Variable Stars Pulse in a New Light

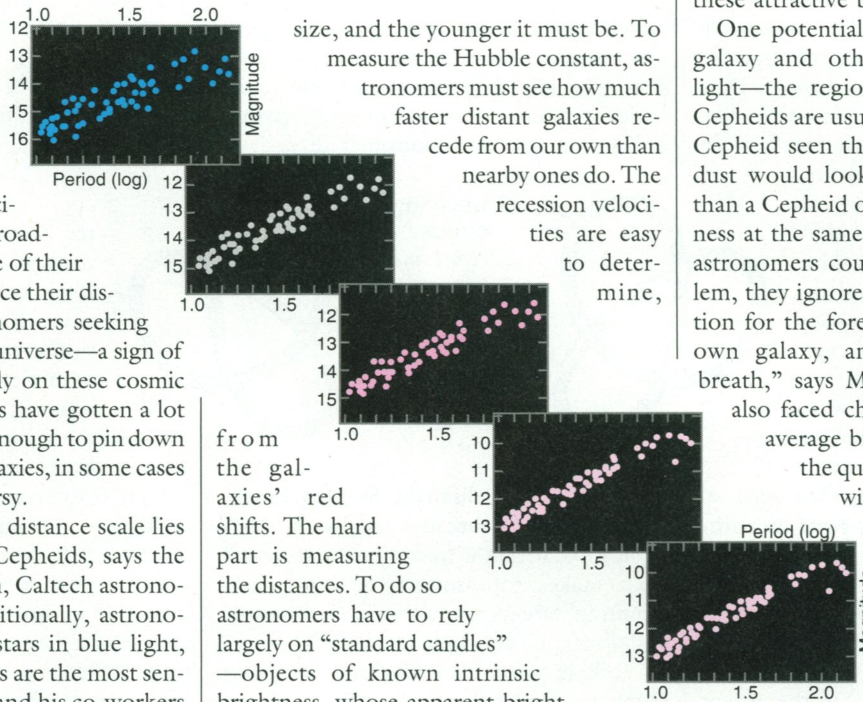
Infrared views of Cepheid variables pin down the distances of nearby galaxies—and maybe even the age of the universe

NOTHING WARMS THE heart of an astronomer fathoming the depths of the universe on a freezing night like a Cepheid variable. These bright yellow stars pulsate with the precision of a Swiss watch, broadcasting an elegant measure of their innate brightness, and hence their distance. For decades astronomers seeking the expansion rate of the universe—a sign of its age—have relied heavily on these cosmic calibrators. Now Cepheids have gotten a lot more accurate—accurate enough to pin down the distances to nearby galaxies, in some cases after decades of controversy.

The key to refining the distance scale lies in the way you look at Cepheids, says the leader of the new research, Caltech astronomer Barry Madore. Traditionally, astronomers have observed the stars in blue light, where photographic plates are the most sensitive. But when Madore and his co-workers tracked Cepheids with state-of-the-art electronic detectors that are sensitive to red and infrared light, they found that the stars' pulsing could provide an even more accurate indication of their brightness and distance than astronomers had thought.

Their colleagues are impressed. "These are absolutely first-rate astronomers doing a very fine job," says University of Chicago cosmologist David Schramm. That's no small tribute, because Schramm is uneasy with the cosmological conclusion Madore and his colleagues are drawing from their work. Like earthly standards of length or weight, the measured galaxies served for calibrating other distance scales far-reaching enough to yield a measure of the expansion rate of the cosmos as a whole. The upshot, which Madore's group announced at last week's meeting of the American Astronomical Society (AAS) in Atlanta: evidence that the universe is no more than 10 billion years old, younger than Schramm and some other cosmologists like to think.

The point of dispute—and the ultimate goal of the Cepheid work—is the Hubble constant, a measure of cosmic expansion. The bigger the Hubble constant is, the less time the universe has had to reach its present size, and the younger it must be. To measure the Hubble constant, astronomers must see how much faster distant galaxies recede from our own than nearby ones do. The recession velocities are easy to determine, from the galaxies' red shifts. The hard part is measuring the distances. To do so astronomers have to rely largely on "standard candles"—objects of known intrinsic brightness, whose apparent brightness then gives the host galaxy's distance. But because astronomers have not been able to settle on a truly reliable standard candle, published values for the Hubble constant lie anywhere between 50 and 100 kilometers per second per megaparsec. That leaves the universe's age uncertain by a factor of two.



Better relations. *Seen in infrared wavelengths* (bottom two graphs), *Cepheids show a tighter link of brightness to period than they do in visible light.*

SOURCE: MADORE AND FREEDMAN ILLUSTRATION: J. CHERRY

No wonder, then, that astronomers have been eager to tune up the precision of Cepheid variables, among the most widely used standard candles. Cepheids first caught astronomers' attention in 1784 because the stars rhythmically brighten and dim over periods ranging from days to months as they expand and contract slightly. Early in the twentieth century, Henrietta Leavitt of the Harvard College Observatory found that when she looked at Cepheids in a single nearby galaxy, the length of each star's pulsation period correlated with its apparent brightness. Since all the galaxy's stars lay at a similar distance, the timing of the Cepheids' variations was giving a measure of their intrinsic brightness. That meant that wherever a Cepheid was spotted, astronomers could determine its distance by timing it, then comparing the calculated intrinsic brightness with its brightness as seen from Earth.

Since then, astronomers have come to rely heavily on Cepheids for their distance estimates to nearby galaxies. As Carnegie Observatories astronomer Wendy Freedman, who has been collaborating with Madore, points out, "They're among the brightest stars that you can find in other galaxies, so they're easily identified." But Madore and his colleagues suspected that these attractive beacons might be flawed.

One potential problem was dust in our galaxy and others, which absorbs blue light—the region of the spectrum where Cepheids are usually observed. As a result, a Cepheid seen through a lot of intervening dust would look fainter and farther away than a Cepheid of the same intrinsic brightness at the same distance. But since earlier astronomers couldn't solve the dust problem, they ignored it. "They made a correction for the foreground absorption in our own galaxy, and then they held their breath," says Madore. Cepheid observers also faced challenges in measuring the average brightness of their targets—the quantity that, when compared with a star's pulsation rate, would give its distance. Cepheids fluctuate more widely in blue light than at redder wavelengths, which makes it easy to spot them but harder to get an average brightness.

Madore and his colleagues suspected that if they systematically surveyed Cepheids at other wavelengths—especially red and infrared—they could cut these problems down to size. Unlike blue light, red and infrared zip through dust, so that only distance should be affecting a Cepheid's brightness—which in turn becomes easier to measure. And as a bonus, stellar theory suggested that pulsation rate is an even better gauge of intrinsic brightness in the infrared than at other wavelengths.

Madore and his students began testing their ideas in the early 1980s, when better infrared detectors became available. They journeyed to observatories in Chile to observe Cepheids in the Large and Small Magellanic Clouds, two satellite galaxies of the Milky Way that lie in the southern sky. Because the Magellanic Clouds are nearby, they teem with visible Cepheids, so Madore and his students could perform the same kind of comparisons of period and brightness Henrietta Leavitt had done 80 years before. But they saw a much tighter relationship than she—or any of her successors—had seen. "It was really quite stunning," Madore says. "Right at the telescope, we could plot up the raw data and see that the dispersion in the period-luminosity relationship was minuscule." All told, the relationship turned out to be three times tighter in infrared than in blue wavelengths.

Because the distance to the Large Magellanic Cloud is already known, Madore and Freedman could turn the fine-tuned Cepheid scale into a measure of absolute distance. Some of the best evidence for the distance to the Large Magellanic Cloud comes from supernova 1987A, which exploded there 5 years ago and produced an expanding ring of light. The light's travel time gave the absolute size of the ring, and last year Hubble Space Telescope investigators measured the ring's angular size, opening the way to a geometric determination of the Magellanic Cloud's distance—163,000 light-years. Says Madore, "Geometry is one of the hardest things to refute."

Madore and Freedman then proceeded to apply their calibrated Cepheid scale to other nearby galaxies, notably Andromeda and M33, two members of the Local Group—the same collection of galaxies that includes our own. They also made forays into the two nearest galaxy groups, the Sculptor group and the M81 group, which lie on opposite sides of us. For some galaxies, the scientists confirmed previously known distances, but for others they laid to rest past disagreements of over 30%.

That still wasn't enough to lead Madore and Freedman to their goal of a more precise figure for the Hubble constant. The distances and velocities of the nearby galaxies in which they observed Cepheids can't pin down the constant, because those galaxies feel the gravitational attraction of each other as much as they feel the universe's overall expansion. Andromeda, for example, actually moves toward us. Likewise, the Local Group perturbs the Sculptor and M81 groups, and all three groups get pulled toward the Virgo galaxy cluster, which lies between 40 million and 70 million light-years away. To determine the Hubble constant, astronomers have to measure distances to galaxies so far away that such effects get averaged out. But at those distances, Cepheids can't be picked out from among other stars.

The researchers' solution was to use the Cepheids to calibrate more far-reaching distance scales, just as they had calibrated the Cepheid scale with the known distance to the Large Magellanic Cloud. Madore and Freedman applied the Cepheid results to distances other workers had estimated using two standard candles—spiral galaxies that have similar rotation rates and planetary nebulae, bubbles of gas blown by aging stars—and a third indicator, the apparent graininess of target galaxies. And all three Cepheid-calibrated scales gave the same answer for the Hubble constant, which Freedman presented at the AAS meeting: 83 plus or minus 13.

That figure, which implies a universe only 8 billion to 10 billion years old, is in line with evidence from some other cosmic surveys. But other researchers, including Schramm, think there are compelling reasons for insisting on an older universe. Chief among them are the Milky Way's globular clusters, the spherical concentrations of stars that include some of the galaxy's oldest residents. Models of how stars evolve imply that the oldest clusters are some 15 billion years old, says Schramm. Even though he has no quarrel with Madore and Freedman's Cepheid work, he is not convinced by the extrapolations from the Cepheid-calibrated galaxies to more distant ones. "'I know the value of the Hubble constant,'" he says, is one of "the famous lies in astronomy." Schramm's own preferred standard candles, supernovae, give a Hubble constant of only 50 or 60, he says, in line with the age inferred from globular clusters.

Madore, not surprisingly, thinks the new Cepheid-based value has the advantage over its competitors, since it emerged from three different techniques for determining cosmological distances. And even Schramm agrees that Cepheids would pin down the Hubble constant if the pulsating stars could be seen at distances large enough to probe the universe's expansion rate directly. That leaves Cepheid aficionados awaiting the verdict of NASA's Hubble Space Telescope, which, when fixed, should have enough resolution to spot Cepheids in the Virgo cluster—and settle much of the present debate. ■ KEN CROSWELL

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Pop! Goes the Pulsar Planet

Andrew Lyne looked strangely distraught for a man about to describe his spectacular discovery, first announced last summer, of what seemed to be the first planet outside the solar system. But the University of Manchester radio astronomer had changed his plans in the days before his scheduled talk at the American Astronomical Society Meeting in Atlanta last week. Instead of telling a tale of triumph, he shocked the audience of several hundred with an anguished confession: The planet was a mistake.

"It was an artifact of the earth's motion around the sun," Lyne told the audience. His hearers reacted sympathetically to his retraction. But it did not sour them on the idea of pulsar planets—as their favorable reception of another talk, about a new crop of pulsar planets, showed.

The now-defunct planet came to Lyne and his colleagues as a seeming stroke of serendipity while they were observing radio pulses emanating from a dense, burned-out star known as a pulsar. The researchers noticed deviations from the usually perfect timing of the pulsar's pulses, and the regularity of the deviations suggested they were the result of an orbiting companion—a pulsar planet.

Some theorists initially suspected that Lyne had been misled by some effect of the Earth's rotation, because the period of his pulsar planet was almost exactly 6 months. "The phase and period both seemed to know about the earth's motion," University of Cambridge theorist Martin Rees recalls. But Lyne, an experienced pulsar observer, had corrected for the Earth's motion. Even Rees said he was convinced by Lyne's careful analysis.

But a week before the meeting, Lyne realized his planet wasn't there. In what he called "a moment of consternation," he reanalyzed his data and "the planet evaporated."

To explain where he went wrong, Lyne showed his listeners a flow chart illustrating the complex, looped procedure he used to home in on the pulsar's location and, at the same time, correct for the effect of Earth's orbit on the pulse rate. Lyne says he normally accounts for Earth's motion in several parts of the procedure. In cases where corrections have a relatively minor effect, he approximates Earth's elliptical orbit as a circle. That works with most pulsars, but in this case small errors and bad luck conspired against him.

This pulsar's location at first eluded him and his colleagues, he says, because the intensity of its pulses kept changing as the researchers scanned their radio telescope in search of it. The unusually large correction they eventually made for the position magnified the normally insignificant effect of the circular-orbit approximation to give a spurious planet signal.

After Lyne's account of pulsar pitfalls, the next speaker might have been daunted. But Aleksander Wolszczan of Cornell, who announced just 2 weeks ago in *Nature* that he had spotted a pulsar with at least two planets (*Science*, 17 January, p. 290), said he had checked and knew he hadn't made the same mistake. The first pulsar planet may have disappeared, but Rees and other theorists agreed that its heirs have a good chance of survival. ■ FAYE FLAM