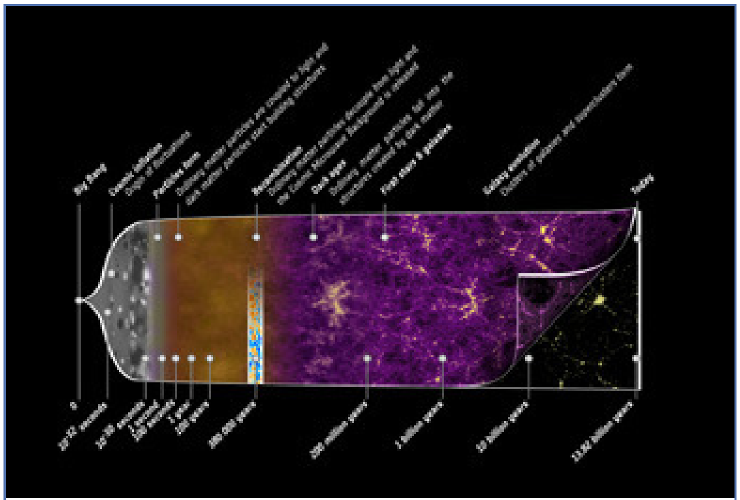
Seeking the Cosmic Dawn

Astronomers detected a pattern in the afterglow of the Big Bang, called lensed B-modes, that might help reveal inflation's signature.



The nearly 14 billion year chronology of our universe from the Big Bang to today. Click on the image to see it full-size.

ESA / C. Carreau

In a tiny fraction of a second, an outburst of energy propelled our universe from a hot, dense point to cosmic size. This theoretical outburst, called inflation, provides a fantastically accurate explanation of why the cosmos is the way it is. Among other things, it predicts the pattern of temperature blotches astronomers observe in their earliest view of the cosmos, the cosmic microwave background (CMB). But there’s still no conclusive evidence that inflation happened.

Now, a team of astronomers using the South Pole Telescope (SPT) in Antarctica has detected a pattern in the CMB that might help reveal inflation’s signature.

The discovered signals are called B-modes, and they’re one of two main patterns of polarization predicted to exist in the CMB. Polarization describes a light wave that prefers to vibrate in a particular direction rather than randomly. On a map of the CMB, you can use a line segment to mark the direction in which the waves oscillate. When you look at the map as a whole, these lines create collective patterns, called E-modes and B-modes. E-modes look like symmetric asterisks or loops, and B-modes curl clockwise or counterclockwise in spiral patterns.

If inflation really did happen, the burst of energy that drove it would have created ripples in spacetime called gravitational waves. These waves should have imprinted E-modes and B-modes into the CMB. But these patterns can also be created in other ways. E-modes also arise due to density fluctuations in the early universe—the same fluctuations that created the temperature blotches in the CMB. And to make matters even more complicated, E-modes can be distorted to look like B-modes.

Scientists have already found E-modes in the CMB, but until now they haven't confirmed that any B-modes exist.

Duncan Hanson (McGill University) and his collaborators spotted signals from the transformed B-modes using data from the 10-meter South Pole Telescope, which measures radiation at millimeter wavelengths, small enough to detect variations in the CMB. These B-modes were originally E-modes that transformed as light from the early universe journeyed to our detectors, passing giant galaxy clusters with enough gravity to bend its path, just as a lens does.

Looking for these lensed B-modes is tricky because the CMB polarization maps largely look like noise rather than distinct patterns. To resolve the maps in more detail, Hanson's team made predictions for what the lensed B-modes should look like. The team used maps of the universe's matter distribution, based on infrared observations by the ESA's (now retired) Hershel spacecraft, to estimate how much gravity should have distorted the E-modes. Once the team had an idea of what shape to look for in their data, they could more easily pick out the lensed B-modes.

“Our method…is sort of like holding up a planisphere when looking for the constellations – it's a lot easier to recognize what you're looking at when you can place it next to a high fidelity template,” adds Duncan Hanson.

“There’s been a longstanding fear that galactic foregrounds (which produce both E- and B-mode polarization fields) would be so bright as to swamp the B-modes or contaminate measurements,” says study coauthor Keith Vanderlinde (University of Toronto). Comparing the data against the infrared-based maps is a clean way of getting around that.

Because lensed B-modes are a distortion of the original inflation signal and don't come directly from the early universe, the signal Hanson’s team found is only one piece of a larger puzzle. Cosmologists are eagerly hunting for the so-called *primordial B-modes* because, unlike E-modes, they would only be created by the spacetime ripples inflation sent through the cosmos. Finding their imprints would be a direct measurement of the energy stored in space at the moment of inflation.

Primordial B-modes will be fainter than both the E-modes and lensed B-modes, requiring intense data analysis to reveal them. But the discovery by Hanson’s team will make this work easier, because it tells astronomers which signals they can eliminate from their observations as noise. They can also use lensed B-modes to map out the distribution of matter in the universe.

“The more exciting bit of this is having a very direct measure of all the matter in the universe...if we’re measuring the lensing B-modes, we’re seeing the [effects] from all the matter in the universe between us and the Big Bang,” says Katherine Mack (University of Melbourne, Australia). “And that’s kind of cool.”

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