Remembering Henrietta Swan Leavitt

How one talented astronomer's meticulous work left an important legacy.

In the century since Henrietta Leavitt died, the observation that she first published in 1908, then elaborated in 1912, has achieved the status of an astrophysical law. Her quiet life has become the subject of books, stage plays, art exhibitions, poems, a doll, and at least one song. It was Leavitt who discovered a yardstick for gauging distances across space, enabling the first realistic appreciation of the size of the Milky Way, and, soon afterward, the breadth of the chasm separating our home galaxy from other island universes.

I first encountered Henrietta Leavitt at a meeting with astronomer Wendy Freedman, who is now the John and Marion Sullivan Professor of Astronomy and Astrophysics at the University of Chicago. At the time of our interview in the early 1990s, Freedman headed the Hubble Space Telescope Key Project to Measure the Hubble Constant to determine the expansion rate of the universe. She mentioned Leavitt as the person who had first documented the noteworthy trait of Cepheid variables that makes such stars useful as deep-space distance markers. Freedman stressed the point for my benefit: The entire research protocol for the Key Project rested on observations made by a little-known woman at the turn of the 20th century.

▲ **LEGAL SCHOLAR** From her desk at the Harvard College Observatory, Henrietta Swan Leavitt discovered that Cepheid variables can serve as deep space distance markers. Her celebrated period-luminosity relation is now becoming widely known as the Leavitt Law.

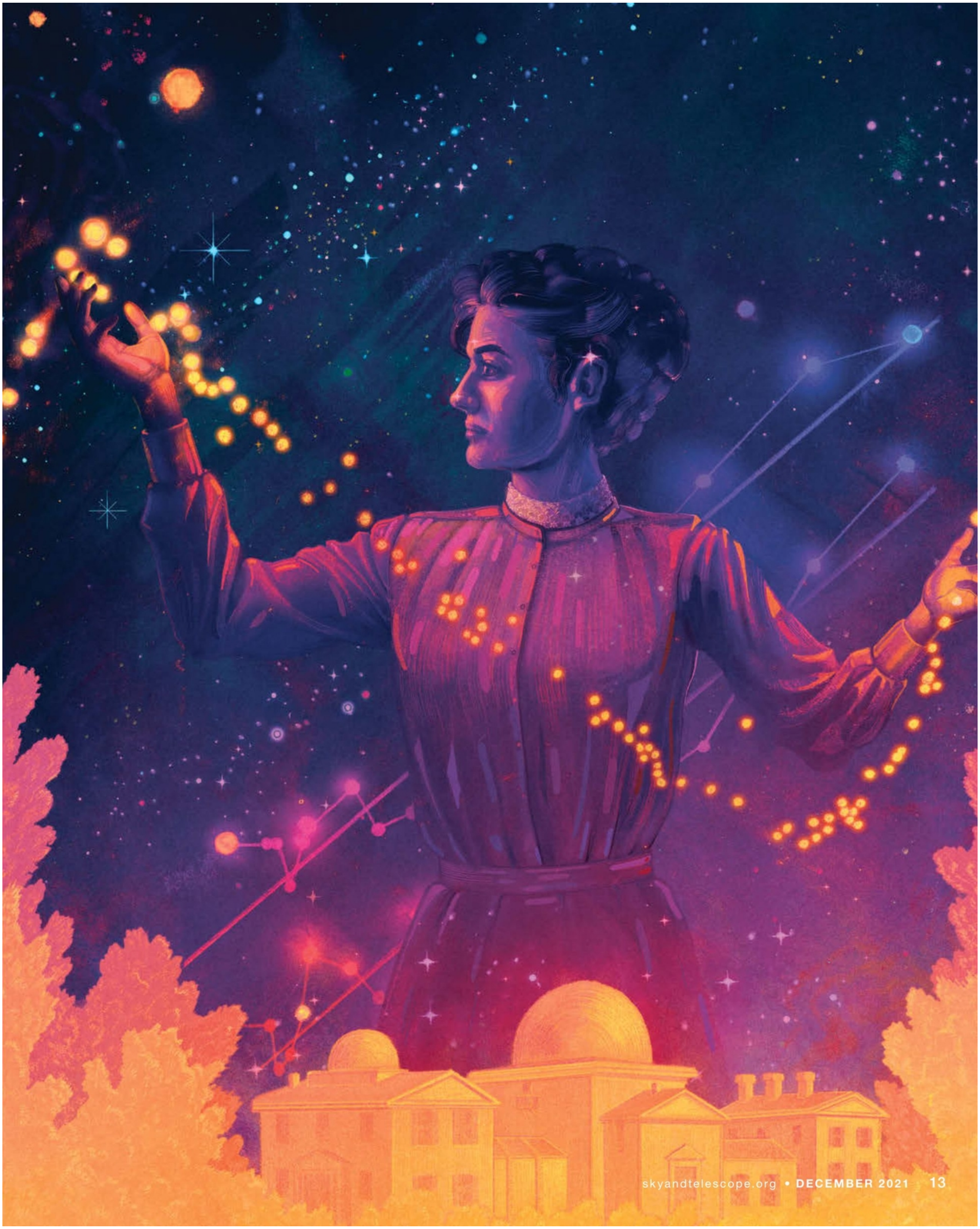
Meeting Miss Leavitt

Her full name, Henrietta Swan Leavitt, suggests she added a husband's surname to her own maiden name, but in fact she never married. She remained "Miss Leavitt" to her associates at the Harvard College Observatory in Cambridge, Massachusetts, throughout the 20-odd years of employment there. Everyone liked her. It was said she had a nature full of sunshine and a talent for seeing the worthiest, most lovable features in others. Her ability to descry the changing brightness of variable stars bordered on the miraculous. However, as her biographer, George Johnson, noted in the preface to his 1995 book *Miss Leavitt's Stars*, his chosen subject had left no diaries and only a few letters to help tell her life story.

Leavitt was born on the 4th of July in 1868, in Lancaster, Massachusetts, the first of seven children and the namesake of her mother, née Henrietta Swan Kendrick. Her father, the Reverend George Roswell Leavitt, moved the family to Cambridge and later to Cleveland, Ohio, serving in both those cities as pastor of Congregational churches. In 1885, 16-year-old Henrietta enrolled at the Oberlin Conservatory of Music in Ohio. She had grown up singing hymns but soon developed trouble hearing them, and over time she became increasingly deaf.

She switched to Oberlin College, where she excelled at mathematics, and after two years returned to Cambridge to continue her studies at the Society for the Collegiate Instruction of Women (later Radcliffe College). She lived with the family of her uncle Erasmus Darwin Leavitt, Jr., a respected

PORTRAIT: HARVARD UNIVERSITY ARCHIVES; ILLUSTRATION: DAVID CURTIS



▲ **LITTLE CITY OF SCIENCE** was the term a journalist used to describe the Harvard College Observatory in the 1890s, when numerous specially built domes and sheds housed a host of newly acquired instruments. The Brick Building, erected for safe storage of the glass photographic plates, is visible at far left. In the background stands the main observatory building with its two domes — the larger one for the Great Refractor and the smaller one for the west equatorial telescope.

▲ **SAFE HAVEN** Fearful of the potential for fire destroying valuable data, Observatory Director Edward Pickering oversaw the construction of a brick repository for the precious glass plate collection. The Brick Building, shown here shortly after its completion in 1893, stood only a few steps from the original wooden observatory. Within 10 years it had reached storage capacity and required a three-story addition to house the ever-growing number of plates.

HARVARD LIBRARY ARCHIVES / PUBLIC DOMAIN (3)

▼ **CHAIN OF STARS** The 1918 female staff of the Harvard College Observatory, plus two of the men, agreed to pose this way in front of the new addition to the director's residence. Henrietta Leavitt stands tall, sixth from left, wearing a dark tie over her white blouse. Annie Jump Cannon is fifth from right. The Brick Building can be seen behind telescope operator Frank E. Hinkley and chief of stellar photography Edward King (far right).

designer of steam engines, who may have encouraged her interest in science. Her four-year program included courses in astronomy, physics, and mathematics, and introduced her to the nearby astronomical observatory. She began volunteering there after graduation in 1892 and was hired as a "computer" to process astronomical data in 1895. Familial obligations and travels in Europe took her away from her post at several junctures, but she signed on in 1902 as a permanent staff member of the Observatory, where she remained until her death in December 1921.

Plates of Starlight

Astronomy was a day job for Henrietta Leavitt. She made all her discoveries without ever looking through a telescope. Instead, she studied images of the night sky recorded on glass photographic plates. Harvard Observatory Director Edward Charles Pickering had instituted a grand-scale program of astrophotography in both the Northern and Southern Hemispheres. The long-exposure pictures captured the light of stars unseen by even the most talented observers at the most powerful telescopes then in use, including Harvard's own 15-inch Merz and Mahler refractor.

Leavitt sometimes worked alongside as many as 20 other women in the so-called Brick Building, an 1893 addition to Harvard Observatory. The Brick Building afforded fireproof protection for the prized, ever-growing collection of hundreds of thousands of glass photographic plates.

Each morning she found a stack of plates awaiting her. They arrived at her desk either from Harvard's darkroom on Madison Street or in boxed shipments from the Observatory's southern outpost at Arequipa, Peru. She examined each plate by securing it in an upright wooden frame, tilted at a viewing angle of about 45°. At the base of this light lectern, an attached mirror caught sunshine from the room's big windows and reflected it up through the glass to illuminate the myriad stars.

Most images were negatives, showing the stars as black dots on a white background. A handheld magnifying loupe brought them more clearly into view. Her particular task was to judge the magnitude of each star. Early assessments of photographic magnitude depended on the relative sizes of star-dots. Leavitt's procedures grew ever more sophisticated, informed by knowledge of the spectral type of each star, as determined by her colleagues Williamina Fleming and Annie Jump Cannon. Two stars of a particular color could be successfully compared, whereas comparing two stars of different types would introduce errors.

She also factored in the limitations of the various telescopes used to create the photographic plates. In her painstaking work on establishing standard sequences of comparison stars, she combined data from more than a dozen telescopes ranging from small-aperture instruments on the Harvard Observatory grounds to the 60-inch reflector at the Mount Wilson Observatory in California.

Leavitt logged her magnitude determinations in ledgers in pencil, and sometimes jotted them right on the glass plates in colored ink. The smooth (non-emulsion) side of the plates provided a convenient writing surface.

A custom-made device known as a fly-spanker aided her labors. This was a small section of a glass plate showing model stars of known brightness — a sort of portable reference key. The miniature rectangle of glass, set in a wire

frame and attached to a long handle, recalled the shape of a flyswatter, though Leavitt liked to joke that it was too small to do a fly much damage.

Thanks in part to the standard sequences of stars that she established as a basis for comparison, as well as conversion factors for relating visual magnitudes to photographic ones, her photometry publications became trusted resources for astronomers everywhere.

Inconstant Suns

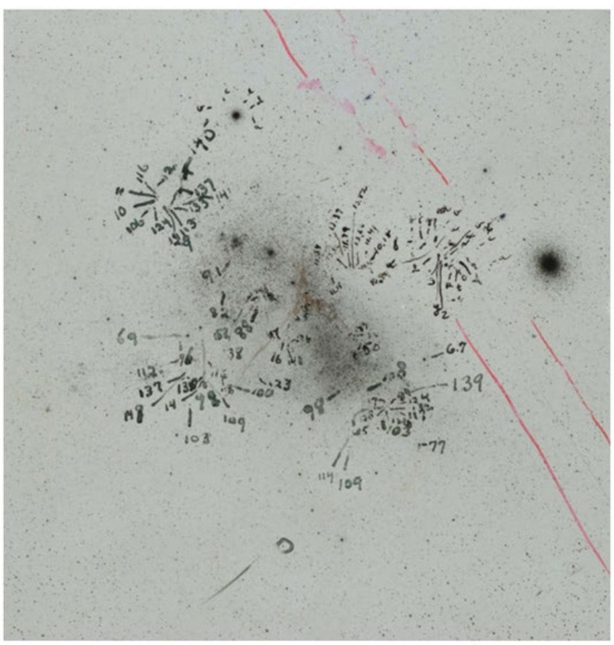
Variable stars attracted particular interest at Harvard in the early 20th century, when only a couple hundred were known, and the causes of their variability remained largely mysterious. In 1903, when Pickering sent Leavitt hunting for variable stars in the Orion Nebula, she complied by stacking a series of negative plates, one at a time, over a glass positive of the region. The black dots generally covered the white blobs of unchanging stars, while white halos around black dots helped her identify 90 new variables within two months' time.

From Orion she moved on to the Magellanic Clouds of the southern sky, the site of her greatest coup. She described these two nebulous regions — now recognized as satellite galaxies of the Milky Way — as unusually difficult targets. They were large and densely crowded with stars. She imposed some order on them by creating a ruled glass grid that she could superpose on the plates, thus corralling their component stars into boxes. Soon she was seeing numerous stars that varied in brightness from one plate to the next — but they were extremely faint, many of them fluctuating near the limits of detection at around 15th magnitude.

By early 1905 she had identified 900 new variables in the Small Magellanic Cloud alone. As she continued to search for more, she tabulated and analyzed her results. In 1908, in the *Annals of the Astronomical Observatory of Harvard College*, she published her compendium of "1777 Variables in the Magellanic Clouds." The lengthy paper included 12 pages of tables of numerical data, plus an analysis of 16 stars for which she had assembled complete light curves.

The 16 selected stars belonged to the class of Cepheid-type variables, so named for their prototype, Delta Cephei, first described in 1785. These stars tend to brighten suddenly, then dim slowly, in a regularly repeating fashion. Given that all her finds lay within the Small Magellanic Cloud, Leavitt assumed them all to be about the same distance from Earth. Therefore, the stars that appeared the brightest actually *were* the brightest. In other words, these stars didn't look brighter simply because they were closer to Earth than other stars in the group. This was a crucial finding. It occurred to Leavitt that the maximum brightness of such a star and the timescale of the variations might be linked. "It is worthy of notice," she concluded, that "the brighter stars have the longer periods."

In December 1908, soon after completing this work, she fell so ill as to require a hospital stay. People were discreet about personal health in those days, and the nature of her illness wasn't reported. The start of the new year found her recuperating at her parents' home in Beloit, Wisconsin.



▲ **PHOTO ID** Leavitt sometimes jotted her magnitude determinations in colored ink directly on the non-emulsion side of a glass photographic plate. In her logbooks, however, she always wrote in pencil, even though erasures weren't permitted.

▲ **VIEW FINDER** Specially constructed light lecterns held the glass plates in place for close study. Illumination came from below, via a mirror that caught daylight from a window and directed it up through the glass image to the observer's eye.

HARVARD COLLEGE OBSERVATORY, PHOTOGRAPHIC GLASS PLATE COLLECTION (2)

As time and her energy permitted, she returned to the observatory and continued to plumb her data by tracking another nine Cepheids in the Small Magellanic Cloud through their cycles. These stars followed the same intriguing trend as the previous 16, confirming her insight. Pickering showed his excitement by rushing her graphs into print on March 3, 1912, in a *Harvard College Observatory Circular* — the bulletin format he had introduced for announcing important new developments ahead of the annual *Annals*. He signed the report, as always, with his own name, but the opening sentence gave full credit where it was due: "The following statement regarding the periods of 25 variable stars in the Small Magellanic Cloud has been prepared by Miss Leavitt." The relation between the period and the brightness of these variables, which she had previously deemed "worthy of notice" she now declared "remarkable."

Other astronomers agreed. Ejnar Hertzsprung in Denmark immediately applied the newfound period-luminosity relation to the problem of distance measurement. He compared the apparent brightness of known Cepheids with those of Leavitt's study that had the same periods. According to the inverse square law, if one star lies twice as far away as its twin, it appears only one-quarter as bright. Hertzsprung estimated the distance to the Small Magellanic Cloud to be in the range of 30,000 light-years. This was an astounding figure at the time. Not only was the number gigantic, but it put a specific value on something long presumed to be unknowable. (Later, with better calibration and further research on Cepheids, the distance would be revised to about 200,000 light-years.)

In 1914, American astronomer Harlow Shapley began using the 60-inch telescope at Mount Wilson to pick out Cepheids in globular clusters, and he gauged their great distances by the period-luminosity relation. Later he extrapolated, extending the reach of the Cepheids to define the vast outlines of the Milky Way.

Stellar Tributes

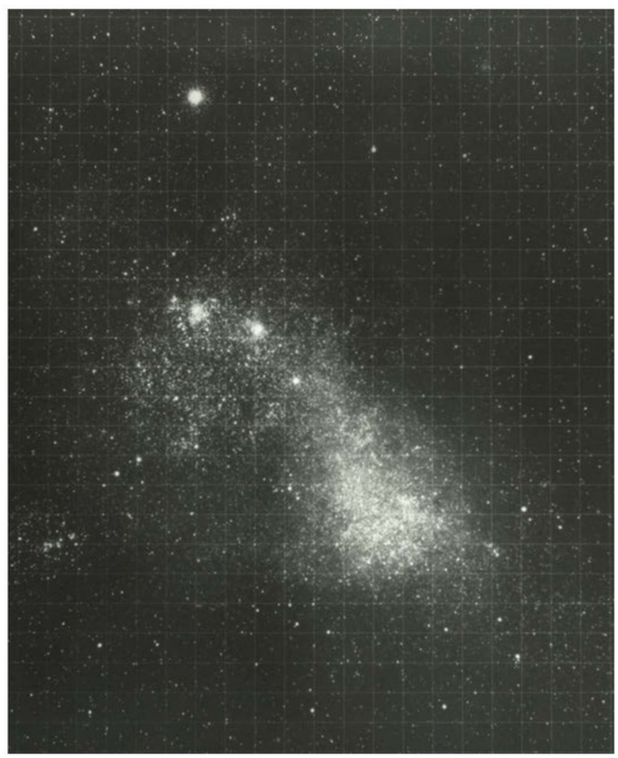
By the spring of 1921 Henrietta Swan Leavitt had lost many members of her family and was sharing an apartment with her widowed mother not far from the Brick Building. The cancer that had often interrupted her work took her life near the end of that year, on December 12, at age 53.

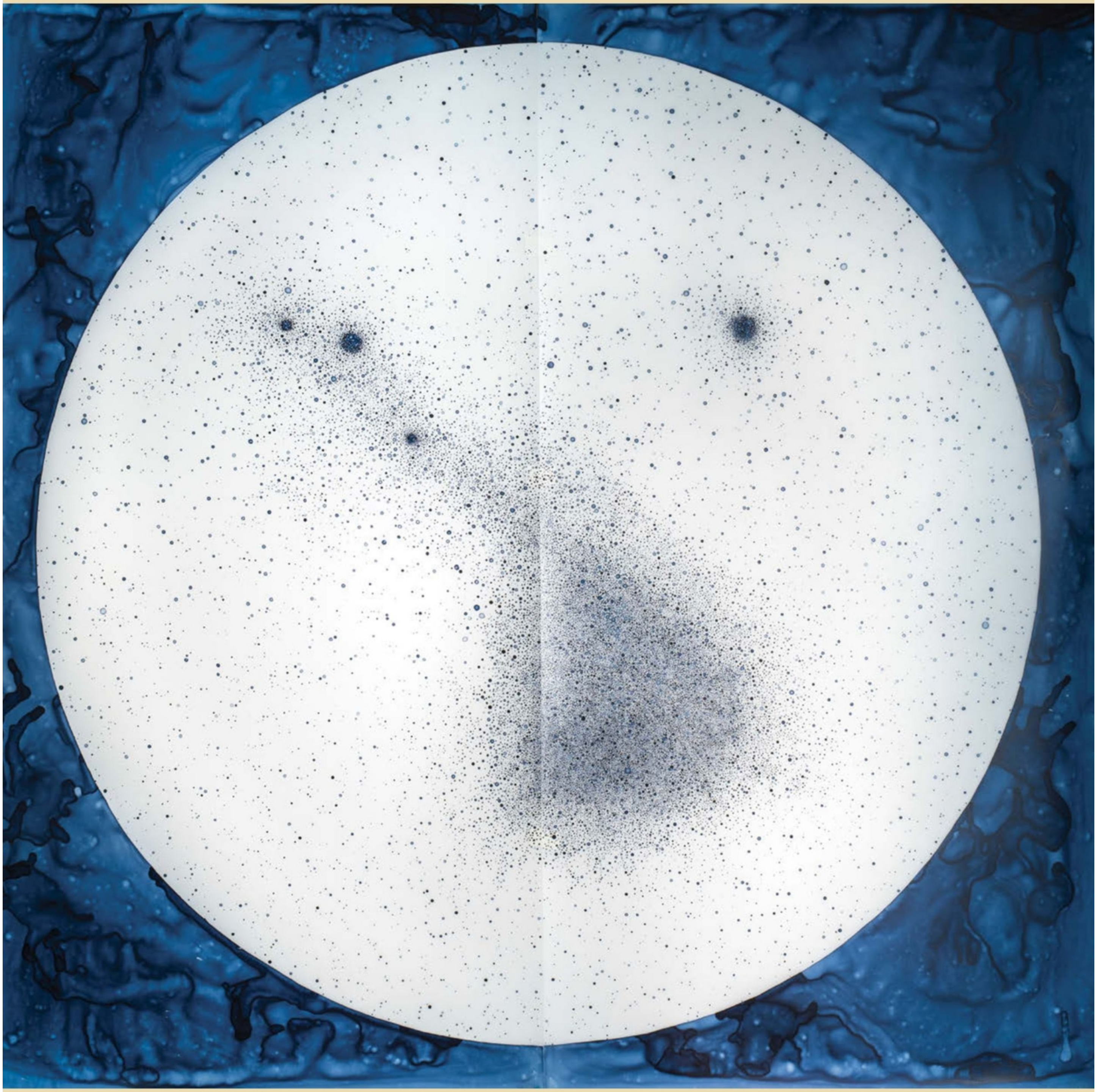
Observatory staff members attended her funeral at the First Congregational Church and wrote her obituary for *Popular Astronomy*. It cited her fruitful efforts to establish the photographic magnitudes for the North Polar Sequence (96 stars very close to the pole), as well as similar strings of standard star sequences for all 48 of Pickering's 1884 subdivisions of the sky. The obituary also noted her contributions to sections of the international *Astrophotographic Catalogue* and Jacobus Kapteyn's *Plan of Selected Areas*. In addition, Leavitt had detected four "new stars" (what would now be called supernovae), several asteroids, and 2,400 variable stars —
(continued on page 20)

HARVARD COLLEGE OBSERVATORY, PHOTOGRAPHIC GLASS PLATE COLLECTION (2)

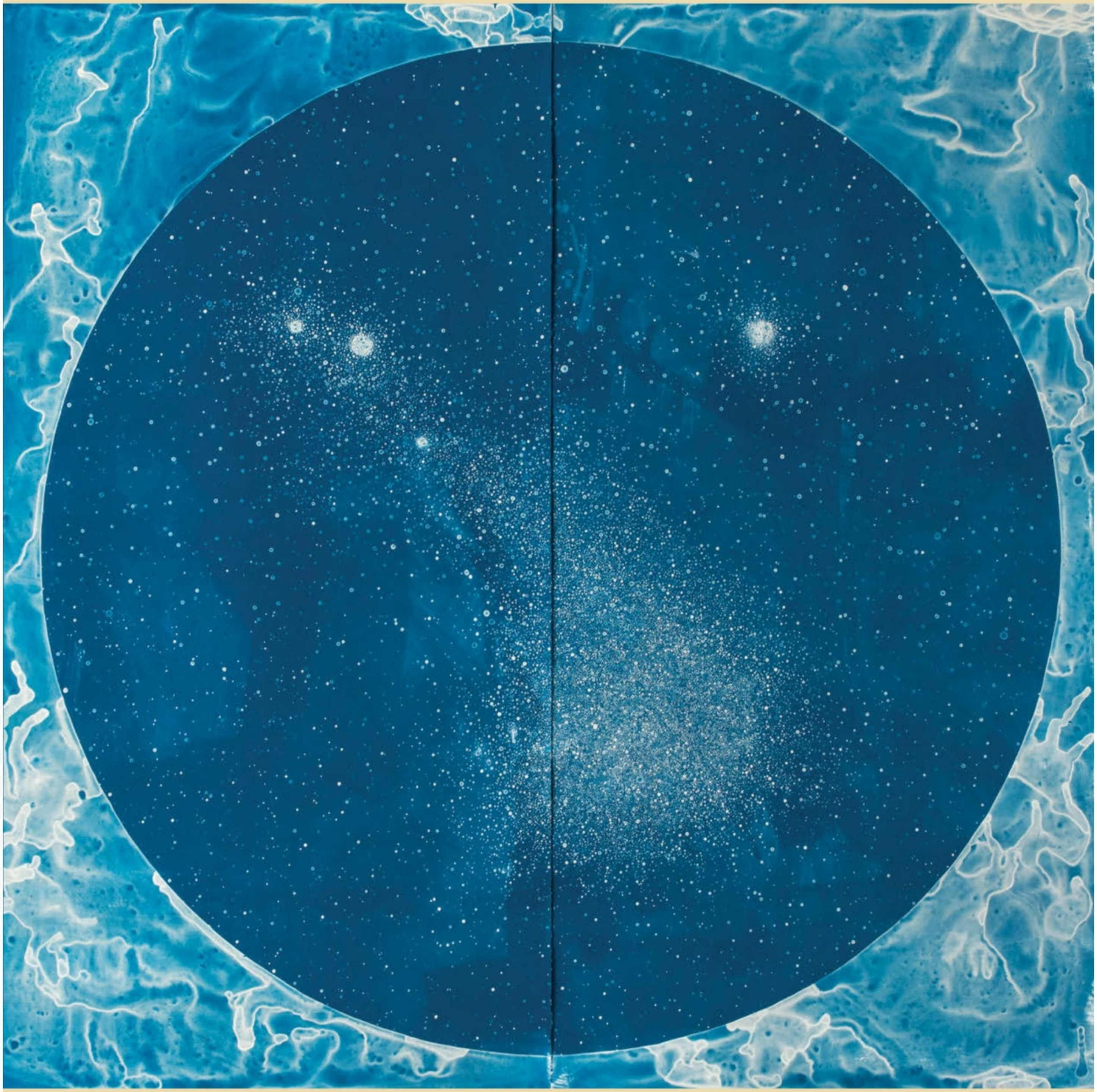
▲ **SWAT TEAM** These helpful tools for assessing stellar magnitudes were called "fly spankers" because of their overall resemblance to miniature fly swatters. Leavitt liked to say they were too small to do a fly much damage.

▼ **STARRY CLOUD** The galaxy pictured here is the Small Magellanic Cloud, one of the Milky Way's satellites, where Henrietta Leavitt discovered more than 900 variable stars. Although many were as faint as 15th magnitude, she nevertheless noticed a startling link between their brightness and the time it took them to cycle through their changes. This plate was captured on November 10, 1898, with the 24-inch Bruce telescope in Peru.





▲▶ **THE SMALL MAGELLANIC CLOUD, AFTER HENRIETTA SWAN LEAVITT** is a cyanotype diptych by artist Lia Halloran from her series Your Body Is a Space that Sees. On the left is Halloran's depiction, in ink on semi-transparent drafting film, of a glass photographic plate originally exposed to starlight at Harvard's southern station in Arequipa, Peru. Using her painted image as a negative, and placing it over an equally large sheet of chemically treated paper, Halloran set the pair outdoors to develop in sunlight, creating the cyanotype print on the right. The artist is represented by Luis de Jesus Los Angeles and is an Associate Professor of Art at Chapman University.



Firefox about:blank

(continued from page 17)
about half of all known at the time. The large total included several hundred beyond the multitude she enumerated in the Magellanic Clouds.

"Miss Leavitt," the obituary concluded, "was of an especially quiet and retiring nature, and absorbed in her work to an unusual degree. She had the highest esteem of all her associates at the Harvard Observatory, where her loss is keenly felt."

In 1925, a member of the Swedish Academy of Sciences thought to nominate the author of the period-luminosity relation for the 1926 Nobel Prize in Physics. Unaware that Leavitt had died, he wrote to her requesting further information. Shapley, who knew the prize could not be awarded posthumously, replied:

> *Miss Leavitt's work on the variable stars in the Magellanic Clouds, which led to the discovery of the relation between period and apparent magnitude, has afforded us a very powerful tool in measuring great stellar distances. To me personally it has also been of highest service, for it was my privilege to interpret the observation by Miss Leavitt, place it on a basis of absolute brightness, and, extending it to the variables of the globular clusters, use it in my measures of the Milky Way. Just recently in Hubble's measures of the distances of the spiral nebulae, he has been able to use the period-luminosity curve I founded on Miss Leavitt's work. Much of the time she was engaged at the Harvard Observatory, her efforts had to be devoted to the heavy routine of establishing standard magnitudes upon which later we can base our studies of the galactic system. If she had been free from those necessary chores, I feel sure that Miss Leavitt's scientific contributions would have been even more brilliant than they were.*

In the absence of any comments from Leavitt herself about her accomplishments, or any complaints about the work she was assigned, others looking back on her life have felt free to fill that vacuum. The North Polar Sequence in particular struck some later astronomers as comparable to the labors of Hercules, coloring their view of its creators so as to turn Pickering into a tyrant who bent the meek Leavitt to his will.

Shapley gave the first hint that Pickering hobbled Leavitt when he rued "those necessary chores" that kept her from making her contributions "even more brilliant than they were." This idea gained strength with Cecilia Payne (later Payne-Gaposchkin), who came to the observatory as a graduate student in 1923 and earned Harvard's first doctoral degree in astronomy. In her autobiography, *The Dyer's Hand* (privately published near the time of her death in 1979), she reported the work of her female predecessors, some of whom were still alive when she arrived in Cambridge, Massachusetts, from England. Although she never met Leavitt or Pickering, she wrote that the director had "ruthlessly relegated Miss Leavitt to the drudgery of fundamental photometry when her real interest lay in the variable stars that she had begun to discover in the Magellanic Clouds. She was the ablest of all the workers at Harvard at the turn of the century, but Pickering was a dictator, and his word was law."

A paragraph later, Payne reiterated her sense that Pickering's "harsh decision" regarding Leavitt had "condemned a brilliant scientist to uncongenial work, and probably set back the study of variable stars for several decades."

Or perhaps, given Leavitt's retiring nature, she would not have been as willing as Payne to follow her instincts and challenge authority on the strength of her own ideas.

The Leavitt Law

In 2012, Jonathan (Josh) Grindlay, who holds Pickering's honorary title as Robert Treat Paine Professor of Astronomy at Harvard, attended a centennial celebration of Henrietta Leavitt's pivotal discovery. At the day-long symposium, he suggested renaming her period-luminosity relation "the Leavitt Law," putting it on a par with the Hubble Law for establishing the distances of receding galaxies.

"All astronomy textbooks should use 'Leavitt Law' in describing the importance of Henrietta's discovery," Grindlay recalls telling the gathering. "It was not just a period-luminosity relation of Cepheid variable stars. It really transformed astronomy."

At Grindlay's urging, the executive council of the American Astronomical Society acted to endorse the name change. Many AAS members have since adopted the "Leavitt Law" in their publications, textbooks, teaching, and public speaking.

Grindlay's office belongs to a complex of interconnected structures on the observatory grounds, known today as the Center for Astrophysics, Harvard & Smithsonian. It incorporates the Brick Building, where approximately half a million glass plates still reside, stored in tall metal cabinets. For the past 15 years, the National Science Foundation has supported an ongoing project to digitize them for ready access by current and future astronomers. Several of the plates scrutinized and annotated by Leavitt, however, have been deemed too historically valuable to be subjected to the routine digitization process, which entails wiping the plates clean of all markings before scanning them. Instead, these particular plates will be scanned as they are, for the valuable data that can be gleaned between the penned notations.

Student groups and other curious visitors to the "plate stacks" learn about the collection from Lindsay Smith Zrull, the current curator of astronomical photographs (a job description born of necessity in 1899). "I always show one of Henrietta Leavitt's plates," Zrull told me. "It's impossible, of course, to know her personal thoughts and feelings, and many people say she was held back. But from looking at her plate notations and reading her notebooks, I think she must have loved what she did."

Some 2,600 logbooks — companion pieces to the glass plates — have been scanned page by page for public perusal. Volume XIX of the Henrietta Leavitt series is one that stands out, as it painstakingly identifies all the comparison stars she

9 of 10 10/29/2021, 2:52 PM

chose for her measurements of variable magnitudes in the Small Magellanic Cloud.

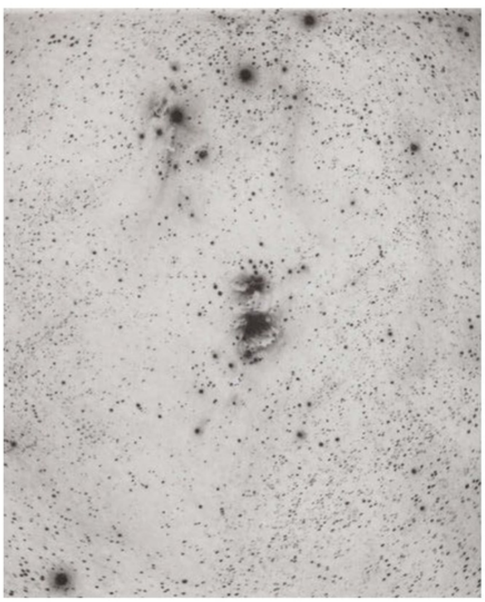
The original of that particular logbook is kept on hand at the John G. Wolbach Library that forms part of the observatory complex. Librarian Maria McEachern holds it up as a paragon of diligence and consistency. Compared to Annie Jump Cannon's notebooks, which McEachern described to me as "just wild," Leavitt progresses neatly and methodically from star to star, plate by plate. In places, she even affixed (with yellowing tape) several inch-square photos of relevant sections of annotated plates.

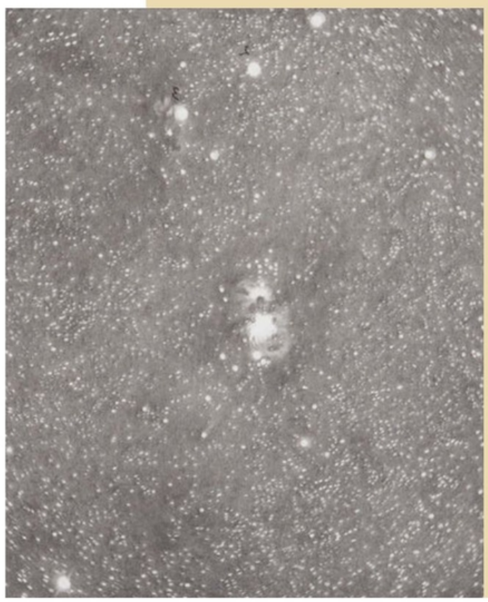
Were Leavitt to gain a window on today's world, she might well be pleased with the recognition afforded her, though she never actively sought any. Of greater satisfaction than the attribution of the Leavitt Law, Wendy Freedman thinks, would be the gratifying persistence of Cepheids as reliable distance indicators, their critical importance for cosmology, and the ever-deeper understanding of their complex behavior through CCD and infrared photometry.

On the day, just a few months ago, when she and I revived our discussion of Henrietta Swan Leavitt, Freedman had learned of observing time granted to her on the James Webb Telescope. "There may be aspects of the physics of pulsation that we don't yet understand," she said, "and, once again, Cepheids will be at the heart of the matter."

■ **DAVA SOBEL** has written about the history of astronomy in her books *Longitude*, *Galileo's Daughter*, *The Planets*, *A More Perfect Heaven*, and, most recently, *The Glass Universe*.

▼ **PAPER PLATE** The process of creating this exact pencil-on-paper rendering of a pair of glass plates helped artist Anna Von Mertens appreciate the extreme attention to detail that characterized Leavitt's work.





ANNA VON MERTENS / COLLECTION OF ARLIE STERN AND MATT TSANG (2)

Appreciation and Inspiration

To appreciate and honor the level of sustained attention that Henrietta Leavitt achieved, artist Anna Von Mertens assigned herself a copying task — not a page of notes from a logbook, but several glass plates that had passed through the astronomer's hands. Except for the medium of pencil on paper, Von Mertens's drawings (below) of "Negative and Positive Plates B20667 and D16409, Nebula in Orion, Oct 26, 1897" are indistinguishable from the glass originals.

"I wanted to inhabit that same space," Von Mertens told me, "to examine those plates as closely as she did. What a gift Henrietta Leavitt gave me. I lived an intimate relationship with her while doing this work."

Von Mertens said that when she first saw pictures of the Harvard women bent over their work the scene reminded her of a quilting bee. As a quilter herself, she thought to stitch the outlines of Leavitt's life in two starscapes: the tracks of stars fading as day breaks on July 4, 1868, and of those coming into view on the evening of December 12, 1921.

The Radcliffe Institute exhibited the quilted diptych and drawings two years ago. Since then Von Mertens has addressed other plates that Leavitt analyzed. These newer pieces, under the title "Artifacts: Drawings from Plate AX3309," will be showcased in fall 2023 at Oberlin College, Leavitt's first alma mater.

Leavitt's fixation with detail is often dismissed — by people who don't understand it — as "women's work," meaning tedious and repetitious. But surely the contemporary men's work at the observatory would seem just as tedious and repetitious to the uninitiated. Pickering, for example, made and recorded more than a million photometric measurements in his career, inspired by the importance he placed on such data. Others patiently guided balky telescopes through the hours required by specific observing goals.

"Henrietta Leavitt looked at tiny black dots in 2D," Von Mertens said. "She held the complexity of their patterns in her mind, and turned them into a way to measure the universe."