FALL . QUARTER / SEPTEMBER . 2017

REFLECTIONS

THE UNIVERSE EXPANDED HERE

The Diffraction Gratings Laboratory

by **ROBERT ANDERSON**

> "Engines" capable of ruling hundreds of thousands of straight, parallel, equally spaced grooves within tolerances of only a few angstroms have led to advances in fields as different as quantum mechanics and astrophysics. — From the introduction to "Diffraction Gratings at the Mount Wilson Observatory" by H. W. Babcock, *Physics Today*, July 1986.

In the subbasement of the Mount Wilson Observatory offices in Pasadena (now headquarters of Carnegie Observatories) rest two marvels of 20th-century technology: Ruling Engine "A" and Ruling Engine "B." Astronomer Allan Sandage compared the two machines to Egyptian sarcophagi hidden away and preserved in separate burial chambers. A bank calendar on the wall, frozen on March 1964, records when the operators set down their tools and oil cans for the last time.

Built with the highest precision available at the time, the machines' sole purpose was to lightly draw a diamond across a reflective metal plate about a half-foot square, making a hundred thousand or more perfectly parallel grooves. The result was a diffraction grating, an optical surface that, like a prism, spreads light into all its wavelengths for analysis — but in many ways better. Diffraction gratings have been critical to numerous scientific discoveries, especially in astrophysics and quantum mechanics. Perhaps with a little bias, George R. Harrison, a pioneering designer of ruling engines at MIT, claimed "No single tool has contributed more to the progress of modern physics than the diffraction grating." And for decades, the best in the world came from Carnegie's subbasement.

TOOLS OF THE TRADE

The genius of George Ellery Hale, founder of Mount Wilson Observatory, was that he foresaw exactly what tools would be needed to advance astrophysics. Only in his mid-teens, he recognized the critical importance of diffraction gratings to spectroscopy, a subject that was already the focus of his tremendous ability and ambition. He was fascinated with all that could be learned from the dark absorption lines seen in the spectra of the Sun, each produced by a specific element. He knew that prisms have many shortcomings for dispersing light into a spectrum. They bend light by refraction, as it passes between mediums with different light-propagating speeds — like air to glass. Precious light is lost in reflections at the surfaces and absorption by the glass,

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A NUMBER OF GRATINGS, protected in their cases, are now retired and stored near the machines that made them at the Carnegie Observatories in Pasadena.

In this issue ...

ANNOUNCEMENTS

Mount Wilson Observatory Welcomes Visitors

Weather and roads permitting, Mount Wilson Observatory is open to the public every day for the season (through November). Come on up to the mountain to enjoy the beautiful weather and uplifting surroundings! The Cosmic Café is open Saturdays and Sundays, 10 A.M. to 5 P.M., offering a variety of freshly made sandwiches and other treats, as well as Observatory souvenirs. At the café you may purchase a National Forest Adventure Pass and tickets for the weekend walking tours. The Cosmic Café is located in the Pavilion overlooking the large parking lot at the entrance to the Observatory. We will see you at the top!

VISIT THE OBSERVATORY

ALL WELCOME

ABOUT US

The Mount Wilson Institute operates Mount Wilson Observatory on behalf of the Carnegie Institution for Science. Mount Wilson Institute is dedicated to preserving the Observatory for scientific research and fostering public appreciation of the historic cultural heritage of the Observatory. *Reflections* is published quarterly by the Mount Wilson Institute.

INFORMATION

For information about the Observatory, including status, activities, tours, and reserving 60-inch and 100-inch telescope time, visit our website — *www.mtwilson.edu.*

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For the use of historical photographs of Mount Wilson, we thank the Observatories of the Carnegie Institution for Science, the Huntington Library, and other sources as noted.

PAGE ONE BANNER PHOTOGRAPHS

X-rays stream off the Sun in this image by NASA's Nuclear Spectroscopic Telescope Array overlaid on an image by the Solar Dynamics Observatory. (Inset) Edwin Hubble at the Newtonian focus of the 100-inch telescope on Mount Wilson, circa 1923.

NEWS + NOTES

THE 2017 SOLAR ECLIPSE AT MOUNT WILSON

The Observatory welcomed more than a thousand visitors to view the August 21 partial eclipse. Donations and purchases from that day will help to maintain the Observatory for education, tours, telescope rentals, and free astronomical events for the public. Visitors were able to view the image of the eclipsing Sun as well as sunspots in the observing room of the 150-foot solar telescope; a live image was projected inside the auditorium from the Observatory's Lunt solar telescope (available for solar viewing each weekend); and of course there was eclipse viewing through solar glasses, whether brought by visitors or provided by the Observatory. (Photo by Chuck Hughes)

"WE CALL LOSS OF SIGNAL."

The Cassini spacecraft ended its 13-year tour of the Saturn system with a deliberately orchestrated plunge at ~77,000 mph into the planet's atmosphere — the Grand Finale, as it was called. The spacecraft began to tumble and cease communications at 3:31 A.M. local time on September 15; loss of signal on Earth was called by spacecraft operations team manager Julie Webster at 4:55 A.M. Information, images, etc. — *saturn.jpl.nasa.gov/grandfinale*.

CARNEGIE OBSERVATORIES OPEN HOUSE

Carnegie Observatories will hold its 16th annual open house on Sunday, October 15 from 2:00 to 5:00 P.M. For information, visit their website — *obs.carnegiescience.edu/*.

PASADENA'S ASTRONOMY WEEK

Last year's Astronomy Week was a great success, with an open house at Mount Wilson. We plan to do a similar evening this year. Details to come on our website — *www.mtwilson.edu*.

CENTENNIAL OF THE 100-INCH TELESCOPE

On November 2, 2017, the 100-inch telescope turns 100. We have three special events planned for the 100-inch centennial (this is preliminary information, so be sure to check our website for updates):

October 28 • Staff and Alumni Night — For past and current operators, superintendents, technicians, and others associated with the management and operation of the 100-inch telescope.

November 1 • First Light Night — Directors of the Carnegie Institution for Science; Directors of the Mount Wilson Institute; federal, state, and county representatives are invited. Speakers will include Sam Hale (Mount Wilson Institute Trustee and CEO) and John Mulchaey (Carnegie Observatories).

November 4 • Public Ticket Night — Free observing for up to 300 people to be reserved though an on-line ticket system.

Help Sustain the Observatory

The Observatory receives no continuing state, institutional, or federal support. We rely on donors, a few small grants, and the revenue from the Cosmic Café and our telescope nights to fund our continued operation. You can help ensure the continued operation of this science heritage site with your tax-deductible gift. We welcome donations of any size and volunteer efforts of all kinds. Visit *www.mtwilson.edu* for information on how to support the Observatory through donations or volunteering.

First Light Doubts on Mount Wilson

by **DON NICHOLSON** *and* **BOB EKLUND**

This account appeared in the July 1995 issue of *Sky & Telescope* and was featured in the November 1999 issue of *Reflections*.

On the evening of November 2, 1917,* six astronomers, 12 technicians and workers, and a poet gathered in the dome of the 100-inch Hooker telescope atop Mount Wilson in California. They wanted to see whether this, the world's largest telescope, would live up to its promise. The poet, Alfred Noyes, was so inspired by the experience that he later wrote his epic poem, "Watchers of the Sky." Since that night, much has been written about the circumstances leading up to the poem, but little about the event itself.

Curiously, no log was kept of the activities involving "first light." Wendell Hoge later began the telescope log with a list of those in attendance that night:

• George E. Hale • Walter S. Adams • George W. Ritchey • Francis G. Pease • Ferdinand Ellerman • Alfred H. Joy • Clement Jacomini (instrument maker) • James Dalton (optician) • Gardner Sherburne (machinist in charge of erection) • Merritt C. Dowd (electrician) • Mr. Howell (machinist) • M. Webb (carpenter) • J. E. Kimple (carpenter) • Mr. Boshardt (machinist) • A. D. Young (machinist) • Herman Seifert (iron worker) • Roy Desmond (helper) • Wendell P. Hoge (night assistant, 60-inch) • Alfred Noyes (poet).

It is evident from the recorded occupations that work on the telescope was not yet complete. Pease's notes and Mount Wilson Observatory's annual reports for 1918 and 1919 show that the Newtonian flat and cage were not finished until 1919, so any observations must have been made at the Cassegrain focus. Joy's memoirs written some 30 years later confirm this assumption.

The only record we found of the sequence of events occurring at first light is in a paper written in 1947 by Walter Adams and published by the Astronomical Society of the Pacific. Adams says that the telescope was first turned to Jupiter, but the image Hale and then Adams saw was so poor they feared Ritchey must have been right about the [compromised] quality of the mirror.

Up there, I knew
The explorers of the sky, the pioneers
Of science, now made ready to attack
That darkness once again,
  and win new worlds.
Tomorrow night they hoped
to crown the toil
Of twenty years....
And, even now, some secret
flaw — none knew
Until tomorrow's test — might waste
it all. Where was the gambler that
would stake so much, —
Time, patience, treasure, on a
single throw?

— Alfred Noyes,
"Watchers of the Sky"

Someone then explained that the dome had been open much of the day and that the Sun might have been shining directly on the mirror. Nothing could be done but to wait until the mirror had cooled uniformly — a long process with such a massive disk. Occasional forays were made to the eyepiece, but the image seemed to improve only slightly, if at all. The principals then decided to retire for several hours. Adams recalls that he and Hale returned around 2:30 or 3:00 A.M. With Jupiter having moved too far to the west, they turned the telescope to Vega. Hale looked into the eyepiece and let out a cry of delight. The image was round and sharp — the telescope was a success.

It is this story that has become a part of the history of the venerable 100-inch telescope, for 30 years the world's largest and in many ways the most important astronomical instrument since Galileo's.

But for all the drama of this first night, many of you must be wondering: Vega at 2:30 A.M. in early November?! Either someone's memory was faulty or the calendars on Mount Wilson were askew. To try to resolve the dilemma, we turned to the U.S. Naval Observatory's Interactive Computer Ephemeris (ICE) to reconstruct the events of November 2–3, 1917. The table on page 7 lists the results.

Would Hale and Adams have tested a new telescope with an untried mirror and mount by tipping them at a large angle and looking through a long atmospheric path? Hale for one was no neophyte when it came to first light. He had done it on the largest telescope in

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* Editor's Note. Some uncertainty surrounds the date. Walter Adams gives the date of November 1, 1917, in his paper "Early Days at Mount Wilson," PASP, vol. 59, no. 351, December 1947. Helen Wright's *Explorer of the Universe: A Biography of George Ellery Hale* quotes Adams, "By the first of November everything was ready for the crucial test." She then quotes from Hale's diary: "Friday, November 2, 1917—With Alfred Noyes to Mountain. First observations with 100"—Jupiter, Moon, Saturn." Ronald Florence's *The Perfect Machine* simply refers to "that cold November night in 1917."

INSIDE THE CLIMATE-CONTROLLED BOOTH of Ruling Engine "A" as it looked in 1922. Master instrument maker Clement Jacomini focuses on the diffraction grating. Above it, a carriage moves back and fourth on twin rails, cutting a line with the diamond and then lifting it for the return stroke, about 10 times a minute. Meanwhile, after each stroke, the grating is advanced on its platform, as precisely as possible, by moving the gear on the left, which turns a screw an imperceptible amount.

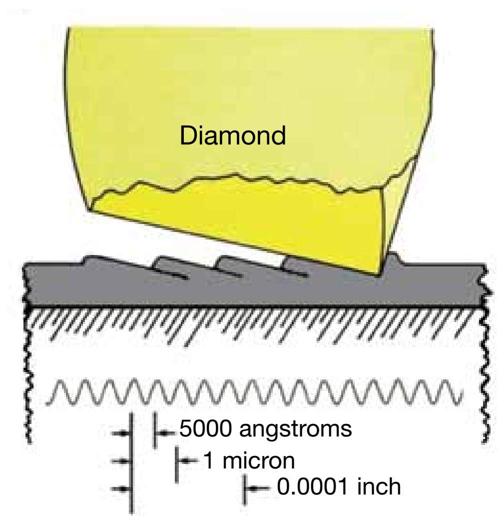
especially in the violet and ultraviolet. Inhomogeneities in the glass and temperature variations degrade the spectrum. And finally, variations of dispersion with wavelength in glass make precise measurements of the positions of spectral lines difficult.

The diffraction grating has none of these problems. Lightwaves are instead diffracted, or bent, as they interact with the grooves. It is like an ocean wave that is bent around a jetty. The accuracy of the spacing of the grooves has to be very precise, however — close to the length of the lightwaves. And very regular. Nature had already managed this feat in countless forms, such as the iridescent feathers of a hummingbird's throat. But for us, engineering on such a small scale was fantastically hard. The unequalled master of the technology in the late 1800s was Henry Rowland, a renowned physicist at Johns Hopkins University in Baltimore. His ruling engines were the world's main source of gratings for several decades.

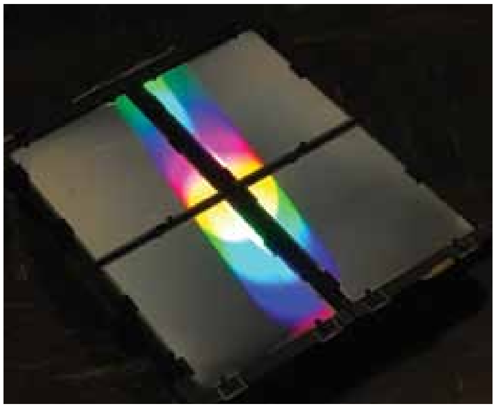
Hale bought his first grating at age 17. It was 1 inch square, ruled on speculum (a reflective alloy of tin and copper) by Rowland and sold through telescope maker John Brashear (who became a lifelong friend of Hale's). With experience, Hale learned that Rowland's gratings did not come close to their theoretical performance, and often were not as good as prisms for many purposes. They had limited resolving power, a function of poor quality and small size. They scattered too much light, wasting it. False lines, some called "Rowland ghosts," were caused by periodic errors in the line spacing. Nevertheless, Rowland's gratings were used by Hale for his first spectroheliograph and at Mount Wilson to discover magnetic fields around sunspots.

BIGGER, BETTER GRATINGS

When Rowland died in 1901, production of gratings ceased. In 1908, Nobel laureate physicist Albert Michelson stepped in and built a ruling engine at the University of Chicago, but it did not perform up to expectations. Nevertheless, a few of his gratings were used at Mount Wilson. By 1912, Hale decided he needed to do something to secure better, and hopefully bigger, diffraction gratings for the spectrographs for his telescopes. Larger gratings meant better resolution of the absorption lines, both for their positions and widths. In the plans for the new Mount Wilson Observatory's offices, he included a special room below the basement to house what became known as Ruling Engine "A." Carnegie funds were allotted to the effort. He invited physicist John Anderson on extended stays to advise on its construction. Anderson had recently revived and improved Rowland's machines at Johns Hopkins. In 1916, Anderson was hired permanently. Hale also recruited master instrument builder Clem- ▶



THE DIAMOND MOVES AWAY from the viewer, leaving a burnished groove in the thin layer of metal on the substrate. Somewhat like a plow cutting furrows in a field, the diamond completely reworks the original surface of the blank by plastic flow of the metal, creating the sawtoothed "blaze." For scale, the sine wave below represents the wavelengths of green light. For comparison, a typical human hair would be about 100 microns in diameter. Reproduced from *Physics Today,* July 1986, p. 37, with the permission of the American Institute of Physics.



THE FOUR PERFECTLY MATCHED GRATINGS used in the Palomar coudé spectrograph for 33 years. The gratings were set in a single mount to handle the wide light beam of the new 200-inch telescope on Palomar Mountain.

ent Jacomini from Italy to do the machining. Before "A" even started producing gratings, Hale promised one to physicist Robert Millikan (who needed one to advance his research in the ultraviolet) to lure him from the University of Chicago to the newly founded Caltech. Along with Millikan came Ira Bowen, who later became the first director of the combined Mount Wilson and Palomar Observatories. Mostly between 1920 and 1934, the "A" machine ruled some 85 gratings, many of which were used to make significant discoveries in astrophysics and atomic physics.

INNOVATION IN DIAMONDS

Of the many innovations that Anderson introduced with Ruling Engine "A," perhaps the most significant was the curved-edge diamond, which was far superior to the previous straight-edged, chisel-like points. The new shape was more durable, which was important because the diamond needed to cut 10 or more miles into each grating. The results were more predictable, and the carefully shaped diamonds were ideally suited to "blazing" the grating, giving the grooves a saw-toothed profile with just the right angle to concentrate the light in a particular wavelength and "order." (The light from a grating is projected in a series of orders, each one becoming progressively dimmer, but with greater dispersion to resolve the absorption lines.) With blazing, each grating could be tailor-made to fit the designed purpose of a spectrograph, for measuring solar magnetic fields or redshifts of distant galaxies, or for the specific needs of laboratory physics.

RULING ENGINE "B," with its much more rigid frame, was a great success. The small mirror mounted to the grating carriage and the optics to the left monitored the line spacing with great precision and made needed corrections as the machine operated.

In 1928, Anderson became the executive officer of the 200-inch telescope project at Palomar Mountain and Harold Babcock took charge of the gratings effort. The original ruling engine had been built to make the largest gratings yet. But in this case, Hale overreached. "A" had too much flex in its large frame. This would affect movement of the main screw and thus the spacing of the lines. Floating the machine on mercury helped greatly, but it was still not good enough. And friction was a problem. From 1929 to 1934, the more compact Ruling Engine "B" was designed and built with the help of Francis Pease, Clement Jacomini, Elmer Prall, and Edgar Nichols. Many innovations were incorporated to reduce each source of error. More attention was given to maintaining a constant temperature around the machine — to within a tenth of degree Celsius. To remove stresses in the frame, it was thermally cycled for two years. Exotic materials were used. Parts made of nitralloy, a low-stress steel, could be hardened to reduce wear. Graphitar was used to reduce friction on the rails. A monorail was adopted for the diamond carriage, and a new mechanism was designed to advance the grating after each stroke. The diamond moved in repeated straight lines for hundreds of thousands of grooves with a tolerance of only a few angstroms — it was one of the first nanotechnologies.

HAROLD BABCOCK'S NEW PROCESS

Instead of forming grooves in hard speculum, Harold Babcock took advantage of a new process for depositing a thin layer of softer aluminum on glass, developed by John Strong at Caltech in the mid 1930s. This, and curved diamond points for blazing, increased the efficiency of the gratings to the point where they replaced all prisms in Mount Wilson spectrographs, resulting in improved resolving power, speed,

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and thermal stability. A year beyond retirement, Harold stayed on to make perhaps the most challenging diffraction grating yet, a set of four perfectly matched ones combined in a special mount to handle the wide light beam of the new 200-inch telescope. It served well for 33 years in the Palomar coudé spectrograph.

Harold's son Horace Babcock took over the ruling engines in 1949, with Elmer Prall, then Oscar Swanson, and then Morton Roberts serving as technicians. In the 1950s, George R. Harrison's spectroscopy lab at MIT succeeded in using interferometry to monitor the spacing of the lines and correct it during the ruling, resulting in much better gratings. This feedback control was added to Ruling Engine "B" in 1959 with another leap in quality.

THE RULING ENGINE LAB IS CLOSED — 1963

When Horace Babcock was appointed director of the Palomar Observatory (1964 to 1978), the decision was made to shutter the ruling engine lab. It was producing nearly flawless gratings but others in the commercial sector were getting involved. Some 300 gratings had been made, and like Carnegie's libraries, were widely distributed at cost to the users. In Horace's 1986 *Physics Today* article, he gives a summary of some of the many discoveries made possible by Mount Wilson diffraction gratings — too many to list here. But one in particular would have greatly pleased Hale. In 1952, the two Babcocks, using one of their larger gratings, built the first solar magnetograph at the Hale Solar Laboratory in Pasadena. With it they soon found the first convincing evidence for a weak general magnetic field of the Sun, a goal that had eluded Hale.

HAROLD AND HORACE BABCOCK standing in from of the Hale Solar Laboratory in Pasadena in 1964. Photo courtesy of Larry Webster.

About the Author

Robert Anderson is the webmaster for Mount Wilson Observatory's website — *www.mtwilson.edu*

SPECIAL THANKS to Larry Webster, CHARA site manager and Mount Wilson Institute Trustee, for his help in researching this article. Thanks to Bruce Reutlinger for the photos not credited.

Sources:

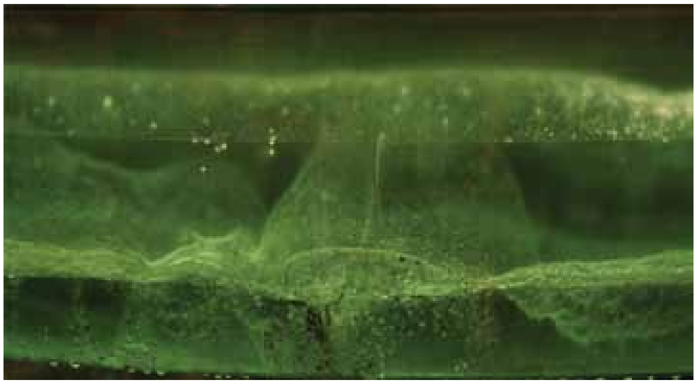
Babcock, Horace W., "Diffraction Gratings at the Mount Wilson Observatory," *Physics Today*, Volume 39, Issue 7, July 1986, pp. 34–50.

Babcock, Harold D. and Babcock, Horace W.,"The Ruling of Diffraction Gratings at Mount Wilson Observatory," *Journal of the Optical Society of America*, Volume 41, Number 11, November 1951, pp. 776–786.

Some of the institutions receiving gratings (produced by Ruling Engine "B") from Carnegie Observatories included: McDonald Observatory, Texas, 82-inch telescope, prime-focus spectrograph; Palomar Observatory, 200-inch telescope, coudé spectrograph, and prime-focus spectrograph; Mount Wilson Observatory, 100-inch telescope, coudé spectrograph; 60-foot solar tower, pit spectrograph, and spectroheliograph, 60-inch telescope, Cassegrain spectrograph; Snow telescope; 150-foot solar tower, pit spectrograph; Dominion Astrophysical Observatory, Victoria, BC, Canada, 48-inch telescope, coudé spectrograph; University of Göttingen, Germany; Oxford University, solar spectrograph; Cambridge University, solar spectrograph' Big Bear Solar Observatory, California; Lick Observatory, University of California, 120-inch telescope, coudé spectrograph; Sacramento Peak Observatory, New Mexico, solar spectrograph.

First Light — continued from page 3

DON NICHOLSON



DESPITE THE BUBBLES AND LAYER-CAKE appearance, the 100-inch mirror proved to be highly homogeneous, despite George Ritchey's misgivings. Ritchey — chief optician for the 100-inch — had been very dissatisfied with the condition of the blank that Hale had decided to accept; he believed it would not hold a good figure because of internal inhomogeneities, while Hale felt that the blank was as good as technology could produce.

the world twice before. It seems unlikely that they waited until Jupiter was far enough above the eastern horizon to be accessible since this was at least 3-1/2 hours after sunset and 2 hours after the end of astronomical twilight. It is hard to believe that they were that casual about first light. Possibly they looked at Vega, though such a bright star is not a very good test object for a 100-inch telescope. A more likely candidate is a lesser naked-eye star near the zenith at about 5:30 or 6:00 P.M.

Adams in his 1947 paper recalls that first light was on the night of November 1–2, 1917. This reference has been cited in other accounts and has given rise to the belief by some that it is the correct date. Both Hale's diary and the postdated log of Wendell Hoge's clearly say November 2–3. Since the latter were written near the time of the actual event, we accept them as valid.

We have been unable to find any written records that address the condition of the reflecting surfaces of the three mirrors used in the Cassegrain configuration. (The 100-inch primary is not perforated.) If all three mirrors were not silvered, the resulting light loss would be about 3-1/2 magnitudes per unsilvered surface. If one or more of the surfaces were unsilvered, it might have been necessary to observe only bright objects. Both Deneb and Altair as well as Vega were near the meridian at 6:00 P.M. In any event, they could not have looked at Vega at 2:30 A.M. since it had set just before midnight. Perhaps it was Jupiter they turned to at 2:30, though Capella and Elnath (Beta Tauri) were nearer the meridian at that time. Hale's terse diary entry makes no mention of any of these stars but lists the Moon, Jupiter, and Saturn as objects observed.

We will probably never know the true sequence of events that memorable night. We do know for certain that some parts of its written history did not happen as described. Two possible scenarios present themselves. A star, perhaps Gamma or Epsilon Cygni, was the first object seen, and the astronomers turned to Jupiter in the early morning hours. Or perhaps Adams was correct in his recollection that Jupiter and Vega were the two objects, but wrong about the order. After the relief experienced when they realized the mirror was satisfactory, they could turn to the Moon and Saturn with light hearts.

Now, nearly 78 years [of course, 100 years in 2017], since the 100-inch's first light, the telescope is back in service after almost 10 years of retirement. Equipped with modern electronics and instrumentation, it begins another period of service to science.

The authors are grateful to Ron Brashear of the Huntington Library, and to the staff of the Millikan Library at Caltech for their help in searching the Mount Wilson archives and the Hale papers, and to Laura Woodard Eklund for her help in that research.

Editor's Note: Don Nicholson, son of astronomer Seth Nicholson and a long-time supporter of Mount Wilson Observatory, passed away on November 11, 2016. Bob Eklund is the Associate Editor of *Reflections* and is the astropoetry blog editor for Astronomers Without Borders (*astronomerswithoutborders.org*).

Sky Events of November 2–3, 1917 (Times are PST)

03:40 P.M.	Vega transits (zenith dist. 4 deg)
04:52 P.M.	Altair transits (zenith dist. 26 deg)
04:59 P.M.	Sun sets
05:16 P.M.	Capella rises
05:25 P.M.	Civil twilight ends
05:25 P.M.	Gamma Cygni transits (mag. 2.2, zenith dist. 6 deg)
05:30 P.M.	Vega (zenith dist. 22.6 deg)
05:44 P.M.	Deneb transits (zenith dist.11 deg)
05:48 P.M.	Epsilon Cygni transits (mag. 2.5, zenith dist. 1 deg)
05:54 P.M.	Nautical twilight ends
06:15 P.M.	Zeta Cygni transits (mag. 3.2, zenith dist. 4 deg)
06:20 P.M.	Upsilon Cygni transits (mag. 4.4, zenith dist. 0 deg)
06:23 P.M.	Astronomical twilight ends
06:34 P.M.	Jupiter rises
07:00 P.M.	Elnath rises
07:44 P.M.	Eta Pegasi transits (mag. 2.9, zenith dist. 4 deg)
07:55 P.M.	Moon rises
11:18 P.M.	Altair sets
11:20 P.M.	Saturn rises
11:55 P.M.	Vega sets
01:37 A.M.	Jupiter transits (zenith dist. 13 deg)
02:18 A.M.	Capella transits (zenith dist. 12 deg)
02:29 A.M.	Elnath transits (zenith dist. 6 deg)
03:20 A.M.	Moon transits (zenith dist. 11 deg)
02:39 A.M.	Deneb sets
04:49 A.M.	Astronomical twilight begins
05:18 A.M.	Nautical twilight begins
05:48 A.M.	Civil twilight begins
06:14 A.M.	Sun rises

MOUNT WILSON OBSERVATORY

Mount Wilson Institute
P. O. Box 94146
Pasadena, CA 91109

WELCOME, VISITORS!

OBSERVATORY STATUS

Welcome hikers, bikers, star-gazers, birders, and visitors of all interests! The Observatory and Skyline Park are open from 10:00 A.M. to 5:00 P.M. daily, weather and roads permitting. The Cosmic Café at the Pavilion, offering fresh-made sandwiches and Observatory memorabilia, is open Saturdays and Sundays from 10:00 A.M. to 5:00 P.M. through November. You may purchase a National Forest Adventure Pass at the Café for parking.

DOCENT-LED WALKING TOURS

Two-hour weekend tours of the Observatory are held on Saturdays and Sundays at 1:00 P.M. Meet at the Cosmic Café at the Pavilion to buy a ticket — $15 for adults; $12 for kids and seniors. Guests on these tours are admitted to the telescope floor right beneath the historic 100-inch telescope. The 2:00 P.M. one-hour weekend tours have ended for the season.

SPECIAL GROUP TOURS

Group daytime tours are available. Reservations are required and a modest fee is charged. Groups can also place orders in advance for box lunches from the Cosmic Café. For information, please visit *www.mtwilson.edu*.

LOOK THROUGH THE TELESCOPES

Mount Wilson's 60-inch telescope and 100-inch telescope provide incredible views of some of the most beautiful objects in the night sky. For details on scheduling a viewing session, see *www.mtwilson.edu*.

PARKING AT THE OBSERVATORY

The U.S. Forest Service requires those parking within the Angeles National Forest and the National Monument (including the Observatory) to display a National Forest Adventure Pass. For information, visit *www.fs.usda.gov/angeles/*. Display of a National Parks Senior Pass or Golden Age Passport is also acceptable.

HOW TO GET TO MOUNT WILSON OBSERVATORY

From the 210 freeway, follow Angeles Crest Highway (State Highway 2 north) from La Cañada Flintridge to the Mount Wilson–Red Box Road; turn right, go 5 miles to the Observatory gate marked Skyline Park, and park in the lot below the Pavilion. Visit the Cosmic Café at the Pavilion, or walk in on the Observatory access road (far left side of parking lot) about 1/4 mile to the Observatory area. The Museum is opposite the 150-foot solar tower.