Stuart Clark

Improving the VLT

How do you improve the world's largest telescope? Stuart Clark visited the Very Large Telescope in Chile to find out.

The European Southern Observatory (ESO) continues to grow. The UK joined ESO in 2002. Now Spain has signed on, as well. As the ESO roster enlarges, so too does its ambition. There are now a number of plans for future telescopes and observatories but firstly, the VLT itself is in the process of being enlarged. If successful, the ESO team will be able to simulate a single telescope of over a 100 metres in diameter.

Dug into the mountain underneath the VLT is a labyrinth of tunnels, some 160 metres long. Inside this man-made lair are rail tracks on which seventeen small mirrors slip silently up and down. They are known as the delay lines and they are the key to making the four telescopes of the VLT behave like a single telescope.

The technique is called interferometry and was pioneered at radio wavelengths by the University of Cambridge in the decades following the Second World War. It is now a standard technique used by radio observatories all across the world. Applying the same technique to optical telescopes, however, requires a major technological leap.

Light from all the telescopes must arrive at the focal point simultaneously so that they can blend together precisely. Get the timing right and an unprecedented level of details jumps out of the mingled light beams. Get it wrong and you are left with a blurry mess. "Everything has to be positioned to within one micron," says Olivier Hainaut, an ESO astronomer who is working on the Interferometer.

In radio interferometry, the signals can be digitised and time-stamped, so that the combination is performed by a computer in one big controlled calculation. Light varies so fast, however, that there is no electronic device in existence that can convert it into a digital signal. Hence the need for the mirrors and delay lines to keep the light beams bouncing up and down until they are all synchronized.

"Optical interferometry is an incredibly difficult thing to do," says John Richer, a radio interferometry expert from the University of Cambridge.

The complication is that if the celestial object is anywhere but directly overhead, its light reaches each individual telescope at a slightly different time. So some rays must be bounced back and forth between the delay line mirrors until the signals from the other telescopes catch up. “Even little whirls of turbulence in the tunnel air can affect the accuracy,” says Richer.

To give some indication of the difficulty involved in engineering the delay lines, each rail track must be absolutely flat. The ESO engineers first run water in troughs along the tunnels. This give a reference level but it is not a true one because, in the longest tunnels the curvature of the Earth is noticeable. So, although the water level appears flat, it is actually curved because each end of the tunnels makes a slightly different angle to the centre of the Earth, where the gravitational field of our planet seems to point. “We use the water level as a reference and then build the delay lines from there, correcting for the curvature of the Earth,” says Hainaut.

Unsurprisingly, it is taking time to perfect the VLT interferometer. At present, it can combine the light from three of the four telescopes. The first science results have just been published. They look at the way planet-forming discs around young stars interact with the ‘wind’ of particles being released by the stars. The detail in the images is extraordinary, even using just three telescopes. Yet, for Andreas Kaufer, the director of the Paranal Observatory, there is a lot more work to be done before he is satisfied.

“The VLT must be easy to use. It is no good if it is an instrument that only a few experts know how to make work,” he says. It is his intention that the VLT Interferometer will become just as easy to understand and work with, as the individual telescopes, themselves. That means the pressure is on to make it work, but it is no easy task. The funding for a similar project at the USA’s Keck telescopes in Hawaii has just been stopped, leaving VLT the clear leader in the field. But the technical challenges remain.

Four smaller telescopes, known as auxiliary units, also dot the mountaintop. These can be moved on their own railway tracks to target specific details in the celestial objects that the astronomers want to look at. The light beams from these telescopes will also be integrated in the tunnels below Paranal, with the result that the interferometer will eventually combine the light of eight telescopes.

As impressive as the VLT is, and as tantalising as the surge in its capabilities that interferometry will bring, astronomers and engineers at ESO are already planning the next step. Inevitably, that means a new telescope, even bigger than the VLT. Earlier this decade, ESO conducted a study of OWL, the Overwhelmingly Large Telescope. This would be a telescope of between 50–100 metres in diameter. Its mirror would be made of dozens of segments, all held together by as much metal work as can be found in the Eiffel Tower. The behemoth would sit under the night sky, collecting information from the first stars, galaxies and black holes in the Universe. Perhaps most excitingly, it would also track down Earth-sized planets.

As the timeframe advances, however, practical considerations are coming into play. ESO are understandably proud of the lead that that the VLT gives to European astronomers. It is a lead that they are not going to surrender easily. Building the OWL will take many decades. Within that time, other organisations around the world will build and use 30-metre-class telescopes, robbing ESO of its world leading status. In particular, there are already several American plans for such large telescopes. So, to compete with those particular plans, in the shorter term ESO has modified its ambitions. It now talks in terms of an ELT, or Extremely Large Telescope.

The ELT is, itself, a massive undertaking. It will be somewhere between 30 metres and 60 metres in diameter. The current mirror size that ESO talk about is 42 metres. 42! Are the backroom boys of ESO fans of Douglas Adams? Headlines about searching for the answer to life, the Universe and everything, are simply irresistible. Nevertheless, Kaufer looked bemused by the suggestion, as if this was the first he had heard of the association with The Hitch-Hikers Guide to the Universe. “It is just the diameter that gives you the average area for a mirror between a thirty and a sixty metres in size,” he explained.

Costs are being discussed at the moment but no one expects ESO to have much change out of a billion Euros. This investment would be shared across the twelve member countries. To keep this in perspective that is only the price of about four jumbo jet planes. To really put it in its place, the new National Health Service computer system currently being installed across the UK is costing the taxpayer £20 billion. For that money, the UK alone could put an ELT in every ESO member country and have enough spare cash to run them all for three decades.

As exciting as the ELT is, by reducing the size of the telescope from its original OWL size, the science will be compromised: in particular, the search for Earth-sized planets. Whilst it seems unlikely that ELT will be able to separate such small planets from the glare of its nearby star, Kaufer remains optimistic. “I would not write off any science just yet. The VLT has surprised us with what it can see. I am sure the ELT will, too,” he said.

As this issue of Astronomy Now goes to press, astronomers from across Europe are meeting in Marseilles to discuss plans for ESO’s ELT, which enters its detailed design phase in 2007.

Price of entry

Joining ESO some 40 years after the organisation started in 1962 meant that the UK had to buy itself in. After some heavy negotiating, the price of entry was fixed at 72 million pounds and a subsequent annual subscription of around 16 million pounds. Offering ESO control of VISTA, the UK’s latest telescope, raised part of the joining fee.

The Visible and Infrared Survey Telescope for Astronomy (VISTA) is a state-of-the-art survey telescope and will ensure that Europe leads the world in surveying in the infrared for the near future. Its 4-metre-diameter mirror and gigantic camera will provide highly accurate charts from which the VLT astronomers can chose targets for further study.

VISTA sits on another mountain peak, somewhat offset from Cerro Paranal and about 100 metres lower. The road up to the VLT forks in two, allowing access to VISTA. ESO were originally going to relocate the New Technology Telescope (NTT) from their La Silla observatory, also in Chile and VISTA was going to sit next to the four domes of the VLT. However, the VLT’s Survey Telescope (VST) took that spot and, when ESO decided to leave the NTT where it was, this adjacent peak was sitting empty, ready for VISTA.

The top of the mountain was blasted again and the remains flattened into a platform. Then the construction workers moved in and began building the four-storey VISTA.

VISTA is more than just a feeder telescope for the VLT. Its infrared surveys will allow the evolution of many classes of celestial objects to be followed. It is also expected to discover whole populations of difficult-to-see objects, such as failed stars, called brown dwarfs, or distant dust-enshrouded galaxies.

"The surveys will allow astronomers to look for the celestial equivalent of needles in haystacks," says Jim Emerson of Queen Mary, University of London, and VISTA's principal investigator. By that, he means the celestial oddballs and rare objects that often provide the most insight into the Universe because of the extreme conditions they display.

To conduct its search of the Universe, VISTA will rely on the largest infrared camera ever built. It contains 64 million pixels and is being constructed in Oxfordshire at the Rutherford Appleton Laboratories. It is so big that it will only just fit into the cargo hold of a 747. When the camera arrives in 2007, the telescope must be tilted on its side, so that the camera can be slotted into position and fixed in place.

VISTA will then be controlled from the same room as the VLT. "I think if you asked astronomers in the UK, most will tell you that joining ESO is the best thing to happen in ground-based UK astronomy for the past ten years," says Emerson.

Next month, in the last part of this series, Stuart Clark looks at ESO's greatest ambition yet: an extraordinary radio telescope array that will discover a distant galaxy every three minutes.

The very small telescope

In 2007, the VLT Survey Telescope (VST) comes on line. This will map the sky at visible wavelengths, providing highly accurate pointer maps for the astronomers in charge of the VLT. With a primary mirror of just 2.61 metres, it is jokingly referred to as the Very Small Telescope but the ESO astronomers quickly point out that no one else should do this.

It has recently suffered a severe setback. When the primary mirror arrived in Chile, it was in a thousand pieces. Engineers estimate that it must have been dropped from a height of more than ten metres. What is ironic about the accident is that ESO requires every part of the construction process at Paranal to be earthquake-proof. The

Andean foothills are in a notorious earthquake zone, lying on the so-called Pacific ring of fire. During the installation of one of the VLT primary mirrors, an earthquake wracked the site; not only did the mirror survive undamaged but so did the engineers who were standing under it at the time of the quake.