Planck map reveals birth, life and death of a cosmos

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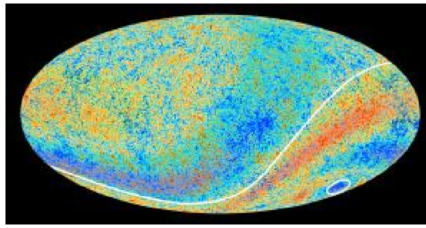
From a beginning that resembles an upside-down bowl to an end called the Big Rip, the Planck telescope's new map is changing our understanding of the universe



The Axis of Evil and a mystery cold spot stand out in this enhanced version of the Planck map *(Image: ESA-Planck collaboration)*

1 more image

Interactive graphic: See how Planck brings the cosmic ripples into focus

"Tomorrow will be like a birthday for cosmologists, with many gifts arranged on the table and us opening them one by one."

So said Dragan Huterer of the University of Michigan, Ann Arbor, the night before the European Space Agency released the highest-resolution map yet of the entire cosmic microwave background (CMB), relic light from the primordial universe.

And what a birthday it turned out to be. Like real-life presents, some of the map's insights are expected, others are complete surprises and not all are exactly welcome (see "Yes, no… maybe?", below). Several anomalies, including a so-called Axis of Evil (white line in picture, right), raise more questions than they answer.

The map, released on 21 March, was drawn from data collected by ESA's Planck satellite, which records temperature variations in the CMB. These arose from quantum fluctuations that were stretched during a brief period of accelerated expansion just after the birth of the universe, known as inflation, and went on to seed the distribution of stars and galaxies we see today.

Whodunnit, Sherlock?

A hotly anticipated insight was new data on whether and how the process of inflation occurred. "Inflation is the initial condition of our universe. It's one of the most fundamental things out there," says Huterer, who is not a member of the Planck team.

Previous, lower resolution maps couldn't distinguish how the process played out. If inflation picks up speed in the same way as a ball rolling down a hill, it wasn't clear whether the hill was like the inside of a bowl – amounting to inflation that is fast to begin with and slows down at the end – or the outside. Also unclear was whether it was a shallow pasta dish or a steep vase.

Planck's improved view of the distribution of CMB hotspots points to a slide down the outside of a shallow bowl; team member Martin White says 70 per cent of the concave models can be ruled out.

Further details still aren't clear though, such as whether the speed-up was a spiral around the bowl or a dash straight down. Nor can we answer the biggest question of all: why inflation happened in the first place. Theories built on the new Planck data will doubtless come up with suggestions. "We absolutely know a crime was committed," says White. "But we're kind of stuck until Sherlock Holmes comes along and tells us what's going on.

Multiple universes

Another Planck gift, if you can call it that, is a package of anomalies, including the Axis of Evil. If inflation follows the simplest path, then the universe should look the same in all directions and the pattern of hot and cold spots should be random, but earlier maps showed this wasn't the case. The most famous anomaly – a line that seems to separate small temperature differences from large ones – came to be known as the Axis of Evil, because it tracked the plane of the solar system.

As its name suggests, many don't like the Axis, taking its apparent alignment with the solar system as a sign that it is an artefact of the way we are viewing the CMB. They hoped it would disappear with Planck's increased resolution, but the opposite has happened. The Planck data confirms the Axis and other anomalies exist, suggesting they are not just errors from dust in the galaxy or the workings of the telescopes as many were hoping.

Planck team member Krzysztof Gorski points out that the Axis is not as aligned with the solar system as previously thought, though it still needs an explanation, such as a bulge in the early fabric of the universe that made inflation asymmetric. "It would be absolutely amazing if there was a fundamental, early-universe reason," says Huterer.

Violent ending

Another anomaly from earlier maps that has survived is a large cold spot (circled in image) that could be a sign of another universe. The suggestion that there are multiple universes pops up in cosmology but remains unproven. When the cold spot showed up in earlier CMB maps, some cosmologists suggested it was a "bruise" caused by a collision with another universe.

Planck may also hold clues to the future. One surprise gift is a new figure for the speed of the universe's expansion. The rate is described by a parameter called the Hubble constant. Pre-Planck, this was obtained from stars called cepheids, which can be used to compare expansion rates in the recent past to now. The CMB solves the problem from the other end, allowing us to deduce the rate at the beginning of the universe.

If the acceleration is constant – and leading theories say it is – the two figures should agree. But they don't. One possible explanation is that the density of dark energy, responsible for the accelerated expansion, is increasing with time, which would pave the way for a universe that ends in a dramatic "Big Rip" rather than the gradual heat death currently expected.

"That's fairly radical," says White, but he admits it is the "kind of thing that people will have to start exploring to figure out what's going on".

Sterile neutrino, RIP

It's a positively welcome development compared with one of the revelations: the Planck data has killed the sterile neutrino. This hypothetical particle promised to explain the identity of dark matter, which makes up 84.5 per cent of the universe's matter, according to Planck.

Earlier CMB maps showed a universe that was smoother than expected. That left room for the sterile neutrino, which would be even ghostlier than the existing muon, tau and electron neutrinos, allowing it to carry energy from one part of the universe to another without getting stuck like ordinary matter does. But Planck showed a universe clumpy enough to be explained by just the three existing neutrinos, removing the need for a fourth.

Finally, the birthday gifts also include an IOU: Planck is set to provide a detailed map of the fluctuations in the orientation, or polarisation, of the CMB. Among other things, this may provide evidence of gravitational waves produced during the universe's early rapid expansion. These are a key prediction of Einstein's theory of general relativity but remain elusive. Planck has measured polarisation, which ESA will release early next year.

This article appeared in print under the headline "Cosmic rise and fall writ in the sky"

Yes, no… maybe?
The Planck telescope's map of the cosmic microwave background (CMB) is a mixed bag for ideas in theoretical physics

Winners

▲ Slow-roll inflation
Did a burst of accelerated expansion shortly after the birth of the universe pick up speed like a ball rolling down the inside of a bowl, or the outside of an inverted one? The Planck map suggests the latter, known as slow-roll inflation. Now physicists can start probing why inflation happened.

▲ Axis of Evil
A line separating large temperature variations in the CMB from smaller ones seemed too strange to be true when it appeared in earlier CMB maps. But the Axis of Evil persists, strengthening the need for an explanation.

▲ Multiple universes
A cold spot in an otherwise smoothly varying CMB also looks more real. Is it the imprint of another universe bumping up against ours?

▲ Big Rip
The Planck map puts a figure on the rate of the universe's early expansion that's slower

than its rate today. That suggests dark energy, the entity responsible for the universe's expansion, may be growing denser. This could lend strength to a theory in which the universe is torn apart in a violent ending known as the Big Rip.

Loser

▼ Sterile neutrino

Ghostly neutrinos come in three flavours. Earlier maps of the CMB showed a super-smooth universe: did a fourth "sterile" neutrino, interacting with matter even more weakly than the other three, smooth things out? Unlikely: the new map is clumpier, so a fourth neutrino is no longer needed.

No verdict

■ Ripples in space-time

Temperature variations in the CMB make up the current Planck map but the plan is to also include variations in this primordial light's polarisation. This could reveal ripples in space-time known as gravitational waves.

Correction: *When this article was first published, it gave the incorrect answer to the question posed under "Slow-roll inflation".*

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