# The Day Time Began

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Can science explain how the universe began? Such questions have provoked an angry and passionate response from many quarters. Religious people tend to see the claim as a move to finally abolish God the Creator. Atheists are equally alarmed, because the notion of the Universe coming into being from nothing looks suspiciously like the creation, *ex nihilo* of Christianity.

The general sense of indignation was well expressed by writer Fay Weldon. "Who cares about half a second after the big bang," she railed in 1991 in a scathing newspaper attack on scientific cosmology. "What about the half a second before?" What indeed. The simple answer is that, in the standard picture of the cosmic origin, there was no such thing as the half-second before.

To see why, we need to examine this standard picture in more detail. The first point to address is why anyone believes the Universe began at a finite time. How do we know it hasn't been around forever? Most cosmologists reject this alternative because of the severe problem of the second law of thermodynamics. Applied to the universe as a whole, this law states that the cosmos is in a one-way slide towards disorder, or entropy. Irreversible changes, such as the gradual consumption of fuel by the Sun and stars, ensure that the Universe must eventually "run down" and exhaust its supplies of useful energy. It follows that the Universe cannot have been drawing on this finite stock of useful energy for all eternity.

**Body of Evidence**

Direct evidence for a cosmic origin in a big bang comes from three observations. The first, and most direct, is that the Universe is still expanding today. The second is the existence of a pervasive heat radiation that is neatly explained as the fading afterglow that accompanied the big bang. The third strand of evidence is the relative abundances of the chemical elements, which can be correctly accounted for in terms of nuclear processes in the hot dense phase that followed the big bang. But what caused the big bang to happen? Where is the centre of the explosion? Where is the edge of the Universe? Why didn't the big bang turn into a black hole?

***Though these questions seem pertinent, they are in fact based on an entirely false picture of the big bang.*** To understand the correct picture, it is first necessary to have a clear idea of what the expansion of the Universe entails: Contrary to popular belief, it is not the explosive dispersal of galaxies from a common centre into the depths of a limitless void.

The best way of viewing The Big Bang is to imagine the space between the galaxies expanding or swelling. The idea that space can stretch, or be warped, is a central prediction of Einstein's general theory of relativity, and has been well enough tested by observation for all professional cosmologists to accept it. According to general relativity, space-time is not a static arena, but an aspect of the gravitational field. This field manifests itself as a warping, or curvature, of space-time geometry, and when it comes to the large scale structure of the Universe, such a warping occurs in the form of space being stretched with time.

A helpful, albeit two-dimensional, analogy for the expanding Universe is a balloon with paper spots stuck to the surface. As the balloon is inflated so the spots, which play the role of galaxies, move apart from each other. Note that it is the surface of the balloon, not the volume within, that represents the three-dimensional Universe. Now, imagine playing the cosmic movie backwards, so that the balloon shrinks rather than expands. If the balloon were perfectly spherical (and the rubber sheet infinitely thin), at a certain time in the past the entire balloon would shrivel to a speck. This is the beginning.

Translated into statements at)out the real Universe, I am describing an origin in which space itself comes into existence at the big bang and expands from nothing to form a larger and larger volume. The matter and energy content of the Universe likewise originates at or near the beginning, and populates the Universe everywhere at all times.

Again, I must stress that the speck from which space emerges Is not located in anything. It is not an object surrounded by emptiness. It is the origin of space itself, infinitely compressed. Note that the speck does not sit there for an infinite duration. It appears instantaneously from nothing and immediately expands. This is why the question of why it does not collapse to a black hole is irrelevant. Indeed, according to the theory of relativity, there is no possibility of the speck existing through time because time itself begins at this point.

This becomes the most difficult and most critical aspect of the big bang theory. The notion that ***the physical universe came into existence with time and not in time*** has a long history, dating back to St. Augustine in the fifth century. But it took Einstein's theory of relativity to give the idea scientific respectability. The key feature of the theory of relativity is that splice and time are part of the physical Universe, and not merely an unexplained background arena in which the Universe happens. Hence the origin of the physical Universe must involve the origin of space and time too.

But where could we look for such an origin? Well, the theory of relativity permits space and time to possess a variety of edges, technically known as singularities. One type of singularity exists in the centre of a black hole. Another corresponds to a past boundary of space and time at the big bang. The idea is that, as you move backwards in time, the Universe becomes more and more compressed and the curvature or warping of space-time escalates without limit, until it becomes infinite at a singularity. Very roughly, it resembles the apex of a cone, where the fabric of the cone tapers to an infinitely sharp point and ceases. It is here that space and time begin.

Once this idea is accepted, it is immediately obvious that the question "What happened before the big bang?" is meaningless. There was no such epoch as "before the big bang". Because time began with the big bang. Unfortunately, the question is often answered with the bald statement "There was nothing before the big bang", and this has caused yet more misunderstandings. Many people interpret "nothing" in this context to mean empty space, but as I have been at pains to point out, space did not exist either prior to the big bang.

**Absolutely Nothing**

Perhaps "nothing" here means something more subtle, like pre-space, or some abstract state from which space emerges? But again, this is not what is intended by the word. As Stephen Hawking has remarked, the question 'What lies north Of the North Pole?" can also be answered by "nothing", not because there is some mysterious land of nothing there but simply because the region referred to does not exist. It is not merely physically, but also logically, non-existent. So too with the epoch before the big bang.

In my experience, people get very upset when told this. They think they have been tricked, verbally or logically. They suspect that scientists can't explain the ultimate origin of the Universe and are resorting to obscure and dubious concepts like the origin of time merely to befuddle their detractors.

The mind-set behind such outraged objection is understandable: our brains are hard wired for us to think in terms of cause and effect. Because normal physical causation takes place within time with effect following cause, there is a natural tendency to think of a chain of causation stretching back in time, either without any beginning, or else terminating in a metaphysical First Cause, or Uncaused Caused, or Prime Mover.

But cosmologists now invite us to contemplate the origin of the Universe as having no prior cause in the normal sense, not because it has an abnormal or supernatural prior cause but because there is simply no prior epoch in which a preceding causative agency-natural or supernatural-can operate.

Nevertheless cosmologists have not explained the origin of the Universe by the simple expedient of abolishing any preceding epoch. After all, why should time and space have suddenly "switched on"?

The latest thinking is that this spontaneous origination of time and space is a natural consequence of quantum mechanics. Quantum mechanics is the branch of physics that applies to atoms and subatomic particles, and it is characterised by Heisenberg's uncertainty principle, according to which sudden and unpredictable fluctuations occur in all observable quantities.

Quantum fluctuations are not “caused” by anything--they are genuinely spontaneous and intrinsic to nature at its deepest level. *[OLSON NOTE: In one sense, they are “caused” by the math guys who went down this one mathematical road, as opposed to others perhaps snoozing in mathematical potential; it’s not a mind-boggling insight to suggest that quantum physics will find itself transforming into something else in the future, something even weirder.]*

**Impossible Predictions**

For example, take a collection of uranium atoms suffering radioactive decay due to quantum processes in their nuclei. There will be a definite time period, the half-life, after which half of the nuclei present should have decayed. But according to Heisenberg it is not possible, even in principle, to predict when a given nucleus will decay.

If you do ask--having seen a particular nucleus decay--why the decay event happened at that moment rather than some other, there is no deeper reason, no underlying set of causes that explains it. It just happens. *[OLSON NOTE: Apparently the big insight here is that something as logically incomplete and intuitively false as this can be true?]*

The key step for cosmogenesis is to apply this same idea not just to matter, but to space and time as well. Because space-time is an aspect of gravitation, this entails applying quantum theory to the gravitational field of the Universe.

The application of quantum mechanics to a field is fairly routine for physicists, though it has to be said that there are special technical problems associated with the gravitational case that have yet to be satisfactorily resolved ("Can gravity take a quantum leap?', 10 September 1994, p 28).

***The quantum theory of the origin of the Universe therefore rests on shaky ground.***

In spite of these technical obstacles, one may say quite generally that once space and time are made subject to quantum principles, the possibility immediately arises of space and time "switching on", or popping into existence, without the need for prior causation, entirely in accordance with the laws of quantum physics. *[OLSON NOTE: This appears to me to be either a con or a superstition; in the latter case cleverly disguised as "science", in the former using a lot of fancy-sounds words to distract you from questioning whether this really makes any sense. What do you think?]*

The details of this process remain both subtle and contentious, and depend to some extent on the interrelationship between space and time. Einstein showed that space and time are closely interwoven, but in the theory of relativity they are still distinct. Quantum physics introduces the new feature that the separate identities of space and time can be "smeared" or "blurred" on an ultramicroscopic scale.

In a theory proposed in 1982 by Hawking and American physicist Jim Hartle, this smearing implies that, closer and closer to the origin, time is more and more likely to adopt the properties of a space dimension, and less and less likely to have the properties of time. This transition is not sudden, but blurred by the uncertainty of quantum physics. Thus time does not switch on abruptly in Hartle and Hawking's theory, but it emerges continuously from space. There is no specific first moment in which time starts, but neither does time extend backwards for all eternity (see Diagram p 34). *[OLSON NOTE: Doesn't "time" mean something moves? Then doesn't it come into being when the first thing moves? If there was nothing and nothing moving "before" creation, wouldn't there be no "time"?]*

Unfortunately, the topic of the quantum origin of the Universe is fraught with confusion because of the publicity given to a preliminary, and in my view wholly unsatisfactory theory of the big bang based on an instability of the quantum vacuum.

According to this alternative theory, first noted by Edward Tryon in 1973, space and time are eternal, but matter is not. It suddenly appears in a pre-existing and unexplained void due to quantum vacuum fluctuations. In such a theory, it would indeed involve a serious misnomer to claim that the Universe originated from nothing: a quantum vacuum in a background space-time is certainly not nothing. *[OLSON NOTE: Wow, this appears to be self-fulfilling elements of a theory. "Quantum vacuum in a background space-time"? I assume this means that these equations* *are back-engineered to create a series of "safety net" equations (equations positing a "quantum vacuum"), because those equations themselves require a "cause"? Oh, brother. But since I don't know what I'm talking about, can somebody help me here?]*

**Law Unto Itself**

However, if there is a finite probability of an explosive appearance of matter, it should have occurred an infinite time ago. In effect, Tryon's theory and others like it run into the same problem of the second law of thermodynamics as most models of an infinitely old Universe.

It will be obvious from what I have said that the attempt to explain the origin of the Universe is based on an application of the laws of physics. This is normal in science: one takes the underlying laws of the Universe as given. But when tangling with ultimate questions, it is only natural that we should also ask about the status of these laws. One must resist the temptation to imagine that the laws of physics, and the quantum state that represents the Universe, somehow exist before the Universe. They don't any more than they exist north of the North Pole. ***In fact, the laws of physics don't exist in space and time at all. They describe the world, they are not "in" it.***

However, this does not mean that the laws of physics came into existence with the Universe. If they did-if the entire package of physical Universe plus laws just popped into being from nothing--then we cannot appeal to the laws to explain the origin of the Universe.

***So to have any chance of understanding scientifically how the Universe came into existence, we have to assume that the laws have an abstract eternal character. The alternative is to shroud the origin in mystery and give up.***

***It might be objected that we haven't finished the job by baldly taking the laws of physics as given. Where did those laws come from? And why those laws rather than some other set? This is a valid objection.***

I have argued that we must eschew the traditional causal chain and focus instead on an explanatory chain, but inevitably we now confront the logical equivalent of the First Cause-the beginning of the chain of explanation.

In my view it is the job of physics to explain the world based on lawlike principles.

Scientists adopt differing attitudes to the metaphysical problem of how to explain the principles themselves. Some simply shrug and say we must just accept the laws as a brute fact. Others suggest that the laws must be what they are from logical necessity. Yet there could exist other entirely different types of universes, each with differing laws, and that only a small subset of these universes possess the rather special laws needed if life and reflective beings like ourselves are to emerge.

Some sceptics rubbish the entire discussion by claiming that the laws of physics have no real existence anyway--they are merely human inventions designed to help us make sense of the physical world. It is hard to see how the origin of the Universe could ever be explained with a view like this.

***In my experience, almost all physicists who work on fundamental problems accept that the laws of physics have some kind of independent reality. With that view, it is possible to argue that the laws of physics are logically prior to the Universe they describe. That is, the laws of physics stand at the base of a rational explanatory chain in the same way that the axioms of Euclid stand at the base of the logical scheme we call geometry. Of course, one cannot prove that the laws of physics have to be the starting point of an explanatory scheme, but any attempt to explain the world rationally has to have some starting point, and for most scientists the laws of physics seem a very satisfactory one.***

In the same way, one need not accept Euclid's axioms as the starting point of geometry; a set of theorems like Pythagoras's would do equally well. But the purpose of science (and mathematics) is to explain the world in as simple and economic a fashion as possible, and Euclid's axioms and the laws of physics are attempts to do just that. In fact, it is possible to quantify the degree of compactness and utility of these explanatory schemes using a branch of mathematics called algorithmic information theory.

Obviously, a law of physics is a more compact description of the world than the phenomena that it describes. For example, compare the succinctness of Newton's laws with the complexity of a set of astronomical tables for the positions of the planets.

Although as a consequence of Godel's famous incompleteness theorem of logic, one cannot prove a given set of laws, or mathematical axioms, to be the most compact set possible, one can investigate mathematically whether other logically self-consistent sets of laws exist. ***[OLSON NOTE: Is this said correctly? Isn't the point of Godel's Incompleteness Theorem specifically that logical analysis can't be proven to be "true", another way to say that there may be other ways of thinking about which we cannot know because of the structure of our brains?]***

***One can also determine whether there is anything unusual or special about the set that characterizes the observed Universe as opposed to other possible universes. Perhaps the observed laws are in some sense an optimal set, producing maximal richness and diversity of physical forms. It may even be that the existence of life or mind relates in some way to this specialness. These are open questions, but I believe they form a more fruitful meeting ground for science and theology than dwelling on the discredited notion of what happened before the big bang.***