THE UNIVERSE'S ORIGINS - Curated Transcript of BBC In Our Time podcast

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In Our Time is hosted by Melvyn Bragg. Melvyn's guests on this podcast are:

Professor Sir Martin Rees, Astronomer Royal and Royal Society Research Professor in Astronomy and Physics, Cambridge University;

Professor Paul Davies, theoretical physicist and Visiting Professor at Imperial College, London.

Transcript:

[Melvyn Bragg] Hello. About 400 years ago in Rome, Giordano Bruno was burnt at the stake for his belief in other inhabited worlds. It's a possibility which has fascinated scientists, writers, artists and the general public for centuries. And any considerations of the origins of life and matter on other planets, and indeed this one, inevitably raises huge do other worlds exist? How did our planet come into existence? How can we know anything at all about the origins of life and matter so many billions of years ago? And how is our thinking on these? Among the deepest of questions changed over the century. With me is the Astronomer Royal Professor Sir Martin Rees, who's also a Royal Society Research Professor in Astronomy and Physics at Cambridge University. A leading researcher on cosmic evolutions, black holes and galaxies, his books include Black Holes in the Universe and Before the Beginning, Our Universe, and others. He's particularly interested in searching for the basic physical laws of life. His most recent book, Just Six Numbers, will be published in the autumn. Professor Paul Davies is a theoretical physicist who's currently a Visiting Pofessor at Imperial College London. A prolific and prize winning writer on cosmology, gravitation and quantum field theory, he is, like Sir Martin, particularly interested in black holes and the origin of the universe. His most recent book, The Fifth Miracle, comes out in paperback next month.

[Melvyn Bragg] Martin, can I ask you how this century, the ideas about how the universe began have developed?

[Martin Rees] Well, 100 years ago, we really knew nothing about our universe as an entire entity. We knew about evolution on the earth from the work of Darwin and the geologists, but we knew nothing about the idea of the scale of the universe or that it was evolving. That has come about by a real crescendo of discovery over the last hundred years to the extent that we can now talk about our entire universe and its history. We can trace everything back, not just the birth of our earth, our sun, but back to the birth of our galaxy, back even to a so called Big Bang, where we believe everything began in a hot, dense state about 12 billion years ago. So it's an amazing achievement that we can talk about what happened at those early times. And sometimes I'm asked, isn't it presumptuous to believe you can say anything about the entire universe? And my response to that is always that what makes things hard to understand is how complicated they are, not how big they are. And the early universe was, in a sense, a simple place because it was very hot, no complex chemistry, etcetera. So Paul Davies has a much harder job explaining life than we have explaining the beginning of the universe.

[Melvyn Bragg] Can we just stick with you for a moment, though, Martin? Can you give us a few of the great landmark discoveries this century, or events this century which suddenly opened up this whole area of knowledge which you call the golden age?

[Martin Rees] Well, if you go back to the 1920s, people realize then that our galaxy, our Milky way, was just one of many, and that the universe was much vaster than our Milky Way. Then...

[Melvyn Bragg] Was this Hubble?

[Martin Rees] This was Hubble and others. But then Hubble's great achievement a few years later was to find that our universe was expanding, that distant galaxies were expanding away from us as though everything started in some hot, dense state a long time ago. There wasn't very good evidence for that until really much more recently, in the last 30 years. Thirty years ago, astronomers discovered the sort of afterglow of the hot, dense beginning, the so called primordial radiation. And since that time, …we've been able to put on a fairly constant footing the ideas of the early universe back to about one second [after the Big Bang]. I say one second because that poses the question, what happened before the first second was up, where of course, a great deal could have happened, which is more speculative. But back to one second, I believe we have a story of cosmic evolution which is as serious as the story which we are told by geologists about the history of the earth. It's based on real evidence, real fossils, real observations of distant objects.

[Melvyn Bragg] So you can tell the story, you think, from one second onwards, before one second we might get back to that later, but that's the story you think has been unraveled this century in detail and is mappable?

[Martin Rees] Well, I wouldn't say in detail. In outline, I think we have the broad picture. We're trying to understand in a bit more detail, how from these simple beginnings, we've ended up with our cosmos with galaxies full of stars, some containing planets, and some on which life can evolve. So the cosmic evolution from simplicity to complexity is something we're still trying to fill the details of. But the broad idea back to one second, and that's an important proviso, I would say is fairly well established in outline.

[Melvyn Bragg] Well, you must remember to come back to that second before the end of these minutes… I was going to bring in the steady state theory and the idea of inflation, but let's keep moving on at the moment, just to take one more point from you, you've said something which will stun some of our listeners, and it's a simple sentence. You said, "a star is really simpler than an insect".

[05:51]

[Martin Rees] Well, it's really because inside a star, everything is so extreme, it's so hot there's no complicated chemistry, so we can really understand it. The inanimate world is not as complicated as the intricate structure in even the simplest organisms. So biologists really have a much tougher challenge, in a way, than cosmologists do. What makes things hard to understand is how many layers of complicated structure they have. And in insects, there's far more complexity than there is in something like the sun, which is so hot in the center that it's mainly just atoms, very hot gas. It's very important what happens in the sun, of course, but the physics of what goes on there is something we can understand.

[Melvyn Bragg] Paul Davies, do theories on the origins of life need to be more complex than theories on the origin of matter?

[Paul Davies] What you're trying to explain is, of course, the emergence not only of complexity, but a very particular type of complexity.

[Melvyn Bragg] You mean us?

[Paul Davies] Well, not necessarily human beings. Even the simplest, most humble bacterium is already immensely complex in a rather specific way. People used to think that life was some sort of magic matter, some particular type of stuff that you could maybe cook up if you had the right chemical recipe. I think we now realize that the living cell is more like a supercomputer. It's an information processing and replicating device. And it is that information-based complexity that is so baffling. And I agree entirely with Martin that something like the sun is much simpler, partly because an object like the sun, its behavior is determined largely by the laws of physics. Whereas in the case of life, history must play an inevitable role, contingency must play a role. There will be certain historical events that are going to be important.

[Melvyn Bragg] You use that word "supercomputer". Do you go along with Schroedinger's suggestion that living organisms are no more than elaborate machines?

[Paul Davies] Well, it depends a little bit on what you mean by machine. Sometimes calling something a machine seems to somehow devalue it. But, of course, we recognize that the secret to life lies in its molecular processes, and molecules in some ways, resemble machines. Certainly, if you look inside the cell, you can see familiar things like pumps and chains and even scissors, bits and pieces of what we would now call nanomachinery, fulfilling their various functions. So I sometimes liken the living cell a little bit, like to a city in its organization and the interweaving of the different components and so on. So I think we need to obviously use this mechanistic language, but I think it also misses out this essential ingredient, which I keep coming back to, which is the information content, the software, if you like. So it's not just a matter of what bits push and pull which, it's somehow got to come under the organizational influence of software.

[Melvyn Bragg] I think that I might just come in for a moment, can I just ask one or two more questions here? You've said that whatever the precise chemical sequence might have been, life must have formed as a result of some sort of molecular self assembly. Yeah. Now, what do you mean by that?

[Paul Davies] Well, I suppose it's my way of saying that it wasn't a miracle, there was no divine intervention, that there would have been some sort of molecular processes which gave rise to replication and information storage.

[Melvyn Bragg] But why did the molecules decide to self assemble?

[Paul Davies] Well, I don't think they.... sat down and thought, well, wouldn't it be a good idea to turn themselves into a living thing...

[Melvyn Bragg] No, and we're using metaphors obviously, but still, it's your phrase. It's a terrific phrase but I would just like it... decoded

[Paul Davies] ... Well, what I have tried to do in my book is to talk also about the formation of crystals and galaxies which also form by themselves.

[Melvyn Bragg] Yes, but this is the origin of life. This is the number one thing, isn't it? So how can you make us understand molecular self assembly?

[Paul Davies] Well, molecules do, of course, stick together and form more complex chains. What we would like to understand,

[Melvyn Bragg] But why did they do that in the very first place, is what I'm probably rather stupidly trying to get at....

[Paul Davies] Why did they do it?

[Melvyn Bragg] Well, in the very first place, you say, life must have been formed, the origin of life must have been.

[Paul Davies] Yes. Well, of course, if we go back, I don't know, four billion years to a time when there was no life on earth, and we imagine, depends on the setting you want, but let's imagine that there was some sort of mix of lifeless chemicals. Somehow they had to turn themselves, transform themselves, into a simple living thing. So there is a transformation process. And seeing as we don't believe that in "vitalism" - that there's anything, any sort of magical, mystical essence that is transforming matter, it's entirely the structural components themselves that had to get rearranged so that they became replicating and information...

[Melvyn Bragg] But that sounds a little bit like a spontaneous generation, which was heavily discredited, I thought.

[Paul Davies] Louis Pasteur performed some famous experiments in the 19th century in which he claimed to have knocked on the head the notion that life could arise from non life. There had been hundreds of years of rather wacky speculation that sweaty underwear and dirty socks and so on could produce lice and maggots, and this was widely believed in the 19th century. Well, what Pasteur showed was that if you have a truly sterile, isolated medium, then life doesn't appear in it. And some people have, at least at the time, took that to mean that you couldn't produce life from non life. But taking the overall view, life had to come from somewhere. If, as we believe, the universe has not always existed, then life has not always existed. If it began simple, and I believe, with Martin, that it did, started out with simplicity, life is a type of complexity that has emerged. And so we want to understand the chemical processes and other physical effects that would have produced this very special type of organised complexity from a simple mix of chemicals.

[Melvyn Bragg] How does that relate to what you were saying, Martin?

[Martin Rees] Well, I think we have to understand what sort of habitat there was on the young earth that allowed this process to get started, because we don't understand how you get from non life to life. That is a difficult question. But what astronomers can now tell us is something about what the young Earth was like, what sort of habitat it provided. And also one development in the last few years is that we are now confident that our solar system is not unique. There are many other stars, like the sun, which have planetary systems, which may include other planets like the Earth. And so this, of course, raises the interesting question, is the process which Paul Davies is addressing a very rare accident which only happened once, or is it something which would happen fairly naturally on any planet which started off vaguely like the young Earth? That's a crucially important question. My view is we don't know enough about the biology to know whether it's likely or unlikely. It's a very key question.

[Melvyn Bragg] Is it possible to put your contention that you've said "we are stardust, the ashes from long dead stars" ... again, so I'm not trying to put you in conflict in the slightest, not if I were intellectually capable of doing it, but your notion of superbugs, Paul Davies, can we try to find a relationship between those two?

[Martin Rees] Well, the stardust idea is that the universe started off in the Big Bang with just the very simplest atoms, hydrogen and helium. And all the atoms we are made of, carbon and oxygen, etcetera, were actually made inside stars, because it's nuclear fusion that keeps stars shining. And when stars explode, they blow out into space the debris. So we are literally the ashes of long dead stars. If you're less romantic, we're the nuclear waste from those long dead stars. And so what astronomers can do is they can understand not only how stars and planets form, but how all the basic atoms of the periodic table form, starting with simple atoms in the Big Bang. But then, of course, it's a very complicated intellectual exercise to understand how those atoms will indeed combine into simple molecules and then into the complicated ones that eventually become replicating.

[Melvyn Bragg] And that goes over to your superbug, [Paul Davies], doesn't it?

[Paul Davies] Yes. Well, one of the things...

[Melvyn Bragg] Can you just tell people what you mean by "superbug"? Well, I think it's something in a comic that they read when they were ten.

[Paul Davies] That's right. I use it to mean organisms that live in extreme environments and particularly in conditions of extreme heat and pressure, deep beneath the ocean or beneath the earth's surface in the solid rocks, under our feet, down some kilometres, and also beneath the seabed. So these are organisms living in some cases, above the normal boiling point of water...

[Melvyn Bragg] Without light, without sun, nothing could live ...

[Paul Davies] That's right. When I was at school, I was taught that sunlight drove all life on planet Earth. But what you have here is the basis of a completely independent food chain that can make a living. From the minerals and materials coming up out of the earth's crust, they look downwards for their sustenance, not upwards. So it opens up the prospect of life actually starting inside the earth, not very deep inside, but some kilometers into the crust, or perhaps beneath the surface of another planet, like Mars.

[Melvyn Bragg] Hmmm. .... I'd like to come back to that superbug thing in a minute, but do you mind if I go in this direction for a second? Martin, you've talked about planets out there, that we're part of a "multiverse", and only in the last few years, I'm told, I've read, do we have conclusive evidence that other planets are out there....Obviously, you believe that. Do we interact with them? Can you give us some way to imagine them? Are they like a cluster of balloons at the end of a string that you let off at some sort of garden fete, or are they like those olympic circles, infinitely ...sort of masses? And what's happening to this multiverse?

[Martin Rees] Well these are two different things.

[Melvyn Bragg] Well that's good, if you can help me...

[Martin Rees] The idea of other universes is something very speculative. I mean, we need a real health warning before mentioning other universes. That's very speculative. The idea to something beyond what we can even in principle, see today. But other solar systems are things we can directly observe, because we can observe other stars and we can even observe the effects of planets around them. So we now have very definite evidence that some other stars have planets around them, and these are about 50 light years away, that sort of distance. So the idea of other solar systems is not at all speculative. What is a bit speculative is what happens on those planets, but that's very different from the idea of other universes, which is a much more different context. If I could just add a slightly frivolous footnote to what Paul was saying. Professor Thomas Gold is the main advocate of life starting underground, and he was, along with Fred Hoyle, one of the two proponents of the steady state theory of the universe. And a slight irony in the fact that those two steady statesmen, as it were, have ended up with rather different eccentricities. Thomas Gold thinks life started off deep underground. Fred Hoyle thinks it came in from outer space. Neither thinks it started on the surface. So it's rather amusing that in their later years, they both espoused these rather eccentric but very different views.

[Melvyn Bragg] Yes. I mean, I was very taken with Fred Hoyle's "The Intelligent Universe" book when I read it. I know that it didn't do a great number of favors in the scientific community.

[Martin Rees] I thought it was fascinating, too.

[Melvyn Bragg] Anyway, let's get back to this. If there are those... what do you think the probability is of life elsewhere, Paul Davies?

[Paul Davies] I think we have to distinguish two things. One is the so called panspermia hypothesis.

[Melvyn Bragg] Can you just explain panspermia?

[Paul Davies] Is it possible that life can hop from planet to planet, or even star system to star system? It's an old idea. It goes back at least 100 years.

[Melvyn Bragg] It goes back to Fred Hoyle's book as well.

[Paul Davies] Well, Fred Hoyle resurrected it, but it's Svensiarenius. In the 19th century, and even before that, Lord Kelvin was speculating that planets could be struck by large bodies that would splatter seed-carrying rocks around the universe, and so life could perhaps propagate from one planet to another. Now, in my opinion, when you look at this in detail, nearest neighbour, cross contamination, like Earth to Mars, Mars to Earth, I think, is almost inevitable. We know that Earth and Mars get hit from time to time by objects big enough to knock rocks right off them into orbit around the sun, and some of these will inevitably find their way to other planets. But going from one star system to another is a very different thing, in my opinion. Now, Fred Hoyle, building on the work of Arrhenius and Fred's co-worker Chandra Wickramasinghe, have put forward this idea that naked microbes can sort-of waft around the galaxy, perhaps carrying life from one place to another. I don't think that's on, because I think the radiation risk is too great. I'm not saying it's never happened, but I think as a systematic way of disseminating life around the galaxy, it won't work. So, therefore, if we leave aside that, the question is, has life happened more than once? Now, supposing we find life on Mars, and we could be absolutely sure it hadn't hopped there from Earth, we would know that life had happened twice. Two out of two in one star system would mean that the universe must be teeming with life, because it would be inconceivable that an accident of that sort had happened just twice in our star system, and so life would be widespread. Now, when I first began getting interested in this subject, I was convinced that life was written into the laws of physics, that it's something that is fundamental to the universe, likely to occur whenever there are earth-like conditions. But the more I investigated it, the more difficult it seemed to me that it would be to get life going, the more skeptical I have become about this. And I think in our present state of knowledge, what we can say is that life is not written into the laws of physics. Contrast crystals, crystals are written into the laws of physics; they form by self assembly. But crystals are very, very simple structures. They can't encode complex information. I don't think the laws of physics can contain information or anything at all, any prediction about the existence of some specific complex structure. It's often said that bricks alone don't make a house. You need something much more to assemble the bricks in the right sort of structure, organized structure, to make the house, while houses aren't contained in the laws of physics, and I don't think life is contained in the laws of physics.

[Melvyn Bragg] What's your reaction to that Martin Rees?

[Martin Rees] Well, it's really cautious scepticism, because I'm a specialist in just the inanimate world, which is a great deal simpler, and I think, as I said earlier, we don't know enough to know whether the assembly of life is likely or unlikely. Still less, of course, do we know what the chance is of getting from this simple life to something we would recognize as complicated, even intelligent life. These are among the most important questions in science, but I think it's...going to be a long time before we can really settle these questions.

[Melvyn Bragg] Briefly, Paul Davies. I know it's intolerable to ask you to brief on this, but never mind. Why do you think it's more likely that we're all descending from Martian microbes, which came here through meteorite hits, rather than microbes present on the Earth?

[Paul Davies] Yeah, that is very easy to explain. I think Mars has the edge over the Earth as an abode for life. It's not an overwhelming case, but being a smaller planet, it cooled quicker. And if, as I'm suggesting, life did begin deep underground, I think I agree with Tommy Gold on that point, then the comfort zone for these superbugs would have been deeper, sooner on Mars, would have been ready 4.2 billion years ago, whereas the Earth was a less congenial place. The asteroids and comets that were battering it for the first 700 million years or so occasionally would have created horrendous conditions. The biggest of these impactors would have stripped away the atmosphere and swathed the earth in incandescent rock vapor at a temperature of about two or 3000 degrees, which was so hot it would have boiled the oceans and created a sort of superheated steam rock vapour atmosphere. It's quite horrible to think about. This would have sent a heat pulse down into the ground to a depth of at least a kilometre, sterilizing everything in its path. This was less bared on Mars. There would have been big impacts, but Mars lacked a global ocean, so these particular type of global furnace conditions wouldn't have occurred. So I think Mars was probably ready before the earth. And it's easier to get stuff off Mars because of its lower gravity. So the chances of things going from Mars to Earth are greater than...

[Melvyn Bragg] So a meteorite went through space. And inside, the microbes were chilled by the ...and landed here despite the length of time it took, and actually buried themselves deep in the ocean. And life began from that?

[Paul Davies] That's pretty well it. Yes, the martian microbes would have hitched a ride on these rocks displaced from Mars by the big impacts. And it may have taken some millions of years for these rocks to arrive here. But we know that martian rocks come to earth. There are 14 that have been identified. Estimates suggest something like 15 per year arrive here and there would have been billions that would have come to earth during this early bombardment phase. And inside a boulder a few metres across would have been very comfortable for a microbe, shielded from radiation, the cold wouldn't have been a problem. It could easily make the journey, no doubt whatever.

[Melvyn Bragg] I can't resist the trivial thought that there are hundreds of people listening to this program throwing their hats in the air and saying "We were right after all, the little men did come from Mars!"

[Paul Davies] They weren't little men, they were little microbes.

[Melvyn Bragg] I'm going to turn to Martin Rees for this last section because you were... very emphatic in your opening remarks about we know from the end of one second what happened. So let's try to talk with you about before that first second. Does that relate to... I'm not... this isn't a plug for your book, but you said something about these six numbers. Our entire universe, I'm quoting you, not just atoms, but stars, galaxies and people, depends on a few basic numbers imprinted in the big bang. One of these is called lambda, and you call just six numbers. Now can you just tell us how our entire universe depends on a few basic numbers imprinted at the big bang? If we can do that, we'll have actually got a real result.

[Paul Davies] You've got five minutes. [laughter]

[Melvyn Bragg] Four... [laughter]

[Martin Rees] Well, I think most people believe that the first second is uncertain because the conditions are so extreme that we're not sure about the physics, the densities, temperatures that were very high. But most people believe that the laws of physics were in some sense laid down in the early universe. And the present way the universe is expanding is a legacy of some physics called the idea of inflation and other processes that happened very early on. So the aim is to extrapolate back not just to the first second, but to the first tiny fraction of a second, and to understand how the properties of our universe, the fact it's expanding, the fact it contains a mixture of atoms and radiation, and other properties, to understand how those were somehow imprinted very early on. Now, this is still something we're groping for, but there is the hope that we will do this. But I'd like to add another proviso, which is that even if we've done that, we will still be faced with a lot of unknown questions, because we can explain how the universe perhaps started from something very small and very dense. But that is not the same as starting from nothing, as some cosmologists loosely say. It's very important, especially when talking to philosophers, to use language more carefully than that, because in cosmology we may understand the very beginning of the expansion of the universe, but even if we have some complete equations describing the early universe, we never understand within the context of science what, as it were, breathes fire into those equations, what actualizes them into a real cosmos that would always be an open question.

[Melvyn Bragg] Couldn't be someone speaking the Word, could it?

[Martin Rees] Well, you wanted to bring in God before the end of the program...

[Melvyn Bragg] You did. You said, "bring in God". I don't mind. [laughter]

[Martin Rees] Well if I were, I'm often asked about whether the study of cosmology, or indeed the study of origin of life, has any impact on one's religious views. It's clear if you ask groups of scientists that they have a range of religious views, even if they work on the same subjects. And my response is very dull. Just as Newton's contemporaries had various religious views, so do my contemporaries today. And if science teaches me anything, it teaches me that even an atom is fairly hard to understand. And that makes me rather skeptical of any claim to more than a very incomplete and metaphorical understanding of any religious truth.

[Melvyn Bragg] When you say we're looking into, we're examining what happened in that first second are you doing it through intellectual speculation or are there ways of finding out? Other ways of, put it bluntly, testing?

[Martin Rees] There are ways. Two kinds. First, there are some features of our present universe which are legacies of that stage, the way it's structured, the radiation in it, etcetera. But also the theories that people are working on that are relevant to this initial incident are theories that may explain other things about our present universe. For instance, it might tell us why the proton is much heavier than [the] electron and tell us other things about the forces of nature. So if we had a theory which explained things we don't yet understand about atoms and the forces of the everyday world, then we would gain confidence in the other implications of that theory.

[Melvyn Bragg] Paul, if Martin gets to where he wants to get, will it illuminate what you're doing?

[Paul Davies] If you stand back now and take a broader picture, we've been talking a little bit about what may have led to the origin of life through chemical self assembly and that sort of thing. But you can now ask, what are the overall conditions that are necessary that life should be here and maybe consciousness, too. Martin mentioned about the origin of carbon. Carbon is the life-giving element. We couldn't, I think, be here in a universe where there was no carbon. So we can certainly look at the conditions in the Big Bang, and we can look at the underlying laws of physics and the parameters that determine such things as the strengths of the fundamental forces and so on, and we can ask, within that framework, just how narrow are the conditions in order that life should arise. In other words, if we could imagine playing God and twiddling the knobs and changing some of these parameters, or some of the initial conditions, could it be that only changing things slightly would lead to circumstances in which there would be no life and no observers and no people sitting around like us, reflecting on the meaning of it all. And when you look at this mathematically, it turns out that you don't have to twiddle the knobs very much before you mess things up. And some people have interpreted that to mean that there is some sort of element of design or purpose in the universe. Other people have given alternative explanations.

[Martin Rees] Well, the explanation I would give is the multiverse. There are many universes most badly tuned - and we are in the one that was well tuned. So that does bring in the multiverse.

[Melvyn Bragg] Thank you very much, Professor Sir Martin Rees and Professor Paul Davies, and thank you for listening.