POLAR STAR

After years of work in the Antarctic, John Kovac and his team have captured strong evidence for a long-held theory about the Universe's birth.

BY RON COWEN

The taxi ride across Cambridge normally takes just 15 minutes. But on 10 March, astronomer John Kovac had a momentous secret to share and wanted to avoid being spotted by reporters or scientific rivals. So he left his office at the Harvard-Smithsonian Center for Astrophysics a few minutes early, and directed his driver to drop him outside the Center for Theoretical Physics at the Massachusetts Institute of Technology (MIT). That left him time to walk around the back of the building and climb a little-used staircase that led straight to the third-floor office of cosmologist Alan Guth.

Back in 1980, Guth had proposed an idea that was both startling and appealing. During the first tiny fraction of a second after the Big Bang, he had theorized, the Universe underwent 'inflation': a process of ultra-rapid expansion that took it from subatomic size to a scale so vast that no one will ever see it all. Because the inflation hypothesis posited that far-flung regions of the Universe had started off close together, it solved several enduring cosmological puzzles, including why distant reaches of the Universe look almost identical. Indeed, most cosmologists believed that inflation, or something very much like it, must have happened. Yet for more than three decades, the theory had lacked definitive proof.

Now, Kovac told Guth, proof seemed to be in hand. Kovac was principal investigator of a team that had spent 2010 to 2012 monitoring the skies over the South Pole with an ultra-sensitive microwave receiver known as BICEP2. By outfitting BICEP2 with the microwave equivalent of polarizing sunglasses, they had been able to detect subtle patterns in the microwave afterglow of the Big Bang. These patterns were the faint imprint of gravitational

waves — tremors in the fabric of space-time generated during inflation. And now, after painstakingly checking and rechecking those measurements, the team was set to make the results public in exactly one week's time.

The distribution and magnitude of the gravitational waves, Kovac told Guth, were just as predicted by the theory of inflation.

Guth grilled Kovac for an hour and a half, going over the team's draft paper line by line to verify the results. At the end of the meeting, Guth was convinced. "This is a wonderful result," he said later — an "incredibly strong piece of evidence for inflation."

The news was announced to the world in a headline-making press briefing at the Center for Astrophysics on 17 March. Everyone involved was well aware that the finding came from just one group, and still needed independent confirmation. Nonetheless, the thoughts of many in the field were voiced by Marc Kamionkowski, a cosmologist at Johns Hopkins University in Baltimore, Maryland, who was one of the first to predict the gravitational-wave imprint detected by BICEP2. After the briefing, he told reporters: "To me, this is as Nobel-prize-worthy as it gets."

But for the 43-year-old Kovac, one of the most gratifying aspects of the day was that two of the founders of inflationary cosmology — the 67-year-old Guth and 66-year-old Andrei Linde of Stanford University in California — were watching from the audience. "It's a rare thing in science that the originators of the theory are around when testable consequences are actually searched for and ultimately found," Kovac says. That is why he had taken time away from the team's feverish pre-announcement

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preparations to make the clandestine trip to see Guth at MIT. "We both realized it would be an important moment," he says.

BACK TO THE BEGINNING

Mention the prospect of a Nobel prize to Kovac, however, and he politely but firmly changes the subject. "I just think about the work," he says. It is a subject he talks about earnestly and methodically, while fixing his listener with a piercing blue-eyed stare.

It took that kind of intensity to detect the imprint of gravitational waves in the Big Bang's afterglow — known more formally as

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the cosmic microwave background (CMB). The BICEP2 researchers had to measure temperature variations in the CMB as small as one ten-millionth of a kelvin. They had to detect the ever-so-slight polarization in the radiation, and how that varied with position. They had to isolate 'B modes': swirling patterns in the polarization that can be caused by gravitational waves. And they had to be extremely careful to make sure that the B modes they saw were actually in the CMB, and not caused by other things such as interstellar dust.

"It's been an emotional roller coaster," says Kovac, thinking back over his team's efforts

to determine that their signal was real. They had to be especially rigorous when they realized that the strength of their B-mode signal was about twice that extrapolated from non-polarization results reported last year from the European Space Agency's Planck spacecraft. The BICEP2 team eventually decided to go with its own data — but the discrepancy is still not fully understood.

Adding to the pressure was the threat of being scooped by several other teams that were racing to find the polarization signal. Kovac and his collaborators had to keep their results secret even from their close companions

working on the South Pole Telescope, which stands just metres from BICEP2. "We eat meals with them all the time," says Kovac. "We're friends. We party together." In fact, the team working on that telescope is led by Kovac's former thesis adviser, John Carlstrom of the University of Chicago in Illinois. "I've been dying to talk with John about this," says Kovac. "But professionally, we all know how these things work."

Despite the urgency, Kovac was a perfectionist about the analysis. But finally, he called a team meeting at the South Pole in early December 2013, laying out all the tests the data had passed and the milestones still to be

achieved. If the data held up, he told his group, the team was ready to publish. It was an intense meeting because so much was at stake, recalls Kovac. But, he says, “my role in this process has been to remain calm at all times.”

Kovac learned this cool, systematic approach to problems from his father Michael, a former dean of engineering at the University of South Florida in Tampa, who died two years ago. “My dad was an amazing guy and full of wisdom on how to lead teams, how to organize efforts in science,” says Kovac; he still has trouble talking about his father without choking up.

It was Michael Kovac who guided John into science. From the time he could talk, Kovac says, he was always asking questions. “My dad was able to feed that by answering every question that I asked him about how the world works in a way that explained to me what I wanted to know and led me to another question.”

When Kovac was nine, he became fascinated by the integrated circuits his father had been studying. “John never met a machine he didn’t want to take apart and find out how it worked,” recalls his mother, Midge. He built a simple calculator from parts his father had brought home from work. Then at the age of ten, he graduated to building a half-a-million-volt van de Graaff generator. “It was fun to zap all my friends at birthday parties,” he says.

Another strong influence was Lottie Peterson, a science teacher at his elementary school. Peterson had studied at the University of Chicago during the tenure of Enrico Fermi, the Nobel-prizewinning particle physicist. “She was able to tell me stories that captivated me about what it really meant to do physics at those high levels,” says Kovac. Peterson also gave Kovac’s family a telescope that he set up behind his house.

By the time Kovac entered secondary school, he was determined to be a scientist. After reading every cosmology book in the school library within the first year, he asked for more. Among them was Steven Weinberg’s 1977 account of the moments that followed the Big Bang, *The First Three Minutes: A Modern View of the Origin of the Universe* (Basic Books). Here, Kovac encountered Weinberg’s description of the CMB: “a diffuse background of radio static left over from near the beginning of the universe.”

Kovac was hooked on exploring the CMB and the clues it held. “As a kid, it seemed clear to me that this was the coolest thing in all of science — there are no bigger questions.”

Kovac chose to go to Princeton University in New Jersey in part because some of the major players in the field of CMB astronomy were there. By a stroke of luck, he says, he was assigned a work-study job with one of those researchers, astronomer David Wilkinson, in a group that was planning to build a telescope at the South Pole to search the apparently uniform CMB for regions that were ever so slightly hotter or colder. These temperature variations

John Kovac and Sarah Kernasovskiy work on part of the Keck Array at the South Pole.

would signal the existence of fluctuations in the density of the rapidly cooling masses of hydrogen and helium that came out of the Big Bang. Measuring them was tantamount to seeing the ‘seeds’ that would eventually contract — as a result of gravity — to form the galaxies and clusters of galaxies seen today.

This prospect so captivated Kovac that he took a year out from university to join the team in Antarctica for the austral summer of 1990–91. Wilkinson’s group was soon beaten to the discovery of the first temperature fluctuations in the CMB by the team analysing data from NASA’s Cosmic Background Explorer

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satellite. But within a year, the Princeton group’s South Pole instrument detected the fluctuations, too, and Kovac was hooked once again. In the years since, he has made a further 22 visits to the South Pole, often stopping over in New Zealand en route to indulge his hobby of mountain-climbing in the nation’s Southern Alps. On one occasion, he stayed at the South Pole for the entire southern winter, a nine-month interval when planes are typically not permitted to fly to the Antarctic because of the dangers posed by the extreme cold.

Kovac is the only principal investigator in the field of CMB astronomy who has ‘wintered over’, says BICEP2 telescope engineer Steffen

Richter. And because of that experience, Richter adds, “he knows the telescope down to the last screw; whatever the problem is, if you get his attention and he starts focusing on it, you can solve it with him in very little time.”

During his years as a graduate student under Carlstrom, Kovac’s Antarctic trips included work on the Degree Angular Scale Interferometer: an array of radio telescopes that the group used to make the first detection of CMB polarization in 2002. “I think the world of John,” says Carlstrom. “He never really needed advising.”

Later, as a postdoc and then a senior fellow at the California Institute of Technology in Pasadena, Kovac worked in Andrew Lange’s laboratory on highly sensitive polarization detectors for the QUAD and BICEP1 radio telescopes, which were also based at the South Pole. “Andrew was an inspiration and a close friend,” says Kovac. “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 leader of BICEP2.”

On his bookshelf, Kovac keeps a picture of the late Caltech astrophysicist, who in 2010 lost his battle with depression and committed suicide. After Lange’s memorial service, Kovac had a meeting with the three other key researchers on the BICEP2 project — Clement Pryke of the University of Minnesota in Minneapolis, Jamie Bock of NASA’s Jet Propulsion Laboratory in Pasadena and Chao-Lin Kuo of Stanford. The four agreed to take an equal share in running the team’s South Pole programme, which has now upgraded BICEP2 into a five times more sensitive detector known as the Keck Array, and which will next year add an equally sensitive telescope called BICEP3 that will measure the CMB polarization at a different wavelength. Bock believes that such shared leadership is unique among CMB projects. “I feel our decisions are always better than what one single person would initially propose,” he says, adding that the unusual arrangement “works for us because we respect and trust each other.” Indeed, at the 17 March press briefing, all four scientists took turns presenting the BICEP2 findings.

The next day, at MIT, Linde addressed a packed lecture hall, giving the first talk on the theoretical implications of the BICEP2 results. Afterwards, Guth reminded the audience that just as the theory of inflation rests on the shoulders of others such as Newton and Einstein, the experimental techniques used by the BICEP2 team members depended on great developments in technology made by those who came before them.

Then, as cups of bubbly cider were poured, Guth proposed a toast: “To the power of scientific reasoning!” Kovac and the rest of the audience cheered. ■

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