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# Cosmos Controversy: The Universe Is Expanding, but How Fast?

A small discrepancy in the value of a long-sought number has fostered a debate about just how well we know the cosmos.

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There is a crisis brewing in the cosmos, or perhaps in the community of cosmologists. The universe seems to be expanding too fast, some astronomers say.

Recent measurements of the distances and velocities of faraway galaxies don't agree with a hard-won "standard model" of the cosmos that has prevailed for the past two decades.

The latest result shows a 9 percent discrepancy in the value of a long-sought number called the Hubble constant, which describes how fast the universe is expanding. But in a measure of how precise cosmologists think their science has become, this small mismatch has fostered a debate about just how well we know the cosmos.

"If it is real, we will learn new physics," said Wendy Freedman of the University of Chicago, who has spent most of her career charting the size and growth of the universe.

The Hubble constant, named after Edwin Hubble, the Mount Wilson and Carnegie Observatories astronomer who discovered that the universe is expanding, has ever given astronomers fits. In an expanding universe, the farther something is away from you, the faster it is receding. Hubble's constant tells by how much.

But measuring it requires divining the distances of lights in the sky — stars and even whole galaxies that we can never visit or recreate in the lab. The strategy since Hubble's day has been to find so-called standard candles, stars or whole galaxies whose distances can be calculated by how bright they look from Earth.

But the calibrators themselves need to be calibrated, which has led to a rickety chain of assumptions and measurements in which small errors and disagreements — about, say, how much dust is interfering with observations — can build up to cosmic proportions. Only three decades ago, renowned astronomers could not agree on whether the universe was 10 billion or 20 billion years old. Now everybody has settled on its age as about 13.8 billion years.

Using a new generation of instruments like the Hubble Space Telescope, astronomers have steadily whittled down the uncertainty in the Hubble constant.

## Getting Closer

In 2001, a team led by Dr. Freedman reported a value of 72 kilometers per second per megaparsec (about 3.3 million lightyears), in the galumphing units astronomers prefer. It meant that for every 3.3 million lightyears a galaxy was farther away from us, it was moving 72 kilometers a second faster.

Hubble's original estimate was much higher, at 500 in the same units of measurement.

Dr. Freedman's result had an error margin that left it happily consistent with other more indirect calculations, that had gotten a slightly slower and lower value of 67 for the Hubble constant. Those were derived from studies of microwaves emitted and still lingering in the sky from the the primordial Big Bang fireball.

As a result, in recent years, astronomers have settled on a recipe for the universe that is as black and as decadent as a double dark chocolate chunk brownie. The universe consists of roughly 5 percent atomic matter by weight, 27 percent mysterious dark matter and 68 percent of the even more mysterious dark energy that is speeding up the cosmic expansion. Never mind that we don't know exactly what all this dark stuff is. Astronomers have a good theory about how it behaves, and that has allowed them to tell a plausible story about how the universe evolved from when it was a trillionth of a second old until today.

But now the Hubble precision has gotten seemingly better, and the universe might be in trouble again.

Last summer a team led by Adam Riess of Johns Hopkins University and the Space Telescope Science Institute, using the Hubble Space Telescope and the giant Keck Telescope on Mauna Kea in Hawaii and supernova explosions as the ultimate distance markers, got a value of 73 plus or minus only 2.4 percent for the elusive constant.

That made waves because it meant that, if true, the Hubble constant as observed today was now clearly incompatible with a result of the lower slower value of 67 inferred from data obtained in 2013 by the European Planck spacecraft of relic radiation from the Big Bang. The Planck mission observations that show the universe when it was only 380,000 years old are considered the gold standard of cosmology.

Whether the standard cosmic recipe might now need to be modified — for example, to account for a new species of subatomic particles streaming through space from the Big Bang — depends on whom you talk to. Some say it is too soon to get excited about new physics sneaking through such a small discrepancy in a field noted for controversy. With more data and better understanding of statistical uncertainties, the discrepancy might disappear, they say.

"No explanation I know of is less ugly than the problem," Lawrence M. Krauss, a theorist at Arizona State, said.

Others say this could be the beginning of something big. David Spergel, a cosmologist at Princeton and the Simons Foundation, called the discrepancy "very intriguing," but said he was not yet convinced that this was the signature of new physics. Michael S. Turner of the University of Chicago said, "If the discrepancy is real, this could be a disruption of the current highly successful standard model of cosmology and just what the younger generation wants — a chance for big discoveries, new insights and breakthroughs."

Dr. Riess and his colleague Stefano Casertano got roughly the same answer of 73later last summer, strengthening the claim for a mismatch of Hubble constants. They used early data from the European spacecraft GAIA, which is measuring the distances of more than a billion stars by triangulation, thus allowing astronomers to skip some of the lower rungs on the distance ladder.

They calculated that the odds of this mismatch being a statistical fluke were less than one part in a hundred — which might sound good in poker but not in physics, which requires odds of less than one in a million to cement a claim of a discovery.

"I think it's a potentially serious issue," said Alex Filippenko, a University of California astronomer who is part of the team. "In this line of research the devil is in the details. And after getting the details right, we're left with a major puzzle."

George Efstathiou, of the University of Cambridge and one of the leaders of the Planck mission responsible for its cosmological analysis, said Dr. Riess and his team had underestimated the errors in their measurement.

"So, in summary, I think that the Planck results are secure," he wrote in an email. "They," he said, referring to the other astronomers, "may be right and we have to modify their standard model, but the evidence looks weak to me."

Dr. Riess and his colleagues have stood by their work, however, and the plot thickened further in December when a group called H0LiCOW (don't ask) from the Max Planck Institute for Astrophysics in Garching, Germany, reported its own value of 72 for the Hubble constant, also inconsistent with the Planck space mission's analysis.

Led by Sherry Suyu of Max Planck, the group measured the delays experienced by light rays from five distant flickering quasars as they followed different paths around massive galaxies on the way from Out There to us. . The technique, they say, depends only on geometry and Einstein's theory of gravity, general relativity, making it independent of other assumptions about dust or the makeup of stars.

Last year, a group known as BOSS, the Baryon Oscillation Spectroscopic

Survey, came up with a Hubble constant of about 68, based on how 1.5 million galaxies were clustered in space and time, but it used data from the cosmic microwave background for calibration.

## What Comes Next?

There is wiggle room, Dr. Riess and others say, for both the modern and the primordial results to be right, because Planck measures the Hubble constant only indirectly as one of several parameters in the standard model of the universe. Other parameters could be tweaked.

That is where new physics might come in.

The most likely candidates to fill the gap, Dr. Riess said, might be a new form of the ghostly particles called neutrinos, already known to be abundant in the cosmos. They come in three types that can change into one another as they traverse space; some physicists have suggested there could be a fourth kind, called sterile neutrinos, that don't interact with anything at all.

Their discovery could unlock new realms in particle physics and perhaps shed light, so to speak, on the quest to understand the dark matter that suffuses space and provides the gravitational scaffolding for galaxies.

Another possibility is that the most popular version of dark energy — known as the cosmological constant, invented by Einstein 100 years ago and then rejected as a blunder — might have to be replaced in the cosmological model by a more virulent and controversial form known as phantom energy, which could cause the universe to eventually expand so fast that even atoms would be torn apart in a Big Rip billions of years from now.

"This is a very interesting tension," Dr. Riess said. "This is why we play the game. We look for something not fitting."

He added, "Clues about the dark sector or about fundamental physics are in play."

This is the age of "precision cosmology," and while everybody agrees that it is still too soon to tell, the avalanche of data from GAIA and the coming James Webb Space Telescope is just beginning, Dr. Freedman said. In the next few years she hopes the Hubble constant can be measured to 1 percent accuracy.

"And that's what makes it interesting — this is feasible, and a lot of work is now ongoing that will allow us to resolve this within the next couple of years," she said. "It's what makes me want to work on this again!"

She said the situation reminded her of the late 1990s, when discrepant distances to distant supernova explosions led to the discovery that the expansion of the universe was accelerating under the influence of dark energy. Dr. Riess won a Nobel Prize for his part in that, and dark energy took its place in cosmic orthodoxy.

"It's not quite 'déjà vu,'" he wrote in an email, "but it's funny that whenever my colleagues and I look at the contemporary universe with our radar guns, it's expanding too fast for the contemporary expectations!"



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