The Struggle to Measure Cosmic Expansion

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Correction Appended

Hoping to understand why the universe seems to be coming apart at its seams, a young astronomer and his colleagues have embarked on one of the oldest quests in cosmology, to measure how fast the universe is growing, how big it is and how old it is.

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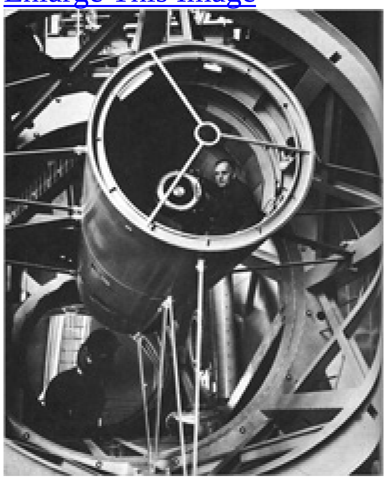

PIONEER Edwin Hubble at the Palomar Observatory, inside the telescope.

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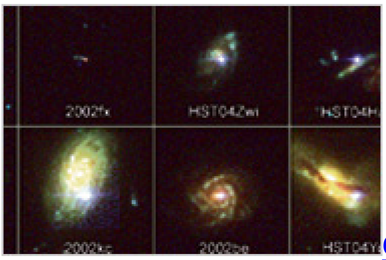
Hubble Before Hubble

 Graphic

Measuring the Constant

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That information is encoded in the value of an elusive number known as the Hubble constant that has led astronomers on a merry chase for three-quarters of a century. “It is the most fundamental number in cosmology,” said Adam Riess, 38, an astronomer at the Space Telescope Science Institute and Johns Hopkins University, and one of the discoverers 10 years ago that some kind of “dark energy” is speeding up the expansion of the universe.

This spring, in what he called “a triumph of metrology,” Dr. Riess announced that he and his comrade, Lucas Macri of Texas A&M University, had used the Hubble Space Telescope to make the newest and most precise measurement yet of this parameter.

Expressed in the quaint terms astronomers favor, the Hubble constant, Dr. Riess reported, is 74 kilometers per second per megaparsec. It means that for every additional million parsecs (about 3.26 million light-years) a galaxy is from us, it is going 74 kilometers per second faster.

The news was not in Dr. Riess’s value, which, reassuringly, agreed roughly with the result from an earlier space telescope team led by Wendy Freedman, the director of Carnegie Observatories, and with calculations based on measurements of relic radiation surmised to be left from the Big Bang, but in the precision with which his group claimed to have measured it: an uncertainty of only 4.3 percent.

Only 30 years ago, distinguished astronomers could not agree within a factor of two on the value of Hubble’s constant, leaving every other parameter in cosmology uncertain by at least the same factor and provoking snickers from other fields of science.

But this is the age of so-called precision cosmology.

“I’m not saying we’re going to get to 1 percent,” Dr. Riess said, “but we might.”

Dr. Riess's announcement was regarded as a hopeful beginning by other astronomers and cosmologists concerned with the fate of the universe and of physics. Knowing the precise value of the rate of expansion of the universe, they explain, has emerged as a key to understanding dark energy. The more precisely they can pin down the value of the Hubble constant, the more precisely they can pin down the properties of that enigmatic, cinematic sounding force.

"I think Adam's work is nice," said Dr. Freedman, who has led a large space telescope effort to measure the constant. But she and others added that some parts of Dr. Riess's scheme could be vulnerable to the sorts of so-called systematic errors that have embroiled previous generations of astronomers in controversy — the effects of dust and galactic chemistry, for example, on the brightness of distant stars.

In an e-mail message, John Huchra of the Harvard-Smithsonian Center for Astrophysics wrote, "we know of several big bugaboos."

The stakes are bigger than just dark energy. Cosmologists would like to know whether their so-called standard model of the universe makes sense. Is the universe in fact 13.7 billion years old, full of dark matter and dark energy, and speckled with galaxies that grew by gravity from random microscopic fluctuations in the Big Bang?

That universe is described mathematically by half a dozen fundamental parameters, from which the Hubble constant can be calculated. But to test the model "at a physically interesting level," in the words of Dr. Huchra, the Hubble constant, as well as other parameters, needs to be actually measured to high accuracy.

Both the telescope and the "constant" are named after Edwin Hubble, the Mount Wilson astronomer who discovered in 1929 that the universe was expanding. It is not really constant. Over cosmic time, gravity tries to slow the expansion while dark energy, as astronomers discovered to their surprise 10 years ago, tries to speed it up. The history of the Hubble constant has seen many hopeful beginnings that have subsequently floundered on the difficulty of divining accurate distances to dim blurry lights in the sky, that is to say, galaxies. Both the 200-inch Hale telescope on Palomar Mountain in California, inaugurated in 1948, and the Hubble Space Telescope, launched 42 years later, were supposed to solve the problem.

Allan Sandage, also of Carnegie Observatories, who inherited the universe when Mr. Hubble died in 1953 and has been measuring and remeasuring the Hubble constant ever since, likes to say that astronomy is an impossible science. "It's marvelous to get a distance," he said once, "because it's almost impossible to believe that you can do it."

Astronomers can triangulate to determine the distances to the nearest stars, looking to see how they shift against background stars as the Earth goes from one side of its orbit around the Sun to the other side, but to gauge deeper distances they depend on finding so-called standard candles. These are stars or other objects whose intrinsic luminosities are known and thus their distances can be inferred from their apparent brightness.

Among the most reliable of these candles are Cepheid variables, pulsating stars that dim and fade in a sawtooth pattern. The more luminous they are the longer their cycle. So such a star in a distant galaxy, by its winking, is broadcasting its luminosity and distance.

Unfortunately, the more luminous and thus more useful such candles are, the rarer they are and the harder it is to find enough examples to calibrate them. So the blue-water sailors of the cosmos have to step outward by a "distance ladder," calibrating stars nearby and then using them to calibrate brighter but rarer "standard candles" in more distant galaxies, stepping ever outward. The standard candles of choice for many astronomers are exploding stars known as Type 1a supernovae, brilliant enough to be seen across the universe.

But as astronomers step outward, small errors multiply and their candles get more uncertain.

According to a recent compilation by Dr. Huchra, more than 500 values of the Hubble constant have been published over the years. Astronomers are now within shouting distance of agreement. In recent years the two main teams using the Hubble telescope to measure the constant, one led by Dr. Freedman and the other led by Dr. Sandage, have arrived at answers 15 percent apart, 70 and 62, respectively, with 10 percent error bars that slightly overlap.

And there things might have stayed, Dr. Riess said. Few Americans are lying awake at night waiting to know the expansion rate of the universe to 1 percent accuracy. For most people, that the universe is expanding is baffling enough.

But dark energy has upped the ante.

More than a few physicists and astronomers are lying awake at night wondering if the dark energy driving this behavior is a fudge factor that Einstein invented in 1917 to keep the universe static, and then abandoned.

Dr. Riess likens the different kinds of cosmological observations that go into making the standard cosmological model to the spokes of a bicycle wheel. To home in on dark energy, "We have to go around the wheel tightening the spokes," he said.

One of the easiest spokes to tighten, Dr. Riess said he realized a couple of years ago, is the Hubble constant. In one typical calculation, for example, an uncertainty in the Hubble constant translates into twice as much uncertainty in a crucial measure of dark energy's oomph. So cutting the Hubble uncertainty goes a long way toward sharpening the estimates of dark energy.

All the measurements of the Hubble constant have suffered from the fact that there are too many rungs on the distance ladder, and thus chances for error, Dr. Riess said.

Measuring the Hubble constant this way, he said, is like measuring a room by laying a ruler end over end. Every time you pick it up and lay it down again you can make a mistake. “What you need is a tape measure,” he said.

Dr. Riess’s tape measure is the Hubble Space Telescope, and its workhorse instrument, the Advanced Camera for Surveys. The pair can find and measure the gold standard Cepheid stars much farther out in space than other telescopes, he said, and thus skip several intermediate calibration steps and the attendant chances for error.

“Better data and techniques come along in time whether anyone likes it or not,” Dr. Riess said via e-mail. “I want to make clear that the Hubble constant can be measured to better precision than the past and should be no more controversial than any other physical parameter we measure.”

Dr. Riess’s distance ladder has only three rungs and one telescope, leaping from the Milky Way’s neighborhood to supernova explosions as distant as a billion light-years.

It starts with a galaxy known as NGC 4258 (a k a Messier 106 in Ursa Major), where astronomers have found clouds emitting radio waves at a frequency characteristic of water vapor circling the center of the galaxy, as well as the all-important Cepheid stars. By tracking the speeds and motion across the sky of these clouds with high resolution radio observations, a team led by James Herrnstein of the National Radio Astronomy Observatory in Socorro, N.M., in 1999 determined its distance as 23.5 million light-years.

Knowing the distance to that galaxy allowed Dr. Riess and his team to calibrate the Cepheids, which they then used to calibrate supernovas.

Several astronomers said it was worrisome that Dr. Riess’s calibration of the Cepheids and thus the whole distance ladder rests on that one galaxy. It would be desirable, they say, to have accurate distances to more such galaxies, a project being pursued by Jim Braatz of the National Radio Astronomy Observatory in Virginia. In the meantime, as a backup technique for calibrating the Cepheids, Dr. Riess and colleagues have used Hubble’s fine guidance sensors, which help the telescope find and track stars, to triangulate the distances to Cepheid variable stars in our galaxy. The results for the Hubble constant are the same, he said.

So, Dr. Riess’s trek along the Hubble trail is just beginning. The results will probably get “a smidgen better” over the coming months, he said.

Astronauts are going to try to repair the advanced camera, which broke down last year, during the final Hubble service call in October. If they are successful, Dr. Riess and his team will be using the camera to extend their search for more supernovas and Cepheid stars. On the other end of the ladder, new telescope surveys, including Pan-STARRS, for Panoramic Survey Telescope and Rapid Response System, whose prototype is in operation on top of Haleakala on Maui, Hawaii, are expected to find thousands of supernovas far out in space, greatly increasing the accuracy of measurements both of dark energy and of Hubble's troublesome constant.

It's never going to be "Yup, now we've nailed it," Dr. Riess said. "This is humankind's quest: to be always doing this. We're looking to always make a cleaner handoff."

Showing no effect of the weight of history, he said, "This is still early days."

This article has been revised to reflect the following correction:

Correction: August 21, 2008
An article on Tuesday about efforts to achieve a precise measurement of the Hubble constant, a number crucial to understanding the expansion of the universe, misstated the academic affiliation of Lucas Macri, one of the scientists who used the Hubble Space Telescope to make the newest and most precise measurement. He is at Texas A&M, not the University of Texas.

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