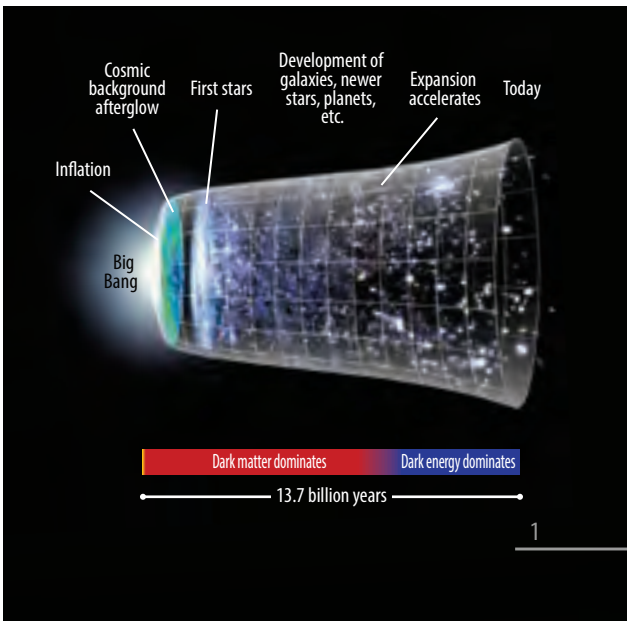

The Palomar Tradition
PREVIEW

WELCOME TO PALOMAR

Through the ages, people from all cultures have shared the same feeling of awe when looking up at the night sky. The wondrous nature of celestial bodies has fueled the human imagination and inspired storytelling, poetry, mythology, music, art, and ultimately science. Though encountering dark skies is unusual for many people, those who do perhaps wonder: What is the nature of our universe, how did it come into being, and what is its eventual fate? What are the stars that we see in the night sky, and how do they relate to the Sun that warms and lights the day? Are there other places like Earth elsewhere in the universe, and do those worlds have inhabitants who see their sky and share the same curiosity? These questions remain as relevant today as they were centuries ago.

Palomar Observatory, atop Palomar Mountain in Southern California, has for seventy years been a tradition and a place dedicated to answering these and similar questions. Conceived of almost a hundred years ago, Palomar and its famed Hale Telescope has been at the forefront of astronomical research since mid-20th century. Today, the observatory operates every night and is an iconic facility for astronomical research, instrument development, and student training. This short publication will introduce the reader to Palomar—the place, the tradition, and the people who have made it special—as well as provide information on how to get involved in its continuing mission.

Cover: The Palomar domes are built in the elegant art deco style. (Palomar Observatory/Caltech) ‣ *Opposite:* The 200-inch Hale Telescope in the moonlight. (Palomar Observatory/Caltech) ‣ *Top:* The Flammarion engraving depicting a medieval man looking beyond the apparent edge of the celestial sphere. (Public domain) ‣ *Middle:* Extended exposure star trails and the 60-inch telescope dome. (Palomar Observatory/Caltech) ‣ *Bottom:* Graphic representation of the evolution of the universe and the role of the two great cosmic unknowns: dark matter and dark energy. (NASA)



Bienvenido a Palomar

A lo largo de la historia, personas de todas las culturas y ocupaciones se han hecho las mismas preguntas al admirar el firmamento estrellado: ¿cuál es la naturaleza del universo?, ¿qué son las estrellas y cómo se relacionan al Sol?, ¿hay otros lugares como la Tierra en el universo donde habitan seres inteligentes? Estas preguntas siguen siendo tan relevantes hoy como lo fueron siglos atrás. El objetivo del Observatorio Palomar es encontrar respuestas a estas y otras preguntas similares. Concebido hace casi un siglo, este observatorio, con su famoso Telescopio Hale, opera cada noche como institución de investigación, educación, e instrumentación. Mediante esta publicación, el lector conocerá a Palomar: el lugar, la tradición y la gente que lo hace especial, y aprenderá cómo participar en su misión.

THE OBSERVATORY AT A GLANCE

The Addison W. Greenway, Jr. Visitor Center

The 200-inch Alan Telescope

The 40-inch Samuel Oschin Telescope

The 60-inch Telescope

BEGINNINGS

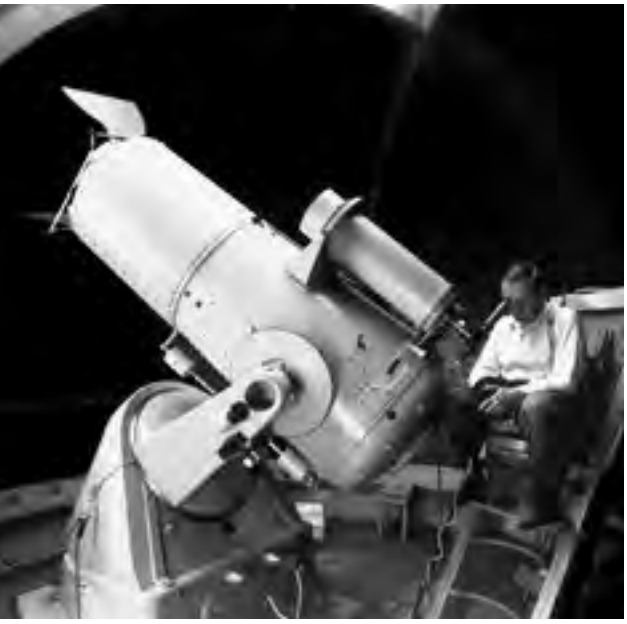
Palomar Observatory resulted from the vision of astronomer and Caltech founder George E. Hale, the man behind the largest telescopes in the world at the beginning of the 20th century. Relentlessly pursuing the creation of the next great astronomical instrument, in 1928 Hale secured Rockefeller Foundation sponsorship for the 200-inch telescope.

Against the backdrop of the Great Depression, preparations for the observatory site began in 1935. On the Caltech campus, the optical and instrument shops were established to support the grinding and polishing of the optics for the 200-inch telescope and the fabrication of auxiliary instruments. The first of the Palomar telescopes to become operational was the 18-inch Schmidt telescope, which saw first light in 1936. Given its immediate success, resources for building the larger 48-inch Schmidt were committed in 1937. Both Schmidts were fabricated by the Caltech and Mt. Wilson shops in Pasadena.

All aspects of building a 200-inch telescope required innovative methods and revolutionary technology—it was designed and engineered at Caltech and its structure fabricated by Westinghouse Electric and Manufacturing Company in Philadelphia. The giant Pyrex blank that would become the primary mirror was cast by Corning Glass Works in New York, arriving at Caltech in 1936 to be painstakingly figured into a nearly-perfect paraboloid.

Top: Polishing of the 200-inch mirror at the Caltech optical shop. (Palomar Observatory/Caltech) ‣ *Middle:* Fabrication of the fork assembly for the 48-inch Schmidt, now the Samuel Oschin Telescope, at the Caltech instrument shop, 1946. (Caltech Archives) ‣ *Bottom left:* Construction of the 200-inch telescope dome, 1937. (Palomar Observatory/Caltech) ‣ *Bottom right:* Guests seated on the observing floor during the dedication of Palomar Observatory and the Hale Telescope on June 3, 1948. Photograph by M. Montgomery. (Palomar Observatory/Caltech)

THE EARLY YEARS



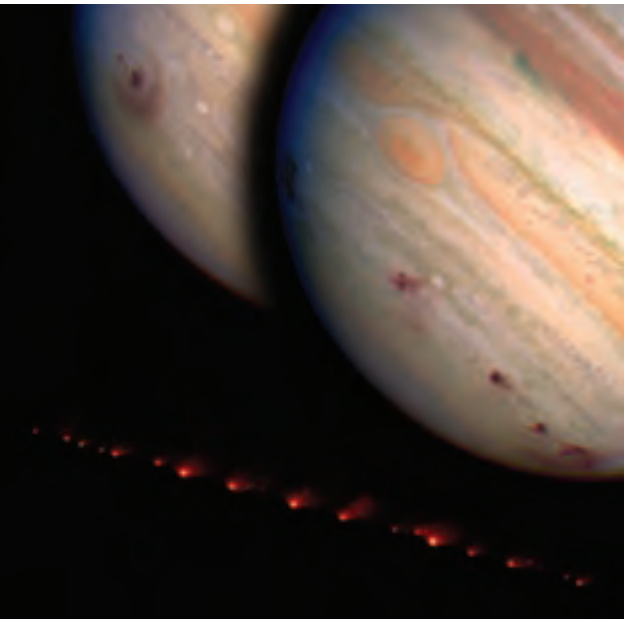
Although the 200-inch telescope was intended as the primary instrument of Palomar Observatory, the "Big Eye" was not the first telescope on the mountain. The 18-inch Schmidt telescope became operational in 1936 and was used primarily by Fritz Zwicky to search for luminous stellar explosions known as supernovae. A total of 19 supernovae were discovered with the 18-inch until World War II interrupted the search program in early 1942.

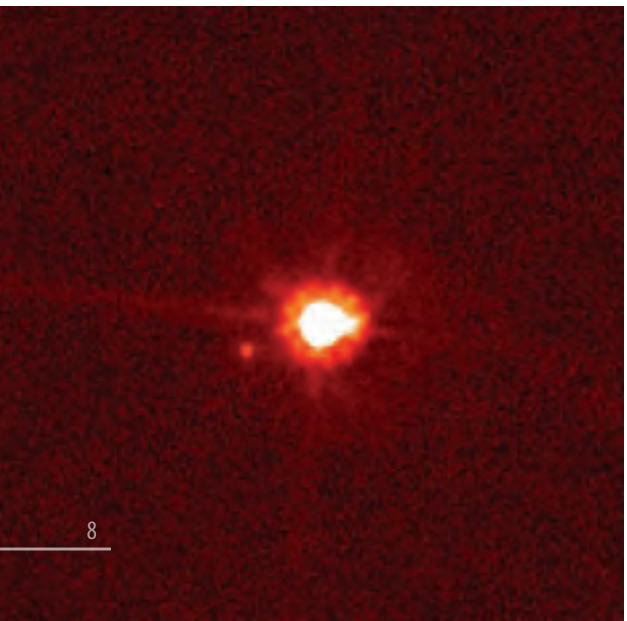
The fabrication of the 48-inch Schmidt was also halted during the war—it was not until 1948 that it took its first official photograph. The next year the 48-inch initiated the ambitious National Geographic Society–Palomar Observatory Sky Survey (POSS I)—a project that photographed the entire northern sky in two colors. POSS I became the standard library reference for every major observatory worldwide.

Once the Hale Telescope was ready for scientific use, Walter Baade turned it to the Andromeda Galaxy. He intended to separately resolve and study a type of variable star—a star that expands and contracts periodically—to use as a distance indicator to the neighboring galaxy. Baade's unsuccessful attempt led to a correction in previous distance estimates to Andromeda: the galaxy was twice as far away as previously thought. To an astronomer, the size of the

Top: Fritz Zwicky looks through the finderscope of the 18-inch Schmidt telescope, 1936. (Caltech Archives) ‣ *Middle:* Edwin Hubble at the guiding eyepiece of the 48-inch Schmidt telescope, 1949. (Caltech Archives) ‣ *Bottom left:* 1950 color image of the Hale Telescope dome in its original paint scheme. (Palomar Observatory/Caltech Archives) ‣ *Bottom right:* Striking image of the star-forming region in Orion obtained with the 200-inch Hale Telescope in 1959. (Caltech/CIW)

THE DIGITAL AGE





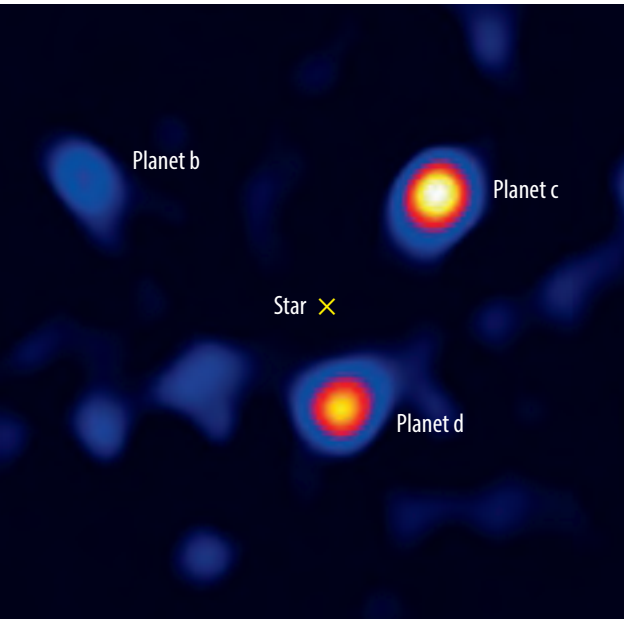
The modernization of Palomar Observatory began in 1971, when Edwin Dennison installed its first computer system. Starting in 1979 James Gunn, James Westphal, and collaborators developed a series of imaging instruments that used charge-coupled devices (CCDs) for the Hale Telescope. The superior efficiency of CCDs over photographic film substantially boosted the sensitivity and reach of the already formidable "Big Eye."

Nonetheless, the 18- and 48-inch (newly named Samuel Oschin) Schmidt telescopes continued using photographic methods to survey the heavens. The Oschin's surveys Quick V and the Second Palomar Observatory Sky Survey (POSS II), which served as bases for the Hubble Space Telescope's Guide Star Catalogs, were scanned and included in the Digitized Sky Survey. Containing a billion objects, POSS II yielded the identification of tens of thousands of galaxy clusters, hundreds of supernovae and quasars, and dozens of comets and asteroids. The 18-inch also produced a string of significant findings—between the 1970s and 1990s, Eleanor Helin, Eugene and Carolyn Shoemaker, and David Levy imaged and mapped hundreds of asteroids and nearly 50 comets, including the famous Comet Shoemaker-Levy 9.

The first brown dwarf ever to be indisputably confirmed, Gliese 229B, was discovered in 1994 by using the 60-inch telescope with a Johns Hopkins University coronagraph.

Top: Composite of the fragmented Comet Shoemaker-Levy 9 and Jupiter showing scars after impact, 1994. (NASA/ESA/STScI/MIT) ‣ *Middle:* Colorized image of the Andromeda Galaxy from the digitized POSS II. (DSS/C. Shahar) ‣ *Bottom left:* The dwarf planet Eris and its satellite Dysnomia. (NASA/ESA/M. Brown/Caltech) ‣ *Bottom right:* James Gunn (center), James Westphal (far right), and their team inside the Hale Telescope's Cassegrain cage with Four-Shooter, the prototype for the Hubble Space Telescope WFPC camera, c. 1984. (J. Gunn)

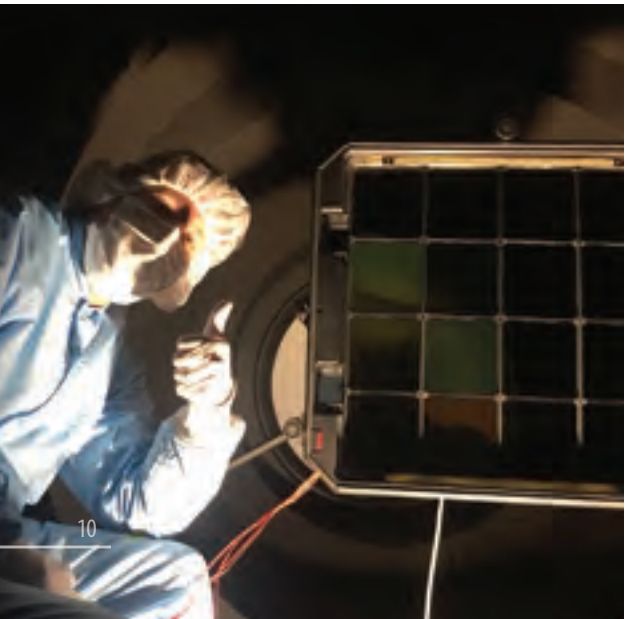
THE ENDLESS FRONTIER

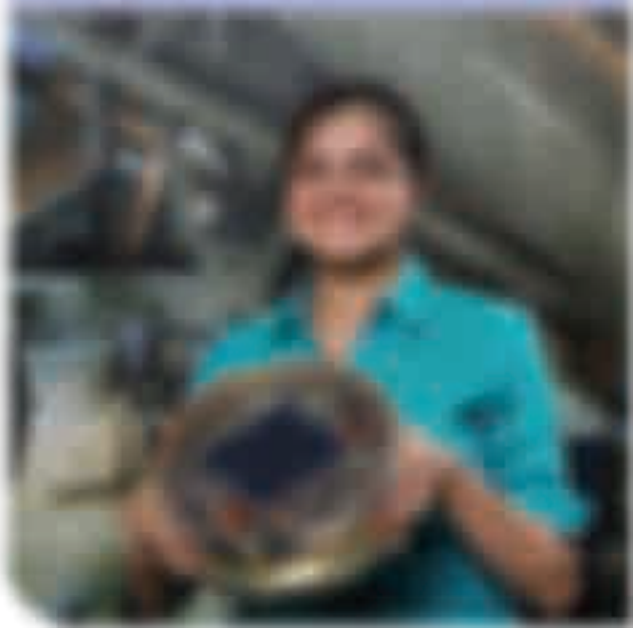


Innovation is critical to Palomar's success as a leading astronomical research center. One of the principal objectives of the observatory in the previous and current decades is to produce images of comparable precision to those of space telescopes. Scientific goals such as surface mapping of Solar System bodies and directly imaging close multiple stellar systems, young planetary disks, and extrasolar planets from the ground require technology capable of correcting for the blurring created by atmospheric turbulence. With this in mind, scientists and engineers from Caltech and associated institutions have developed superb adaptive optics (AO) equipment for the Palomar telescopes.

PALM-3000 is the AO system for the 200-inch Hale Telescope. The heart of the system is a deformable mirror with over 3000 actuators that rapidly change the mirror shape. The reflective surface is adjusted in real time, hundreds to thousands of times a second, to correct for atmospheric distortions—what causes the apparent twinkling of stars. These rapid corrections help to refocus starlight into sharp images. Richard Dekany and his team designed PALM-3000 to work in conjunction with other image-sharpening devices on the telescope, including high-resolution visible and near-infrared cameras, spectrographs, and specialized coronagraphs.

Top: The HR8799 planetary system—each of the three planets several times more massive than Jupiter—as observed by the Hale Telescope aided by a specialized coronagraph. (NASA/JPL/Caltech) ‣ *Middle:* The supernova SN2011fe in the Pinwheel Galaxy, M101, was discovered by PTF. (B. J. Fulton/LCOGT/Caltech) ‣ *Bottom left:* Engineer inside the Samuel Oschin Telescope tube during the installation of the ZTF camera, 2017. (COO/M. Feeney) ‣ *Bottom right:* The Samuel Oschin Telescope with the ZTF electronics cabinet. (COO/J. Belicki)





REFLECTIONS

In June 1948 the Palomar 200-inch telescope was dedicated as the Hale Telescope to posthumously recognize the extraordinary career of George Ellery Hale. Over a forty-year period Hale was the driving force in revolutionizing observational astronomy in the early 20th century, setting humankind firmly on a path to understanding its place in and connection to the universe. Hale's crowning achievement, the 200-inch telescope and dome, stood as a monument both to his vision, and to the dedication and commitment of hundreds of engineers, scientists, and builders in their long effort to complete the project against the backdrop of the Great Depression and World War II. That June day at Palomar President Lee DuBridge spoke on behalf of the Caltech Trustees in dedicating both Palomar Observatory as a whole, and its monumental centerpiece, to Hale's enduring legacy.

In the seventy years since the Hale's dedication, the telescope and its user communities have produced a record of seminal discoveries worthy of the namesake's legacy. From establishing observational cosmology as a viable discipline, to framing our knowledge of stellar populations, galactic structure and elemental evolution, to studying the broad diversity and architecture of the Solar System, the Hale (together with its sister telescope the Samuel Oschin Telescope) dominated observational astronomy in the second half of the 20th century. Such

Top: Observatory staff inspect the 200-inch mirror after recoating. (Palomar Observatory/ Caltech) ‣ *Middle:* Observatory staff and Caltech faculty, postdoctoral fellows, and students collaborate in the data room during an observing run with the Hale Telescope. (Caltech/ B. Youngblood) ‣ *Bottom left:* The Samuel Oschin Telescope dome scans the northern sky every clear night. (I. Arcavi) ‣ *Bottom right:* Engineer holds one of the three ZTF camera filters used in the Samuel Oschin Telescope. (Caltech Optical Observatories/J. Belicki)

THE PALOMAR COMMUNITY

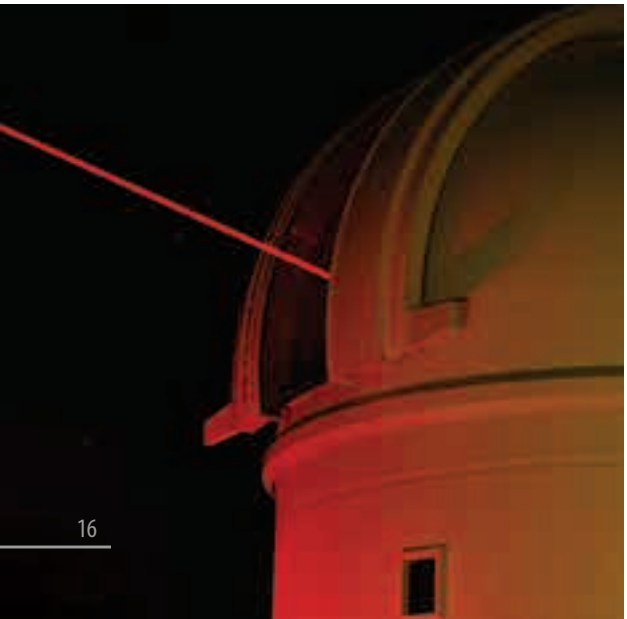
While visiting scientists stay as guests at the Monastery (observers' quarters) during observing runs, two dozen on-site staff call Palomar Observatory home. Palomar's family, the driving force behind the facility, is a team of administrative, technical, maintenance, service, and telescope support personnel that ensure smooth day-to-day operations and effective instrument performance.

Although primarily a research facility, Palomar maintains a vibrant outreach program to share its research mission and tradition with visitors and astronomy enthusiasts. Tens of thousands from all over the world come every year to see the iconic 200-inch Hale Telescope and its monumental dome. Visitors are welcome to explore the museum and pick up a souvenir at the Addison White Greenway, Jr. Visitor Center. The telescope itself can be viewed from the Visitors' Gallery inside the dome, up the stairs through the main entrance.

The observatory is honored to work with a group of knowledgeable and enthusiastic volunteer docents who offer guided tours during the weekends from April through October. The tours cover the history and current scientific research of the observatory, and include a memorable visit to the Hale Telescope dome interior.

Top: Small section of the Big Picture showing a group of galaxies known as Markarian's Chain, located in the core of the Virgo cluster of galaxies. (Palomar–QUEST Team/Caltech) ‣ *Middle:* Palomar Observatory docents outside the Outreach Center, 2018. (Palomar Observatory/Caltech) ‣ *Bottom left:* Asteroid Tukmit, Father Sky in the Luiseño language, discovered in 1991. (POSS II/Caltech) ‣ *Bottom right:* Palomar Observatory staff with the newly-coated 200-inch mirror, 2016. (Palomar Observatory/Caltech)

BECOME INVOLVED



Experience the Palomar tradition by visiting one of the most important astronomical facilities in the world. Palomar Observatory opens its doors to the public, weather permitting, most days of the year during daytime for self-guided tours of the Visitor Center and the 200-inch Hale Telescope Visitors' Gallery. For additional information including hours, driving directions, and docent-led weekend tours schedule, go to palomar.caltech.edu or call 760.742.2131.

Those who delight in astronomy and are interested in staying up-to-date on Palomar's scientific advancements may go a step further and join the organization Friends of Palomar Observatory. Membership benefits include invitations to events such as lectures by guest astronomers, special tours, and star parties at Palomar. The annual membership fees support the observatory's educational outreach program. For more information please visit friends.palomar.caltech.edu.

Palomar Observatory has greatly benefited over the years from major financial support from its patrons, as improving the instruments requires significant financial investments. Be involved in the effort to keep Palomar Observatory at the cutting-edge of astronomical research. For specific giving opportunities, please visit the Palomar Observatory webpage give.palomar.caltech.edu.

Top: Public solar viewing led by an observatory docent. (K. Searcy) ‣ *Middle:* Friends of Palomar star party on the observatory grounds. (Palomar Observatory/Caltech) ‣ *Bottom:* An ultraviolet laser, used to create an artificial star for focusing its camera system, emerges from the 60-inch telescope. (C. Baranec/Caltech) ‣ *Opposite:* Lupine wildflowers, a summer bloom on Palomar Mountain. (Palomar Observatory/Caltech) ‣ *Back cover:* Composite from a pastel by R. W. Porter, a black and white photograph, and a contemporary digital image. (Palomar Observatory/Caltech)

Participe

Visite una de las instituciones de astronomía más importantes del mundo. El Observatorio Palomar abre sus puertas al público casi todos los días del año para visitas diurnas. Información adicional se puede obtener llamando al teléfono 760.742.2131 o en palomar.caltech.edu. La organización Amigos de Palomar, friends.palomar.caltech.edu, cuyos beneficios incluyen invitaciones a eventos especiales como visitas guiadas y charlas dadas por astrónomos profesionales, fue establecida para quienes disfrutan de la astronomía y desean estar actualizados con respecto a los avances científicos hechos en Palomar. También puede participar mediante patrocinio monetario, necesario para asegurar que el Observatorio Palomar se mantenga a la vanguardia de la investigación astronómica, visitando give.palomar.caltech.edu.

Palomar Observatory dedication

70th anniversary edition

1948 ∽ 2018