are objectively true, but is our entire view of the universe, based on our current scientific theories, true? Is it even close?

Throughout history, scientists have assumed that their view of the universe was close to being true. Each time, they were proven wrong. It is probably equally wrong to make the same assumption today. We can't even assume that we are making substantial progress toward knowing the truth about the universe, because we don't know how far our current theories are from the truth. Our progress to date might be negligible compared with the distance we have yet to go. However, we can measure the extent to which our present theories explain what we can currently examine. We observe natural phenomena, try to fit them into the framework of current theories, and try to think up explanations for them. Making new observations leads to new theories, which leads to technological advancements, which are applied to building new experimental tools, which enable us to observe natural phenomena that we could not detect previously, which means we have to revise our theories. The process continues in a never-ending feedback loop.

Let me pose a question: Can you arrive at the truth by a method other than science? My answer: That depends on what you mean by "science." We consider Western science to be motivated by natural philosophy going back to the ancient Greeks, which includes a framework of logical reasoning and the scientific method. That approach has been very successful. However, for centuries, the Chinese were able to make scientific progress without that Western tradition, which proves that it is possible, even though their science later stagnated compared with the West's.

Jeffery Winkler
(jefferywinkler@mail.com)
Hanford, California

In his July 2016 editorial, Charles Day asks readers to imagine what extraterrestrial science might look like. Here's my response:

Planet Q is cold and dark by our standards, but it is teeming with life. Its inhabitants are microscopic; so small, in fact, that their tiny eyes can see one photon at a time. With their hands they can feel a single atom. They experience a world of quantum jumps, where nothing is gradual or smooth. They do not think of time as a continuously flowing quantity because the only way they can detect its passage is through some kind of change, and all the changes they see are spontaneous and unpredictable. For them, time lurches forward in fits and starts.

Their advanced understanding of quantum mechanics has enabled them to produce sophisticated technology—what we would call nanotechnology. But their science is based on discrete mathematics and number theory; they would be puzzled by our concept of a smooth, differentiable curve. They would be surprised to learn about our Schrödinger equation because it leaves out the quantum jump, the most prominent feature of the physical world.

It would be hard to convince the inhabitants of Planet Q that such things as electromagnetic waves exist, although, of course, they have analogues of diffraction and interference in their own equations. It would be like telling a couple of ants crawling across a pointillistic painting that they are actually standing on a drawing of an umbrella. That would seem unnecessarily abstract to them: Why would you group together those dots and call them something else? If you understand photons, you have no need of an electromagnetic field.

And the residents of Planet Q really would not recognize our ray optics. Even terrestrial physicists agree that such a thing as a light ray does not exist, yet they nevertheless calculate its displacement and direction as it goes through a lens. Earth-bound scientists might patiently explain that the light ray is a convenient fiction, a calculational tool; however, the beings from planet Q have brains that work like quantum computers, so they have no need of such mental crutches.

By contrast, the Shadow people are unimaginably large, each blood cell larger than a solar system, their bodies the size of a galaxy. They move slowly, think slowly, and pay no attention to us. Their physics describes their kind of matter, dark matter, and does not include any details about our familiar electrons, protons, and neutrons, since they hardly interact with those particles.

Zooming out from our galaxy, we see our whole universe, and then a myriad of other universes, coming into existence and expanding like the bubbles in a pot of water that has just come to a boil. That is the multiverse. It was created as a science fair project by an alien being whose name roughly translates to Timmy. He mixed together what we might call—in a very crude analogy—chemicals and heated them on the stove. (The secret, his mom said, is to add just the right amount of inflatons.)

As the pot started to boil, Timmy's eyes grew wide with delight. He leaned forward to take a closer look, and as our universe floated up, he said, "Wow!"—an exclamation that took, by our reckoning, 100 billion years.

Greg Keaton
(gkeaton1@mindspring.com)
San Francisco, California

Footnote on femtochemistry

Marcos Dantus commented on the femtosecond bond formation by bringing readers' attention to his and others' early contributions in the 1990s (PHYSICS TODAY, November 2015, page 10). I would like to add to the discussion an interesting interview comment by Yuan T. Lee, who shared the 1986 Nobel Prize in Chemistry for his work on molecular beams.[1]

When Lee was asked, "Do you think that what is called femtochemistry has overtaken what you had been doing?," he replied,

> Not really. The people doing femtochemistry always say that for studying the molecular beams they have to go to femtochemistry. However, when we do chemical reactions, we already have the rotational period as a clock. In the reaction of potassium and methyliodide, what Dudley Herschbach was doing, it was possible to see the product bouncing backward in the time period of one rotation. That clock is a picosecond clock. It made it possible to tell how fast that chemical reaction took place. One of the reactions was particularly interesting. It was a charge transfer reaction between potassium and oxygen. At a long distance there is an electron transfer and the oxygen starts vibrating. Then at some point the electron jumps back to potassium. By looking at the angular distribution, it was possible to see the oscillation of electron jump probability based on the molecular vibration. It is a femtosecond phenomenon. In the beam experiments, there is a lot of information provided on a femtosecond timescale. Of course, when you use spectroscopy, you can see electronic excited states and how they decay on a femtosecond scale. However, it won't tell you anything about approach and molecular alignment and other spatial characteristics. Neither will it give information about angular momentum and the conservation of angular momentum.

Lee's arguments about the pico- and femto-clocking capability of molecular rotations and vibrations can be traced back to his Nobel lecture, in which he referred to more detailed expositions in the lecture by Herschbach, his co-laureate. In molecular-beam studies, the intrinsic clocking capability and insights gained from angular distributions of reactants and products are admittedly powerful and revealing. But rather than overshadowing traditional molecular-beam achievements, femtochemistry has contributed fundamentally to our understanding of molecular-reaction dynamics. Even for the seemingly simple bond-formation mechanisms mentioned by Dantus, there is still much more to discover. But that will happen only as we welcome more innovative theoretical and experimental advancements, following the legacy of Lee, Manfred Eigen, Ronald Norrish, Herschbach, Ahmed Zewail, and more.

Reference

1. I. Hargittai, M. Hargittai, *Candid Science VI: More Conversations with Famous Scientists*, Imperial College Press (2006), p. 445.

Yang Gan
(ygan@hit.edu.cn)
Harbin Institute of Technology
Harbin, China PT