NEWS IN FOCUS

BIOLOGY Acid-bath stem-cell study found to contain 'serious errors' **p.283**

POLICY Astrophysicist approved as the head of US National Science Foundation **p.285**

ECOLOGY Dam release set to flood Colorado River with new life **p.286**

GENOMICS Sequencing costs get close to the magic number **p.294**

STEFFEN RICHTER/HARVARD UNIVERSITY

The BICEP2 instrument (foreground) at the South Pole has detected signs of ripples from the Universe's first moments.

COSMOLOGY

Telescope captures view of gravitational waves

Images of the infant Universe reveal evidence for rapid inflation after the Big Bang.

BY RON COWEN IN CAMBRIDGE, MASSACHUSETTS

Astronomers have peered back to nearly the dawn of time and found what seems to be the long-sought 'smoking gun' for the theory that the Universe underwent a spurt of wrenching, exponential growth called inflation during the first tiny fraction of a second of its existence.

Using a radio telescope at the South Pole, the US-led team has detected the first evidence of primordial gravitational waves, ripples in space that inflation generated 13.8 billion years ago when the Universe first started to expand.

The telescope captured a snapshot of the waves as they continued to ripple through the Universe some 380,000 years later, when stars had not yet formed and matter was still scattered across space as a broth of plasma. The image was seen in the cosmic microwave background (CMB), the glow that radiated from that white-hot plasma and that over billions of years of cosmic expansion has cooled to microwave energies.

> **➲ NATURE.COM**
> For more on cosmic ripples from the Big Bang:
> go.nature.com/cjjh5y

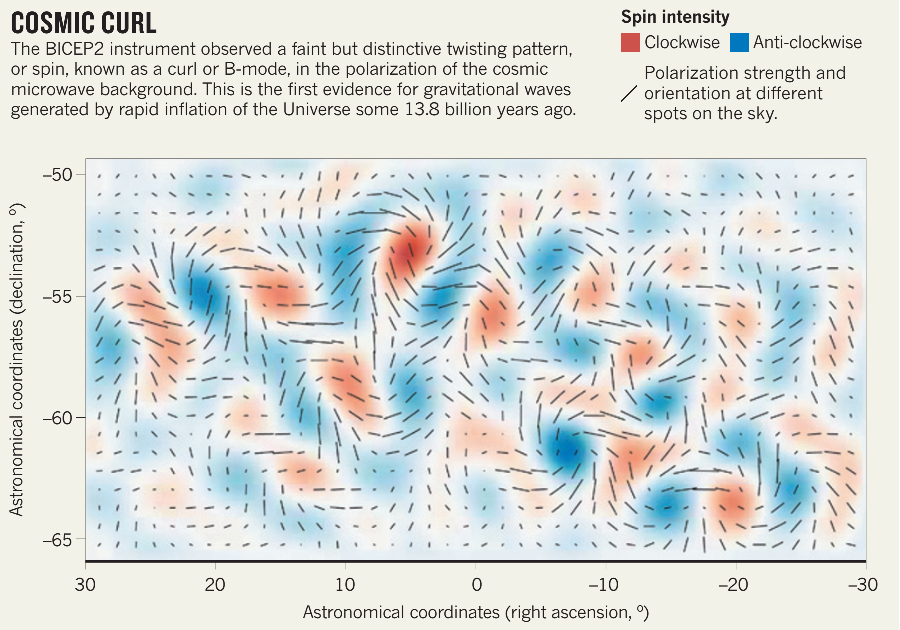
The fact that inflation, a quantum ▶

phenomenon, produced gravitational waves demonstrates that gravity has a quantum nature just like the other known fundamental forces of nature, experts say. Moreover, it provides a window into interactions much more energetic than are accessible in any laboratory experiment. In addition, the way that the team confirmed inflation is itself of major significance: it is the most direct evidence yet that gravitational waves — a key but elusive prediction of Albert Einstein's general theory of relativity — exist.

"This is a totally new, independent piece of cosmological evidence that the inflationary picture fits together," says theoretical physicist Alan Guth of the Massachusetts Institute of Technology (MIT) in Cambridge, who proposed the idea of inflation in 1980. He adds that the study is "definitely" worthy of a Nobel prize.

COSMIC CURL

The BICEP2 instrument observed a faint but distinctive twisting pattern, or spin, known as a curl or B-mode, in the polarization of the cosmic microwave background. This is the first evidence for gravitational waves generated by rapid inflation of the Universe some 13.8 billion years ago.



SOURCE: BICEP2 COLLABORATION

INSTANT INFLATION

Guth's idea was that the cosmos expanded at an exponential rate for a few tens of trillionths of trillionths of trillionths of seconds after the Big Bang, ballooning from subatomic to football size. Inflation solves several long-standing cosmic conundrums, such as why the observable Universe appears uniform from one end to the other. Although the theory has proved to be consistent with all cosmological data collected so far, conclusive evidence for it has been lacking.

Cosmologists knew, however, that inflation would have a distinctive signature: the brief but violent period of expansion would have generated gravitational waves, which compress space in one direction while stretching it along another (see 'Ripple effect'). Although the primordial waves would still be propagating across the Universe, they would now be too feeble to detect directly. But they would have left a distinctive mark in the CMB: they would have polarized the radiation in a curly, vortex-like pattern known as the B mode (see 'Cosmic curl').

Last year, another telescope in Antarctica — the South Pole Telescope (SPT) — became the first observatory to detect a B-mode polarization in the CMB (see *Nature* http://doi.org/rwt; 2013). That signal, however, was over angular scales of less than one degree (about twice the apparent size of the Moon in the sky), and was attributed to how galaxies in the foreground curve the space through which the CMB travels (D. Hanson *et al. Phys. Rev. Lett.* **111,** 141301; 2013). But the signal from primordial gravitational waves is expected to peak at angular scales between one and five degrees.

And that is exactly what John Kovac of the Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Massachusetts, and his colleagues now say they have detected, using an instrument dubbed BICEP2 that is located just metres away from its competitor, the SPT.

Detecting the tiny B mode required measuring the CMB with a precision of one ten-millionth of a kelvin and distinguishing the primordial effect from other possible sources, such as galactic dust.

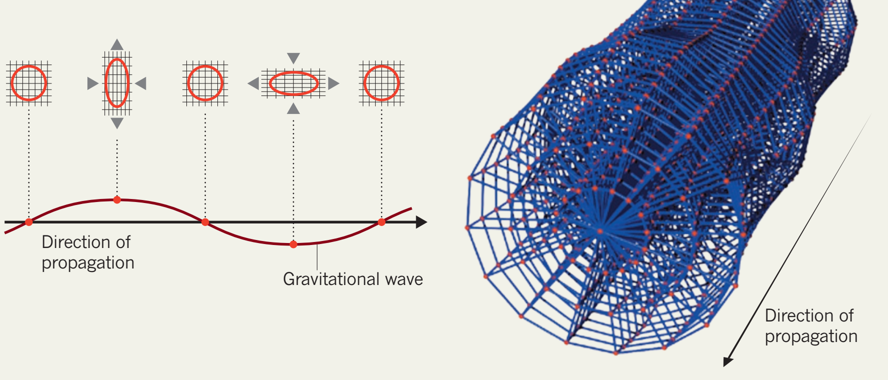
"The key question," says Daniel Eisenstein, an astrophysicist at the CfA, "is whether there could be a foreground that masquerades like this signal". But the team has all but ruled out that possibility, he says. First, the researchers were careful to point BICEP2 — an array of 512 superconducting microwave detectors — at the Southern Hole, a patch of sky that is known to contain only tiny amounts of such emissions. They also compared their data with those taken by an earlier experiment, BICEP1, and showed that a dust-generated signal would have had a different colour and spectrum.

Furthermore, data taken with a newer, more sensitive polarization experiment, the Keck array, which the team finished installing at the South Pole in 2012 and will continue operating for two more years, showed the same characteristics. "To see this same signal emerge from two other, different telescopes was for us very convincing," says Kovac.

"The details have to be worked out, but from what I know it's highly likely this is what we've all been waiting for," says astronomer John Carlstrom of the University of Chicago, Illinois, who is the lead researcher on the SPT. "This is the discovery of inflationary gravitational waves."

RIPPLE EFFECT

When a gravitational wave passes through space, it compresses it in one direction and stretches it in another, both at right angles to the wave's direction (red line). The effects of the wave moving along a blue tube are shown.



SOURCE: MARKUS PÖSSEL/EINSTEIN-ONLINE.INFO

SOLID SIGNATURE

Cosmologist Marc Kamionkowski adds: "To me, this looks really, really solid." He was one of the first cosmologists to calculate what the signature of primordial gravitational waves should look like in the CMB. The findings are "on a par with dark energy, or the discovery of the CMB — something that happens once every several decades", says Kamionkowski, who is at Johns Hopkins University in Baltimore, Maryland.

The strength of the signal measured by BICEP2, although entirely consistent with inflation, initially surprised the researchers because it is nearly twice as large as estimated from previous experiments. According to theory, the intensity of a B-mode signal reveals how fast the Universe expanded during inflation, and therefore suggests the energy scale of the cosmos during that epoch. The data pinpoint the time when inflation occurred — about 10^{-37} seconds into the Universe's life — and its temperature at the time, corresponding to energies of about 10^{16} gigaelectronvolts, says cosmologist Michael Turner of the University of Chicago. That is the same energy at which three of the four fundamental forces of nature — the weak, strong and electromagnetic force — are expected to become indistinguishable from one another in a model known as the grand unified theory.

Because inflation took place in the realm of quantum physics, seeing gravitational waves arise from that epoch provides "the first-ever experimental evidence for quantum gravity", says MIT cosmologist Max Tegmark — in other words, it shows that gravity is at heart a quantum phenomenon, just like the other three fundamental forces. Physicists, however, have yet to fully understand how to reconcile general relativity with quantum physics from a theory standpoint.

The researchers reported the findings on 17 March at a press briefing at the CfA, held just after they described their results to scientists in a technical talk. The team also released several papers describing the results. In so doing, it seems to have beaten the SPT and also several other groups racing to find the fingerprint of inflation using an assortment of balloon-borne and ground-based experiments and one satellite, the European Space Agency's Planck spacecraft.

More-extensive maps of the B-mode polarization, and especially a full-sky survey, which the Planck telescope may be able to obtain later this year, should provide more clues about how inflation unfolded and what drove it. In addition to looking farther back in time than ever before, the discovery "is opening a window a trillion times higher in energy than we can access with the Large Hadron Collider", the world's premiere atom smasher, notes cosmologist Avi Loeb of the CfA, who is not part of the BICEP2 team. ■

CELL BIOLOGY

Stem-cell method faces fresh questions

Papers describing acid-bath technique under more scrutiny after institute's investigation finds errors in methodology.

BY DAVID CYRANOSKI

The veracity of two papers that detailed a method to reprogram mature cells into an embryonic state by exposing them to stress has come under more pressure. Days after the first author's institute reported "serious errors" in the papers' methodology, questions were raised over the same researcher's doctoral dissertation and the cells used in the study.

On 14 March, RIKEN, Japan's largest research organization, which runs the Center for Developmental Biology (CDB) in Kobe where first author Haruko Obokata and several of her co-authors work, announced the interim findings of its investigation into allegations of irregularities in the method. One RIKEN investigator advised them to retract the papers. Then, in further developments, Obokata called into question the quality of her own doctoral thesis, which is already under investigation by the university that granted it. And a co-author on the reprogramming papers says that he is sending some of the cells produced in the experiments for independent verification.

The two papers made headlines around the world when they were published in *Nature* on 30 January (H. Obokata *et al. Nature* **505,** 641–647 and 676–680; 2014). The technique, which the team called stimulus-triggered acquisition of pluripotency (STAP), is important because cells reprogrammed into an embryonic state are ideal for studying the development of disease or the effectiveness of drugs.

But within weeks, the papers were attacked by scientists over their use of several duplicated images and by those who could not reproduce the work, prompting RIKEN to investigate.

At the press conference, a five-person panel, including RIKEN director and Nobel-prize-winner Ryoji Noyori, noted six problems. Two were dismissed as unintentional mistakes. Four others — including an image of an electrophoresis gel that seemed to have had a lane added in later, and plagiarism in part of the methods section — were deemed more serious and are still under investigation. The panel offered no clear answers about whether the STAP phenomenon is real, but noted that RIKEN co-author Hitoshi Niwa was attempting to replicate the method. It added that there were no signs of fraud.

Panel member Masatoshi Takeichi, director of the CDB, also told reporters that the three co-authors from the institute — Obokata, Niwa and Yoshiki Sasai — had agreed to retract the paper at his request. But a statement in Japanese by the trio, delivered at the press conference, said only that they were "considering a retraction and contacting outside authors to discuss that possibility". Charles Vacanti, of Harvard Medical School in Boston, Massachusetts, who is the senior corresponding author on the first of the two papers (H. Obokata *et al. Nature* **505,** 641–647; 2014), has made it clear that he has no intention of retracting unless there is compelling evidence that the data are incorrect.

To add confusion, the first 20 pages of Obokata's thesis, completed in 2011 at Waseda University in Tokyo, were found by Nature News to be taken from a US National Institutes of Health primer on stem cells, and one image in the results section has been reproduced from a commercial website without a citation. Moreover, Vacanti, who was listed on the thesis as a member of the examination committee that approved it, told Nature News: "I was not presented with or asked to read a copy of her dissertation."

"What did I inject into those blastocysts? This is what I want to know."

Last week, Obokata wrote to an unnamed professor at Waseda University indicating that she wanted to retract the thesis. She has not, however, formally requested a retraction.

A desire to resolve the STAP controversy has led to an investigation into the identity of the cells in the papers. Teruhiko Wakayama of the University of Yamanashi, a senior author on the second paper (H. Obokata *et al. Nature* **505,** 676–680; 2014), helped to test the pluripotency of Obokata's STAP stem cells by injecting them into mouse embryos. By turning into different cell types within these mice, the cells proved they had the developmental capacity that STAP promises. But he has now sent the cells that Obokata gave him to an independent institute for genetic analysis to see if they are really STAP cells. "What did I inject into those blastocysts?" Wakayama asks. "This is what I want to know more than anything else." He hopes to have his answer in the next few months. ■

Nature News is editorially independent of the research publications section of *Nature*.