

# First Lights

*"Where was the  
gambler that  
would stake so  
much . . . on a  
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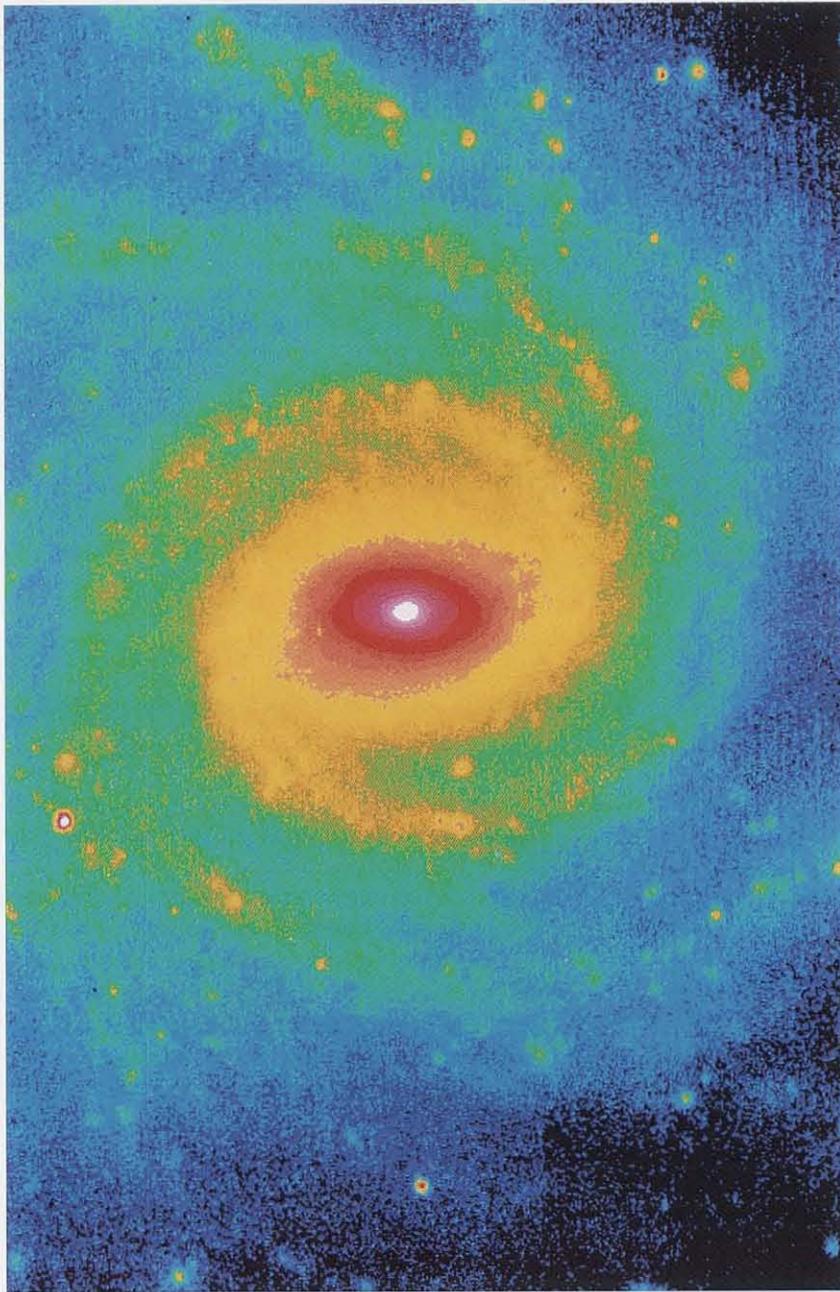
Their hundred inch reflector, the clear  
pool,  
The polished flawless pool that it must be  
To hold the perfect image of a star.  
And, even now, some secret flaw—none  
knew  
Until to-morrow's test—might waste it all.  
Where was the gambler that would stake  
so much,—  
Time, patience, treasure, on a single throw?  
The cost of it,—they'd not find that again,  
Either in gold or life-stuff! All their youth  
Was fuel to the flame of this one work.  
Once in a lifetime to the man of science,  
Despite what fools believe his ice-cooled  
blood,  
There comes this drama.  
If he fails, he fails  
Utterly.

So English poet Alfred Noyes, in his epic poem *Watchers of the Sky*, versified George Ellery Hale's invitation to attend "first light" at the 100-inch Hooker Telescope on Mount Wilson in 1917. What poet could resist such an opportunity? First light—the moment when starlight first falls upon a telescope's mirror—was a more clearly defined event in those days, and it was a simple task to bring a poet along to capture the emotion of the moment. But, while the first reflection of starlight might appeal to poets, it's not necessarily very interesting to scientists today. With the complex technology of current instruments like the 10-meter Keck Telescope, "first light" is no longer simply a matter of opening up the dome and taking a peek. "First light really is the first time the telescope works as a system,"

says Edward Stone, Caltech professor of physics and chairman of the board of the California Association for Research in Astronomy (CARA). "It tells you that you have a concept that works." "It's the first time you can see astronomical objects well enough to know you can do research," says physicist Terry Mast (BS '64), one of two scientist members of the Keck project.

Even when scientists can define the scheduling of first light, it's still a big gamble on a single throw—especially when it involves a revolutionary design and costs \$94.2 million. The Keck Telescope, when completed at the end of this year on Mauna Kea in Hawaii, will be the largest in the world. Its 10-meter (33-foot) segmented mirror consists of 36 hexagonal mirrors, each about 6 feet wide, 3 inches thick, and weighing 880 pounds, packed closely together in a honeycomb arrangement. Because the mirrors have slightly different curvatures dictated by their respective places in the total hyperboloid, an innovative procedure called stressed mirror polishing (which involves forcibly distorting the mirrors, polishing them, and then allowing them to relax into the desired aspherical shape) had to be developed. Cradled in position by devices that minimize mechanical stresses, the mirrors have their alignment controlled electronically to an accuracy of a millionth of an inch to act in concert as a single optical surface. Exquisitely delicate sensors and actuators on the back of the mirrors perform this alignment twice a second. Jerry Nelson (BS '65), professor of astronomy at UC Berkeley and the Keck's project scientist, had been developing the innovative design for

**With 9 hexagonal segments in place out of an eventual total of 36, the 10-meter mirror of the Keck Telescope demonstrated that its revolutionary concept would work.**



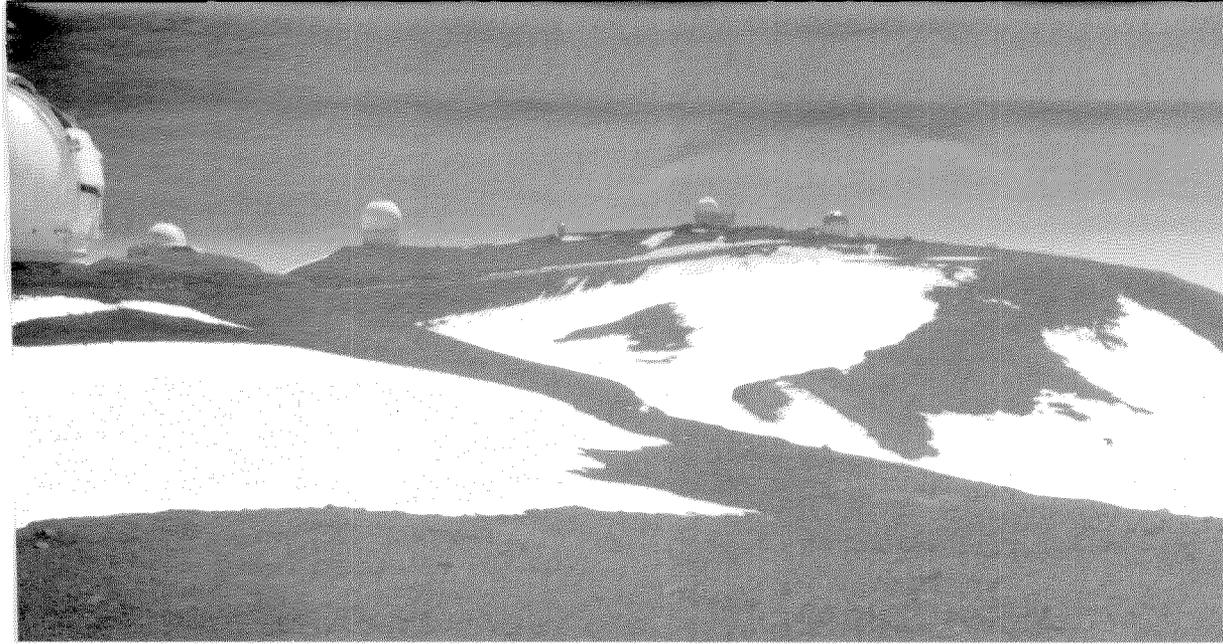
**For its first celestial photograph, taken with a CCD engineering camera at the prime focus, the Keck Telescope was trained on NGC 1232, a spiral galaxy 65 million light years away. This is a color-enhanced mosaic of four successive exposures. Blue represents the faintest regions, while white indicates the galaxy's brightest area. Bright spots in the spiral arms are compact star-forming regions.**



eight years before a \$70 million gift to Caltech from the W. M. Keck Foundation made its construction possible. Much doubt and criticism has been expressed along the way. "The exciting thing about building this telescope," says Mast, who has been with the project since its beginning, "is that you're not sure the parts will all play together, even though you've tested them individually."

They found out on the night of November 24, 1990. With a telescope that "grows" mirror by mirror, it's difficult to say exactly at what point it should be considered ready for first light. How many mirrors were enough to demonstrate that the whole system worked? Whatever the decision, there would be a "moment of truth" when it would be clear whether it was successful. CARA decided to regard the first astronomical image with the 9-segment array of mirrors as first light. This was one quarter of the instrument's eventual size and equal in light-gathering power to Caltech's 200-inch Hale Telescope on Palomar Mountain, providing a valid comparison for determining the success of the new technology—the optics, the polishing procedure, and the control system.

On the night when all this technology came together the Keck scientists picked one of a list of photogenic (rather than scientific) objects to look at. NGC 1232 (also known as Arp 41), a spiral galaxy 65 million light years away, was located in a region of the sky within the telescope's range (the drive and control system for pointing the telescope was not yet fully operational), and it would do just fine for revealing



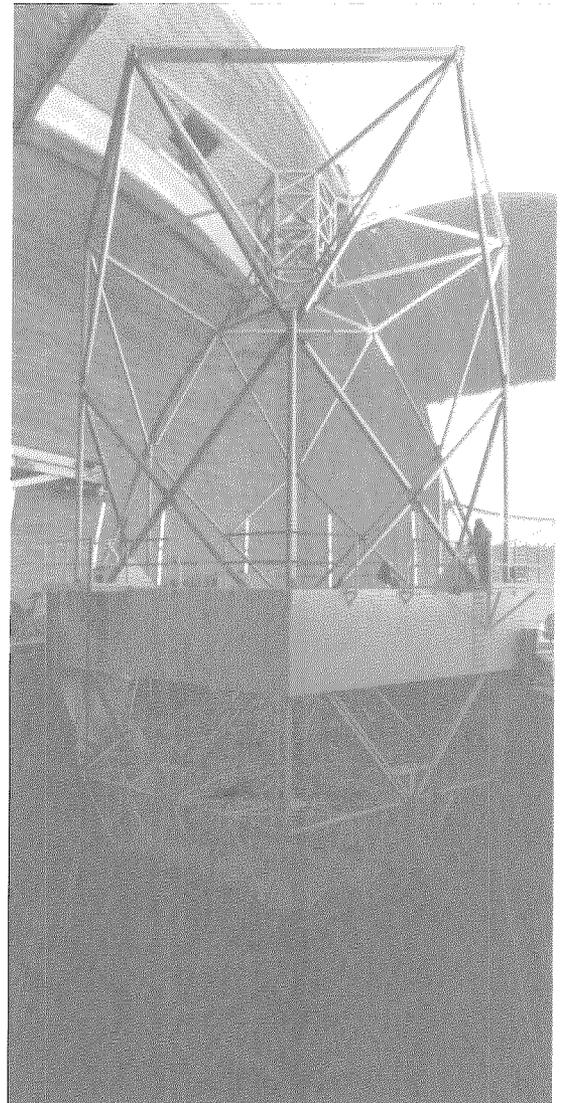
**The W. M. Keck Observatory (left) sits with a group of international companions atop Mauna Kea, an extinct Hawaiian volcano, where the astronomical "seeing" is ideal.**

**Below: The telescope's structure, still lacking mirror segments (the mirror's skeleton is at bottom), is positioned inside the dome. Below left: A mirror segment is hoisted into place.**

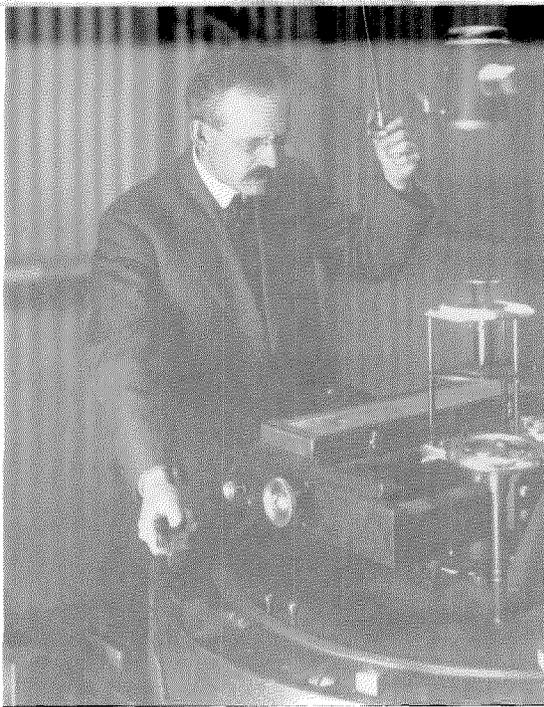
the mirror's optical qualities. Nelson describes the evening as frustrating, as the group struggled with bad weather and failing computers. But when the galaxy's image from the engineering camera emerged on the monitor, "we were elated," says Nelson. "We were all hopping up and down." Already the picture is comparable to the best images from Palomar, according to Stone. And telescope performance can only get better when the telescope is tuned up and equipped with scientific cameras.

Had no one sneaked a peek before November 24? Mast admits that the real moment of truth had come when 5 mirrors were in place. "We knew with 5 segments that it was going to work." But tests with the 5 allowed the scientists to solve a number of problems which then enabled the 9-mirror configuration to demonstrate conclusively that the system worked. The high-quality image was proof. "We're convinced that if it works with 9 mirrors, it will work with all 36," said Project Manager Jerry Smith. It was a milestone, according to Nelson (even if not absolutely the first milestone)—and one obviously worth hopping up and down about.

For the Keck's predecessors in the role of world's largest telescope the milestones were not very precisely placed either. George Ellery Hale first aimed Mount Wilson's 100-inch Hooker Telescope at Jupiter in 1917. In 1903 Hale had decided on Mount Wilson as the site of his new solar observatory, and when the Carnegie Institution of Washington provided support for his 60-inch telescope, he built that on the mountain above Pasadena also. Convinced that bigger and



**Right: George Ellery Hale uses his spectroheliograph in the Hale Solar Laboratory. Below: The 100-inch and 60-inch telescopes nestle side by side on Mount Wilson.**



bigger telescopes would open undreamed-of vistas to astronomers, Hale persuaded local hardware magnate John D. Hooker to donate \$45,000 for a 100-inch mirror in 1906. Carnegie again chipped in the rest. A decade of difficulties, not the least of them World War I, retarded construction. (Hale was also busy creating Caltech and luring its other two founders to Pasadena—Arthur Amos Noyes first came in 1913 and Robert Andrews Millikan in 1916.

All was ready on the night of November 2, 1917. W. P. Hoge, night assistant on the 60-inch, provided a prosaic description in the telescope's observing logbook (now part of the Mount Wilson Observatory collection in the Huntington Library) for that night: "The 100 inch telescope was pointed to the sky for the first time on this night—Visual observations were made of a star image, Jupiter, moon and Saturn . . ." Hoge records as present on the occasion (besides Hale) Walter S. Adams, the assistant director; Francis Pease, who designed the telescope; and an assortment of astronomers, designers, instrument makers, machinists, electricians, and carpenters. "Alfred Noyes celebrated English poet was the only visitor on this occasion."

Noyes was inspired by the event to compose his 281-page poem on the history of astronomy, *Watchers of the Sky*, which supplied the drama that the scientists had eschewed. In supplying perhaps a bit too much drama, he appears to have missed the big scene. The poem's prologue describes Noyes's "unforgettable experience" on Mount Wilson:

Then, into the glimmering dome, with bated breath,  
We entered, and, above us, in the gloom  
Saw that majestic weapon of the light  
Uptowering like the shaft of some huge gun  
Through one arched rift of sky.

.....  
The switchboard shone  
With elfin lamps of white and red, and  
keys  
Whence, at a finger's touch, that monstrous  
tube  
Moved like a creature dowered with life  
and will,  
To peer from deep to deep.

Below it pulsed  
The clock-machine that slowly, throbb'd  
throbb'd,  
*Timed to the pace of the revolving earth,*  
Drove the titanic muzzle on and on,  
Fixed to the chosen star that else would  
glide  
Out of its field of vision.

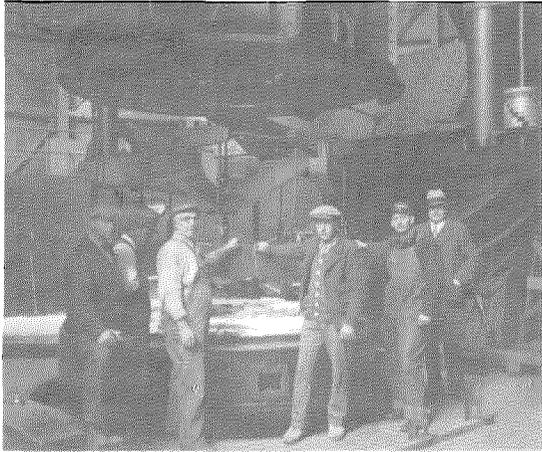
Noyes goes on to describe in elaborate detail seeing a moon of Jupiter. The sight was

. . . clearer far  
Than mortal eyes had seen before from  
earth,  
O, beautiful and clear beyond all dreams . . .

Perhaps tears of emotion blurred Noyes's vision at the proper moment, for Walter Adams, who became Mount Wilson's director on Hale's retirement from that position in 1923, told quite a different story (*Publications of the Astronomical*

**Right: The 100-inch mirror is removed for resilvering in 1931. Francis Pease, who designed this mirror as well as the 200-inch, stands at far right.**

**Below: English mathematician and physicist Sir James Jeans (left), who was a research associate at the Mount Wilson Observatory for 20 years, and Walter Adams, who succeeded Hale as observatory director in 1923, perch on the structure of the Hooker Telescope.**



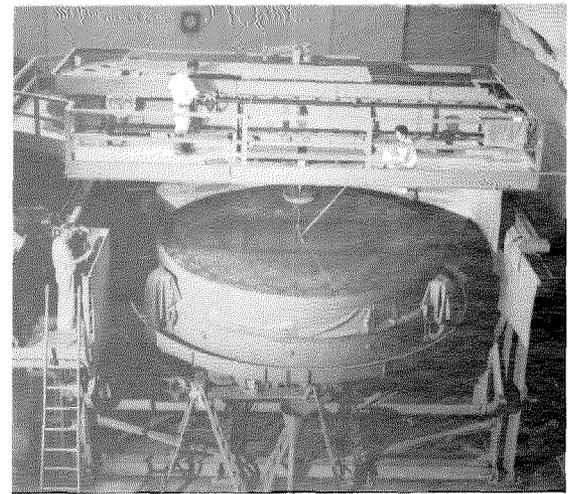
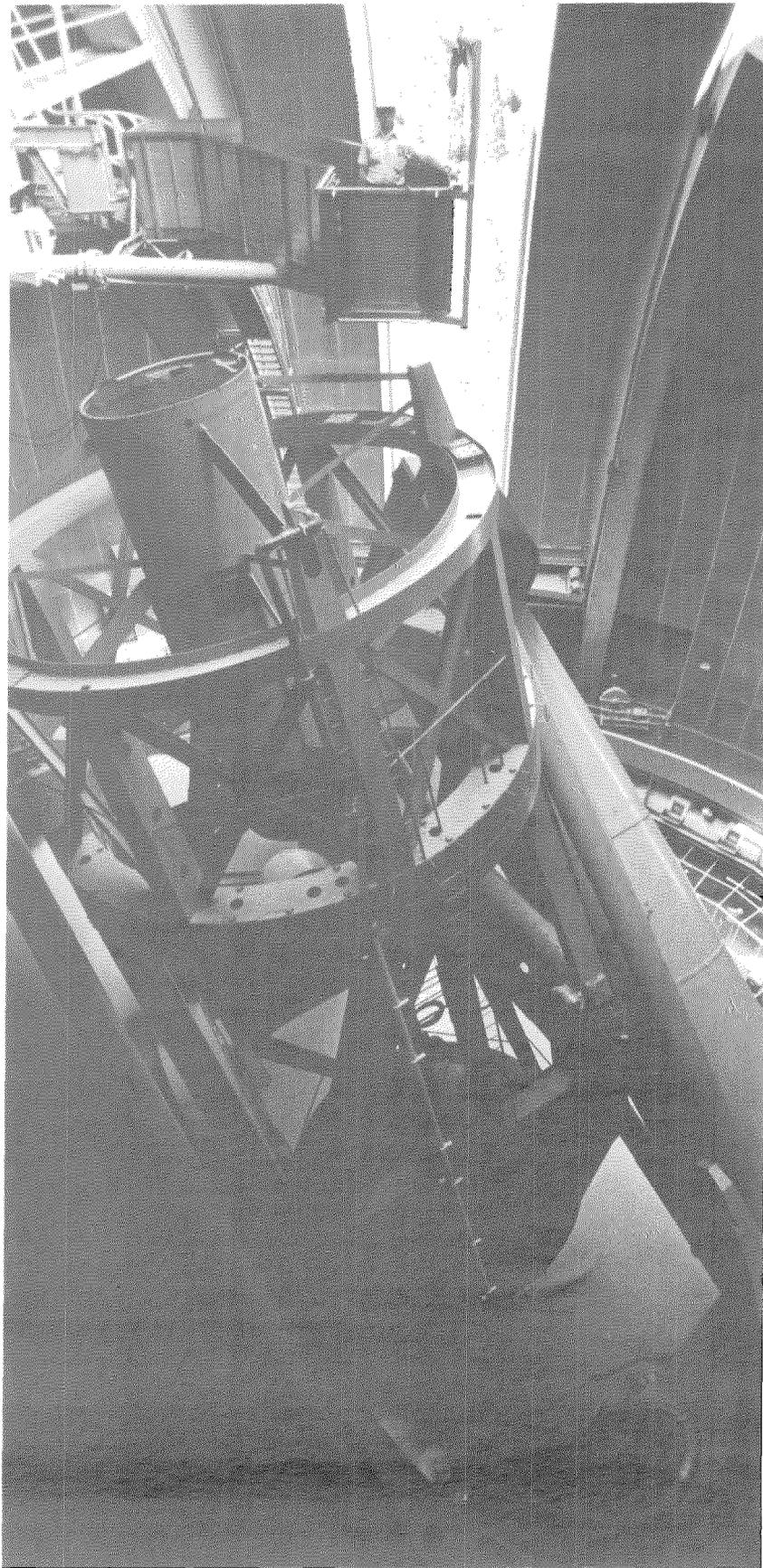
*Society of the Pacific*, vol. 59, 1947): "Soon after dark the telescope was swung over to the eastward and set on the planet Jupiter, and we had our first look through the great instrument. The sight appalled us, for instead of a single image we had six or seven partially overlapping images irregularly spaced and filling much of the eyepiece. It appeared as if the surface of the mirror had been distorted into a number of facets, each of which was contributing its own image."

Guessing that the sun shining on the mirror or its cover through the open dome may have distorted its surface, Hale and Adams met again at 3:00 a.m. According to Adams, they trained the telescope on the star Vega. "With his first glimpse Hale's depression vanished: the mirror had resumed its normal figure during the long cool hours of the night, and the image of the star stood out in the eyepiece as a small sharp point of light, almost dazzling in its brilliancy." Whew! Helen Wright's 1966 biography of Hale, *Explorer of the Universe*, repeats this account, quoting Adams.

Adams's own memory may have been somewhat distorted by the 30 years between the happening and the telling. Bob Eklund, a volunteer with the Mount Wilson Institute, the observatory's current operator, remembers a recent discussion among a group of amateur astronomers about Vega's position on that night. Eklund, who knew that Vega was overhead in July, took his "handy-dandy little star finder" and figured out that Hale and Adams couldn't possibly have seen Vega, which at 3:00 a.m. on November 3 was below the horizon. Ron Brashear, assistant curator of science at the Huntington Library, confirmed this with a calculator program. Hale himself mentioned neither Vega nor the distortion problems. His diary (quoted in Wright's biography) notes for the evening of Friday, November 2: "With Alfred Noyes to Mountain. First observations with 100"—Jupiter, Moon, Saturn."

Hale was not long satisfied with the 100-inch telescope's limited reach into the heavens, and by 1923 (in an article in *Popular Astronomy*) was already advocating bigger mirrors. Although Pease, designer of the Hooker, was pushing for 300 inches, Hale settled for a more easily funded 200-inch mirror and in 1928 persuaded the Rockefeller Foundation to provide \$6 million to build it under the joint administration of Caltech and the Carnegie Institution of Washington. Hale died in 1938 before its completion, which war had again delayed.

In December 1947 the first stars were seen reflected in the mirror of the newly christened



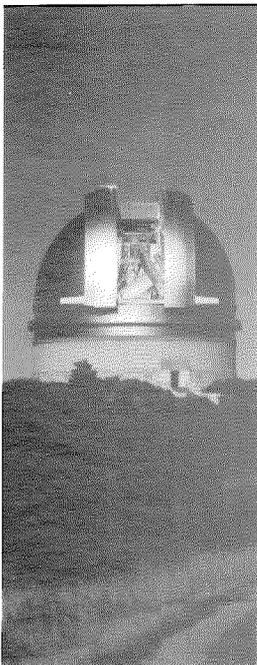
Hale Telescope on Palomar Mountain. John A. Anderson, executive officer of Caltech's Observatory Council and under whose direction the mirror was ground, polished, and figured, was the first to look. According to the June 1948 issue of *Engineering and Science Monthly*, "There was nothing spectacular about the 'first look.' Dr. Anderson used a small reading glass for an eye piece and peered into the big mirror. Asked what he saw, his noncommittal answer was, 'Oh, some stars.'" (This anecdote is also recounted in the forthcoming history of Caltech, *Millikan's School*, by Archivist Judith Goodstein.)

According to Brashear at the Huntington Library, the telescope's designers and builders had been concerned before the first look that the big mirror turned up a bit too much at its edges, but had decided to wait to see how it performed with the mirror support system. Unfortunately, the telescope mount sagged under the 14.5-ton mirror so that, even though Anderson could see some stars in it, the mirror couldn't be tested. A new support system was finally installed in October of 1948, and only then was it discovered that the mirror's figure (its light-focusing shape) was indeed slightly off. But because Ira Bowen, director of the Palomar and Mount Wilson Observatories, was under some pressure to show off the world's largest telescope, says Brashear, what could be called "second light" took place in January 1949. The May 1949 *E&S* reported: "Quietly and without fanfare, on the night of January 26th, 1949, at 10:06 p.m. P.S.T., Dr. Edwin Hubble pulled the slide of the plate holder starting the exposure on plate

**Far left: The prime focus cage at the top of the Hale Telescope's tube is 55 feet above the mirror. Left: Before installation the 200-inch mirror is given its final polishing in Caltech's optical shop. The mirror occupied the optical shop from 1936 till 1947.**

**Below: The Hale Telescope's shutters open on a moonlit night on Palomar Mountain in 1950.**

**Right: One of the first pictures to be taken with the 200-inch graces a 1949 E&S cover. Another pretty spiral galaxy, this one is called Messier 81 and is 3 million light years away.**



number P.H.-1. The P stands for Palomar, the H for Hale, and the 1 means that this was the first astronomical photograph taken on the first observing schedule of the 200-inch Hale telescope at Palomar Mountain." (Actually, Bowen had taken test photographs a year earlier, already logged in as P.H.-1 through P.H.-5, which Brashear unearthed recently at Carnegie's Santa Barbara Street headquarters.)

No wonder the ceremony took place "quietly and without fanfare." At about the same time that *E&S* was exhibiting the Hale's first pictures, the mirror was removed to be refigured. This was completed by September 1949, says Brashear. It was realuminized in October, and finally in November 1949, nearly two years after first light, the 200-inch began normal operation. Bowen was lucky his telescope was on the ground and not in orbit 381 miles above the earth.

Its difficult birth did not affect the Hale Telescope's ultimate success, and for decades the 5-meter instrument reigned as the largest effective optical telescope in the world. By extending man's view of galaxies as far as 8 billion light years—or, in terms of time, halfway back to the beginning of the universe—it has been the site of most of this century's discoveries in astronomy and cosmology. Of course, astronomers want to look still farther, but a bigger (and consequently heavier) mirror would be impossible to manufacture and support. Looking farther back in time would require a new telescope technology—and money. The contributions of Rockefeller, Carnegie, and Hoker seem almost paltry



compared to the cost of a giant telescope today. (And the 60-inch mirror for Hale's early venture on Mount Wilson was donated by his father.)

Technology and funding came together in January 1985 with the announcement of the W. M. Keck Observatory. A mutually advantageous alliance was forged between the University of California, which had been working on the segmented design of a 10-meter telescope since 1977, and Caltech, which was the recipient of a \$70 million gift from the W. M. Keck Foundation, the largest private gift ever made to a single scientific enterprise. The two institutions work together under CARA, directed by Ed Stone (now also the new director of the Jet Propulsion Laboratory). UC will supply the operating expenses and funds for the initial complement of scientific instruments, and observing time will be shared (also with the University of Hawaii, which provided the site). When the telescope begins operating in another year, astronomers expect to be able to see galaxies as they were 12 billion years ago—only 3 billion years or so short of the Big Bang.

But, like Hale, today's astronomers are already looking ahead to seeing still farther. The Keck Telescope's successful first light brings closer the possibility of building a twin 10-meter telescope on Mauna Kea. The two would act as an interferometer, in effect forming a mirror as large as the distance between them. With the staggering potential of seeing galaxies only 1 to 2 billion years after the Big Bang (and quasars even earlier), one can only hope that a good poet will be lined up for the occasion. □—JD