The end of the beginning

Cosmology's big bang breakthrough is a triumph. But the joy is not unalloyed, says Stuart Clark

SUITABLE clients at Milliways, Douglas Adams's Restaurant at the End of the Universe, would have experienced six impossible things before breakfast. In the past decade or so, cosmologists have looked like they were halfway there.

Strike one: dark matter. Galaxies are whirling round faster than normal gravity alone can explain, so 80 per cent plus of the universe's matter is in a form neither we nor, so far, our detectors can see.

Strike two: dark energy. Contrary to all expectations, the universe's expansion is apparently accelerating, so the inwards gravitational tug of both normal and dark matter is being trumped by the effect of another substance so exotic no one knows for certain what it might be.

Strike three: inflation. After all that, the universe still looks rather less crinkly than we would expect, so it must have been smoothed out by a spontaneous faster-than-light expansion in the earliest phase of its existence, which then just stopped.

Extraordinary claims, requiring extraordinary evidence. So you could almost feel the collective sigh of relief last month when the team running the BICEP2 telescope, situated at the South Pole, announced that they had seen a sign of one of this terrible trio. Distinctive patterns of light polarisation in the cosmic microwave background (CMB) radiation were in fact two for the price of one. They represented an apparently unmistakable signature of inflation, but also provided indirect evidence for the existence of gravitational waves from the same era – another theoretically predicted phenomenon that has so far shied away from the limelight.

If the result is confirmed, it is heady stuff.

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Cosmologists will be able to begin whittling down a forest of ideas about how inflation might have happened, and close in on an understanding of the first microscopic moments of the universe's history.

But there is sobriety amid the popping of champagne corks. Besides the question of that all-important confirmation, there are wider-ranging considerations. "Although this is a historic advance, it is also a limit," says John Peacock, a cosmologist at the Royal Observatory in Edinburgh, UK. "We have now seen as far back in time as it is possible to see, and it is not to the very beginning." We may now know more about the moments following the big bang than ever – at the price of never knowing any more about the event itself.

Cosmic inflation was dreamed up in the 1980s to overcome the problem that the overall temperature and density of the universe is much more uniform than models predicted. At the big bang, space-time was squashed in on itself like a screwed-up piece of paper. Even expanding it to the size of the currently observable universe would not have erased all of its creases.

Inflation violently unfurls that scrunched-up ball. The basic idea is that in the universe's first instants, the vacuum of space held vast reserves of energy. Quantum fluctuations jolted the vacuum to start shedding this energy in what became a cascade that spread right across the infant universe. This drove an exponential expansion that doubled the size of the universe about eighty times – from just 10^{-28} metres across to no more than a centimetre across – in just 10^{-36} seconds. The result was a featureless, flat sheet of space-time in which stars and galaxies could begin to form.

This process also generated the CMB radiation that the BICEP2 team scrutinised. This oldest light in the universe suffuses all of space. Originally trapped by the sheer density of matter in the early universe, it was finally released to flee in all directions some 380,000 years on, when the universe had cooled enough for the first atoms to form.

The expansion of the universe in the 13.8 billion years since has stretched the CMB and cooled it from its initial, stupendously high, energy to feeble microwaves capable of heating molecules to only about 2.7 kelvin – a value often referred to as the temperature of space. On large scales, this temperature and other characteristics are more or less evenly distributed. Take a closer look, however, and things appear rather different. Fixing its eye on one patch of the sky, the BICEP2 telescope ›