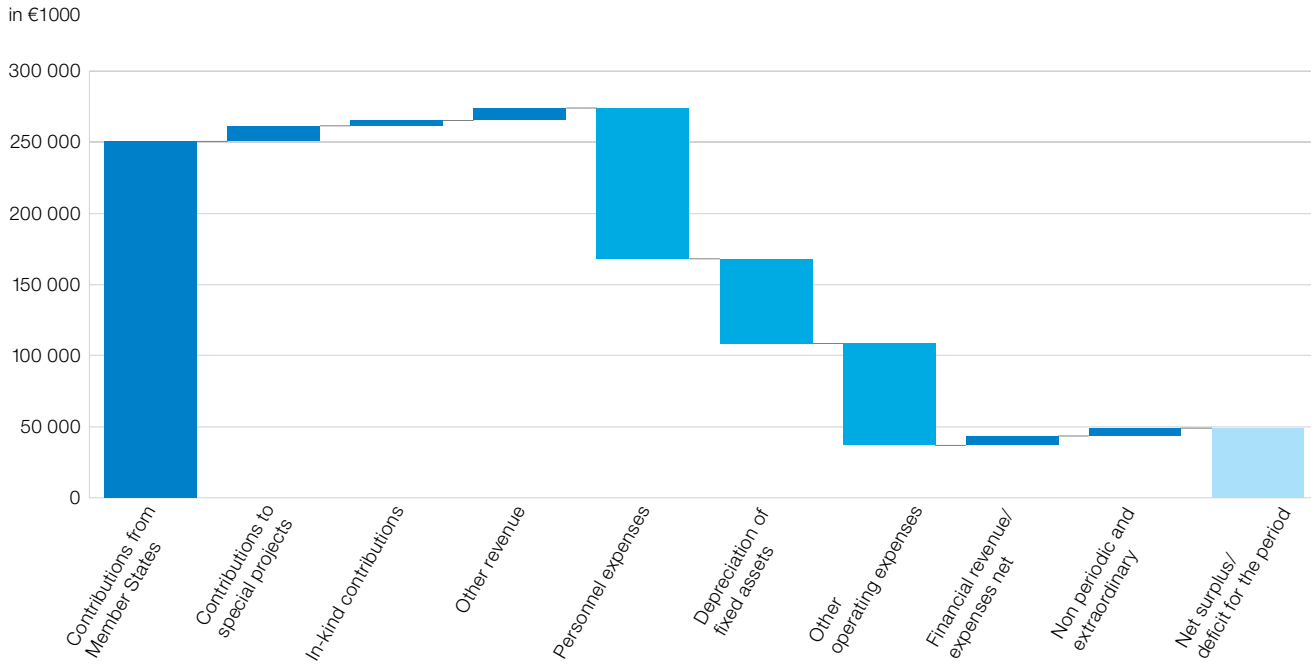
Statement of Financial Performance	2024	2023
Operating Revenue		
Contributions from Member States	250 512	365 514
Contributions to special projects	10 880	8 878
In-kind contributions	3 826	9 534
Other revenue	8 692	5 338
Total Operating Revenue	**273 910**	**392 369**
Operating Expenses		
Personnel expenses	105 950	90 616
Depreciation of fixed assets	59 462	62 778
Other operating expenses	71 670	62 678
Total Operating Expenses	**237 082**	**216 072**
Net Surplus/Deficit from Operating Activities	**36 828**	**176 297**
Net Surplus/Deficit from Financial Activities	**6 373**	**10 302**
Net Surplus/Deficit from Non-periodic and Extraordinary Activities	**5 568**	**–4 248**
Net Surplus/Deficit for the Period	**48 769**	**182 351**

Budgetary Reports 2024
(in €1000)

Income Budget	Actual	Budget
Contributions from Member States	234 328	228 331
Income from partnerships	10 035	13 368
Income from third parties	4 463	4 120
Other income	8 492	10 737
Consolidated entities	4 248	2 978
Total Income Budget	**261 566**	**259 534**

Expenditure Budget	Actual	Budget
Programme	149 976	233 698
Technical infrastructure and production	8 086	10 653
Operations	84 312	107 229
Science support	8 547	11 006
Other expenses	5 014	4 064
General activities	37 698	42 066
Total Expenditure Budget	**293 633**	**408 716**

Statement of Financial Performance



Budget for 2025
(in €1000)

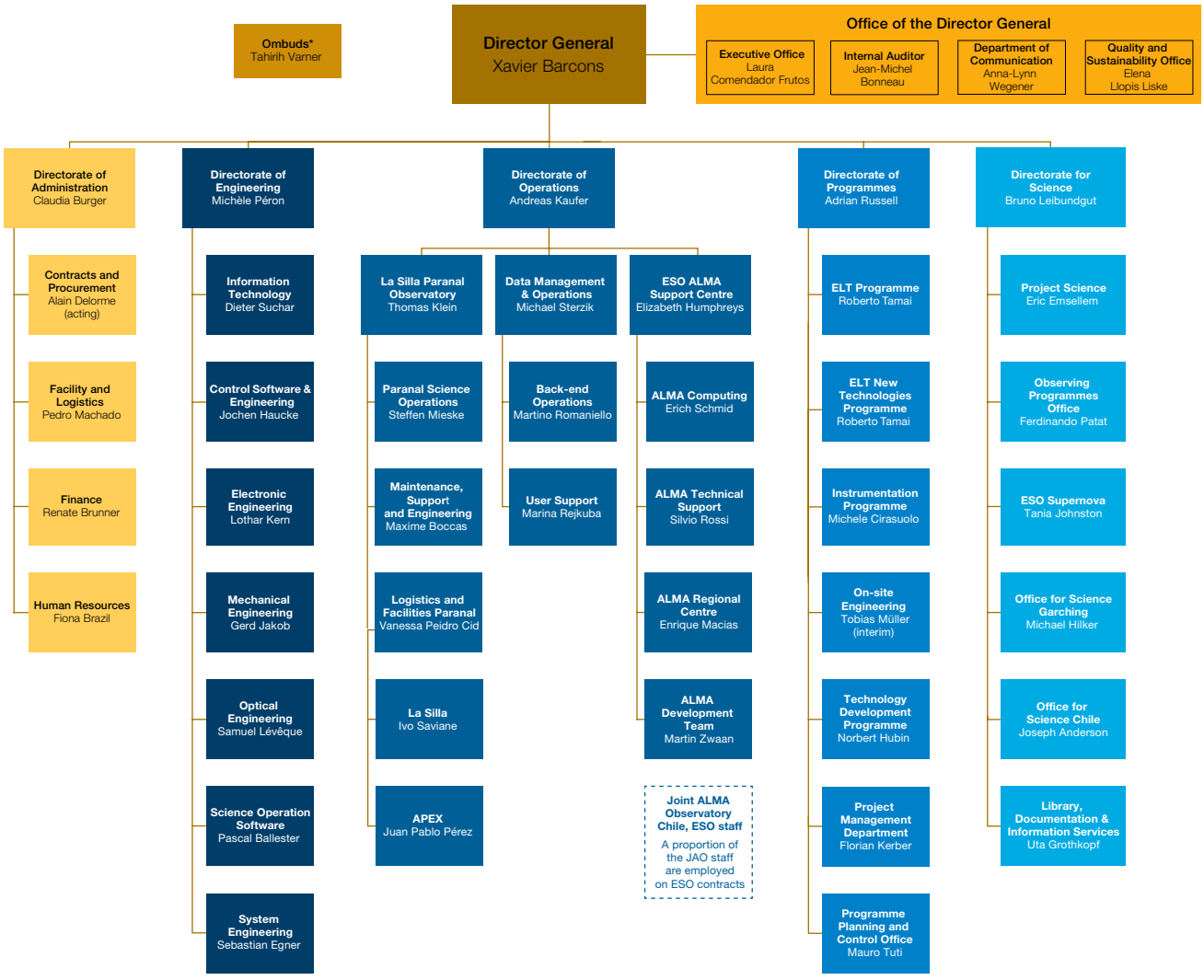
Income Budget	2025 (Approved)
Contributions from Member States	**235 134**
Income from partnerships	22 054
Income from third parties	3 616
Other income	3 717
Consolidated entities	3 441
Total Income Budget	**267 962**

Expenditure Budget	2025 (Approved)
Programmes	**202 867**
Technical infrastructure and production	9 622
Operations	109 149
Science support	11 066
General activities	44 304
Other expenses	4 175
Total Expenditure Budget	**381 183**

Income Budget

Expenditure Budget

Organisational structure



*Independent as per Terms of Reference

Directorate of Administration

The Directorate of Administration comprises ESO's administration in Garching and in Chile, in charge of all administrative matters across the organisation. It also hosts the ESO-wide Quality and Information Systems (QIS) Programme. The Director of Administration is responsible for site safety in Garching, Vitacura and the Santiago Guesthouse.

Contracts and Procurement Department is responsible for performing the procurements and sales needed by ESO, in compliance with the organisation's policies and procedures. The department also contributes to the administration of contracts after their award and provides commercial and contractual advice wherever requested internally.

Facilities and Logistics Department plans, constructs, operates, and maintains ESO facilities, grounds, and infrastructure on the Garching and Vitacura campus, focusing on safety, as well as social, environmental, and economic sustainability. The department manages logistics operations, namely reception, imports/exports of goods into/from Germany and Chile, inland transports in Chile and Europe, shipments for the ESO web shop, and removals for staff in Europe and in Chile.

Finance Department ensures that the financial resources entrusted to ESO are used according to the applicable rules and regulations, and in line with the directions defined by ESO's governing bodies. The department's activities cover four main areas: budgeting & controlling, accounting, invoice control and treasury.

Human Resources Department manages all services connected with employment at ESO, in Garching and Chile, including hiring, pay, benefits, training and development, travel, health, social security and wellbeing.

Directorate of Engineering

The Directorate of Engineering provides engineering resources and services to all ESO programmes and to the operations teams at the observatories and at ESO Headquarters. In addition, the directorate provides information technology (IT) services to the whole organisation.

Information Technology Department
delivers IT services and supports users and science operations in fulfilling the ESO mission, provides expertise and resources to ESO projects, programmes and collaborations, all while ensuring user satisfaction, continuous operation and appropriate project completion.

Control Software and Engineering Department
is responsible for the design, implementation, verification and commissioning of control systems and for the development of control software for telescopes and astronomical instruments over the full software lifecycle. This includes the development and maintenance of software frameworks and infrastructure projects, and the evaluation and definition of related engineering standards.

Electronic Engineering Department
is responsible for the definition, design and manufacturing of control electronic and detector systems and subsystems for telescopes and instruments, as well electrical compliance verification for all ESO projects. The department's expertise ranges from instrument and telescope control electronics and automation to detector system design, production, qualification and testing.

Mechanical Engineering Department
provides mechanical engineering expertise to all ESO programmes including design, analysis, manufacturing and assembly, integration and verification of mechanical, opto-mechanical, cryogenics, instrumentation, telescope and infrastructure systems.

Optical Engineering Department
provides engineering expertise to the whole suite of ESO projects, in the areas of optical design and analysis, active optics, phasing, metrology for telescope alignment, laser guide stars, photonics technology and assembly, integration and testing of optical systems and instruments.

Science Operation Software Department
is responsible for all science operation software for end-to-end operations of ESO observatories. This includes all components required for proposal submission, observation preparation, scheduling, execution, archiving, data processing, and quality control of observations. This software is used within the organisation as well as by the user community.

Systems Engineering Department
provides all systems engineering functions for the programmes at ESO, such as requirements and configuration management, system architecture, technical coordination, analysis, verification, and interface and technical performance management.

Directorate of Operations

The Directorate of Operations is responsible for all science operations activities, encompassing preparation and execution of observing programmes, operation of the La Silla Paranal Observatory, and delivery of raw and calibrated data, including user support, data flow management, and science archive facilities. It also includes ESO's contribution to ALMA operations and development, and the construction support and future operation of the southern Cherenkov Telescope Array (CTAO-South).

La Silla Paranal Observatory

provides and operates telescopes and other facilities at the La Silla, Paranal, and APEX sites, including the VLT and VLTI, VISTA, ESO 3.6-metre telescope, and NTT, as well as several hosted telescopes including APEX. Paranal will also be responsible for operation of the ELT on Cerro Armazones, and CTAO-South.

Paranal Science Operations Department
is responsible for executing all scheduled observations and producing astronomical data of the highest quality. The department also maintains and improves the scientific and operational performance of the Paranal telescopes and instruments, and its instrument scientists lead the Instrument Operations Teams of all VLT and VLTI instruments.

Maintenance, Support and Engineering Department
is responsible for keeping the Paranal Observatory telescopes, instruments and key technical infrastructure operational, and at the expected technical performance, for use by Paranal Science Operations every day and every night of the year. To maximise the availability of our systems, we run an ongoing programme of maintenance and improvement.

Paranal Logistics and Facilities Department
ensures the delivery of consistent, budget-focused logistics and facilities services for the entire Paranal community, while maintaining the effective running of civil infrastructure on the site.

La Silla Department
is in charge of operating the NTT and 3.6-m telescopes, and supporting hosted projects on the La Silla site.

APEX Department
supports the operation by ESO of the APEX (Atacama Pathfinder Experiment) telescope, including the telescope site at 5100 metres altitude on Chajnantor, the base station at Sequitor near San Pedro de Atacama, and related logistics activities, as a hosted project on behalf of the Max Planck Institute for Radioastronomy.

Data Management and Operations Division

is responsible for off-site operations and user support of the La Silla Paranal Observatory in the framework of an end-to-end data flow system, maintaining the archive facility and its data holdings as a powerful scientific and operational resource. It owns and executes a development programme for integrated scientific operations of the VLT, VLTI and ELT.

User Support Department
ensures optimal preparation and efficient execution of Service Mode observations for the La Silla Paranal Observatory (LPO) and related reporting; implements and operates the support helpdesk; prepares and maintains LPO telescope schedules; organises Visiting Astronomer travel; and is responsible for user requirements and scientific oversight of operations support tools.

Back-end Operations Department
is responsible for the management of the science data stream from the La Silla Paranal Observatory. This includes the development and operations of the ESO Science Archive Facility, and the scientific oversight of the data processing tools, and encompasses the generation of science data products and the handling of those provided by the community.

An aerial view of ESO's Paranal Observatory.

ESO ALMA Support Centre

carries out all ALMA operations-related activities within ESO and with the ALMA partners and Joint ALMA Observatory, including operation of the European ALMA Regional Centre (ARC), offsite engineering maintenance support to JAO, software development, and delivery of the studies and projects of the European ALMA development programme.

ALMA Computing Team
develops and maintains ALMA software supporting the full observing lifecycle, including archive services, observing preparation, project tracking and reporting, quality control, telescope calibration and automation & testing. It contributes to data processing software and ALMA development projects and is part of the global ALMA Integrated Computing Team.

ALMA Technical Team
supports the global ALMA Integrated Engineering Team as the ESO component of the team. It supports the JAO Department of Engineering, coordinates and performs maintenance activities, especially tier-3 corrective maintenance of ESO deliverables, identifies opportunities for improvement, especially for ESO deliverables, and develops projects.

ALMA Regional Centre Department
supports ALMA global science operations in policy, data flow, and execution of science programmes. It develops enhanced observing and data processing techniques and coordinates delivery of subsystem software. It also delivers quality-assured, high-quality data products, and facilitates science through coordination of user support.

ALMA Development Team
is responsible for delivering the Wideband Sensitivity Upgrade (WSU) as well as longer-term European ALMA development. It oversees and financially manages development projects and studies, strategically plans the European ALMA development priorities, and liaises with ALMA partners, industry, and institutes in Europe.

Directorate of Programmes

The Directorate of Programmes is responsible for the management and delivery of ESO's construction programmes and projects within ESO's matrix organisation. The overall work is broken down into the programmes for ELT Construction and ELT New Technologies, Armazones Instrumentation, Paranal Instrumentation, and Technology Development. Each programme encompasses many projects.

ELT Construction Programme
is responsible for the delivery of a fully functional and complete ELT, including the telescope with all the optics and optomechanics, the dome, and infrastructure, as well as the verification of the telescope with the first scientific instrument.

ELT New Technologies Programme
comprises all technology development activities directly needed to fulfil the objectives of the ELT Construction Programme. The programme is managed by the ELT Construction Programme Manager.

On-Site Engineering Department
is a matrixed department primarily hosting engineers and technicians needed on-site for ELT assembly, integration and verification (AIV), as well as staff for dome and main structure, and ELT Supporting Systems, activities on site. Once full AIV activities on Armazones begin, the department will move to the Directorate of Engineering.

Instrumentation Programme
is the framework within which ESO develops, delivers, and upgrades optical and infrared instruments for the ELT and ESO facilities at Paranal and La Silla.

Technology Development Programme
develops and secures key technologies which will maintain ESO's facilities at the cutting edge of astronomy, contributing to achieving ESO's mission, and supports technology development for new ESO standards.

Project Management Department
provides leadership and management to the full range of ESO's projects — telescopes, instruments, and organisational — from inception to delivery using the triple constraints of scope, cost and schedule. The department owns ESO's project management framework and processes, and develops them in order to meet the evolving needs of the organisation.

Programme Planning and Control Office
provides support to projects and programmes within the Directorate of Programmes with respect to all financial and programmatic aspects. This includes material and level-of-effort budgeting, financial planning, schedule and cost control, reporting, estimating, risk management and performance measurement

Directorate for Science

The Directorate for Science provides guidance to all science-related projects at ESO, supports community science with ESO facilities, provides the scientific environment for the astronomers at ESO, and runs the ESO student and fellowship programmes.

Project Science Department
hosts and supports ESO Project Scientists, providing scientific leadership, guidance and monitoring for the design, development and implementation of ESO instrumentation. Project Scientists are responsible for developing and maintaining the science requirements, ensuring compliance with the scientific goals of the respective programmes and with operation standards while maximising scientific exploitation.

Observing Programmes Office
manages the entire process for telescope time proposals at ESO, from issuing Calls for Proposals to providing statistics on time allocations to both internal and external stakeholders.

ESO Supernova Department
operates the visitor centre and planetarium at the ESO Garching Headquarters, bringing the fascinating world of astronomy closer to the general public. This includes planning, promoting and implementing a varied programme of activities for the general public and schools and coordinating the technical maintenance of the facility.

Offices for Science in Garching and in Chile
run the Science Programmes at ESO, fostering a stimulating scientific environment that allows the students, Fellows, and staff astronomers at ESO to develop and conduct cutting-edge science and to disseminate ESO expertise into the scientific community.

Library, Documentation, & Information Services Department
manages and supports the central organisation of ESO institutional, project and product documentation; provides access to scientific and technical publications; develops tools that help assess ESO's scientific impact including the ESO Telescope Bibliography (telbib); and shares developments in publishing and research communication.

Office of the Director General

The Office of the Director General deals with activities that are under the direct authority of the Director General, including corporate and organisation-wide horizontal activities that are not delegated to the directorates.

Executive Office
supports the Director General's internal and external duties, including the ESO Representation in Chile, and legal and institutional affairs. The office also supports Council with the development and implementation of ESO's strategy, and provides executive and secretarial support to Council, the Directors Team, and other auxiliary bodies.

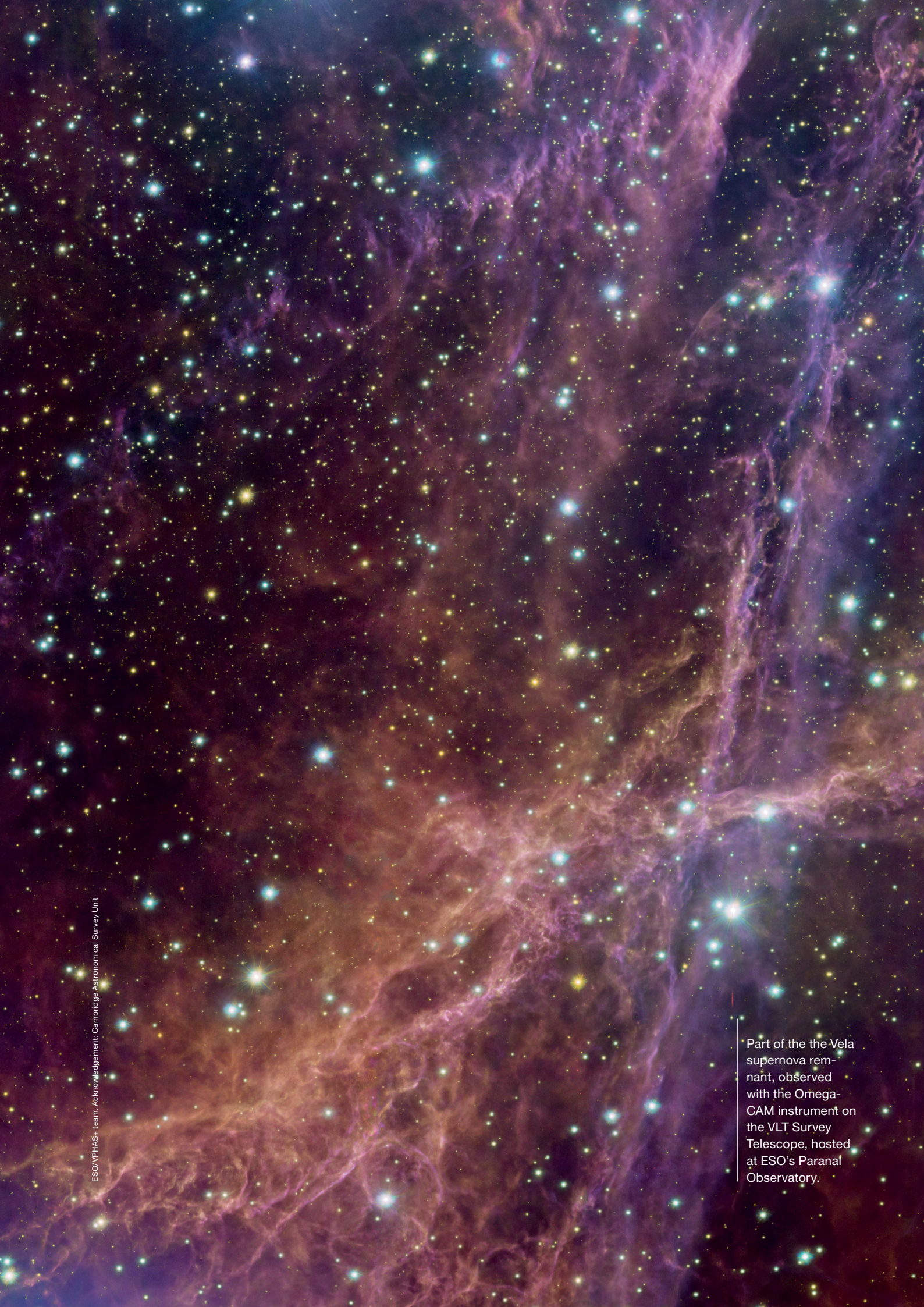
Department of Communication
is responsible for internal and external communication for ESO in areas including media relations, content production, public and local outreach, digital communication and internal communication, engaging with audiences from scientists, decision-makers and industry partners to journalists and the public.

Quality and Sustainability Office
provides corporate services and support across ESO in matters related to quality management, corporate risk management, and sustainability and diversity.

Internal Audit
carries out independent, objective assurance and consulting activities to add value and improve ESO's operations, assisting all levels in the organisation. Internal Audit liaises and cooperates with ESO's external auditors. The Internal Auditor reports organisationally to the Director General, and has direct and independent access to the ESO Council President.

Ombuds

is a designated neutral person providing independent, impartial and confidential assistance to people working at ESO and the Joint ALMA Observatory for informal resolution of work-related disputes, in accordance with the Standards of Practice and Code of Ethics of the International Ombudsman Association. The Ombuds works independently, with unrestricted access to the ESO Council President.



ESO/VPHAS+ team. Acknowledgement: Cambridge Astronomical Survey Unit

Part of the the Vela supernova remnant, observed with the Omega-CAM instrument on the VLT Survey Telescope, hosted at ESO's Paranal Observatory.

ESO's Governing Bodies

ESO's ruling body is its Council, which delegates day-to-day responsibility to the Executive under ESO's Director General. Other governing bodies of ESO are: the Finance Committee, the Scientific Technical Committee, the Observing Programmes Committee and the Users Committee.

Council

The ESO Council decides the organisation's policies regarding scientific, technical, and administrative matters, and is the main governing body of ESO.

Council and Committee of Council 2024

President	Tom Ray
Austria	Daniel Weselka João Alves
Belgium	Sophie Pireaux Emmanuël Jehin
Czechia	Jan Buriánek Soňa Ehlerová
Denmark	René Michelsen Lise Christensen
Finland	Oskari Miettinen Seppo Mattila
France	Guy Perrin Karine Perraut
Germany	Martin Thomé (until 6 December 2024) Sabine Carl (as of 6 December 2024) Matthias Steinmetz
Ireland	Peter Healy Paul Callanan (as of 20 February 2024)
Italy	Vincenzo Fiorentini (until 30 June 2024) Piergiorgio Alotto (as of 2 July 2024) Marco Tavani (until 2 June 2024) Roberto Ragazzoni (as of 3 June 2024)
The Netherlands	Mirjam Lieshout-Vijverberg Amina Helmi
Poland	Dariusz Drewniak Marek Sarna
Portugal	Ricardo Conde Marta Gonçalves (alternate for Ricardo Conde as of 29 April 2024) Paulo Garcia
Spain	Inmaculada Figueroa Rafael Bachiller
Sweden	Camilla Jakobsson Sofia Feltzing
Switzerland	Xavier Reymond (until 15 March 2024) Kevin Reymond (as of 15 March 2024) Francesco Pepe
United Kingdom	Jenny Hiscock Vikram Dhillon

Observers

Australia	Janean Richards (until 12 May 2024) Nick Purtell (from 13 May until end of June 2024) Natalie Weddell (as of 10 September 2024) Sarah Brough

Finance Committee

The ESO Finance Committee (FC) advises the ESO Council on all dealings related to administrative and financial management.

Finance Committee 2024

Chair	Harald Haakh
Austria	Susanne Sulzbacher
Belgium	Alain Heynen
Czechia	Pavel Křeček
Denmark	Mads Rugaard Christensen
Finland	Peter Salo
France	Carine Bernard
Germany	Sarah Kudling
Ireland	Lola Hourihane
Italy	Salvatore Vizzini
The Netherlands	Jelle Stronks
Poland	Dariusz Drewniak
Portugal	Filipa Batista Coelho
Spain	Ana Aricha
Sweden	Sofie Björling
Switzerland	Astrid Vassella
United Kingdom	Chris Woolford

Observers

Australia	Bridgette Hargreave

Scientific Technical Committee

The Scientific Technical Committee (STC) determines ESO's scientific and technical priorities, and advises the ESO Council and Director General on relevant decisions for ESO's projects and programmes.

Scientific Technical Committee 2024

Austria	Stefan Kimeswenger
Belgium	Olivier Absil
Chile	Laura M. Pérez
Czechia	Dušan Mandát
Denmark	Marianne Vestergaard
Finland	Talvikki Hovatta
France	Audrey Delsanti
Germany	Natascha Foerster Schreiber
Ireland	Rebeca Garcia Lopez
Italy	Marcella Marconi
The Netherlands	Serena Viti (Chair) Ignas Snellen
Poland	Tomasz Kamiński
Portugal	Jarle Brinchmann
Spain	Javier Cenarro Frédéric Courbin
Sweden	Kirsten Kraiberg Knudsen
United Kingdom	Nial Tanvir

Observers

Australia	Michael Murphy

Members at Large

Australia	Claudia Lagos

Observing Programmes Committee

The Observing Programmes Committee (OPC) receives and evaluates proposals submitted to ESO for observations.

The Observing Programmes Committee 2024	
Sabine Schindler	(Chair)
Paul Barklem	(Vice Chair)
Simon Albrecht	
Catherine Boisson	(P114)
Andrea Chiavassa	(P115)
Ilse De Looze	(P114)
Luca Fossati	
Karl Glazebrook	
Jacqueline Hodge	(P115)
James Jenkins	
Kate Maguire	(P114)
David Martinez Delgado	
Mikako Matsuura	
Simona Mei	(P114)
Joseph Mohr	
Paola Pinilla	
Sandra Savaglio	(P115)
Marco Scodeggio	(P114)
Antonella Vallenari	
Susanna Vergani	(P115)
Norbert Werner	(P115)
Konstanze Zwintz	

Users Committee

The Users Committee (UC) advises the Director General on matters related to La Silla Paranal Observatory and ALMA, providing feedback and recommendations on operations.

Users Committee 2024	
Austria	Miguel A. Urbaneja Perez
Belgium	Arjen van der Wel
Czechia	Daniela Korčáková
Denmark	Thomas Rodriguez Greve
Finland	Rubina Kotak
France	Philippe Salomé
Germany	Peter Schilke
Ireland	Emma Whelan
Italy	Enrichetta Iodice (co-Chair)
The Netherlands	Søren Schack Larsen
Poland	Agnieszka Maria Pollo
Portugal	Ana Paulino-Afonso
Spain	Nicolas Lodieu
Sweden	Elvire De Beck (Chair)
Switzerland	Xavier Dumusque
United Kingdom	Timothy Davis
Australia	Sarah Sweet
Chile	Timo Anguita

ESO/VPHAS+ team. Acknowledgement: CASU

A dark cloud of cosmic gas and dust with an elongated tail, known as a cometary globule, observed with the VLT Survey Telescope, hosted at ESO's Paranal Observatory.

Cover: The star cluster RCW 38, observed with ESO's Visible and Infrared Survey Telescope for Astronomy (VISTA). VISTA's infrared light observations reveal a dramatic landscape of gas, dust and stars.

Credit: ESO/VVVX survey

ESO Europe

Headquarters
Karl-Schwarzschild-Straße 2
85748 Garching bei München
Germany
Phone +49 89 320 06-0
Fax +49 89 320 06-664
information@eso.org
www.eso.org

ESO Chile

Santiago Office
Alonso de Córdova 3107
Vitacura
Casilla 19001
Santiago
Chile
Phone +56 2 2463 3000

La Silla Paranal Observatory
La Silla Site
Región de Coquimbo
Chile
Phone +56 2 2464 4100

La Silla Paranal Observatory
Paranal Site
Región de Antofagasta
Chile
Phone +56 55 2435 100

La Serena Office
Avenida Colo-Colo 4416
La Florida
La Serena
Chile
Phone +56 51 2272 601

Guesthouse
Rey Gustavo Adolfo 4634
Las Condes
Santiago
Chile
Phone +56 2 2208 4254

Antofagasta Office
Avenida Balmaceda 2536
Office 504
Edificio "Don Guillermo"
Antofagasta
Chile
Phone +56 55 2260 032

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

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

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