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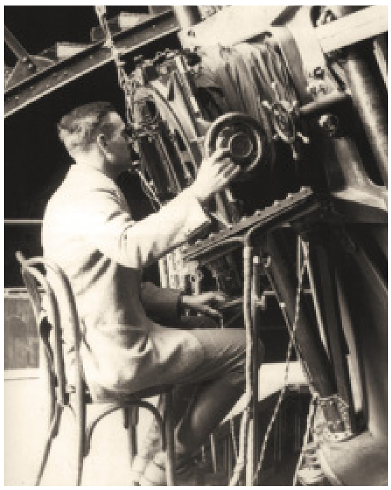
Hubble's Eureka Moment

Edwin Hubble's historic 1923 insight upended our understanding of the universe at the time.

In October 1923, Edwin Hubble photographed a star in the Andromeda Galaxy. This seminal observation would eventually prove not only that *spiral nebulae* truly lay outside the Milky Way, but it also opened the door for Hubble to discover and research numerous galaxies. And thus he demonstrated that the universe was not static as had been thought for millennia, but instead it was expanding. David Soderblom of the Space Telescope Science Institute once called this Cepheid variable "the most important star in the history of cosmology." Hubble's eponymous telescope imaged the star in 2010–2011 with the input of American Association of Variable Star Observers (AAVSO) members. When I first heard of this work, I asked myself, "Can this star be seen *visually* in an amateur instrument?"



▲ **HUBBLE WITH THE 100-INCH HOOKER** In the 1920s professional astronomy was still a very hands-on experience. Here Edwin Hubble is seated at the focus of the 100-inch Hooker telescope. He'd go on to make many significant discoveries with this instrument.

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Inconstant Stars

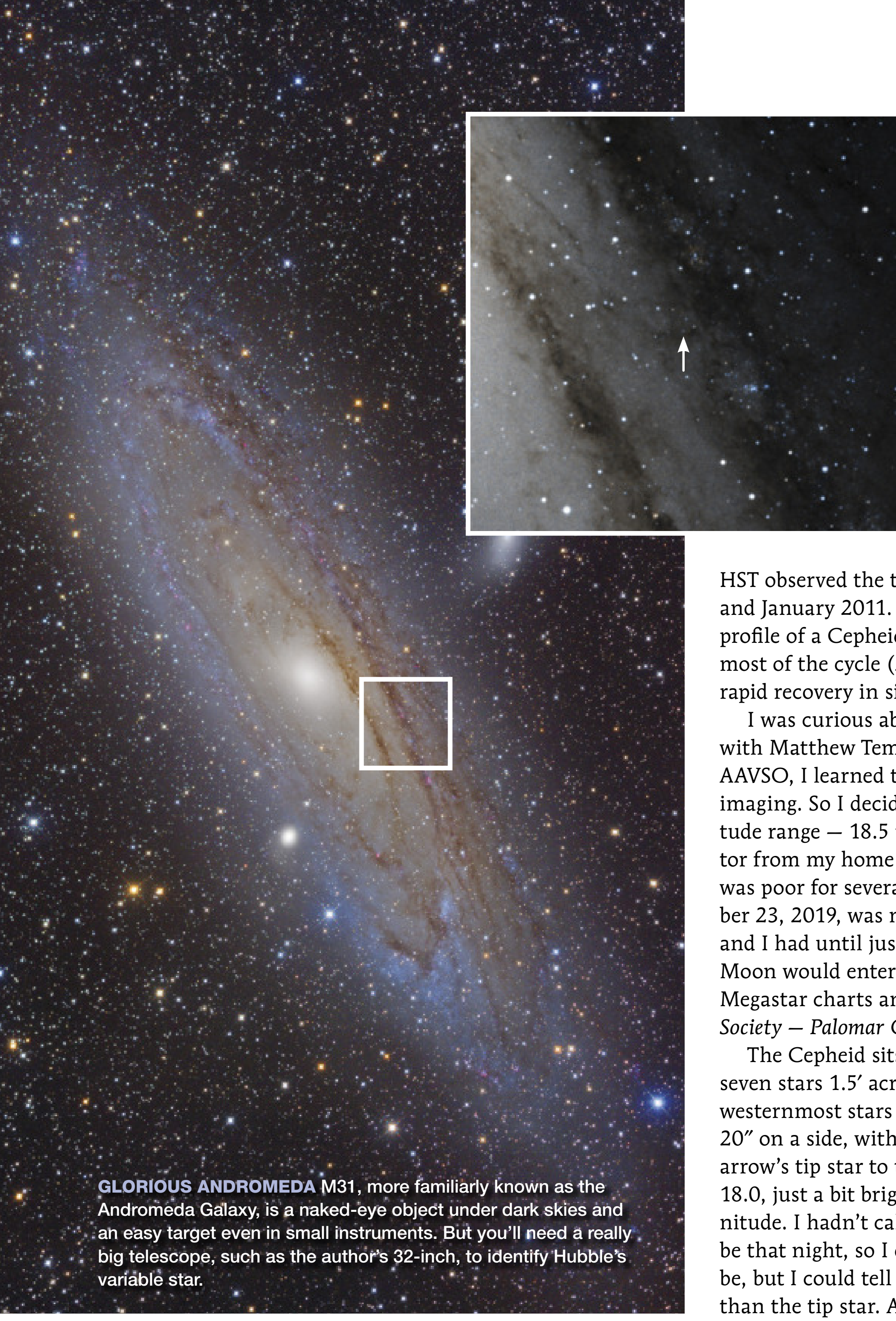
Documentation of variable stars (those that exhibit changes in brightness) exists in ancient Chinese and Korean texts, while German pastor David Fabricius reported the first European discovery, which was of Omicron Ceti, or Mira, in 1596. English observer John Goodricke studied variable stars in the 1780s with his neighbor Edward Pigott, who had a well-equipped observatory. The Royal Society awarded Goodricke its highest honor, the Copley Medal, for his interpretation of Algol's variability. He was also credited with the discovery of Delta Cephei, now considered the prototypical Cepheid variable. These are massive, very bright stars that vary in a specific manner on time scales of days or weeks — and the longer the star's pulsation period, the greater its luminosity.

Henrietta Swan Leavitt, working at the Harvard College Observatory, published the period-luminosity relation based on her studies of nearly 1,800 Cepheid variables in the Small Magellanic Cloud in 1908. (See *S&T:* Dec. 2021, p. 12 for an in-depth story on Leavitt's life and work.) The linear relationship between the log of Cepheids' periods and their luminosities is now called the Leavitt Law in her honor, and it's a fundamental cornerstone of modern cosmology.

In 1906, George Ellery Hale initiated plans for work to begin on the glass and building to house a 100-inch reflector on Mount Wilson. On the morning of November 2, 1917, a small group gathered to see first light for the world's largest telescope. Among the invitees was the English poet Alfred Noyes, who later wrote in his poem entitled "Watchers of the Sky" that the telescope would ". . . attack / That darkness . . . and win new worlds." After several attempts, the astronomers eventually aimed their instrument at a star, which they saw as a finely focused pinpoint, justifying the collaborators' toil and trouble.

Hubble, who had accepted Hale's offer to join the staff at Mount Wilson in 1919, knew of the Cepheid period-luminosity relation and initiated a search for these variables in the Andromeda Galaxy (M31) with the Hooker 100-inch telescope. The nature of spiral nebulae was at the center of astronomical debate at the time, with many believing the Milky Way to be the whole of what existed. On the night of October 5–6, 1923, Hubble noted that a star southwest of M31's core that he had marked with an "N" for nova was, in fact, dimming and rebrightening, which defied the known behavior of novae. Hubble crossed out the "N" and instead marked "VAR!" in bright red. This was the first of several dozen Cepheids he would find in this galaxy, after which he identified many more in M33 and other galaxies.

His distance calculations quickly led him to surmise that all these "nebulae" were extragalactic, that is, outside the bounds of the Milky Way. Hubble's results were first reported to the public about a year after the find in the *New York Times* on November 23, 1924, and then presented at the January 1, 1925, meeting of the American Astronomical Society. It wasn't until more than four years later that Hubble published his



GLORIOUS ANDROMEDA M31, more familiarly known as the Andromeda Galaxy, is a naked-eye object under dark skies and an easy target even in small instruments. But you'll need a really big telescope, such as the author's 32-inch, to identify Hubble's variable star.

◀ **TINY VARIABLE** M31-V1's coordinates are RA $00^h\ 41^m\ 27.3^s$, Dec. +41° 10′ 10.4″. If you center the small arrow-shape asterism in your field of view (12′ × 12′ at left), you should be able to spot Hubble's variable star (arrowed).

WIDE VIEW OF M31: MASIL IMAGING TEAM; ZOOM: POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY

observations in the *Astrophysical Journal*. That same year, 1929, Hubble recognized the relationship between galaxies' distances and their speeds of recession — the farther a galaxy lies from us, the faster it's receding. The universe was expanding! These two revelations must have offered the young astronomer a profound sense of discovery and accomplishment.

Homing in on M31-V1

In a tribute to the legendary man and his observations of this star, in late 2010 NASA planned to point the Hubble Space Telescope (HST) at M31's famous Cepheid, M31-V1 (officially cataloged as M31 V0619). AAVSO members observed the star for about six months beforehand in order to generate multiple light curves over the star's period of 31.4 days. This was so Hubble scientists would know when to aim the telescope at the star — they wanted to catch it at or near maximum and minimum brightness, and detailed studies of the star's phase didn't exist (even if basic parameters were known). HST observed the target four times between December 2010 and January 2011. M31-V1's light curve displayed the typical profile of a Cepheid: a relatively slow decline in brightness for most of the cycle (25 days for M31-V1), followed by a more rapid recovery in six to seven days.

I was curious about M31-V1, and in my correspondence with Matthew Templeton, then science director at the AAVSO, I learned that all observations thus far had been imaging. So I decided to observe it visually. The star's magnitude range — 18.5 to 19.8 — is accessible in my 32-inch reflector from my home in Minnesota. But the autumn weather was poor for several years. Then, the late evening of September 23, 2019, was magnificent. There was no dew or wind, and I had until just past midnight before a waning crescent Moon would enter the sky. I rapidly found the field using Megastar charts and a red plate from the *National Geographic Society — Palomar Observatory Sky Survey*.

The Cepheid sits within an arrowhead-shape asterism of seven stars 1.5′ across, with the tip pointing west. The three westernmost stars of that group form an equilateral triangle 20″ on a side, with M31-V1 its southeastern member. The arrow's tip star to the Cepheid's west-northwest is magnitude 18.0, just a bit brighter than our target star's brightest magnitude. I hadn't calculated where in its cycle the star would be that night, so I didn't know what its magnitude should be, but I could tell right away that it was quite a bit fainter than the tip star. As chance had it, the Cepheid was on day 23 of its 31.4-day cycle, just before the minimum magnitude of 19.8. I observed the area for about 75 minutes, employing a number of eyepieces that gave magnifications from 363× to 650×, in seeing that was 7/10 and transparency 7–8/10. Finally, with a 6-mm Zeiss Abbe Ortho at 521×, I confirmed M31-V1 just before midnight. Being sure to see it several times, I rejoiced in a journey retracing the history — and appreciating the importance — of this singular star.

■ **DAVE TOSTESON** enjoys when history and cosmology combine with atmospheric clarity to recreate "Eureka!" moments of observation.