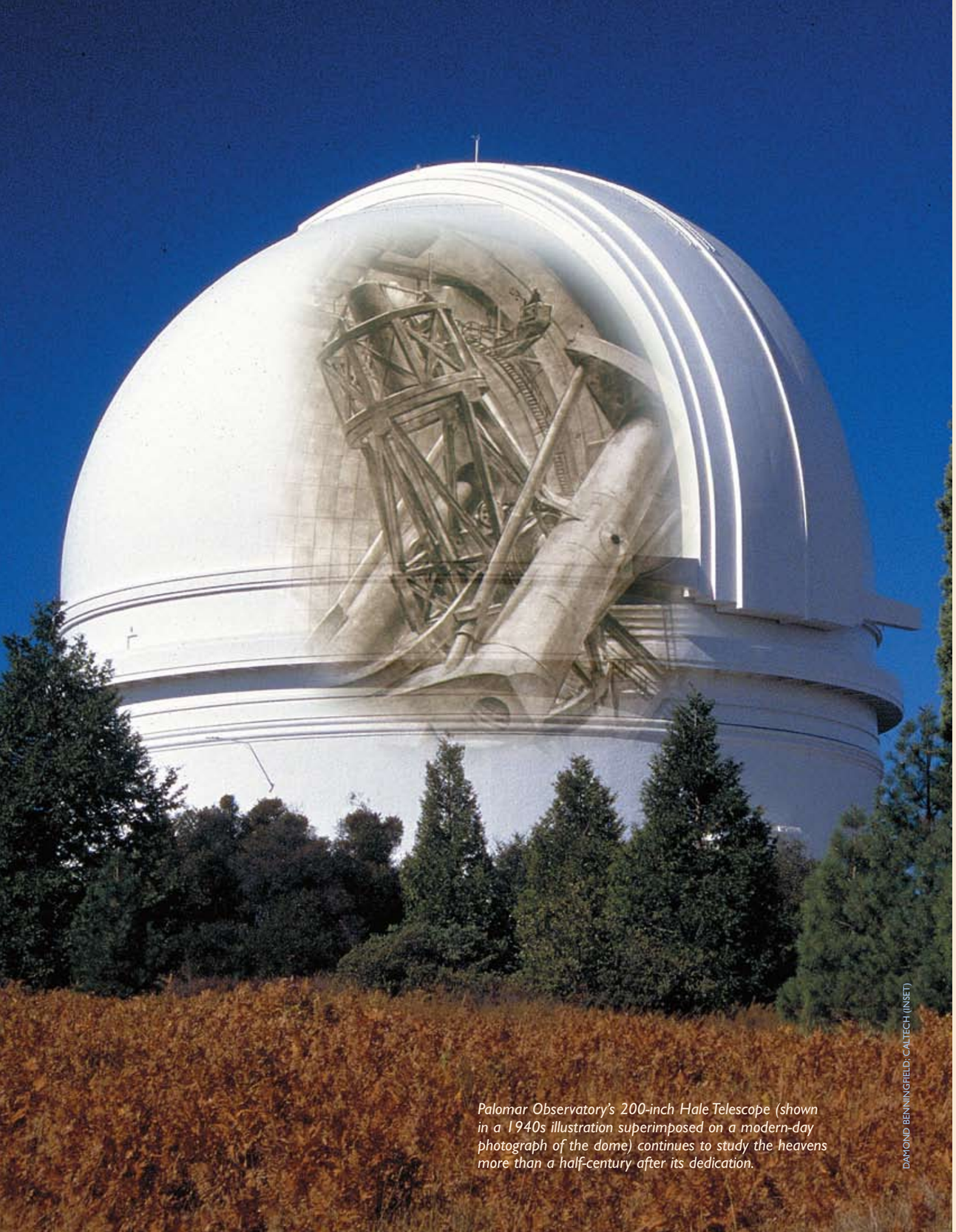


Palomar Observatory's 200-inch Hale Telescope (shown in a 1940s illustration superimposed on a modern-day photograph of the dome) continues to study the heavens more than a half-century after its dedication.

DAMOND BENNINGFIELD; CALTECH (INSET)

H. SIDDONS MOWBRAY

Grand Old Telescopes

New technology and new ideas are keeping three classic telescopes in service decades after they first gazed skyward

By Damond Benningfield

Judith Cohen gazes briefly at a cluster of computer and video monitors, assures herself that photons of light from a distant star are trickling into an electronic detector, then returns to the topic of conversation for the last couple of hours: her historic surroundings.

Cohen, a professor of astronomy at the California Institute of Technology, is sitting inside a bright control room just a few paces from the 200-inch telescope at Palomar Observatory northeast of San Diego. For more than four decades, it reigned as the most powerful telescope on the planet, boosting human knowledge of everything from the craters of the Moon to the age of the universe.

"I was a graduate student at Caltech from 1967 to '71, but I did my thesis research at Mount Wilson," Cohen says. "Palomar was for the gods, not graduate students."

But like the gods of Olympus, the gods of astronomy are a fickle lot. Show them more glass — a telescope with the ability to gather more light — and they're off to new observatories, new mountaintops, even new countries in their quest to see ever deeper into the universe.

When the 10-meter (400-inch) Keck telescope opened in Hawaii a decade ago, Palomar lost its number-one ranking and much of its cachet. It remains one of the biggest telescopes in the world, but it's dropping down the list in a hurry. What's more, it lacks the technological finesse of newer models, like an old Victrola compared to a modern CD or MP3 player.

Palomar's 200-inch telescope isn't alone in its fall from Olympian heights. Two other telescopes that helped open the frontiers of astronomy — telescopes at least a half-century old, that ranked first or second in the world when they entered service — are being relinquished to backup roles, like aging running backs relegated to the bench because younger guys cut upfield or explode away from closing defensive backs better than the old vets.

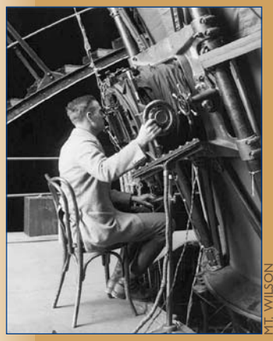
The 100-inch telescope at Mount Wilson, California — the instrument with which Edwin Hubble proved that the universe is expanding — faces increasingly troublesome light pollution and electromagnetic interference. And the 82-inch telescope at McDonald Observatory in West Texas — second only to Mount Wilson at its dedication in 1939 — sometimes is described as a cranky beast that requires an experienced hand to operate. Most

astronomers prefer the more modern 107-inch just down the mountain, or the slick new 9.2-meter Hobby-Eberly Telescope one mountaintop away.

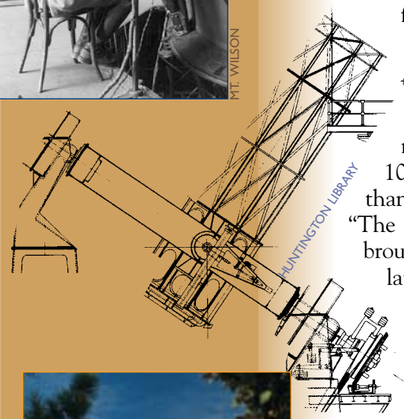
Yet few astronomers suggest retiring any of these grand old telescopes — at least not yet. The telescopes themselves have lost none of their ability to eye the heavens; they still perform as well as they did when they were built, if not better. With improved detectors and control systems, they remain effective tools for certain types of research. They serve as scouts, picking out interesting targets for the big new telescopes to study in detail. And they help students learn how to operate and build instruments for the newer telescopes.

"A telescope is a tool," says McDonald Observatory Director Frank Bash. "It's a bucket for collecting light. Its usefulness depends on its light-gathering power, the site where it's located, and the cleverness of the people who use it." Clever people have adapted the telescopes to changing technology many times in the past. With a little more cleverness — and lots of tender loving care — they may keep all three in service well into the 21st century.

SMITHSONIAN INSTITUTION



MT. WILSON



HUNTINGTON LIBRARY

Mount Wilson: The Granddaddy

Television announcers often describe college football's Rose Bowl game in Pasadena as "the granddaddy of them all." It was first played in 1902, decades before any other major bowl game, then disappeared until the teens. By then, another "granddaddy" was under construction overlooking Pasadena — the 100-inch telescope atop Mount Wilson.

The telescope was the handiwork of George Ellery Hale, the son of a wealthy Chicago industrialist. Hale had already built two "world's-largest" telescopes: a 40-inch refractor (which uses lenses to gather and focus starlight) at Yerkes Observatory in Wisconsin, and a 60-inch reflector on Mount Wilson, which saw "first light" in 1908. Both telescopes are still in use today.

But Hale yearned for bigger telescopes to advance the new science of astrophysics, which seeks to understand how stars work. While astronomers of the 19th century largely contented themselves with measuring the positions and brightnesses of stars, new techniques in the new century were making it possible to decipher more about the stars themselves.

In particular, astronomers were using a technique called spectroscopy to split the light from an astronomical object into its individual wavelengths or colors. This rainbow of light carries an enormous amount of information, including the object's composition, temperature, and motion through space. From these bits of data, astronomers were trying to understand the process that powers stars, how stars are born and how they evolve, and much more.

Hale realized that he needed a telescope with a bigger primary mirror, which could collect and focus more starlight, to study faint, distant stars. So he ordered the 100-inch mirror even before the 60-inch telescope was completed. (The size of a telescope mirror refers to its diameter; the 100-inch mirror spans a bit more than eight feet, or 2.5 meters.) "The day the 60-inch mirror was brought to the mountain for installation, the mirror blank for the 100-inch arrived from France," says Don Nicholson, associate director of the nonprofit institute that operates Mount Wilson Observatory. "That's courage."

DAMOND BENNINGFIELD

From top: Mount Wilson's 100-inch telescope; Hubble at the helm; a schematic of the one-time world's largest telescope; the dome today, surrounded by the Angeles National Forest.

Today, the telescope looks about like it did on the night it first gazed at the heavens — November 2, 1917, just a few months after the United States entered World War I. The mirror, open steel tube, and support structure are original equipment. The way astronomers use the telescope has changed dramatically, though. For one thing, they record data on electronic detectors instead of photographic plates. For another, they operate the telescope from an enclosed control room instead of sitting directly beneath it and guiding it by hand.

"You would look through an eyepiece to line up on a guide star," explains Nicholson, who helped his father, a staff astronomer, operate the telescope while he was a high school student. "You would have to keep the star in the crosshairs for hours. In the wintertime it gets cold in here, but you couldn't get up to go to the bathroom, or even move around to keep warm."

Despite the lack of creature comforts, Mount Wilson was "the place astronomers wanted to come," Nicholson says. The most famous of its astronomers was Edwin Hubble, for whom the Hubble Space Telescope is named. "Hubble was the right guy in the right place at the right time," Nicholson says.

By the 1920s, a great debate was raging about the "spiral nebulae" sprinkled throughout the cosmos. Some thought these structures were motes of matter inside our Milky Way galaxy, and that the Milky Way encompassed the entire universe. Others thought the nebulae were galaxies of stars outside the Milky Way.

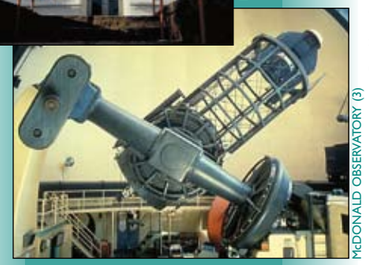
Hubble settled the matter when he discovered several Cepheid variable stars in M31, the Andromeda Nebula. A Cepheid pulsates like a beating heart, and the length of its pulsations reveals its true brightness; comparing this to its apparent brightness yields its distance. With the great light-gathering power of the 100-inch, Hubble found that M31's Cepheids are far outside the Milky Way, proving that the nebula is actually a galaxy containing billions of stars.

This discovery increased the size of the known universe by many orders of magnitude and assured both Hubble and the telescope a place in history.

Hubble's work was just beginning, though. As he studied M31 and other newly identified galaxies, he noticed something startling: Almost all of the galaxies are moving away from us, with those that are farthest moving fastest. Hubble had discovered that the universe itself is expanding, and provided the first piece of evidence that eventually would lead to the Big Bang theory of creation.

The 100-inch telescope remained the largest in the world for three decades. But today, it doesn't even rate in the top two dozen. Light pollution from Los Angeles overpowers faint astronomical objects, and a jumble of nearby broadcast antennas sets up an electromagnetic clatter that interferes with telescope operations. Many astronomers consider the problems insurmountable, and aren't sure the telescope will reach its centennial.

DAMOND BENNINGFIELD



McDONALD OBSERVATORY (3)

The art-deco dome of McDonald Observatory's 82-inch telescope (top); the telescope today; inspecting the 82-inch mirror before the telescope was built; workers pose on the dome framework in 1934.

But a new technology is extending the telescope's life. Called adaptive optics, it passes light from the main mirror through a smaller mirror that flexes to compensate for the turbulence in Earth's atmosphere, sharpening the view of distant objects. Using the adaptive optics system, astronomers have discovered several brown dwarfs — objects that are more massive than planets but not massive enough to shine as stars. Other astronomers are trying to map the surfaces of several asteroids.

"So far, we've kept pace, and this continues to be a useful instrument," says Nicholson. "It's no longer the biggest in the world, but you don't need the biggest in the world to do a lot of things....There's a tremendous amount of work that can be done, and I see no reason why this [telescope] shouldn't continue."

McDonald: A Grand 'Beast'

Anita Cochran was afraid one of her first observing runs with McDonald Observatory's 82-inch telescope would be her last. In 1977, as a University of Texas graduate student, she and a colleague were studying a class of hot stars. "We snagged a cable across the railing, and as the telescope continued to track, the cable got pulled tighter and tighter," Cochran recalls. "Something had to give. Instead of simply unplugging, the cable ripped out of the other end with loads of sparks. I thought they'd never let us use a telescope again."

The cable was repaired, though, and Cochran, now a senior research scientist, has spent the last quarter-century using McDonald telescopes to study stars, planets, moons, and the solar system's littlest members, comets and asteroids.

On a chilly night in November, with the Leonid meteor shower building toward its dramatic peak and fog creeping up from the valley below Mount Locke, Cochran handles the 82-inch like an aging family pet. Yes, it's a "cranky old beast," she says as she scrambles around the telescope to correct a minor problem, but it's also "a classic beast" — "a grand old telescope."

It looks the part, too, from the art-deco

dome to the original alignment wheels to the battleship-gray paint job. Like the 100-inch at Mount Wilson, its appearance has changed little since its dedication. But the gizmos that surround and hang from the telescope are anything but original equipment — and they're part of the secret to its longevity.

"The 82-inch spans very interesting epochs," says Frank Bash, "from the era of photographic plates, which at best were a fraction of a percent efficient [less than one percent of the light that struck them was converted into a photographic image], to the current epoch, using charge-coupled devices, which are commonly 90 percent efficient, with a lot of steps between. The 82-inch has been made a lot better by having better detectors put on it."

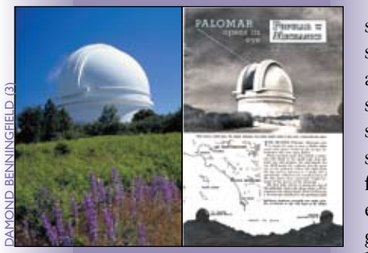
The telescope was born from a collaboration between the University of Texas and the University of Chicago. Paris, Texas, banker William J. McDonald had bequeathed about $1 million to Texas to build a telescope. But the university had no astronomy department, so it allied with Chicago to operate the new McDonald Observatory.

Chicago astronomer Otto Struve, the son and grandson of famous European astronomers, picked the site for the observatory and oversaw its design and its sometimes difficult and contentious construction. It was dedicated in 1939.

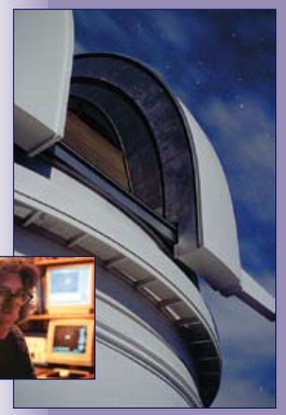
Under Struve's direction, the Chicago astronomers established a vigorous program of stellar spectroscopy — piecing together the secrets of stellar life and death one star at a time. They measured the rotation of galaxies, which led to the discovery of dark matter. After Texas assumed control of the observatory, its astronomers found water vapor on Mars and began measuring rapid changes in the brightness of many astronomical objects.

Astronomers continue to pursue a wide range of research interests on the 82-inch (which is named for Struve). During her November observing run, for example, Cochran studies a bright comet and a handful of asteroids that may be chipped from Vesta, one of the largest asteroids.

CALTECH



DAMOND BENNINGFIELD (3)



Looking down on the 200-inch telescope and its observer's capsule (top); the telescope dome today and as it appeared in a June 1948 magazine; with the shutter open at night; Judith Cohen in the control room.

But the telescope is showing its age. It sometimes sticks as it tracks an object across the sky ("it has arthritis," Bash explains), and it has leather bearings that are hard to maintain. Upgrading it to accommodate a fully automated tracking system would be costly.

"We've been questioning it a lot lately," says Cochran. "A lot depends on how much maintenance it requires. Some people want to close it down. Others think it's still doing good research."

Bash falls into the latter category, and says it's not quite time to retire the telescope. Over time, it might be dedicated to a specific research project, such as a new search for planets in other star systems. The search, which is already underway, measures tiny variations in the pulses of light from old, collapsed stars for hints of planets. Just as important, the telescope is a good training tool for students, who can build instruments for it at a fraction of the cost of instruments for giant new telescopes.

"I look at the 82-inch telescope, and say to myself that maybe a new one will have to built in its place in the next 50 years — ugly and computerized," Bash says with a smile. "But the 82-inch is still very useful. It's a beautiful old telescope — the Queen Mary of telescopes at McDonald Observatory."

Palomar: The *Grand Dame*

When the 200-inch Palomar telescope was dedicated in June 1948, *Popular Mechanics* noted that the "giant eye" should see a billion light-years into space, allowing it to "confirm or disprove a number of theories" about the universe. "Is the shift to the red in the spectra of distant nebulae and galaxies a true indication that the universe is expanding? If so, are nebulae as uniformly distributed through the outer reaches of space as they appear to be closer to us? The 200-inch telescope will be able to reach a large enough section of the universe to permit a fair sampling of it."

As it turns out, the magazine's prediction was amazingly conservative. Over the decades, equipped with ever-more-sensitive instruments, the telescope has helped astronomers confirm the expansion of the universe, map the clumpy distribution of galaxies, and discover bizarre objects undreamed of at the time of its dedication — some of them more than 10 billion light-years from Earth.

"I've always felt that this is a shrine to science," says Judith Cohen. "When you think of the people who have worked here, it's awe-inspiring."

Like the 100-inch at Mount Wilson, the 200-inch telescope owes its existence to George Ellery Hale, who convinced the Rockefeller Foundation to donate $6 million for its construction in 1928. (The telescope is named in Hale's honor.) Work began in the 1930s, but World War II delayed completion until 1948.

"The telescope is an engineering showpiece," says Palomar Director Richard Ellis, a professor at Caltech, which owns and operates the 200-inch. "The mirror was innovative — one of the first lightweight designs. A number of traditional techniques were tried and failed, so they tried riskier technologies that worked....There's a professional finish to it that you don't often see today."

Despite its heft, this *grand dame* of giant telescopes retains an artistic elegance that many newer models lack. "There's great craftsmanship in this telescope," says Mike Doyle, assistant superintendent of Palomar Observatory. "They just really put this thing together."

Doyle recites its vital statistics as he rides an open-air elevator car to the top of the telescope: Its moving parts weigh 530 tons; the mirror tops 14 tons and requires 36 counterweights on its backside to keep it from warping under its own weight. (The Soviet Union completed a 236-inch telescope in 1976, but the mirror sags, so it's much less effective than the 200-inch.)

As the elevator reaches its pinnacle, Doyle climbs into a barrel-shaped capsule at the top of the telescope. In the early days, astronomers controlled the telescope from here, using a microscope eyepiece to keep a guide star aligned in a crosshair.

Today, although the capsule is used when new instruments are installed and tested, astronomers operate the telescope from a cozy control room. Computers do most of the tracking, allowing the astronomers to concentrate on their research, not moving the telescope around.

Much of that research is aimed at supporting the twin Keck telescopes in Hawaii. "It's like a food chain," says Cohen, "with Keck at the top, Palomar in the middle, and smaller telescopes at the bottom."

Cohen and her colleagues are using all three links in the chain to study stars with "low metallicities" — tiny concentrations of elements heavier than hydrogen and helium. They use a small telescope in Chile to pick out candidate stars, the 200-inch to narrow the list, and the Kecks to conduct highly detailed analyses of the finalists. The research will help trace the creation of heavy elements in the earliest days of our Milky Way galaxy.

During her 10-night Palomar run — some of her first observing with the telescope since the 1980s — Cohen will take spectra of about 200 stars. "This is a fabulous telescope," she says. "It's so well designed that it's possible to keep adding on and modernizing." One example is a new adaptive optics system that is producing images of the outer planets that rival those of Hubble Space Telescope.

Because of its great size, its engineering, and its adaptability, the 200-inch would seem to have the most secure future of these three grand old telescopes. Yet even it faces challenges. Light pollution from San Diego is limiting the telescope's ability to see the faintest astronomical objects, and competition with the Kecks and potential larger telescopes could siphon money.

"I'm certain that in five years, people will still be going to the telescope and doing world-class research," says Ellis. "But there's been more change [in astronomy] in the last 10 years than in the previous 40, so only a fool would predict what will happen 10 years from now. My job is to encourage the engineers and instrument builders to develop new ideas, to not be too conservative."

"If we can survive these issues and find a mode of operation that's affordable, the telescope has a good future," adds Cohen. "We shouldn't junk it."

World's Largest Active Optical/Infrared Telescopes

Rank	Name	Location	Size‡
1	Keck I	Hawaii	10
	Keck II	Hawaii	10
3	Hobby-Eberly	McDonald	9.2
4	Subaru	Hawaii	8.2
	Antu*	Chile	8.2
	Kueyen*	Chile	8.2
	Melipal*	Chile	8.2
	Yepun*	Chile	8.2
9	Gemini North	Hawaii	8.1
	Gemini South	Hawaii	8.1
	. . . . .		
14	Hale (200-inch)	Palomar	5.1
35	Hooker (100-inch)	Mount Wilson	2.5
50	Struve (82-inch)	McDonald	2.1

‡Meters
* These will form the European Southern Observatory's Very Large Telescope

Resources

All three telescopes are available for viewing through public galleries or guided tours.

Mount Wilson
Open 10-4 weekends, weather permitting. Guided tours at 1 p.m. April-October. Free admission, although a $5 parking pass is required from the U.S. Forest Service.
www.mwoa.org

McDonald
Open 9-5 daily, with twice daily guided tours of all major McDonald telescopes, plus star parties three nights per week. Fees vary. Public viewing night on 82-inch telescope offered by reservation, $50 per person.
mcdonaldobservatory.org

Palomar
Open 9-4 daily, no guided tours. Gift shop open daily during summer, weekends only rest of the year. Free.
www.astro.caltech.edu/observatories/palomar