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Why physicists can't avoid a creation event

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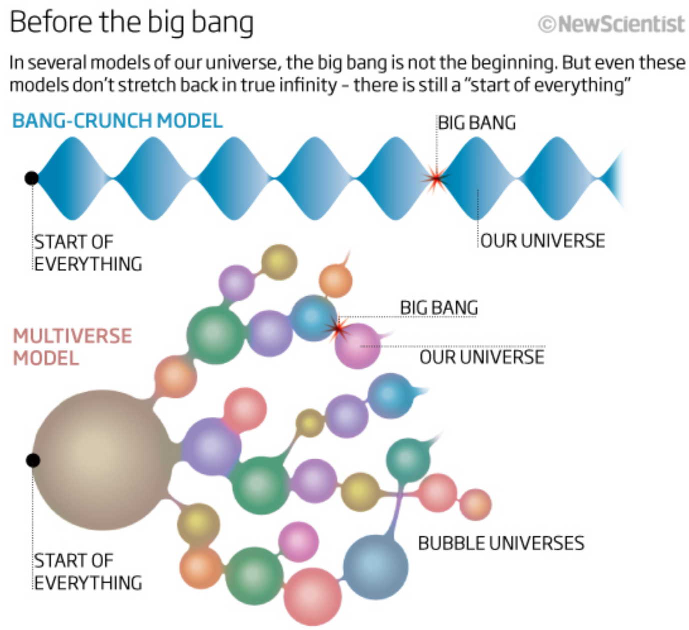
It wasn't always here *(Image: Jupe/Alamy)*



The big bang may not have been the beginning of everything – but new calculations suggest we still need a cosmic starter gun

Editorial: "The Genesis problem"

YOU could call them the worst birthday presents ever. At the meeting of minds convened last week to honour Stephen Hawking's 70th birthday - loftily titled "State of the Universe" - two bold proposals posed serious threats to our existing understanding of the cosmos.

One shows that a problematic object called a naked singularity is a lot more likely to exist than previously assumed (see "Naked black-hole hearts live in the fifth dimension"). The other suggests that the universe is not eternal, resurrecting the thorny question of how to kick-start the cosmos without the hand of a supernatural creator.

While many of us may be OK with the idea of the big bang simply starting everything, physicists, including Hawking, tend to shy away from cosmic genesis. "A point of creation would be a place where science broke down. One would have to appeal to religion and the hand of God," Hawking told the meeting, at the University of Cambridge, in a pre-recorded speech.

For a while it looked like it might be possible to dodge this problem, by relying on models such as an eternally inflating or cyclic universe, both of which seemed to continue infinitely in the past as well as the future. Perhaps surprisingly, these were also both compatible with the big bang, the idea that the universe most likely burst forth from an extremely dense, hot state about 13.7 billion years ago.

However, as cosmologist Alexander Vilenkin of Tufts University in Boston explained last week, that hope has been gradually fading and may now be dead. He showed that all these theories still demand a beginning.

His first target was eternal inflation. Proposed by Alan Guth of the Massachusetts Institute of Technology in 1981, inflation says that in the few slivers of a second after the big bang, the universe doubled in size thousands of times before settling into the calmer expansion we see today. This helped to explain why parts of the universe so distant that they could never have communicated with each other look the same. Eternal inflation is essentially an expansion of Guth's idea, and says that the universe grows at this breakneck pace forever, by constantly giving birth to smaller "bubble" universes within an ever-expanding multiverse, each of which goes through its own initial period of inflation. Crucially, some versions of eternal inflation applied to time as well as space, with the bubbles forming both backwards and forwards in time (see diagram).

But in 2003, a team including Vilenkin and Guth considered what eternal inflation would mean for the Hubble constant, which describes mathematically the expansion of the universe. They found that the equations didn't work (*Physical Review Letters*, DOI: 10.1103/physrevlett.90.151301). "You can't construct a space-time with this property," says Vilenkin. It turns out that the constant has a lower limit that prevents inflation in both time directions. "It can't possibly be eternal in the past," says Vilenkin. "There must be some kind of boundary."

Not everyone subscribes to eternal inflation, however, so the idea of an eternal universe still had a foothold. Another option is a cyclic universe, in which the big bang is not really the beginning but more of a bounce back following a previous collapsed universe. The universe goes through infinite cycles of big bangs and crunches with no specific beginning. Cyclic universes have an "irresistible poetic charm and bring to mind the Phoenix", says Vilenkin, quoting Georges Lemaître, an astronomer who died in 1966. Yet when he looked at what this would mean for the universe's disorder, again the figures didn't add up.

Disorder increases with time. So following each cycle, the universe must get more and more disordered. But if there has already been an infinite number of cycles, the universe we inhabit now should be in a state of maximum disorder. Such a universe would be uniformly lukewarm and featureless, and definitely lacking such complicated beings as stars, planets and physicists - nothing like the one we see around us.

One way around that is to propose that the universe just gets bigger with every cycle. Then the amount of disorder per volume doesn't increase, so needn't reach the maximum. But Vilenkin found that this scenario falls prey to the same mathematical argument as eternal inflation: if your universe keeps getting bigger, it must have started somewhere.

Vilenkin's final strike is an attack on a third, lesser-known proposal that the cosmos existed eternally in a static state called the cosmic egg. This finally "cracked" to create the big bang, leading to the expanding universe we see today. Late last year Vilenkin and graduate student Audrey Mithani showed that the egg could not have existed forever after all, as quantum instabilities would force it to collapse after a finite amount of time (arxiv.org/abs/1110.4096). If it cracked instead, leading to the big bang, then this must have happened before it collapsed - and therefore also after a finite amount of time.

"This is also not a good candidate for a beginningless universe," Vilenkin concludes. "All the evidence we have says that the universe had a beginning."