Joseph Smith and Modern Cosmology

by Ron Hellings

The subject of my talk today is Joseph Smith and Modern Cosmology. The goal is to look at some of the teachings of Joseph Smith that have cosmic implications and to try to understand these and see what they mean in light of modern cosmology.

Modern cosmology

This is an extremely exciting time to be doing work in cosmology. In the last 20 years we have learned so much about the universe that we are now completely mystified and profoundly confused. We know about less than five percent of the content of the universe—atoms and molecules and fields and radiation and the things we are familiar with. Ninety-five percent of what fills the universe is completely unknown. Twenty percent of that is what's called dark matter. We know several things that it isn't, but we do not know what it is. But, at least, it acts like matter. The remaining 75 percent of the universe is something that we don't even have very good ideas for. It is something called dark energy. Whatever dark energy turns out to be, it's going to require a revolution in our understanding of physics. The simplest thing we could do would be to reinstate Einstein's cosmological constant and give it just the right value to have the effect we need. This is somewhat like having a theory that says 2 + 2 = 5 and saying that it's a great theory as long as you remember to subtract 1 from the answer. Another possibility is that the dark energy is actually a quantum mechanical vacuum energy density. The only problem here is that when we calculate what that energy density should be, we get an answer that's 10^{120} times too big. Even in astronomy, it's tough to get an answer that's *that* wrong. So, many people feel that there is just some new dynamical fluid out there. They have given it a name, they call it quintessence. It makes up 75 percent of the universe, and there are lots of mathematical models used to describe it. But it has to be a very strange stuff. It has to have a negative pressure as its equation of state, and no normal energy or normal matter could produce that. And finally some have suggested that Einstein's theory of relativity, the gravitational theory that holds everything together, is simply fundamentally wrong and will have to be replaced. Whatever happens, there is going to be a radical change, and the ideas that would have labeled someone a crackpot 10 years ago are now being published in the finest journals. And everyone, as I said, is quite confused.

One of the things that I did when I was at NASA Headquarters was to serve as the NASA representative to a group that NASA and NSF and the Department of Energy had put together called the Dark Energy Task Force. Their goal was to discuss this problem and advise the agencies what the best way was to try to figure out the problem of dark energy. I went to the first meeting, and there were a lot of people there that I didn't know and a few people that I did. At the first coffee break, I went out and got something and came back and sat back down at the table and I noticed that there was this little knot of people sitting and talking at one end of the table. One of them was holding forth on Mormonism. It turns out that, just the weekend before, Time Magazine had come out with one of their regular articles explaining Mormonism to the world. And so he was explaining about the church and about how silly some of the Mormon doctrines were. I just got to the point where I was thinking I should get up and go over there and say something, when they called a meeting to order again. One of the guys who had been in the group, a guy I knew, came over and sat down next to me, and he leaned over and said, "You're a Mormon, aren't you?" And I said, "Yes I am. And I've got to tell you I think it's ironic for any member of the Dark Energy Task Force to be ridiculing anyone else's beliefs." They say you should start a talk by stating your main points, and so here's one of my main points. This is no time for anyone to be criticizing anyone's beliefs based on what cosmologists know.

LORD KELVIN ON PHYSICS

The other thing, the other point I would like you to take away, is the content of these next two slides. And, if you remember nothing else, I hope you'll remember these. These are two quotations by famous men. The first is William Thomson, also known as Lord Kelvin, he was speaking in about 1900 and here is the statement he made: "There is nothing new to be discovered in physics now, all that remains is more and more precise measurement". So, let's see what he was missing—special relativity, general relativity, quantum mechanics, semi-conductor physics, black holes, elementary particles. So let's be clear—he was wrong. Okay? But why? How could someone like Lord Kelvin be that wrong? I don't know if you know who he is, but he was not stupid, he was not uneducated. He was a giant in the field. He made huge contributions in electrodynamics and thermodynamics. We name the absolute temperature scale "the Kelvin scale" in his honor. The only thing I can think of is that, you know, he was a very well educated man, very bright, and he came to a conclusion based on what he knew, but there are some things he didn't know, and he didn't know that he didn't know them. So when someone as bright and well-informed as Lord Kelvin can make a mistake this bad, it should remind all scientists to maintain a little bit of humility when they come to conclusions.

JOSEPH FIELDING SMITH ON SPACE TRAVEL

Here's another statement that you may recognize. This is by Joseph Fielding Smith. The time is 1961, and the statement is: "It is doubtful that man will ever be permitted to make any instrument or ship to travel through space and visit the moon or any distant planet". Elder Smith's conclusion was based on his understanding of the gospel; this is not a scientific conclusion. He did not analyze the rocket equation and the weight and escape velocities and things like that. His conclusion was that man was supposed to be on earth and the Lord would not let him leave the place he's supposed to be. But let's be clear—he was wrong. And you all know who Joseph Fielding Smith was, so I don't have to remind you that he was not stupid and he was not ignorant of the gospel. He was an extremely intelligent man, and his understanding of the scriptures and the revelations was legend. So how could someone like that come to a religious conclusion that was this wrong? I think the answer is basically the same. There were things he didn't understand and he didn't understand that he didn't understand.

So, I'd like to end this with a quiz question for you. "If you ever see what appears to be a conflict between science and religion, can you think of at least *two* places where the problem might lie?" We will let you think about that for a little while.

Joseph Smith's cosmology

So let me move on to try to understand something about Joseph Smith's Cosmology. I have two goals as I'm going to do this. The first is I'd like to say something worthwhile, and the second is I would like to keep the nonsense to a minimum.

Let me explain what I mean by the first goal. It would be the easiest thing in the world for me to stand up here and weasel and waffle and wave my hands and say, "You know, Joseph Smith was speaking the language of his time and we don't know what he was claiming prophetic inspiration for and so really we don't know anything about what Joseph Smith really taught." But I don't believe that. Here is one of my favorite non-scriptural statements of Joseph Smith's: "Thy mind, O man! If thou wilt lead a soul unto salvation, must stretch as high as the utmost heavens, and search into and contemplate the darkest abyss, and the broad expanse of eternity, thou must commune with God." Joseph Smith was an intelligent and an inquisitive man. I am convinced that he wondered about these things—that he took these questions to the Lord. And the last five words indicate to me that he was taught some things that the rest of his contemporaries did not know. There *is* something for us to learn about the cosmos by looking at the statements of Joseph Smith. Now, I'd like you to consider the following statement he made as well. He said, "There is no such thing as immaterial matter", Doctrine and Covenants, Section 131, "All spirit is matter, but it is more fine or pure." He said this. He did not say, "There is no such thing as immaterial matter. All spirit is matter, but it coupleth to a different metric". Now, I wish he had said that because then I would understand what he meant. But, of course, if he had said that it would have been proof positive that he was a prophet of God—not because it's right, but because he had no business talking like that in 1840. If he could presage what scientists were going to call these things, it would have been a miracle. Well this is not a miracle or a sign that was given. Joseph Smith clearly had to express the understanding he had in the language that he had available. So, I believe that it's true that Joseph Smith knew something about the cosmos and that he tried to explain it to the saints in the language he had at his command.

Now this leads me to the second point—I want to keep the nonsense to a minimum. Let me read you another statement of Joseph Smith's. This is in Doctrine and Covenants Section 88: "This is the light of Christ. As also he is in the sun and the light of the sun and the power thereof by which it was made. As also he is in the moon and he is in the light of the moon and the power thereof by which it was made. As also the light of the stars and the power thereof by which they were made. And the earth also, and the power thereof, even the earth upon which you stand. And the light which shineth, which giveth you light, is through him who enlightened your eyes, which is the same light that quickeneth your understandings, which light proceedeth forth from the presence of God to fill the immensity of space." I look at that and say, "All right. Light. I'm a physicist. I know everything there is to know about light." This is light—Maxwell's equations. There is no question about light that I cannot answer because I know these things. But then, when I try to apply what I know about light to Section 88, I realize that I don't really know what Joseph Smith was talking about. It is certainly not electromagnetic radiation. So, keeping the nonsense to a minimum means that I am not going to go out and try to pick up every statement Joseph Smith ever made that seems to have some cosmic content and force it to have some explanation that fits into some theory that I want to put together about Joseph Smith. I will only consider elements of Joseph Smith's teachings that are relatively unambiguous and that remain consistent throughout his teachings.

MATTER-ENERGY IS CONSERVED

So, now, onto the task. Let's talk about Joseph Smith's cosmology. I'd like to read you a statement that he made—two of them actually. The first is in 1839. This is a statement he made to the apostles and 70s as they were going off on a mission. "Anything created cannot be eternal; and earth, water, etc., had their existence in an elementary state from eternity." And then from the King Follett Discourse, "The pure principles of element are principles which can never be destroyed; they may be organized and reorganized, but not destroyed. They had no beginning and can have no end." Pure principles of element. Once again I am not quite sure what he meant by that. He was trying to express something that he had learned, in the language that he had available. Now I need to tell you that, at the time that Joseph Smith was writing, energy was not a very important concept. It was not a conserved quantity. It was just being understood that you could talk about heat as a form of energy. But certainly today, we realize that there is something that is absolutely conserved in this sense, which is not created or destroyed. And that thing is "total energy." Today we understand that energy and matter, or mass, are just terms for the same thing. The only difference is the units we use. So, I would translate what Joseph Smith taught into this: that matter-energy is conserved was a teaching of Joseph Smith—that you cannot create it and it cannot be destroyed. It may change form but nothing is going to happen to eliminate it.

EVERYTHING IS MATTER-ENERGY

Here are a couple of other statements of Joseph Smith's. We already read the one. "There is no such"—I love this—"no such thing as immaterial matter." I think that's really important. "All spirit is matter, but it is more fine or pure." And finally, "The Father has a body of flesh and bones as tangible as man's." We are talking about real things. There is nothing intangible or imaginary about the universe, as taught by the Prophet Joseph Smith. It is real stuff. It is all matter, meaning it is all energy, so that everything in the universe is matter-energy. There is nothing that is not included in that category. I think it's fair to say this is one of the teachings of Joseph Smith.

THE UNIVERSE IS INFINITE AND ETERNAL

Now the other ones are little more dicey, but I think it's –.. Let me read you three statements and we'll learn something from those. And I think what we learn will be consistent through many other statements of Joseph Smith's. In his last discourse, Joseph Smith taught, "Intelligences exist one above another so that there is no end to them." An infinite number of intelligences. "Intelligence of spirits had no beginning, neither will it have an end." So there is an infinite existence to those. And finally, just to just remind you, "There is no such thing as immaterial matter." Therefore, all this stuff is material, and we are committed to a universe which is infinite in size, because it has to hold an infinite amount of these things, and eternal in scope. These are things—the statements that we can recognize from Joseph Smith's cosmology.

COSMOLOGY IN THE 1840S

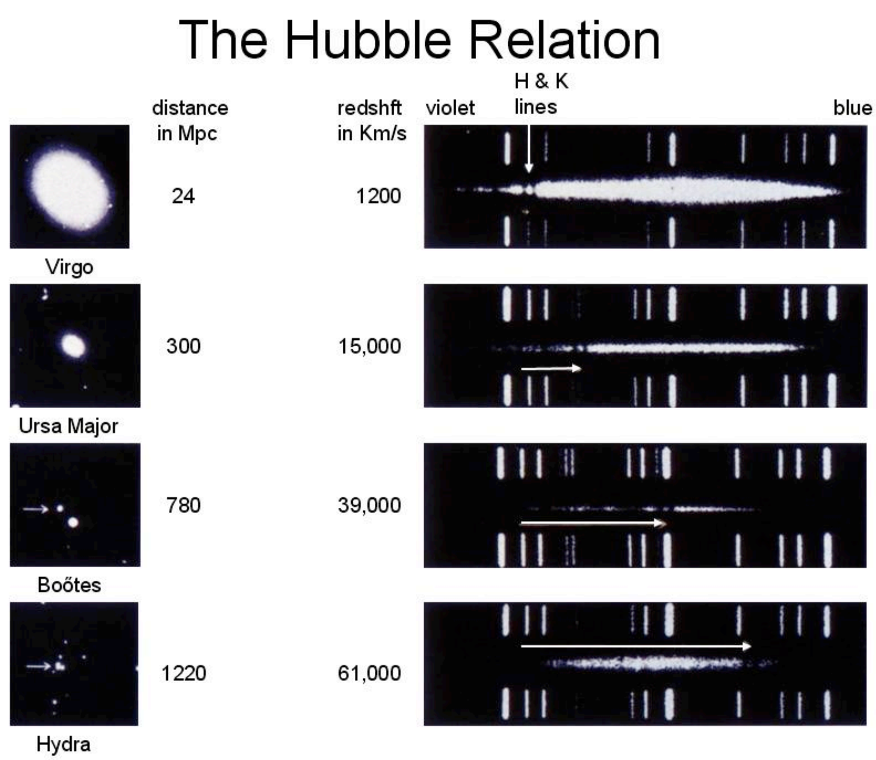
Now let's compare this with what was known at the time that he was saying these things. Let's look at cosmology in the 1840s. Well, in the first place, Lavoisier had just worked out from his chemical experiments that matter was in fact conserved. It cannot be created or destroyed. And the truth of the matter is that Joseph Smith *could* have picked this up from Lavoisier. There's no evidence that he did, but at least it was consistent with what was known at the time. The other main underpinning for cosmology at the time of Joseph Smith was due to the work of Isaac Newton. First, all massive objects attract all other massive objects with a gravitational force. So any two things will pull on each other, no matter where they are in the universe. Second, by looking at the universe, everyone knew that the universe is static. So this creates an interesting problem, in a way, if you consider this picture. I don't know if you can see dots. Are there dots up there? Okay, those dots represent stars in the universe. If we take a little piece of that and blow it up this way and look at one particular star, we see that it is sitting in the gravitational field of all the other stars in the universe. Now, if the universe is static, since all those things are pulling on it, all of the forces have to exactly balance. It turns out the only way you can do that is if you have a universe that is infinite and homogenous. That was the theory. No one discovered until the late 1800s that this universe is unstable, and, in fact, if you move anything a little ways, the whole thing collapses. But it was understood at the time of Joseph Smith that this was the situation. Now I remind you where this came from and where Joseph Smith's infinite and eternal universe came from. They are not related to each other. There is no way that Joseph Smith was reproducing Newtonian cosmology. He came to his infinite universe from a different direction.

COSMOLOGY—1840 TO 1930

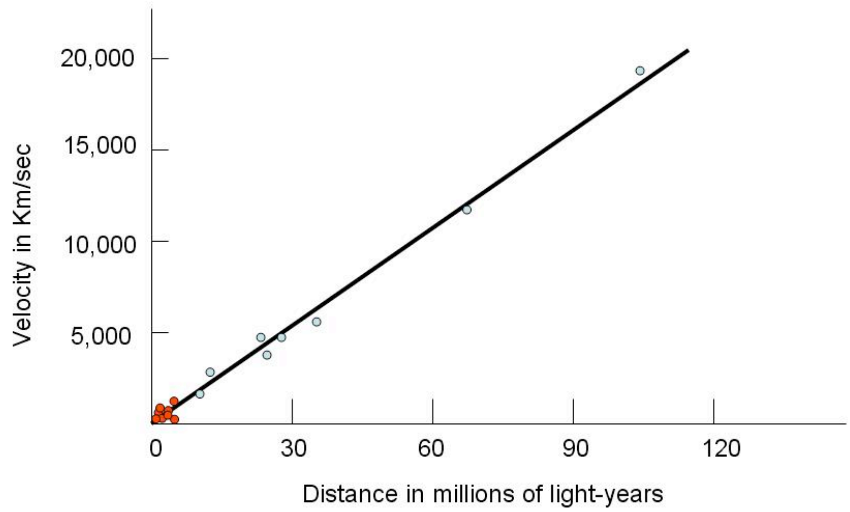
Nevertheless, during the next 100 years or so, the church looked pretty good in contrast to the poor Catholics and Protestants who were stuck with creation from nothing, *ex nihilo*. The Mormons, for a change, had scientific opinion on their side. During this hundred years, "matter" became "matter and energy" became "matter plus energy" became "matter-energy"—energy of which matter is a form or matter of which energy is a form. And so, by 1930, everyone would agree that matter-energy is conserved. You may have seen something like this that on a previous slide. Of course, by this time everything—heat, fields, everything—was understood as part of this. And so, during that 100 years it became clear that everything was matter-energy. And, of course, for Newtonian reasons, the universe is infinite and eternal.

THE EXPANDING UNIVERSE

So what happened in 1930 to change all that (and this takes us to the era of Modern Cosmology)? I'd like to begin by talking about the relation that was discovered by Edwin Hubble. This is a picture of a galaxy in the constellation Virgo. When the light from that galaxy is spread out in spectrum—we see that it goes from the violet to the blue; this is just one piece of the spectrum—we see that there are two absorption lines here. These are the H and K lines of ionized calcium, and they are almost exactly where they would belong if the calcium ions were in the laboratory. By looking at the brightness of the galaxy we can tell the distance to it in megaparsecs and it turns out that's 24 megaparsecs away. By looking at this Doppler shift, the red shift, we can tell what the velocity of that galaxy is relative to us. It's moving away from us, and the velocity is 1,200 kilometers per second. Now we do that with a galaxy further away in Ursa Major. You'll notice those same two lines are there, and they're now moved over toward the blue, this way, from the violet. The distance is greater and the red shift is greater. We can do the same thing with a galaxy further away, Bootes. It's further away and moving much faster. And finally a little galaxy you can barely see, there in Hydra. And now those two absorption lines are almost off the plate to the right, out of the spectrum. And the speed is very fast indeed.

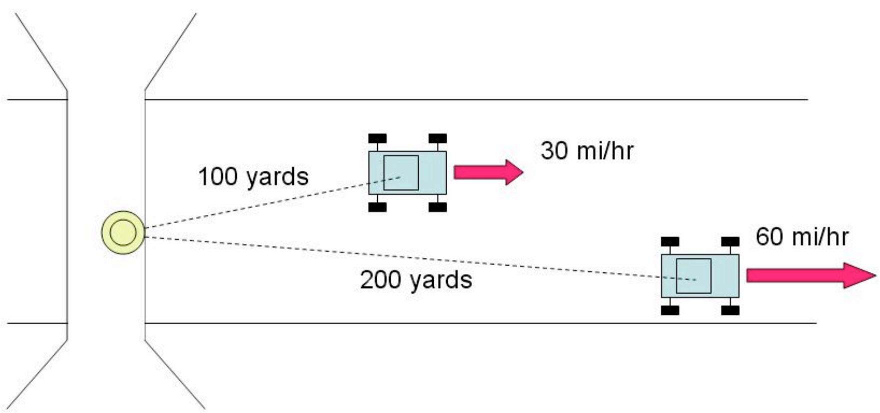


If we were to graph all of the galaxy distances and speeds, we would find that there is a fairly strict proportionality. The further away a galaxy is, the faster it's going. The relation



is linear.

Now this presents an interesting situation. Think about what this means. You are standing on a freeway bridge. There is the freeway, there is the bridge, and that's you wearing a



large straw hat. Yes, that's as good as my art skills get. You're looking down from the freeway bridge and you see two cars, one of them 100 yards away in the left-hand lane, going 30 miles an hour. That would be what we do in California. And one that's twice as far away is going twice as fast, 60 miles an hour. There's something really important about this linear relationship if you think about it. The one twice as far away is going twice as fast. What this tells us about those two cars is they have something in common. You can see what it is by running time backward. The one that was going faster is farther away, so there was a time when both those cars were under the bridge together. And so, as I look out at the universe and see a universe filled with stuff that's moving away from me at a speed proportional to its distance, I know that if I back up time there was a time when all of that stuff was right here in this room. And that of course is the basis for the idea of the Big Bang.

THE BIG BANG

So the idea is if we take a little blob of the universe, with matter and stuff in it, and say, okay, at the present time it might have this size, then this came from something that was smaller a little earlier, which came from something smaller than that. And as we go back in time, this little piece is shrinking and shrinking until it was pretty small. And then that came from this, a single point. Everything began at one point in time and at one point in space, and it was right here in this room. In fact it was smaller than the room– in fact it was smaller than this, in fact it was much smaller than this. Okay? So everything comes from a single point.

Now here's an important question, where did the point come from? Catholics and Protestants were delighted with this, because they had a great idea in the wings. Their idea is that God who exists outside of space and time created this little fireball out of nothing.

AN ASIDE ON CREATION *EX NIHILO*

Despite the fact that "existing outside of time" is a self-contradictory statement –. Okay. I know we like to defend our own doctrine and not criticize others', but I can't help it. I've got to tell you there are a few problems I see with this—a few things that have just driven me crazy that no one else seems to worry about. Try this. "God, who lacks nothing, needs nothing, desires nothing he does not already have, nevertheless creates a universe and people who live in it." Why would he do that? Or, "God loves good and hates suffering, yet the result of his action is that most of his creations will suffer forever, eternally shut out from his presence." Why would he do that? That seems mean, and he's not mean. And finally, and I don't know if this one bothers you but it really bothers me. "And he makes it all so big." Why would he *do* that?

THE ORIGIN OF THE UNIVERSE

Well, I'm sorry. That was a little aside. Let me—let me go back here. Okay, so where did this little point come from? It's a valid question. It's a question that ought to have an answer, and the scientists and the atheists need to come up with an answer too. And here it is. Actually you're looking at it…. There *is* no good answer. They—they think well, they're not quite sure, but maybe it came from a quantum fluctuation in, well, in something. Okay we're not sure what. This is a really tough question and the serious answer is that no one has a good solution to this. But it is a valid question and—and people are concerned about it. Scientists are concerned about it and they're trying to answer this question. It's just that no one can agree. But there is one thing in which they all agree, Joseph Smith was wrong.

JOSEPH SMITH VS. THE BIG BANG

So, in fact this was the basis—the fact that the universe begin 13.7 billion years ago and 13.8 billion years ago there was nothing—was the basis for criticism of the church that was in an article in a recent book called the New Mormon Challenge. The article was called "Craftsman or Creator? An Examination of the Mormon Doctrine of Creation and a Defense of Creatio ex nihilo." And I—I'd like to quote and read to you one of my favorite quotes from this. "The big bang represents the origin of all matter and energy even of physical space and time themselves"—and that's right. "As we have seen, therefore, it is irreconcilable with the theory to hold that matter-energy are eternal or that God is the physical product of a beginningless progression. Thus, big bang cosmogony is a veritable dagger at the throat of Mormon theology." I know. I just like that dagger-at-the-throat quote. So, what's the response to this and what's the problem? In the first place, you'll notice that the date of the quote is 2002. Unfortunately for these guys, when they wrote this, it was already at least 20 years out of date. Because, in fact, everyone has known for about 20 years that there are big problems with standard big bang cosmology, and I want to talk about that for a minute.

COSMIC EVOLUTION

To do that we have to look a little bit more at cosmic evolution. If we have a universe that's empty, the equations of general relativity tell us that it will expand at a constant rate.

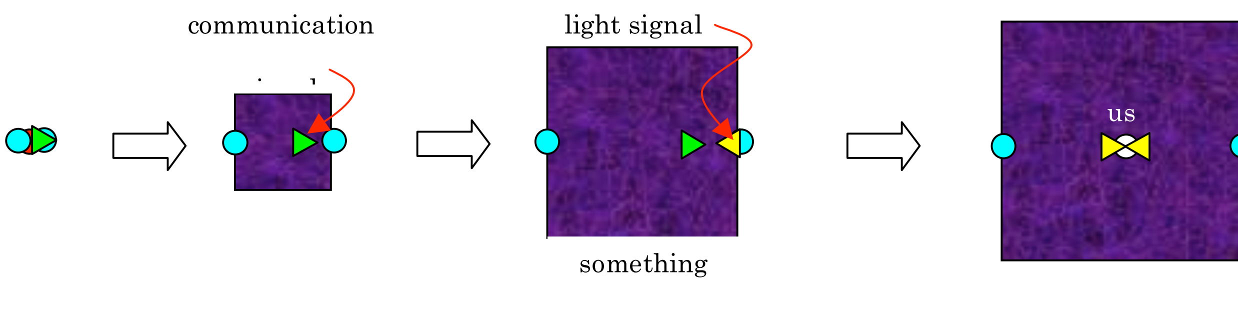
That's my best job animating that.

How about a non-empty universe? Well it turns out—and this is absolutely true—a universe filled with matter will always slow its expansion due to the self-gravity of the matter it contains. So if you have any matter in the universe, this will always happen. In fact, there is a critical density, which is currently about 10^{-26} kilograms per cubic meter, and if you have a universe with energy density less than or equal to the critical density, the universe will expand forever, always slowing but never coming to a stop. And so it would look like this big burst, to begin with, and then go slower and slower as time goes by.

However, if the universe has an energy density greater than that critical density, it will eventually come to a stop and turn around and re-contract. So the little big bang expands and slows up and eventually stops and then re-contracts again and comes down to a big crunch. In the 50s, the big question was, which is it? Will the universe expand forever or will it eventually come to a stop and re-contract? And, as that question was being investigated, this was the timeframe when it began to be clear that there were problems with the big bang.

THE HORIZON PROBLEM

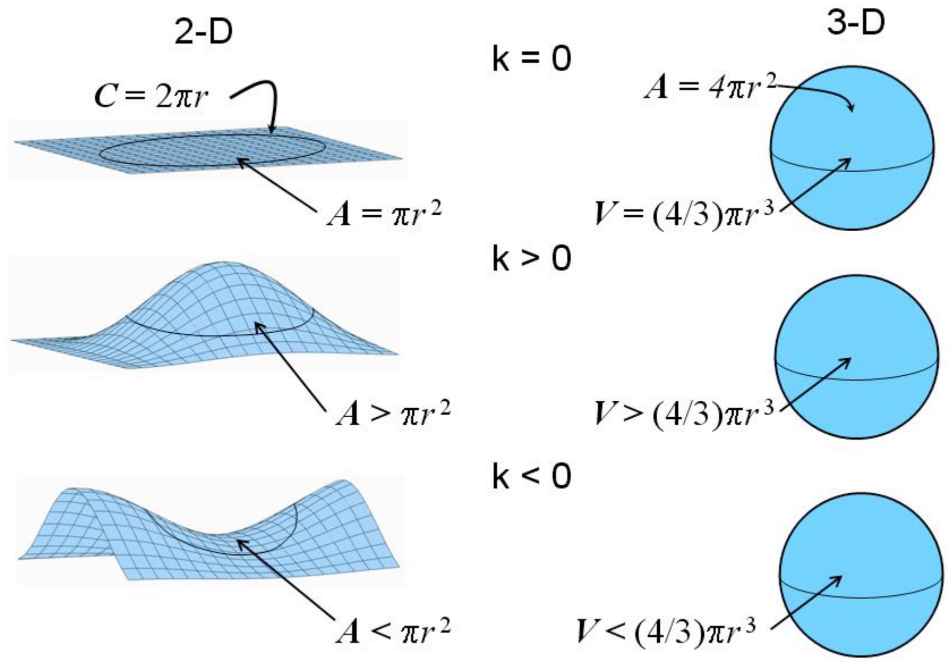
So let me talk about the problems. The first of these is called the horizon problem. I'd like you take through the big bang again, there is the big bang and I'd like you to concentrate—can you see those at all? What you see are two sides of the big bang—two little blue pieces of the universe coming out of the big bang together. At first, everything expands quickly and then slows up and these two little pieces end up far away from each other. I want you to watch that again, only this time one of the pieces, the one on the left is going to try to send a little signal to communicate with the other one. Did that show up? Yeah. It's hard to see, but there is a little green communication arrow. There it is. The reason it's falling behind is that this signal is only going at the speed of light, at its fastest, while this galaxy is moving faster than the speed of light relative to the point where it started and it's going double the speed of light away from what's over here on the left.



So the point is that if, at this point in time during the expansion, something important happened—like maybe recombination of ions to form neutral atoms so that signals can now stream through the universe (this is the basis for the blackbody radiation)—then this little piece of the universe at this point could send a light signal back along the way it came showing what it looked like. That signal would eventually reach us, and we would see then from that direction what the universe looked like at the time when this recombination occurred. And of course I'll remind you that, at that time, this little green communication signal had not yet caught up to the piece of the universe on the right. So this piece of the universe and that piece of the universe had never been in contact with each other. Now of course during the time that this signal was coming to us from the right, there is another signal that's coming to us from the left. And so, at this point in time, if we were to look to the left and to the right, we would be looking at two regions of the universe that have never been in communication with each other. And yet, when we look at those, we find out that they are at exactly the same temperature to five decimal places. This is the basis for what's called the horizon problem. It's a big problem. There is no way—I mean the big bang was this big random chaotic thing. It doesn't produce a uniform temperature, and, unless these two pieces of the universe can communicate with each other enough to exchange energy and come to equilibrium, they can never end up at a single temperature. And yet this is what we see.

THE FLATNESS PROBLEM

The other problem is the flatness problem. This is going to be a disaster. Oh well. In order to understand this, I have to tell you a little about curved space. Nobody can picture curved three-dimensional space. Everyone sort of pictures an analogy in two dimensions. So, we'll get the analogy from two dimensions and then we'll try to learn something from that and learn what we can about three dimensions.



A two dimensional space with zero curvature. That would be a flat space that would look like this—just a little piece of a plane. If I draw a circle on it, and then define the radius of the circle by measuring around the circumference, I would find if I then measure the area of that circle, the area would be equal to πr^2. That's what happens in a flat space. In three dimensions, instead of drawing a circle, I draw a sphere that encloses a region of space and define the radius of the sphere, r, from the total surface area of this sphere. Then I would find that in a flat space the total volume, the number of cubic inches inside, is the famous high school formula $(4/3)\pi r^3$. All right? So that's in a flat space, a space with zero curvature. What happens if I go to a positively curved space? Well, in two dimensions, a positively curved space would look like this. If I draw a circle on it and define the radius from the circumference the same way I did before, then, as you can see, the actual number of square inches inside that circle is greater than πr^2. And that's right. In three dimensions, if I drew a sphere and if space was positively curved, I would calculate—I could measure the volume inside and I would find that the volume is greater than $(4/3)\pi r^3$. There are more cubic inches inside that sphere than there ought to be. A negative curvature in two dimensions would look like this, just a little piece of a saddle. If I draw a circle on that, I would find that the area inside there is less than πr^2. And similarly, in three dimensions, if our space is negatively curved, the volume inside of the sphere of a given surface area is less than $(4/3)\pi r^3$. There are fewer cubic inches inside there than there ought to be.

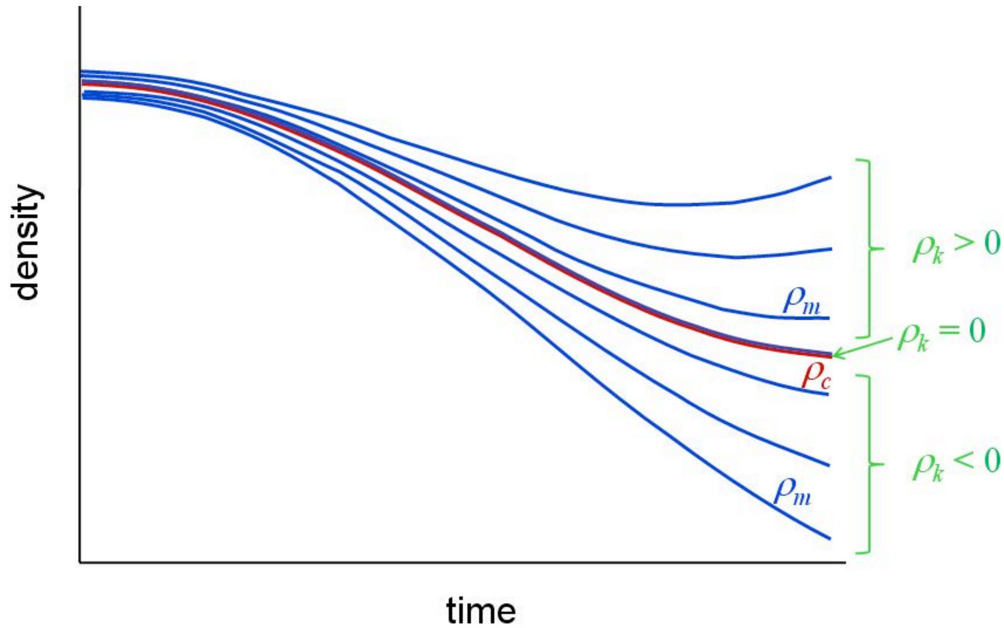
So, if you're still okay with that, let's go on. And the question is, we live in a three dimensional universe, and is the universe flat, positively curved or negatively curved? Which is it? Well, Einstein's equations tell us. They tell us how the curvature is determined by the density of matter in the universe. The equation goes like this.

$$\rho_m(a) - \rho_c(a) = \rho_k(a)$$

The first term is the matter-energy density. That's all the stuff that fills the universe that we know. We make it a function—it's really a function of time, but we'll use instead the universal scale size, a. So as universe expands, this will change. This $\rho_c(a)$ is the critical energy density. It is a function of a as well. This is the quantity whose current value is 10^{-26} kilograms per cubic meter. This last term is called the curvature energy density. It is zero if the universe is flat, positive if it's positive, negative if it's negative. There is a formula for $\rho_k(a)$ as a function of the size of the universe, and it looks like this.

$$\rho_k = A\frac{k}{\alpha^2} \ .$$

The quantity k can either be plus one, zero, or minus one. The constant A is a bunch of constants we don't care about. But the key here is α. This α is the speed at which the universe is expanding. It's in the denominator. I see the eyes glazing over out there. I'll try to get you back here in a second. What this means is that, if the universe is slowing due to self



gravity, then alpha is getting smaller. And if I divide by a smaller number, then the result is getting bigger. So a universe that is slowing due to its own self gravity will increase its curvature, $\rho_k(a)$. If it's positive it will get bigger positive, if it's negative it will get bigger negative. The only way it will stay zero is if it's exactly zero. So, let's look at the evolution of the density of the universe. If the critical density were to evolve as a function of time like this, and if I take the case where the curvature is exactly zero, then the zero curvature could only happen if the matter density is exactly the same as the critical density. If the matter density is anything else, I get things like this, where, no matter how it starts—it could have a very small curvature to begin with—that formula I showed you means that the curvature is going to grow. It's going to be a very large positive or very large negative. And here is the problem. When we look now, the universe is pretty nearly flat, which means a long time ago it must have been very, very flat. Let's see how much. Today the difference between matter density and the critical density that determines the curvature is about 20 percent. That's really conservative. It's probably much less than that when we have the real values. At the time of recombination—that three-degree pictured I showed you—those two numbers would have had to be the same to within 1/1000 of one percent. And at the time of the big bang, that combination would have to be point zero-zero-zero ... 50 more zeros... and then a few more zeros and a one. Remember, the big bang is this random chaotic thing. You are not going to get a number that is exactly zero to that accuracy. And so this is a big problem.

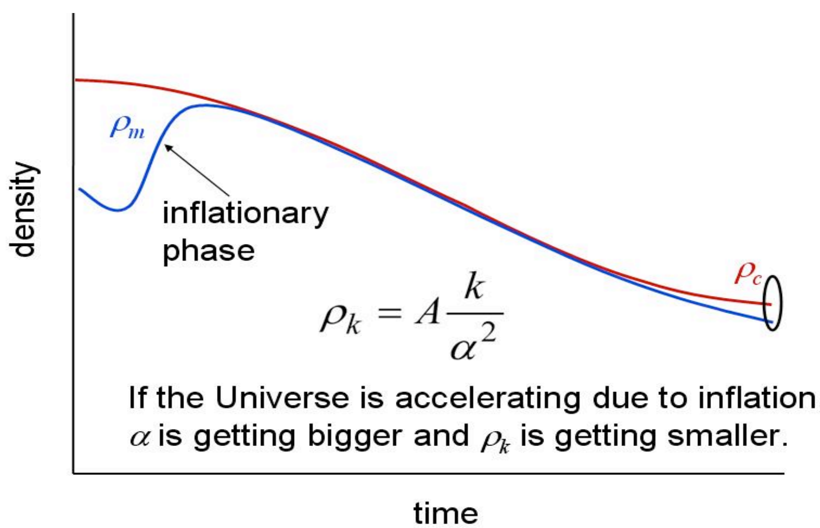
INFLATION

The solution to this is inflation, inflationary cosmology. The solution to the horizon problem comes this way. The universe starts out expanding very slowly, and then inflation starts and it suddenly takes off. And then, of course, after it takes off, it slows up a little bit to do its self-gravity. So let's watch again, during the time it's inflating slowly, there's plenty of time for the universe to communicate with everything inside it, so that when it does take off, everything is in equilibrium. And so, when we go to the horizon problem, and we look in these two directions, we see two regions of space that were long in communication with each other. So there's no surprise that they have come to the same temperature to five decimal places. The horizon problem is solved by inflation.

So let's look at the flatness problem. I remind you of the formula that determines the curvature.

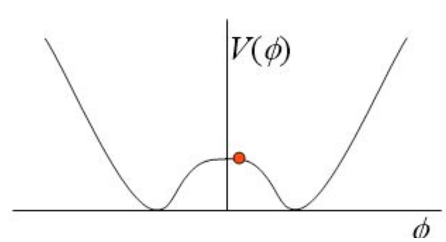
$$\rho_k = A\frac{k}{\alpha^2}.$$

So if, during inflation, the universe is accelerating, then α is actually getting bigger and $\rho_k(\alpha)$ is getting smaller. Whatever the initial matter density is, it's driven close to the critical density to high accuracy. So it's no surprise that the curvature is so nearly zero now. It starts far from zero, is driven very close to zero, and then, after a little while, it diverges little bit from that. The flatness problem is solved.



So, here is one of my favorite questions. So what? Haven't we just replaced a simple big bang with a more complicated one? Isn't there still a single creation from something out of nothing? You will be interested to find out that the answer is no. That's not all we've done.

THE INFLATON FIELD

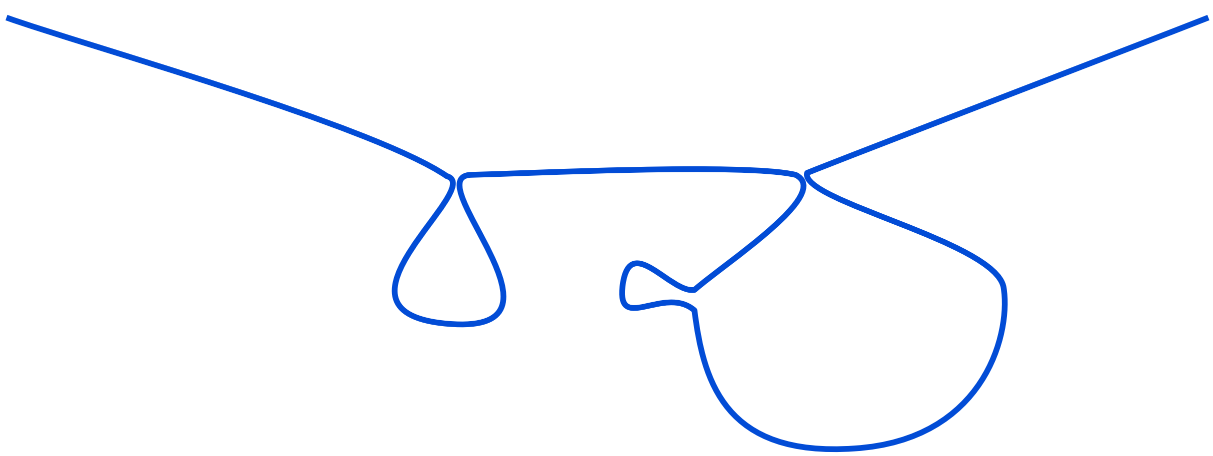


Here is the reason: because inflation has to have a mechanism. A typical one is to postulate the existence of a scalar field called the inflaton that has a particular potential energy at the creation of the universe. At the beginning, it starts off in this false vacuum state, near $\phi = 0$, and then, as time goes on, it slowly rolls down and ends up here. During the time it's slowly rolling, it produces inflation. Quantum mechanics can also make it fluctuate a little bit. But the point is that this thing has to exist for inflation to take place, and so that mechanism still has to be available in the universe today.

Eternal inflation

And so one is led to the idea that, even in our universe, there are still regions of false vacuum or still places for a quantum fluctuation to create new inflation. This leads to the idea of eternal inflation. This is a big deal, and a lot of cosmologists believe this. So let me show you what it means. Suppose we have no inflaton and the universe is expanding, inflating. It just looks like this.

That's pretty easy. Now we'll add the inflaton field, and we'll say, okay, we start here, and then a little inflation can take place, and, as time goes on, that daughter universe can get bigger and bigger. And then over here another one starts up. And then here is one starting in the daughter. So what we have done with this mechanism in place is we've find that the universe, with an inflaton, will eventually become the multiverse. This is a separate universe, this is a separate daughter universe, this is a granddaughter universe. There are, in fact, an infinite number of these that are allowed and can be created.



So the inflationary cosmology would say that matter-energy is conserved, everything is matter-energy, and the multiverse can be infinite and eternal.

My time is nearly up and I have one other thing I wanted to talk about. Are you—okay, by acclamation, I'm sorry Scott. Thanks guys, I appreciate that. Okay.

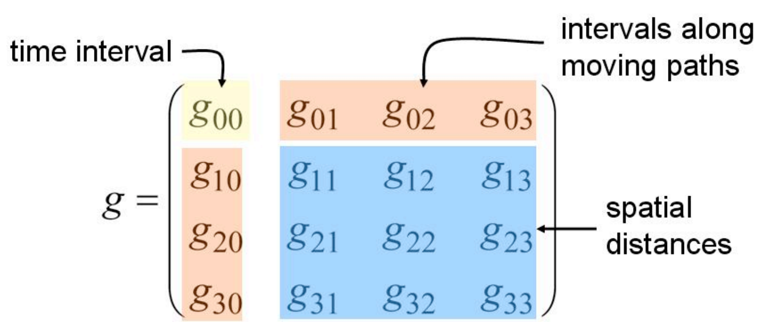
PROBLEMS WITH A COSMIC SPEED LIMIT

There are three little problems with this picture that I've given you. One of them is that, in 1993, Bordé and Vilenkin proved that the multiverse has to have a past singularity along timelike geodesics—that is, for paths that are slower than light. The result of this is, according to this proof, that the multiverse can be future-infinite but it cannot be past-infinite. So Joseph Smith looks like he is still in trouble there. But there is another sort of related problem, if we want to put God into this picture. And that is, since most of this little bubble universe is expanding faster than light, how does God get into his new universe and how can he travel around inside of it, because nothing can travel faster than light? And, finally… Actually, this sort of bothered me when I was younger. Since nothing, no signal, no information can ever travel faster than light, how does God answer my prayers? All of these problems arise if there is an absolute speed limit—the speed of light—on all signals and travel.

Well, you will be happy to know that, contrary to popular opinion even among physicists, things can travel faster than light. And I'm going to explain to you why that is. And then you'll *want* me to quit.

HYPERLIGHT TRAVEL IN TWO-TENSOR THEORIES

The idea is that the way normal physics goes is that we take some coordinate system, we locate the cosmic distribution of matter in this coordinate system, and then we let Einstein's field equations determine the values of the 16 elements of the metric tensor. These are the 16 guys. They determine distances and times between events whose coordinates we know.



If I have space-time coordinates of two events, I can use this to tell distances and times. This little part gives the time interval, this little block tells me how to calculate spatial differences for things that are rest, and these other two little blocks tell me how to calculate intervals along moving paths. Now it is the nature of the way we define a coordinate system that I can always find one system that's moving at the correct speed to make the metric end up looking like this.

$$
g = \begin{pmatrix} g_{00} & 0 & 0 & 0 \\ 0 & g_{11} & g_{12} & g_{13} \\ 0 & g_{21} & g_{22} & g_{23} \\ 0 & g_{31} & g_{32} & g_{33} \end{pmatrix}
$$

So this is the simplest I can get things. But if I orient and scale my space and time axes just right, I can always adjust them so that the metric tensor looks like what is called Minkowski tensor,

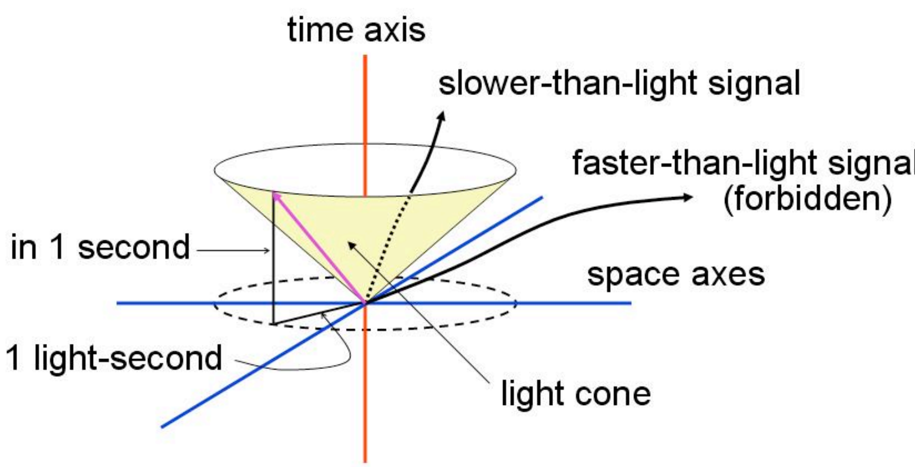
$$
g = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}
$$

The one up here means that I am measuring time in seconds, and the fact that I have minus ones down here says that I'm measuring distance in light seconds. By the way, this tensor does not change form if I now go to a coordinate system moving at constant velocity relative to this one.

So let's create a space-time diagram where, in order to see the time, I only have two dimensions in space. I have an x and a y axis in space, and this vertical axis becomes the time axis. Let's look at the signal that starts here at $t = 0$, at the origin of the axes, and moves away from there along some path, so that it covers one light second of space in one second of time. Let's see. One light second per second—that would be light. So this, in fact, is just one light signal of all possible light signals that exist on the light cone. Anything moving slower than light will have a world line that moves inside the light cone and any world line outside that would represent something moving faster than light. It's the nature of physics with the Minkowski metric that this is forbidden. It cannot happen. You cannot have normal matter that moves faster than light.

THE SPIRIT METRIC TENSOR

But, let's suppose that there is a second tensor in our theory. This could be just another tensor that couples, say, to the gravitational energy of the universe. But one thing I like is maybe it's one whose elements are determined by other field equations and are tied, not to matter, but to spirit. Maybe this is a spirit tensor, determined by where the spirit of the



universe is. Anyway it would look like this. It would have to be a different tensor.

$$h = \begin{pmatrix} h_{00} & h_{01} & h_{02} & h_{03} \\ h_{10} & h_{11} & h_{12} & h_{13} \\ h_{20} & h_{21} & h_{22} & h_{23} \\ h_{30} & h_{31} & h_{32} & h_{33} \end{pmatrix}$$

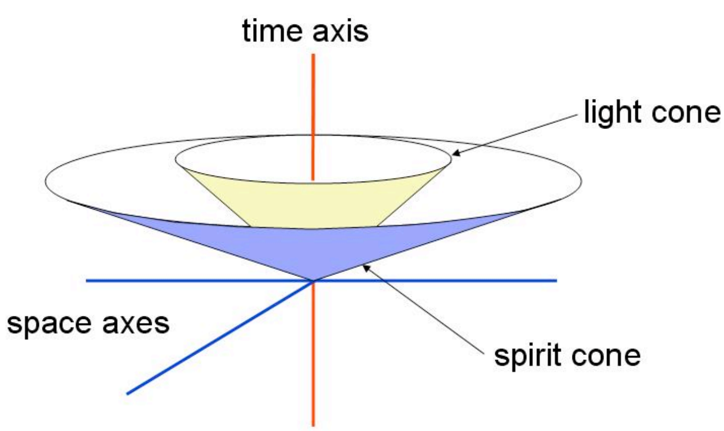
Now I can always find a coordinate system, moving at one particular velocity, that will simplify the spirit metric without changing the Minkowski metric. The new metric will then look like this,

$$h = \begin{pmatrix} h_{00} & 0 & 0 & 0 \\ 0 & h_{11} & h_{12} & h_{13} \\ 0 & h_{21} & h_{22} & h_{23} \\ 0 & h_{31} & h_{32} & h_{33} \end{pmatrix}$$

That's the best I can do with the freedom to change coordinates. But, if it also happens that the spirit matter is distributed uniformly relative to normal matter, then, by symmetry arguments, I know that the spirit tensor will take this form,

$$h = \begin{pmatrix} a^2 & 0 & 0 & 0 \\ 0 & -b^2 & 0 & 0 \\ 0 & 0 & -b^2 & 0 \\ 0 & 0 & 0 & -b^2 \end{pmatrix}$$

where a and b are still determined by some kind of spiritual field equations and by the spirit density in the universe. In the case where a is greater than b—and that's determined by equations that I don't know—then the counterparts of the light cones would be cones, spirit cones, with a speed that is greater than the speed of light. And so we would have a situation like this, where the signal will travel along the wider spirit cone. All normal matter has to stay inside the light cone, but spirit, because it has a different tensor, could travel much faster than that. And so, the spirit has no speed limit. That's reassuring, isn't it?



So let me end with my last two points, and we're done. These are the takeaway points. I'd like to take you back to your quiz question and we'll just go through the answer real quickly. Okay? The first point is to remember that scientists can misinterpret what they see and that Mormons can misinterpret what they read. The second point was the first one that I started with. This is no time for anyone to criticize anyone else's beliefs based on what *cosmologists* know. Thanks.

(applause)

Scott, if you want me to not answer questions I'll sit down. Okay.

Q: "If Kolob is outside our solar system and God lives…" Well, I'm sorry. You wrote this before that last section, didn't you? "—and God lives there, how does God hear and answer our prayers in less than a day?"

A: I answered that, didn't I?

Q: "Why does the universe seem to be expanding in every direction from us? Do we just happen to be at the center or does it have something to do with the fact that we are doing the looking?"

A: If I didn't, if I had more than five minutes, I actually have a nifty little slide here that shows that. But it is due to the fact that if you pictured –. Let's assume I'm on one side of the universe and I see the universe out there. Something a long ways away is moving fast, something that's close to me is moving slower, and everything is proportional. I would see, from me right here, that everything is moving away. But if I went over and stood there, I would find also that the universe is moving exactly away from me. So this case of proportional expansion means that every point in the universe is expanding away from every other point.

Q: "What about the possible unreliable accounts of Joseph Smith's discussions about moon-men and sun-men?"

A: I don't know.

Q: "Do you see any correspondence between information theory increasing entropy and the Mormon idea of intelligence?"

A: I'm afraid I can't think that one over in five minutes well enough to be able to answer it. I don't see anything offhand, but I'd like to talk to whoever asked that question.

Q: "Quantum theory states that a positive-negative particle pair—a matter, anti-matter pair—can pop into existence out of the vacuum and then disappear again unless the pair appears near the event horizon of a black hole. Doesn't this contradict the idea that matter is eternal?"

A: These things do not create any net energy that lasts for any amount of time, and the fact that a black hole is present just means that the energy that goes into the black hole goes somewhere else and the energy that comes into our universe stays in the universe. But that doesn't change the fact that, in the multiverse, we are still not creating something out of nothing. Now it is true in most cosmological scenarios, especially the ones with a flat universe, that the matter of the new universe is created from negative gravitational self-energy. So, once again, matter-energy is conserved but matter can be created out of what's already there.

Q: "If everything is matter, what of the idea of perfect justice or perfect triangles or mathematic equations? These are clearly not material, what are they?"

A: They don't exist. If you died they would go away.

Q: "What are your thoughts on the validity of the big bang theory?"

A: I think we answered that.

Q: "What about string theory?"

A: I had one slide that you should be glad I didn't show you. One of the other things that I just love is, instead of inflation, Turok and Steinhardt put together this idea of the Ekpyrotic Universe in which the universe is really a ten-dimensional space. Six of the dimensions are curled up in a tight six-dimensional ball, and their only effect is to give us the Yang-Mills fields and the coupling constants. The other four dimensions are divided into a space of three dimensions—a three-dimensional membrane which is the universe we live in—and a fourth dimension. There are other membranes in the large four-dimensional space and a universe is created when one of those membranes slams into the other and suddenly fills it with matter and energy, after which it has all the earmarks of what we see in the universe today. This is a cute theory. And, by the way, it's eternal, energy is conserved, and it's infinite.

Q: "What's your opinion on the plasma hypothesis of the origin of the universe?"

A: I think my time's up and—and I'd like to talk to whoever asked that question as well. I'm not sure I know what you mean. Thank you very much.