On the ground and in space, a global family of giant telescopes – present and future – is designed to gather visible and invisible light from across the Cosmos.

**BIG TELESCOPES**

A rainbow is the spectrum of colours that make up visible light. But there are other types of light that our eyes can’t see. The full range of light is called the electromagnetic spectrum. Each research telescope is designed to detect light from a specific part of this spectrum, helping astronomers to understand more about the story of the Universe.

**JWST (James Webb Space Telescope)**
- JWST will be the largest telescope in space. Its mirror will be cooled by a shield that is half the size of a football pitch.
- Location: 1.5 million kilometres from Earth, near the point where the gravity of the Earth and Sun balance each other.
- Launch date: 2021.

**ALMA (Atacama Large Millimetre Array)**
- ALMA is a giant array of 66 antennas controlling or observing at submillimetre wavelengths.
- Location: at 5000 metres in the Atacama Desert, Chile.

**SKA (Square Kilometre Array)**
- SKA will be the world’s largest radio telescope.
- Location: sites in Southern Africa and Australia.
- First light: early designs are being tested, phase 1 fully operational by 2020.

**XMM-Newton**
- XMM-Newton is a multi-spectral, x-ray observatory.
- Location: 7000 to 134,000 kilometres from Earth, in an environment that allows for long observation periods.
- Launch date: 2009.

**Gaia**
- Gaia is a space mission designed to chart in 3D 1 billion stars in our galaxy. Its carried is the largest space telescope ever built and is protected by a sunshield that is half the size of a tennis court.
- Location: 1.5 million kilometres from Earth at L2.
- Launch date: 2013.

**E-ELT (European Extremely Large Telescope)**
- E-ELT is the world’s largest optical and infrared telescope with a 39.3-metre mirror.
- Location: on Cerro Armazones in the Atacama desert, Chile.

**Atmospheric opacity**

<table>
<thead>
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<th>WAVELENGTH</th>
<th>1 km</th>
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<th>10 m</th>
<th>1 m</th>
<th>1 mm</th>
<th>100 μm</th>
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<th>100 nm</th>
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</tbody>
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**APPLICATIONS**

- Microwave ovens
- Mobile phones
- Lasers/Scanners
- Silicon chips
- Medical imaging
- Nuclear power

**TEMPERATURE OF A SURFACE EMITTING AT THAT WAVELENGTH**

- 0.001 K (–273°C)
- 100 K
- 5000 K
- 30,000 K
- 30,000,000 K
WHY DO WE NEED BIG TELESCOPES?

On 26 July 1609, the Englishman Thomas Harriott was the first astronomer to use a telescope to make drawings of the Moon. Four months later, Galileo did the same thing. Their telescopes were a couple of centimetres across in diameter. For more than 400 years, astronomers have been using ever larger telescopes to gather light from fainter and more distant objects in the Universe. The new generation of optical and infrared telescopes are reflecting mirrors many metres across.

Combining the light waves from many detectors massively increases the sharpness of an image. This is why both SKA and the ALMA consist of large arrays of receivers spanning a wide area.

Seeing further into the past

As we look out into the depths of space we are also looking back in time. "Large telescopes can look back to when the first stars and galaxies were forming. They can chart how the Universe evolved, learn more about the pervasive dark matter that holds it together, as well as the mysterious dark energy that is rapidly pushing it apart. For the first time, we will be able to create a comprehensive history of the Cosmos, mapping billions of galaxies in amazing detail," says Victoria Bruck who studies distant galaxies at the Royal Observatory (Edinburgh).

Exoplanets and alien life

The discovery of hundreds of planets around other solar systems is revolutionising our view of our place in the Universe. Data will be able to locate many of the millions of Jupiter-like exoplanets that likely exist in our Galaxy. The E-ELT may study Earth-like planets from the gravitationally-induced wobble of their host stars, and directly images (larger planets). SKA will even be able to analyse their atmospheres and look for the characteristic chemical constituents that indicate the presence of life. We may, for the first time in human history, answer the question: "Are we alone?"

Big and small

Engineers designing large telescopes are faced with both large and small-scale challenges. Large heavy optical mirrors are prevented from "sagging" with a technology called active optics. The E-ELT’s large parabolic mirror will be divided into hexagonal segments whose precise shape is maintained by supporting actuators. The SKA will use hundreds of thousands of radio telescopes, in three unique configurations, which will enable astronomers to monitor the sky in unprecedented detail and survey the entire sky thousands of times faster than any system currently in existence. The SKA will produce 10 times the data traffic of the global internet.

Hot and cold

Telescope engineers handle extreme temperatures. Telescopes must operate on mountaintops and in space where they are subject to high temperature variation. Also, the instruments on some telescopes need to be cooled to ultra-low temperatures so they can detect the faint light -- or "heat" -- from distant objects.

Space telescopes like JWST are subject to the extreme heat of the Sun. The sun-facing side of JWST’s giant sunshade will be heated to 85 °C, but the shield will cool the telescope, allowing it to operate at -231 °C (40 degrees above absolute zero, or 0 Kelvin). The telescope’s mirror is made from beryllium, a metal that contracts less on cooling than typical materials used on ground-based telescopes. "Micro and millimetre detectors are sensitive to heat so require ultra-cold surroundings. ALMA has state-of-the-art superconducting cryogenic receivers that cool its instruments to -263 °C (1K)."

Further information

For more information about the involvement of UK scientists and engineers with big telescopes:
www.esa.int/akb/bigtelescopes
The UK is a member of three international telescope organizations:
■ European Space Agency
www.esa.int
■ European Southern Observatory
www.eso.org
■ Square Kilometre Array
www.skateloscope.org

Astronomical and telescope images
Credit: NASA, ESA and ESO
The ALMA project is funded by the National Institute for Health Research Investments Innovation Programme.

SEEING THE UNIVERSE IN ALL ITS LIGHT

For schools
Schools have access to three mountain-top robotic telescopes that can be used remotely from the classroom:
■ National Schools Observatory www.nsolar.org
■ Faulkes Telescopes Project www.faultes-telescope.com
■ Bradford Telescope www.telescope.org
For other telescope-based resources, skin and support:
■ The "Big Telescopes" Collection of on-line resources on the national STEM e-Book
■ www.nationalstemcentre.org.uk/ebook
■ ESRC UK: the UK Space Education Office www.esro.org.uk
For information on the UK Space Agency: resources for students, teachers and careers in the UK: Space sector: www.bep.uk.com/ukspaceengineering/discover-and-learn

Science & Technology Facilities Council

DAVE MELORIO at the STFC Rutherford Appleton Laboratory was co-author of "JWST's Infirmary", M80