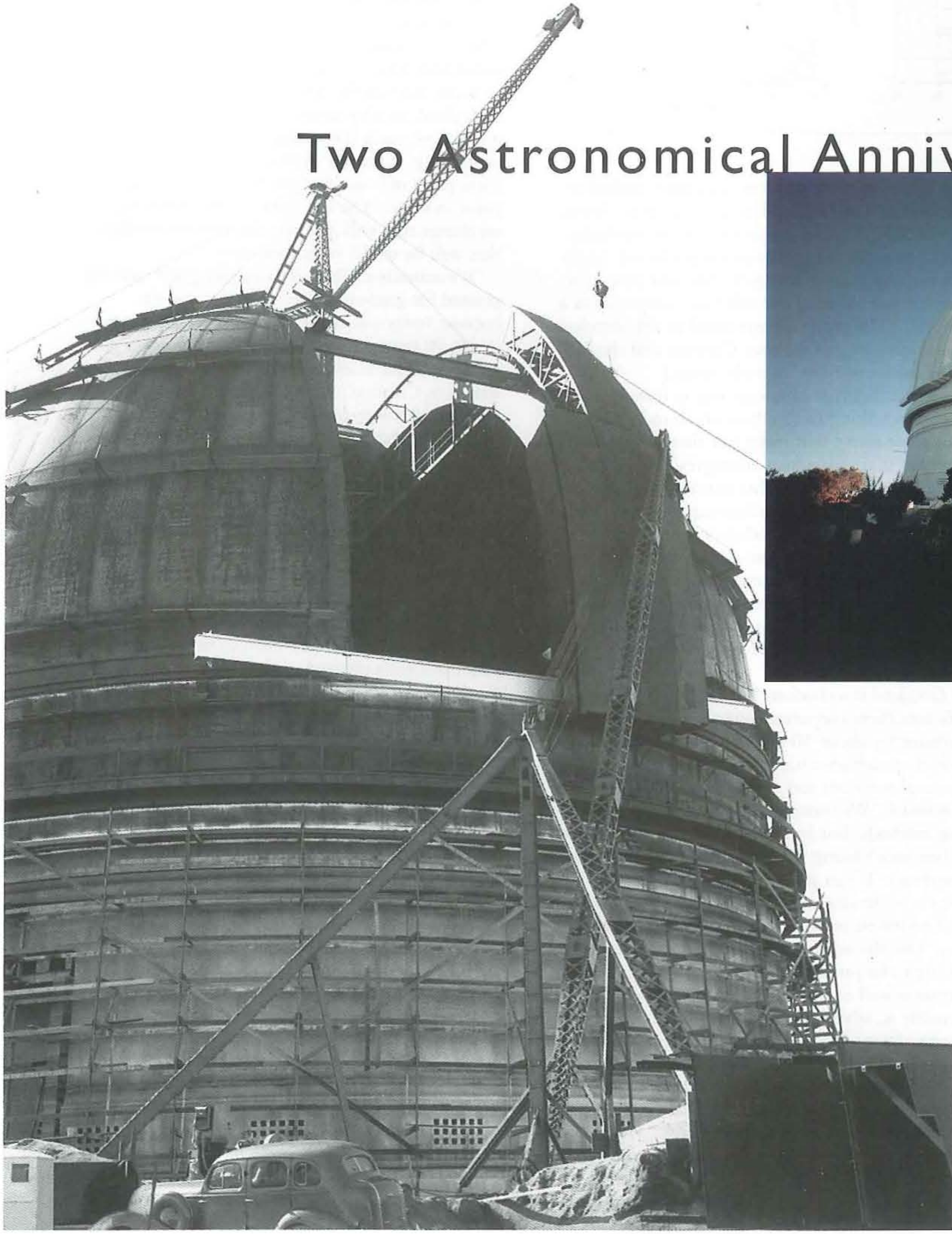
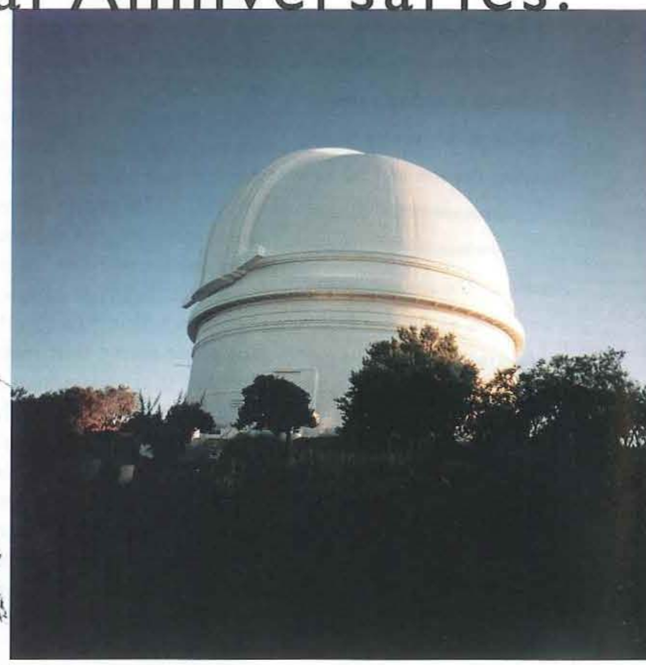
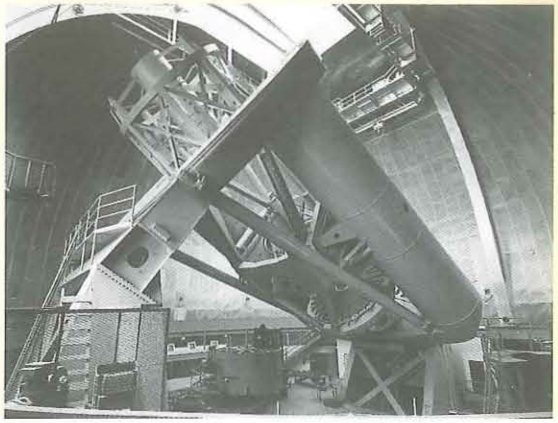
Two Astronomical Anniversaries:





Left: Progress continues on the giant dome and its shutter in December 1937. Above: The Hale Telescope dome today.

Palomar at 50



Right: Among the dignitaries who spoke at the dedication of the Hale Telescope were President Lee DuBridge (foreground, with Mrs. Hale), and representatives of the Rockefeller Foundation, the Carnegie Institution of Washington, Caltech's Board of Trustees, and the Observatory Council.

Left: Palomar's current director, Wallace Sargent, the Ira Bowen Professor of Astronomy (far left), talks to journalists touring the 200-inch telescope in conjunction with the 50th anniversary celebration.

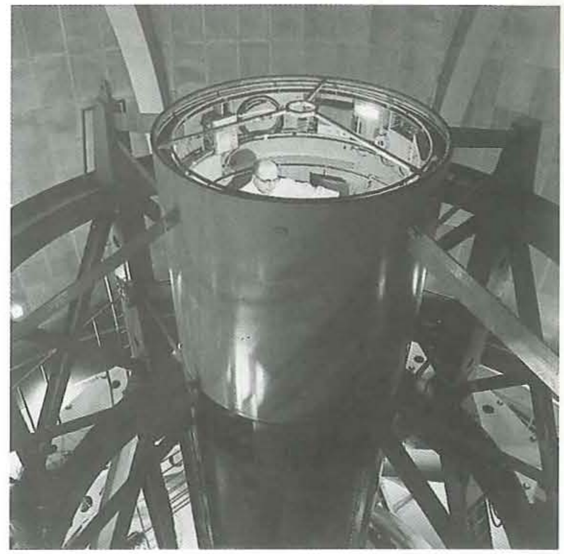
On June 3, 1948, about a thousand invited guests (and reporters) witnessed the dedication of the world's largest telescope—the 200-inch, newly christened Hale Telescope on Palomar Mountain.

On June 3, 1998, a smaller group of about 200 gathered for a dinner beneath the telescope's giant horseshoe mount to celebrate the birthday of the magnificent instrument, still healthy and working hard at 50.

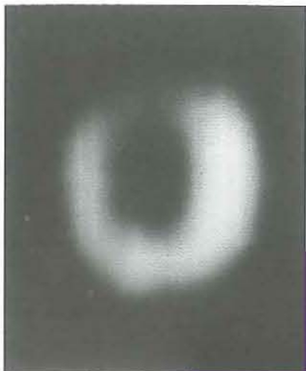
If its lifetime were to be measured from conception, however, it would be 70. It was in June 1928 that George Ellery Hale received assurance of funding from the Rockefeller Foundation's International Education Board to allow Caltech to start building the telescope. No one then dreamed that it would take 20 years (with a war intervening) to solve the engineering problems of pouring, transporting, polishing, and supporting so large a piece of glass. The mirror's progress and the telescope's construction captured the imagination of the nation and the world. Even its housing, in a dome that rivaled Rome's Pantheon in size, inspired awe. *The New York Times*, in commemorating the 50th anniversary, called it a "cathedral of science," a phrase quoted by Caltech President David Baltimore in his opening remarks at the recent dinner.

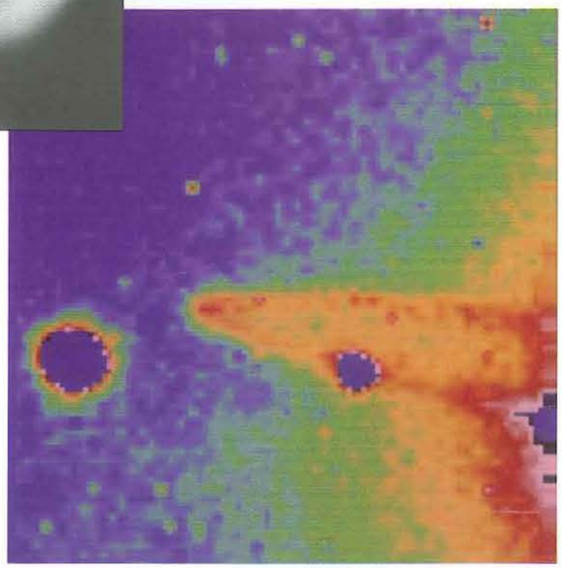
Probably the only person who attended both celebrations was Jesse Greenstein, now the DuBridge Professor of Astrophysics, Emeritus. In his talk to the 1998 audience, he noted that he had arrived at Caltech just a few weeks before the dedication of the 200-inch to take the position of "organizer" of astronomy. His only professional colleague was Fritz Zwicky, "a man of great originality," and the astronomy office in Robinson was filled with World War II debris. Within a few years of his arrival, however, Greenstein would be able to add a professorship per year for a dozen years, and Caltech's stature in astronomy grew to fit its telescope.

Greenstein began observing with the 200-inch



Jesse Greenstein at the prime focus of the Hale Telescope, his home for 30 nights a year over 40 years.





Technology marches on. The top picture dates from 1978, and is the first ever taken of the rings around Uranus. (The rings had been discovered in March 1977, when Uranus occulted a star named SAO 158687.) The planet was shot at two infrared wavelengths—one at which the planet was relatively bright, and one at which it was darker. Subtracting the two left just the rings. But the process wasn't nearly that straightforward. There were no two-dimensional CCD arrays in those days, so the Hale Telescope was repeatedly scanned across the planet and the light directed onto a pair of single-element detectors, generating two channels of analog intensity data that were recorded on magnetic tape. The tape was played through a machine that subtracted one channel from the other and output the difference as a strip chart. The strip chart was converted to digital format with a ruler and a pencil by Keith Matthews, member of the professional staff, and the digital data punched on cards that were fed into a computer. The computer interpolated the data, filling in the gaps between the points, and output the (digital) results onto another magnetic tape, which was fed into a Geology Department computer that had a video display—a rarity back then; most computers talked to their operators through teletype machines. A Polaroid photo was taken of the video screen, and that's what you see here. The entire process took months. By contrast, the recent infrared image of Jupiter's rings above took about 20 seconds to produce.

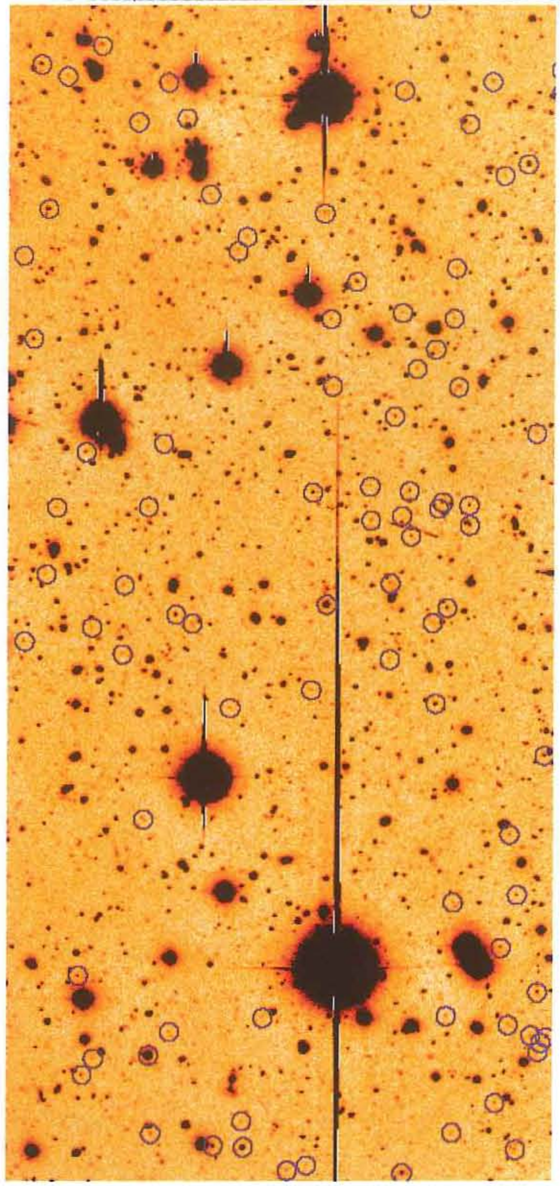
in 1952 and continued to use it for about 30 nights a year for the next 40 years. He also "fell in love with this 500-ton monster of steel and glass, still one of the great instruments of the world."

"There are hundreds of astronomers from all over the world who share my personal affection for that gray giant," Greenstein said. "It has performed miracles, observed the faintest objects possible, and seen to the edge of the expanding universe—an edge that remains ever more unreachable as larger instruments are built."

Augustus Oemler, director of the Observatories of the Carnegie Institution of Washington, outlined "50 Years of Research at Palomar" for the anniversary guests. Carnegie had been Caltech's partner in the Palomar Observatory until 1979, when Carnegie turned its attention to building newer telescopes. During those 50 years the Hale Telescope dominated astronomy. Already in 1952, the 200-inch had doubled the size of the visible universe, and Allan Sandage, PhD '53, of Carnegie continued to refine the Hubble constant and define the age and size of the universe. Sandage also observed on the telescope a new class of objects, dubbed quasi-stellar radio sources, or quasars, which Maarten Schmidt determined had huge red shifts and were the most distant and luminous objects in the universe. The 200-inch also was used to explain the evolution of stars, to discover large-scale structures in the universe, and to identify radio sources with optical counterparts.

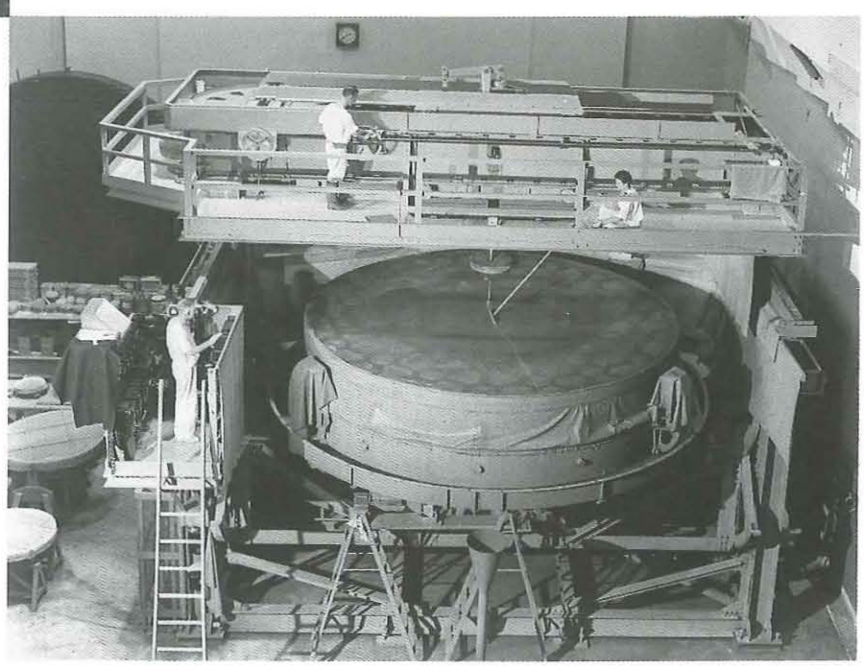
Technology has enabled the Hale Telescope to keep up with the times. In the '70s, charge-coupled devices (CCDs), which greatly improved sensitivity to light, revolutionized telescopes. The "4-shooter," a CCD camera built for the 200-inch telescope, was developed at Caltech and was one of the first adaptations of the technology to ground-based astronomy.

And the upgrading continues. "The observatory is not a museum—it is a vital facility which is

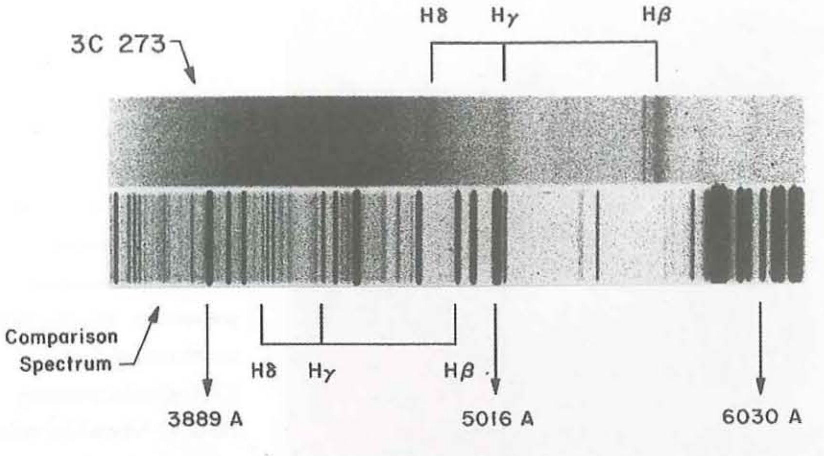


Professor of Astronomy Charles Steidel (PhD '90) is using the Hale Telescope to map the universe as it was at about one-tenth its present age. The star field at left contains some 2,000 galaxies, including about 75 "ultraviolet drop-outs" (circled) that are visible in red and green light, but not ultraviolet. Because of their age, absorption features that should lie in the far ultraviolet have been redshifted into shorter ultraviolet wavelengths that penetrate Earth's atmosphere. Thus comparing scans of the sky through three different filters provides a quick and easy way of separating galaxies that go way back—in both senses!—from more recent ones.

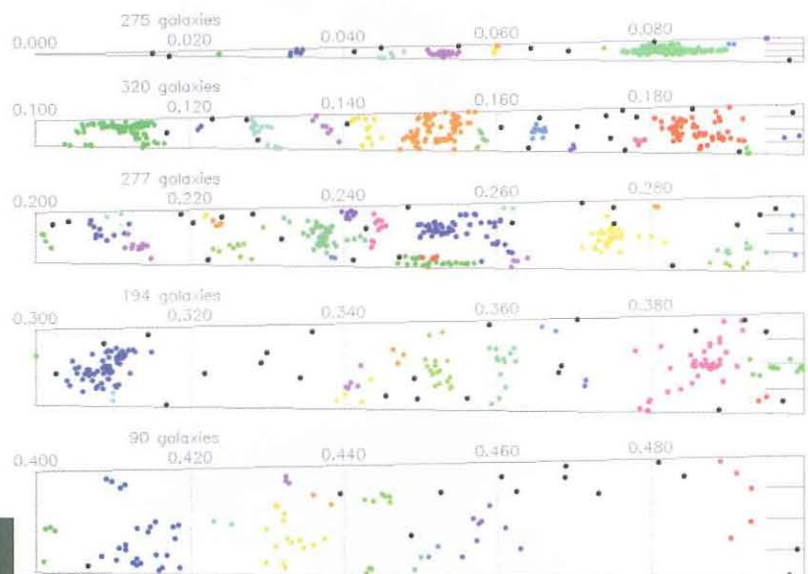
Left: The prime focus cage was so large that the Westinghouse factory door had to be enlarged and the track lowered four feet to get it out.



Right: After it was shipped across country from Corning, New York, as crowds lined the tracks to watch, the giant mirror spent nine years (and occupied 180,000 man hours) being ground and polished in Caltech's optical shop (later reincarnated as the synchrotron building). About 30 tons of abrasives were used to grind it down from 20 tons of Pyrex to less than 15 tons.



Left: A spectrum of 3C273, the Rosetta Stone of quasars (top), and a reference spectrum (bottom). Note the relative positions of the lines labeled Hδ, Hγ, and Hβ. The key to matching objects seen through different telescopes is to have accurate location data. Early radio telescopes could only plot a source to within several arc minutes, but in 1962, the moon occulted 3C273 several times, giving its position to within an arc second. Astronomers got a second lucky break when the Hale Telescope was trained on the refined coordinates, in that the spectrum of the object they saw there was redshifted by 16 percent—unusually far for something that looked like a star (it isn't), but not so far that Maarten Schmidt (below, left) couldn't eventually identify the spectral lines.



Left: Research Fellow Don Hamilton and the Norris Spectrograph, which was built for the Hale Telescope in 1990. A robotic arm (at Hamilton's right elbow) deploys optical fibers anywhere in the instrument's field of view to carry light to a CCD detector; up to 176 spectra can be collected simultaneously, each by its own fiber.

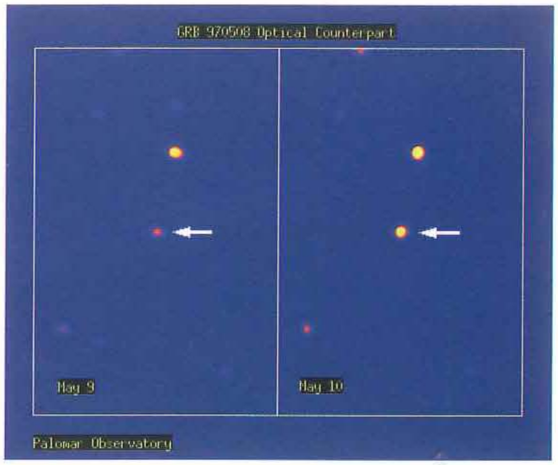
Above: Postdoc Todd Small and Professor Wallace Sargent are using the instrument to construct detailed maps of the large-scale distribution of galaxies out to redshifts of 0.5, or about 4 billion light years. This data slice from the autumn sky starts in the upper left-hand corner, at redshift 0.0; each succeeding row picks up where the one above it left off. The colored dots are groups and clusters of galaxies, packed at least five times more densely than the field as a whole. Black dots are galaxies without nearby neighbors. The slice is about as thick as it is wide (2°), so in three dimensions it's a very tall, thin pyramid.

continually being upgraded and improved," said Wallace Sargent in his talk on "The Next 50 Years." Sargent is the Bowen Professor of Astronomy and current director of the Palomar Observatory. He noted the role of computers and described the adaptive optics system developed by new Palomar partners JPL and Cornell, which should provide "a dramatic improvement in image quality over small areas in the sky." Because of these efforts, "there is absolutely no doubt that the 200-inch today is a better telescope than it was 50 years ago. And how many 50-year-olds can say that?"

The Hale Telescope is no longer the biggest in the world; the two 10-meter W. M. Keck Telescopes (another Caltech undertaking) in Hawaii are. In describing some recent astronomical discoveries, Sargent emphasized the collaboration between Palomar and Keck. In the discovery of the first brown dwarf, of optical counterparts to gamma-ray bursts, and of newly forming galaxies in the very early days of the universe, Palomar first identified the objects as interesting, whereupon they were followed up and confirmed spectroscopically at the Keck Observatory.

Sargent warned of the danger that the new generation of great telescopes might freeze grad students and postdocs out of hands-on experience with the instruments themselves, whereas Palomar will be able to keep alive this important astronomical tradition. He closed with the reaffirmation of a statement then-President Lee DuBridge made at the 1948 dedication:

"The word 'dedicate' in the English language means to set apart by a promise. It is essentially synonymous with 'consecrate,' which means to make holy by a special act. The word has more than a formal or material significance. It also carries spiritual implications. It is in this sense actually that we do today set aside this temple of learning, and promise that it shall be devoted henceforth to deepening man's intellectual and spiritual understanding."



Above: Gamma-ray bursts suffered from the same identity crisis that quasars did, until BeppoSAX, an Italian/Dutch satellite, began providing accurate position information. On May 8, 1997, BeppoSax saw a gamma-ray burst for which the Hale telescope was able to find an optical counterpart (marked with an arrow, and still increasing in brightness two days after the burst). A spectrum taken at the Keck Observatory on May 11, by a team led by Professor of Astronomy and Planetary Science Shri Kulkarni, proved that the source is more than halfway across the observable universe from us, meaning that the burst was among the most energetic events in the universe. There's still debate as to whether all gamma-ray bursts are as distant, so it's too early to tell if this is the Rosetta Stone of gamma-ray bursts.

Below: In the media spotlights, the mirror is rolled out and prepared for its final journey to the top of Palomar Mountain. That journey (bottom), which took place on November 19, 1947, required two pushers and a puller to get up the sleet-slick road.