Keeping a ‘Big Eye’ on the Universe

Palomar Observatory’s Hale Telescope still delivers discoveries 75 years after its first light.

By Whitney Clavin

In January 1949, renowned astronomer Edwin Hubble rode an elevator at Palomar Observatory up 78 feet to the prime focus cage of the giant, 200-inch Hale Telescope, known during its development as the “Big Eye.” His mission was simple: to capture the machine’s first official picture, known in astronomy as its first light. Begun in 1928 by Caltech cofounder George Ellery Hale, considered one of the greatest telescope builders of all time, the telescope came to life thanks to a $6 million grant (which equates to roughly $106 million today) from the Rockefeller Foundation.

Nearly two decades later, including an arduous 11-year period in which the Hale’s large mirror was ground and polished under fastidiously clean conditions in the Caltech Optical Shop, Hubble slid open a photographic plate holder and exposed the telescope’s first images. Shortly after, he proclaimed to reporters that humanity could at last peer farther into the universe than ever before.

Since then, the Hale Telescope—which was the world’s largest effective optical telescope for more than 40 years—and its sister instruments have collected myriad findings and illuminated details about a host of celestial objects. “I am from a generation that grew up reading about Palomar as this icon,” says Andy Boden, deputy director of Palomar, which is owned by Caltech. “In a quiet moment, I stop and pinch myself because I feel so incredibly lucky to be here.”

Some of the many discoveries made using Palomar telescopes include the first known quasar, identified in 1963 by Caltech astronomer Maarten Schmidt, and the first confirmed brown dwarf, captured in 1994 by former Palomar director Shri Kulkarni, Caltech’s George Ellery Hale Professor of Astronomy and Planetary Science, together with instrument specialist Keith Matthews (BS ’62) and others. Early observations made by Allan Sandage (PhD ’53) of the Carnegie Observatories narrowed in on the age and expansion rate of the universe, validating the scientific legitimacy of observational cosmology. And, in 2005, Mike Brown, Caltech’s Richard and Barbara Rosenberg Professor of Planetary Astronomy, used the 48-inch Samuel Oschin Telescope to discover the dwarf planet Eris, whose similarity in size to Pluto resulted in the infamous demotion of the former ninth planet in our solar system.

The People of Palomar

To prepare the massive Hale Telescope for a night observing the stars, more than 20 Caltech staff members work round the clock to make sure everything is in order. They inspect the instruments being used, chill the equipment with liquid nitrogen, and set the telescope to point in the direction of target stars.

Above left: Edwin Hubble in the prime focus cage of the Hale Telescope in 1950.

When the telescope operators—who align the telescope to the part of the sky an astronomer wants to investigate—start their shift at sunset, they check weather reports and head outside to the catwalk circling the giant white dome. From there, with views stretching out to forests and blue mountains beyond, they assess condensation levels on the dome. If there is too much moisture, they will not open the dome, so as to protect the telescope’s mirror from falling water droplets.

“People call the Hale Telescope the ‘perfect machine,’” says Carolyn Heffner, Palomar’s night operations supervisor. “But it’s really the almost-perfect machine. It takes care and maintenance. Our goal is to provide as much help as possible to ensure that the astronomers can get ‘on sky’ efficiently.” During each shift, the telescope operators work through the night, while Heffner and other support staff work until about 10 p.m.

“We have nicknamed our nightly group the Dark Side because we all love *Star Wars*,” says Diana Roderick, a telescope operator at Palomar who lives in a cottage on the mountain with her husband, Drew Roderick, a grounds and mechanics supervisor. “I love the camaraderie. Everybody pitches in when something needs to get done.”

The Observatory Today

Despite its long history, Palomar remains at the forefront of astronomy. New instruments are continually invented by Caltech astronomers and students and tested on-site. The wildly successful Zwicky Transient Facility (ZTF), a robotic camera installed on the Samuel Oschin Telescope in 2017, has led to many breakthroughs, including the discovery of the first asteroid known to reside entirely inside the orbit of Venus, the first glimpse of a star swallowing a planet, about 10,000 classified supernovae, and more than 100,000 supernovae candidates.

Palomar’s smaller telescopes include Gattini-IR and WINTER (Wide-field INfrared Transient ExploreR), which scan the skies using infrared light to sleuth out objects such as dusty supernovae hidden in optical light. Professor of Astronomy Mansi Kasliwal (PhD ’11), who developed these telescopes with her students, says Palomar is the “best playground for new ideas in astronomy. Even as a grad student, you can do innovative work there.”

The Hale Telescope also serves as the receiving end for NASA’s Deep Space Optical Communications experiment. The mission, run by a team at JPL, which Caltech manages for NASA, is testing a high-bandwidth laser communication system between Earth and the Psyche spacecraft, which launched in October 2023 and is now on its way to a unique metal-rich asteroid, also called Psyche. “Palomar may be old, but it’s a unique place where the old and new come together to advance astronomy,” Heffner says.

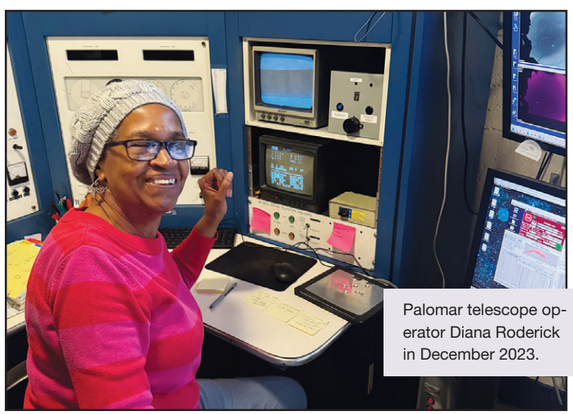
Here are some of the most memorable images captured at Palomar through the years:

Hubble's Variable Nebula

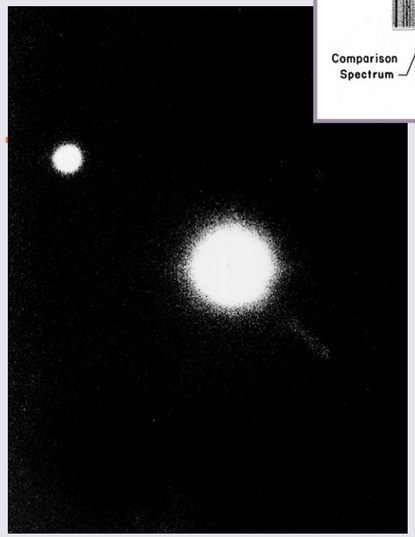
Captured on January 26, 1949, by Edwin Hubble, this is the "first-light" image taken by the Hale Telescope. The billowing fan-shaped cloud the image revealed is now known as Hubble's Variable Nebula, or NGC 2261, and is located 2,500 light-years away in the constellation Monoceros. After taking the image, Hubble announced to reporters that the "200-inch [telescope] opens to exploration a volume of space about eight times greater than that previously accessible for study," according to the book *The Perfect Machine*, a 1994 history of the Palomar Observatory by Ronald Florence. The now-defunct *Collier's* magazine, which secured exclusive rights to the telescope's first images, wrote in its May 7, 1949, issue in an article titled "Behold, the Universe!": "The promise of such vast new information should humble the most arrogant. For, although only astronomers can make these tremendous voyages into space, all of us may gain new spiritual dimensions from what they find."

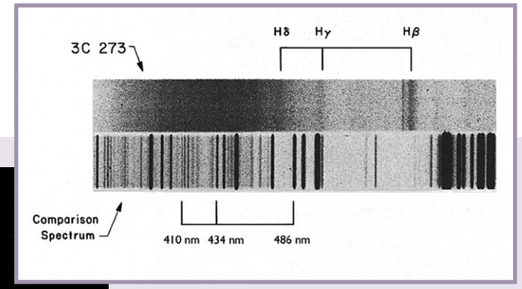
Dumbbell Nebula

This image of the Dumbbell Nebula (which resides more than 1,200 light-years away in the constellation Vulpecula) was taken by the Hale Telescope in 1961. It is one of the earliest color images of the cosmos. Optical engineer William C. Miller created this image and several others between 1958–65 using a new ultrafast color photographic film known as Super Anscochrome. Miller's photographs, which revealed what could not be seen with human vision alone, made headlines in popular science and news publications in the late 1950s and early '60s. In this image, the outer ejected layers of a dying star glow in dazzling colors. The remaining core of the star, a white dwarf, can be seen as a white dot in the center of the nebula. Also known as Messier 27, the nebula got its common name thanks to its two bright lobes. "This image has extraordinary astrophysical information, showing a rich and complex structure," says Christopher Martin, director of Caltech Optical Observatories and the Edward C. Stone Professor of Physics at Caltech. "It is also one of the first images to show the ineffable beauty of the cosmos. It is both a work of science and a work of art."



Palomar telescope operator Diana Roderick in December 2023.



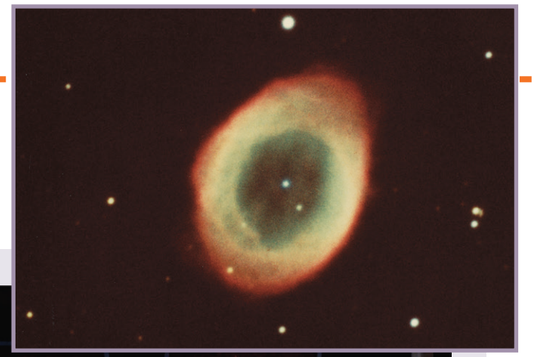


Quasar

In the early 1960s, Caltech astronomer Maarten Schmidt spent a couple of nights using the Hale Telescope to capture the spectrum of a strange source of radio waves called 3C 273 (the bright blob in the center pictured here). A spectrum breaks light apart into its different wavelengths, revealing signatures of different atoms and molecules. The resulting spectrum's chemical signatures (see inset) remained a mystery until Schmidt ultimately realized that the signatures for hydrogen atoms had been shifted to the red end of the visible spectrum due to the expansion of the universe. That meant 3C 273 was a shocking 3 billion light-years away, yet still incredibly bright in the sky: It turns out that Schmidt had discovered the first-known quasar, distant objects we now understand are ferociously bright and powered by gas falling into supermassive black holes. "With that single finding, Schmidt dramatically expanded the region of the universe that we can explore," says George Djorgovski, professor of astronomy and data science at Caltech.

Orion Nebula

One of the most scrutinized regions of space, the Milky Way galaxy's Orion Nebula is a cauldron of star formation lying 1,500 light-years away in the "sword" of Orion, the famous hunter constellation. The gaseous nebula is bright enough that it can be seen with the naked eye in dark skies. In fact, astronomer Henry Draper took the first image of the nebula in 1880 using only an 11-inch telescope at his observatory in New York. But it wasn't until William C. Miller's 1959 Hale Telescope image that the region's true colors shone through. "Miller's photograph metaphorically opened our eyes to the region's stunning beauty to complement its astrophysical significance," says Andy Boden, Palomar's deputy director.



Ring Nebula and Andromeda Galaxy

In the 1966 *Star Trek* episode "The Naked Time," the starship *USS Enterprise*'s crew becomes infected with an alien virus that causes them to go mad. During one of the episode's frenzied moments, two photos taken at Palomar Observatory can be seen on the ship's bridge. Both pictures, created by William C. Miller, are among the first-ever color images of cosmic objects. On the left in the *Star Trek* photo is the Andromeda Galaxy (2.5 million light-years away), as seen by Palomar's 48-inch Samuel Oschin Telescope in 1958, and on the right is the Ring Nebula (2,000 light-years away), as seen by the 200-inch Hale Telescope also in 1958 (see inset). Because the 48-inch has a much larger field of view than the 200-inch (making it better suited to survey large regions of the sky compared with the Hale's ability to zero in on specific objects), it was able to reveal Andromeda in its entirety like no other telescope had before. "When we look up into night skies and spot the smudge that is Andromeda, that's only its center," says Robert Brucato, Palomar's assistant director from 1982–2003. "The actual diameter of the galaxy stretches across a patch of sky equivalent to a row of six full moons. It is shocking how big the galaxy actually is."

Veil Nebula

The Veil Nebula, a cloud of heated and ionized gas and dust in the constellation Cygnus, can be seen in this image taken during the second Palomar Observatory Sky Survey (POSS II), which operated between 1985–2000 using the 48-inch Samuel Oschin Telescope. The survey served as a fundamental atlas of the sky for many years, leading to the identification of tens of thousands of galaxy clusters, hundreds of supernovae and quasars, and dozens of comets and asteroids. "The Veil Nebula, also known as the Cygnus Loop, is one of the closest supernova remnants to Earth," says Caltech astronomy professor Lynne Hillenbrand. "The ever-expanding emission nebula that we see today will continue to delight amateurs and intrigue professionals, who are still seeking the probable neutron star that was left behind after the explosion."

Palomar night operations supervisor Carolyn Heffner in December 2023.

Palomar electronic technician Greg Van Idsinga in December 2023.

Andromeda Galaxy (ZTF)

Andromeda, our nearest large galactic neighbor, was captured in its full glory by the Zwicky Transient Facility (ZTF) in 2019. ZTF, a robotic camera attached to Palomar's 48-inch Samuel Oschin Telescope, has been scanning the skies every night since 2017 for objects that explode, burst, or otherwise change in brightness. The camera's incredibly large field of view—which is 16 times larger than this image of Andromeda—is the reason it can rapidly scan the skies for such changing, or transient, objects. "You take an image and then come back the next night and compare the two images. The things that change pop out," Kulkarni says. "The sheer volume of data means we need machine learning algorithms to find the objects and classify them. The ultimate goal is to automate the discovery. Once ZTF identifies interesting objects with its wide field of view, we use other telescopes with narrow views to learn more." [C]