How Far to a Star? (It’s All in the Spectra)

By Robert Anderson

This fall we will celebrate the centennial of the first measurement of the size of a distant star in 1920, a monumental achievement by Albert Michelson and Francis Pease at Mount Wilson Observatory (see the previous issue of Reflections, Winter, 2019, archived on the web). That astronomical feat was made possible by another made at Mount Wilson. Starting in 1913, Walter Sydney Adams (who later became the second director of the Observatory after our founder, George Ellery Hale) figured out how to use the light from stars, as spectra spread out into all the visible wavelengths, to measure how far away they are. This technique, called spectroscopic parallax, is one of the rungs of today’s cosmic distance ladder, by which astronomers map the Universe. By 1920, Adams was ready to extend it to thousands of stars.

Finding out how far away stars are posed an enormous challenge to 19th-century astronomers.

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Mount Wilson Observatory Status

Due to the resurgence of COVID-19 in California, we have decided that, in the interest of public health, we will remain closed for the time being. During the coming months, please check our current status on our website mtwilson.edu to see what access is available. While we are closed, hikers are allowed onto the grounds to access the trails and obtain water near the pavilion, but the main gate is closed to vehicular traffic.
NEWS + NOTES

EDWIN HUBBLE RETURNS TO MOUNT WILSON OBSERVATORY!

Well sort of. To mark the centennial of his first full year at the Observatory, we have made a life-sized cutout of our most famous astronomer. Shown to the right is the image we used for the faux Hubble. This shot was taken in the early twenties around the time he proved the existence of other galaxies. The tall Missourian is standing outside the Monastery kitchen, looking very British. No doubt when we fully reopen, he will want a selfie with you.

COSMIC CAFÉ

The Cosmic Café will remain closed for the time being to limit exposure to the virus.

Please keep social distancing and mask wearing going when you visit!

REMOTE TELESCOPES IN 2020!

Our favorite thing at the Observatory is getting the public to look into the eyepiece of one our big, historic telescopes for a look at galaxies, planets and stars. Unfortunately, we have had to cancel most, if not all, of our public viewing this year due to the virus. So we are planning to do remote astronomy with the 60 and 100-inch telescopes instead. We have a new digital camera that captures remarkable images, broadcast-ready, in a minute that are amazing. Live and recorded observing sessions are planned with Carnegie astronomers, some specifically for students. Some are doing remote data collection. When this pandemic is over, we will retain the capability for schools and anyone in the world to participate remotely in an observing session on the 60 & 100-inch telescopes. Check the website homepage for more information as these events are scheduled. Until we can be climbing ladders to eyepieces again, it will be the next best thing!

Subscribe to Mount Wilson Observatory News for updates on concerts, lectures, public telescope nights, and other events. Sign up at mtwilson.edu

Help Sustain the Observatory

This year, with very little revenue coming in, we will be relying on our donors and grants more than ever. We understand that economic times are not good, but if you are in the position to support science, education, and this remarkable historic site with a small donation now would be especially welcome. Best wishes to all in our community. Visit mtwilson.edu for information on how to support the Observatory through donations, memberships, or volunteering. Thanks.
Science & the 100-inch Telescope

Early this spring, we completed a major repair of the telescope’s dome. Last October, the 102-year-old cable system that opens and closes the 50-ton shutters failed, prompting the replacement of four steel cables and an overhaul of the entire system. The dome is an iconic monument to American science. The 100-ton telescope within was financed by Andrew Carnegie and John Hooker, and it marked the advent of “big science.” It made possible Edwin Hubble’s proof of distant galaxies in 1924 and the expansion of the Universe in 1929—the beginnings of modern cosmology. Maintaining this historic instrument in perfect working order is a great responsibility, and one we take pride in. But it is our many supporters who make such repairs possible.

Science has served our country well. It is the foundation of our modern, technologic society, of our economy. In the realm of pure scientific discovery, Mount Wilson Observatory holds a special place in human history. In normal years, astronomy and science enthusiasts from all over the world come to visit to see the site where we discovered our place in the Cosmos. It was an American achievement, but one that belongs to the world. It inspires many visitors to learn more about the natural world, to have a deeper appreciation for scientific knowledge. This magical site, high above Los Angeles, will touch generations to come, prompting some to go even further, exploring careers in astrophysics, chemistry, biology, or some other scientific field.

Sadly, our telescopes, museum, and other facilities are currently closed to help limit the spread of COVID-19. But during this year’s downtime, we are hard at work maintaining and restoring the Observatory’s facilities for the day when we can safely open (see, for instance, the story on page 7 about the Snow Telescope). The CHARA array on the mountain is in full operation, delivering scientific data with the highest resolution of any optical telescope system in the world. We have purchased cameras and other equipment needed to conduct virtual observing for schools in the fall. But still, we really miss having thousands of people looking through telescopes, attending astronomy lectures and concerts, and taking tours. We miss students.

Our future would benefit from a rededication to broad scientific literacy. It is essential to a healthy society, literally. We will play our part. If you are able, please consider joining those who have helped us in 2020 with a membership or a donation (see page 7). This year, it is especially appreciated.

In better times, we will see all of you on the mountain! Best Wishes,

Tom Meneghini

Executive Director, Mount Wilson Institute
All the stars appeared motionless as our planet swept through space from one side of the Sun to the other during a year. If any were close, one might expect them to shift against the more distant, background stars, just like your thumb held at arm’s length will shift when viewed from one eye and then the other. Finally, in 1838, Friedrich Bessel, a German astronomer, measured a minute shift in the position of 61 Cygni—a third of an arcsecond. (One degree of the sky is divided into 3,600 arcseconds.) Knowing this angle and the diameter of the Earth’s orbit, he calculated a distance of 10.3 light years—the first trigonometric parallax for a star. (The modern value to this double star is 11.4 ly.)

Other astronomers followed quickly, with trigonometric parallaxes to Vega and Alpha Centuri. But the technique was severely limited by the need to measure the tiny shifts; most of which were just beyond the limits of their ability to resolve. At the time Mount Wilson Observatory was founded in 1904, only about 60 stellar distances had been nailed down. But Adams would change that.

In the shadow of Hale, Adams is often passed over. Nevertheless his leadership was key to the astounding productively and fame of the Observatory, and his contributions in the new science of astrophysics were numerous. Adams, a New Englander who had just graduated from Dartmouth, decided to follow his professor, Edwin Frost to Yerkes Observatory in 1898. There, he met Hale, its director, and they soon formed a close bond that lasted until Hale’s death in 1938. After a couple of years at Yerkes and the University of Chicago, Adams went to Munich to study, but in May 1901, Hale summoned him back to use Yerkes’ new spectrograph to study stellar spectra.

When Hale left Yerkes in 1904 to set up his new observatory on Mount Wilson, he brought three men with him whom he considered indispensable to the endeavor: master optician George Ritchey, solar observer and photographer Ferdinand Ellerman, and Adams, the superb spectroscopist who had a broad university education.

Adams became Hale’s confident and righthand man. In 1913, Hale elevated him to assistant director of the Observatory, a position of absolute trust given that Adams was frequently acting director during Hale’s many travels and medical absences. That same year Adams embarked on his most important contribution to astronomy: spectroscopic parallax. (“Parallax” in astronomy had come to mean distance, so think “spectroscopic distance.” No trig involved.)

The method is simple in concept. If you can figure out how much light a star is emitting, its “wattage,” you can then measure the amount of light reaching you at the telescope and calculate how far away its must be. This is called the star’s luminosity or absolute magnitude.

In 1908, Harvard astronomer Henrietta Swan Leavitt, (originally called a computer) figured out how to derive the absolute magnitudes of extremely bright variable stars called Cepheids by measuring how long they took to cycle from bright to dim. She found that the longer the period, the brighter the star was. Harlow Shapley used Leavitt’s discovery to map the extent of our Milky Way Galaxy (1918) and then Edwin Hubble used it to measure the first distance to another galaxy (1924).

But Cepheid variable stars are relatively rare. Astronomers needed a way to know the luminosities of the rest of the stars in order to measure their distances. Another astronomer in Harvard’s pool of “computers,” Antonia Maury, laid the groundwork. She spent years studying and classifying stars according to their spectrograms, the
photographic strips on glass recording their light at all the visible wavelengths. These were populated with numerous dark bands, evidence of various elements in the stars’ cooler atmospheres absorbing the emitted light. (See the spectrograms on page one, which represent stars from each of the seven types of main sequence stars, from O, the hottest to M the coolest.) In her catalogue of stellar spectra, published in 1897, Maury used the relative thickness, or strengths, of certain lines of hydrogen, helium, and other distinctive elements to sort the stars into various types and groups. Her detailed analysis was used as a starting point for much of the work by Ejnar Hertzsprung and Henry Russell who independently developed the famous HR diagram around 1910. It became the key to understanding stellar evolution. Maury, Russell, and Hertzsprung were beginning to see that a star’s spectra revealed its temperature and luminosity.

Maury’s classifications also jump started Adams’ development of spectroscopic parallax. Initially, Adams worked with Arnold Kohlschütter, a German astronomer visiting Mount Wilson. In their paper, published in 1914, they proposed a spectroscopic method for determining stellar distances. In simplest terms, the spectrum of a star can tell you how much light it’s emitting, thus providing a means of determining its distance. For 71 stars of known distance and luminosity, the authors calculated their absolute magnitudes based only on their spectral class. They found the numbers were in good agreement. But in reality, reading spectra and determining a luminosity, is not so simple. Take a careful look at the spectra on page one and you will see dark absorption lines waxing and waning in a distinctive pattern as one moves down from the hottest “O” stars to the coolest “M” stars. The various lines can broaden or thin as temperature drops. But the key is that they do so in a particular pattern tied to the surface temperature of the star. The spectra give you the surface temperature, and the surface temperature gives you the luminosity, or absolute magnitude of the star. And comparing that to the amount of the star’s light reaching Earth, allows you to calculate the distance.

But there are complications. If you look at the HR diagram, you’ll notice that cool red stars on the main sequence lie in the same vertical strip as red super giants. They have same temperature and overall “color,” yet giants clearly radiate more light than dwarfs due to their immense surface area. Adams and Kohlschütter found that by measuring the relative intensities of certain spectral lines, for instance those of calcium and iron, they could distinguish giants from main sequence stars and so they could determine absolute magnitudes of both.

Shortly after their 1914 paper, WWI interceded, and Kohlschütter while attempting to return to Germany was captured by the British and incarcerated in Gibraltar until the end of the war in 1918. This left Adams to work out many of the details. For gathering starlight, he had Mount Wilson’s 60-inch Telescope, the largest in the world. And it was the first modern reflecting telescope with an essentially perfect mirror. It could feed the light to a large spectrograph below the observing deck or one mounted at the coudé focus. It was built for astrophysics. Night after night, he and others collected stellar spectra onto glass photographic plates with the intensity of lepidopterists collecting new species of butterflies.

In 1916, Adams published, “A Spectroscopic Method of Determining Stellar Parallax.” At the time there were a grand total of 124 stars for which there were reliable trigonometric distances and spectra. Adams took them all, sorted them into spectral types, and used them to calibrate and test the new method. He showed with examples that it was an accurate new way of determining stellar distances. And with the details worked out, the spectrum of any star could be quickly compared to the reference stars, giving its absolute magnitude and distance.

In the 1920 Carnegie yearbook, Hale wrote: “The reductions of Mr. Adams’s determinations of stellar luminosity and parallax have been finished during the year, and the complete tables will be published within a few weeks. The spectroscopic method of measuring parallaxes has proved increasingly satisfactory, and the detailed
comparison of the results with the best trigonometric parallaxes indicates a very high order of precision.” In 1923, when Hale retired, he chose Adams to succeed him.

In 1935, Adams published his monumental “Spectroscopic Absolute Magnitudes and Distances of 4179 Stars.” The coauthors were Mount Wilson astronomers Alfred Joy, Milton Humason, and “computer” Ada Brayton. The number of stars of known distance had increased nearly a 100-fold from when Mount Wilson Observatory was founded. Adams would continue to add a few thousand more “parallaxes” to the list.

Today, the stellar classification system has been refined, with five luminosity “groups” to account for the giant stars. And of course the spectra are no longer recorded on glass plates, but come in digital form. We can rapidly classify stars with software. And with the torrent of data from space telescopes, like Hipparcos and Gaia, we now have distances to millions of stars.

Robert Garrisond, an astronomer at the University of Toronto’s Dunlap Observatory, wrote an excellent summery of Adams’ contributions to the development of spectroscopic parallax in 1988. He began the article with this: “The American Astronomical Society is not normally an emotionally demonstrative audience. However, in 1951 they gave W. W. Morgan a standing ovation for his announcement of the spiral structure of the Milky Way Galaxy, a result which was obtained by the use of spectroscopic parallaxes based on the system of spectral classification. This was one of the high points in the history of astronomy, but many of the other peak achievements during the past 40 years have also depended on this remarkable method. The work of Adams and Kohlschütter at Mount Wilson was one of the important first steps in the recognition and development of the method of spectroscopic parallaxes. Much of what we know about the universe today is based on this fundamental technique for determining distances.”

Adams officially retired from the Observatory in 1946, but continued his research, publishing his last paper just months before he passed away in Pasadena in 1956 at age 79. His contributions to astrophysics are too many to list, but his development of spectroscopic parallax was his most important. His rung on the cosmic distance ladder provided a crucial tool to explore the Universe.

Adams and Einstein chat outside the dining room at the “Monastery,” during his visit in to the mountain in January, 1931. Carnegie Observatories/Huntington Library

Editor’s Note: The Observatory’s productivity during this period was remarkable given the disruptions of WWI and the “Spanish” flu, which killed some 675,000 Americans, many in their prime. The effects of the war on the staff are well documented, but in the Carnegie Yearbooks for 1918, 19, and 20, there is no mention of the flu, except that their Department of Embryology had studied the effects of the virus on pregnancies. As far as we know, it left the Observatory unscathed.

Adams received many awards for his achievements, but perhaps the highest praise for his abilities can be found in an obituary written by his longtime friend and collaborator, Alfred Joy. “As an observer with the spectrograph Dr. Adams was at his best. A well-exposed spectrogram of an unusual object was his greatest delight and he often spoke of his observing trips to Mount Wilson as “the only fun I have.” Of the astronomers with whom I have worked no other except E. E. Barnard took so much pleasure in actual observing at the telescope. Adams was a superb observer and made the most of the time available to him. Although not by nature mechanically inclined he had, by intense application, trained himself until his adjustments of optical instruments were well-nigh perfect. If the weather was not favorable for good results he was able to take his misfortune with good grace whereas others, Barnard among them, would be thrown into the depths of despair.”
The Snow Solar Telescope Gets Some Love!

With our public events suspended, the Observatory staff is taking the opportunity to refurbish the Snow Solar Telescope, the oldest telescope on the mountain. It was originally given by Helen Snow to Yerkes Observatory in Wisconsin, and named in honor of her father, the inventor of the modern construction technique of “balloon framing.” In 1904, Hale brought it to Mount Wilson on a “temporary” expedition. Instead, it became the world’s first permanently mounted solar telescope, instead of remaining mobile for studying eclipses. Many discoveries about our star were made with it, but the most significant was the revelation that sunspots are relatively cool patches on the Sun. Before this no one really knew what these dark spots were.

In recent years, the Snow has been in regular use for teaching Los Angeles students about spectroscopy. With our telescope operator, Patricia Hill, and astronomers from Carnegie Observatories, the students learn how the light from a star is spread out into a spectrum and analyzed. Using the same equipment that Hale used, they get to look at a live spectrum from our star (similar to the “G” star spectrum on the front page). In addition to this program for local students, the telescope is used every year by our CUREA summer program for undergraduates invited from all over the world.

During the renovation, the two flat coelostat mirrors, as well as the parabolic primary, will be sent off for a fresh coat of aluminum and a protective layer. While the mirrors are out, the metal components of the mount will be stripped and repainted, giving new life to this venerable scientific instrument.

From left: Blake Estes, telescope maintenance, Patricia Hill, Snow Telescope operator, and David Cendejas, superintendent, prepare to lift one of the heavy coelostat mirrors from its mount. This mirror is flat and tracks the Sun as it moves across the sky. The light reflects off a second flat and beams into the building, where it is focused into a solar image by a third, parabolic mirror.

We Thank Our Lucky Stars!

The Observatory relies solely on the generosity of our many supporters, to whom we are always extremely thankful. This year, with our revenue from tours, events, and telescope rentals cut off, we are especially grateful to those who have helped us with a donation or a membership. If you would like to join them and help us “weather the storm,” please visit our website mtwilson.edu. Thanks and best wishes to all.

The Greg Smith Estate
Hal McAlister
Nikki and Mark Shields
The Thornton Trust
Warner Brothers
Mitchell Finer
Linda Deacon
Deborah Shapley
Sam Hale
Ed Wishnow
Paul Aguilar
Amy Asher
Catherine Sabinash
Jeffery Skinner
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Scott and Kathryn Landry
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Peter Parker
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Patricia Hill
Scott Roberts
Andrew Douglass
Ruthe Hintze
David Batteau
John Dollins
John Roemmelt
Paul Hoover
Marc Caratao
Fred Smith
Anshul Puri
Steven Rainey
William R. Smith
Kristin Braly
Nijhawan Pardeep
WELCOME, VISITORS!

Due to the COVID-19 pandemic, the Observatory remains largely closed. The situation is constantly changing, so please check our website homepage, mtwilson.edu for our current status. Normally, the Observatory is open from 10:00 a.m. to 5:00 p.m. daily. The Cosmic Café at the Pavilion is currently closed along with our Weekend Public Tours of the Observatory.

SELF-GUIDED TOURS

If the grounds are open, you are welcome to walk around the outside public areas of the Observatory. On our website you can find printouts for self-guided tours. When we eventually reopen, the Observatory and the CHARA array both have small museums to check out, and the 100-inch Telescope dome has a visitor’s gallery to look at the famous 100-inch Telescope.

PRIVATE GROUP TOURS

In normal times, group daytime tours are available on any date. Advance notice and reservations are required and a modest fee is charged. Currently, all tours are suspended.

LOOK THROUGH THE TELESCOPEs

Mount Wilson’s historic 60-inch telescope and 100-inch telescope are currently not available for public observing due to the virus.

PARKING AT THE OBSERVATORY

Check our website to see if we are open, and if the parking area is open. Normally, we are open almost everyday of the year. 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.