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First direct evidence of cosmic inflation (Update)

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In this 2007 photo provided by Steffen Richter, the sun sets behind the BICEP2 telescope, foreground, and the South Pole Telescope in Antarctica. In the faint glowing remains of the Big Bang, scientists found "smoking gun" evidence that the universe began with a split-second of astonishingly rapid growth from a seed far smaller than an atom. To find a pattern of polarization in the faint light left over from the Big Bang, astronomers scanned about 2 percent of the sky for three years with the BICEP2 at the south pole, chosen for its very dry air to aid in the observations, said the leader of the collaboration, John Kovac of Harvard. (AP Photo/Steffen Richter)

(Phys.org) —Almost 14 billion years ago, the universe we inhabit burst into existence in an extraordinary event that initiated the Big Bang. In the first fleeting fraction of a second, the universe expanded exponentially, stretching far beyond the view of our best telescopes. All this, of course, was just theory.

Researchers from the BICEP2 collaboration today announced the first direct evidence for this cosmic inflation. Their data also represent the first images of gravitational waves, or ripples in space-time. These waves have been described as the "first tremors of the Big Bang." Finally, the data confirm a deep connection between quantum mechanics and general relativity.

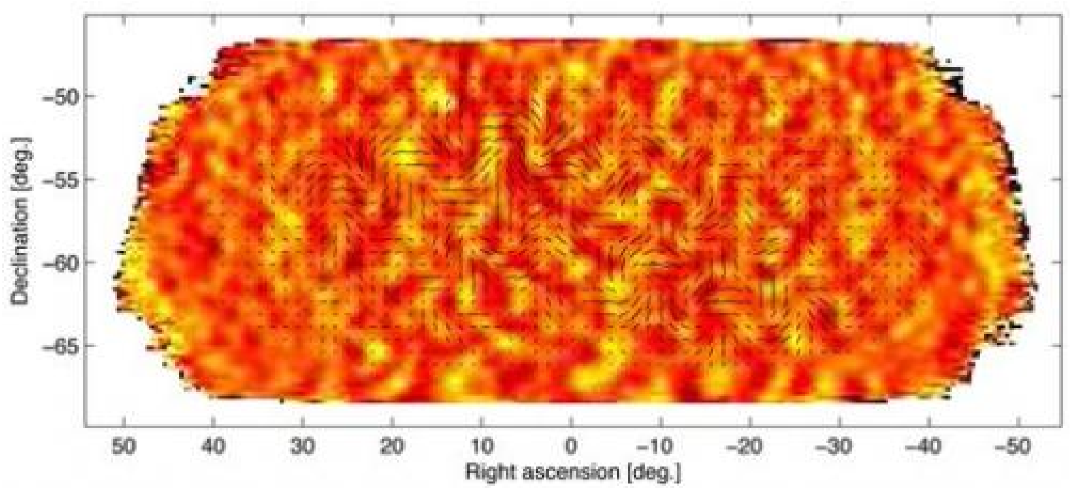
"Detecting this signal is one of the most important goals in cosmology today. A lot of work by a lot of people has led up to this point," said John Kovac (Harvard-Smithsonian Center for Astrophysics), leader of the BICEP2 collaboration.

These groundbreaking results came from observations by the BICEP2 telescope of the cosmic microwave background—a faint glow left over from the Big Bang. Tiny fluctuations in this afterglow provide clues to conditions in the early universe. For example, small differences in temperature across the sky show where parts of the universe were denser, eventually condensing into galaxies and galactic clusters.

Since the cosmic microwave background is a form of light, it exhibits all the properties of light, including polarization. On Earth, sunlight is scattered by the atmosphere and becomes polarized, which is why polarized sunglasses help reduce glare. In space, the cosmic microwave background was scattered by atoms and electrons and became polarized too.

"Our team hunted for a special type of polarization called 'B-modes,' which represents a twisting or 'curl' pattern in the polarized orientations of the ancient light," said co-leader Jamie Bock (Caltech/JPL).

Gravitational waves squeeze space as they travel, and this squeezing produces a distinct pattern in the cosmic microwave background. Gravitational waves have a "handedness," much like light waves, and can have left- and right-handed polarizations.

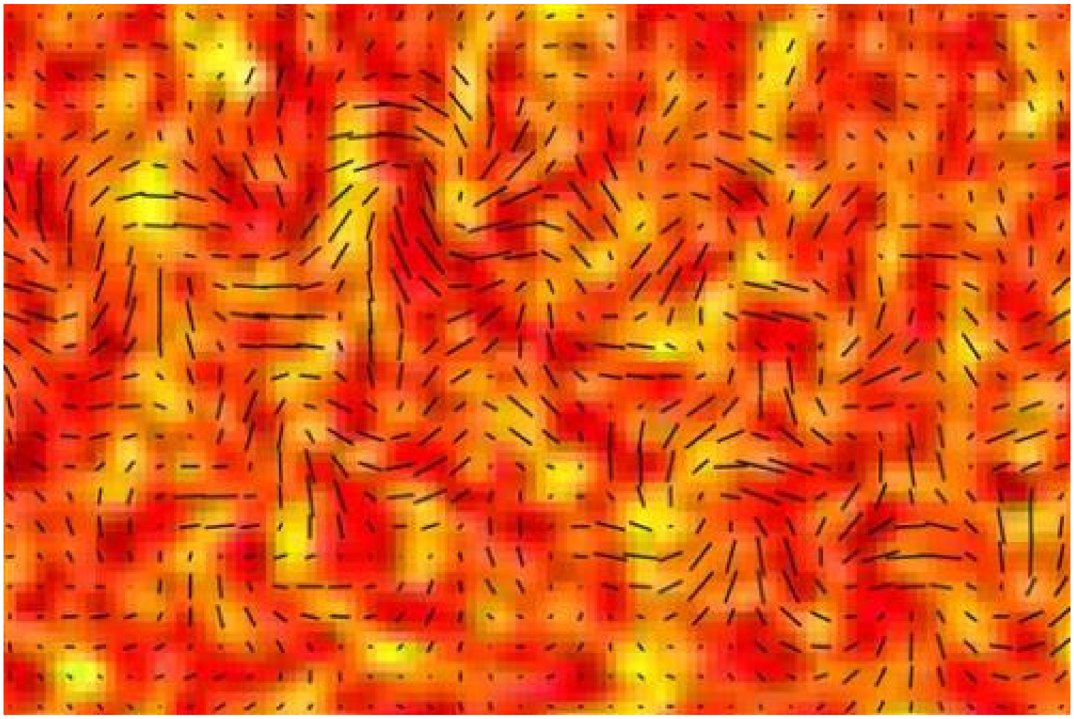


This image provided by the BICEP2 Collaboration shows slight temperature fluctuations, indicated by variations in color, of the cosmic microwave background of a small patch of sky and the orientation of its polarization, shown as short black lines. Researchers say since the cosmic microwave background is a form of light, it exhibits all the properties of light, including polarization. The changes in a particular type of polarization, indicated here, are theorized to be caused by gravitational waves. These waves are signals of an extremely rapid inflation of the universe in its first moments. (AP Photo/BICEP2 Collaboration)

"The swirly B-mode pattern is a unique signature of gravitational waves because of their handedness. This is the first direct image of gravitational waves across the primordial sky," said co-leader Chao-Lin

Kuo (Stanford/SLAC).

The team examined spatial scales on the sky spanning about one to five degrees (two to ten times the width of the full Moon). To do this, they traveled to the South Pole to take advantage of its cold, dry, stable air.



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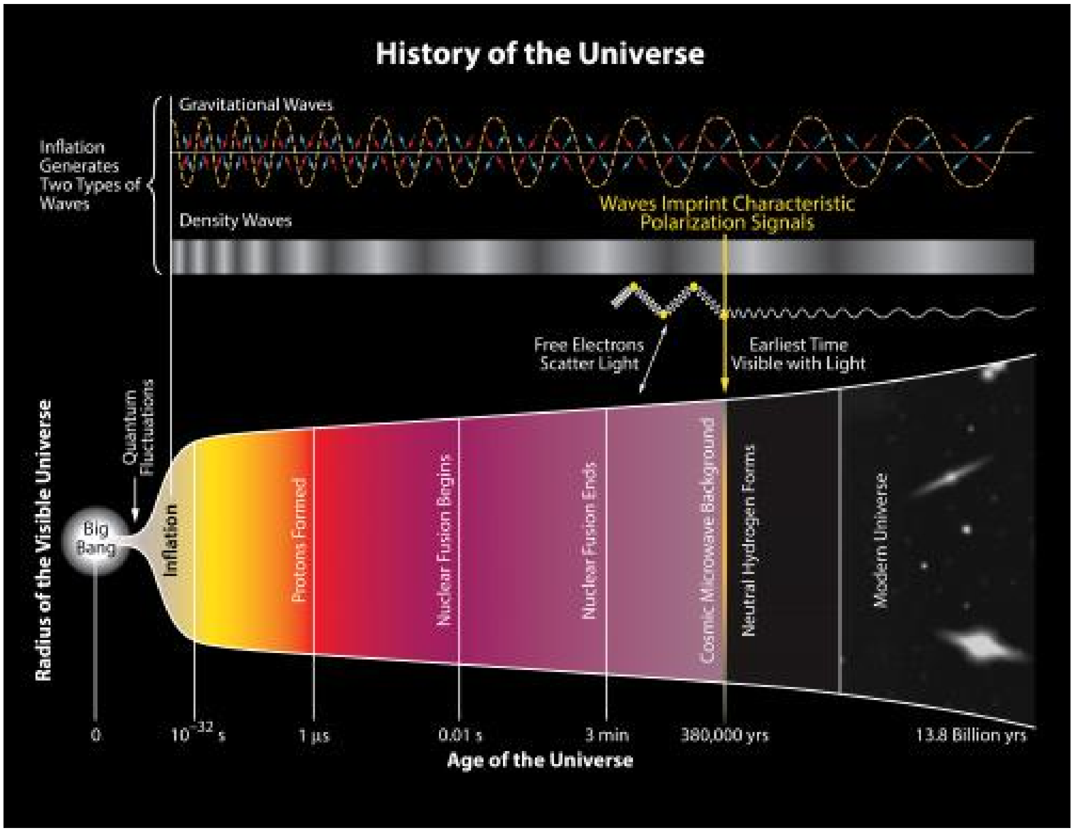
"The South Pole is the closest you can get to space and still be on the ground," said Kovac. "It's one of the driest and clearest locations on Earth, perfect for observing the faint microwaves from the Big Bang."

They were surprised to detect a B-mode polarization signal considerably stronger than many cosmologists expected. The team analyzed their data for more than three years in an effort to rule out any errors. They also considered whether dust in our galaxy could produce the observed pattern, but the data suggest this is highly unlikely.



The bottom part of this illustration shows the scale of the universe versus time. Specific events are shown such as the formation of neutral Hydrogen at 380 000 years after the big bang. Prior to this time, the constant interaction between matter (electrons) and light (photons) made the universe opaque. After this time, the photons we now call the CMB started streaming freely. The fluctuations (differences from place to place) in the matter distribution left their imprint on the CMB photons. The density waves appear as temperature and "E-mode" polarization. The gravitational waves leave a characteristic signature in the CMB polarization: the "B-modes". Both density and gravitational waves come from quantum fluctuations which have been magnified by inflation to be present at the time when the CMB photons were emitted.

"This has been like looking for a needle in a haystack, but instead we found a crowbar," said co-leader Clem Pryke (University of Minnesota).

When asked to comment on the implications of this discovery, Harvard theorist Avi Loeb said, "This work offers new insights into some of our most basic questions: Why do we exist? How did the universe begin? These results are not only a smoking gun for inflation, they also tell us when inflation took place and how powerful the process was."

More information: bicepkeck.org/

Provided by Harvard-Smithsonian Center for Astrophysics

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