Cosmic Cycles

Excerpt from Paul Halpern, "When the End is Just the Beginning: Exploring Cosmic Cycles," NOVΛ Newsletter, August 12, 2014

This is how it all could end: heat death, the moment when the universe expends its last drop of usable energy and settles into lifelessness. Like the ultimate junkyard, only relics of once-burning stars and their planetary companions remain. Wait long enough and even black holes vanish through the slow trickle of Hawking radiation.

That is a bleak and humbling thought. But might nature enjoy an encore or even a revival? A second act for the universe, even if it were many billions of years from now, would offer a source of comfort. We'd know that even if our own civilization – and indeed all possible living worlds in space – blew out like a flame in the wind, flickers of new life could eventually relight.

In the olden days of cosmology – that is, before the 1998 discovery that the universe's expansion is accelerating – there was hope that the universe might bounce back from a "Big Crunch." In that scenario, the universe's sheer heft would eventually cause it to stop expanding, switch gears and shift into reverse. Like a film of the Big Bang played backward, all of space would collapse to a single point. Cosmologist Stephen Hawking once speculated that time itself would switch directions during the contraction phase. (Later, after discussions with his assistant Raymond Laflamme, he changed his mind.) Today, with no end in sight for cosmic expansion, the "Big Crunch" is out of fashion. But new theories are offering some hope that the heat death may not be terminal.

Cosmic cycles have a long tradition in philosophy and religion. From the ancient Chinese to the Mayans, numerous cultures embraced the idea of time as an ever-turning wheel. Many ancient peoples imagined that a cosmic "spring" would follow each cosmic "winter" in a perpetual sequence of phases, just like the seasons on Earth. Scientific cosmology followed suit. Shortly after Edwin Hubble discovered that galaxies were receding from each other – an observation that beautifully matched Belgian scientist and cleric Georges Lemaître's hypothesis that the universe is expanding – physicist Richard Tolman began to investigate the possibility that the cosmos was eternally oscillating through cycles of creation and destruction. The idea was that each Big Crunch would be followed by a new Big Bang, tracing an endless accordion of expansions and contractions. Unfortunately, Tolman later realized that the second law of thermodynamics, which states that entropy in a closed process can't decrease, would force each cycle to be longer with less usable energy, a scenario that seems less like renewal and more like modulated decay.

But it's not all bad news for cosmic cycles. Believers in eternal renewal can take heart that researchers have advanced several cyclic cosmologies that are consistent with the latest discoveries about cosmic acceleration and dark energy.

Excerpt from Neil Turok, "The Cyclic Universe," Edge (edge.org), May 16, 2007

For the last ten years I have mainly been working on the question of how the universe began — or didn't begin. What happened at the Big Bang? To me this seems like one of the most fundamental questions in science, because everything we know of emerged from the Big Bang. Whether it's particles or planets or stars or, ultimately, even life itself.

In recent years, the search for the fundamental laws of nature has forced us to think about the Big Bang much more deeply. According to our best theories – string theory and M theory – all of the details of the laws of physics are actually determined by the structure of the universe; specifically, by the arrangement of tiny, curled-up extra dimensions of space. This is a very beautiful picture: particle physics itself is now just another aspect of cosmology. But if you want to understand why the extra dimensions are arranged as they are, you have to understand the Big Bang because that's where everything came from.

Somehow, until quite recently, fundamental physics had gotten along without really tackling that problem. Even back in the 1920's, Einstein, Friedmann and Lemaitre – the founders of modern cosmology – realized there was a singularity at the Big Bang. That somehow, when you trace the universe back, everything went wrong about 14 billion years ago. By go wrong, I mean all the laws of physics break down: they give infinities and meaningless results. Einstein himself didn't interpret this as the beginning of time; he just said, well, my theory fails. Most theories fail in some regime, and then you need a better theory. Isaac Newton's theory fails when particles go very fast; it fails to describe that. You need relativity. Likewise, Einstein said, we need a better theory of gravity than mine.

But in the 1960's, when the observational evidence for the Big Bang became very strong, physicists somehow leapt to the conclusion that it must have been the beginning of time. I am not sure why they did so, but perhaps it was due to Fred Hoyle – the main proponent of the rival steady-state theory – who seems to have successfully ridiculed the Big Bang theory by saying it did not make sense because it implied a beginning of time and that sounded nonsensical.

Then the Big Bang was confirmed by observation. And I think everyone just bought Hoyle's argument and said, oh well, the Big Bang is true, okay, so time must have begun. So we slipped into this way of thinking: that somehow time began and that the process, or event, whereby it began is not describable by physics. That's very sad. Everything we see around us rests completely on that event, and yet that is the event we can't describe. That's basically where things stood in cosmology, and people just worried about other questions for the next 20 years.

Excerpt from Charles Choi, "In the Beginning," NOVΛ Newsletter, June 13, 2012

Did the universe have a beginning? What, if anything, came before the Big Bang?

Today, we see galaxies rushing away from us in every direction, suggesting that, if you could press the rewind button on the entire universe, the whole thing would screech to a halt at a moment about 13.7 billion years in the past, when the entire cosmos was apparently compressed into a singularity – an infinitely small, dense point.

"How does the universe begin from such a state?" asks Alexander Vilenkin, a theoretical physicist at Tufts University. Indeed, the laws of physics as we know them break down around singularities, so physicists have devised a number of ways to sidestep the singularity problem.

One possibility is that the universe is cyclic: Every Big Bang expansion is followed by a contraction, ending in a "Big Crunch" from which a new Big Bang emerges, and so on and so on in an infinite series that extends eternally into the past and future. The idea was first proposed centuries ago, but received a fresh take from the physicists Paul Steinhardt and Neil Turok in 2002. There is a problem with this elegant idea, though: the second law of thermodynamics, which states that the total amount of disorder or entropy in a system increases over time – the party-pooper law that prevents the existence of perpetual motion machines. A universe that experienced repeated cycles of expansion and contraction would have get more and more disordered over time until it began completely disordered, something we do not see in our universe. One way to avoid such increasing entropy would be for the volume of the cosmos to increase with each cycle. However, if one ran this scenario backward in time, one would still be forced to conclude the universe began with a singularity.

If our Big Bang wasn't preceded by a Big Crunch, perhaps our universe instead existed as kind of dormant seed – "like a cosmic egg," says Vilenkin – before suddenly breaking open in the Big Bang. But here, too, there is a problem: In the uncertain world of quantum physics, the "egg" couldn't stay stable forever. It would have expanded and contracted and could have even collapsed into nothingness. "This means it couldn't have existed forever in the past," Vilenkin said, findings he and his student Audrey Mithani detailed in the January issue of the Journal of Cosmology and Astroparticle Physics.

But the same quantum fluctuations that could have cracked the cosmic egg could be birthing new universes as you read this, says Vilenkin. This idea, called eternal inflation, suggests that our universe is just one bubble within a larger multiverse which is perpetually popping out new bubble universes. Although inflation may have stopped in bubbles such as ours, new instances of inflation occur in the multiverse forever into the future, keeping the idea of eternal inflation true to its name. But what about the past? If one assumes that the multiverse is expanding and not contracting, then it had to have expanded from a certain point in time, Vilenkin explains. Even eternal inflation must have a beginning.

Even if the universe did have a beginning, it likely occurred so very far in the past that the cosmos might as well appear as if began an eternity ago, says theoretical physicist Leonard Susskind at Stanford University in California. "We're talking about the beginning potentially occurring at time scales vastly, vastly larger than the age of our universe, longer than any time that you can name," Susskind explains. "Statistically, given this extremely long amount of time, we probably occurred very, very late in history, making us very far from the beginning, so most of the information about the beginning would be lost to us. I think we're really in the dark about what it would've been like."

Excerpt from Suraj Radhakrishnan, "4D World: Light Moving In Fourth Dimension Observed During Quantum Hall Experiment," International Business Times, January 8, 2018

But two recent quantum experiments have for the first time shown the existence of a fourth spatial dimension.

The teams of scientists from the U.S. and Europe have shown that, in addition to the conventional three-axis where an object can move up-down, left-right or forward-backward to an observer, there exists a fourth spatial dimension which could introduce new directions of motion.

The discovery was made by studying the results of two quantum hall experiments. "The quantum Hall effect" occurs when the motion of an electron in a material is restricted to only 2D. When electrons are confined to two dimensions, and a magnetic field passes through perpendicularly, some of the system's electrical properties become restricted to multiples of exact number values.

During this effect, it is observed that electrons can only move in well-defined topological pathways that are predetermined. For particular strengths of the magnetic field, the electric current can only flow along the edges of the material. This effect, which was observed 20 years ago, was said to be similar to what would happen to particles in the fourth-dimension.

Oded Zilberberg, ETH researcher, and a professor at the Institute for Theoretical Physics overlooked the two experiments that provided the data for the discovery. By placing together two specially designed 2D setups to study the quantum Hall effect, they were able to catch a glimpse of this fourth spatial dimension.