Overview

- What is astronomy?
- ESO history
- What is ESO?
- La Silla
- VLT
- ALMA
- E-ELT
Why are we here?

What is astronomy?

And what is all this good for?
What is astronomy?

Astronomy is the study of all celestial objects. It is the study of almost every property of the Universe from stars, planets and comets to the largest cosmological structures and phenomena; across the entire electromagnetic spectrum and more.

It is the study of all that has been, all there is and all that there ever will be. From the effects of the smallest atoms to the appearance of the Universe on the largest scales.
Astronomy is the oldest of the natural sciences, dating back to antiquity, with its origins in the religious, mythological, and astrological practices of the ancient civilisations.

Early astronomy involved observing the regular patterns of the motions of visible celestial objects, especially the Sun, Moon, stars and naked eye observations of the planets.

The changing position of the Sun along the horizon or the changing appearances of stars in the course of the year was used to establish agricultural or ritual calendars.
Astronomy in the ancient world

Australian Aboriginals belong to the oldest continuous culture in the world, stretching back some 50,000 years...

It is said that they were the first astronomers.
Astronomy in the ancient world

Goseck Circle
c. 47th Century BCE

Mnajdra Temple Complex
c. 36th Century BCE
Astronomy in the ancient world

Nebra Sky Disc
c. 1600 BCE

Antikythera Mechanism
c. 1st century BCE
Astronomical Research Today

Astronomical objects are far and faint…

We only have access to limited information about their nature.

We need large and powerful instruments: resolution and sensitivity.

Astronomers combine different types of observations and in different wavelengths.
Astronomers observe electromagnetic waves from all parts of the spectrum. Every type of visible and invisible light reveals a different piece of the great cosmic puzzle.
Astronomical Research Today

Astronomers around the world study the workings of the Universe.

Today, this is being done through a combination of many disciplines and sub-fields using many different approaches:

- Ground-based telescopes
- Space-based observatories
- Robotic spacecrafts
- Theoretical calculations and simulations

Astronomers study the Universe not only to further our understanding of the cosmos, but to advance other fields of science and technology too (spin-off technologies).
Spin-off Technologies

CCD (Charge Coupled Devices)

Willard Boyle and George Smith were awarded the Nobel Prize in 2009 for their work in developing CCDs.

They are used for a wide range of applications, from the early detection of breast cancer to modern digital cameras.
Spin-off Technologies

X-ray Detectors

Astronomers are interested in detecting X-ray signals that while containing very high energy photons are still very weak.

To do this, high sensitivity X-ray detectors, capable of detecting single X-ray photons were developed a number of years ago.

The technology behind these detectors has been adopted by airport security services for scanning passengers’ luggage.
ESO: the European Southern Observatory

- Created in 1962
- Its member states are Austria, Belgium, Brazil, the Czech Republic, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.
- ESO’s headquarters are in Garching near Munich, Germany.
- ESO operates observatories at three sites in Chile, located at La Silla, Paranal and Chajnantor.
The Governments of the States parties to this convention […] desirous of jointly creating an observatory equipped with powerful instruments in the Southern Hemisphere and accordingly promoting and organising co-operation in astronomical research […]

From the preamble to the ESO Convention, 1962
An evolving organisation

<table>
<thead>
<tr>
<th>The beginning...</th>
<th>Building up expertise...</th>
<th>Among world leaders</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954 ESO Declaration</td>
<td>1976 3.6-m Telescope</td>
<td>1989 New Technology Telescope</td>
</tr>
<tr>
<td></td>
<td>1998</td>
<td>present ALMA E-ELT -</td>
</tr>
</tbody>
</table>

The beginning... Building up expertise... Among world leaders
ESO today

- 15 member states, several others interested
- Collaborations with Chile, US, East Asia, Canada — a global world
- ~ 680 (630) staff at 5 main sites, 5 small sites
- ESO is the driving force behind ground-based astronomy, and the foremost intergovernmental astronomy organisation in the world.
- ESO is the most productive observatory in the world (871 refereed academic papers in 2012, Hubble 844).
Why Chile?

- Privileged atmospheric conditions
- Over 300 clear nights per year
- Political and economical stability
- Excellent view of the centre of the Milky Way, and both Large and Small Magellanic Clouds
- Free from radio interference…
...and light pollution!
ESO’s observatory sites in Chile

- Paranal (2600 m)
- La Silla (2400 m)
- Chajnantor (5000 m)
La Silla, ESO’s first observatory site
La Silla

- ESO’s first observatory site, inaugurated in 1969, became the largest astronomical observatory of its time, and led Europe to the frontline of astronomical research.

- La Silla remains one of the most scientifically productive observatories in the world.

- Equipped with medium-sized and small optical telescopes, including the most successful exoplanet hunter (HARPS on ESO 3.6-metre Telescope). Almost 2/3 of all confirmed exoplanets below Neptune mass have been discovered by HARPS.
Paranal and the ESO Very Large Telescope
Paranal and the Very Large Telescope

- VLT is located on Cerro Paranal, a 2600 m mountain south of Antofagasta, Chile.
- The VLT is the world’s most advanced visible-light astronomical observatory, a formidable science machine, and the flagship facility of ground-based astronomy.
- It is the most productive individual ground-based astronomical facility.
The ESO Very Large Telescope

- Four 8.2-m “Unit Telescopes”, called Antu, Kueyen, Melipal and Yepun.
- Four 1.8-m movable “Auxiliary Telescopes”
- The 8.2-m diameter primary mirrors weigh 23 tonnes and are only 175 mm thick.
- VLT uses active optics, adaptive optics and interferometry to improve image quality.
The Technology of ESO

Since its invention 400 years ago, the astronomical telescope has evolved from a small, manually pointed device for visual observations to a large, sophisticated, computer-controlled instrument with full digital output. Throughout this development, two properties have been particularly important:

- The light-colllecting power, or diameter of the telescope's mirror (allowing for the detection of fainter and more distant objects).
- The image sharpness, or angular resolution (allowing smaller and fainter objects to be seen).

ESO has developed several advanced technologies that have enabled the construction of ever larger telescope mirrors, while maintaining optical accuracy:

- Active optics
- Adaptive optics
- Interferometry
Active Optics

Each of ESO’s four VLT Unit Telescopes has a semi-flexible primary mirror with a diameter of 8.2 metres. When the telescope moves to observe in a different direction, the shape of the giant mirror distorts under its own weight.

Active optics corrects for these distortions by continuously monitoring a reference star during the observations, and a computerised image analyser detects even the smallest deviations from the optimum image quality.

Based on the signals from this device, the shape and position of the telescope mirror are then automatically and slowly adjusted. In this way, the stellar images always remain as round and sharp as possible.
The Technology of ESO

Adaptive Optics

When starlight passes through the Earth’s atmosphere, changes in heat and density combined with particles in the air cause the star to “twinkle” or blur.

To compensate for this blurring, the Unit Telescopes of the VLT make use of a Laser Guide Star (LGS). The LGS is shone high into the atmosphere and used as an artificial star to measure the amount of distortion caused by the atmosphere. Those measurements are fed into the computer and the mirror actuators are rapidly adjusted, allowing the main mirror to change shape, therefore maintaining a high image quality.

ESO has led the way in developing adaptive optics and Laser Guide Star technologies. The VLT Laser Guide Star Facility was the first of its kind in the southern hemisphere.
Interferometry

Combining the light collected by two or more telescopes in a technique known as *interferometry* can boost the resolution beyond what a single telescope can accomplish. ESO has been a pioneer in this field with the Very Large Telescope Interferometer (VLTI) at Paranal.

The VLTI gives astronomers the ability to study celestial objects in unprecedented detail. The VLTI has allowed astronomers to obtain one of the sharpest images ever of a star, with a spatial resolution of only 4 milliarcseconds. This is equivalent to picking out the head of a screw at a distance of 300 km.
Keeping the observatory at Cerro Paranal, at 2600-metre altitude running smoothly presents challenges…
Keeping the observatory at Cerro Paranal, at 2600-metre altitude running smoothly presents challenges…
The Atacama Desert is the driest place on Earth. It is difficult to live here...
If the VLT is an island in the desert, then its associated Residencia is an oasis!

(Residencia shown here, as it was under construction)
La Residencia was finished in 2002 and provides ESO staff and visitors with a haven away from the harsh Atacama Desert.
About 60,000 litres of water are consumed at Paranal each day, with two delivery trucks making the daily trip from Antofagasta.
James Bond at Paranal
Spectacular stellar nursery
IC 2944
VISTA Survey Telescope at Paranal

- VISTA is the largest survey telescope in existence and the most powerful near-infrared survey telescope ever built.
- VISTA has a 4.1-m primary mirror, and is dedicated to conducting wide-angle surveys of the skies.
- At the heart of VISTA is a 3-tonne camera containing 16 special detectors sensitive to infrared light with a combined total of 67 megapixels.
- The VISTA camera has the widest coverage of any astronomical near-infrared camera.
This is Cerro Chajnantor, at 5000-m altitude in the Atacama Desert.
European Extremely Large Telescope
E-ELT is incredible…

- With its 39-m diameter mirror, the E-ELT is the largest optical/near-infrared telescope in the world: “the biggest eye on the sky”.
- E-ELT will gather 15 times more light than any other telescope today.
- The science to be done with the E-ELT is extremely exciting: extrasolar planets and discs, galaxy formation, dark energy/dark matter, and frontiers of physics.
- The E-ELT will be able to correct for the atmospheric distortions (i.e. fully adaptive) from the start.
E-ELT 39-metre mirror

VLT 8-metre mirror
…and more

- The E-ELT will have a novel five mirror design that no other telescope has.

- To preserve and further expand the community’s leading role in astronomy, new and innovative steps must be taken – E-ELT.

- The E-ELT has wide support in the scientific community by being included as the sole project in its field of optical astronomy in roadmap for the European Strategy Forum on Research Infrastructures. It also features prominently in the ASTRONET European Roadmap for astronomy.
More than thirty scientific institutes and high-tech companies developed crucial technologies within the E-ELT Design Study.

The E-ELT offers numerous possibilities for technology spin-off and transfer, together with high technology contract opportunities and offers a dramatic showcase for the industry.

Our leadership of this major flagship project will indisputably raise the scientific, technological and industrial profile of the Member States.
What will the E-ELT’s vision be like?
The ESO Council has selected Cerro Armazones as the site for the E-ELT.

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.

The go-ahead for E-ELT construction is planned for December 2013, with start of operations planned for early in the next decade.
Thank you!