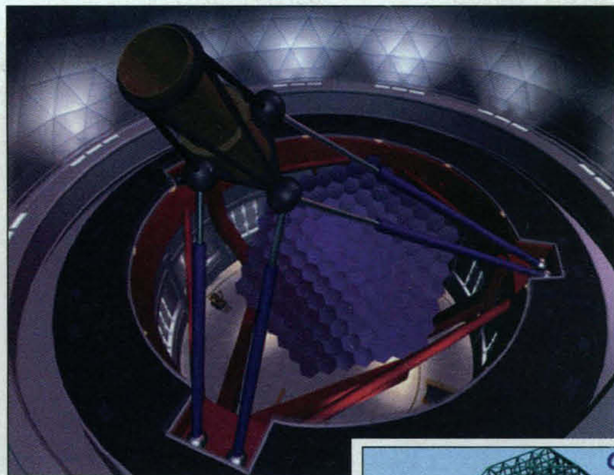
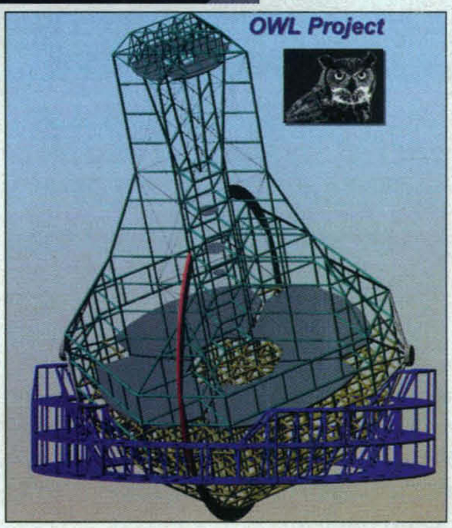
ASTRONOMY

Telescope Builders Think Big—Really Big

They have seen the future, and it is a telescope with a mirror the size of a football field and a structure rising to match the Great Pyramid

BÄCKASKOG, SWEDEN—In the 389 years since Galileo Galilei first turned his 4-centimeter telescope toward the heavens, telescope sizes have grown steadily, culminating in today's 10-meter mammoths. Now some astronomers are talking about climbing off this steady slope and taking an unprecedented leap to telescopes 25, 50, and even 100 meters across. Says Matt Mountain, director of the Gemini Observatory on Mauna Kea, Hawaii, "We are talking about a *very* large step."





Megascopes. NOAO's 30-meter Extremely Large Telescope *(above)* and ESO's 100-meter Overwhelmingly Large Telescope.

CREDITS: (TOP TO BOTTOM) NOAO; ESO

The idea of bypassing the incremental approach and jumping straight to a giant scope got its first airing last summer at a workshop on "maximum-aperture telescopes" in Madison, Wisconsin (*Science*, 4 September 1998, p. 1428), and was renewed here earlier this month. Meeting at the medieval Bäckaskog Castle in southern Sweden for a 2-day workshop organized by Lund University, some 70 astronomers, optical and structural engineers, and observatory directors turned over plenty of ideas about how to build a gargantuan telescope and found no obvious showstoppers. Says Ray Wilson, a retired telescope designer from the European Southern Observatory (ESO), "Let us rejoice if there's technical diversity. All solutions discussed at this conference are valid."

A 100-meter telescope is the stuff of astronomers' dreams. Although an array of more modest instruments that merges its light to form a so-called interferometer, such as ESO's Very Large Telescope at Cerro Paranal, Chile (*Science*, 1 May 1998, p. 671), provides the same ultrasharp vision, a giant mirror would gather much more light. That would let it detect and spectroscopically analyze the light of extremely dim sources. For instance, it would be able to dissect light reflected from nearby extrasolar planets to see if their atmospheres harbor compounds that are the signature of life. And it could inspect extremely distant galaxies, which offer a view of the very early universe, as if they were on Earth's doorstep.

Technology should now make it possible to realize these visions at a less-than-astronomical cost, or so researchers hope. In the past, each doubling of telescopes' aperture has increased the cost sixfold, says ESO's Roberto Gilmozzi. "According to this rule of thumb, a 100-meter telescope would cost at least $20 or $30 billion," he says. He and his ESO colleagues believe they could build one for less than $1 billion—less than twice the total cost of ESO's Very Large Telescope. Even so, "you don't go from paper studies to a 100-meter telescope," says Jerry Nelson, director of the Keck Observatory at Mauna Kea. "We need 25-meter prototypes."

Different visions of the next step toward the 100-meter dream-scope were on view at the Bäckaskog workshop. For example, even though most of the proposals called for segmented mirrors, made of hundreds or even thousands of individual pieces of glass, some telescope designers argued that it would be possible to make a 50-meter mirror out of a single glass slab. Such a monolithic mirror might offer better image quality and would not require such sophisticated supports to keep it optically true.

Casting, polishing, and aluminizing a single slab five times the size of a basketball court could be done at the telescope site, or the mirror could be transported from the factory to the site by airships, says Wilson. "Large monolithic mirrors are something we have to keep in mind," agrees Mary Edwards of glassmaker Corning Inc. of Corning, New York, which produced the 8.3-meter monolithic mirror blank—the largest ever—for the Japanese Subaru telescope, recently completed at Mauna Kea.

Lund astronomers Torben Andersen and Arne Ardeberg, while agreeing that a 50-meter monolithic mirror "is a very attractive possibility, with many advantages," have a different vision for their Extremely Large Telescope. They propose a "mega-Keck solution"—a giant mirror built of segments about the same size as those in the 10-meter Keck Telescope. The 50-meter mirror would consist of 585 hexagonal segments of 63 different types. Together, the 2-meter segments would form a parabolic reflecting surface, focusing star light to a 4-meter secondary mirror some 70 or 80 meters above the primary. The secondary would reflect the light back through a central hole in the main mirror, where it would be analyzed by cameras and spectrographs.

The size and hence the number of the individual segments is not fixed. "We even discussed a design with 104,000 15-centimeter segments," says Andersen. However, getting so many mirrors properly aligned with computerized actuators would be a major problem, he says. But Nelson says the technology for such a task may soon be available: "Smaller segments will make [production] much simpler. I don't know where the limit is. One-centimeter segments could even be flat."

Another way to cut costs is to abandon the usual parabolic mirror, which reflects light to a precise focus, in favor of a spherical mirror, at the cost of some distortion, which would have to be corrected later. The advantage would be that all segments of the mirror would be identical, with exactly the same easy-to-polish curvature. "This is a low-risk option with more bang for the buck," says Thomas Sebring of the National Optical Astronomy Observatories (NOAO) in Tucson, Arizona. Together with astronomers from the University of Texas and Pennsylvania State University, Sebring is proposing a 30-meter telescope based on the design of the Hobby-Eberly Telescope at McDonald Observatory in Fort Davis, Texas.

Besides having a spherical mirror, Sebring's instrument, also called the Extremely Large Telescope, would be built on a rotating platform, aimed at a fixed altitude of 55 degrees above the horizon, making the structure easy and cheap to build. "We're talking about $250 million, which is probably a conservative estimate," Sebring says. The design would limit the amount of sky the scope could survey, however, and to compensate for image distortions created by the spherical primary mirror, it would need at least three additional corrective mirrors, introducing additional light loss. This makes little sense to Nelson. "The purpose of a telescope is to collect light," he says. "If you're throwing away light, you're throwing away money—tens of millions of dollars."

That drawback has not stopped a team at ESO from proposing an instrument with a full 100-meter spherical mirror, a behemoth known as the "Overwhelmingly Large," or OWL, Telescope. With a primary mirror as large as a football field and a telescope structure nearly as high as the Great Pyramid, the OWL is an exercise in superlatives. OWL would have 10 times the light collecting area of all professional telescopes ever built before, says project manager Gilmozzi. And unlike less ambitious giant telescope concepts, OWL would be fully steerable.

ESO recently established a special project office for OWL. Optical engineer Philippe Dierickx says a final choice for the optical design of OWL is expected at the end of this year, but the current design incorporates 2000 identical 2.3-meter mirror segments. A mirror factory would have to produce one segment per day to complete the job in 8 years. Mechanical engineers Enzo Brunetto and Franz Koch have completed detailed designs for the highly modular Eiffel Tower–like telescope structure. "It will consist of 4100 identical pipes and 850 nodes, fitted together like the elements of a construction kit," says Gilmozzi.

OWL would require a hangarlike enclosure, which would slide over the telescope when it is in a horizontal position, and four petallike, air-conditioned mirror covers to keep the reflecting surface cool during the day. The total moving mass is expected to be some 17,000 tons—more than 35 times the moving mass of the 5-meter Hale telescope at Palomar Mountain in California, for example. Gilmozzi hopes to complete a design study in 2002 and build the scope for $900 million. OWL is an ambitious project, but "we're using the technology we have," says Gilmozzi. "The telescope could be fully commissioned some 20 years from now, just around the time of my retirement."

Because of the costs of the monster telescopes discussed at the Bäckaskog workshop, they will certainly require international cooperation. They will also require major advances in the field of adaptive optics, needed to compensate for the blurring effect of Earth's atmosphere. Current adaptive optics systems use small, deformable mirrors in the light path to compensate for atmospheric blur, but unblurring the image in a 50- or 100-meter telescope will be much harder, because the distortion could vary across the width of the mirror. "We need to reconstruct a three-dimensional view of atmospheric disturbances," explains adaptive optics specialist Roberto Ragazzoni of Padua University in Italy. Despite these challenges, even cautious people like Nelson say there are no serious limits on the size of ground-based telescopes. "These things don't violate the laws of physics."

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Lofty Observatory Gets Boost

The United States and Europe have breathed life into plans to build a giant new astronomical observatory in Chile that could be fully operational in 2009. Last week, science officials from both continents signed an agreement in Washington, D.C., laying out a 3-year plan for the design and development of the Atacama Large Millimeter Array (ALMA).

Located 5000 meters above sea level on the Chajnantor plain in the Chilean Andes, ALMA (Spanish for "soul") will be Earth's highest continuously operated observatory. It will consist of 64 12-meter dishes, observing the universe at millimeter and submillimeter wavelengths. This relatively unexplored part of the electromagnetic spectrum, between infrared and radio waves, opens a window into some of the coolest and dustiest objects in the universe, such as the clouds of dust and gas that form planetary systems, as well as into the farthest reaches of space and time. ALMA will have a collecting area of some 7000 square meters, larger than a football field and far surpassing any existing millimeter-wave telescope. And its high, dry location is largely free of atmospheric water vapor, which absorbs millimeter waves (*Science*, 19 March, p. 1836).

ALMA's eyes. An artist's conception shows some of the 64 dishes that will make up the planned millimeter array.

CREDIT: ESO

"It will take us back to the era where we see galaxies form," says Bob Dickman, coordinator of the Radio Astronomy Unit at the U.S. National Science Foundation (NSF). "No matter how distant the first galaxies are, ALMA will detect them," adds Ewine van Dishoeck of Leiden University in the Netherlands. By combining signals from multiple dishes—a technique called interferometry—the array will create images of these distant objects as sharp as a single imaginary dish spanning the 10-kilometer width of the array. Interferometry is a household word in radio astronomy, but it requires great finesse at the shorter millimeter and submillimeter wavelengths that ALMA will observe.

Major partners in the agreement are the U.S. National Radio Astronomy Observatory and the European Southern Observatory, an intergovernmental organization with eight member states. Research institutes in France, Germany, the Netherlands, and the United Kingdom will also take part, while Japan is expected to join later. Europe will chip in $16 million and the United States $26 million for the first phase of design and development; in 2001 the partners will make a final decision about whether to proceed. The observatory's total cost is expected to exceed $400 million.

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