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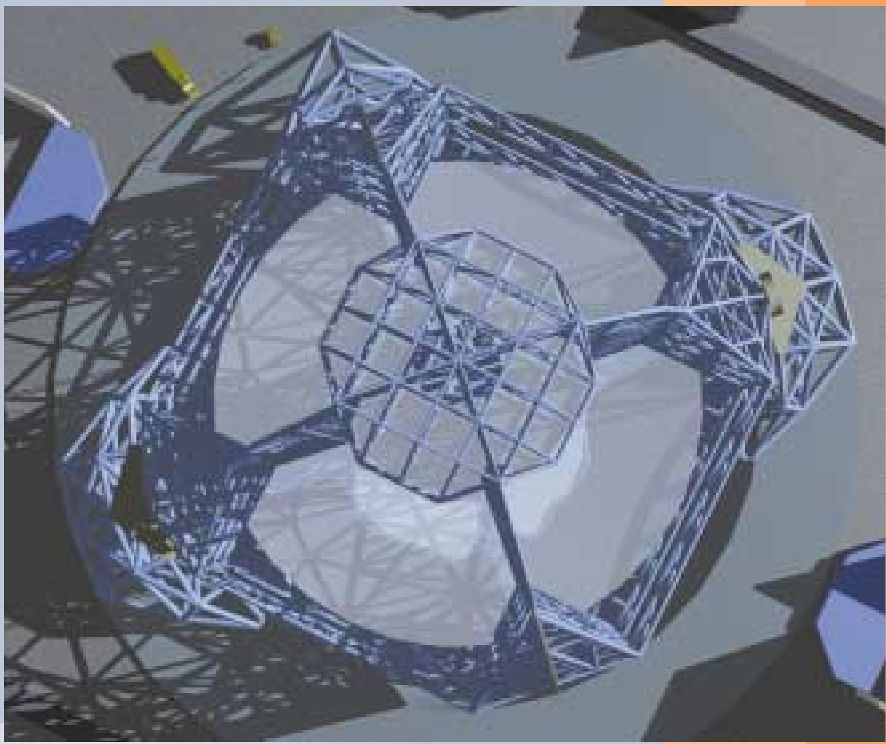
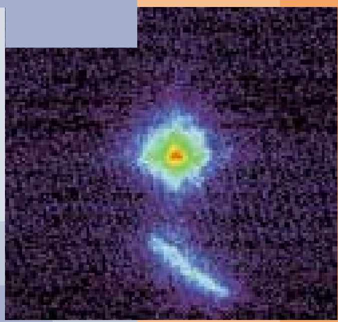


The 100-metre Overwhelmingly Large Telescope (OWL) as seen from above

ESO

Mega-telescopes

The next generation of telescopes with mirrors up to 100 metres across will revolutionise astronomy



An image of asteroid 2002 NY40, taken with the William Herschel Telescope, using the important new technique of adaptive optics

The ING NAOMI team

VISIONS 13
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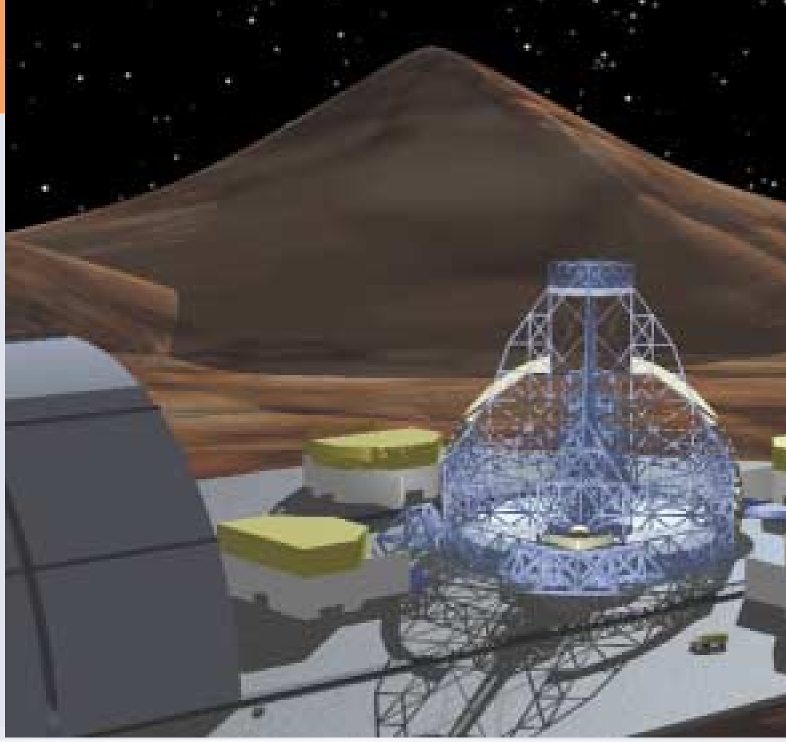


Today, we can peer into the farthest reaches of the Universe, thanks to a range of powerful telescopes which can detect light at various wavelengths. The optical and infrared varieties have huge mirrors up to 10 metres across which can gather and focus the faint smudges of light from very distant galaxies.

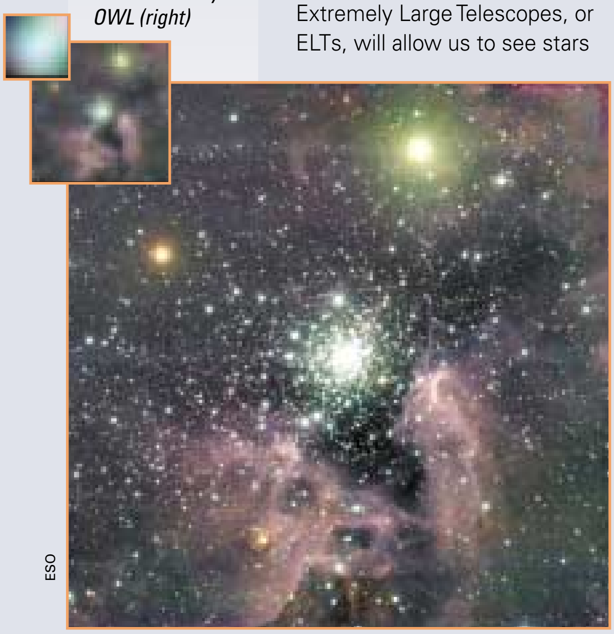
However, ambitious plans are now afoot to build a new

On the shoulders of astronomical

generation of gargantuan telescopes with mirrors up to 100 metres in diameter, dramatically outclassing instruments such as America's 10-metre Keck telescopes (and the 8-metre Gemini telescopes – in which the UK has a share). A 100-metre telescope would have 100 times more light-gathering power, resulting in a leap in performance equivalent to that yielded by Galileo's invention of the telescope 400 years ago. Extremely Large Telescopes, or ELTs, will allow us to see stars in remote galaxies and Earth-like planets in other solar systems.

Several projects around the world are being considered. In the US, for example, 30-metre concepts have been proposed by the National Optical Astronomy Observatory (the Giant Segmented Mirror Telescope, GSMT), and by an academic collaboration in California (CELT). European astronomers are more ambitious: Sweden, Spain, Finland and Ireland are working on a 50-metre design called Euro-50; while the European Southern Observatory, which the UK recently joined, is studying a proposal for the aptly-named 100-metre Overwhelmingly Large Telescope, or OWL.

OWL is a breathtakingly audacious project – and, of course, presents some formidable technical challenges. The telescope might not sit in a traditional dome but be open to the air, perhaps shielded from wind by being recessed into the ground. To keep costs down, a mass-production approach to structural parts and the segments for the giant mirrors will be essential. It isn't possible to build a single primary mirror, effectively the size of a football pitch, so – based on the Keck design – it will be segmented, comprising more than 2000 hexagonal mirrors, 2.3-metres across. Each segment will have a system of sensors and actuators to ensure that the mirror maintains the correct shape. It is likely also that the mirror segments will have spherical surfaces with additional correcting mirrors to give the required focus.



A comparison of the resolution of images taken with current ground-based telescopes (left), the Hubble Space Telescope (centre) and what will be seen by OWL (right)

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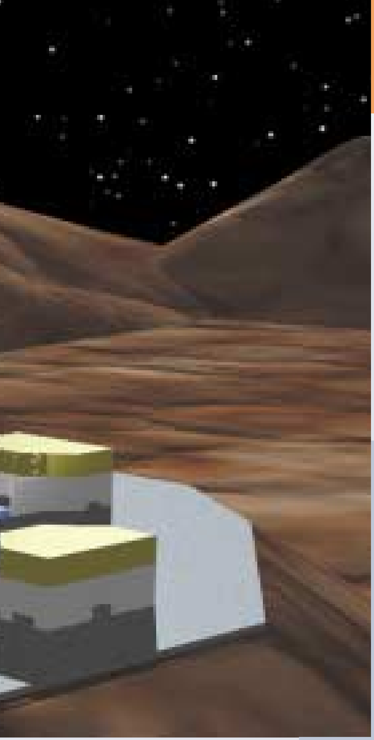
Adaptive optics

Most important of all, however, will be the optimal exploitation of a technology that is already radically improving ground-based observations – adaptive optics (AO). One of the problems with terrestrial telescopes is that atmospheric turbulence causes blurring of an image, which means that the instrument can never pick out the finest detail allowed by the natural limit of the wave-nature of light – the diffraction limit. It is now possible to remove the effects of atmospheric distortions by

Thanks go to John Davies and Tim Hawarden of the UK Astronomy Technology Centre,



The ground-based OWL observatory proposed by ESO

giants

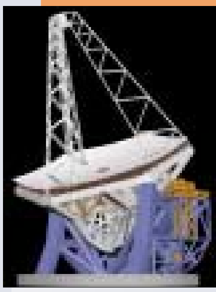
analysing the light from a bright 'reference' star, close in the sky to the target being observed, to give a map of the distortions. This information is rapidly fed in real time to a mechanical system controlling a deformable mirror which then alters shape to compensate for the blurring. Bright enough stars may be too sparse, so laser beams could be used to create a patch of light high in the atmosphere, as an artificial guide star, whose position can be then be controlled. Taking this technology forward is a priority for ELTs. An AO system consisting of several guide stars and mirrors is a likely option for OWL.

Exciting science

What could a 100-metre telescope do? OWL would allow us to observe the Universe in extraordinary detail, throwing new light on many intriguing cosmological and astrophysical problems. For example, astronomers would like to determine precisely the Hubble constant which gives a measure of the rate of expansion of the Universe and sets absolute distances on a cosmic scale. There are several methods of measuring the Hubble constant, but a convenient one is to use a type of star called a Cepheid variable (whose intrinsic luminosity is known) as a 'standard candle'. An ELT would be able to observe these stars in very distant galaxies so that the Hubble constant could be measured accurately right across the cosmos.

Seeing far into space also means looking back in time (because light takes billions of years to reach us from distant parts of the Universe), and ELTs could also probe cosmological evolution by observing in detail the earliest galaxies and stars forming. Nearer home, it would be possible to study the surfaces of stars in the way we observe the Sun. Perhaps the possibility that most stirs the imagination is that an ELT like OWL might find planets just like the Earth orbiting nearby stars, even detecting water and oxygen in their atmospheres – a possible signature of extraterrestrial life.

ESO astronomers estimate that OWL will indeed be good value for money; costing about a billion euros (£600 million), it compares well with £100 million for a typical 8-metre telescope. The UK is now well-positioned to take a role in OWL's development programme via its ESO membership and the EU OPTICON network which sponsors activities in optical and infrared astronomy. A 100-metre telescope will probably take a decade to design and even longer to build but it will be worth waiting for.



Three designs of proposed Extremely Large Telescopes (top to bottom): the 30-metre GSMT, the 30-metre CELT and 50-metre Euro-50

LONGER WAVELENGTHS

Radio astronomers are also designing very large telescopes that operate at millimetre and radio wavelengths. A giant millimetre telescope, funded jointly by the US and Europe, called the Atacama Large Millimetre Array (ALMA), is to be built in the high, dry Chilean desert. It will comprise 64 antennas, each 12 metres in diameter, and will be able to study dust and gas in objects throughout the Universe.

The next-generation radiotelescope will be the Square Kilometre Array (SKA). Like OWL, SKA will cost about a billion euros and will be constructed at about the same time. The two instruments will complement each other, by studying the formation of the earliest galaxies and stars in different wavebands. The instrument, with its one million square metres of collecting area, will be able to use studies of hydrogen, the most common element in the Universe, to probe the era before galaxies formed.

SKA is a global project, and several designs are being considered to solve various technical issues. No choices have yet been made but one possible prototype is the privately-funded American Allen Telescope Array (ATA), which will use 350 antennas, each 6.1 metres across, to study pulsars, transient phenomena and, more speculatively, to search for signs of extraterrestrial life.

One possible configuration of the Square Kilometre Array

AND TO IAN MORISON AND PHILIP DIAMOND OF JODRELL BANK

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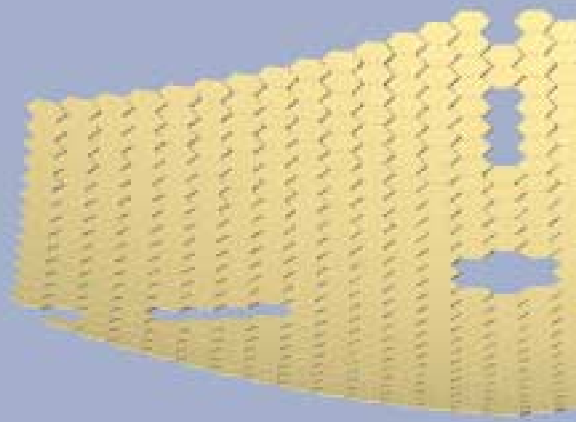

The array of hexagonal mirrors as proposed for Euro-50

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The Institute of Physics is an international learned society and professional body for physicists. The Institute has more than 37,000 individual members.

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More information about large telescopes can be found at the following websites:
OWL: www.eso.org/projects/owl/
Euro 50: http://nastol.astro.lu.se/%7Etorben/50m/50m.html
CELT: http://celt.ucolick.org/
Giant Segmented Mirror Telescope: www.aura-nio.noao.edu/
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