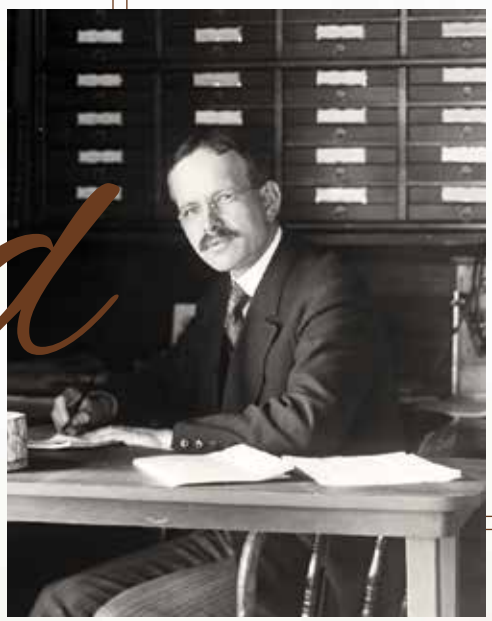
A Crowded Life

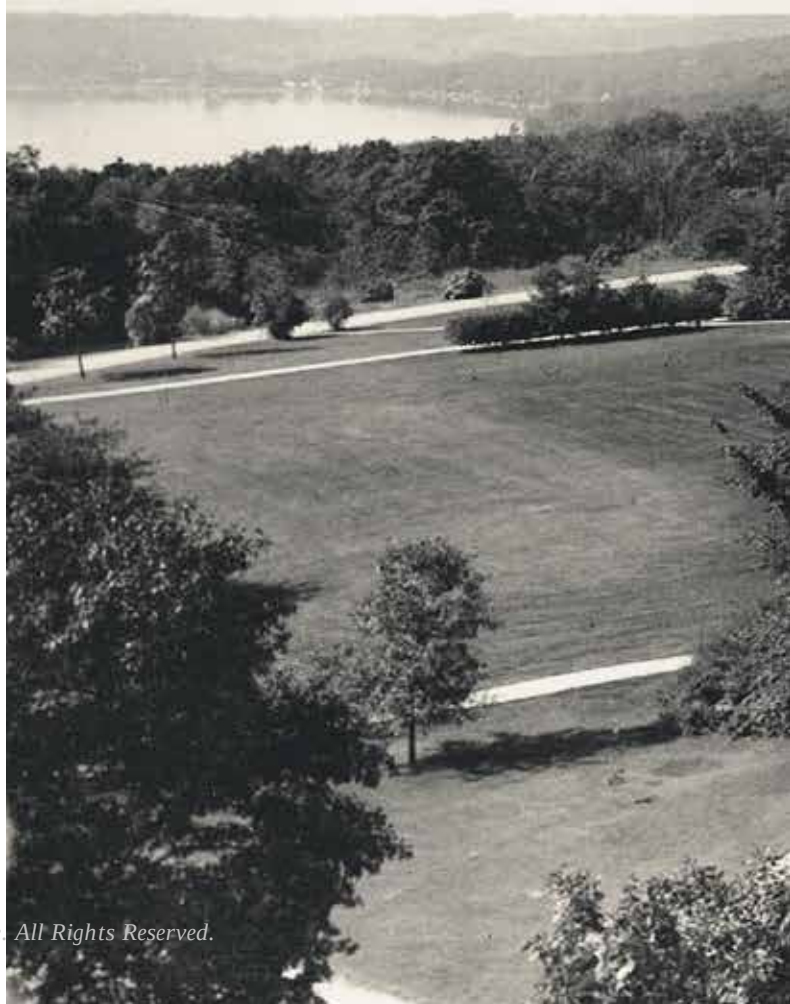
A curious mind and an inventive spirit helped George Ellery Hale transform modern astronomy.



▲ **ASTRONOMER AT WORK** George Hale poses at his desk in the "Monastery," the quarters of staff and visiting scientists at Mount Wilson Observatory.

"Palomar Observatory is my favorite mount-top in the world," says Mansi Kasliwal (Caltech). She and her students use spectra obtained with the observatory's 200-inch Hale Telescope to study optical and infrared transients — supernovae, gamma-ray bursts, and black holes feeding on stars. The big reflector was the last telescope developed by George Hale, a scientist who made pioneering discoveries about the Sun, gave astrophysics some of its most powerful tools, and helped to shape both national and international scholarly institutions. It was a crowded life, and one that transformed modern astronomy.

George Ellery Hale was born June 29, 1868, into a wealthy Chicago family that encouraged his science interests. Hale's father, William Ellery Hale, helped his son during his youth and through his early career, providing him with tools and instruments. Hale's mother, Mary Scranton (née Brown) Hale, encouraged his creative development, sharing with him works of poetry, literature, and history during his formative years. His interests were diverse, taking him from the woodworking shop and laboratory he built with his brother, to observing the Moon and planets with a 4-inch Clark refracting telescope mounted on the roof of the family home when Hale was 14, to informally studying architecture with the Chicago architect Daniel H. Burnham. His inquisitive nature, supported by a family that encouraged intellectual



▶ **IMPRESSIVE INVESTMENT** At the invitation of university president William R. Harper, George Ellery Hale joined the faculty of the University of Chicago in 1892. During the hiring negotiations, Hale extracted a promise from Harper that the university would build a new observatory and install a great refractor within three years of his appointment. This photograph, taken by Frank E. Ross in 1925, shows the end result of Hale's deal. Funded in large part by Chicago businessman Charles Yerkes, the Yerkes Observatory was dedicated in 1897, five years after Hale joined the university. The great dome still houses the 40-inch telescope, the world's largest refractor.

robustness, served Hale well as he grew and moved on to study at the collegiate level.

During Hale's student years at the Massachusetts Institute of Technology (MIT), he volunteered at the Harvard College Observatory. Edward Pickering, the observatory director, was an early believer in the "new" astronomy — studying the physical properties of stars rather than just their positions and movements — and their experience together likely influenced Hale's own ideas about the science. Hale's first technological contribution was the *spectroheliograph*, a device he invented to photograph the Sun at a single wavelength of light. With it, he determined that sunspots are vortices in the solar atmosphere, a discovery that formed the basis for his baccalaureate thesis.

Hale married two days after his graduation from MIT and, when he returned from his honeymoon, he set up a personal observatory at the family's Kenwood (Chicago) home with a 12-inch refractor, a gift from his father. He spent the next two years conducting research and teaching until he was recruited as a faculty member to the newly established University of Chicago in 1892. Hale wanted a bigger research telescope and hoped that the university might be a path to better equipment.

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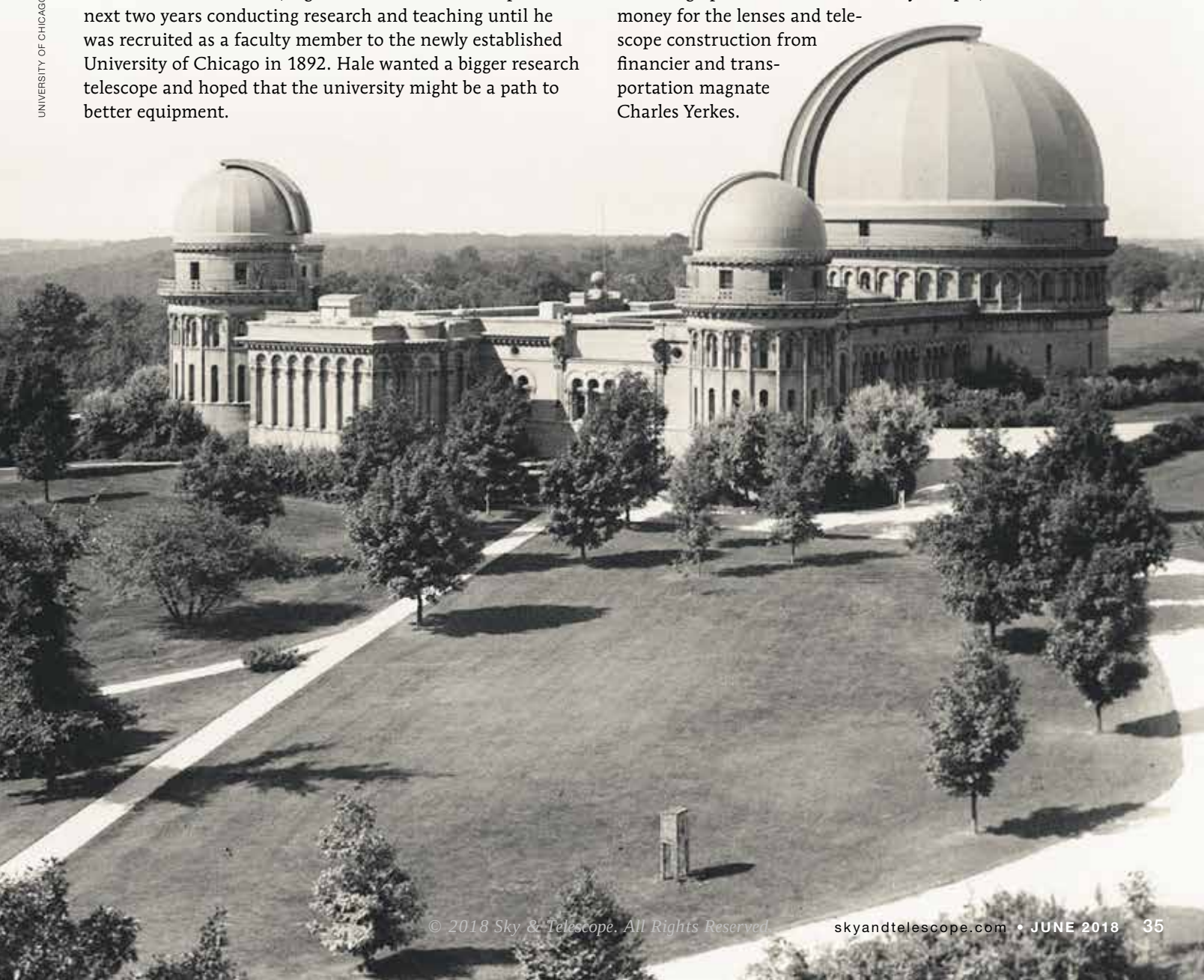
The same year he joined the University of Chicago, Hale addressed a meeting of the American Association for the Advancement of Science (AAAS) in New York, where he learned that the University of Southern California had ordered two 40-inch lenses for a new telescope on Mount Wilson, California, but had been unable to complete payment on them. Hale instantly went to work on a plan to bring the lenses to the Midwest. With the help of University of Chicago president William Rainey Harper, Hale obtained money for the lenses and telescope construction from financier and transportation magnate Charles Yerkes.



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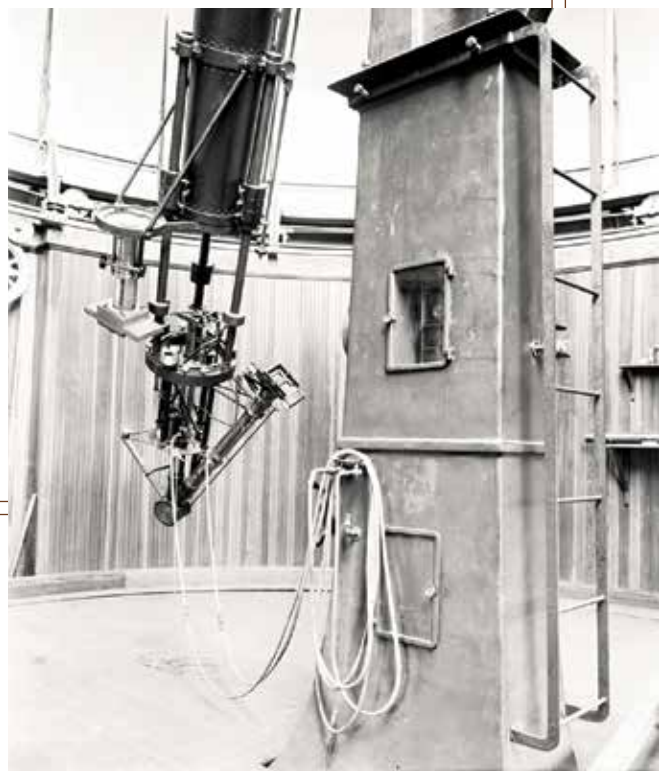

◀ **SOLAR STUDY** As part of the terms of his employment, Hale agreed to cede his own Kenwood Observatory, complete with 12-inch refractor, to the University of Chicago. This photograph, taken in the 1890s, shows Hale's spectroheliograph attached to the refractor.

Hale appealed to Yerkes' ego by assuring him that his name would be on the largest refractor in the world. Displaying what would become lifelong confidence in his own plans, Hale began hiring a technical staff even before his financial support was confirmed.

Yerkes Observatory was established in 1897 in the village of Williams Bay on the north side of Geneva Lake, Wisconsin. To realize Hale's vision of "laboratories for optical, spectroscopic, and chemical work," an approach that would be repeated on Mount Wilson, the observatory was designed as more than a conventional telescope-and-dome facility. It was the ability to test chemical and physical processes in the laboratory, and to compare them with stellar observations, that eventually enabled so many of the astrophysics discoveries made with Hale's telescopes.

Hale's satisfaction with the new telescope only lasted a few years, however. Soon, he was planning for yet bigger instruments. More light-gathering capability was necessary for increased spectral line dispersion and a better chance of identifying chemical elements. By this time, Hale also shared the view of many astronomers that refractor telescopes had reached their practical limit, and that only reflectors could provide the apertures required for better spectroscopy. In 1894, William Hale had donated a 60-inch glass disk to the university to support his son's aspirations. He had urged the institution to provide a mounting for it as well, but the university had refused. While the elder Hale was still inclined to fund the entire effort, he died in 1898 and the disk was put into storage.

George Hale saw an opportunity again in 1902 when the Carnegie Institution of Washington was established with a $10 million gift from Andrew Carnegie. Hale was one of the original advisors to the philanthropic organization, which was intended to fund pure research projects. In June 1903, Hale tested the solar seeing at Mount Wilson. Pleased with his observations, he applied to the Carnegie Institution to finance a solar observatory on the mountain. When his proposal for a 60-foot solar observatory won approval from the institution, it was time to move to California. "I doubt that he ever intended to stay in Wisconsin permanently," says Dan Koehler (Yerkes Observatory). "For Hale, Williams Bay was no competition to Pasadena."

▲ **HANDLE WITH CARE** The mounting and tube of the 40-inch refractor manufactured by Warner & Swasey Company were displayed at the Columbian Exposition of 1893 in Chicago before being installed in Yerkes Observatory. The telescope housing was put in place in the observatory in 1896. This image, taken in November of that year, shows construction workers hoisting the polar axis to the top of the mount.

It All Comes Together

The initial Carnegie message of approval didn't commit funds to the Mount Wilson project. Hale nevertheless moved west in December 1903, using his own money and family loans. He had the Snow Solar Telescope shipped to Mount Wilson on loan from Yerkes and spent the winter setting it up. (He would later add a 60-foot and a 150-foot solar telescope — the

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largest in the world until 1962 — to the observatory's instruments.) He signed a 99-year lease for the observatory land in June 1904 and commenced moving his Yerkes colleagues to California. His confidence was again rewarded in December of that year when he finally received the Carnegie funding message. Hale resigned from Yerkes Observatory two weeks later.

1908 was a big year on Mount Wilson. Hale used a modified spectroheliograph to show that sunspots were magnetic, the first time that magnetic fields were identified on an extraterrestrial body. Later work would yield the Hale-Nicholson Law, which states that magnetic polarities in sunspots are symmetric across the solar equator and that polarities in each hemisphere switch from one sunspot cycle to the next — phenomena that are still being investigated today (*S&T:* Jan. 2018, p. 18).

> Hale was the ultimate networking specialist at a time when networking wasn't even a concept.

The 60-inch mirror that might have earlier found a home at Yerkes was installed in its telescope mount in December 1908 after four years of grinding and figuring by Hale's chief optical engineer, George Ritchey. It was the first major telescope to use a *coudé focus*, which sent light to a point outside the telescope, allowing astronomers to change instruments without disturbing the telescope's tracking. The design also featured a mercury-filled bearing system that supported 95% of the structure's weight. Successful operation of the 60-inch telescope effectively marked the end of refractors for research.

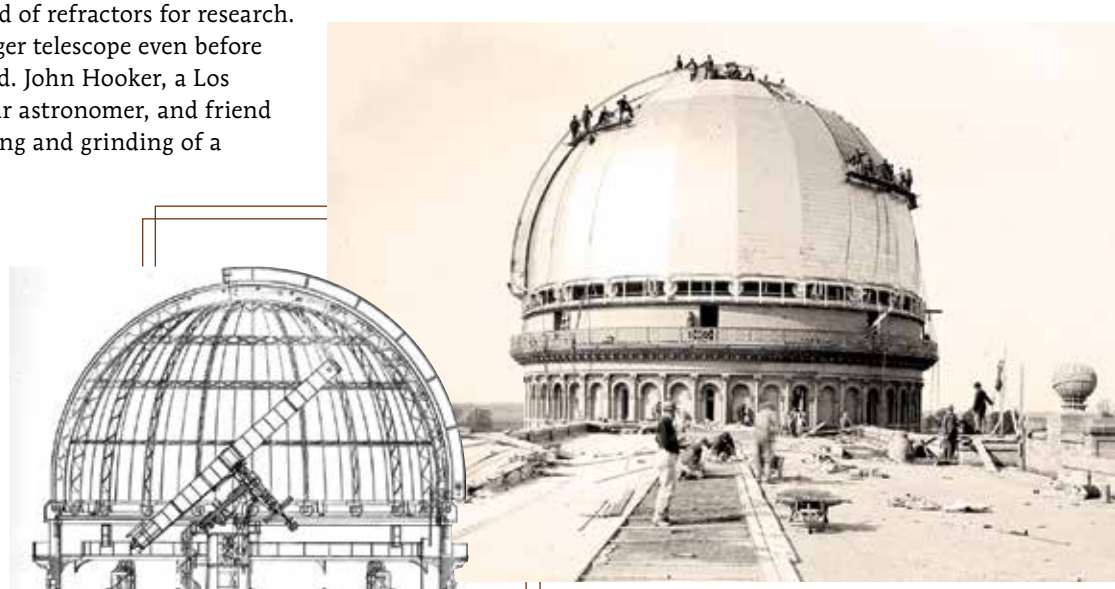
But Hale was planning for a bigger telescope even before the 60-inch reflector was completed. John Hooker, a Los Angeles business executive, amateur astronomer, and friend to Hale, offered to pay for the casting and grinding of a 100-inch disk, with the understanding that it would be the biggest telescope in the world and would be named after him. It was a risky commitment, as the 60-inch telescope hadn't yet been fully checked out, but Hale pressed forward in September 1906 with a disk order to the Saint-Gobain glassworks, the French company that had cast the 60-inch disk and the only operation willing to attempt a bigger one.

The first disk looked like a failure. It contained air bubbles, and Ritchey doubted it would withstand grinding and polishing. Saint-Gobain tried again with new methods and equipment, but without success. In desperation, Hale gambled that the original disk was salvageable and decided to have it completed over Ritchey's strong objections. The mirror was finished after seven years but, given their tensions over the mirror, so was the relationship between Hale and Ritchey (*S&T:* Oct. 2016, p. 66).

As before, Hale began the project boldly, but without sufficient financing: Hooker's money wouldn't cover critical components like the mount and housing, and other engineering difficulties raised the total price. Eventually, Hale had to convince Andrew Carnegie to supply another $10 million via the Carnegie Institution to complete the work.

First light for the 100-inch on November 1, 1917, came with some suspense. Several hours were needed for the mirror to adjust to ambient temperatures. Once the mirror had stabilized, however, it showed its true potential, and attendees realized that Hale had produced another "world's largest telescope."

Some of the most important work of 20th-century astronomy happened inside the Hooker dome on Mount Wilson. Edwin Hubble determined that Andromeda was a galaxy outside our own by measuring distances to Cepheid variables and established that the universe was expanding. A. A. Michelson used a 20-foot interferometer to make the first measurement of a star's diameter. Fritz Zwicky determined that the gravi-



▲ **TOPPING IT OFF** The great dome of Yerkes Observatory was tinned and cemented in the autumn of 1896.

◀ **MAKING PLANS** Telescope makers Warner & Swasey Company included this drawing of the Yerkes Observatory's 40-inch scope, 90-foot great dome, and 75-foot elevating floor in a 1900 circular describing their latest work.

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tational mass of galaxy clusters was far greater than expected from their luminosity, offering an early hint of dark matter. Walter Baade identified two types of Cepheid variables and, with that discovery, doubled the size of the universe calculated by Hubble.

The Hooker remained the world's largest telescope until 1949, when Hale beat his own record on Mount Palomar.

A "Type A" Astronomer

Hale's industriousness affected science far beyond the construction of telescopes. While still at the University of Chicago he founded *The Astrophysical Journal* with James Keeler in 1895, and he was a major driver in establishing the American Astronomical Society in 1899. In 1904 he founded the International Union for Cooperation in Solar Research, which later became the International Astronomical Union, and he played a major role in transforming the Throop Polytechnic Institute into the California Institute of Technology. In 1916, he was instrumental in creating the National Research Council to harness scientific expertise for national needs.

▼ **SUN SPOTTING** The Snow horizontal telescope (coelostat) was a gift to Yerkes Observatory from Helen E. Snow in memory of her father, George W. Snow. Hale transported the instrument to California in 1904 to make solar observations. The scope had a 60-foot (18-meter) focal length so was housed in a long building, next to which was built the 60-foot solar tower.

"I've been struck by the huge number of scientists living at the time that Hale corresponded with and knew personally. He was the ultimate networking specialist at a time when networking wasn't even a concept," says Koehler.

Over time, the frenetic pace took a toll. Hale had long suffered from headaches and bouts of depression. Worsening symptoms led to nervous breakdowns serious enough to make him decline meetings and spend repeated periods in sanitariums. Weakened by ill health, Hale resigned as director of the Mount Wilson Observatory in 1923. The next year, he built a small solar laboratory in Pasadena, where he did much of his scientific writing and planned for his next big telescope.

Hale was aware that light pollution from greater Los Angeles was a growing problem for Mount Wilson, and in 1928 he opened a new chapter in astronomy farther south in California with a $6 million award from the Rockefeller Foundation. His initial ambition was to build a 300-inch telescope on Palomar Mountain, north of San Diego. After being convinced that it would be too difficult to construct, however, he scaled his design back to 200 inches. Regrettably, the enterprise would stretch a decade beyond his life. Hale died on February 21, 1938, at a sanitarium, where he had been admitted a few months earlier after a stroke. He was 69 years old.

Sponsors named the new reflector at Palomar Observatory in his honor at its 1948

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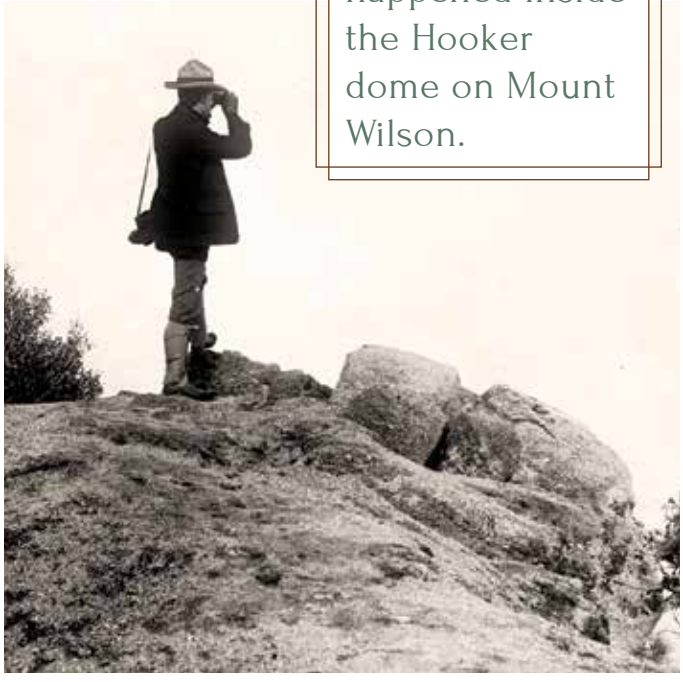
▼ **MAN ON A MISSION** George Hale takes in the view from Mount Wilson, c. 1904.



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◀ **RECORD BREAKER** Mount Wilson's 60-inch scope saw first light on December 13, 1908. It was the world's largest functional telescope until the completion of the observatory's 100-inch scope in 1917.

▼ **HUMANS FOR SCALE** Two (unidentified) men stand on the unpolished 200-inch Pyrex mirror disk made by Corning Glass Works for the Hale Telescope at Palomar Observatory.

▼▼ **GIGANTIC GLASS** The 200-inch Hale Telescope dwarfed the crowd that gathered at Palomar Observatory on the occasion of the telescope's dedication on June 3, 1948.

60-INCH SCOPE: DENNIS DI CICCO / *S&T*; MIRROR DISK: UNIVERSITY OF CHICAGO / YERKES OBSERVATORY; 200-INCH TELESCOPE: PALOMAR OBSERVATORY / CALTECH

dedication ceremony. The Hale Telescope saw first light in January 1949, and Edwin Hubble was the first astronomer to use it. With four times the light-gathering power of the Hooker, it remained the largest telescope in the world until 1975, when the Russian BTA-6 telescope (238 inches, or 6 meters) saw first light. Because the BTA-6 suffered from several design problems, however, many astronomers extend the Hale record to 1993 when the Keck Telescope began operation.

Time ultimately caught up with the telescopes at Williams Bay and Mount Wilson. The 40-inch refractor at Yerkes Observatory transitioned to a teaching tool after 1990; the observatory is scheduled to close permanently in October 2018. The last research project on the 60-inch Mount Wilson telescope ended in the mid-1990s. Although the Hooker Telescope was retired in 2015, Mount Wilson Observatory celebrated the famous reflector on November 1, 2017, the date of its centennial. Viewing opportunities through both telescopes on Mount Wilson are now available to the public (*S&T:* Sept. 2016, p. 22).

◀ **MR. MONEYBAGS** Andrew Carnegie's money played a pivotal role in the construction of Mount Wilson, funding the construction of Hale's dreams via the Carnegie Institution of Washington. This photo shows Hale and Carnegie in front of the steel dome of the 60-inch telescope, c. 1910.

Of all Hale's telescopes, only the 200-inch reflector is still used for research. Mansi Kasliwal has been working with it since she was a student at Caltech. "When you enter the main dome for the first time," she says, "you feel a part of something much bigger. You get a feeling of awe and inspiration and history that really leaves an impression. If you're a young student, it can change your life."

■ **STEVE MURRAY** is a freelance science and technology writer who stargazes from his home in San Diego, California. He'll travel anywhere to explore new observatories.

George Hale's Telescopes Today

All of Hale's telescopes are open for public visits at present. With the exception of the Hale reflector on Mount Wilson (still used for research), the observatories offer opportunities to stargaze through them, too.

Yerkes Observatory (https://is.gd/yerkes): The University of Chicago recently announced plans to close Yerkes Observatory. In the meantime, scheduled public tours are offered Monday–Saturday and are the only way to see the building interior and the 40-inch refractor. There's a nominal charge for the tour. Private group tours can be arranged on request. Because of its dated architecture, the building isn't handicapped accessible.

Public observing with the 40-inch refractor and 24-inch reflector (used by George Ritchey to test his design concepts) is offered monthly at selected times, weather permitting.

This Memorial Day weekend, Yerkes Observatory will host Starlight 2018, an event tied to Hale's 150th birthday. Speakers from Mount Wilson, Palomar, and Caltech have been invited to participate in the free event.

Mount Wilson Observatory (https://is.gd/mtwilson): Grounds are open daily, weather permitting. Two-hour docent-led tours are offered on weekends between April 1st and November 30th, with one-hour tours added between June and August. Private group tours are available with advance registration. There's a nominal charge for the tour. Visitors are free to take a self-guided tour with downloadable guide. Distances and hilly terrain limit access for individuals with health or mobility concerns.

In keeping with Mount Wilson's history of solar astronomy, free solar viewing is available to the public on weekends.

The famous 60-inch and 100-inch telescopes can be rented by groups for half- or full-night viewing sessions. The observatory also sets aside a number of ticketed evenings throughout the year for stargazing by individuals.

In honor of Hale's 150th birthday, Mount Wilson Observatory has planned a range of celebrations, beginning in May. Events include a photographic retrospective, a lecture series, a concert series in the 100-inch dome, and weekend open house activities with free nighttime observing (July or August).

Palomar Observatory (https://is.gd/palomar): Observatory grounds are open to the public daily, weather permitting, except December 24–25 and during some maintenance operations. Visitors can tour public areas on their own or participate in one-hour guided tours of the Hale Telescope on weekends, spring through fall. There's a nominal charge for tours, but they're free for youth and student groups. Some areas — including the Hale Telescope dome — are not accessible to mobility-impaired visitors.

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