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World Without End?

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Try asking a bunch of cosmologists about the origin of the Universe; it's hard to get a clear answer.

"The Universe didn't start. It's infinite." says British cosmologist Fred Hoyle.

"It's an open question." says Steven Weinberg, Nobel prize-winning particle physicist from the University of Texas.

"It's up in the air." says Paul Steinhardt from Pennsylvania State University. co-developer in the 1980s of a key theory about the early Universe.

"It must have had a beginning," says cosmologist Alexander Vilenkin of Cruft, University in Massachusetts.

The standard big-bang model is agreed, says Roger Penrose and everything else is embellishments and flights of fancy. So what gives? Well, Hoyle is convinced that the big bang is a myth, and that the Universe is eternal, with matter continuously created at the centres of galaxies. But virtually everyone else is happy with the big bang model, at least as far back as the early stages of the Universe. Says Weinberg, "We are in an expanding Universe which at one time, before any of the stars or galaxies formed was very hot and dense. I don't think there is any serious argument that in that sense there was a big bang, and the part of the Universe that we live in had a start, but beyond that we really don't know."

To try to trace the history of the Universe back to its origin, cosmologists picture the expansion running backwards to a point where the Universe was almost unimaginably small and dense. The first problem they meet when they do this is that the concept of time comes apart in their hands. The reason is that at the so-called Planck scale (a mere IO^-35 metres), two theories begin to clash: Einstein's smooth, large-scale, classical theory of gravity makes no provision for the fuzzy, indeterminate quantum theory of tiny particles. And all bets are off.

"Questions about what happened before what begin to lose meaning," says Steinhardt "Before only makes sense if there is a sensible time ordering to things, and that notion breaks down at the Planck scale."

Weinberg agrees: "Any description that tries to go to earlier times has to give up the idea of time. It's no longer a meaningful concept."

Glimmers of hope for reconciling relativity and quantum theory come from an idea called superstrings-in which all matter is made up of tiny 10-dimensional strings. Although we appear to live in a Universe with just four dimensions, three for space and one for time, the theory goes that the other dimensions present are curled up so tightly that we can't detect them directly.

But this cause, even greater problems, because at the Planck Scale the tightly curled extra dimension, become significant. "You go back in time and it looks like you're heading towards a singularity and all of a sudden—wham!--physics changes because all those extra dimensions that you weren't aware of suddenly come into play," says Steinhardt.

It is usually easy to tell time and space apart. But, says Steinhardt, "When you unwrap the extra dimensions, you don't know what they'll be like. It may be that you even have two time-like coordinates, or more."

The idea of before and after would then be shakier. How could the Universe appear from nothing in the first place? In 1982, Vilenkin came up with the idea that the universe literally tunneled its way into existence, something allowed by quantum theory but impossible on an everyday large scale.

In the classical world, if you have a heavy object lying in a dip it will need a push to climb over the edge and roll down the other side. But in the quantum world, there is a small, but non-zero probability that the object can simply tunnel to the other side of the dip without any outside help. The only condition is that it does not gain any energy in the process.

So how does this relate to the Universe? Well, say you start with nothing at all-not even space or time. Presumably the total energy of this system would be zero. Is it possible to make a Universe of space, time and matter whose total energy is still zero? The answer is yes. "You can't create something out of nothing," says Vilenkin. "But the Universe is an exception.

Gravitational energy is negative and matter energy is positive. In a closed Universe, one where if you keep going in one direction you come back to the same point-the negative energy of gravity exactly cancels the positive energy of matter, so the total energy is zero."

In the classical picture, the Universe cannot appear out of nothing because it is forbidden to adopt a certain range of sizes. But in quantum theory, the Universe can tunnel through this size barrier, and appear spontaneously with a size greater than the critical value.

Can we ever know if the universe began at a single point or has simply been going on forever? There is yet another complication which may make the whole question academic. It stems from an idea called inflation, first developed in the early 1980s to solve some vexing problems with the standard big bang model. In its earliest versions inflation theory stipulated that immediately after the big bang, the Universe suddenly ballooned, increasing its diameter by more than a trillion trillion times in just a tiny fraction of a second. After this, the Universe switched to a noninflationary phase, and expanded at a more sedate rate.

But in the mid 1980s. cosmologist Andrei Linde at Stanford University realised that such a system would be self-replicating. Once you kicked it off with a big bang, it would go on forever. Even when most of the Universe had moved out of the inflationary phase, Linde reasoned, tiny fluctuating regions would still be capable of undergoing inflation. These would then go from being infinitesimal regions to sizeable chunks of Universe in a split second, and would themselves go on to spawn new patches of Universe and so on. In each case, once inflation was over, the patch would evolve according to standard big bang theory.

If this is true, the whole Universe could be made up of a huge number of expanding patches which could be quite different from our own.

The problem is that we can never know. "We are removed be a tremendous distance from regions that underwent a different history." says Steinhardt. "Inflation casts a pall on things because it makes the part of the Universe we see so infinitesimal compared to the entire Universe, and perhaps not even representative. We will never be able to see the edge of the patch we live in, and this puts us beyond the ability to be able to probe things through observations."

What's more, an eternal, self-replicating Universe may not even need a big bang. Vilenkin says he has proved in a theorem that the inflationary Universe must have had an origin, but Linde is skeptical. He thinks it likely but unproved that there was an initial big bang from which all of the "pretty big bangs" came. However, he adds that the question is so far removed from our experience that it is irrelevant: "Say you have an infinite number of bubbles, all producing new ones. You live in one of these bubbles and you look at the point the bubble was formed. For all practical purposes that's the beginning of your Universe." Because there are infinitely many such bubbles, we have no reason to believe that ours is the first, or even the hundredth. It's more likely, says Linde, that our own personal big bang is actually a pretty insignificant one, way down the list from the one that set the Universe going.