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Is there an end to cosmology?

In the far future, astronomers will have only one galaxy to study, and all evidence for the Big Bang will be lost. by Abraham Loeb

Each January, when the President of the United States delivers the State of the Union address, I find myself imagining a brief statement about the bigger picture. To put it bluntly, the state of our universe is not looking good for future observers.

Over the past decade, cosmologists have reached their best-ever observational understanding of the universe. First, thanks to the finite speed of light, scientists actually can observe the universe as it looked in the past. Light we observe today from a distant galaxy must have been emitted at an earlier time in order to reach us now. So, by looking deeper into space, astronomers see the cosmos as it looked at earlier times.

Since the 1920s, astronomers have known that all distant galaxies are moving away from us due to the expansion of space. By measuring ever-farther distances, astronomers can establish how the rate of expansion changed during the universe's history.

Because gravity acts to bring matter together, we might naturally expect the expansion slowed down with time. But did it? In the past 2 decades, astronomers worked to test this conclusion through telescopic observation.

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Light a standard candle

If you know that all streetlights have, say, 100-watt bulbs, you can determine the distance to any streetlight you see just by measuring how bright its light appears. The bulb's energy spreads out spherically in a manner that increases with the square of the distance to the source. Because the radiation we see from a bulb dilutes with the distance squared, we can calculate its distance.

The accelerating universe makes cosmology a fleeting scientific endeavor.

Fortunately for astronomers, a particular type of exploding star — type Ia supernovae — provides a standardized "light bulb" that can be seen to the edge of the observable universe. A decade ago, two groups of astronomers inferred distances to many supernovae. They discovered that, contrary to expectations, cosmic expansion has been speeding up for the past 5 billion years.

Until the supernova studies, physicists had only upper limits for the mass or energy density of empty space. Intuition suggests this value should be zero, but it isn't necessarily so.

Einstein's 1915 theory of relativity says that if the vacuum's mass density is more than half the universe's matter density, then space has a negative pressure. If the expanding universe's vacuum energy remains constant (as Einstein originally thought), eventually this condition will be met. That is, there will be a time when the universe's matter density drops to half the vacuum's mass density. The result: accelerating expansion that pushes galaxies away from each other at an ever increasing rate.

Out of sight

If the universe is dominated by a cosmological constant of the sort Einstein envisioned, then, as the universe ages by another 10 times, the accelerated expansion will push all galaxies outside our immediate vicinity beyond the observable universe. In 2002, I showed that all galaxies beyond redshift 1.8 (about 10 billion light-years away) already are outside our horizon.

These galaxies emitted the light we see from them a long time ago, when the universe was one-third its present 13.7-billion-year age. What we see does not represent their current state. If their light contains some message from a distant civilization, any reply we make will never reach them. Within a finite time, the accelerated expansion of space moves any distant galaxy away from us at a speed that exceeds even that of light.

The situation is similar to watching a friend cross a black hole's event horizon. From a distance, we would see our adventurous friend's image heading toward a black hole, getting fainter, and eventually freezing just outside the horizon. Beyond that moment, classical general relativity offers no way to retrieve additional information.

Likewise, the image of each galaxy will freeze sometime in the future. We will never be able to study the evolution of a galaxy beyond some finite age in its own frame of reference. The more distant a galaxy is, the earlier its image will freeze, and the less information will be available to us about the way it ages.

Of course, systems held together by a force stronger than the cosmological constant do not participate in the cosmic expansion. This includes electrons bound to atoms by the electromagnetic force, planets bound to the Sun, and galaxies held by a gravitational pull stronger than cosmic repulsion.

So, which galaxies will remain in sight? I worked with Ken Nagamine, now at the University of California at San Diego, to simulate the future evolution of all galaxies within 100 million light-years of the Milky Way. Our simulation, which was based on data on the local distribution of galaxies, indicated that no galaxy more than 3 million light-years away will remain in our horizon. All will be pushed out of our view as the cosmos expands.

The Andromeda Galaxy (M31) and the Milky Way are the only two large galaxies within this range — and they happen to be on a collision course. Harvard's T. J. Cox and I showed that the two galaxies will merge to make a new one, which I call Milkomeda (see "Our galaxy's date with destruction," June 2008). Ultimately, Milkomeda is the only galaxy that will remain visible to astronomers.

Suppose some future cataclysm destroys all scientific archives. Could future astronomers, who are able to study only Milkomeda, be able to reveal it originated from the Big Bang? No, wrote Lawrence M. Krauss (Case Western Reserve University, Cleveland) and Robert J. Scherrer (Vanderbilt University, Nashville) in an award-winning essay last year (see arxiv.org/abs/0704.0221).

To future astronomers, the universe will appear to be static and occupied by only one galaxy, the merged remnant of the Milky Way and the Andromeda Galaxy known as Milkomeda. The accelerated expansion of the cosmos will erase all evidence it arose in a Big Bang. *Astronomy*: Theo Cobb and Chuck Braasch

The accelerating universe makes the study of cosmology a transient episode in our long-term scientific endeavor. We had better observe the universe in the next tens of billions of years and document our findings for the benefit of future scientists who won't be able to do so. Perhaps funding agencies should take notice and allocate funds for cosmology now. One day, such studies be impossible.

Once that happens, any presidential State of the Union address will be fully justified in ignoring the universe at large.