Reflecting the Infinite: Tucson’s Giant Mirrors

Human beings have worshipped, marveled at, charted, followed and passed down stories about the stars for as long as we have been able to see and speak. Records of astronomical phenomena found in Mesopotamia date to as early as 2500 BCE—almost as far back as the earliest evidence of written language—leaving no mystery as to why astronomy is often called the first science.
Although rapid technological advancement over the course of the last century has catapulted observational capabilities forward, it has become clear that our understanding of the universe is still in its infancy. It was not until 1924, when Edwin Hubble discovered the first galaxies outside our own, that we began to comprehend the incredible vastness of space. His observations of these galaxies led to the formulation of Hubble's Law in 1929, which proved that the universe was expanding, and this, in turn, gave way to the Big Bang theory.

Hubble’s discoveries were earth-shattering, and in classic scientific tradition they left astronomers with the impression that there was a lot more out there that had yet to be discovered. And they were right.

The quest to build the enormous telescopes necessary to make those discoveries, however, presented challenges. Glass mirrors, for instance, are incredibly heavy and cumbersome to move. Solid pieces of glass also take a long time to adjust to ambient temperature changes, thus making large solid mirrors difficult or impossible to calibrate under certain environmental conditions.

In the 1980s, many experts believed that taking mirrors beyond the limits reached by the 200-inch (5.1m) Hale Telescope at Palomar Observatory in California would be impossible without piecing the mirror from much smaller segments. This solution, however, presented its own set of problems—the more mirrors you have, for instance, the more difficult it is to keep them all in alignment, or “co-phased,” to use the industry term.

The spaces between the mirror segments also present gaps in light collection area, which can translate to a loss in valuable data to scientists who are looking to collect photons of the faintest traces of light in the universe. Roger Angel, who founded the Steward Observatory Mirror Lab (SOML) at the University of Arizona in 1984, was not deterred. He began experimenting with honeycomb structures by fusing two hexagonal pieces of Pyrex cookware in a kiln at his home. Today his mirror lab produces the most sophisticated optical imaging devices in the world in a state-of-the-art facility tucked beneath Arizona Stadium.

Dae Wook Kim, assistant research professor of Optical Sciences, specializes in the fabrication of large optics. He smiles with his entire face, and though he’s 34 years old, looks all of 19—like a kid who never outgrew his love of space.

During a tour of the lab, Kim said that the mirrors now in production “represent a completely new category [of telescope]—something that has never existed before.”

He explained that in telescope design, astronomers are looking for two things: light from farther, fainter stars and better resolution. Both of these goals are best accomplished through the use of larger telescopes, which necessitate large mirrors.

And no one makes larger mirrors than SOML. The two 8.4-meter behemoths currently under production will be the largest mirrors ever made and, appropriately, they each will become integral installments in two of...
One of the LBT mirrors removed after cooling displays a number of load spreaders that will later attach to actuators that allow for the movement of the 8.4m mirror.

The Large Synoptic Survey Telescope (LSST), also under production at SOML for a Chilean observatory, will have an unprecedented field of view and function almost like a cosmic movie camera. Using the largest digital camera ever made (3,200 megapixels, compared to the 8 megapixels in an iPhone), the LSST will be able to survey the entire sky in just a few nights—a process that once took months or years—and then repeat the process, measuring constantly for minute changes. In this way, LSST will be able to detect objects like potentially dangerous asteroids, supernovae, and even evidence of dark matter and dark energy.

According to Zabludoff, “there’s a very nice synergy between what the LSST and the GMT would provide” for projects like hers that are looking for faint traces of light marking the beginning of time, or even in the search for distant earth-like planets.

Kim says that sheer ingenuity is what keeps SOML ahead of its competitors. SOML was the first to use water-soluble alumina-silica molds to obtain the hollow, honeycomb structure of its mirrors, not only making them substantially lighter, but also significantly reducing the amount of time necessary to allow the finished mirrors to reach thermal equilibrium.

SOML also pioneered a method of “spin casting” in which the kiln used to heat the 18 tons of glass for each mirror to a molten 2,130 degrees Fahrenheit rotates constantly throughout the several-month-long casting and cooling process. This gives the mirror a parabolic shape, which cuts polishing time by several months and saves hundreds of thousands of dollars in glass raw material that otherwise would be wasted.

Another feature of SOML that distinguishes it from competing labs is its polishing process. Other scientists and engineers have tried to duplicate the one-of-a-kind, 1.2-meter “stressed lap,” says Kim, though none have succeeded. The tool consists of a 2-inch thick aluminum plate, the surface of which is manipulated by computer to within an accuracy of a few microns (millionths of a meter). The smaller Rigid Conformal (RC) Lap is also exclusive to SOML and its patented use of a non-Newtonian fluid (known to laypersons as Silly Putty) as its not-so-secret ingredient.

The constant application of one of these two unique tools intermittently over the course of several hundred hours produces a smooth glass lens that is precisely the shape of a specified parabola to within about 20 nanometers (billionths of a meter) of accuracy—or about 1/4000 the width of a human hair—over its entire 28-foot-diameter surface. The reflective property of the mirror comes from a thin film of aluminum that is applied at the mirror’s final installation site.

Though one might expect this space-age workshop to be hermetically sealed-off from outside influence, it is, in fact, open to the public. Anyone in the Tucson area can arrange to see this local marvel of modern engineering, under the tutelage of a qualified and knowledgeable tour guide—visitors need only contact SOML for a reservation.

The British Broadcasting Corporation (BBC) once asked Edwin Hubble if he and other researchers hoped to find with the then newly installed Hale Telescope. His response: “We hope to find something we hadn’t expected.”

Enthusiasm permeates the atmosphere at SOML. It is the thrill of what lies on the horizon which keeps its $20 million mirrors in demand, and that is precisely what visitors to the lab can expect to find there for themselves.

Craig Baker is a local freelance writer. Comments for publication should be addressed to letters@desertleaf.com.

SOML Tours
Public tours of SOML (http://mirrorlab.as.arizona.edu) are available Monday through Friday. Adults $15; students 7-22 $8; children under 7 are not permitted on the tour. Advance reservations are required. Call (520) 626-8792 or email somltours@gmail.com for more information.

The Large Synoptic Survey Telescope, active since 1999, boasts two 8.4m mirrors spun-cast at SOML.

The edge of one of one of the 8.4m mirrors, like this one intended for use in the GMT, is about 1 m thick, making the mirror relatively about as thick as a dime.