Finding a Cosmic Yardstick

By Marcia Bartusiak

Henrietta Swan Leavitt's painstaking observations inspired a new way to determine the distances to far-off celestial objects.

Henrietta Swan Leavitt, at work for the Harvard College Observatory, Cambridge, Massachusetts

First-time travelers to the Southern Hemisphere might mistake the deep-space nebular clouds visible there for high cirrus formations, somehow made luminous in the dark of night. Yet the Large and Small Magellanic Clouds are each a chaotic collection of stars, richly diffused with glowing gas. Such novel and fascinating sights were a compelling reason for early European and American astronomers to set up observatories in the Southern Hemisphere.

In the early 1890s, the Harvard College Observatory established a southern station in the highlands of Peru. For more than a decade, Harvard had been cataloging every star in the northern sky and accurately gauging its color and brightness. With a sizable endowment for a program in spectroscopy, observatory director Edward C. Pickering resolved to further classify the brightest stars by their chemical spectra. The Peruvian observatory allowed Harvard to extend all those endeavors to the southern sky. Pickering was helping astronomy move beyond just tracking the motions of stars across the sky to figuring out their basic properties.

With a huge number of glass photographic plates of the northern and southern skies stacking up, Pickering shrewdly recognized the value of smart young women yearning to contribute in an era that generally denied them full access to scientific institutions. These woman "computers," as they were called, some with college degrees in science, could be hired for less than half the pay of a man. Stationed at the observatory's headquarters in Cambridge, Massachusetts, they peered at plates all day through magnifying glasses, swiftly and accurately numbering each star, determining its exact position, and assigning it either a spectral class or a photographic magnitude.

One of Pickering's most brilliant hires was Henrietta Swan Leavitt, who began work as a volunteer soon after graduating, in 1892, from what later became Radcliffe College. She proved herself an expert in stellar photometry, gauging the magnitude of a star by assessing the size of the spot it imprinted upon a photographic plate. As she worked, she was also instructed to keep an eye out for variable stars, those that regularly increase and decrease in brightness.

Leavitt left Harvard in 1896, first traveling through Europe for two years and then moving to Wisconsin to be with her father. In 1902, she returned to Harvard as a paid employee. Two years later, variable stars came back into her life in full force. Looking through a magnifying eyepiece at two plates of the Small Magellanic Cloud, taken at different times, she noticed that several stars had changed in brightness, as if they were undergoing a slow-motion twinkle. Over the following year, she looked at additional images of the cloud and found dozens more variable stars. Soon she included old plates, going back to 1893, in her tally, and then the Large Magellanic Cloud. By 1907 she had found a record-setting total of 1,777 new variable stars within the prominent, mistlike clouds.

Leavitt dutifully reported her findings in the 1908 *Annals of the Astronomical Observatory of Harvard College,* paying particular attention to a special group of sixteen variable stars in the Small Magellanic Cloud. They were later identified as Cepheid variables, stars thousands of times more luminous than our Sun. One sentence in Leavitt's report would become her most venerated statement. "It is worthy of notice," she wrote, "that . . . the brighter variables have the longer periods." Because all her Cepheids were situated in the Small Magellanic Cloud, Leavitt could assume they were all roughly the same distance from Earth. Their periods, therefore, were directly associated not only with their apparent brightness as seen from Earth, but with the actual emission of light. Leavitt's discovery would lead to a new cosmic yardstick, one that would allow astronomers to determine the distances to far-off celestial objects, which had never been measurable before.

Composite image of the Large Magellanic Cloud. Leavitt studied variable stars—ones that regularly brighten and dim—within that galaxy and its neighbor, the Small Magellanic Cloud.

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Leavitt was on track to discover the celestial equivalents of lighthouses on Earth. A sailor at sea who knows the intensity of light emitted by a lighthouse can estimate how far away it is by how bright the beacon appears. Similarly, if an astronomer could know the absolute brightness of a Cepheid—how luminous it would appear up close—he could estimate how far away it must be to appear as the faint point of light seen from Earth. But, just as some lighthouses shine with brighter lights than others, so do Cepheids. Only their relative intensities can be measured from afar. The promise of Leavitt's discovery was this: if the absolute brightness of just one Cepheid could be known, the absolute brightness of the others could be figured out based on the differences in their periods. In this way, each Cepheid could become an invaluable "standard candle" (as astronomers call it) for gauging distances deep into space.

In 1908, however, Leavitt was wary that her initial sample of sixteen Cepheids was too small to secure a firm and predictable "period–luminosity" law. She needed more, but chronic illnesses, one of which had earlier left her deaf, and the death of her father delayed her a few years. Moreover, Cepheids, though very bright, are also very rare. Not until 1912 was Leavitt able to add nine more Small Magellanic Cepheids to her list. With twenty-five in hand, all at roughly the same distance from Earth, she could at last establish a distinct mathematical relationship between the rate of a Cepheid's blinking and its perceived brightness. In a logarithmic-scale graph of her data, the visible brightness of her Cepheids rises in a sure, straight diagonal line as the stars' periods get longer and longer.

Cepheids stood ready to be the perfect standard candles, but first Leavitt needed to know the true brightness of at least one. From that one, her graph could be calibrated such that an astronomer could pick out a far-off Cepheid anywhere in the sky, measure its period, and infer its actual luminosity. Knowing that, the star's distance could be calculated from its much fainter apparent brightness.

First, however, Leavitt required the reverse: knowing the distance to one bona fide Cepheid was the only way to calculate its true brightness! But Leavitt's going to a telescope to pursue an answer was out of the question, not only because women were denied access to the best telescopes at the time, but because of her frail condition. She had been advised by her doctor to avoid the chilly night air habitually braved by observers. If she had the know-how, she could have carried out a calculation from her desk, using stellar data from previously published work, but Pickering held the strong conviction that his observatory's prime function was to collect and classify data, rather than apply it to solve problems. At his behest, Leavitt instead dedicated herself for several years to a project on stellar magnitudes. Ultimately, her work served as the basis for an internationally accepted system that is still in use, though now revised.

In the meantime, recognizing the value in Leavitt's truncated research, the Danish astronomer Ejnar Hertzsprung picked up where she left off. In 1913, he devised a statistical model using known Cepheids in the Milky Way to calibrate Leavitt's period–luminosity graph. From that, he calculated the first intergalactic distance, to the Small Magellanic Cloud, thereby fulfilling the momentous promise of her work.

Yet Leavitt's desire to pursue further research on the variables never left her. Soon after Pickering's death in 1919, she at last divulged her interest to the observatory's soon-to-be director, Harlow Shapley. But just as she was on the verge of completing her prolonged stellar-magnitude project—when she might have at last returned to her work on variables—Henrietta Leavitt passed away, at the age of fifty-three. She had endured a grueling struggle with stomach cancer. By the time of her death, on December 12, 1921, she had discovered some 2,400 variable stars, about half the number then known to exist.

Unaware of Leavitt's passing, four years after her death a member of the Royal Swedish Academy of Sciences contacted the Harvard Observatory to inquire about her discovery, intending to use the information to nominate her for a Nobel Prize in Physics. By the rules of the award, however, the names of deceased individuals could not be submitted.

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In recognition of 2009 being the International Year of Astronomy, this article is the second of several on the events and scientists that have advanced our understanding of the cosmos during the last hundred years. This article was adapted from *The Day We Found the Universe*, by Marcia Bartusiak, © 2009. Reprinted with permission from Pantheon Books. All rights reserved.