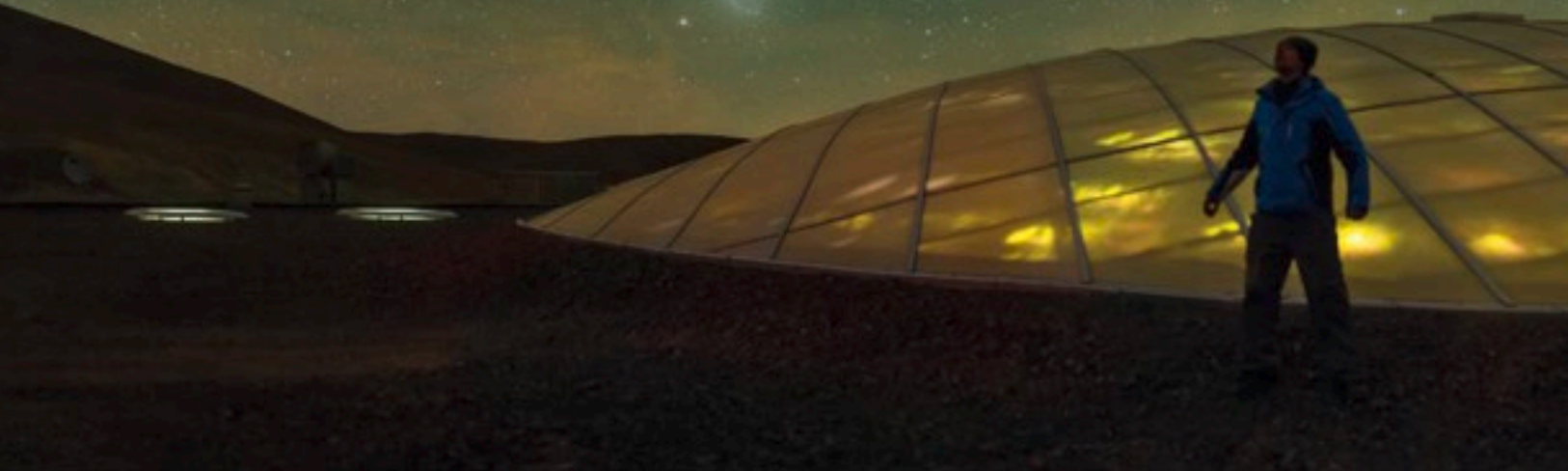




Astronomy and Society

Summary of ESO–Chile Cooperation 2020





Milky Way over Paranal Observatory, Antofagasta region.





Cerro Armazones, Antofagasta region.

Cooperation for Mutual Benefit

In 1963, the European Southern Observatory (ESO) and Chile signed a visionary agreement which paved the way for the construction of an astronomical observatory on Cerro La Silla, Coquimbo region. This partnership, reinforced by mutual trust, has led ESO, almost 60 years later, to operate all of its observatories in Chile, including some of the most powerful in the world (such as those on Cerro Paranal and Llano de Chajnantor) and to currently plan to deploy new, ambitious projects in the country.

Apart from obtaining key findings about the Universe, ESO's observatories generate business opportunities, stimulate local development and, above all, play a role in training new generations. Nowadays, Chile is a world-class option for studying and working in fields directly or indirectly related to astronomy.

The impressive growth of ESO has had a direct and tangible impact on the development of astronomy in Chile, which is part of the national identity nowadays. Chilean astronomy has grown in numbers and prestige, reaching international visibility in the scientific community and in the press. Today, astronomical sciences are part of Chilean popular heritage and ESO is proud to have contributed to this transformation.

The renewed Chilean scientific institutional structure, with its Ministry of Science, Technology, Knowledge and Innovation, regional secretariats and the National Agency for Research and Development (ANID), is aimed at moving forward in the fields of data science, artificial intelligence, and automation. The new national strategy is focused on enhancing natural laboratories, encouraging decentralisation and strengthening international partnerships, areas in which ESO can contribute through a cooperative relationship with the country.

Therefore, at this historical time when science and technology play a fundamental role in the challenges facing humanity, we would like to consolidate the memory of the road behind us.

We hope this brief report will provide an overview of what has been accomplished through this strong relationship of collaboration and trust which ESO and Chile have forged for almost 60 years. On that basis, we also pause to consider the opportunities that cooperation can offer in the future.



Xavier Barcons, Astronomer
ESO Director General.



Claudio Melo, Astronomer
ESO Representative in Chile.

ESO's Contribution to Chile – Highlights



Science and education

- + 10% of observing time is reserved on ESO telescopes for the Chilean astronomical community.
- + In 2020, the ESO–Government of Chile Joint Committee allocated CLP \$ 450 million (500 000 euros).
- + Chilean students account for the highest proportion of ESO PhD studentships in astronomy.
- + ESO has contributed to tripling the productivity of Chilean astronomy in the last decade.



ALMA

- + ESO provides 37.5% of ALMA's annual budget.
- + The ALMA–ANID Fund, funded projects for around CLP \$ 610 million (669 000 euros) in 2020.
- + In 2020 the ALMA–Region II Fund contributed around CLP \$ 260 million (297 000 euros).



Regional focus

- + In 2019 ESO created a regional relations office to promote links with areas within the vicinity of observatories.
- + 19% of ESO procurement in Chile was made in the Antofagasta region, in the last decade.
- + ESO provides a scholarship programme for young students from Taltal (Antofagasta region).



Financial investment

- ✦ The operations of the ESO facilities in Chile entail an estimated annual investment of CLP \$ 59 billion (66 million euros).
- ✦ 25% of ESO staff are Chilean, representing the largest national group in the Organisation.
- ✦ In the last decade, 30% of ESO commitments to purchase have been made in Chile, a larger share than in any other country, including the 16 ESO Member States.



ELT

- ✦ 81% of the total budget (about CLP \$ 1.2 trillion, equivalent to 1.3 billion euros), is earmarked for contracts with the industry, mostly in Europe but also in Chile.



Sustainability

- ✦ Since 2016, La Silla Observatory has been using 100% renewable energy.
- ✦ ESO is gradually replacing its fleet of vehicles by electric cars.
- ✦ ESO engages in the protection of dark skies and in the implementation of lighting regulations in Chile.



Outreach

- ✦ La Silla and Paranal receive some 8000 visitors per year. Tours are open to the public, free of charge.



ALMA Building in the ESO premises, Vitacura, Santiago, Chile.

ESO/C. Brammer



ESO Headquarters in Garching, near Munich, Germany.

ESO/C. Malin

58 years Contributing to the Development of Astronomy in Chile



Thanks to a fruitful collaboration with Chile, ESO has been operating in the country since 1963, with its main offices in Vitacura, Santiago, and its observatories in the Coquimbo and Antofagasta regions.

Established in 1962, the European Southern Observatory (ESO) – formally known as the European Organisation for Astronomical Research in the Southern Hemisphere – is the foremost intergovernmental astronomy organisation in Europe, with headquarters in Garching, Germany.

ESO carries out an ambitious programme focused on the design, construction and operation of powerful ground-based observing facilities, all of which are located in Chile.

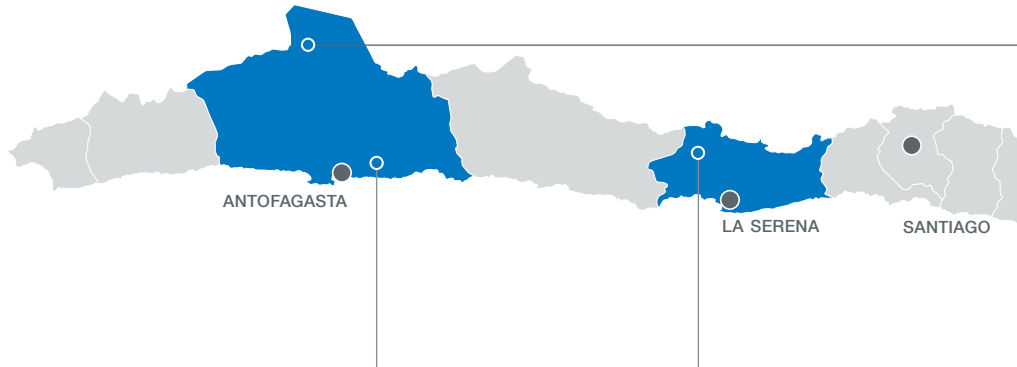
ESO is an international organisation currently composed of 16 Member States: Austria, Belgium, the Czech Republic, Denmark, France, Finland, Germany, Ireland, Italy, the Netherlands, Poland, Portugal, Spain, Sweden, Switzerland and the United Kingdom, along with Australia as a Strategic Partner and the Host State of Chile, a fundamental partner since 1963.

Through the joint and coordinated operation of all its sites in Chile and Germany, ESO carries out its mission as a non-profit intergovernmental organisation, enabling key scientific findings and fostering technological development, financial investment, the education of younger generations, and the dissemination of science and international cooperation in the field of astronomical research and related disciplines.

As an international organisation, ESO's operations in the country are framed by a number of official agreements signed with the Republic of Chile, the Ministry of Foreign Affairs being the main interlocutor. ESO also liaises with a number of government-related agencies, such as the National Agency for Research and Development (ANID) – formerly National Commission for Scientific and Technological Research (CONICYT) – and, more recently, with the Ministry of Science, Technology, Knowledge and Innovation.

Observational Facilities

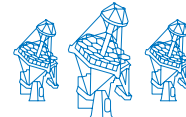
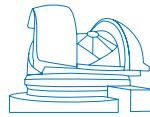
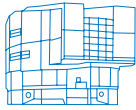
The sites in the north of Chile are a privileged window onto the Universe, offering a dry, quiet atmosphere, over 300 clear nights a year and remoteness from sources of artificial light.



Paranal Observatory
Home to the VLT

ELT
The forthcoming
biggest eye on the sky

CTA South Project
The world's largest
gamma-ray observatory



Antofagasta region,
district of Taltal

Antofagasta region,
district of Antofagasta

Antofagasta region,
district of Taltal

Altitude: 2635 m.a.s.l

Altitude: 3046 m.a.s.l

Altitude: 2100 m.a.s.l

The Very Large Telescope (VLT), with its interferometer (VLTI), **is the world's most advanced optical/near-infrared telescope**, consisting of four Unit Telescopes, each with a main mirror 8.2-metres in diameter, and four 1.8-metre Auxiliary Telescopes, equipped with a set of sophisticated instruments and state-of-the-art technology, such as interferometry and adaptive optics. It started scientific operations in 1999.

Two powerful survey telescopes are also sited in Paranal: the VLT Survey Telescope (VST) and the Visible and Infrared Survey Telescope for Astronomy (VISTA).

The Extremely Large Telescope (ELT) is currently being built on Cerro Armazones, about 20 kilometres from Paranal Observatory and will be **the largest ground-based, optical/near-infrared telescope in the world**.

The ELT will tackle detailed studies of subjects including planets around other stars, the first galaxies in the Universe, supermassive black holes and the nature and distribution of dark matter and dark energy. The ELT is planned to start operating during the second half of this decade.

ESO will host and operate the southern-hemisphere array of the Cherenkov Telescope Array (CTA), an astronomical project for the detection of high-energy gamma rays, sited around 11 km from Paranal. Its construction will begin within the next few years.

CTA South will comprise almost a hundred telescopes, with diameters ranging from 4 to 23 metres, and will complement the 19 telescopes of the northern array, located at Roque Los Muchachos, on the island of La Palma, in the Canary Islands.

Further information regarding CTA governance is available here: www.cta-observatory.org



La Silla Observatory

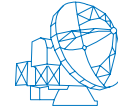
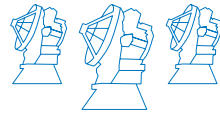
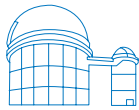
ESO's first observatory

ALMA Observatory

Example of an international partnership

APEX Observatory

Pioneer at the Chajnantor Plateau



Coquimbo region,
district of La Higuera

Antofagasta region, district of
San Pedro de Atacama

Antofagasta region, district of
San Pedro de Atacama

Altitude: 2400 m.a.s.l

Altitude: 5000 m.a.s.l

Altitude: 5050 m.a.s.l

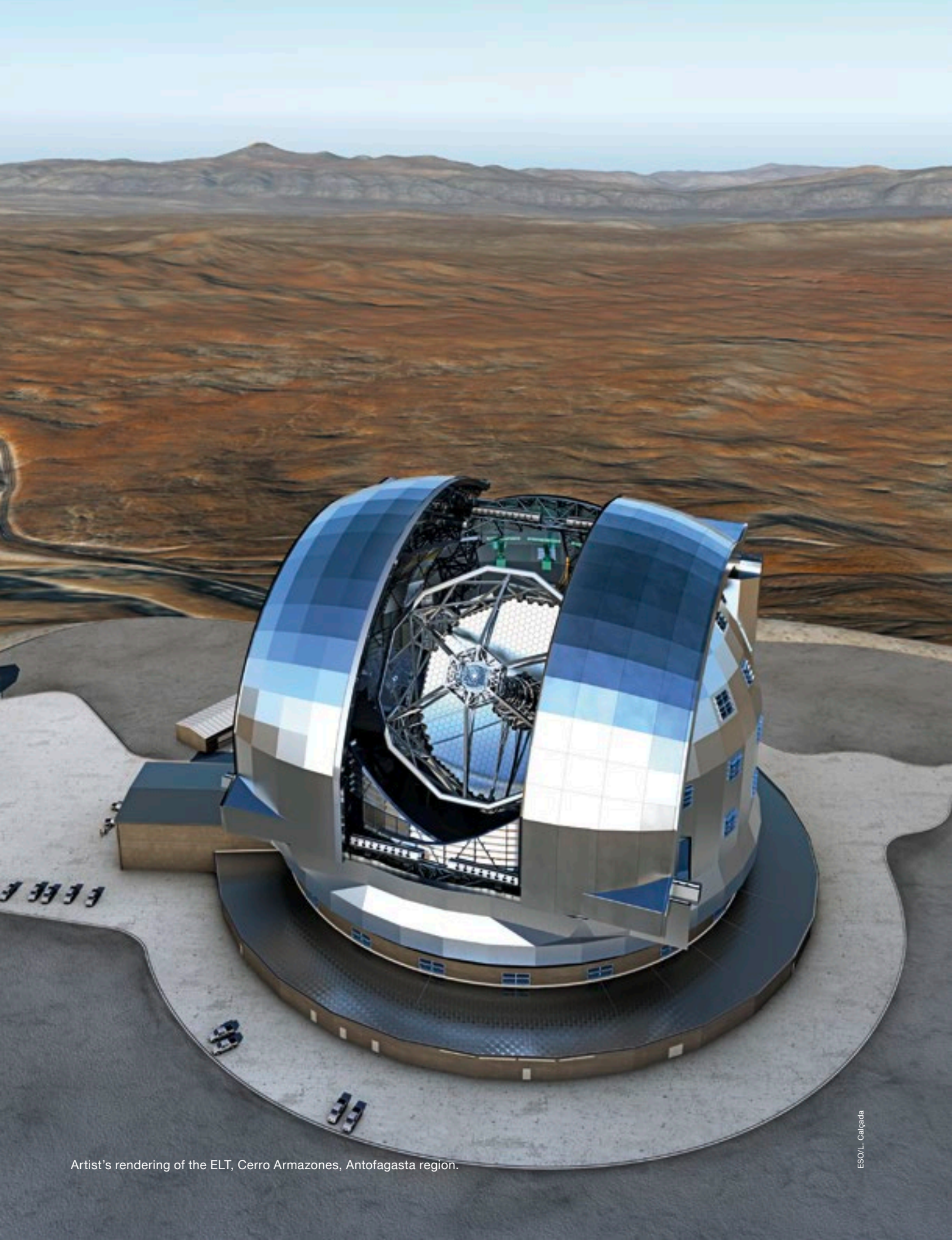
La Silla Observatory was inaugurated in 1969 and has been the home of several generations of telescopes and instruments. **ESO still operates two of the most productive 4-metre-class telescopes in the world:** The ESO 3.6-metre telescope, currently home to the world's foremost extrasolar planet hunter, the High Accuracy Radial velocity Planet Searcher (HARPS), and the New Technology Telescope (NTT), a pioneer in technological breakthroughs, such as active optics, which paved the way for the next generation of large telescopes, among them the VLT.

The Atacama Large Millimeter/submillimeter Array (ALMA) is the largest radiotelescope in the world, and **comprises 66 antennas, 50 of them with 12-metre-diameter dishes and 16 with a diameter of 7 metres, spread over distances of up to 16 kilometres.**

Inaugurated in 2013, ALMA is an international partnership between Europe, North America and East Asia, in cooperation with the Republic of Chile.

The Atacama Pathfinder Experiment (APEX) is a **12-metre-diameter radiotelescope observing the Universe at millimetre and sub-millimetre wavelengths.** It was inaugurated in 2005.

Pioneer of the ALMA Observatory in the Llano de Chajnantor, APEX is an international collaboration between ESO, the Onsala Space Observatory (Sweden) and the Max Planck Institute for Radio-astronomy (Germany).



Artist's rendering of the ELT, Cerro Armazones, Antofagasta region.

ELT

The World's Biggest Eye on the Sky



With the ELT, a door opens from Chile to enable discoveries that will revolutionise our understanding of the cosmos.

Extremely large telescopes are the next step for ground-based astronomy. Of the three existing projects worldwide, two will be located in Chile. One of them is ESO's ELT.

This revolutionary project will have a 39-metre main mirror and will be the largest optical/near-infrared telescope in the world.

Its huge light collecting area, novel design and cutting-edge technology will enable astronomers to track down Earth-like planets around other stars, measure the acceleration of the Universe's expansion and search for possible variations in the fundamental physical constants across space and time.

Since 2005 ESO has been working with its community and industry to develop this telescope, whose first light is expected in the second half of this decade.

ELT Construction Stages



April 2010

Cerro Armazones selected as site for the ELT.



June 2014

Blasting of Cerro Armazones peak.



December 2018

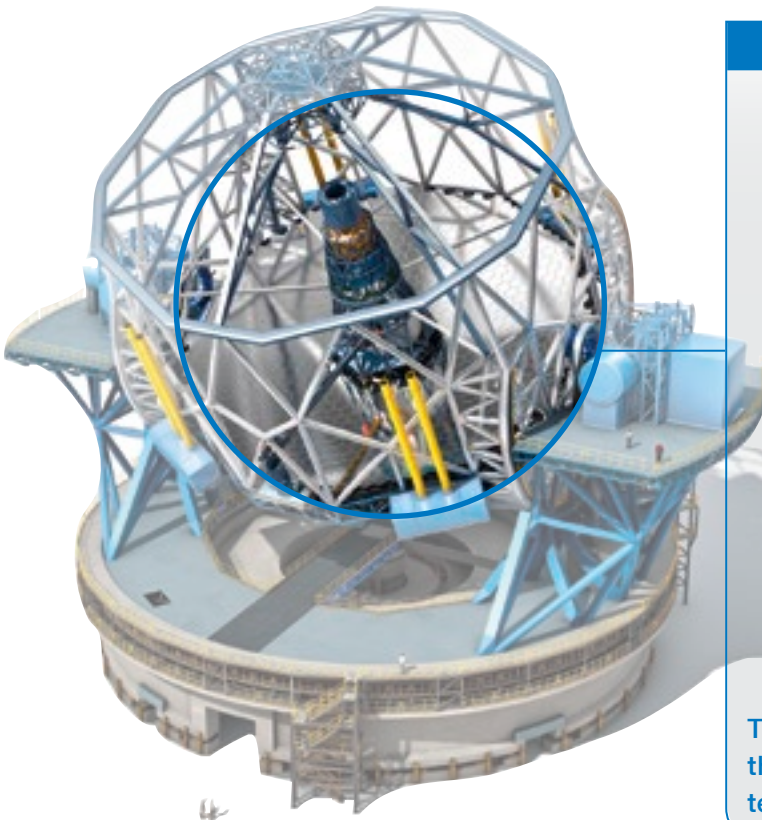
Construction of dome and main structure starts.



Foreseen for the second half of the decade

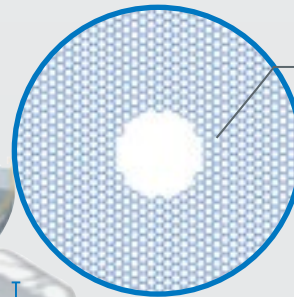
First light planned.

▼ Drawing of the telescope's main structure.



Main mirror

— Diameter: 39 m —



— Ø 1.4 m —

No. of segments:
798

Light collecting
area: 978 m²

The ELT's main mirror will collect more light than all of the existing 8-metre-class optical telescopes currently operating, combined.

Chile and the ELT

The ELT has a budget of around CLP \$ 1.2 trillion (1.3 billion euros), of which 81% is being spent on contracts with the industry, mainly European and also Chilean. The many disciplines that revolve around astronomy pave the way for new knowledge and services to be created in Chile. These can be fostered through joint strategic actions in areas of interest to the country.

To achieve this goal, ESO will sign a cooperation agreement with Chile, within the framework of the construction, commissioning and operation of the ELT. The agreement includes:

- ✦ **Astronomy and engineering call for proposals.** An annual call for proposals, issued by ANID and the Chilean Ministry for Science, Technology, Knowledge and Innovation, open to research and development projects in the areas of engineering, informatics and others, to be executed by researchers affiliated to Chilean public or private institutions.
- ✦ **Academic contracts.** ESO will fund up to two positions per year at the Paranal Observatory, as well as visits to Europe by professionals from areas of science and engineering in Chile. To promote knowledge exchange, the participation of students from institutions in the Antofagasta region will be encouraged.
- ✦ **Internships and exchange.** Academic internships in Chilean institutions for professionals affiliated to institutions from ESO Member States, in the fields of science and engineering, to promote the exchange of technological knowledge in academia.
- ✦ **Reserved observing time.** Once in operation the ELT, like other ESO telescopes, will set aside 10% of observing time for scientific teams from Chilean institutions.

▼ Scale rendering of the ELT and Portada de Antofagasta.





Milky Way over ALMA Observatory, Antofagasta region.

ALMA

Exploring our Cosmic Origins from Chile



ALMA comprises 66 movable antennas, which work as a single telescope, spread over distances of up to 16 kilometres, for astronomical observation at millimetre and submillimetre wavelengths.

ALMA was built high on the Chajnantor Plateau (5000 metres above sea level), some 50 kilometres east of San Pedro de Atacama. It is the largest astronomical observatory in the world, and unique in terms of science, technology, location and international cooperation.

Inaugurated in 2013, thanks to an investment of 1.1 billion euros, ALMA is a partnership between ESO, the US National Science Foundation and the National Institutes of Natural Sciences of Japan, in cooperation with the Republic of Chile.

ALMA collects millimetre and submillimetre wavelength radiation, which is invisible to the human eye and is key to studying light from the coldest regions where interstellar matter lies, to unveil star and planet formation. It can also detect the first structures that formed in the Universe.

ESO has played a fundamental role in the technological, technical and scientific development of ALMA, providing 25 antennas for the array and two specially designed vehicles, the antenna transporters. In addition, ESO developed a number of state-of-the-art receivers for the radio telescope, and provided critical infrastructure for the project, both at the observatory site and in the Vitacura premises. ESO contributes 37.5% of ALMA's annual budget.

Contribution to Science in Chile

Through ALMA, Chilean scientific institutions have access to annual research funds and preferential observing time and are able to participate actively in knowledge-sharing between the scientific groups associated to the project.

The ALMA–ANID Fund (formerly the ALMA–CONICYT Fund) was established to strengthen scientific research and the development of astronomy in Chile. In 2020 it funded projects for approximately CLP \$ 610 million (around 669 000 euros) and, since its implementation, has provided funding of over CLP \$ 9 billion (around 10 million euros). ESO contributes 37.5% of this amount, and also funds the ESO–Government of Chile Joint Committee (see page 24), as well as co-financing the ELT cooperation agreement (see page 13).

Chilean institutions have access to 10% of observing time. Moreover, several Chilean scientific groups have participated in creating crucial technology and infrastructure for the observatory, such as some antenna receivers for ALMA.



Aerial view of ALMA Observatory, Antofagasta region.

Support to Local Communities

The benefits derived from ALMA go beyond the scientific realm and have an impact at a local and national level.

Through the ALMA–Region II Fund, the observatory contributes to the productive, social and economic sectors of the region, particularly in the district of San Pedro de Atacama. **In 2020 this fund provided around CLP \$ 260 million (297 000 euros), totalling over CLP \$ 3.5 billion (about 3.9 million euros) since its inception in 2004.**

Moreover, ALMA endeavours to have a positive impact on its neighbours. It supports an educational programme at the local school in Toconao, the nearest village, to improve and enhance English and science subjects, directly benefitting children in the community.

ESO's main contributions to ALMA include:



37.5%
of the project's
annual budget.



25 antennas
with a diameter of 12 metres.



ALMA antenna trans-
porters Otto and Lore.



The technical building at the
Operations Support Facility.

The ALMA Residence, with
bedrooms for staff.

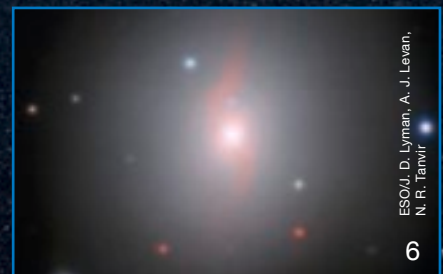
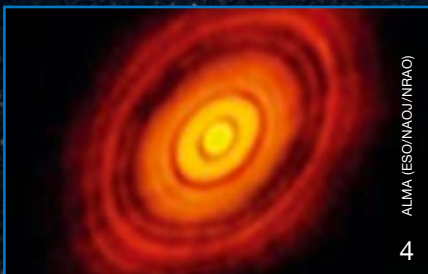
The head offices of ALMA in
Vitacura.



Ground-Breaking Discoveries

During the last decade, ESO has consolidated its position as the world's most productive ground-based observatory.

Besides enabling scientific breakthroughs, ESO contributes to the dissemination of science in the country and promotes the image of Chile as the world's capital for astronomy.



Black holes

- 1 First-ever image of a black hole obtained with the Event Horizon Telescope, a planet-scale array of eight ground-based radio telescopes, including ALMA and APEX.
- 2 Tracking stars orbiting the centre of the Milky Way for over 25 years has enabled study of the supermassive black hole at the heart of our galaxy. This image captured by the VLT shows the surrounding region.

Exoplanets

- 3 Discovery of a planet (Proxima b) in the habitable zone around the nearest star (with ESO's 3.6-metre Telescope, among others). First image of an exoplanet (shown in photo) and first image of two exoplanets orbiting Solar-type star, both captured with the VLT.
- 4 Images of planet formation. Images obtained by ALMA of the planet-forming disc around HL Tauri.

Cosmology

- 5 Accelerating expansion of the Universe, using data from ESO's 3.6-metre Telescope and NTT, among others.
- 6 Detection of one of the first gravitational wave sources, using ALMA and telescopes in La Silla and Paranal, among others.



Nebula Messier 78, in the constellation of Orion. Image taken from La Silla Observatory.

How ESO Cooperation Benefits the Chilean Astronomical Community



Through agreements between ESO and the Republic of Chile, 10% of observing time on ESO telescopes is set aside for Chilean research institutions.

The history of astronomy in Chile and ESO's own history are closely related. Astronomy is one of the most relevant sciences in Chile today, largely thanks to cooperation between Chile and ESO.

Since the sixties — with the construction of La Silla Observatory and its telescopes — ESO has continuously served the astronomical community, operating state-of-the-art scientific facilities. Since then, ESO contributes astronomical observation data to various research groups around the world, including Chile. At the same time the Chilean astronomical community has increased in numbers. From small local groups, it has grown into a large community throughout the country.

Currently, there are more than 250 professional astronomers working in 17 Chilean institutions, achieving excellent scientific results, in part through ESO's presence.

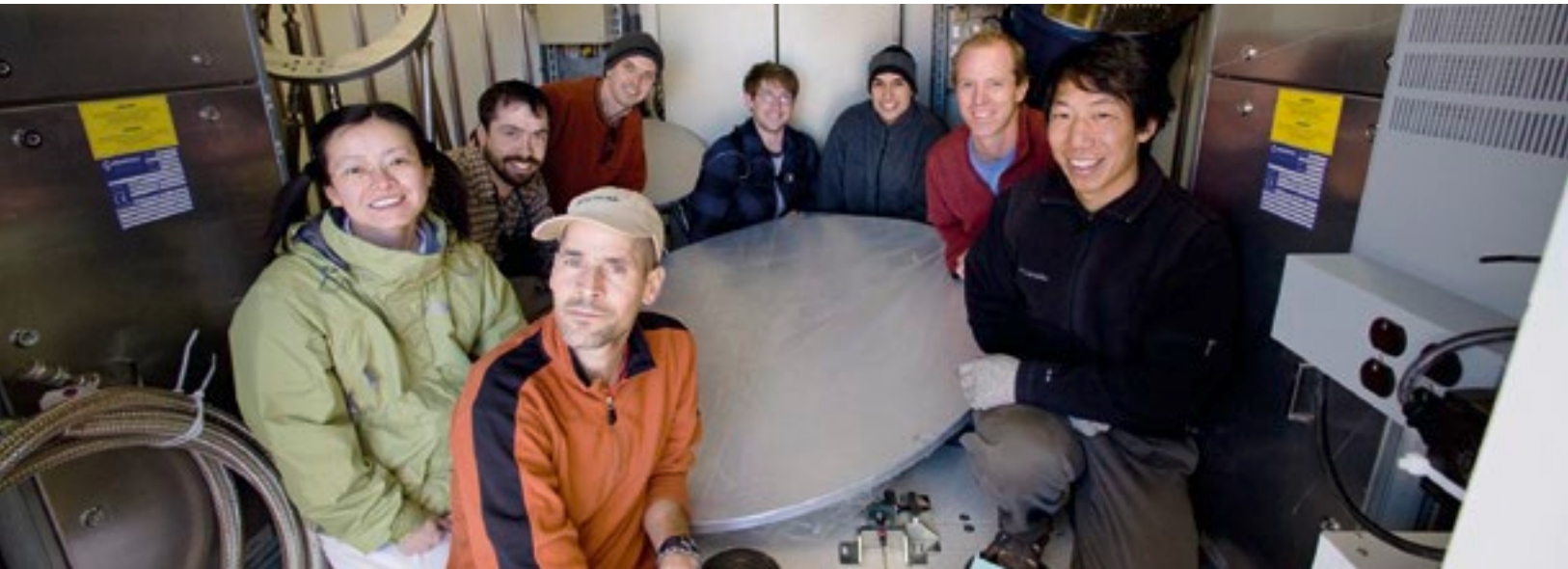
Today, thanks to this synergy, the scientific institutions of Chile and ESO can work on more ambitious, diverse and revolutionary projects.

Direct Support to the Astronomical Community

The Chilean scientific community has expanded rapidly since the 1990s. Its vitality is boosted by the development of international observatories in the country, including Paranal, La Silla and ALMA.

Under agreements between ESO and the Republic of Chile, Chilean research institutions are granted 10% observing time on ESO telescopes. According to data from SOCHIAS (the Chilean Astronomical Society), in 2019, almost 500 researchers from 21 universities across the country have applied for this observing time.

Moreover, since 1996 ESO Chile has increased funding, through an annual call for proposals, to support scientific research and the development of astronomy in Chile (page 24).



Creating and Strengthening Scientific Exchange

The construction of new observatories generates an ideal scenario for exchange between Chilean and international scientific communities.

Between 1999 and 2018, ESO has held and sponsored — as main organiser or participant — 38 international conferences on astronomy in Chile, attended by over 400 researchers from 16 Chilean universities.

The scientific meetings organised by ESO provide unique opportunities for the Chilean astronomical community to establish and strengthen contacts with representatives of the international scientific community without having to leave the country.

Scientific Productivity

The Chilean astronomical community participates actively in the discussion and exchange of new ideas in several areas of astronomy. Its scientific productivity reflects this fact.

The number of published papers with authors from Chilean institutions using data from ESO telescopes has increased sharply in the last 10 years.

Similarly, the number of papers published by international astronomy groups with at least one author from Chile has increased exponentially. In 2009 72 papers were published, while in 2018 there were 246, a total of 1747 papers in this period.

▼ Aerial view of the VLT platform, Cerro Paranal.



Astronomy in Chile today



17 Chilean institutions

carry out research.



255 professional astronomers

work in national institutions.



163 researchers

related to astronomy.



Over 500 undergraduate astronomy students.

Source: SOCHIAS

ESO–Government of Chile Joint Committee

In 1996 ESO and the Republic of Chile signed an agreement whereby 10% of observing time on ESO telescopes was set aside for astronomers in Chile. In addition, to strengthen this scientific capital the Joint Committee was established and since 1998 its annual funds have contributed to the development of astronomy and related technologies in the country. Representatives of ESO and the Chilean Government assess the allocation of funds to be awarded to public and private academic institutions and related organisations throughout the country. The fund is meant to support the development of local research and technology, as well as strengthening astronomical awareness among Chileans.

ESO allocated approximately CLP \$ 450 million (around 500 000 euros) to the Joint Committee fund for the 2020 call for proposals. Every year the Joint Committee promotes the following areas:

- + **Post-docs.** Postdoctoral programmes in astronomy at Chilean academic institutions. Young researchers have had a positive impact on the number of scientific papers published by their institutions, one of the main indicators to assess the quality of universities.
- + **Academic education.** Academic faculty positions for periods of up to two years at Chilean academic institutions. This start-up funding enables universities to demonstrate the positive impact these positions have on research and hence to secure further funding so that they can be made permanent.
- + **Technology.** Funding to support development programmes and the construction of technological systems for astronomy. This area has generated local hubs that could lead to breakthroughs in applied science, such as the production of astronomical mirrors in Chile.
- + **Education and outreach.** Funding to support the development and presentation of educational programmes for the teaching and dissemination of astronomy in Chile; training teachers in primary and secondary schools, as well as funding exhibitions in museums and outreach materials on various platforms for the general public.
- + **Others.** Funding to support the development of astronomy in areas not covered by the above four categories.

The Joint Committee annual call for proposals is announced on the ESO website in June-July each year.

During the period 2013–2019 the Joint Committee funded:

29 post-docs

for two years: 1/3 in Santiago and 2/3 in other regions in Chile.

13 academic faculty positions:

Grant for early years at new faculty positions in Chilean universities.

23 science outreach programmes.

12 instrumentation projects.

Featured projects in recent years:

Universidad de Antofagasta: Seed funding for academic positions.

Universidad de Valparaíso: Production of astronomical mirrors.

Pontificia Universidad Católica: PLATO-Spec instrument to study stars and orbiting planets.


Regional Funds

In order to devise a new model of cooperation between ESO and the regions that host observatories, a review of the allocation of funds for the Antofagasta and Coquimbo regions was initiated in 2019, through a working group comprising local authorities and the Ministry of Foreign Affairs.

This initiative seeks to give priority to regional participation in decision-making that involves strategic interests for regional development.



Star-forming region IC 2944. Image taken with FORS 1 on the VLT at Paranal Observatory.



Field around star WR22, in the Carina Nebula.
Image taken with the MPG/ESO 2.2-metre telescope at La Silla Observatory.

Young Talents for the Country and the World

ESO opens its doors to young professionals seeking to advance their careers in astronomy. Whether in Chile or Germany, ESO postdoctoral fellows play an important role, both in the science offices and in ESO observatories. Once they finish their programmes at ESO, many fellows extend and deepen their work, enhancing the national and international astronomical community.

“ESO networks have been crucial for me and my students, who today benefit from these connections.”



Claudia Lagos (Chile), Researcher and teacher at the International Centre for Radio Astronomy Research (ICRAR), Australia.

“My time at ESO was spent at the headquarters in Garching (Germany), and I think it was crucial for my career. While working at the Organisation I forged my profile as a researcher. I am interested in galaxy formation and evolution: how galaxies form, what role dark matter plays, and what observations could be made to distinguish different physical processes in them.

The experience gained during my doctorate was mainly theoretical, and my stay at ESO allowed me to establish contacts required to work in observation, searches and surveys of galaxies.”

“What I most enjoyed about my stay at ESO was the freedom to seek new challenges.”



Oscar González (Chile), Astronomer at the United Kingdom Astronomy Technology Centre (UK ATC).

“My stay at ESO forged my professional profile. I work as a scientist in charge of projects in one of the United Kingdom’s largest national laboratories (UK ATC), which develops technology for astronomy.

My job is to identify new ideas for astronomical instrumentation. I must determine the requirements of the scientific community, work with engineers during the design, construction and installation of instruments and then lead their scientific operation. ESO gave me the perfect environment to develop the necessary skills to do this. The knowhow I acquired at ESO, first during my PhD at ESO Headquarters in Garching (Germany) and, afterwards, operating instruments at the Paranal Observatory as a fellow, provided this unique expertise.

The time I spent at Paranal was wonderful. Behind the structure required to operate such a large organisation, it was great to find many opportunities to boost my career. Moreover, I was able to teach astronomy to children from regions outside Santiago, as I myself once used to be.”

“I learnt a great deal about technology, and about how rewarding it can be to work side by side with people from engineering and technical areas.”



Amelia Bayo (Spain), Professor at Universidad de Valparaíso, Director of the Núcleo Milenio Formación Planetaria (NPF).

“My time at ESO was a landmark for my professional career, and Paranal Observatory became my second home. It was a great opportunity to gain comprehensive knowledge. Being permanently exposed to different research topics expanded my own science and strengthened my collaboration. Everyone works together to offer the best possible service to the scientific community.

The working structure and the method of communication between engineering and astronomy groups have been exceptionally useful for leading the NPF. There are 40 of us, with very different backgrounds. Together, we have started a unique project in Chile: manufacturing mirrors based on carbon fibre. Having a routine of documents, procedures and validation — such as ESO’s — may sound boring, but it has a huge impact and improves R&D efficiency.”



Working in the integration laboratory, ESO Garching, Germany.

Support by Training New Generations



Through scholarships and internships, ESO offers and finances educational programmes at the undergraduate, postgraduate, doctoral and postdoctoral levels.

ESO offers scholarship and internship programmes in science and engineering, enabling students from Chile and the rest of the world to join the local and international astronomical community.

Students who apply for these scholarships enhance their experience, interacting with ESO professionals and visitors from all over the world and experts in different areas of astronomy and engineering, in a multicultural and diverse environment.

The knowledge gained, both at a technical level and in soft skills, is crucial to the development of their careers.

Between 2010 and 2020, 15 students have carried out PhD studentships and post-doctoral fellowships at ESO's Office for Science in Chile, while eight have done so at ESO's Office for Science in Germany.

PhD Studentships in Astronomy

ESO provides the opportunity for PhD students to spend up to two years at ESO's Office for Science in Santiago, to carry out research work under the joint supervision of their thesis director at their home university and an ESO astronomer. In the last decade, eight students from Chile have been awarded this scholarship. This represents 18% of ESO doctoral students in the country, establishing Chile as the country which most benefits from these scholarships, above ESO Member States and the rest of the world.

“It is a privilege to be an astronomy student on the site chosen for world-class observatories, particularly given the preferential access to observing time for the Chilean community.”



Sebastián Zúñiga (Chile), Electronic Engineer and Master of Electronic Engineering of the Universidad Federico Santa María. Currently a doctoral student in astrophysics at the Universidad de Valparaíso and ESO Chile.

“Being chosen for the ESO scholarship was a great step for my career, particularly for my plans to build a hybrid profile, doing my science and gaining experience related to operations and instrumentation at ESO's observatories in Chile.

During the application process, I realised there were preferential posts for local students, and that seemed like a good idea, to develop future astronomers trained in our country.

Obviously, there are Chilean (and Latin American) students with great intellectual capacity who might not need a preferential position, but sciences in Chile and Latin America do not yet have the resources of developed countries. Therefore, these positions help to “level the field”, and also foster collaboration networks between Chilean universities and researchers from around the world.

ESO also provides financial stability and security for the family, which are usually difficult for students to get, and which allow students to focus on research.”

Postdoctoral Fellowships for Research in Astronomy

These fellowships last four years, with the chance to spend the last year at another institution. Fellows who carry out postdoctoral research spend 50% of their time assigned to operational support duties at Paranal Observatory or at ALMA. The rest of the time is spent on their own scientific research. During the last decade, four Chileans have been selected for the fellowship programme, representing 7.5% of all ESO Fellows and placing Chile in fifth place.

As well as this, several ESO Fellows have continued their careers at Chilean universities, contributing to the development of Chilean astronomical research.

“ESO brings together in Chile astronomers from different nationalities, who carry out cutting-edge research in astrophysics. This rich working environment allows me to evolve as a researcher and to extend my scientific interests.”



Camila Navarrete (Chile), Doctor in Astrophysics, Pontificia Universidad Católica de Chile. She conducted part of her research work at the University of Cambridge. In 2017 she received the L’Oreal-UNESCO award for women in science.

“My current line of research entails the discovery and characterisation of areas in the Milky Way halo with excess stellar density. I use several methods and astronomical instruments to measure the position, distance, movement and chemical composition of these stars, to reconstruct the early stages of the Milky Way’s formation.

As an ESO Fellow, I have duties as a support astronomer at Paranal on 80 nights per year. I carry out programmed observations with the UT2 (Kueyen) telescope and provide support and follow-up to the Ultraviolet and Visual Echelle Spectrograph.

Being on shifts of up to 14 nights at the observatory can be exhausting, but it is an amazing experience. By working side by side with engineers, technicians and telescope operators, in a pleasant and welcoming environment every day, or rather every night, one learns something new.

Postdoctoral fellowships provide a unique opportunity for astronomers from the Chilean community since, unlike many other postdoctoral positions, they complement research and work in the most productive optical observatory in the world.”

La Silla Observing School

Every second summer since 2016 ESO has organised its popular observing schools at La Silla Observatory. Three events have been held to date, attended by a total of 14 Chilean undergraduate students. The schools aim at preparing the next generations of astronomy professionals.

During two weeks of intense work at ESO's Vitacura offices and La Silla Observatory, participants have the opportunity to get hands-on real-life experience of the full scientific process, from proposal preparation to data reduction.

Short-term internships in astronomy:

From 2001 to 2019, the ESO Office for Science hosted **22 Chilean graduate students** in astronomy, from six universities for internships of three to five months.

La Silla under the Milky Way, Coquimbo region.

Paranal Short-term Engineering Internships

ESO offers Chilean students from different areas of engineering the opportunity of a professional internship at Paranal Observatory, giving them the unique experience of participating in projects and duties at the observatory's engineering and maintenance department. These internships last between two and six months.

Each year the programme awards six summer internships, reserved for Chilean students, which has been increased to 14 students as of the end of 2020. Also, each year three winter internships are open to students from European universities.



“My experience at the observatory exceeded my expectations: working conditions are exemplary.”



Vicente Lizana (Chile), Computer Engineer from Universidad Federico Santa María. In 2019 he was chosen for an internship at the optical and systems group of Paranal Observatory. In March 2020 he became part of the software group at the observatory, as an ESO staff engineer.

“During an internship one is usually willing to do tasks that others don't want to perform, but Paranal offered very interesting projects, real opportunities to make a difference at the observatory and to learn in the process. This enhanced my career and gave me tools, helping me to cope with the working world.

These opportunities are quite rare in Chile and are essential for the development of future professionals in the country. Just as this experience had a great positive impact on my career, a negative early work experience is likely to have a negative impact on other future engineers. It is not easy for some to approach the world of work, but conditions at the observatory are excellent.”

Scholarship Programme for Taltal Students

ESO's annual contribution for students from the district of Taltal, Antofagasta region, where Paranal Observatory is situated, has provided support to generations of high school students and particularly to outstanding university students.

During the last decade, over 20 students from Taltal with outstanding academic performance received full coverage of their university fees, enabling them to finish their undergraduate education with success.

In addition, every year ESO awards funds that partially cover university fees for another group of 40 students, which translates into significant financial support for their families.



Funds to Support Regional Universities

ESO contributes funds for two of the most important universities in the Antofagasta region:

Universidad Católica del Norte. Since 1998, through the Centre for Astronomical Outreach and managed by the university's Institute of Astronomy, which provides scientific outreach activities and content on a regular basis for hundreds of students and the general public.

Universidad de Antofagasta. Since 2015, to support the Centre for Research, Technology, Education in Astronomy, to strengthen the Masters in astronomy programme, and to develop astronomy outreach activities for students and the general public. These include an annual training programme for teachers and tourism guides, as well as educational lectures, visits and nights of observation in the desert.





AMDS

The VLT on the summit of Cerro Paranal, Antofagasta region.

Financial Management in the Country



The operation of ESO's fleet of telescopes and facilities in Chile entails an annual expenditure of approximately CLP \$ 59 billion (around 66 million euros).

To carry out its mission, ESO receives an annual contribution from its Member States amounting to about CLP \$ 168 billion (188 million euros). Other contributions and additional income make up an annual budget of around CLP \$ 314 billion (350 million euros), almost half of which is allocated to the ELT.

The financial management of these funds is carefully regulated by ESO's main governing bodies.

ESO's investment in Chile is mainly distributed in funds and financing instruments to develop science and national astronomy, educational funds, contracts to purchase goods and services from professionals and companies at a national and regional level, and in staffing.

The Importance of Local Talent

ESO employs around 750 staff members worldwide, of which **25% are Chilean**, outnumbering staff from other nationalities, including those of each of the 16 ESO Member States. 176 Chileans work in Chile and 14 at ESO headquarters in Germany.

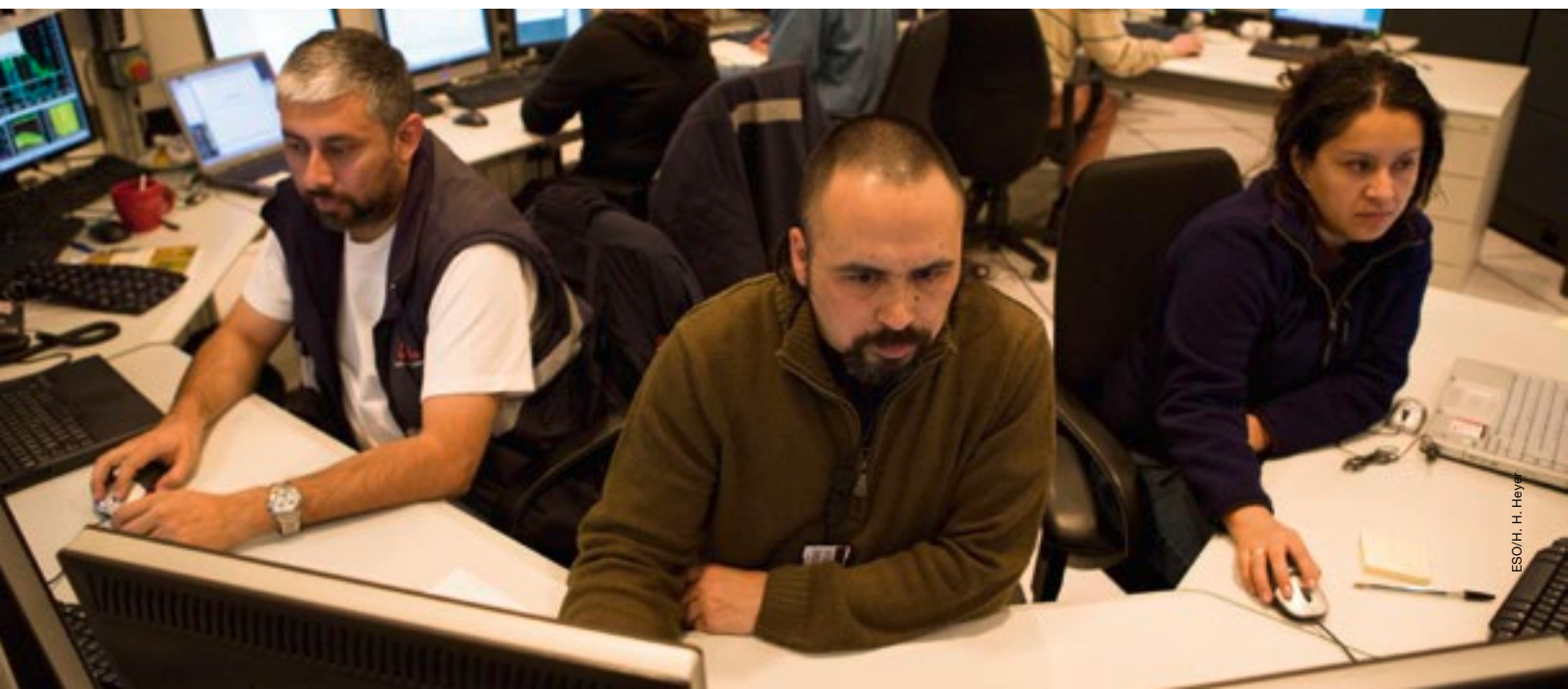
Currently, 60% of Chilean staff, both in Chile and in Germany, work in engineering areas, followed by 20% in administrative areas and 15% in technical support. The rest are staff who hold positions as astronomers or in management within the Organisation.

The predominance of local engineers is particularly evident at La Silla and APEX sites, where 100% of engineers are Chilean, while In Paranal, over 80% of engineers are also Chilean.

Although the majority of Chilean staff are male, in the last decade there has been a slight increase in female staff, shifting from 20% in 2008 to 26% in 2019. ESO is committed to inclusion and equal opportunities and is taking measures to promote the recruitment of female staff, particularly in the areas of science, technology, engineering and mathematics (STEM).

In addition to the opportunity to work in a multicultural environment, ESO offers competitive salaries to its staff in Chile, as well as a comprehensive benefits package. These include an education grant for dependent children, from early childhood to postgraduate university education. Likewise, ESO contributes to staff pension funds, insurance and partial coverage of medical expenses, among other benefits.

▼ Control Room of the VLT Interferometer (VLTi), Paranal Observatory.



“I feel confident that I will be able to face any challenge safely, thanks to the support of the ESO family.”



Carlos Durán (Chile), Civil Electrical Engineer, Master’s degree of Engineering Science from Pontificia Universidad Católica de Chile, PhD in Astrophysics from University of Bonn and expert on astronomical instrumentation, currently Operations Manager at APEX Observatory.

“I lead the administrative, technical and scientific operations of the observatory, coordinating internal operations on the site, and the work of the APEX consortium institutes and of the scientific community that carries out research on the site. Above all, I ensure the safety and integrity of a team of over 25 colleagues, providing conditions for working efficiently and safely.”

Carlos’s professional career is closely linked to ESO and goes back more than 15 years. Between 2004 and 2015, he was an APEX Electronic Engineer, later became Deputy Chief Engineer, and then went to Germany to obtain his PhD. Regarding this period, he says: “I grew up professionally, open to learning from seniors in the group, always working on the front line.”

After a few years at the Sub-millimeter Technology Division of the Max Planck Institute for Radio Astronomy, he decided to apply for the position of APEX Operations Manager, which brought him back to ESO in 2020: “It felt like coming back home. The team welcomed me warmly.”

▼ APEX radio telescope on the Chajnantor Plateau, Antofagasta region, Chile.



Transactions with National and Regional Companies

The operational success of ESO in Chile is closely related to the management of local contracts and procurement, done locally to obtain the best quality in goods and services at a competitive price, fulfilling the Organisation's mission.

During the last decade, ESO's procurement of goods and services in Chile accounted for 30% of all purchase commitments made by the Organisation in this period, reaching an annual average of approximately CLP \$ 40 billion (around 45 million euros) spent in the country.

These requirements include a wide range of goods and services, from construction work and new technology development with industrial partners, to purchasing regular items needed for day-to-day operations and household support for facilities, among others. The supply of drinking water for the observatories, construction of the ALMA residence, air and ground transport services for staff and cargo, specialised engineering services for instrument maintenance in the observatories, are a few examples.

In the last ten years, ESO made more purchases in Chile than in any of its Member States. In this period, 19% of ESO's procurement in Chile was in the Antofagasta region, representing 6% of the Organisation's total procurement budget. This expenditure in the Antofagasta region was only surpassed by disbursements at a national level in Germany, Italy and France.

▼ Signature of the contract (2018) with engineering and construction company Abengoa Chile, to build facilities hosting the assembly and maintenance of the ELT mirrors. The image shows the ESO team and the company involved in the contract.





G. Hudepohl/ESO

▲ Aerial view of the ELT technical support building at Paranal Observatory, completed in 2020.

MT Mecatrónica: Highly Specialised Support and Maintenance in the North of Chile

MT Mecatrónica SpA — currently OHB Chile — engineering and assembly services company that offers highly specialised support in two large and expanding areas in Chile: astronomical facilities and renewable energy plants in the north of the country.

MT Mecatrónica SpA was established in 2009 as a Chilean subsidiary of the German company MT-Mechatronics GmbH, after acting as local partner in the assembly of the 25 European antennas which are part of the ALMA array. With 30 technicians and engineers, the MT Mecatrónica SpA team had provided for more than eight years services at Paranal Observatory, carrying out preventive and corrective maintenance on the telescopes and technical facilities, as well as projects for the assembly, improvement and manufacture of specialised components on site.

“During this period, we have established a solid relationship between ESO and MT Mechatrónica, marked by trust, collaboration and service at a high standard. We were able to participate in a new project: implementing industrial maintenance and information guidelines, in such a highly specialised area as astronomical facilities in Chile.”

Pierre Chapus, General Manager, MT Mecatrónica SpA.



2019 Total solar eclipse, La Silla Observatory, Coquimbo region.

ESO/P. Horálek

ESO for Everyone



A scientific organisation such as ESO has a responsibility to share the discoveries that result from its scientific activities with society at large. To this end, ESO deploys a wide range of communication and outreach activities, particularly within its Member States and in Chile.

One of the most relevant public events held by the Organisation took place in 2019. Three months after the observatory's fiftieth anniversary, La Silla witnessed a total solar eclipse.

“This shows that when science opens up and gets involved with all citizens, it can become a celebration of how humans have explored the Universe, unravelling mysteries through creativity and critical thinking.”

Andrés Couve, Minister for Science, Technology, Knowledge and Innovation
(2 July 2019, when the solar eclipse passed over La Silla).

To celebrate this rare event, which will not be visible again in this area for two centuries, La Silla hosted, for the first time ever, more than 1000 visitors in a single day, including over 50 students and 30 senior citizens from the Coquimbo region, as well as another group of 30 high school students from all Chilean regions, selected by Explora CONICYT (now known as ANID).

“Our young students had a wonderful time at the observatory... I am happy to know that they will never forget this amazing experience. It will touch the lives of our students,” said María Rebeca López Santander, who is in charge of the astronomy programme of Corporación Gabriel Gonzalez Videla, La Serena. Invited guests included tourists from four continents, scientists, ESO staff, and almost 70 representatives from national and international media. Chilean authorities also attended, including two Ministers and the President of the Republic.

Media

The press is a key ally in bringing observatories to a larger audience than those who are able to visit. For this purpose, **ESO receives an average of 50 visits from national and international media each year** at Paranal, La Silla, APEX and ALMA observatories. This helps to increase awareness about astronomy and ESO's work in the host country. Through international media, the image of Chile as an astronomical country is promoted, including innovative research and tourism, **potentially reaching hundreds of millions of people around the world.**

On special occasions, such as the total solar eclipse on 2 July 2019 at La Silla Observatory, or the ELT ground breaking event in May 2017, ESO has invited delegations of national and international journalists to enhance media coverage. With this in mind, in 2017 ESO established a strategic partnership with Imagen de Chile, a government organisation that promotes the country brand abroad.

In addition to attending visits to the observatories, ESO's Department of Communications in Chile handles **over 60 requests for interviews every year, from Chilean or foreign media based in Chile and Latin America.**



◀ The alliance with Televisión Nacional de Chile allowed La Silla to be one of the five locations chosen to live broadcast the 2019 total solar eclipse to viewers across Chile, from early morning to sunset.

First Image of a Black Hole

On 10 April 2019, a coordinated press conference was held across Brussels, Washington, Taipei, Tokyo and Santiago, to announce one of the most important astronomical discoveries of the decade: the first image of the shadow of a black hole at the centre of the galaxy M87. In Santiago, the ALMA offices in Vitacura hosted this global event.

▼ First image of a black hole, captured by the Event Horizon Telescope (EHT), a planet-scale array of eight radio telescopes, including ALMA and APEX.

EHT Collaboration



Coverage and audience



Over 35 media

attended the event.



**An audience of
over 700 million,**

across the world,
received news from
the EHT, which
includes ALMA/APEX.



**Over 291 000
visitors**

on ESO social media
and website.

Public and Educational Visits

ESO opens the doors of its observatories to anyone interested in the Organisation's work, which is carried out at remote sites to gain and expand our knowledge of the Universe. The public visits programme envisages weekly guided tours to La Silla and Paranal Observatories, free of charge.

In order to provide more opportunities to school groups and create a bond with younger generations from neighbouring districts, ESO has arranged a special programme of monthly guided educational tours to La Silla and Paranal observatories, during school days. This programme, which includes transport from the school to the observatory, is aimed at low-income schools from the Coquimbo and Antofagasta regions. Around 1000 elementary and high-school students will benefit from the programme each year, once it starts.

Receiving visitors safely in remote sites not designed for this purpose requires engaging expert professional services, which imply an estimated cost of CLP \$ 25 000 (around 28 euros) per visitor, to be borne entirely by ESO.

Virtual guided tours were inaugurated in July 2020, during the pandemic, as an alternative to visits in person, and have become a very effective tool for reaching the public by offering an immersive and interactive experience, a space shared by science and society. These tours, which are accessible via social media, are held twice a week (one in Spanish and another in English) and have thrilled audiences around the world.

Every year:

La Silla and Paranal Observatories receive around 8000 visitors from across the world, adding up to 84000 visitors during the last decade.

▼ Tourists on a public visit to Paranal Observatory.



Events and Exhibitions

Public educational events and exhibitions are a means for society to engage directly with astronomy. Collaboration with associated institutions throughout Chile is crucial for this purpose.

ESO regularly participates in science outreach activities, through lectures, printed and audio-visual material, monitors and workshops at various events, such as the National Science Week and the National Astronomy Day, and also cooperates in a series of public educational events, in particular in the Antofagasta, Coquimbo and Metropolitan regions, reaching tens of thousands of people each year.

Making a contribution and having a presence in spaces that have high cultural and educational significance, such as museums and planetariums, is also a very effective way of providing content to the general public and contributing to the enrichment of the country's cultural activity. Through this **contribution to permanent exhibitions, ESO reaches an audience of around 650 000 people per year**. When initiatives in high-flow public areas are included, this number rises to several million.





The Large Magellanic Cloud in the night sky at Paranal.

Collaboration for Sustainable Development



The challenges posed by astronomical sciences will drive technological development in Chile and increase specialised human capital.

A new chapter of ground-based astronomy is beginning and Chile will continue to be at the forefront. A new generation of large telescopes will start operating towards the end of this decade, in the Antofagasta, Atacama and Coquimbo Regions. ESO faces several challenges in harnessing the full potential of its existing and future facilities. To achieve this, valuable collaborations and partnerships have been established, which involve and benefit Chile.

Industry 4.0, Astronomy 4.0

The ELT and some operational aspects of the CTA South array will become integrated into the VLT at Paranal Observatory, which is not feasible under the current model of operations. This integration will require incorporating the tools and methods of Industry 4.0 (I4.0), such as: Artificial Intelligence (AI), machine learning, deep learning, Internet of Things (IoT) and intelligent machines and systems.

This entails a significant investment on IoT devices, cloud computing, and training staff from science and engineering areas. To this end, ESO has established collaborations with Chilean universities and companies such as Microsoft Chile and MetricArts who, along with ESO staff, are using the VLT as an I4.0 laboratory, to enable the so-called “Astronomy 4.0”.

Within the framework of this collaboration, on 28 August 2019 Microsoft Chile received the “Digital Transformation and Industry 4.0” award from the Chilean Association of Information Technology Companies.

The engineering internship programme at Paranal is including training in I4.0. These programmes, together with more Research and Development (R&D) projects, will be considerably enhanced by the ELT Cooperation Agreement.

Diversity and Inclusion

Addressing complex problems requires teamwork to bring together different skills and perspectives. Through its organisational values, ESO is committed to promoting diversity in its workforce.

As a starting point, on 30 January 2020 ESO and UN Women signed a memorandum of Understanding. ESO strives to use the UN's women empowerment principles to structure and measure the progress of its diversity and inclusion actions.

This cooperation with UN Women Chile aims to assess the gender gap in STEM careers and to establish a recruitment strategy to achieve more equity in future engineering positions related to the construction and operation of the ELT.

Besides promoting science and engineering careers for young girls in Chile, ESO and UN Women will join forces to create training opportunities for disadvantaged women who have struggled to finish their formal education, particularly in the Antofagasta region.

ESO contributes by:

Promoting STEM among young girls, through outreach activities with ESO astronomers and engineers.

Running a pilot programme of joint internships with Laboratoria, a non-profit organisation focused on training low-income young women in programming and web development, promoting their employability in the digital sector.



◀ María Noel Vaeza, UN Women Regional Director for the Americas and the Caribbean, and Xavier Barcons, ESO Director General, signed a Memorandum of Understanding between both organisations on 30 January 2020.

Sustainability

ESO recognises the significance of building and operating astronomical observatories in sites that offer unique qualities, such as those found in the Atacama Desert. Environmental protection is an extremely important component and adds value to our projects and operations.

ESO is making an effort to develop and implement a comprehensive environmental strategy, in order to reduce the Organisation's carbon footprint, in the medium term.

ESO has implemented a number of measures to enable it to work in the most sustainable manner, so that the impact of operations on the environment can be reduced.

- ✦ **La Silla photovoltaic plant.** Built and operated by ENEL Green Power, inaugurated in 2016. The total capacity amounts to 1.7 MW and avoids the emission of over 2000 tonnes of CO₂ per year. 50% of the output at the site goes to the observatory's power consumption, while the rest is delivered to the Central Inter-connected System.
- ✦ **Armazones-Paranal photovoltaic plant and power conditioning system.** Next year, a power conditioning system and photovoltaic plant will be installed at the site of ESO's ELT, with operations of both systems starting two years later. These facilities will supply renewable energy to Paranal Observatory (including the ELT).
- ✦ **Vitacura Office.** Electric cars and recycling containers have been introduced; rainwater is collected and used for irrigation of extensive grass areas.
- ✦ **Gradual replacement of vehicles with electric cars and zero plastics policy at Paranal.** Other initiatives at Paranal Observatory include: the gradual introduction of electric cars to replace 75% of the petrol cars over the next 10 years; recycling and management of hazardous materials such as batteries, chemicals, oil etc.; monitoring organic and food waste and eliminating plastic bottles used to dispense water throughout the facility. Also, an upgrade of the sewage plant, suppression of the use of gas heaters and general logistical improvements to reduce the CO₂ footprint of operations.



Light Pollution: Helping to Protect Dark Skies

Chile's future as a world capital of astronomy relies on the preservation of dark skies. Light pollution is a global problem that threatens the unique quality of skies, and seriously disturbs ecosystems and people's physical and mental health.

Preserving the darkness of the northern Chilean sky as a natural laboratory is essential for the continuity of astronomical operations in the country, for astro-tourism and for all scientific, economic and outreach activities related to astronomy. ESO participates actively in initiatives to support the implementation of lighting regulations in the country.

Office for the Protection of Sky Quality in the North of Chile. ESO was party to the agreement that created this Office in 2000 and contributes to its financing, together with the then National Committee for the Environment, the Association of Universities for Research in Astronomy, and the Carnegie Observatories, recently joined by the Giant Magellan Telescope. Currently, new partners include the Ministry of Science, Technology, Knowledge and Innovation, the Ministry of the Environment and the Ministry of Foreign Affairs. ESO's annual funding amounts to CLP \$ 66 million (around 72 000 euros).

Fundación Cielos de Chile. ESO is part of the directorate of this non-profit institution created in 2019.





Astro-tourism

Another business opportunity offered by the consolidation of astronomy in Chile is tourism around this science, known as astro-tourism, opening the way for world leadership for the country in this field. ESO believes that astro-tourism can generate a sustainable industry, bringing numerous benefits to the community. ESO has supported this strategy through the Astroturismo Chile initiative, a programme also supported by the Undersecretariat of Tourism, the Chilean Foreign Investment Committee, Turismo Chile, Associated Universities, Inc., Pontificia Universidad Católica de Chile and Fundación Planetario, among other institutions.



Artistic rendering of the ELT on Cerro Armazones, Antofagasta region.

Looking Ahead

ESO will continue to cooperate with all interested sectors in Chile to disseminate the benefits of science and astronomy to all of society.

The challenges that ESO will face in terms of digital transformation, diversity and inclusion, and the urgent need for action to stop climate change, overlap with global challenges for the coming decades.

Accordingly, it is necessary to develop a closer relationship with the regional communities who live in the vicinity of ESO sites, to ensure that they directly benefit from ESO's presence in the country.

The creation of ESO's regional relations office at the end of 2019 is a clear sign of our commitment to strengthening our presence and dialogue with the communities of Antofagasta and Coquimbo. The management of regional cooperation funds is also being redefined to include these two regions in the decision-making process.



Flame Nebula in the constellation of Orion, taken by VISTA at Paranal Observatory.





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European Southern Observatory (ESO)

Alonso de Córdova 3107
Vitacura, Santiago de Chile
contacto@eso.org

Karl-Schwarzschild-Straße 2
85748 Garching bei München, Germany
information@eso.org