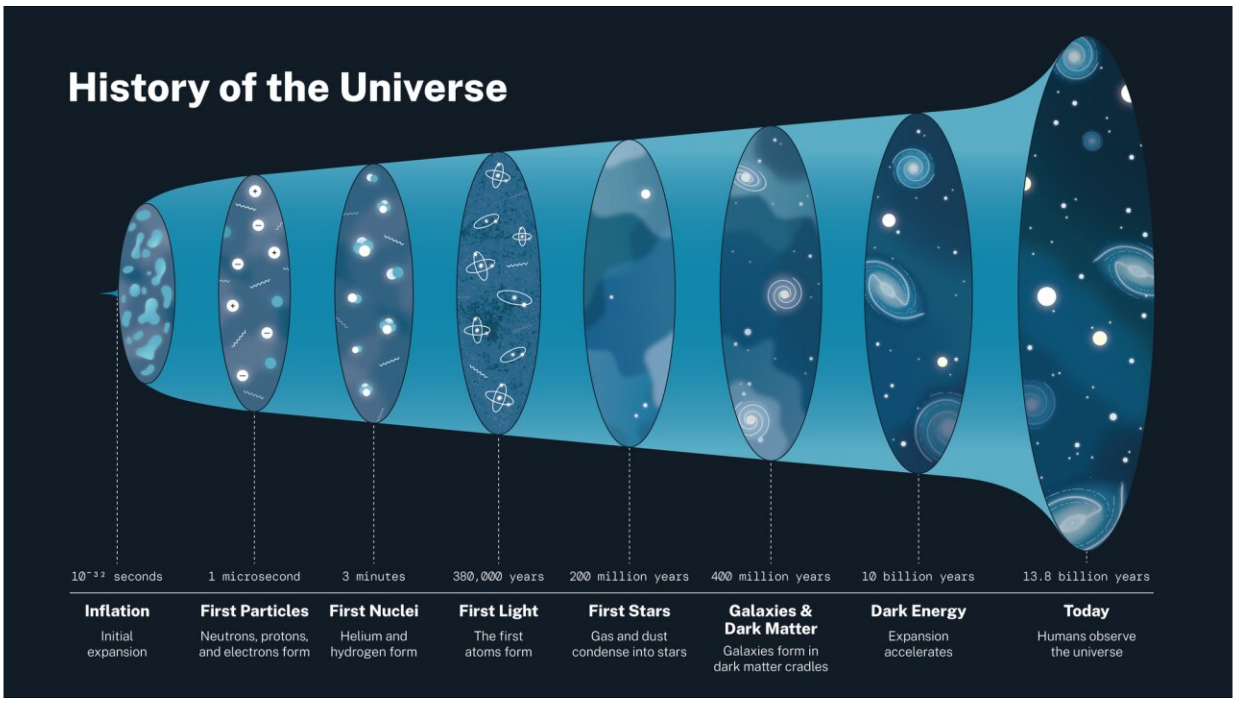
Growing evidence for evolving dark energy could inspire a new model of the universe

June 30 2025, by Christian Reichardt



The Big Bang started around 13.8 billion years ago. Credit: NASA

The birth, growth and future of our universe are eternally fascinating.

In the last decades, telescopes have been able to observe the skies with unprecedented precision and sensitivity.

[Our research team on the South Pole Telescope](#) is studying how the universe evolved and has changed over time. We have just released two years' worth of mapping of the infant universe over 1/25th of the sky.

These observations have sharpened our understanding of the nature of dark energy and the rate at which the universe is expanding.

What is the current theory of how our universe began?

Our current model for the early universe is known as the "hot Big Bang."

It describes the first stage of our universe as a primordial fireball composed of a very hot plasma, much like our sun.

The Big Bang started about 13.8 billion years ago when a phenomenon known as cosmic inflation caused the universe to expand at a rate faster than the speed of light for a fraction of a second.

As the universe expanded and cooled after inflation, the ordinary matter (the type we can see and interact with) looked very much like our sun, a super-heated plasma made up of photons, electrons and ionized (or charged) hydrogen and helium nuclei.

Modern telescopes can detect faint radiation from 400,000 years after the Big Bang, known as the cosmic microwave background (CMB). The CMB is a snapshot of the plasma and conditions at that time, when the plasma's temperature had cooled to about half that of the sun.

This cooling allowed the plasma to recombine, forming atoms like hydrogen and helium. At the time of the CMB, the universe was nearly perfectly uniform with only 1 part in 100,000 variations in density across the entire sky.

Our current theory predicts that dark matter collapses to form dense regions that pull in nearby ordinary matter. The gas in these dense regions then cools and collapses to form galaxies and stars we see today.

Together, these stages comprise the current best model of the formation of the cosmos, known as the lambda-cold dark matter or Lambda-CDM model.

What is dark energy and why is it so important?

If the universe only contained ordinary matter and dark matter, we would expect the gravitational pull of all the mass in the universe to be slowing down the universe's expansion in the same way that if you throw a ball up, Earth's gravity pulls it back down.

However, in 1998, astronomers measuring the distance to far-away supernovae discovered that the expansion had started to get faster instead of slower.

To explain this, scientists invoked dark energy, an unknown something that, unlike matter, gravitationally repels instead of attracts, pushing the universe apart almost like "anti-gravity." The simplest version of dark energy is Einstein's original idea for a cosmological constant, as a way to balance the action of gravity in his theory of general relativity.

The mysterious dark energy constitutes nearly 70% of the universe today. And while we can't see dark energy directly, it determines how our universe is expanding and its eventual fate.

What are the new observations?

The South Pole Telescope is a 10-meter telescope with 16,000 detectors sensitive to millimeter-wavelength light, located at the Amundsen-Scott South Pole Station in Antarctica.

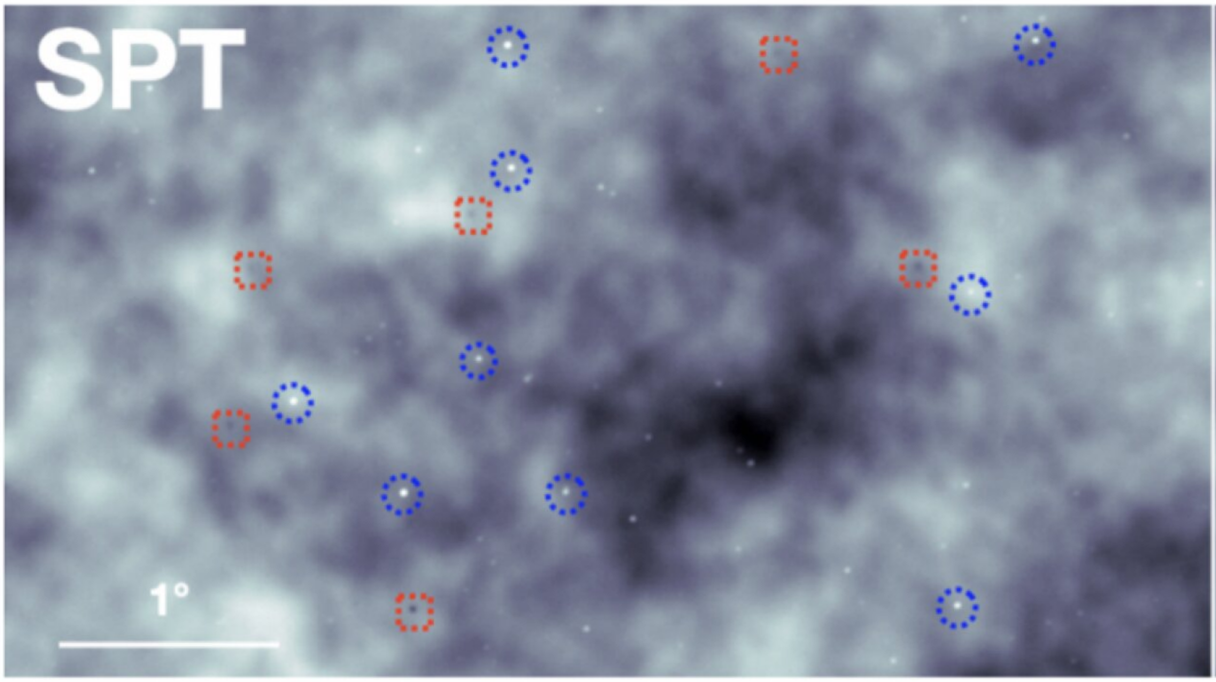


Image of South Pole Telescope (SPT) data. Dark dots (circled in red) are galaxy clusters and white dots (circled in blue) are active galactic nuclei containing supermassive black holes that emit bright light. Credit: South Pole Telescope

Our international team collected data over two years with the main instrument.

We analyzed this data, which covers 1/25th of the sky, to make precise measurements of temperature and polarization patterns caused by the distribution of matter in the cosmic microwave background of the early universe.

We combined the maps of the early universe from the South Pole Telescope with observations of the 3D distribution of galaxies made previously by the Dark Energy Spectroscopic Instrument (DESI) collaboration.

What we saw in the DESI experiments, and now strengthened by our South Pole Telescope observations, is that dark energy is becoming weaker with time, or time-evolving. Dark energy's acceleration of the universe's expansion may stop far in the future.

The results are now available to access and have been submitted for peer review.

Why might the theory of the universe need updating?

The new measurements with the South Pole Telescope enable more precise constraints on our cosmological models. In particular, the data tighten our measurement of the sound horizon scale 13.8 billion years ago.

Previously, the gold standard for cosmic microwave background measurements was provided by Planck satellite data, taken a decade ago.

The improved measurements from the South Pole Telescope, when combined with the DESI experiment and other CMB datasets, reduce the likelihood of a cosmological constant and increase the preference for time-evolving dark energy models.

The significance further increases when observations of supernovae are added.

So, is Einstein's theory of relativity wrong, or does it

just need a tweak?

When Einstein first formulated his theory of relativity in the early 1900s, the prevailing model was a static universe, unlike today's expanding universe.

To prevent gravitational collapse and allow an eternal static universe, Einstein added a repelling term to his theory, called a "cosmological constant." Einstein later retracted this after Edwin Hubble's discovery that the universe was expanding in 1929.

Three decades after his death, astronomers looking at supernovae discovered the universe's expansion was accelerating. The simplest explanation for this acceleration was to revive Einstein's cosmological constant as a repelling force.

Until recently, our observations of the universe could be entirely explained by a cosmological constant.

If the current hints that dark energy is weakening are supported by further research, it will mean that we need to go beyond the cosmological constant, be it a change to the theory of general relativity or to include time-evolving dark energy.

When will we know if we need a new theory?

It's hard to say! The current evidence for evolving dark energy is still less than the gold standard, which is less than 1 chance in 3.5 million to be false (also known as 5 sigma).

The DESI collaboration is planning an upgraded instrument, DESI-2, after the current survey, and eventually wants to build a much more ambitious spectroscopy experiment, Spec-S5.

We can look forward to an upgraded receiver being installed on the South Pole Telescope in 2028, as well as future results from the Simons Observatory (beginning survey observations towards the end of this year) and in the 2030s the CMB-S4 experiment.

Sometime along this track, we will hopefully have enough evidence to definitively say if the accelerating expansion of the universe is truly losing steam.

More information: SPT-3G D1: CMB temperature and polarization power spectra and cosmology from
2019 and 2020 observations of the SPT-3G Main field.
pole.uchicago.edu/public/data/camphuis25/C25.pdf

Provided by University of Melbourne

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