How astronomers saw gravitational waves from the Big Bang

Lead discoverer John Kovac describes his work at the BICEP2 radio telescope and how his career took him there.

Ron Cowen

17 March 2014

On 17 March, John Kovac announced to the world that he and his team of radio astronomers had found the imprint of gravitational waves from the Big Bang. They did so by looking at the cosmic microwave background (CMB), sometimes called the 'afterglow' of the Big Bang, using BICEP2, a telescope experiment based at the South Pole. This signal of gravitational waves was seen in the polarization of the CMB — similar to the kind of polarization that certain sunglasses block — over a small patch of sky.

Denis Barkats

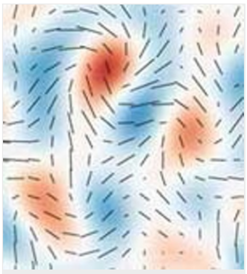
John Kovac

This polarization map, which is reminiscent of the way iron filings arrange themselves on a surface under the effects of a magnetic field, was found to have particular vortex-like, or curly, patterns known as B modes. The presence of B modes is a tell-tale sign of the passage of gravitational waves generated during inflation, a brief period during which the Universe underwent an exponential expansion, right after its birth. If the findings stand up, they will put the current preferred picture of cosmology on solid foundations, and could have significant implications on fundamental physics as well.

Kovac is a radio astronomer at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. Here he talks to *Nature* about the findings and some of their implications.

What are we seeing in BICEP2's snapshots of the CMB polarization?
The most important result we're focused on is the implications of the signal we detected for models of inflation. We are seeing a direct image of a [primordial] gravitational wave, causing light to be polarized in a particular way. The CMB is a snapshot of the Universe 380,000 years after the Big Bang, when the radiation first streamed freely into space, but the gravitational-wave signal was imprinted on the CMB a tiny fraction of a second after the birth of the Universe.

What else is important about the finding?
Everyone in cosmology knows — but it is not widely appreciated — that the prediction about B modes from inflation relies not just on the phenomenon of gravitational waves but on the quantization of gravity itself. Inflation assumes that everything started out as quantum fluctuations that then got amplified by inflation. So at a very deep level, this finding relies on the connection between quantum mechanics and gravity being right.



Did it cause concern that BICEP2 had detected a B-mode polarization signal that was nearly twice as high as data from the Planck spacecraft suggested?

***Nature* special:** Waves from the Big Bang

The Planck data [released so far] came from a temperature map of the CMB, not from a direct polarization measurement. We were always committed to doing an extra careful job on this analysis, but I will admit that the presence of a larger signal-to-noise ratio in our data [compared with the Planck data] sharpened our focus in thinking about every possible systematic explanation over the past three years that could have falsified the signal. We've done the most extensive systematic analysis that I've ever been involved in by far.

When did you first realize that you had detected the long-sought 'smoking gun for inflation'?
Last fall, when we first compared the BICEP2 signal with BICEP1. That was very powerful because BICEP1 had very different detectors and used much older technology. So the fact that we were able to see the same signal with this completely different kind of telescope laid a lot of lingering doubts to rest. The remaining sceptics on our team were convinced at that point.

In early December I was at the South Pole and we had a very intense meeting where I laid out all the tests the data had passed and the milestones still to be achieved, and that we would publish if those remaining tests were passed.

Did you celebrate at that point, or have you celebrated since then?
My role in this process has been to remain calm at all times. The time to celebrate, I think, will be once we have published our results and presented them to the scientific community.

What got you interested in the CMB in the first place?
In high school, I read Steven Weinberg's excellent popular book on cosmology, *The First Three Minutes* [Basic Books, 1977], and it captured my imagination. I remember reading the words:

"Now we come to a different kind of astronomy, to a story that could not have been told a decade ago. We will be dealing not with observations of light emitted in the last few hundred million years from galaxies more or less like our own, but with observations of a diffuse background of radio static left over from near the beginning of the universe."

That's how Weinberg introduced the discovery of the CMB and its implications, then still very fresh, for cosmology. As a kid, it seemed clear to me that this was the coolest thing in all of science — there are no bigger questions.

I chose to go to Princeton University as an undergrad partly because I read about it in that book. [Some of the major players in the field of CMB astronomy] Jim Peebles, Robert Dicke and David Wilkinson were there, and by an incredible stroke of fortune I was assigned to Dave Wilkinson for a work-study job. He directed me to a CMB lab that was planning to try to build a CMB telescope at the South Pole. I became so captured that I actually took a year out of school to get a chance to go to the South Pole myself. That was 1990–91, not long before the Cosmic Background Explorer (COBE) satellite discovered the first fluctuations in the CMB. Our telescope at the South Pole saw them, too, less than a year later. I've been doing it ever since: 23 trips to the pole and a career in which I've been fortunate to work at the frontiers of CMB.

You have a picture of the late astrophysicist Andrew Lange, of the California Institute of Technology in Pasadena, on your bookshelf. He mentored many students who were conducting CMB experiments before he lost his battle with depression and committed suicide in 2010. What role did he play in shaping your career?
I worked in Andrew's lab as a postdoc at Caltech and then as a senior fellow before moving to Harvard. Andrew was an inspiration and a close friend. He entrusted me with a huge amount of responsibility, encouraging me to take charge of the deployment and operation of the BICEP1 telescope and then to step into the role of [principal investigator] and leader of the next one, BICEP2.

Andrew was fond of describing the quest for B-mode polarization as "cosmology's great wild goose chase". He would have enjoyed seeing this result, and knowing that we found not a goose but an ostrich!

I was also a graduate student of [University of Chicago astronomer] John Carlstrom. While John is currently a competitor [at the South Pole Telescope], he is also one of my closest friends. I have had two amazing mentors.

How old is your son, and what does he think about all of this?

Nine. He's very excited and it's amazing how much he can absorb and understand and explain to my wife. He would go to the South Pole with me if he was old enough.

Nature | doi:10.1038/nature.2014.14885

Nature ISSN 0028-0836 EISSN 1476-4687

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