ASTRONOMY

World's Biggest Telescope Is About to See the Light

CERRO PARANAL, CHILE—Nearly 400 years ago, Galileo Galilei began a revolution in astronomy when he pointed his homebuilt telescope at the night sky and saw planetary satellites and the countless stars of the Milky Way. Within the next few weeks, European astronomers hope to give the revolution Galileo started another big push when they turn a new telescope toward the heavens. By the time it is fully operational in 2001, the Very Large Telescope (VLT) will be the largest in the world. Built by the European Southern Observatory (ESO), the VLT will have 70,000 times the light-gathering power of Galileo's simple instrument and 2000 times the image sharpness. To get the best possible viewing conditions for the $800 million instrument, ESO has sited it far from the shores of Galileo's native Italy: on this 2632-meter peak in the arid Atacama desert of northern Chile.

"We're putting together a science machine that will permit us to look back in the past and study the early universe," says ESO's director-general, Riccardo Giacconi. Using a clutch of new ultrasensitive optical and infrared cameras and spectrometers, researchers plan to use the VLT to probe the riddle of the origin of cosmic structure, to help answer the question of how the first generation of galaxies came into being, and to unveil the true nature of the dark matter permeating the universe.

"The VLT is … a forefront research facility," says Robert Williams, director of the Space Telescope Science Institute in Baltimore. "[It has] greater light-gathering power [than the Hubble Space Telescope], constant accessibility to new instrumentation, and availability of observing time." According to John Bahcall of the Institute for Advanced Study in Princeton, New Jersey: "The VLT will be the premier observing facility in the world for certain types of observations. If the VLT project works as advertised, then leadership in a number of important areas of optical and infrared astronomy may pass from U.S. to European astronomers."

Crystal-clear view. Right now, 300 people are working shifts around the clock on Cerro Paranal to keep construction of the VLT on schedule. As a result, the site is bathed in artificial light during the night, marring its exceptional view of the stars. But briefly, at the beginning of March, the site was blacked out while a new power station was installed. For the first time, astronomers, technicians, and administrators could look up and view the cosmos from what the VLT site selection committee concluded was the best astronomical vantage point in the Southern Hemisphere.

ESO first came to Chile in the 1960s to take advantage of the clear, dry air. Its La Silla observatory, 600 kilometers north of the capital Santiago de Chile, is now home to 14 optical telescopes with diameters ranging up to 3.6 meters, and a 15-meter submillimeter radio telescope. The VLT is by far its most ambitious project so far. The brainchild of former ESO Director-General Lodewijk Woltjer, it consists of four linked scopes each 8.2 meters in diameter, creating the effect of a giant 16.4-meter telescope.

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Taking shape. To the right of the VLT's four main telescopes is the interferometer tunnel and auxiliary scope sites.

When ESO began looking for a site in the late 1980s, Paranal—140 kilometers south of Antofagasta in northern Chile—appeared to be perfect. The mountain has 350 clear nights a year, and rain is extremely rare—in 1997, for instance, there was only half a millimeter of precipitation. The exceptional dryness makes the atmosphere very transparent to infrared wavelengths, which are normally absorbed by water vapor.

The Chilean government donated the mountain and 725 square kilometers of the surrounding land to ESO in 1988, and the way seemed clear for the mammoth project. But after construction of the VLT had begun in the early 1990s, it ran into its biggest obstacle: Descendants of local war hero Admiral Juan La Torre claimed ownership of some of the land and sued ESO to block construction. The legal skirmishing delayed construction of the telescope by almost a year. After ESO's eight member states applied diplomatic pressure, ESO and Chile signed a supplementary treaty confirming ESO's ownership of Paranal, and in return ESO guaranteed better rights for Chilean staff at La Silla and Paranal and more viewing time for Chilean astronomers on its telescopes (*Science*, 28 April 1995, p. 491). Eventually, the Chilean government compensated the La Torre family.

Since the disputes were settled, construction has proceeded smoothly, and in a few weeks' time, the first of the four giant telescopes will receive "first light." Says Paranal site manager Jörg Eschweij, "[It's] comparable to the launching of a ship." Although ESO is planning a big celebration to mark the inauguration of Unit Telescope 1 (UT1), the commissioning team, headed by Jason Spyromilio, will need the better part of a year to fine-tune the telescope to the specific needs of the astronomical community. "The first regular science observations are not foreseen before April 1999," says Spyromilio.

By then, work will have progressed on the other three 8.2-meter telescopes. Right now, Paranal is one big construction site. Unit Telescope 2 is half finished; UT3 is an empty enclosure; and UT4 is still having its outer cladding installed. But in the first year of the new millennium, the VLT will be completed, ready to take astronomers on a 21st century tour of the universe.

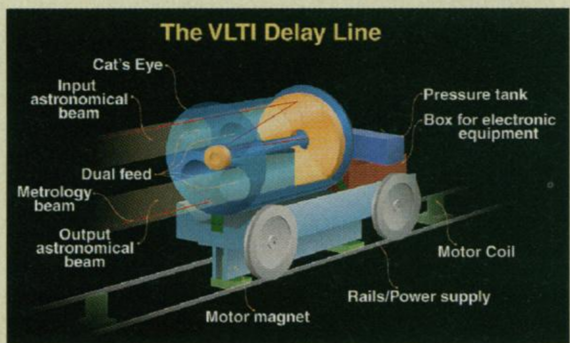
Quadruple vision. It would be impossible with today's technology to cast a single mirror 16.4 meters across, hence the VLT's set of four 8.2-meter scopes. When observing very faint objects, such as dim galaxies at the edge of the observable universe, the four telescopes will work in unison collecting as many photons from a single source as possible. However, in observing programs where sensitivity is less important, the four individual telescopes can home in on different parts of the sky.

The separation between the four scopes has another very important advantage: The instrument can be used as an interferometer (see sidebar). "Interferometry is an essential part of the VLT," says Eschweij. "It's the project's future." Using the VLT in this way will provide the image sharpness of a gigantic 130-meter telescope, enabling astronomers to study the hearts of distant galaxies and planet-forming

How to Turn a Big Scope Into a Virtual Behemoth

With an effective diameter of 16.4 meters, the European Southern Observatory's (ESO's) Very Large Telescope (VLT) will be the biggest in the world. But with a bit of high-precision tinkering, it can provide the angular resolution, or image sharpness, of a telescope almost eight times bigger: a behemoth with a 130-meter-wide mirror. The trick is to treat the VLT's four 8.2-meter mirrors as if they were part of an imaginary mirror as wide as the 130 meters that separates the VLT's two end scopes. "This is a major step in telescope resolution," says Francesco Paresce, ESO's program scientist for the interferometer. "It's as revolutionary as the invention of the telescope" 400 years ago.

If you took a 130-meter telescope and painted most of its parabolic mirror black except for four circular 8.2-meter patches around the perimeter, the instrument would be much less light-sensitive, but it would provide the same image sharpness. The reason: The four clear patches would all still reflect light to a single focus, producing a coherent image of a distant object. The four VLT mirrors can be made to work in much the same way. Some complex corrections will be needed, however, because starlight reflected from each telescope would travel different distances and arrive at the detector out of step, or "phase." To compensate, the light collected and focused by the four telescopes will be combined via complicated sets of mirrors called optical delay lines installed in tunnels underneath the scopes. These correct for the different arrival times of light at the four telescopes, so that the light can be added together in phase and provide astronomers with eagle-eyed vision.



ESO

Error correction. Fast-moving mirrors will adjust path lengths to transform the four scopes into one.

To improve the simulation of a 130-meter mirror even further, ESO is installing three auxiliary telescopes, with 1.8-meter mirrors, at the Paranal site. These can be moved to a number of fixed positions on the mountaintop to provide a large number of extra "baselines" for the interferometer.

The concept may sound simple, but it poses a severe engineering challenge, because the whole optical system must be controlled with a precision better than the wavelength of the observed light. The optical delay lines for the VLT, to be built by Fokker Space in Leiden, the Netherlands, will consist of 55-centimeter mirrors mounted on movable carriages. A laser beam shining along the delay lines will provide information on the changing path length, and linear induction motors will move the carriages along 60-meter rails with a top speed of 50 centimeters per second to compensate for the constantly changing path length differences as objects move across the sky. The system also compensates for very fast and small variations in the path lengths, caused by atmospheric turbulence and seismic noise, using piezoelectric crystals on the back of the moving mirrors. The system is expected to be accurate to 50 nanometers, one-tenth the wavelength of visible light.

ESO hopes to make its first interferometric observations in 2000. Says ESO Director-General Riccardo Giacconi: "It's one of the few [telescope] projects I know of which are on schedule and within budget. It makes you wonder if there's something wrong." –G.S.

circumstellar nebulae in unprecedented detail.

A few small experimental optical interferometers are in development across the globe. But the real rival to the VLT interferometer is the two 10-meter Keck telescopes on Mauna Kea, Hawaii, which will be linked as an interferometer by 2000. However, Keck can only be used by a relatively small community of researchers dominated by the University of California and the California Institute of Technology. "With the VLT, this type of research will now come within reach of the whole research community of the eight ESO member states," says ESO Council member Ed van den Heuvel of the University of Amsterdam in the Netherlands.

The VLT interferometer will also play a key role in the search for planets around other stars. With its exceptional spatial resolution, the VLT interferometer will be able to measure tiny wobbles in a star's motion, revealing the existence of orbiting planets. Michel Mayor of the Geneva Observatory, who discovered the first known planet around another sunlike star, 51 Pegasi B, says the VLT interferometer may even be able to separate out reflected light from the planets themselves. "It looks feasible," he says.

Technology test-bed. One of the main advantages of the VLT over the Keck twin, apart from its 33% larger light-collecting area, is the flexibility of its science instruments, says ESO's Peter Gray, who is responsible for integrating the VLT's scopes. "Each telescope has three fixed foci," he explains, "so eventually, we will have 12 large science instruments up and running." As it is relatively easy to switch from one focus to another, there is no need to exchange the bulky instruments themselves. According to cosmologist George Miley of Leiden University in the Netherlands, the VLT's planned instrumentation program "is more ambitious than any other of the large, ground-based telescopes."

Gray, who has served on many large telescope projects, says the VLT's mirror design is also unique. Despite their 8.2-meter diameter, the meniscus-shaped main mirrors, cast by Schott Glasswerke in Mainz, Germany, are just 18 centimeters thick and weigh only 22 tons each. Each of these thin mirrors is supported by 150 computer-controlled actuators, which keep the curved reflecting surface in the right shape, irrespective of wind buffeting, temperature differences, and gravitational bending. In addition to this "active optics," the VLT will use "adaptive optics" to compensate for the blurring effects of atmospheric turbulence (*Science*, 27 June 1997, p. 1994).

The mirror for UT1 was installed just 2 weeks ago. The other three mirrors are still being polished in the REOSC factory outside Paris before being shipped to Chile. This month should see the first cosmic snapshots taken by UT1. And within a few years, the barren mountaintop, now bustling with building activity, will be a serene and dark temple of science, dedicated to the study of the universe. "I like to compare modern telescopes to the cathedrals of the Middle Ages," says Miley. "The VLT is perhaps the most impressive of these modern cathedrals."

–Govert Schilling

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