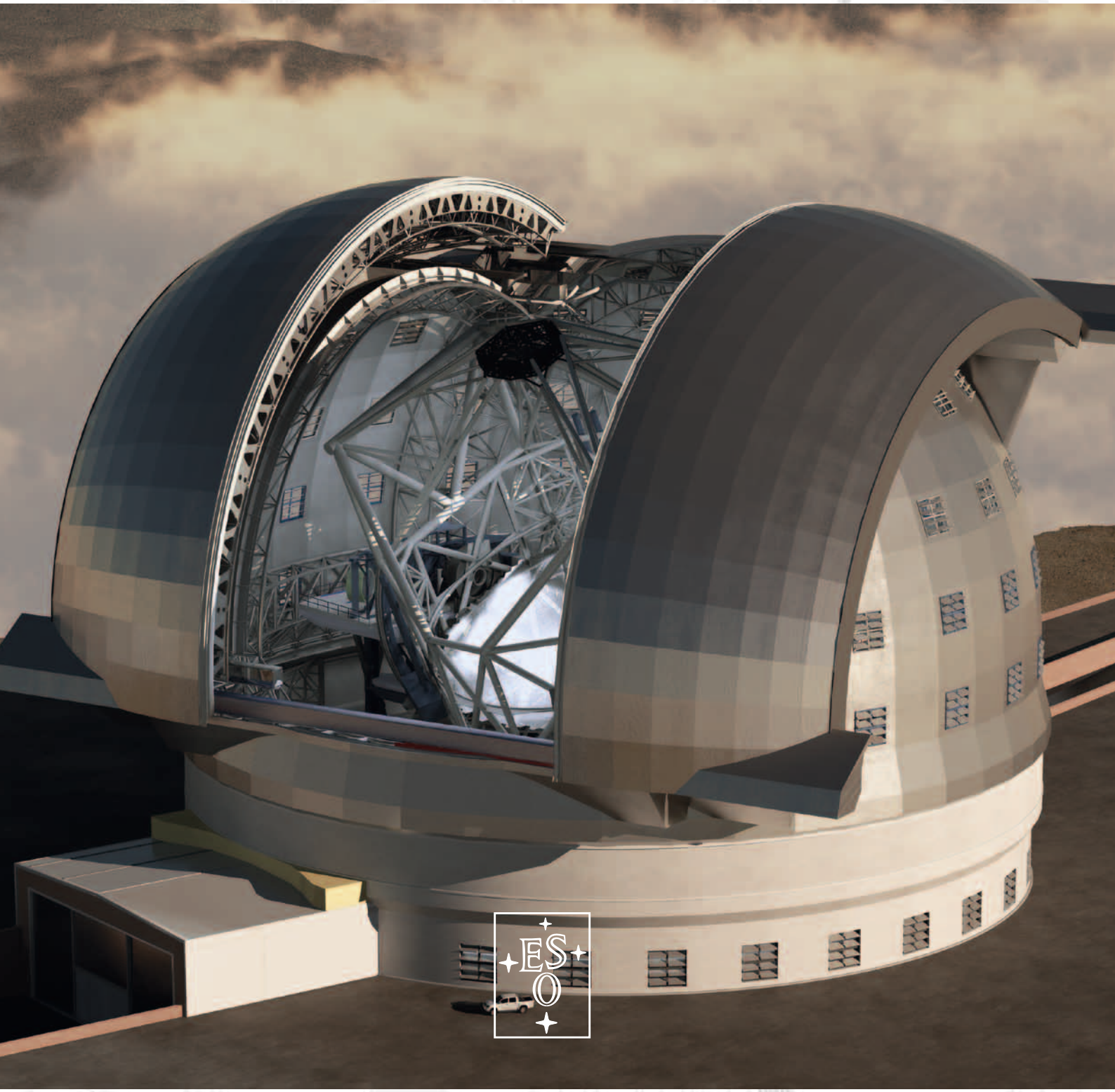
The European Extremely Large Telescope

Press Kit



Contents

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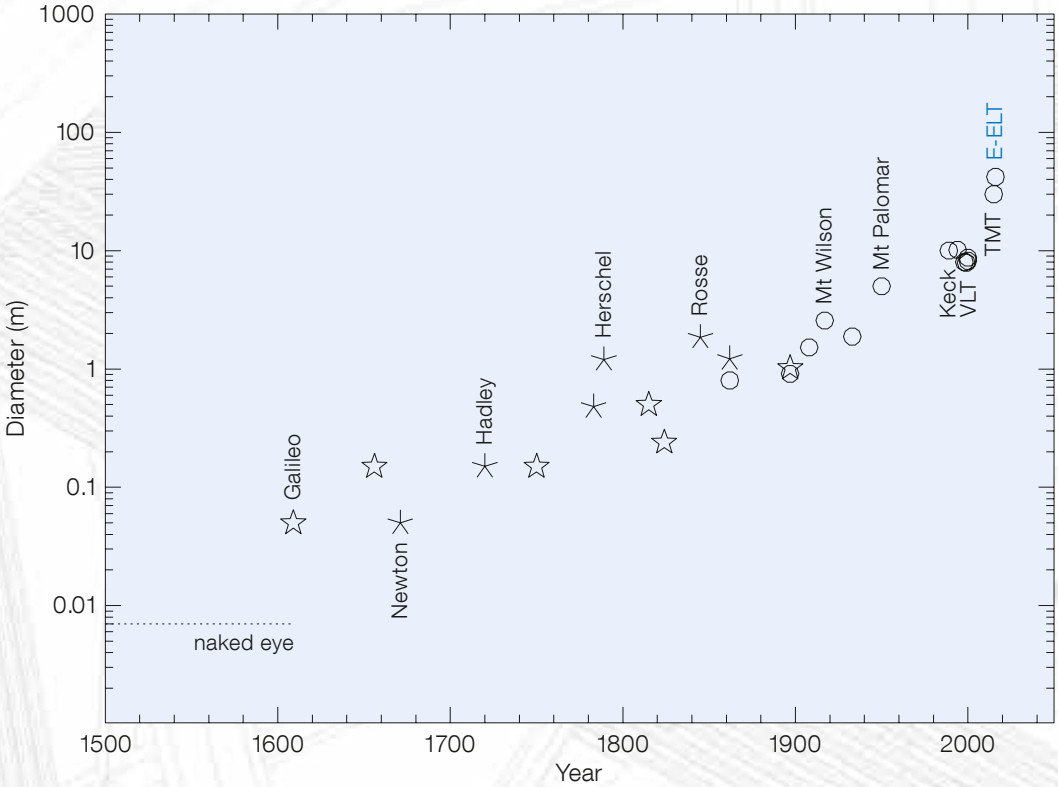
Why Do We Need an E-ELT?

Astronomers tackle key questions that challenge our minds and our imagination. How do planets form? Is life ubiquitous in the Universe? How did galaxies form? What are dark matter and dark energy?

Astronomy is experiencing a golden era. The current generation of large telescopes, such as Europe's flagship facility, ESO's Very Large Telescope (VLT) array of four 8.2-metre telescopes, has allowed astronomers to make tremendous discoveries, opening up whole new areas of study. For example, the VLT has allowed us to take the first pictures of planets orbiting around other stars. Our knowledge in astronomy continues to progress at an incredible pace, answering many questions, but also raising exciting new ones. To address these questions, a new generation of Extremely Large Telescopes (ELTs) with diameters of 22 to 42 metres is currently being planned. Such telescopes may, eventually, revolutionise our perception of the Universe as much as Galileo's telescope did, 400 years ago.

These future giants are expected to come into operation before 2020. They will tackle the scientific challenges of their time, including peering at the Dark Ages of our Universe — its first hundreds of millions of years — as well as tracking down and characterising Earth-like planets in the habitable zones around other stars.

Working together with the European community of astronomers and industry, ESO has developed the design of an Extremely Large Telescope for Europe's astronomers, known as the E-ELT.



Brief history of the telescope. The star symbols mark refracting telescopes, asterisks stand for speculum reflectors, circles for glass reflectors.

The European Extremely Large Telescope

Europe is at the forefront of all areas of contemporary astronomy, thanks, in particular, to the flagship ground-based facilities operated by ESO, the pre-eminent intergovernmental science and technology organisation in astronomy. The challenge is to consolidate and strengthen this position for the future. This will be achieved with a revolutionary new ground-based telescope concept, the European Extremely Large Telescope (E-ELT). A majestic 42 metres in diameter, it will be the world's biggest eye on the sky.

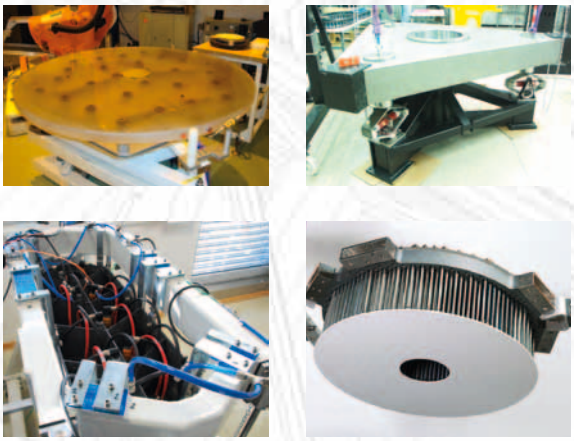
The telescope has an innovative five-mirror design that includes advanced adaptive optics to correct for the turbulent atmosphere, giving exceptional image quality. The main mirror will consist of almost 1000 hexagonal segments, each 1.4 metres across. The gain is substantial: the E-ELT will gather 15 times more light than the largest optical telescopes operating today.

The basic reference design for the European Extremely Large Telescope was completed in 2006. The project is currently in a detailed design phase during which critical components are being prototyped. During this phase, the project placed contracts with industry and institutes in Europe amounting to about 60 million euros. In addition to these design activities, more than 30 European scientific institutes and high-tech companies studied the technological aspects of large telescopes within the EU Framework Programmes 6 and 7, partially funded by the European Commission. Ten studies for instruments and adaptive optics systems have also been completed during this phase, allowing the project to build a most competitive instrumentation plan for the first decade.

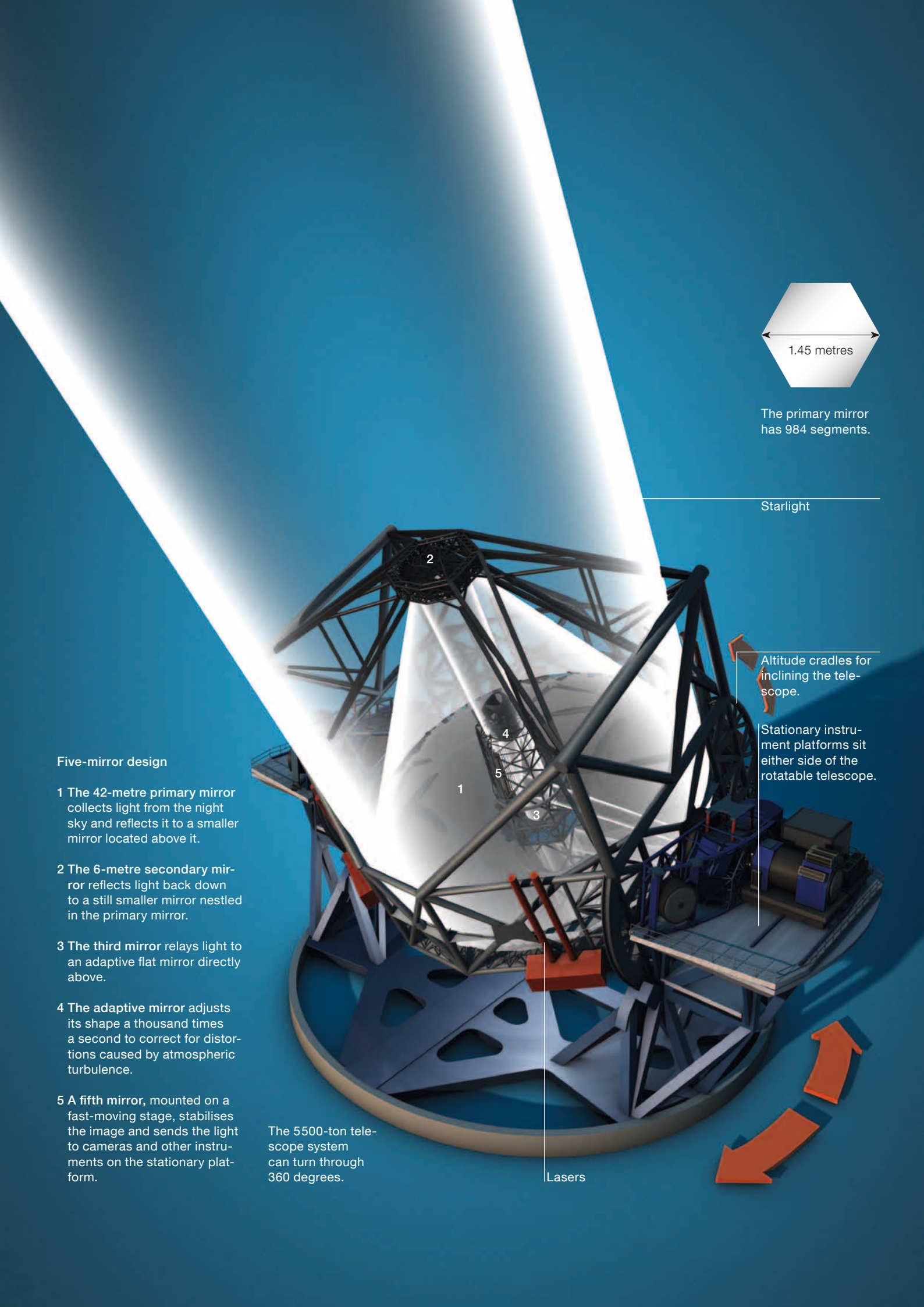
The construction phase is planned to start in 2011. The construction cost is estimated to be close to a billion euros. The E-ELT is a high technology, highly prestigious science-driven project that incorporates many innovative developments, offering numerous possibilities for technology spin-off and transfer, together with challenging technology contract opportunities and providing a dramatic showcase for European industry.

The E-ELT has already gained wide support in the European scientific community. It is the only visible-light astronomy project selected in the roadmap of the European Strategy Forum on Research Infrastructures. It also features as the top priority in ground-based astronomy in the *ASTRONET European Science Vision and Infrastructure Roadmap for Astronomy.*

With the start of operations planned for 2018, the E-ELT will address many of the most pressing unsolved questions in astronomy. It may, eventually, revolutionise our perception of the Universe, much as Galileo's telescope did, 400 years ago.



Prototypes for key components, developed during the detailed design study.



Five-mirror design

1 **The 42-metre primary mirror** collects light from the night sky and reflects it to a smaller mirror located above it.

2 **The 6-metre secondary mirror** reflects light back down to a still smaller mirror nestled in the primary mirror.

3 **The third mirror** relays light to an adaptive flat mirror directly above.

4 **The adaptive mirror** adjusts its shape a thousand times a second to correct for distortions caused by atmospheric turbulence.

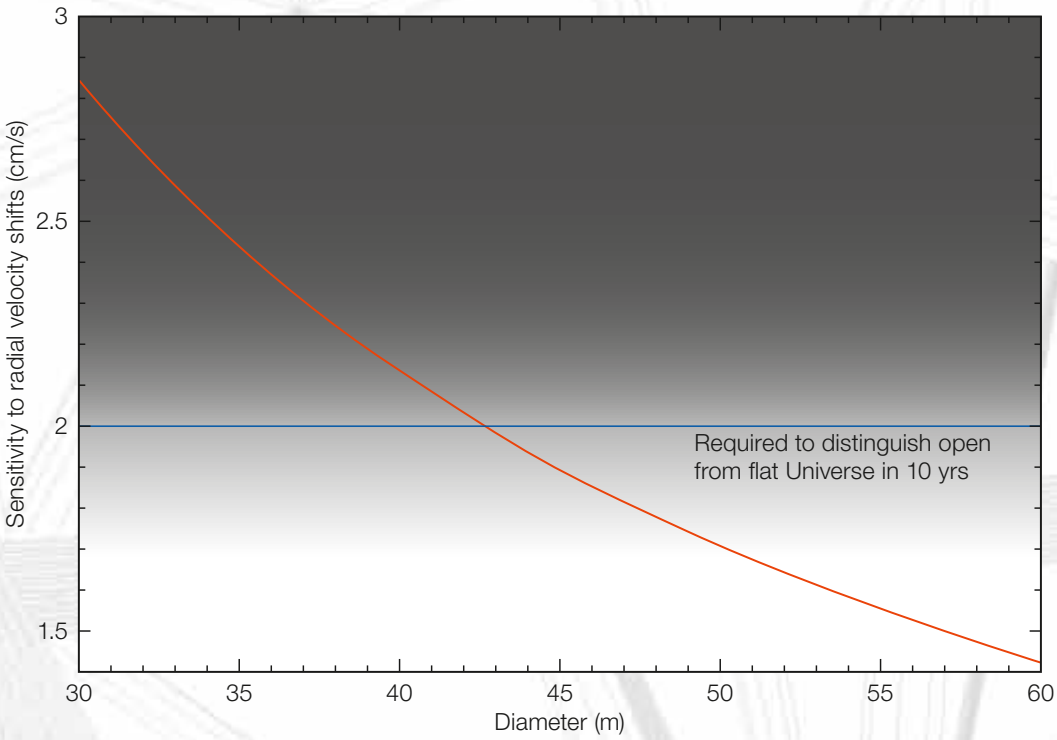
5 **A fifth mirror,** mounted on a fast-moving stage, stabilises the image and sends the light to cameras and other instruments on the stationary platform.

Why 42 metres?

The present concept features as a baseline a 42-metre diameter mirror telescope. The primary mirror is composed of almost 1000 hexagonal segments, each 1.45 metres across, while the secondary mirror is 6 metres in diameter. To overcome the fuzziness introduced into stellar images by atmospheric turbulence the telescope incorporates adaptive mirrors into its optics, and a tertiary mirror, 4.2 metres in diameter, relays the light to the adaptive optics system, composed of two mirrors: a 2.5-metre mirror supported by 5000 or more actuators, which can adjust the shape of the mirror several hundred times per second, and a second mirror 2.7 metres in diameter that corrects for the effects of the wind. This five-mirror approach results in exceptional image quality, with no significant aberrations in the field of view.

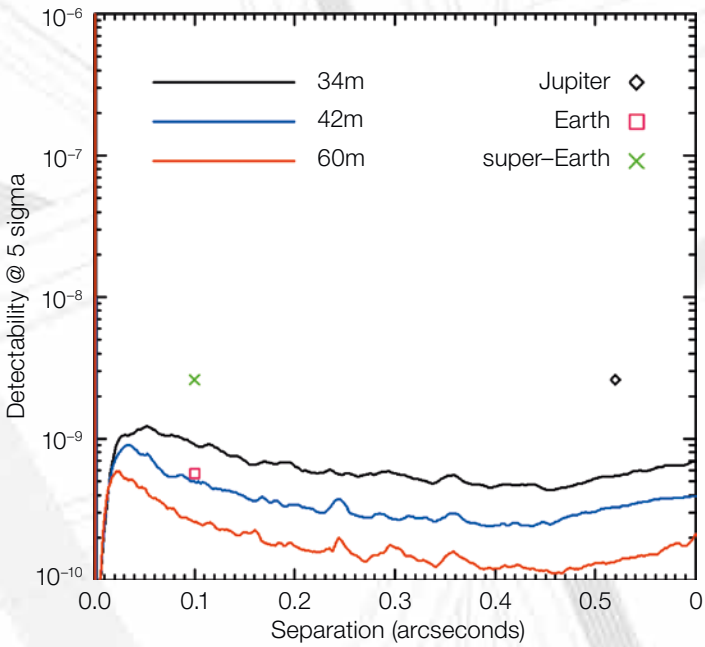
The size of a telescope is important for two reasons: one is the amount of light it can collect and the other is the level of detail it can see. With its 42-metre diameter, the E-ELT will gather 15 times more light than the largest optical telescopes operating today. It will also provide images 15 times sharper than those from the Hubble Space Telescope. The E-ELT performances are thus orders of magnitude better than the currently existing facilities.

The 42-metre diameter was chosen because it is the minimum diameter needed to achieve some of the driving science cases: to image rocky exoplanets to characterise their atmospheres, and to measure the acceleration of the expansion of the Universe directly.



Fundamental physics: the cosmic expansion experiment. The red line shows how the E-ELT's capability of recovering the cosmological redshift drift depends on the telescope's diameter. Cosmologically interesting results can be achieved over the timescale of a decade if the sensitivity to radial velocity shifts is below approximately 2 cm/s. Incidentally, this is the precision required to detect Earth-like exoplanets with the radial velocity method.

Results of high-contrast direct-imaging simulations for three telescope diameters. The curves show the level of suppression of stellar light as a function of angular distance, and tell us which exoplanets are detectable at a given separation from the star. These simulations correspond to an idealised case with respect to telescope, instrument and coronagraph, i.e. show the very limit of the performance of a system of given primary telescope mirror diameter. While super-Earths are detectable with a 30-metre (or potentially smaller telescope), the imaging and characterisation of Earth twins require a telescope of at least 42 metres in diameter and would still remain challenging.

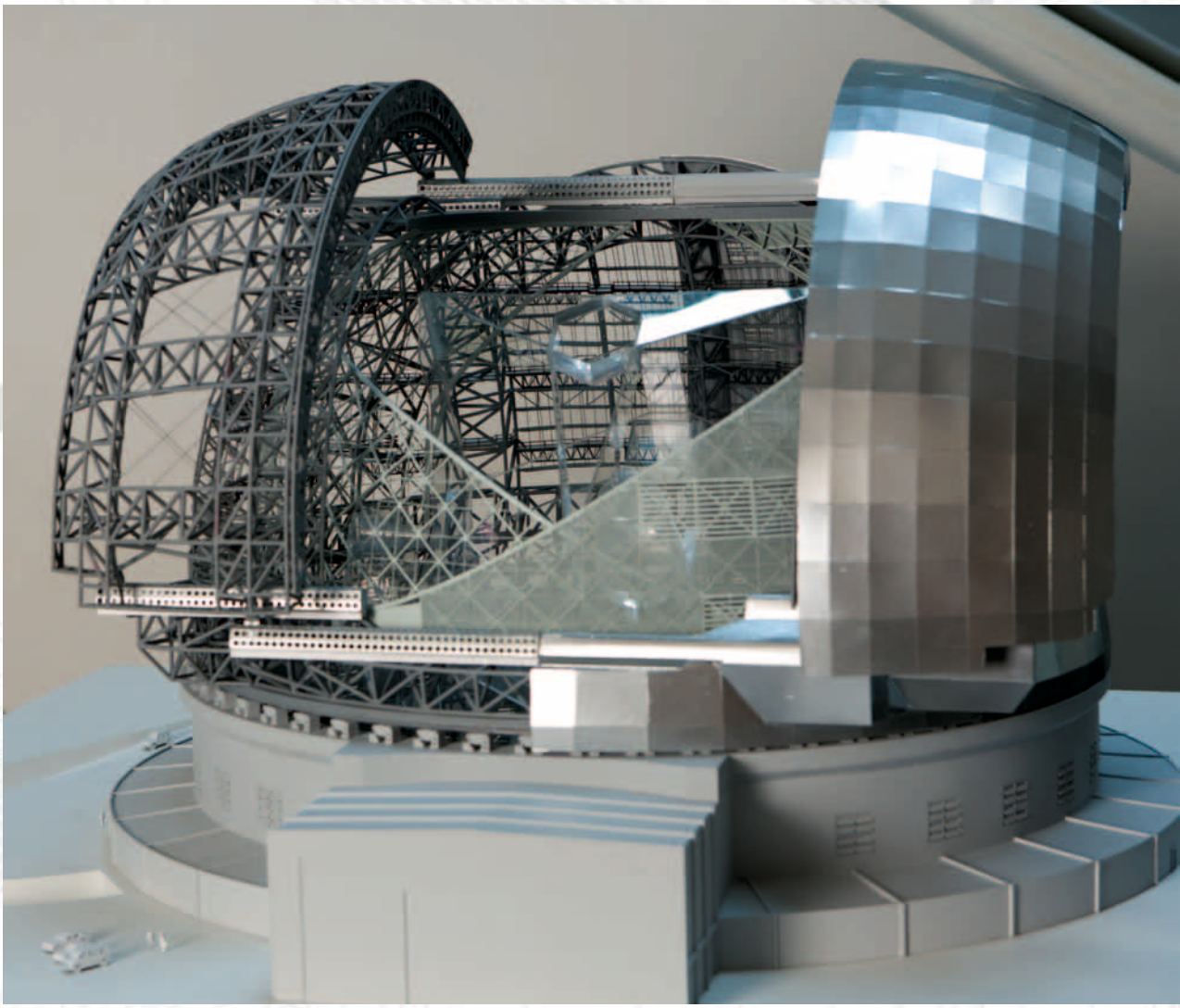


The Dome

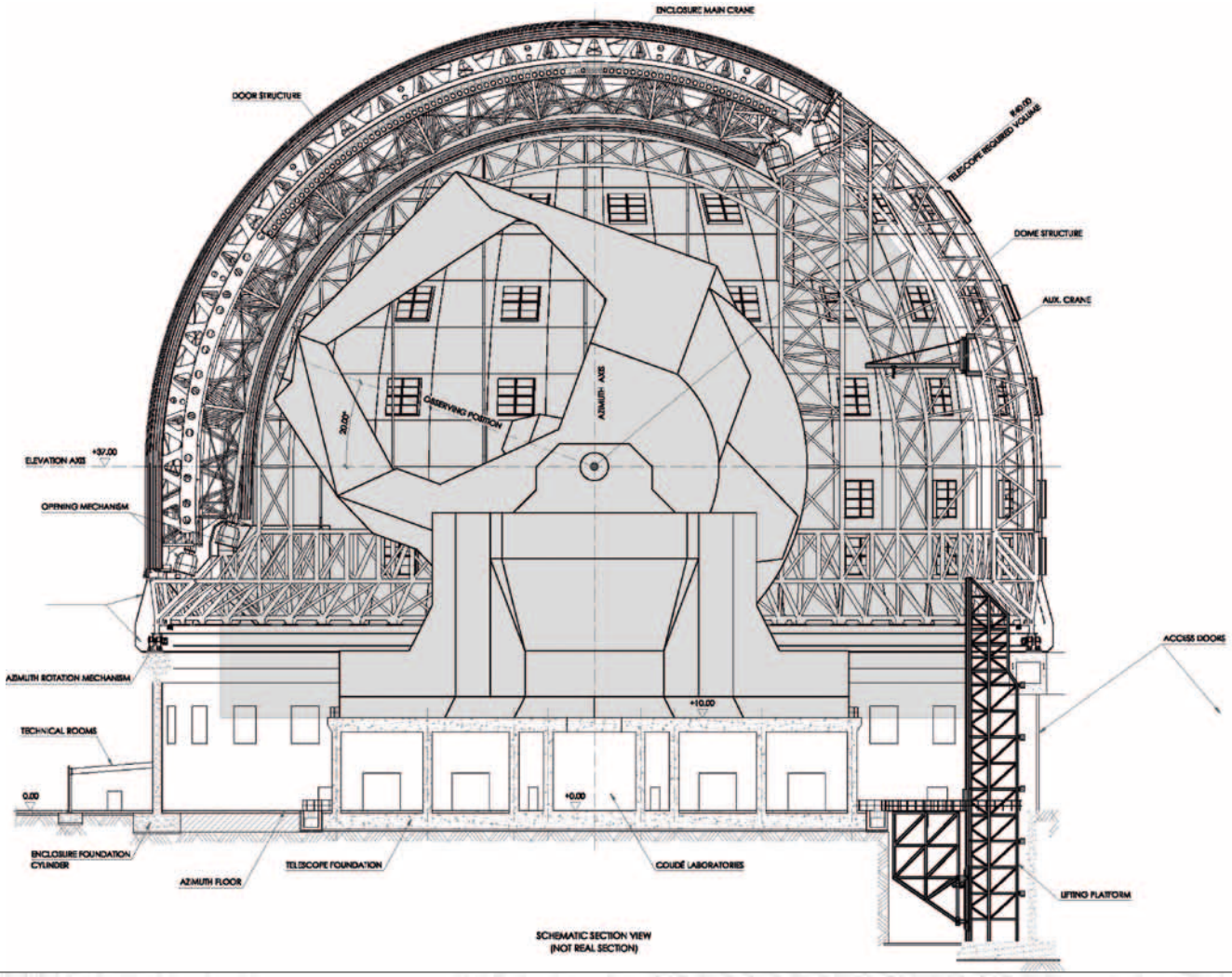
The E-ELT dome will be similar in size to a football stadium with a diameter at its base of order 100 metres and a height of order 80 metres.

Extensive investigation is being undertaken to assess the impact of the wind on the dome and the telescope. Wind tunnel measurements have already started, computational fluid dynamical simulations are ongoing and a campaign of fast wind speed measurements was undertaken at Paranal, home of ESO's Very Large Telescope.

A model of the proposed E-ELT dome.



A cross-section of the proposed E-ELT dome.



The Site

The E-ELT Site Selection Advisory Committee has been investigating several possible sites worldwide in great detail. Similar efforts have been carried out by the Thirty-Meter Telescope (TMT) site selection team from the US. For the sake of efficiency, the sites pre-selected by the TMT team (all in North and South America) were not included in the E-ELT study, but the data were shared.

Various factors needed to be considered in the site selection process. Obviously the "astronomical quality" of the atmosphere, for instance, the number of clear nights, the amount of water vapour, and the "stability" of the atmosphere (also known as seeing) played a crucial role. But other parameters had to be taken into account as well, such as the costs of construction and operations, and the operational and scientific synergy with other major facilities (VLT/VLTI, VISTA, VST, ALMA, etc.).

From all the sites studied, a shortlist comprising four sites in Chile and one in the Canary Islands, Spain, was then drawn up. On 2–3 March 2010, the E-ELT Site Selection Advisory Committee presented a report to the ESO Council, confirming that all the sites examined in the final shortlist have very good conditions for astronomical observing, each one with its particular strengths. The technical report concluded that Cerro Armazones, near Paranal, stands out as the clearly preferred site, because it has the best balance of sky quality across all the factors considered and it can be operated in an integrated fashion with the existing ESO Paranal Observatory. The ESO Council, ESO's governing body, convened on 26 April 2010, and, taking into account the recommendations of the Site Selection Advisory Committee and all other relevant aspects, selected Cerro Armazones.

This decision is based on an extensive comparative meteorological investigation. Several years of precise measurements have led to the conclusion that Armazones is the preferred site for installing the visible/near-infrared light European Extremely Large Telescope (E-ELT).

Cerro Armazones is an isolated mountain at 3060 metres altitude in the central part of Chile's Atacama Desert, some 130 kilometres south of the town of Antofagasta and about 20 kilometres from Cerro Paranal, home of ESO's Very Large Telescope. Cerro Armazones and Paranal share the same ideal conditions for astronomical observations. In particular, over 320 nights are clear per year.

In anticipation of the choice of Cerro Armazones as the future site of the E-ELT and to facilitate and support the project, the Chilean Government has agreed to donate to ESO a substantial tract of land contiguous to ESO's Paranal property and containing Armazones in order to ensure the continued protection of the site against all adverse influences, in particular light pollution and mining activities.

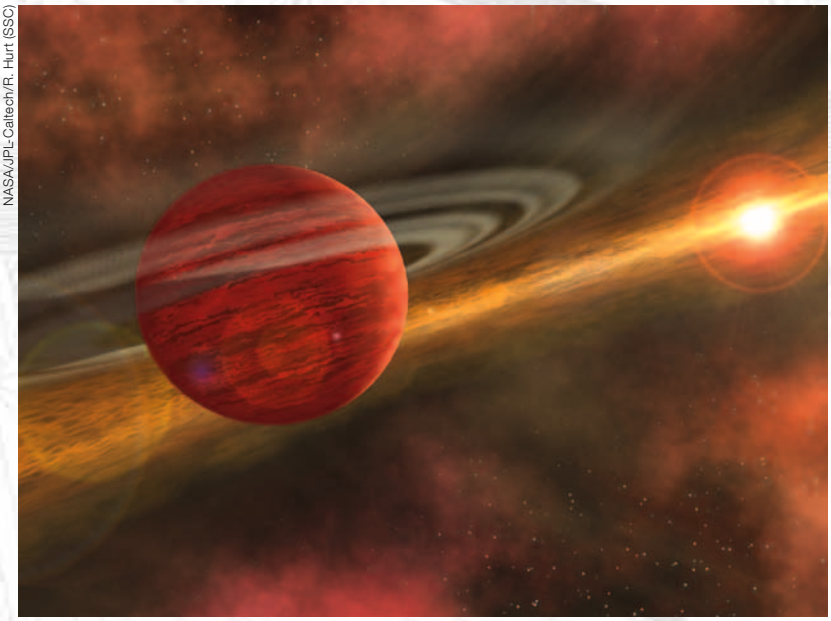
Google Earth

Cerro Armazones in the Chilean Atacama Desert.

ESO/S. Brunier

Science with the E-ELT

Since the invention of the telescope, generations of astronomers have expanded the boundaries of the known Universe ever further. We now think of the Universe to be of finite age and thus of finite observable dimension. However, it is extremely large, and existing telescopes simply lack the sensitivity and angular resolution to explore its plentiful secrets. The European Extremely Large Telescope (E-ELT) will be able to address these problems and answer some of the most prominent open questions.



NASA/JPL-Caltech/R. Hurt (SSC)

In this artist's view, a newfound planet orbits through a cleared region in a nearby star's dusty, planet-forming disc.

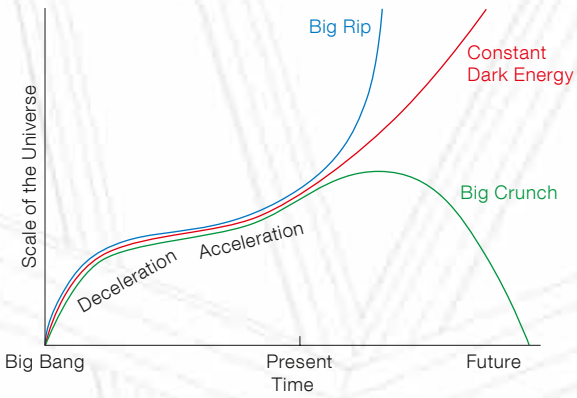
Exoplanets: are we alone?

For over a decade, we have known that exoplanets exist, but we have not yet been able to detect the faint signatures of Earth-like planets directly. The E-ELT will have the resolution to obtain the first direct images of such objects, and even analyse their atmospheres for the biomarker molecules that might indicate the presence of life.

Are planetary systems like the Solar System common? How frequently do rocky planets settle in "habitable zones", where water is liquid? Do the atmospheres of exoplanets resemble the ones in the Solar System? How is pre-biotic material distributed in protoplanetary discs? Are there signs of life on any exoplanet?

Fundamental physics: are the laws of nature universal?

As far back in time and as far out in distance as we can observe, all the phenomena investigated so far seem to indicate that the laws of physics are universal and unchanging. Yet, uncomfortable gaps exist in our understanding: gravity and general relativity remain to be tested under extreme conditions, the amazingly rapid expansion (inflation) of the Universe after the Big Bang is not understood, dark matter seems to dominate the formation of the large scale structure but its nature remains unknown, and the recently discovered acceleration of the expansion of the Universe requires a mysterious dark energy that is even less comprehensible.



The evolution of the Universe is strongly dependent on dark energy.

Were the physical constants indeed constant over the history of the Universe? How did the expansion history of the Universe really proceed? Can we infer the nature of dark energy?

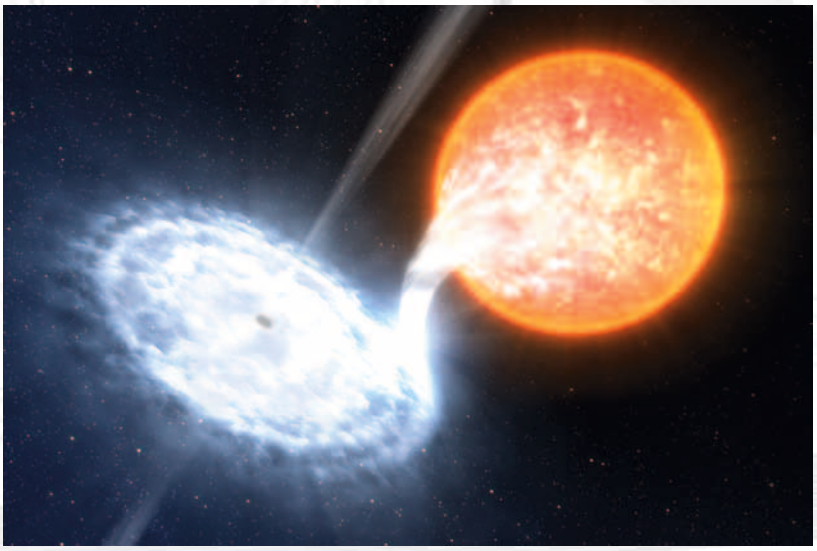
Black holes: what was their role in shaping the Universe?

Black holes have puzzled physicists and astronomers since they were first postulated in relativistic form a century ago by Karl Schwarzschild. Observations have demonstrated that these bizarre objects really exist. And on a grand scale, too: not only have black holes been found with masses comparable to stars, but also supermassive black holes, a million or even a billion times heavier than the Sun, have been found at the centres of many galaxies. These black holes also seem to "know" about the galaxies they live in, as their properties are closely correlated with the surrounding galaxy, with more massive black holes found in more massive galaxies.

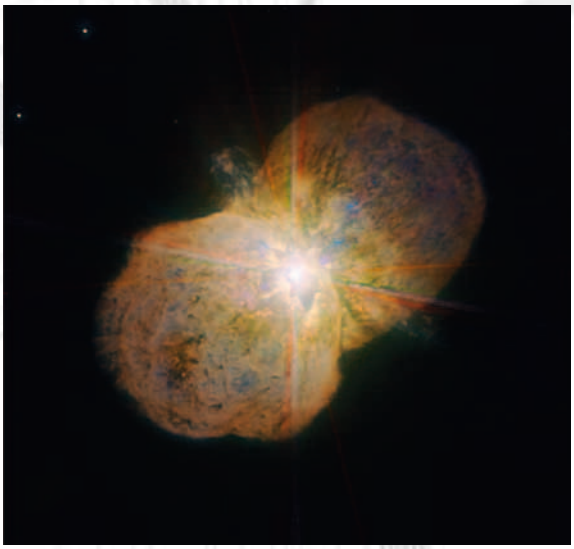
Will the supermassive black hole at the centre of the Milky Way reveal the nature of these objects? Do theories of gravitation and general relativity as we know them hold near a black hole's horizon? How do supermassive black holes grow? And what is their role in the formation of galaxies?

Stars: don't we know all there is to know?

Stars are the nuclear furnaces of the Universe in which chemical elements, including the building blocks of life, are synthesised and recycled: without stars there would be no life. Accordingly, stellar astrophysics has long been a core activity for astronomers. But much remains to be understood. With higher angular resolution and greater sensitivity astronomers will be able to observe the faintest, least massive stars, allowing us to close the current huge gap in our knowledge concerning star and planet formation. Nucleocosmochronometry — the radiocarbon-14 method as applied to stars — will become possible for stars right across the Milky Way, allowing us to study galactic prehistory by dating the very first stars. And some of the brightest stellar phenomena, including the violent deaths of stars in supernovae and gamma-ray



An artist's impression of a black hole accreting material from a nearby star.



The luminous blue variable star Eta Carinae is expected to explode as a supernova in the astronomically near future.

bursts, will be traced out to very large distances, offering a direct map of the star formation history of the entire Universe.

What are the details of star formation, and how does this process connect with the formation of planets? When did the first stars form? What triggers the most energetic events that we know of in the Universe, the deaths of stars in gamma-ray bursts?

Galaxies: how do "island universes" form?

The term "island universes" was introduced in 1755 by Immanuel Kant, and used at the beginning of the 20th century to define spiral nebulae as independent galaxies outside the Milky Way. Trying to understand galaxy formation and evolution has become one of the most active fields of astronomical research over the last few decades, as large telescopes have reached out beyond the Milky Way. Yet, even nearby giant galaxies have remained diffuse nebulae that cannot be resolved into individual stars. The unique angular resolution of the E-ELT will revolutionise this field by allowing us to observe individual stars in galaxies out to distances of tens of millions of light-years. Even at greater distances, we will be able to make the kind of observations of the structure of galaxies and the motions of their constituent stars that previously have only been possible in the nearby Universe: by taking advantage of the finite speed of light, we can peer back in time to see how and when galaxies were assembled.

The galaxy NGC 300.

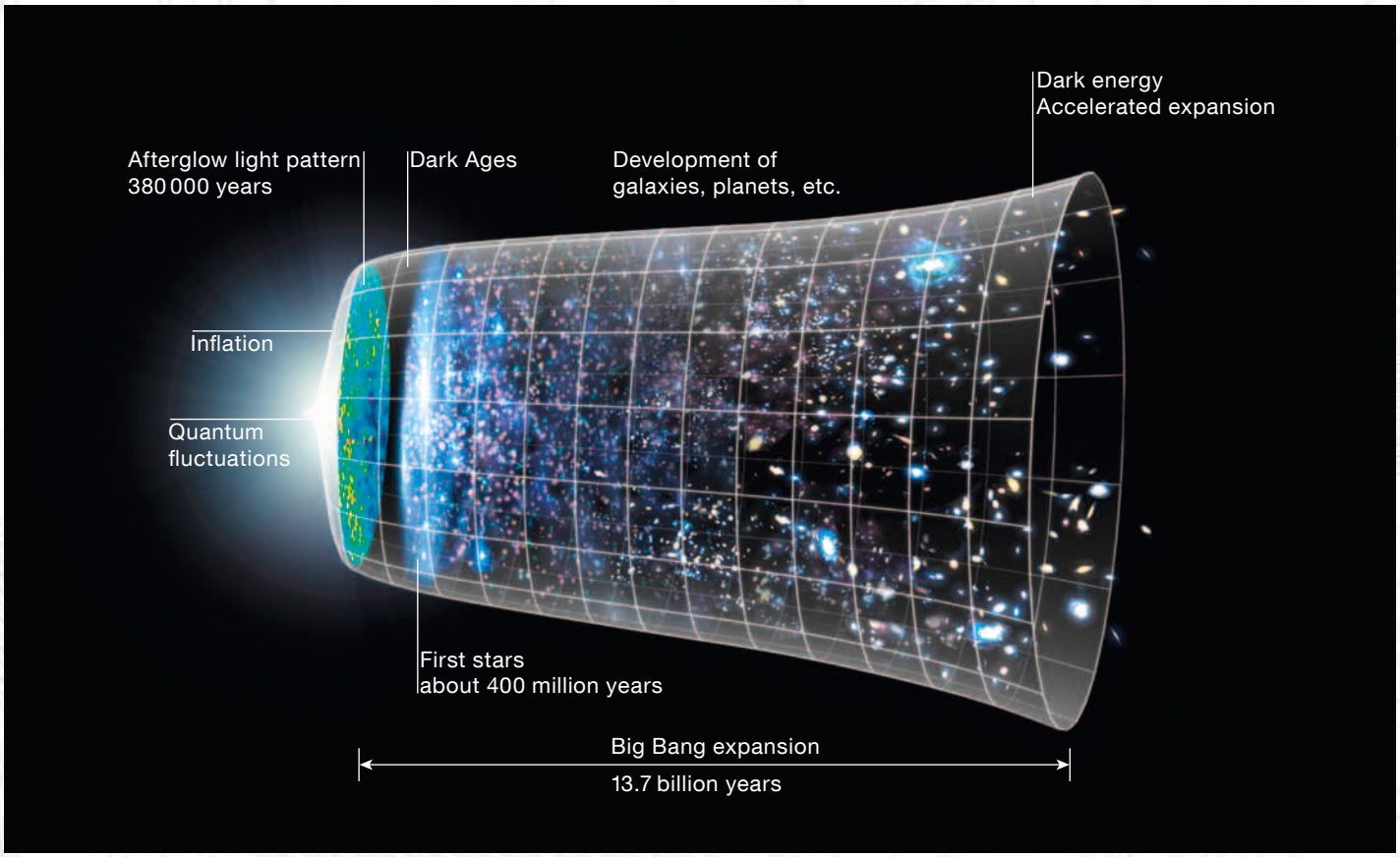
What stars are galaxies made of? How many generations of stars do galaxies host and when did they form? What is the star formation history of the Universe? When and how did galaxies as we see them today form? How did galaxies evolve through time?

The Dark Ages: can we observe the earliest epoch of the Universe?

For the first 380 000 years after the Big Bang, the Universe was so dense and hot that light and matter were closely coupled. Only once the Universe had expanded and cooled sufficiently, could electrons and protons "recombine" to form the simplest element, neutral hydrogen, and photons could decouple from matter. Only then could the first stars form and start to become organised into larger structures. The E-ELT will allow scientists to look all the way back to these earliest times (dubbed the "Dark Ages") to see how this first phase of astrophysical evolution began.

What was the nature of the first stars? When did the first galaxies assemble and what were their properties? When did galaxies assemble into larger scale structures, shaping the distribution of matter as we see it today?

The above illustrations only scratch the surface of the science that the E-ELT will carry out, but they give a flavour of the range of problems, from the origins of the laws of physics to the prevalence of life in the Universe, that it will enable us to tackle. It will allow scientists to address some of the most fundamental current questions, as well as opening up whole new frontiers of human understanding.



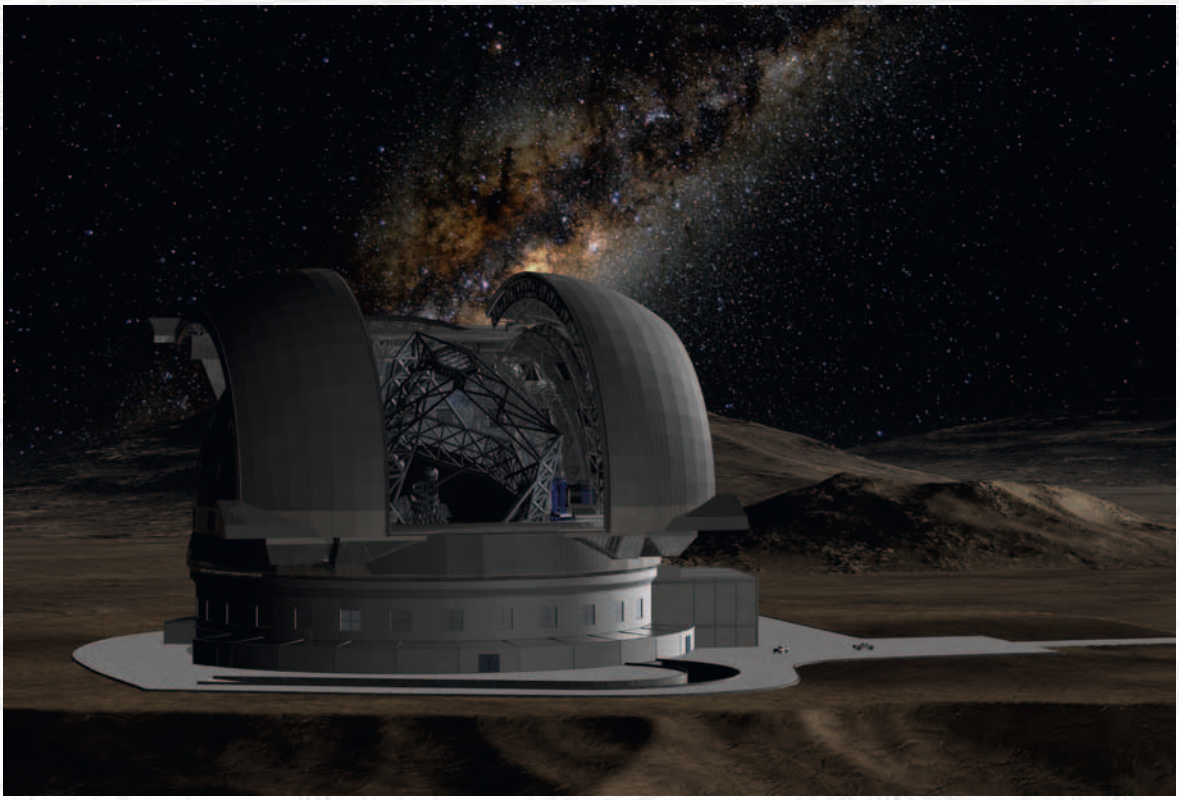
NASA/WMAP team

Timeline of the Universe: A representation of the evolution of the Universe over 13.7 billion years. The far left depicts the earliest moment we can now probe, when a period of "inflation" produced a burst of exponential growth in the Universe. (Size is depicted by the vertical extent of the grid in this graphic.) For the next several billion years, the expansion of the Universe gradually slowed down as the gravitational pull of the matter in the Universe on itself dominated. More recently, the expansion has begun to speed up again as the repulsive effects of dark energy have come to dominate the expansion of the Universe. The afterglow light seen by WMAP was emitted about 380 000 years after inflation and has traversed the Universe largely unimpeded since then. The conditions of earlier times are imprinted on this light; it also forms a backlight for later developments of the Universe.

Discovery Potential — Expect the Unexpected!

The previous pages presented the great scientific achievements to be anticipated with the E-ELT. These alone represent a giant leap in our understanding of the Universe and potentially the first step towards finding life beyond the Solar System. Yet, all previous telescopes have shown that, no matter how hard scientists have tried to predict the future, the greatest discoveries come as totally unexpected. Is this still possible in the case of the E-ELT?

The discovery potential of a telescope is, by definition, hard to quantify. However, astronomer Martin Harwit pointed out in his landmark book that one key indicator is the opening of a new parameter space: by looking somewhere where no one has been able to look before, one is very likely to make new discoveries. The E-ELT will open such new frontiers in at least three ways. First, the E-ELT will, thanks to its immense collecting power, increase the sensitivity of observations by up to a factor of 600. Furthermore, the E-ELT will increase the spatial resolution of images by an order of magnitude (even improving on the sharpness of future space telescopes). Finally, the E-ELT will open a new window on time resolution, enabling observation in the nanosecond regime. These leaps forward in what a telescope can do, coupled with other advances such as unprecedented spectral resolution, new abilities to study polarised light, and new levels of contrast allowing us to see the very faint next to the very bright, mean that we will open up an entire new universe of possibilities. It is in this great unknown that the ultimate excitement of the E-ELT lies.



E-ELT — the most inspiring ground-based observatory project today (artist's impression).

The E-ELT in Context

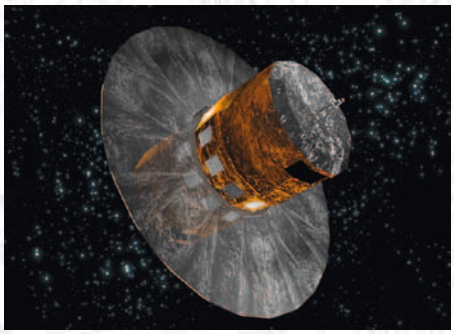
When the E-ELT starts operations a decade from now, astronomy will be in a golden era. By that time, a rich heritage will have been gathered from today's working facilities. In addition, new and ambitious facilities complementing the E-ELT will be deployed on the same timescale.

By 2018 observations with current telescopes will have led to a significant accumulation of knowledge and inevitably invited many new questions. Discoveries with ground-based telescopes such as ESO's Very Large Telescope (VLT) and its interferometer (VLTI), and other 8–10-metre class telescopes will have prepared the scene for further fascinating discoveries with the E-ELT. For example, it is expected that in the field of exoplanets, many candidates for E-ELT follow-up will have been identified, and the first galaxies emerging from the Dark Ages will have been tentatively identified and awaiting the E-ELT to be characterised and understood.

At the start of E-ELT operations, the Atacama Large Millimeter/submillimeter Array (ALMA) will have been exploring the cold Universe for a little less than a decade. A recent consultation of the ALMA and E-ELT communities revealed a wealth of synergies between these facilities: while ALMA will see the molecular gas in distant galaxies, the E-ELT will reveal the ionised gas — together ALMA and the E-ELT will revolutionise our understanding of star formation. Similarly, the two facilities will probe different regions in nearby protoplanetary discs, ideally complementing each other in exploring the early phases of planetary systems.

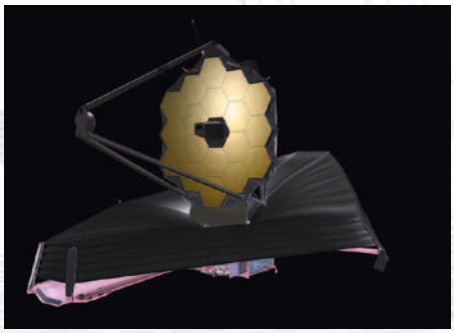
The VLT, located on Cerro Paranal in Chile, is the most advanced and efficient observatory in the world.

ALMA is the largest astronomical project in existence and will start observing the southern sky in 2011.



ESA/C. Carreau

The Kepler Mission



NASA

ESA/AOES Medialab, background: Hubble Space Telescope image (NASA/ESA/STScI)

Several space observatories will work together with the E-ELT. Shown from left to right are Gaia, Kepler and Herschel. The James Webb Space Telescope (bottom) is expected to be launched in 2014.

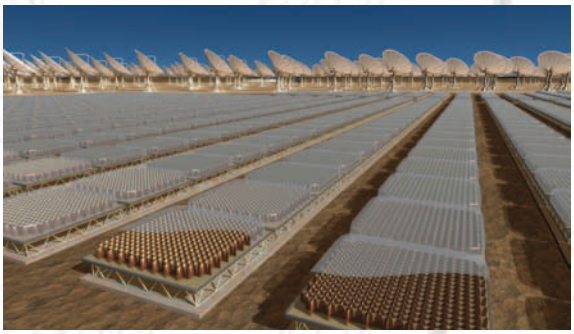
The next decade will also see the advent of many survey telescopes. ESO's 2.6-metre VLT Survey Telescope (VST) and the 4.1-metre Visible and Infrared Survey Telescope for Astronomy (VISTA) will have been surveying the sky for a decade, supplemented by many similar facilities worldwide. These telescopes will be complemented by even more powerful survey facilities, such as the Pan-STARRS network and the 8-metre Large Synoptic Survey Telescope (LSST), which will ramp up over the next decade. While much exciting science will come out of these surveys directly, a wealth of understanding will follow from more detailed follow-up observations of targets identified by such projects, and it will only be with the larger, more sophisticated E-ELT that such an understanding can be obtained.

Existing or soon-to-be-launched space telescopes such as Hubble, Spitzer, Chandra, XMM-Newton, Herschel, Planck, CoRoT, Kepler and Gaia will have been working for a number of years as the E-ELT starts operations. These missions will have produced a major legacy for the E-ELT to exploit. For example CoRoT and Kepler will reveal nearby exoplanets transiting making them perfect candidates for exoplanet atmosphere studies with the E-ELT. Gaia will have studied a billion stars in the Milky Way in detail, revealing rare jewels such as the first stars that can be followed up with nucleocosmochronometry with the E-ELT. Herschel, together with ALMA, will collect a sample of galaxies in the early Universe, awaiting the E-ELT to be resolved and analysed. The list goes on; it is only by using the amazing power of the E-ELT to understand the detailed physics of the objects discovered by these missions that the benefits from the huge investment in space technology will be fully realised.

An exciting scientific interplay can be foreseen between the E-ELT and Hubble's successor, the James Webb Space Telescope (JWST), the ambitious optical/infrared space observatory

scheduled for launch in 2014. Indeed, just as the combination of 8–10-metre class telescopes and the Hubble offered two decades of discoveries, the E-ELT and JWST complement each other perfectly. The 6.5-metre JWST, unhindered by the atmosphere, will be able to obtain deeper images, in particular in the infrared, while the 42-metre E-ELT will have almost seven times higher spatial resolution and will be able to collect fifty times more photons for high resolution spectroscopy and studies of rapid time variability.

Finally, the plans for the Square Kilometre Array (SKA) could have it starting operations soon after the E-ELT. Despite the very different wavelength regimes, the cosmology science drivers of the E-ELT and SKA are remarkably complementary. Survey observations with the SKA are likely to follow-up on the studies of the fundamental constants and dark energy made with the E-ELT. In many other fields the SKA will probe the cold Universe, where the E-ELT can see the luminous one.



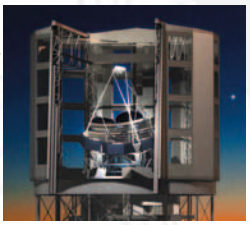
SKA and Xilostudios

An artist's view of the planned Square Kilometre Array radio telescope.

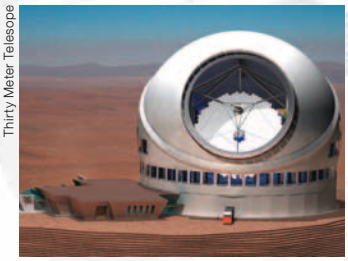
In summary, the E-ELT will be built on the most solid foundations. In the coming decade enormous progress is expected from the many ground-based and space observatories. While the E-ELT will have a sharper eye and higher sensitivity than all of them, it will profit from their capabilities to observe at other wavelengths or wider areas of the sky. The synergy between all these facilities will enable the most fascinating discoveries with the E-ELT.

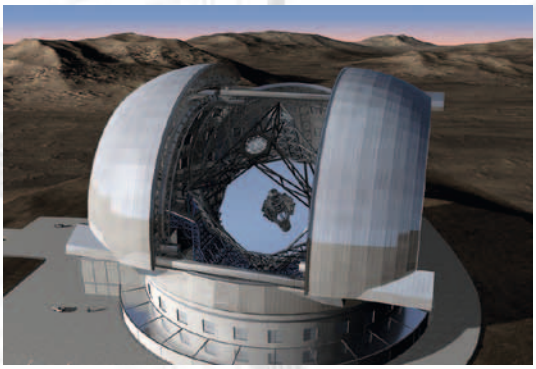
The E-ELT compared to other ELTs

GMTO Corporation



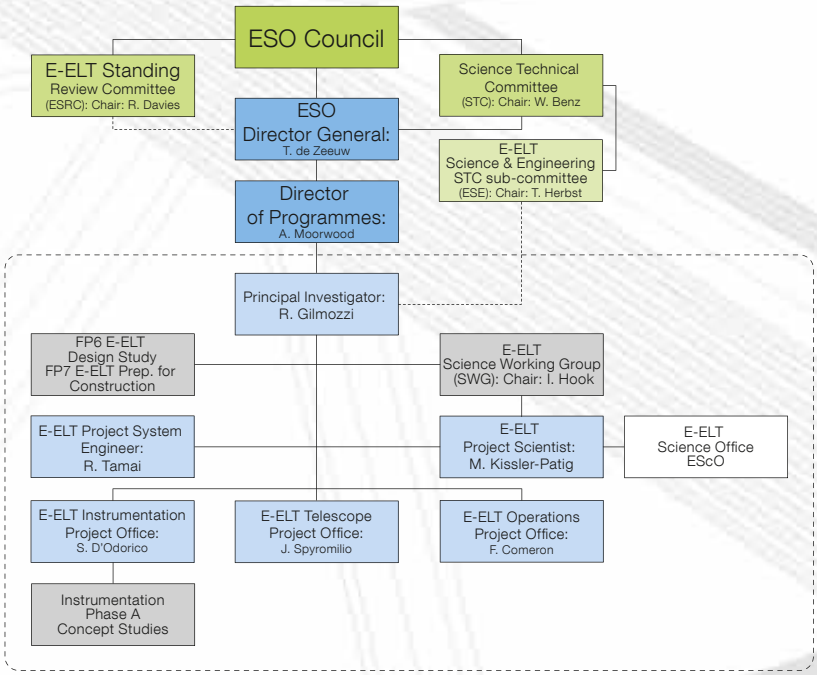
Thirty Meter Telesope





	GMT-project	TMT-project	E-ELT-project
Diameter (m)	24 m	30 m	42 m
Collecting area (m^2)	~ 400 m^2	~ 600 m^2	~ 1200 m^2
Diffraction limit at 1 µm Milli-arcseconds (mas)	8.6 mas	6.9 mas	4.9 mas

Project Management



The challenge of designing, constructing and operating a 42-metre telescope is substantial. Extrapolating technical solutions for light collectors from an 8-metre diameter to 42 metres, while achieving an excellent image quality in a sizable field of view, poses numerous challenges. ESO is working with more than thirty European scientific institutes and high-tech companies towards establishing the key enabling technologies needed to make the ELT feasible at an affordable cost within the next decade. Two highly important aspects of the E-ELT's development are the control of high precision optics over the huge scale of the telescope, and the design of an efficient suite of instruments that allow astronomers to achieve the E-ELT's ambitious science goals.

As far as instrumentation is concerned, the goal is to create a flexible suite of instruments to deal with the wide variety of science questions that astronomers would like to see resolved in the coming decades. The ability to observe over a large range of wavelengths from the optical to mid-infrared, with multi-user instruments, will allow scientists to exploit the telescope's size to the full. Streamlined integration of the instruments with the active and adaptive control systems could be challenging. ESO will coordinate the development of five or six first generation instruments. This also requires a considerable investment in skilled human resources, and management of these projects over a host of collaborating institutions will be a challenge in itself. Only by tapping the intellectual resources all over Europe can this development be successful, as it has been for the VLT instrument suite.

The E-ELT Programme Office coordinates the E-ELT activities within ESO. It is headed by the Principal Investigator and includes three project offices: one for the telescope, one for the instrumentation and one for the operational aspects. The Programme Office is further complemented by the Project System Engineer and the Project Scientist (in charge of the E-ELT Science Office).

The Principal Investigator coordinates the ESO and community efforts in the framework of the EU-sponsored FP6 and FP7 activities. The Principal Investigator and the Project Scientist are advised by the Science Working Group.

The Instrument Project Office coordinates ten instrument studies.

The following bodies oversee the project:
- ESE: ELT Science and Engineering subcommittee of the STC
- STC: Science and Technology Committee reporting to ESO Director General (DG) and Council
- ESRC: ELT standing review committee reporting to Council
- Council

E-ELT Phase A Instrumentation Studies

Name	Instrument Type	Principal Investigator and Institutes
CODEX	High Resolution, High Stability Visual Spectrograph	Luca Pasquini, ESO Instituto Nazionale di Astrofisica (INAF), Osservatori Trieste and Brera; Instituto de Astrofisica de Canarias (IAC); Institute of Astronomy, University of Cambridge; Observatoire Astronomique de l'Université de Genève
EAGLE	Wide Field, Multi Integral Field Unit Near-infrared Spectrograph with Multi Object Adaptive Optics	Jean-Gabriel Cuby, Laboratoire d'Astrophysique de Marseille (LAM) Observatoire Paris-Meudon (OPM), Laboratoire d'Etudes des Galaxies, Etoiles, Physique et Instrumentation (GEPI) and Laboratoire d'Etudes Spatiales et d'Instrumentation en Astrophysique (LESIA); Ofice National d'Etudes et Recherches Aérospatiale (ONERA); United Kingdom Astronomy Technology Centre (UK ATC); Durham University, Centre for Advanced Instrumentation
EPICS	Planet Imager and Spectrograph with Extreme Adaptive Optics	Markus Kasper, ESO Laboratoire d'Astrophysique de l'Observatoire de Grenoble (LAOG); LESIA; Université de Nice; LAM; ONERA; University of Oxford; INAF, Osservatorio Padova; ETH Zurich; NOVA, Universities of Amsterdam and Utrecht
HARMONI	Single Field, Wide Band Spectrograph	Niranjan Thatte, University of Oxford Centre de Recherche Astrophysique, Lyon; Departamento de Astrofisica Molecular e Infraroja, Consejo Superior de Investigaciones Cientificas, Madrid; IAC; UK ATC
METIS	Mid-infrared Imager and Spectrograph with Adaptive Optics	Bernhard Brandl, NOVA, University of Leiden MPIA; Commissariat a l'Energie Atomique (CEA) Saclay, Direction des Sciences de la Matiere (DSM)/Institut de Recherches sur les lois Fondamentales de l'Univers (IRFU)/Service d'Astrophysique (SAp); Katholieke Universiteit Leuven; UK ATC
MICADO	Diffraction-limited Near-infrared Camera	Reinhard Genzel, Max-Planck Institute for Extraterrestrial Physics (MPE) Max-Planck Institute for Astronomy (MPIA); Universitäts-Sternwarte München (USM); INAF, Osservatorio Padova; Nederlandse Onderzoekschool Voor Astronomie (NOVA), Universities of Leiden and Groningen
OPTIMOS	Wide Field Visual and Near-infrared Multi Object Spectrograph	Negotiations under way with a Consortium of Science and Technology Facilities Council, Rutherford Appleton Laboratory; University of Oxford; LAM; INAF, Istituto di Astrofisica Spaziale e Fisica Cosmica, Milan; GEPI; NOVA, University of Amsterdam; INAF, Osservatori Trieste and Brera; Niels Bohr Institute, University of Copenhagen
SIMPLE	High Spectral Resolution Near-infrared Spectrograph	Livia Origlia, INAF, Osservatorio Bologna INAF, Osservatorio Arcetri; INAF, Osservatorio Roma; Uppsala Astronomical Observatory; Thüringer Landessternwarte; Pontificia Universidad Catolica de Chile
ATLAS	Laser Tomography Adaptive Optics Module	Thierry Fusco, ONERA GEPI and LESIA
MAORY	Multi Conjugate Adaptive Optics Module	Emiliano Diolaiti, INAF, Osservatorio Bologna INAF, Osservatorio Arcetri; INAF, Osservatorio Padua; University of Bologna; ONERA

The Decision Process

In December 2004, the ESO Council defined "*the retention of European astronomical leadership and excellence in the era of Extremely Large Telescopes (ELT)*" as ESO's highest priority strategic goal, asking that "*the construction of an ELT on a competitive timescale be addressed by radical strategic planning*".

Following an extensive international review in October 2005 of a first concept study — the OWL project — the ESO project offices conducted a new study in 2006, produced with the help of more than 100 astronomers and engineers, to carefully evaluate performance, cost, schedule and risk. In November 2006, the results were subject to detailed discussions by more than 250 European astronomers at a conference in Marseille. Their enthusiastic support paved the way for the decision in December 2006 by the ESO Council to move to the crucial next phase of detailed design of the full facility, followed a year later by the decision to approve the launch of ten instrument design studies.

The choice in April 2010 of the selected site for the E-ELT allows the consortia to finalise their studies. These studies are scheduled to last until the end of 2010, at which time the ESO Director General will present a construction proposal to the ESO Council. This construction proposal will first have been submitted to an extended review by several committees involving leading world experts drawn from the community.

It is estimated that the construction of the E-ELT will last seven years. Thus, if construction can start in 2011, the E-ELT could have first light in late 2018.

Timeline

- Dec 2004: ESO Council asks that "*the construction of an ELT on a competitive timescale be addressed by radical strategic planning*".
- Oct 2005: First concept study is reviewed.
- 2006: Baseline design study.
- Nov 2006: 250 astronomers gather to discuss the study.
- Dec 2006: ESO Council approves the start of the E-ELT Detailed Design Study.
- Dec 2007: ESO Council approves the launch of the ten instrument design studies.
- Mar 2010: Armazones is recommended to Council as the baseline reference site by the Site Selection Advisory Committee.
- Apr 2010: ESO Council chooses Armazones as the site for the E-ELT.
- Sep 2010: Four-day External Review of E-ELT Construction Proposal by a board of technical experts.
- Oct 2010: Presentation of E-ELT Construction Proposal to Committee of Council and ESRC.
- Oct 2010: Presentation of E-ELT Construction Proposal to STC for recommendation.
- Dec 2010: Formal presentation of E-ELT Construction Proposal to Council by DG for approval.

Frequently Asked Questions

Q: Which site has been selected for the E-ELT?
A: The ESO Council has selected Cerro Armazones as the site for the world's biggest eye on the sky, the revolutionary 42-metre European Extremely Large Telescope. Armazones is a peak in the Chilean Atacama Desert, with an altitude slightly above 3000 metres. It is located roughly 20 km away from Cerro Paranal, home of the Very Large Telescope, and is another exceptional site for astronomical observations. In anticipation of the choice of Cerro Armazones as the future site of the E-ELT and to facilitate and support the project, the Chilean Government has agreed to donate to ESO a substantial tract of land contiguous to ESO's Paranal property and containing Armazones in order to ensure the continued protection of the site against all adverse influences, in particular light pollution and mining activities. There is no cost associated with this donation.

Q: What was the process leading up to the decision for the E-ELT site and who took the final decision?
A: The independent E-ELT Site Selection Advisory Committee (SSAC) has been analysing in great detail results from several possible sites worldwide. Similar efforts have been carried out by the Thirty-Meter Telescope (TMT) site selection team from the US. For the sake of efficiency, the sites pre-selected by the TMT team (all in North and South America) were not studied by the SSAC, as the TMT team shared their data with the SSAC. The SSAC drew up a shortlist comprising four sites in Chile and one in the Canary Islands, Spain. Two of the sites on the SSAC short list, including Armazones, were on the TMT list.

On 2–3 March 2010, the E-ELT Site Selection Advisory Committee presented their report to the ESO Council, confirming that all the sites examined in the final shortlist have very good conditions for astronomical observing, each one with its particular strengths. The technical report concluded that Cerro Armazones, near Paranal, stands out as the clearly preferred site, because it has the best balance of sky quality across all the aspects considered, and it can be operated in an integrated fashion with the existing ESO Paranal Observatory. The ESO Council, ESO's governing body, convened on 26 April 2010, and, taking into account the recommendations of the Site Selection Advisory Committee and all other relevant aspects, selected Cerro Armazones.

Q: Will the E-ELT site-testing data be made public?
A: The majority of the site-testing data will be made public in the course of the year.

Q: What is the next step for the E-ELT?
A: The E-ELT Project Office will now finalise the design of the telescope and its observatory, taking into account the selected site, and submit a construction proposal to the ESO Council. The Council will then decide whether construction of the telescope can start.

Q: When will construction of E-ELT start?
A: Construction will start upon approval by the ESO governing body, the Council. This could be as early as 2011.

Q: When will the E-ELT be operational?
A: It is estimated that the construction of the E-ELT will last seven years. Thus, if construction can start in 2011, the E-ELT could have first light in late 2018.

Q: What is the cost of the E-ELT?
A: The construction cost is estimated to be close to a billion euros.

Q: What is the operating cost of the E-ELT?
A: The E-ELT will be operated as an integral part of the ESO observatories. The operating cost includes not only the cost of running the observatory in Chile, but also the cost of operation support in Garching as well as re-investment costs for telescope upgrades and new instruments/cameras for the telescope. The total operating cost is estimated to be 50 million euros per year.

Q: For how long will the E-ELT be used?
A: The current operation plan foresees that the E-ELT will be used for at least 30 years. This is a typical lifetime for such a large facility and implies, as is the case for example at the Very Large Telescope, regular maintenance and a programme of new instrument development. Note that ESO's La Silla Observatory had its 40th anniversary in 2009 and is still in operation.

Q: Have you raised all the funding for E-ELT?
A: Part of the construction costs are already provided for in the planned ESO budget for the next decade. Several options to cover the additional funding have been proposed to the ESO governing body, the Council.

Q: Where will the E-ELT money be spent?
A: The money will be primarily spent in the ESO Member States through industrial contracts. A fair industrial return to all partners is an important component of the endeavour and is carefully evaluated at all phases of the project.

Q: Why spend such a considerable amount of money on astronomical research?
A: Astronomy contributes to our cultural and economic well-being in a number of ways. It is an integral part of our culture and contributes to a better understanding of our fragile environment. Astronomers tackle key questions that challenge our minds and our imagination. How did the planets form? Is life ubiquitous in the Universe? What is the Universe made of? What are dark matter and dark energy?

Beyond these questions, astronomy often inspires young people to choose natural sciences as a career, from where they go on to scientific and technical careers in academia and industry in a wide range of other field, and thus contributes to a balanced, future-oriented society.

Astronomy is also a modern, high-tech science relying on a strong collaboration with industry to realise challenging large-scale engineering tasks. This brings benefits to both sides.

The E-ELT, as an example, is a high technology science-driven project that incorporates many innovative developments, offering numerous possibilities for technology spin-off and transfer, together with challenging technology contract opportunities and providing a dramatic showcase for European industry. It will create many high technology jobs, as well as business opportunities for local companies in the host country (Chile).

Q: Why do we need such a large telescope as the E-ELT?
A: The current generation of large telescopes has allowed astronomers to make tremendous discoveries, opening up whole new areas of study. For example, the current generation of 8–10-metre class telescopes allowed us to take the first pictures of planets orbiting around other stars. Our knowledge in astronomy continues to progress at an incredible pace, answering many questions, but also raising exciting new ones. The E-ELT will address these new questions, but will also make discoveries that we cannot even imagine yet.

Q: Why does the E-ELT have a mirror diameter of 42 metres?
A: The size of a telescope is important for two reasons: one is the amount of light it can collect and the other is the level of detail it can see. With its 42-metre diameter, the E-ELT will gather 15 times more light than the largest optical telescopes operating today. It will also provide images 15 times sharper than those from the Hubble Space Telescope. The E-ELT performance is thus orders of magnitude better than the currently existing facilities. Such a telescope may, eventually, revolutionise our perception of the Universe, much as Galileo's telescope did, 400 years ago.

The 42-metre diameter turned out to be the minimum diameter needed to achieve some of the driving science cases: to image rocky exoplanets to characterise their atmospheres and to directly measure the acceleration of the expansion of the Universe.

Q: How could I work with the E-ELT?
A: If you are not yet an astronomer and are considering becoming one, you could have a look at the new IAU Theme on Careers in astronomy: http://www.iau.org/public_press/themes/careers/

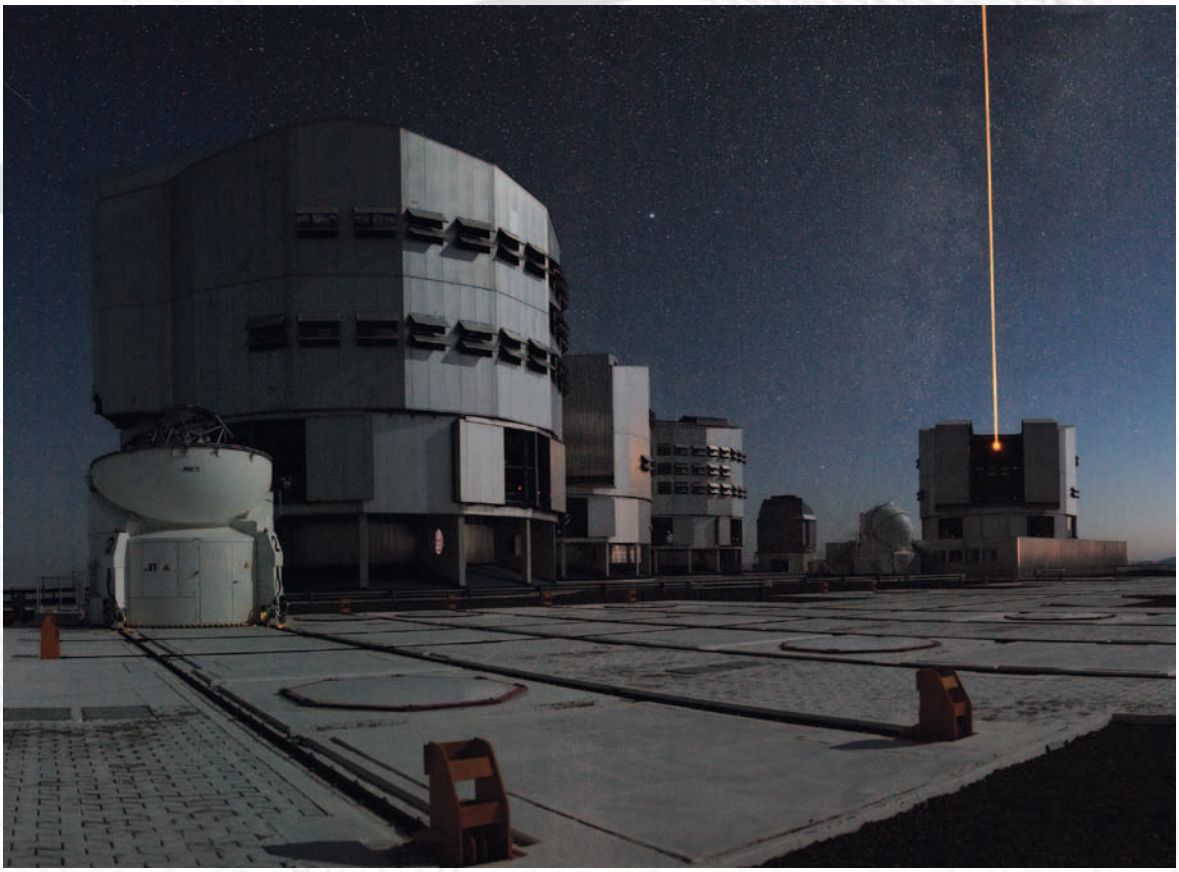
Q: Aren't earthquakes a problem for the E-ELT?
A: The E-ELT Project Office has considered the seismic risk in all of the design aspects of the telescope. The quantification of seismic risk was the subject of extensive analysis at the time of the selection of Paranal for the VLT. The design criteria for the E-ELT follow closely those used for the VLT in terms of accelerations, but take into account the most recent international norms for their application. Two studies were commissioned to re-evaluate the design criteria and this work was reviewed by three independent teams of experts. In addition to these studies, four independent contractors developed options for seismically isolating the telescope and the dome. Most of the resulting precautions against rapid accelerations for the telescope, its optical systems and the dome, would have to be in place in any case to avoid accidental damage. These protections do not carry large budgetary impacts for the telescopes.

About ESO

ESO, the European Southern Observatory, is the foremost intergovernmental astronomy organisation in Europe and the world's most productive astronomical observatory. ESO provides state-of-the-art research facilities to astronomers and is supported by Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Several other countries have expressed an interest in membership.

ESO's main mission, laid down in the 1962 Convention, is to provide state-of-the-art research facilities to astronomers and astrophysicists, allowing them to conduct front-line science in the best conditions. The annual member state contributions to ESO are approximately 140 million euros and ESO employs around 700 staff members. By building and operating a suite of the world's most powerful ground-based astronomical telescopes enabling important scientific discoveries, ESO offers numerous possibilities for technology spin-off and transfer, together with high technology contract opportunities and is a dramatic showcase for European industry.

Whilst the Headquarters (comprising the scientific, technical and administrative centre of the organisation) are located in Garching near Munich, Germany, ESO operates, in addition to the Santiago Centre, three unique observing sites in Chile.



At La Silla, ESO operates several medium-sized optical telescopes, including the most successful low-mass exoplanet hunter.

The Very Large Telescope (VLT), the world's most advanced visible-light astronomical observatory, is located on the 2600-metre high mountain of Paranal, which also hosts the VLT Interferometer and two survey telescopes, the VST and VISTA. The third site is the 5000-metre high Llano de Chajnantor, near San Pedro de Atacama. Here a submillimetre telescope (APEX) is in operation, and a revolutionary telescope – a giant array of 12-metre submillimetre antennas (ALMA) – is being constructed in collaboration with North America, East Asia and Chile.

ESO is currently planning a 42-metre European Extremely Large optical/near-infrared Telescope, the E-ELT, which will become "the world's biggest eye on the sky".

With ESO's telescopes, astronomers tackle key questions that challenge our minds and our imagination. Astronomy is the study of origins. It is also the study of grandiose events. And great mysteries. Most of all, however, it is humanity's boldest attempt to understand the world in which we live.

Each year, about 2000 proposals are submitted for the use of ESO telescopes, requesting between four and six times more nights than are available. ESO is the most productive ground-based observatory in the world, which annually results in many peer-reviewed publications: in 2009 alone, almost 700 refereed papers based on ESO data were published. Moreover, research articles based on VLT data are quoted twice as often as the average.

The very high efficiency of the ESO's "science machines" now generates huge amounts of data at a very high rate. These are stored in a permanent science archive facility at ESO Headquarters.

ESO also hosts the European Coordinating Facility for the Hubble Space Telescope, a collaboration between ESA and NASA. Hubble is a long-term, space-based observatory. The observations are carried out in visible, infrared and ultraviolet light. In many ways Hubble has revolutionised modern astronomy, by not only being an efficient tool for making new discoveries, but also by driving astronomical research in general.

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