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Welcome by Dean Joaquin Ruiz, UA College of Science

Welcome all of you. My name is Joaquin Ruiz. I'm the Dean of the College of Science and I thank you all for coming tonight. We started this lecture series 5 years ago, more or less, with a lecture on evolution. It was a time when Kansas and parts of the country were debating whether we should be teaching intelligent design. We decided in the College of Science that it was important not only to teach our own students but to try to teach our community what we knew about science and it was a great time. We started with very few people and today were turning people away. Thank you so much for coming

Last year's lecture series dealt with the magic of our brain and how we think and how we perceive are our universe. And I think it's fitting that this year we continue with how we perceive our universe, in a very different way. Today where the talk about cosmology, how our universe was created, the origin of matter, the evolution of time, the evolution of dark matter, the evolution of mass. Really it comes down to the nitty-gritty of what we're all about.

Today I am pleased to, first and foremost, thank all of those that make this possible. The lecture series is not a cheap endeavor and people in our community have really come up and supported us. The Arizona Daily Star, Cox Communications, Bob Davis and Innovation Park, Galileo Circle, which are friends of the College of Science, Godat Design, Raytheon, Research Corporation for Science Advancement, UniSource Energy, and Ventana Medical have paid for this. I thank you all.

Last year we asked all you what would be an exciting lecture series for this year and many of you did respond by e-mail of your interests and I guess we got it right. And the interest was cosmology and today I'm as close to God as I've ever been with Guy who's come and giving a lecture about cosmology.

Let me tell you little bit about Brother Guy Consolmagno. He is actually an alumni of the University of Arizona. He was the fourth student that came out of the Planetary Sciences department which we're so proud of, right? Which came out of the Sputnik era. So Guy is the fourth and obviously one of the most extraordinary as students that we've had. He's been in the Vatican Observatory since 1993, his research explores connections between meteorites, asteroids, and the evolution of small solar system bodies. With the Vatican's 1.8 meter advanced technology telescope, he surveys the broadband colors and light curves of Kuiper Belt objects using these data to develop an understanding of the composition and internal structures. Guy is truly an amazing individual. He earned his undergraduate and master's

degree at MIT. He came to the UofA, to a much better place, to study planetary sciences. He arrived the year that the department was actually open. As I said before he was a fourth graduate student out of the place. He's been a researcher at Harvard and MIT, served in the Peace Corps in Kenya and taught physics at Lafayette College in Pennsylvania before deciding that the whole thing was a mess and he entered the Jesuit Order in 1989.

I don't know how many of saw Guy, but he was actually on the Colbert Report and he's the only person ever on the Colbert Report who had Colbert speechless. That a feat in itself. He's a multifaceted scientist. I want to ask you to welcome him as our first speaker in this extraordinary series.

Brother Guy

Thank you very much. Thank you. It's fantastic to be back here. I think the only other time I've been in Centennial Hall was to hear the Preservation Hall Jazz Band in 1977 and I understand that coming back and I wonder if it's the same guys.

Tonight, as you probably know, is the first of six lectures on cosmology and you've got a wonderful group of experts coming in and talking about everything from the Big Bang, to dark energy, to the origin of life. By contrast my expertise is not cosmology it's actually the study of meteorites - this is about the only time I get to mention meteoroids tonight. My role is a little bit different from the other speakers. I am here to give you an introduction to the topic of cosmology itself as someone who is an outsider, albeit a close outsider. Most of the speakers here have been close friends of mine for years - Michael Turner actually was the one who taught me general relativity back at the University Chicago 20 years ago. And so what I want to do, I want to show you with some historical examples, with a few stories, what cosmology is and why it's interesting. In fact, why it matters. Now having gotten that reaction I probably shouldn't mention one connection that the Jesuits have with cosmology. We're both worried about missing mass.

But since I'm standing up here in a clerical collar I do want to start with tonight's lecture with some readings from St. Paul. The first, Paul's letter to Timothy has in it there is one God there is also one mediator between God and humankind, *Jesus Christ himself human who gave himself as a ransom for this and was tested to at the right time* and then in Paul's letter to the Ephesians we read *God put this power to work in Christ when he raised him from the dead and seated him at his right hand in the heavenly places far above all rule and authority and power and dominion above every name that is named not only in this age but in the age to come* and goes on to say *You were dead through the trespasses and sins in which he once lived following the course of this world following the ruler of the power of the air now at work among those who*

are disobedient. In his letter to the Colossians, Paul says of Jesus that *He is the image of the unseen God, the firstborn of all creation in him were created all things in heaven on earth everything visible everything invisible thrones, ruling forces, sovereignties, powers. all things were created through him and for him.*

Now, one of the remarkable things about the letters of St. Paul, especially if you ever hear them in church on Sunday, is how utterly forgettable they are. You see these words whooshing past you and you think that sounds all oriental and you say What was he talking about? If you're lucky you might catch a couple of keywords that only caught your attention because you have no idea what he was talking about. A mediator? What's this Jesus as mediator? You pray to God, god prays back or doesn't. The heavenly places... what heavenly places? Far above rule and authority and power and dominion throne's ruling forces sovereignty ... What the heck is he talking about?

What he's talking about is cosmology. Paul was assuming that his readers and he were sharing a common cosmology that use these terms and knew with these terms were all about. Now most of us are familiar with the classical view of the universe, with the Earth at the center and all the planets going around the sun with the earth. When you hear it described what you're probably thinking of the earth at the center, that blue ball, and the moon with its craters whizzing by and Saturn with its rings whizzing by and Jupiter with its moons whizzing by. No, that's not what this picture is talking about. Cosmology is more than just how the pieces are assembled. It's about the very nature of the pieces themselves.

Cosmology comes from the Greek word that means words about the universe. It's a term coined by the 17th century German philosopher Christian Wolff. And he wanted to describe a kind of metaphysics that talked about the totality of everything that existed or the nature of the universe based on logic and reason. That's the 17th century they are big and logic and reason in those days. More generally it's a word we can use to refer to the world picture of a culture of school of thought until in that sense a cosmology is the sum of all the assumptions you make about how the universe works. Some of those are assumptions that you've set them if they guess I'm going to assume it is. And some of those are assumptions that you didn't even know you were making because there's so built into the culture, so built into the way you were raised, so built into the language that you use, that you don't even appreciate how those assumptions have colored, but not only because you come up with but the questions you decide to ask.

In the early 20th century, after the advent of quantum physics in Einstein's theory of relativity, the word cosmology was taken over by the astronomers and so nowadays it

represents the scientific description of the origin and nature of the physical universe. But a cosmology can be outlined in a way that doesn't rely necessarily on physics or astronomy and these non-physics cosmologies have played important roles in the development of human thought, in the way we understand ourselves, and there's this constant feedback between the assumptions we make about what the universe is about **and** the science we decide to do, the literature we decide to write, the art we decide to make.

Ancient cosmologies started with the observation that the world was flat - go outside you can see the world was flat - there is a dome - go out and you can see the dome. Obviously there must be things above the dome where you're hiding the hail and the snow and the rain that leaks through the holes because that's what comes from. Underneath the ground is fire and brimstone - you don't believe me I can show you a volcano, the fire and brimstone is there, anybody can see it. And they're waters underneath the earth because that's where the water goes after it's stopped raining. There are a lot of different cultures that come up with a similar picture and in many cases they've even develop the pictures so that each of those things that you see crossing across the sky wandering through are themselves their own skies, there are different levels of sky there was one sky for the moon is another sky for each of the planets, there's another sky for the sun.

I remember I was giving a talk on meteorites through group of Native Americans in northern Wisconsin and I was trying to describe what is a meteorite. Well a meteorite is a rock that falls from the sky and an older woman reaches her hand and says "Pardon me. Which sky?" And I'm thinking, wow, that's a question that Aristotle or Thomas Aquinas might've asked because it's out of that cosmology. In a sense it's like saying which planet does it come from. But actually it is different because it's not thinking of planets as places the way that we used to thinking of them. They're thinking of them as realms of sky.

Now determining the shape of the universe from observation and reason began with the Greeks - Parmenides, Pythagoras, Plato - all of them understood by 5th century BC that the world was round, that the planets the moon and the sun were other bodies traveling somewhere between the Earth and the stars. In one of his dialogues, **Timaeus**, Plato discusses whether or not the universe was always in existence or whether it had a starting point. He argues that all things are in the process of continually being created and that's in opposition to what Parmenides said. He said that all matter was eternal. But the point is that they were already arguing these points 500 years BC. The Pythagorean mathematician Udoctrus(?) explained the motions of the planets, which are not simply going past the start and sometimes wander back

and sometimes go forward. He described them in terms of a series of concentric spheres that were crystalized that would rotate on axes that themselves would rotate so it was a very complicated set of nested spheres. But out of this he could explain what anyone with eyes could see. Aristotle of course took this and adapted it to his physical universe and he had the notion that things in the universe the material that you and I are familiar with made of 4 elements: earth, water, air, and fire. And one of the natures of these objects was that they would try to travel to their natural place so that earth, the brown stuff, is at the center, water is outside of the brown stuff, air is outside of the water fire is outside of - because that's why fire element in the flame is always going upwards - so that if you were to travel from the Earth to the sphere of the moon you would wind up traveling through a ring of fire.

Now since there's only one natural resting place for earth, obviously by necessity the only one earth. And by necessity there is therefore only one universe. About 400 years after Aristotle the Roman era astronomer Ptolemy used the observations of the Babylonians and the Greeks to flesh out this geocentric cosmology. With mathematical rigor he was able to work out the idea of these little epicycles (I'm told there's a laser pointer here) so that you have Mercury traveling around the Earth but Mercury itself is also traveling in little circles in order to explain why when you observe Mercury - sometimes it goes back - and likewise all of the planets traveling around circles which are not exactly centered on the Earth because these circles have to be a little bit off-center in order to actually match the observed motions of the planets.

But the thing was, it worked. It worked to within the limits of their observations and mathematically. He was able to demonstrate the accuracy of this geocentric cosmology. You've got a theory, you've got observations, the observations match the theory, hey, that's good science. It must be true. That's the assumption that scientists worked on all along. And so this is accepted for another thousand years. Now the Ptolemaic system is a long cry from that biblical version of a flat earth with a dome with water above and below. St. Augustine knew that. Writing well after Ptolemy had been established he wrote a book called **On the Literal Interpretation of Genesis**. And he warned his fellow Christians, he said even a non-Christian knows something about the earth the heavens and the other elements of the world about the motion in the orbits of the stars even about their sizes in relative positions because Ptolemy was able to work out that the stars were very far away, the planets very far away. Using the geometry available to him even with naked eye observations and this was well-known throughout the world, throughout the educated world. This knowledge an educated person holds, as Augustine goes on, as being sort from reason and from experience and he concludes it is a disgraceful

and dangerous thing when an infidel, here's a Christian presumably giving the meaning of holy Scripture talking nonsense about these things.

It's clear that, you know he had as literalists, but it's also clear that the educated Christians understood that's not how you interpret Scripture. Of course one of the ironies is that the sure knowledge of science he is talking about is the Ptolemaic system that we now know is nonsense. And so rather than this conflict within the Ptolemaic system in the biblical system leading to some kind of Galileo trial in the early Middle Ages what really happened was that most theologians at that time and through the Middle Ages saw in this Ptolemaic cosmology a reflection of the non-physical universe even if you assume a spherical earth you still have this idea that the physical universe is a mirror of the metaphysical universe. And if you have that picture of the earth at the center and the planets going around the earth that doesn't mean the earth is the most important part. No, the Earth is not at the center. It is at the bottom of the chain of creation. The only thing lower is the inferno of fire and brimstone i was talking about. And it's only after you get past the *lunarian* sphere that you finally get to the realm where things move eternally in perfect circular motion. So it was not self-centeredness that said the earth was the center of the universe it was a kind of degradation that said the earth is the bottom of the universe and, in fact there are those writing in the Middle Ages, who make the point that we human beings are seeing the entire universe inside out. The way that really works you see is that there is God we see at the outside. Because of a love of God the stars move, literally move by love, to try to imitate the perfection of God by spinning at a constant rate. And their spin in turn influences the inner spheres to spin and so this influence travels down from sphere to sphere to sphere until you get to the translunarian. But of course these influences continue on to be the astrology that influences our lives on earth. That was the chain they saw but that chain is obviously diverted from reality because God is the center and we are the ones that are on the outside, so far out that we're barely noticeable. That was the medieval cosmology.

A great source for this kind of information, if you want to look up further, is a wonderful book by C.S. Lewis called **The Discarded Image**. Everybody knows that C. S. Lewis was the guy who wrote the **Narnia** books. You forget he had a day job at his day job was being a professor of Renaissance and medieval literature at Oxford. And he wrote this based on a series of lectures he gave so that his students would be able to understand medieval literature which itself assumed this cosmology. You can't read Dante without reading this stuff. You can't read Chaucer without understanding the cosmology that Chaucer thought described the universe. And so , to quote from **The Discarded Image** "the spheres are moved by the love of God in

each sphere or something resident in the sphere is a conscious and intellectual being moved by intellectual love of God the planetary intelligences make a very small part of the angelic population which inhabits the ethereal regions especially the region between the moon in the Prima Mobilia so that from the earth and the moon on out to where you find God those regions are called thrones, dominations, etc.” Remember we heard those terms. “Below the moon is the realm of aerial beings which are known as demons and some sources the demons can be good or bad other sources divide good demons into the upper air and the bad demons in the lower air. By the time the Middle Ages, Lewis tells us, the view gained ground that all demons were bad. In fact they were the fallen angels and that's where DAEMON became a DEM.

And this is just the beginning of a census of all the strange and marvelous creatures that people assumed existed that we only see the faintest reflection and modern fantasies with **Lord of the Rings**. All over the different kinds of creatures you see **Lord of the Rings** were - Tolkien was a scholar reflecting this medieval view of the universe and in fact this view of the universe, this cosmology, was a beautiful system and it underlay not only the physics and astronomy of the day it provided the framework for the literature of the day, Chaucer and Dante, it provided the framework for the artwork of the day. To quote Lewis again “there are few constructions of the imagination to have combined such splendors of sobriety and coherence to the same degree.” He then goes on to write “it may be possible that some readers have long been itching to remind me that they have a serious defect it wasn't true. It sure was beautiful.

And this was the point of Paul's letters the things that I read in the first place. Brian Purfield is read on the British Jesuit website **Thinking Faith** interprets Paul's letters as a reaction against the cosmology and I'm going to quote him again: “Clearly the people in Ephesus, as well as those in nearby Colossae, already had a view about this world and their place in it. According to this worldview, the gods were ‘up there’ beyond the sky and the people were ‘down here’ on earth. Between the gods and themselves were a whole host of intermediaries. Furthermore, if you were to live a happy life ‘down here’, you had to keep all these intermediaries happy as they were in charge of some area of your earthly life.” Now, Paul had gotten word from Colossae that the people there were adopting Christianity to their culture so when the gospel preached to the Colossians says that Jesus is their mediator they say, well, we already have a mediator. We've already got these demons doing mediating, what do we need Jesus for? Or at the very least how does Jesus fit into the system? Is He like the super mediator? In other words they were trying to take the gospel and superimpose upon the already existing worldview. And Paul doesn't want them to do that.

But of course, as you can see, it's a hopeless case. It's such an all encompassing worldview that they could not conceive of life, religion, living, without assuming, of course, the schema. You expect. You don't believe in the gods? I can point them to you up in the sky moving back and forth anybody can see them for themselves.

Meanwhile back in India we have a very different cosmology and a very different take on things. Around the year 500 Aryabhata was this marvelous mathematician and astronomer. In India at that time they have not only phenomenally good mathematics but they had the benefit of having had the Greeks around a few hundred years earlier who had brought them all observational evidence of the Babylonians. So they had about 1000 years worth of observations of the planets. And Aryabhata about the year 500 has this radical idea it that maybe the reason we see the stars moving from night to night during the night is because the earth which everybody knows is round is spinning. He came up with this idea 500 years before Copernicus. And if it's the Earth spinning then it's the stars that are standing still. Then what's really interesting is how long does it take for each of the planets to move a complete circuit through the fixed stars?

So he looks through the records and these are the number that he comes up with. He says for Mercury if you wait 125 Earth years Mercury makes 519 circuits through the stars. Venus 251 Earth years gives you 408 Venus years. On Mars 205 Earth years gives your 109 planet years. So, put this in a spreadsheet due the division for yourself the calculated period for Mercury is point 240948 Earth years, Venus point 61519 Earth years Mars 1 point 88073 Earth years. These are the modern accepted periods. Pretty darn good! Now I'm only pointing these out to some 5 decimal places for the reason that is not that we don't know the period of Mars for more than five places it's because the period of Mars is only constant to within five places. It actually varies slightly in the sixth place depending on the perturbation of Jupiter that year. So that this is as good, as accurate, as you're going to get. You can't do any better than that.

But Aryabhata is a Hindu in a culture that believes that the universe repeats itself. And in a culture that has phenomenal mathematics but hasn't yet invented the decimal point. So he can't make this calculation all he can do is give you these sets of numbers. But this divided by that is a rational number and this is actually an irrational number and the difference is only in the fifth decimal place. But the difference is enough because being of a culture that expected to find a repeating universe he then takes these numbers and multiplies them together to find a common denominator which would be the amount of time it takes for the universe to repeat itself. It is a brilliant calculation and it's only off in the fifth decimal place. But you can see how is culture, his

cosmology, has led him to ask a question we would never ask, because we know the planets don't repeat themselves, they started arguing and his followers started arguing about was there a time when all the planets were exactly lined? And, oh by the way, since the position of the planet controls your astrological horoscope this is clearly scientific proof that not only does the universe repeat itself but that every human action repeats itself and runs endless cycle and endless chain. A very different cosmology using the same observations coming up with a very different set of conclusions based on the questions you expect to ask and the answers that you think you're looking for.

Now, while this is going on, (skip ahead here to my cheat sheet ... too many things in my hand ... I'm going to drop that and say who needs those pages .. get rid of that ... yes!) going to move ahead now to the Middle Ages to the year 1000. By the time of the Middle Ages the high Middle Ages most of this Greek and Roman learning had been lost to the west. But it wasn't lost to the Arabs and it wasn't lost in the Islamic world. There was a little bit of crossover. Around the year 990 ... 980 there was an enterprising young French scholar Gerbert of Aurillac who grew up near the border with Spain which was Islamic in those days. He traveled to Barcelona. He learned the secrets of the abacus and the armillaries. He's the one who introduced Arabic numerals to the west. His knowledge was so frightening that people started rumors that he was really a sorcerer I was looking for a picture of the Internet of an armillary sphere and a picture of Gerbert and this is what I came up with because, yes, he became Pope Sylvester II. He was the one who introduced Arabic numerals to the Western world and he was the one that people thought was a sorcerer because he could do mathematics. What finally happened was about 100 years later in 1085 the University in Toledo Spain was captured by Christian forces its library was then translated into Latin and finally the ancient knowledge was reintroduced to the European universities.

At that time a certain aspects to Aristotle thought that appeared to be in great conflict with Christian teaching. For instance Aristotle taught that the universe was eternal. Genesis says God created the universe - now which is it? In fact, Thomas Aquinas by the 1200s had worked out a system that meshed the two. He did it so well that within a generation people thought that Aristotle actually was a Christian. He just didn't know it. However the fact that there were conflicts between theology and the ancient wisdom inspired a number of medieval thinkers and here are two of them Maimonides and Bishop Nicholas of Cusa. To look with a critical eye at the Aristotelian thought and to try to develop new ideas and to try to expand or alter the cosmology

of Aristotle rather than simply glomming it on wholeheartedly and assuming that Christianity could be built on top of it.

It's sometimes thought that the Renaissance would have happened by around the mid-1400s if it hadn't been for the Black Death, the plague reduced the population of Europe by a third. And the population of Europe didn't recover to where it was in these years until the time of the Renaissance, that we actually know. And it is worth noting that anyone who tried to develop an alternate cosmology had to face certain serious scientific ideas. We know the Copernican system that explains why Venus has phases and such things. Tycho Brahe, the fellow to the left here, actually developed a system where the Earth is at the center, the moon goes around the Earth, as the sun goes around Europe all the other planets will round the sun and in this way he actually had all the benefits of the Copernican system without any of the disadvantages.

For example, Brahe also measured the positions of stars very carefully and was able to show no parallax no little dodging of the stars back and forth from one time of year to another time of year, thus proving the earth doesn't move. In fact, there is a marvelous thing that's just come out, a fellow named Grainy(?) who's doing the history of science. If you wanted to show whether or not there was parallax - as the earth moves shouldn't you see the relative positions of the stars shift about it? To do that you would want two stars that were really close to each other but one much closer to you than the other so that you know if you move your head back and forth- my head moves differently from the screen moves because I'm in a different position and that's how you know that actually you're moving. Well what you need is two stars of very different brightness so that obviously the brighter stars closer to you and the dimmer stars further away that are real close to each other. Galileo observed Mizar, the easiest double star, and he observed it very carefully over a period of two years looking for such a motion because rather than understanding that Mizar is a dim star orbiting a bright star he thought it was two stars that just happened to be in the same line an optical double but one further away. He was unable, obviously, to see such a motion which disapproved the Copernican system, so like a good scientist he never bothered to publish his results.

But the real story I want to talk about here is the start cosmology, not the story of Brahe but the story the fellow next him, Johannes Kepler. Kepler basically inherited Brahe's data but we also have along with this wonderfully precise description of the positions of the planets over time, which Brahe's system more or less is able to produce, he had an interesting philosophical system now let's actually look at the Ptolemaic system versus the Brahe system. Or the

Copernican and the Ptolemaic. Here you've got the earth and things are go around in little epicycles. Copernicus moves the sun to the center, and he's got everything going around the sun but still the planets have little epicycles and still each of the planets is orbiting a spot that's not exactly the center of the sun and in fact the song itself is making a little dodgy circle. And he needs to do this in order to preserve the appearances, in order to actually accurately predict where a planet can be seen on any given night. Because both of these systems assume that planets move in perfect circles.

Now Kepler had a different idea. Kepler insight is that we all know the physical universe mirrors the metaphysical universe. If you are going to put the sun at the center - the sun is the most brilliant, the sun most liberal - obviously this sun represents God. But since he's a Christian he believes in the Trinity so it is God the father. The light that comes off of the sun is the Holy Spirit pouring off of God the father and when it falls on the sphere of the Earth, the Earth is the second person of the Trinity. Now, if the sun is actually the mirror of God it can't be making this stupid little dance around nothing. God doesn't do that. Instead what must be happening is that the sun must be standing still and the planets are doing so by the kind of motion and the kind of motion that allows this cosmology to work is if you assume the planets are moving in ellipses. It was on the basis of this wacko theology, which nobody at the time but him believed. But in order to make the sun look beautiful - I'm stealing all of this from a book by Job Kozhamthadam who taught me philosophy of science. He's got a wonderful letter in this book. This is a letter from Kepler to Herwart von Hohenberg "The center is the origin in the beginning of the sphere. Indeed the origin has precedence everywhere and is by nature always the first. When we applied this consideration to the most Holy Trinity, the center refers to the image of God the Father. Hence the center of this material world-sphere should be adorned by the most ornate body, that is the Sun." Now the fact that he had this ludicrous theology meant that nobody really paid much attention to the rest of his astronomy. He would send these books to Galileo and Galileo would say of him, "That nut!" and toss them in the corner and never read them. And most of the people did that. The only person apparently who did read them was Edmund Halley who then told that the Newton about in that gave rise to Newton's attempting and succeeding in using his law of gravity to explain the elliptical orbits.

Now notice a common trait in all of the different ways of putting the universe together so far. Up to point there is an unspoken assumption, an assumption that nobody even knew they were making because it was so obvious to them. That when you're talking about astronomy you're also talking about religion. One tells you how to go to heaven the other tells you how the

heavens go, that's the famous quote that Cardinal Baronius said that in defense of Galileo at the time of Galileo, and it's a marvelous quote except that they're still referring to the same heaven. The physical and metaphysical really don't divide until you get to Isaac Newton.

The physics of Isaac Newton finally provided a viable replacement - you recognize what it is? This, according to the sign there, that's the tree planted by one of the apples that hit Isaac Newton in the head. This is actually in Cambridge. I got it off the Internet. The new physics of Isaac Newton provided a viable replacement for Aristotle systems. Finally you not only have a different way of describing where the planets were, you have a different way of explaining why the planets were where they were. And it relied on physical laws that applied exactly the same to objects in space as the apples from trees and that was the magic and remarkable breakthrough and the totally disrupting of the old way of thinking of the universe into a new way of thinking of the universe. The Earth and everything on it was no longer at the bottom of creation it had been elevated to equality with the rest of the planets. This new way of looking at the universe gave rise to an overt assumption one that is carried forth in all cosmology even today. There is no privileged place in the universe. The laws that govern the universe are the same everywhere, material is the same everywhere, and deductions about the universe derived in one place in the universe based on observations from that place also ought to be true in any other place.

This cosmological assumption is still the fundamental assumption that underlies everything you're going to hear in the next six weeks. Just as the Earth is one place among several places, the sun now becomes one star among the many stars and so speculations about other worlds which have been going on since medieval times. The medieval idea of another world was basically a parallel universe now it's simply another star with other planets going around it. Galileo's telescope had show that the Milky Way was actually a collection of individual stars and a lack of parallax of the stars shows that those stars are really far away. So the stars can't be shining by reflected sunlight. They must actually have their own light.

Then in 1755 Immanuel Kant, writing in the **Universal Natural History and Theory of the Heavens** carries this one step further and says those discs of light that we see may themselves be island universes and analogous to our own Milky Way. And this discussion, this idea, was argued vehemently over the next 200 years. This is a paper via William Herschel - where he actually, that bright star in the center there - represents the sun and this is his idea of the farthest star he can see in every direction away from the sun based on his telescope out of

which he deduces that we are in a disk of stars. Of course he still has the Earth and the Sun at the center of the disc but he has it that we're a disc.

He realizes that there are other discs that may well be other Milky Ways. As we are used to calling the appearances of the heavens were surrounded with bright zones, the Milky Way, it may not be a myth to point out some other very remarkable nebulae which cannot well be less but probably much larger than our own system. And being also extended the inhabitants of the planets that attend to the stars which compose them most likewise receive the same phenomena for which reason they may also be called Milky Ways by way of distinction. This is 1795.

That was the development of cosmology in the Newtonian era. And then Einstein comes along. In 1916 Einstein described in his general theory of relativity how space and time and matter all interrelated, how the force of gravity can be understood as a warping of space-time and that he's got a problem, because if gravity is the working of space and the universe is infinite in space and time then given the infinite amount of time the universe is around all of the universe should have worked itself in to the one point. Obviously it hasn't. What's going on? The best Einstein can come up with is to find a place in his equations we can stick a number that he's calling the cosmological constant. Okay, there's a fudge factor here that's keeping the universe separated. I hate it. It looks inelegant but there it is.

At the same time there is a Russian Freedman who has the idea that the expansion of the universe could obviate the need for this cosmological constant but it's actually this guy in the familiar collar, who also has a familiar ring because he was an MIT graduate, but he was not a Jesuit ,he hated being called a Jesuit. He was a Diocesan priest. He was from Belgium and his name was George Lemaître and he actually had two PhD's. His first PhD was from Louvian in mathematics. He was fundamentally a mathematician. But he did postdoctoral work with Eddington in Cambridge came across the equations that Einstein used to describe general relativity and being a mathematician he could read the equations of mathematics the way that an English major can read a poem and pull out information and see the implications within the math. And he says you know all expansion is in these equations. The cosmological constant is not necessarily a bad idea don't get rid of it. But expansion is built into it. You can build an entire cosmology based on the idea of an expanding universe. And this fits in fact with quantum theory which is also being developed at the same time. What the universe started at a point of incredibly high quantum number and because of the energy of this point is expanding from what

he calls a cosmic seed. This, of course, means that the universe has a starting point in time - and this guy's a priest. We know where this is going.

Fred Hoyle, who was another cosmologist of the era, made fun of this theory by referring to it as "his Big Bang Theory." Fred Hoyle was viciously anti-clerical you can picture what would happen Fred Hoyle and George Lemaître meet, they were best of friends actually, they went on vacations together, they were good buddies. They got along great because they're both interested in the same things but they came out of different systems. To Hoyle the idea of a universe that was not eternal and infinite was so contrary to the way he had been raised as a cosmologist because it says that there is not a particular place that is special a particular time that's special, then it violates the cosmological principle. Forgetting that the cosmological principle is just an assumption.

Lemaître, on the other hand, was very much at pains to say no, I'm not coming up with this as a way to try to rescue Genesis please don't say that. It's because it's in the equations you look at the equations you can see the same thing. I will test it, I will ask Edwin Hubble does he see galaxies moving apart or not and, of course, he does see galaxies moving apart. So, you know, Hoyle comes up with an alternate cosmology and you'll get all of the story in the next [six weeks].

The one interesting story is the 1951 Pope Pius XII - this is him visiting our observatory and about that time - gave an address to the Pontifical Academy of Sciences which is a group of about 100 scientists from around the world who are there to advise the church and scientific issues. They are not all Catholics, they are not all believers, Stephen Hawking is a member of the Pontifical Academy. And as addressing these people he says, isn't it interesting that modern cosmology is now talking about a beginning point. Cute. And Lemaître hears about this. He says, no, no, don't say that. You are undoing everything I've been trying to say.

In 1952, the year after the account, the IAU, the International Astronomical Union was scheduled to meet in Rome and they had invited the Pope to give some opening remarks and suddenly the rumors going around the Pope is going to endorse the Big Bang theory as Catholic doctrine Lemaître who after all invented the Big Bang theory is terrified and he goes and he gets an audience with the Pope and says, please, don't. And in fact if you actually read the Pope's earlier statements it's very clear that he understands now this is just a curiosity. I'm not actually saying this is the way it really happened because who knows what cosmology is going to look like in 1000 years. And when it came time for the Pope to address the people at the IAU all he

said was, you guys I love what you're doing, keep it up. What more can you ask a head of state to say?

The point is that even today people trying to use the Big Bang theory either as a proof of or proof against - Stephen Hawking has a book that just came out that shows that while he figured out a way that though there's gravitational interactions in a vacuum to actually lead to the spark that is the Big Bang we don't need God anymore and spontaneously occurred. This cartoon appeared as a result. The fact is, of course, that Stephen Hawking is right. That using God to explain all the things we can't whether it's a start of the universe or the motions of the planets or why trees grow, reduces God to nothing more than the God of thunder and lightning and He's just Zeus. Or at the very least one physical force alongside all the other physical forces. Going back to what St. Paul was trying to tell his followers: that's not the way to think of God. You can't tie your religion to any one cosmology. But this does have an interesting twist about the nature of our deeper beliefs, our culture, and our cosmology.

I love this wonderful phrase from Chesterton "The earth so very large, and the cosmos so very small. The cosmos is about the smallest hole that a man can hide his head in." What is he talking about here? He's talking about the Earth, the reality of our lives, the cosmos, as the ideas we have in our head about how the universe works compared to the way the universe really is. And what is fascinating is that the major religions that have been around for a long time - whether it's Christianity, Judaism, Islam, Animists, Hindus - religions that have survived a change in cosmology grow as a result. They get wiser as a result. They recognize what stuff is essential and what stuff is just cultural baggage. Sometimes the way you learn is to run into somebody you disagree with vehemently. Works in science - you get a paper in the mail and you say, "That's not right. That can't be right." Okay where did he go wrong? And in working that out you learn something that you never would've thought about before. Sometimes recognizing that the cosmology that we're in, the culture that we're in, is inadequate, is a brilliant way of growing both our own culture, our own religion, our own philosophy and our cosmologies. Because one thing I think you will find all the next speakers agreeing on is that half of what you do hear in the next five weeks is wrong. We just don't know which half yet. But that's okay. That's what makes it fun. And rather than being afraid of a new cosmology we have to look at it as an opportunity to recognize how much more wonderful and how much more beautiful this universe is.

I end with one last quote from Chesterton which I just stumbled across as I was putting the talk together and I think gives us a sense of the proper attitude that every scientist has

towards the universe. He says “The essence of all pantheism is that nature is our mother. The main point of Christianity is that nature is not our mother: Nature is our sister. Nature was a solemn mother to the worshippers of Isis and Cybele... to Wordsworth or to Emerson. But to St. Francis, Nature is a sister, and even more a younger sister: a little dancing sister to be laughed at as well as loved. And that is the attitude that we can embrace and enjoy the universe and our study of the universe.” Thanks a whole lot for coming. [applause]

Dean Ruiz invites questions

We'll have a few minutes here for question and answers. There's going to be a few folks walking around with microphones. But just in case you don't get to get the answers you want today, Brother Guy is going to be on [astronet.com](http://www.astronet.com) [note: Dean Ruiz might have meant ASTRONET <http://www.astronet-eu.org/> because *astronet dot com* is an astrology website] tomorrow at 12 noon. You can get on the computer and talk to him through the computer. I guess it's the new cosmology.

Q: So, do you see any supernatural aspect or evidence to universe and if so how would it look different absent that aspect.

Brother Guy: I think my religion informs my way of looking at the universe but it doesn't define it or control it. It rather explains why I'm interested in looking in the universe in the first place. It doesn't tell me what to do it tells me why I want to do it. The fact that I find astronomy not only rational but also fun, that I find the ability to guess that this theory is better than that theory because it's more beautiful. To me those are reflections of the nature of the Creator and that's very different from saying it must've been this way could I know God and God would have done it this way. That doesn't work because I don't know God that well. I can't get away with that.

Q: I'm just dying to know what did you tell the Indian woman who said “Which sky?”

Brother Guy: I don't remember. Probably something like “that's a wonderful question.” I don't know how to answer it. And if you asked it today I don't know how to answer it.

Q: A fascinating lecture. What I gather from this is that you view all cosmologies as transient.

Brother Guy: All of science is transient in the fact that you know in a thousand years from now all the science books are going to look very different from what they are now. But where we are now is a necessary place to be to get to where we are going to be in a thousand years.

Q: Good segue. I wanted to ask you a question. How will we recognize, those of us in the public, when a new cosmology is arising? And how will we test it?

Brother Guy: In the public it's really hard. The trouble is that the things that get reported in the news are new. And by their nature they are uncertain. People have done studies of science as

it's covered in the newspapers and it's generally wildly inaccurate not because of any fault of the reporters but because the new stuff itself turns out to be wildly inaccurate 50% wrong and we didn't know yet where the 50% was. So my sense is to allow yourself to be entertained by new ideas but don't sell your soul to them. Essentially it takes about a generation for an idea to become well enough established that you can have some confidence that it's a sure steppingstone to go further. And science does proceed rather slowly. There is a consensus effect when a lot of scientists think that we can get someplace with this. But there's also the sense of "Does it bear fruit?" Do new good ideas come out of it that we wouldn't of had before that explain things that maybe we didn't even know needed explaining before? Things like string theory are so suspect because the string theorists seem to have run into a brick wall. There is a guy in our community, a Jesuit from Italy, who's doing string theory and he's as frustrated as anyone, but it could be the next breakthrough around the road that you don't want to give up on it yet still one of the best things we've got going. But there a lot of places were stuck. This stuff is hard. One of the things that I worry about, and I've mentioned the unspoken assumptions. We have a generation, we have how many generation of physics students, who have been educated in our universities since the advent of quantum theory, since the realization that Newtonian physics is fundamentally untrue and yet how do we teach them? We teach them Newtonian physics. There's a lot of practical reasons. You can build bridges; you can get a job with it. But when it comes to trying to understand the nature of physics and physical reality are we doing our students a disservice by getting them to go think in the habit of Newtonian physics, when in fact maybe those are the wrong habits to think in. And yet how would you teach a 17-year-old quantum physics without teaching him Newtonian physics first? We haven't figured it out yet. So we've got a long way to go. And that's why it's so much fun.

Dean Ruiz: Next week we will have Chris Impey. [conclusion of lecture]

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