What Happened before the Big Bang?

by Michio Kaku

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What's the farthest object in the Universe?

I was sometimes asked that age-old question during a 15-city lecture tour for my book Hyperspace.

I pointed out that with the naked eye, one can easily see out to hundreds -- or even thousands -- of light-years, the distance to the flickering stars making up the dazzling firmament on a clear night.

With a pair of binoculars turned on the milky Way itself, a dim white haze becomes a brilliant sheet of stars lying tens of thousands of light-years away.

With the world's most powerful telescopes, you can detect the very distant quasars. because of their enormous redshifts, we estimate that they lie billions of light-years away -- close to the very edge of the visible universe.

At even farther distances, we are peering into Creation itself. In 1982, the COBE satellite allowed astronomers to carry out detailed measurements on the echo of Creation -- the 3^{o}K. microwave radiation that uniformly fills the Universe. This ancient, relic radiation -- older than the stars themselves -- dates back to just 300,000 years after the Big Bang (which took place perhaps 10-to-20 billion years ago).

Without fail, however, someone in the audience would then ask the innocent-sounding question: *"But Professor, what happened before the Big Bang?"*

At this point, I usually detected a faint, satisfied smirk developing on the faces of a few people in the audience as if they had finally stumped the lecturer. I knew that they expected me to throw up my hands, gaze glassy-eyed into the heavens, and sigh philosophically: "We scientists just don't know. We don't even have a clue. It's one of the great unanswered mysteries of nature. Perhaps we'll never know why."

Actually, I saw of lot of startled faces when I replied: "I'm glad you asked because that is the subject of today's lecture. Today, we will discuss what probably happened before Creation. Analyzing this question is what I do for a living."

A New Science Is Born

What catches them off-guard is that in the leading physics laboratories around the world, the Universe before the Big Bang has become one of the hottest areas of research. There is a tangible air of excitement as we witness the birth of a new science called **Quantum Cosmology**.

Although there is no experimental proof as yet for it, the theory is so compelling and beautiful that it has become the center of intense research. Already, the theory has forced us -- almost against our will -- to confront the bizarre possibilities of parallel universes, wormholes, and the 10^{th} dimension. Many physicists are leaping into this game following the lead of such pioneers as Stephen Hawking and Nobel laureate Murray Gell-Mann.

At first, "quantum cosmology" appears to be a contraction in terms like "jumbo shrimp". After all, Cosmology is based on Einstein's General Theory of Relativity (a theory of gravity). Physicists use General Relativity to describe the expanding Universe which can be compared to a smooth balloon being inflated by a child with trillions of tiny galaxies sprinkled on the surface like surface dust. By contrast, Quantum Theory refers to the subatomic world populated by thousands of strange denizens such as electrons, protons, quarks, and possibly "superstrings".

Like oil and water, General Relativity and Quantum Theory don't mix. For example, they take opposite strategies in describing gravity. General Relativity views gravity emerging from the warping of the continuous smooth fabric of space-time. On the other hand, Quantum Theory sees gravity as emerging by the exchange of tiny packets of energy called "gravitons".

For the past 50 years, a cold war has existed between General Relativity and Quantum Theory. Each theory has developed independently of the other. And each has had unparalleled success as long as it has stayed within its domain.

However, the two theories must necessarily collide at the instant of the Big Bang when gravitational forces and temperatures were so fierce that even particles would have been ripped apart. At these energies, Einstein's theory becomes useless and Quantum Theory takes over. Quantum effects overwhelm General Relativity at a temperature of 10^{32} Kelvins, which is a trillion trillion times hotter than the center of a hydrogen bomb explosion.

In other words, the secret of the Big Bang's origin lies with merging the the two theories into a higher one -- a "Theory of Everything" that includes both GM and QM. Physicists need a "quantum theory of gravity" that simultaneously describes both the subatomic quantum world and the structgure of the Universe. And this shotgun marriage of GM and QM is spawning even more bizarre progeny such as "parallel universes" and "hyperspace".

Parallel Universes

One of the principles of Quantum Cosmology is that we must treat the Universe just like we treat a quantum particle. And the simplest such particle is the electron.

As students learn in chemistry class, we nevber know for certain which energy level an electron occupies. Quantum fluctuations are always bouncing an electron into various energy levels simultaneously. Similarly, once we treat the Universe like an electron, then we are forced to conclude that it can exist in several states simultaneously (i.e., parallel universes).

The simplest analogy is boiling water, which is a quantum effect. Tiny bubbles constantly form in the water and then expand very rapidly. If we treat the Universe like a bubble, then we see that our universe coexists with a sea of other bubbles.

Our universe, then, may be nothing but a quantum bubble, the result of a quantum fluctuation in an infinite ocean frothing with universes. In this infinite ocean -- called the "**Multiverse**" -- the vacuum is constantly spawning new universes. In this picture, "big bangs" constantly take place -- each representing a quantum fluctuation in the vacuum.

Creating universes out of nothing may seem to violate cherished conservation principles until we realize that it takes no energy to create a universe. If the universe is closed liked a bubble, then the energy content of its matter is positive while the energy of its gravity is negative. The sum is exactly zero (i.e., because it requires positive energy to lift an object out of a gravitation well, the object's gravitational energy is negative). Thus it takes no net energy to create new bubbles which are contantly being created in the "sea of nothing". Universe are for free!

But this doesn't help if you want to create a universe in the laboratory. As Alan Guth (the originator of the inflationary model of the Big Bang) has pointed out, you would have to heat matter up to 1,000 trillion trillion degrees to create a baby universe in your basement. (The net energy of this system, however, might still be zero since the positive energy concentrated in your basement in turn generates a large gravitational field which surrounds the system whose energy is negative.)

Andrei Linde of Stanford University -- one of the pioneers of the inflationary universe -- believes that these bubbles are constantly churning and peeling off other bubbles. In the cover article for the November, 1994 issue of Scientific American, he wrote:

> "If my colleagues and I are right, we may soon be saying goodbye to the idea that our Universe was a single fireball created in the Big Bang."

This new picture of cosmology creates a new twist on religious mythology. In theology, most myths concerning the origin of our Universe fall into one of two categories: (1) the Judeo-Christian myth of Genesis which describes a definite instant called "Creation", or (2) the Hindu-Buddhist myth of "Nirvana" which describes an endless universe that has no beginning in time or space.

In this new picture, we combine these 2 mythologies into one coherent picture. We have a constant genesis (or boiling of universes) in an ocean of cosmic nothing (or Nirvana).

Life in a Parallel Universe

I was once involved in a discussion with Nobel laureate Steve Weinberg. When I mentioned this picture of millions of big bangs constantly emerging from nothing, Weinberg said:

> "I find this an attractive picture and it's certainly worth thinking about very seriously. An important implication is that there wasn't a beginning -- that there were increasingly larger big bangs so that the Multiverse goes on forever. One doesn't have to grapple with the question of it before the 'bang'. The Multiverse has just been here all along. I find that a very satisfying picture."

Weinberg cautioned, however, that there may not be life in these other universes. Most of them, in fact, are probably dead universes where the proton lifetime is less than, say, 10 billion years (the minimum time necessary to create stable organic chemicals, DNA, and Life itself). This is because physicists find it difficult to construct theories in which protons have lifetimes long enough to create the chemicals for Life. These other universes may be lifeless seas of neutrinos, photons, and electrons -- incapable of combining to form life. Our Universe, in fact, may be one of the few universes that are compatible with Life.

This compelling picture of creation emerging from Quantum Cosmology may also solve the curious puzzle of the **anthropic principle**. Physicists have long observed the remarkable coincidence that the fundamental constants of the Universe fall within an exceeding narrow band that is compatible with Life.

Is Life, therefore, a special property of the Universe? As Freeman Dyson of the Institute for Advanced Study has said: "It's as if the Universe was expecting us." For example, if the electric charge or the gravitational constant were changed slightly, then stable DNA molecules would not be possible. The strong anthropic principle, in fact, concludes that this proves the existence of a divine entity or "God".

In Quantum Cosmology, however, we have a simple explanation. Perhaps there are an infinite number of possible universes with different physical constants. We just happen to live in the one that is compatible with Life. That explains why we are here to discuss the question in the first place.

So it is not an accident at all that the physical constants are compatible with Life. We coexist with plenty of dead universes where the physical constants are incompatible with stable DNA-type molecules.

But if most of the universes are dead, this raises the ticklish question of whether some of them might look just like ours. Some of them, in fact, may be carbon copies of our owne Universe except with a tiny quantum twist.

There is the story of a Russian physicist visiting the United States for the first time, asking to be taken to Las Vegas. Considering him to be a seasoned gambler, his American hosts were curious to learn what his gambling strategy might be. The Russian said that he would put all his money -- every penny! -- on the first bet. But, his hosts protested, "That's a ridiculous strategy!". "Yes," he replied. "But in one parallel universe, I shall be rich beyond my wildest imagination."

Strange, but perhaps true. In millions of other universes, however, he will be broke.

This raises another delicate question. Can we visit these parallel universe? Can we walk down Main Street one day to find a hole in space emerging in front of us leading us to another dimension or universe like some episode of the *Twilight Zone?* Or can we wake up one morning finding ourselves in a world where our loved ones never heard of us?

This is not an idle question. Stephen Hawking visualizes our Universe as being connected by a vast, infinite network of invisible threads with all the other bubble universes. This web connecting these universes consists of **wormholes** which are tunnel or gateways in space itself (see "Of Wormholes, Time Machines, and Paradoxes," *Astronomy*, February 1996).

So in principle, the answer is yes -- wormholesconnect our Universe with others. But don't worry about falling into one. After performing a rough back-of-the-envelope estimate of the probability of such an event, I found that it won't happen within the lifetime of our known Universe.

The 10th Dimension

An important defect remains, however, in this picture.

Once we try to mathematically calculate the quantum fluctuations that give rise to new unieverses, the answer "blows up". In other words, the theory becomes meaningless. Simply splicing Einstein's General Theory of Relativity with Quantum Theory is too crude. The problem of constructing a true, rigorous quantum theory of Gravity -- a unification of QM with GR -- has frustrated the finest minds of the 20th Century including Einstein himself.

Once, Nobel laureate Wolfgang Pauli presented his proposal for a "Theory of Everything" while Niels Bohr was in the audience. Bohr was not impressed. He raised his hand and said: "We in the audience are all agreed that you theory is crazy. But what divides us is whether your theory is crazy enough."

All the sane proposals for a "Theory of Everything" have been shown to be mathematically inconsistent. We are forced, in fact, to go to a higher theory which united both General Relativity and Quantum Theory into a coherent whole. At present, the only (and I repeat: only) candidate for a "theory of everything" is the superstring theory.

Superstring theory is certainly "crazy" enough. It postulates that the particles we see in the Universe (including the atoms in our bodies) are composed of tiny vibrating strings. The reasonances or "notes" of the strings determine the particle zoo (i.e., electrons, quarks, photos, etc.). The Universe is a symphony of vibrating strings. And the laws of harmony are the known laws of Physics.

What is surprising, however, is that superstring theory is so constrained that it fixes the dimension of space and time to be 10. The unique feature of superstring theory is that these tiny strings (about 100 billion billion times smaller than a proton) can only vibrate in 10-dimensional space-time.

Mystics, philosophers, and science-fiction writers have always been fascinated by higher dimensions. But we now have a mathematical reason for believing in a 10-dimensional space-time for it is only in such a universe that we have enough "room" to accommodate both Quantum Theory and Einstein's Relativity. (If we write superstring theories in, say, 12 or 13 dimensions, the theory becomes mathematically inconsistent. A universe starting out in these dimensions is apparently unstable and will decay to 10 dimensions.)

This gives us a startling new picture of Quantum Cosmology. These bubble universe are actually 10-dimensional bubbles. But they are unstable. Soon after its creation, our bubble fissioned in half into 4- and 6-dimensional universes.

The 6-dimensional universe collapsed. Its dimensions are so curled up (i.e., they are 10 trillion trillion times smaller than an atom!) that we can't see them. But the collapse of the 6-dimensional universe allowed our 4-dimensional universe to expand, giving us the expanding Universe that we see today. The expanding Universe is a byproduct of a much more cataclysmic event -- the shattering of 10-dimensional space-time.

This also means that bubbles might exist that fission into 5, 6, 7, 8, or 9 dimensions. However, one can show that these bubbles are probably not compatible with Life. Physics tells us that stable solar systems, atoms, and protons can probably exist only in our 4-dimensional universe. Out Universe is probably 4-dimensional because if it were not, we wouldn't be here to debate the question in the first place.

Testing the Untestable

There is a fundamental difference between Religious Mythology and Quantum Cosmology.

Mythology makes no pretense of being scientific. It fails the test of being falsifiable. There is no experiment that can rigorously exclude the possibilitity of miracles, angels, and the like which are not -- by definition -- reproducible.

Quantum Cosmology, however, may eventually be verified or falsified. But we do not have to wait until we fall into a parallel universe to test these ideas.

For example, the COBE satellite detected tiny tipples in the otherwise uniform microwave background radiation. This is significant because these ripples most like correspond to quantum fluctuations that existed at the instant of the Big Bang. We are, in fact, children of these ripples.

The quantum fluctuations at the beginning of (our Universe's) time gradually grew in size over billons of years to become the galaxies, stars, and planets that we see today.

Other tests of this scenario may come from **dark matter**. Numerous observations have verified the existence of a mysterious, invisible form of matter that makes up perhaps 90 percent of the mass of the Universe. For example, our own galaxy cluster (the Local Group) would have disintegrated billions of years ago if it weren't held together by enormous quantities of unseen matter.

One of the leading candidates for dark matter is a new form of matter called **sparticles** (short for "super particles) which are some of the lowest frequency vibrations of the superstring. Early in the next century, we should be able to identify the precise nature of dark matter which in turn should verify or rule out many of the conjectures in superstring theory and Quantum Cosmology.

Looking further ahead, we may one day even detect a new form of relic radiation left over from the Big Bang -- the **neutrino background** (see "Curtains at the Edge of the Universe", *Astronomy* magazine, November 1995). If this notoriously elusive radiation can be detected, then we will have a snapshot of the Universe when it was only 3 seconds old. Then ripples on the neutrino background will give us a breathtaking looking into the cosmic fireball itself when quantum fluctuations created by the superstring were the dominant forces shaping cosmic expansion.

The next century should be an exciting one as astrophysicists prove the nature of dark matter and the microwave and neutrino background. What they find will tell us much about the first instant of Creation and perhaps confirm the existence of other universes.

So what's the farthest object in the Multiverse? Probably something floating in a buble-universe and dimension far, far way. As the British philosopher J.B.S. Haldane once said:

"The Universe I not only queerer than we suppose but queerer than we can suupose."

About the Author

Michio Kaku (MKAKU@aol.com) is professor of theoretical physics at the City University of New York. He is the cofounder of string theory and the author of the bestseller Hyperspace: A Scientific Odyssey through Parallel Universes, Time Warps, and the 10th Dimension.

[StealthSkater note: a more detailed account of superstring theory is an abstract from Kaku's book archived in the doc pdf URL-doc URL-pdf file. There were at least 5 versions of string theory which were unified by Ed Witten's M-brane theory (requiring yet another dimension). This gave rise to an "Ekopyrotic" model of creation that replaced the older "Big Bang" inflationary model. Instead of expanding from an infinitesimally-small point of infinite density, 5-dimensional parallel branes in the Multiverse collide with one another. The energy has to go somewhere and thus creates bubble-universes. The new theory gives the same results as the old one but without the need for magnetic monopoles and gravitational waves (which have never been observed). Refer to doc pdf URL .

String theory had its origins with trying to find a mathematical description of how the strong nuclear force (which keeps protons in the nucleus) works. Unlike the electromagnetic force whose intensity decreases inversely with the square of the distance, the strong nuclear force actually increases exponentially as the positively-charged protons try to repel each other. I find it helpful to think of a stiff car spring or strut which absorbs bumps and shocks. It's probably easier to squeeze it than to try to pull it apart. An Italian physicist found that an obscure geometry formula of Euler precisely described the strong nuclear force's action. But the price that had to be paid was that the size of these strings had to be unbelievably small (on the order of the Planck length).

Just because adding more dimensions (more rigorously referred to as "higher degrees of freedom") to the math allows a unification of sub-theories does not necessarily mean that the new grand theory is "true" in the philosophical sense. Certainly experimental verification of these postulated dimensions would go a long way in validating that argument. But it should be noted that there are competing theories to unite GM and QM including Loop-Quantum Gravity and Matti Pitkenen's Topological GeometroDynamics (TGD). And these do not require 10 dimensions. They are referenced on the general Science page doc pdf URL .

Finally, it seems that sci-fi "magic" cannot take place in the cruelly rigid Macroscopic GM world. It's only in the fantastically-small quantum arena that "impossible" deeds can take place (e.g., tunneling through energy barriers or being at multiple locations at the same time). Perhaps it because of this that caused mysterious billionaire Robert Bigelow (of the one-time NIDS *paranormal* studies facility) to back off researching UFO physical craft claims (e.g., Bob Lazar) and pour research into Consciousness studies (doc pdf URL). I have witnessed many so-called "nuts&bolts" conservative theorists entering the once mainstream-taboo world of ESP and remote-viewing.

Along these lines, UNITEL (doc pdf URL) proposed to achieve quantum "magic" by faking Mother Nature into believing a Macro-sized object was really a micro-sized quantum particle. Instantaneous travel could be achieved since there is no speed-of-light limit to so-called "nonlocalized" teleportation (Einstein himself could not explain it by GM and called it a "spooky action at a distance"). And perhaps the same was inadvertently done in the fabled Philadelphia Experiment (doc pdf URL). Tom Skeggs' "Star Chamber" allows for real-time interaction between remote-viewers using holographic projections that have no time or distance barriers.]

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We observed the Big Bang (The hot dense state is the Big Bang)â€¦. so, we know it happened. We do not have observations of what was going on before that.Â So, that means â€œeverythingâ€ existed before the Big Bang, logicallyâ€¦. and, as a hot dense state is the opposite of â€œnothingâ€, and, is a plas. Continue Reading. What happened before the Big Bang and did it even happen? We observed the Big Bang (The hot dense state is the Big Bang)â€¦. so, we know it happened. We do not have observations of what was going on before that. According to the Big Bang theory, one of the main contenders vying to explain how the universe came to be, all the matter in the cosmos -- all of space itself -- existed in a form smaller than a subatomic particle [source: Wall]. Once you think about that, an even more difficult question arises: What existed just before the big bang occurred? Advertisement. Advertisement. The question itself predates modern cosmology by at least 1,600 years. Fourth-century theologian St. Augustine wrestled with question of what existed before God created the universe. His conclusion was that the Biblical phras...Â "Probing Question: What happened before the Big Bang?" Aug. 3, 2006. Our universe may have had a life before this violent moment of creation. Horizon takes the ultimate trip into the unknown, to explore a dizzying world of cosmic bounces, rips and multiple universes, and finds out what happened before the big bang. Neil Turok, Director of Perimeter Institute for Theoretical Physics in Canada, working with Paul Steinhardt at Princeton, has proposed a radical new answer to cosmologyâ€™s deepest question: What banged? Answer: Instead of the universe inexplicably springing into existence from a mysterious initial singularity, the Big Bang was a collision between two "Since events before the Big Bang have no observational consequences, one may as well cut them out of the theory and say that time began at the Big Bang," he said in an interview on the National Geographic show "StarTalk" in 2018. Or perhaps there was something else before the Big Bang that's worth pondering. One idea is that the Big Bang isn't the beginning of time, but rather that it was a moment of symmetry. In this idea, prior to the Big Bang, there was another universe, identical to this one but with entropy increasing toward the past instead of toward the fu