Modern Cosmology
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Roundtable

Participants: Piet Hut, Janna Lavin, Charles Liu, Dimitri Nanopoulos (moderator), Tu Weiming

Levy: I am now pleased to present Dimitri Nanopoulos. Dr. Nanopoulos is Distinguished Professor of Physics and Mitchell/Heap Chair of High Energy Physics at Texas A&M University. He is a fellow of the Economy of Athens, Greece. Dr. Nanopoulos, who previously participated in the Philoctetes roundtable "Mind Versus Soul" will moderate "Modern Cosmology," and introduce the other panelists. Thank you.

Nanopoulos: Good afternoon. I'm very pleased to be back here. Let me introduce the fellow panelists here. Let me start with Janna Lavin, who is a Professor of Physics and Astronomy at Barnard College. Her work focuses on early universe, chaos and black holes. She's the author of *How the Universe Got its Spots*, and of the novel *A Madman Dreams of Turing Machines*. Welcome.

Lavin: Thank you.

Nanopoulos: Let me continue with Professor Weiming Tu. He is a chair Professor of Chinese History and Philosophy and Confucian Studies at Harvard University. He is director of Harvard-Yenching institute and a fellow of the American Academy of Arts and Sciences. His research interests are Asian philosophies, comparative religion and dialog among civilizations. He has published extensively on the modern transformation of Confucian humanism.

Let me go on with an old friend of mine, Piet Hut, who is professor at the Institute for Advanced Study at Princeton. He heads the program of interdisciplinary studies; he's an astrophysicist with an interest in the history of the universe and computational science. He's the author of many books and articles that explore these areas.

Last but not least, Professor Charles Liu, who is Professor of Astrophysics at the City University of New York in Staten Island, and also an associate in astrophysics at the Hayden Planetarium in the American Museum of Natural History. His research focuses on the star formation history of the universe. He is the author of *Black Holes, Quasars, Time Warps*, and also author of *One Universe at Home in the Cosmos*.

Now let me say a few words about what we're going to do today. As you have seen, the theme of our discussion here is modern cosmology. The word "modern" has a very special meaning here because during the last, let's say, 10 years or something like that, we have an explosion of knowledge in this thing that we're calling "cosmology." This is related to the origin or the appearance of the universe and its evolution until today. Cosmology is really led with the first moments of the universe. Despite the fact that this sounds a bit metaphysical or philosophical, during the last10-15 years there has been an explosion of experimental and observational data that has changed, really, our view about the universe.

It is clear that the new view that we have from this point of view definitely is going to change, I think, the whole world as we see it today. After the 17th and 18th century, in which we had this explosion of knowledge after the Dark Ages of 1,000 years, we have this development—we have Galileo, Kepler, and Newton. And then, starting with Voltaire, we have the kind of new development in society, so that this knowledge that has been developed and is related to specific quarters has been really used in the society. And then we have the whole revolution develop until today.

I believe that we're living a kind of new type of era like that, that the data and the new knowledge that we are getting at this moment is going to change, completely, our views of the universe. And I have no doubt that eventually—maybe not in our generation, because these things are passing through very slowly, as you know—they will trickle down to this thing. But it is going to change us—our way of living, the way we're looking at the world and what we believe, in a very dramatic way.

We have a panel of very important people who have contributed to these things. Also, we have here a professor who is working on how these things can pass through to the society. So we're going to discuss a little bit this new development in a very simple way. We're going to present a central way that we're thinking about the universe today. Then we're going to discuss it a little bit between ourselves, and then we're going to open the floor to discussion.

So in order to start, I would like Professor Lavin now to tell us a few things.

Lavin: I was kind of amazed because you stole some words that I literally wrote about a week ago, which is that something about cosmology changes our conception of the world and thereby changes us. That's a very strange notion. I was thinking back to Copernicus. I mean, can you imagine living before we realized we were not the center of the cosmos? This is such a major shift. And then I think about some of the things that are going on now: the idea that we know that the universe is expanding, and not only is it expanding, but the expansion is getting faster and faster—it's accelerating.

We don't understand what the major constituents of the cosmos are. We don't know what the kind of matter is that's out there. We don't know about the major component of the energy—the dark energy. We know it's not like us. And these things should be enormous changes in the way that we view the world. And yet, I think they're a little too abstract for us to grasp in our everyday lives. I mean, displacing us from the center of the universe is huge; you can see how that changes everything. But it's hard to know if people really realize that the universe is expanding, and how that's really going to change them.

I don't know if you know this Woody Allen line in *Annie Hall*: he says he won't do his homework because he's having an anxiety attack because he realizes the universe is expanding. And his mother tells him, "You live in Brooklyn. Brooklyn is not expanding." So when people learn that, there is this moment of, maybe, anxiety, but there's also a sense in which we don't relate to it. So I'm bandying about these same ideas: how much is it going to fundamentally change the culture that we live in?

Hut: As you already said, it's so amazing that in the last ten years or so, we have learned so much about cosmology. When I was student, cosmology was the part of astronomy that was most uncertain; it was almost like mythology. We knew a little bit, and it was already enormously interesting, because 100 years ago we knew virtually nothing. What little bit we knew was still very general and vague compared to the rest of astronomy. To put it in context, 100 years ago we did not even know whether the universe had a finite age. Actually, the general idea was that the universe must have been infinitely old. It would be too human—too limited—to think that the universe is born and maybe dies; that is something humans do, but the universe as a whole has to be infinite. That is the most appropriate, most logical idea, even to the point that Einstein famously invented his cosmological factor to make the universe able to have an infinite age, which he later retracted.

Lavin: Because he can't make a mistake even when he tries.

Hut: So we now know that the universe is finitely old. And for most of my career I had to tell my friends that the universe is between 10 billion and 20 billion years old. And for me, that was an enormous position—the fact that it is finite. That was already important that within a factor of 2 we could know how old it was. That was incredible. But then, in the last several years, we suddenly have this flood of new observational data with the WMAP satellite, and now we know the age of the universe to within 1%. We know that the universe is 13.7 billion years old within a certainty of 1%. And most of my friends—I have no idea how their exact age is within one percent. I know they're 44 or 45. The universe is probably my most accurate acquaintance at this point.

Liu: My introductory students say, "What's the point of taking astronomy?" Aside from fulfilling your general educational requirement, the actual value of astronomy is very intangible, just as Janna was saying. But I like to say that it won't change the price of bread today, but it could change the course of civilization tomorrow. Cosmology may be, as Piet said, perhaps the most abstract and most grand of those things that can change civilization tomorrow.

What kinds of things do we have to think about when we know the age of the universe more accurately than we know the age of our friends sitting next to us? It's a remarkable shift in how we have to think about things. I would love, later on, to get into concepts about the beauty of the universe: how beautiful is the cosmological constant—things like that which are odd but interesting questions to ask.

I was delighted when I saw that professor Tu was going to be on this panel with us. Years ago, as a ruddy-faced freshman, I took a class with him—one of hundreds of anonymous, faceless freshmen in a course about ancient civilizations in China. And I remember him giving fascinating lectures about Buddhism, about what Confucian ideals were, and so forth. And it impacted me quite unexpectedly last summer. My mother had brought her older brother and his wife to the United States for a few weeks' visit. Naturally, it was only appropriate that I take them to the Rose Center of Earth and Space and show them the Hayden Planetarium. And as we

were walking through, I was speaking Mandarin Chinese and a little bit of Hakka, and saying, "Well, this is the nature of this. This expression explains what the universe is, and so forth." There is an exhibit display which shows the entire 13.7 +/- .2 billion year history of the universe. It's a pathway that spirals down from the big Hayden Planetarium sphere. It's about 350 feet long, and every inch represents millions of years of the history of the universe.
And I was walking and explaining to my relatives, in Chinese, "Well, this many billions of years ago, this is what happened. This many billions of years ago, this is what happened." And I noticed that there were several people walking behind me who were also Chinese. This often happens, actually. Any time somebody is walking around in a museum and looks like he knows what he's talking about, a small cometary tail forms, imagining that this person actually has a clue about what's happening. But as I was walking, I was down to about 10 billion years or so after the big bang, and the gentleman about the age of my uncle came down and said, in Chinese, "Hi, I just wanted to let you know that this is very interesting, but it's all incorrect." And I said, "Oh, really?" He said, "Yes." I don't remember exactly what he said at this point—it became a blur because it kind of went outside my normal cognitive thought on the universe.
He said, "Well, you see, the great and mighty Buddha has decreed that this is actually the sixth incarnation of the universe. It's not 13 billion years old; it's more like 170 billion, and it has happened five times before—the great power of the Buddha has created a cyclical cosmos, and we just happen to be aware of this one." And he went on, and I don't even remember what the numbers were; the numbers I said are probably incorrect, but it was roughly of that nature. And I thought, "Wow, that's really something." I tried to listen. He kept going and going for several minutes. I was trying to absorb it not in a closed fashion—"You're wrong, go away" kind of thing—but sort of saying, "What motivated this gentleman to feel that he was more comfortable with that kind of cosmology—that kind of a universal structure—than that which is displayed here in this building, which he can touch and is tangible and has been brought down over years, decades of scientific work?" So this was something that I hope that professor Tu can address to some extent over the course of the next hour. It doesn't have to be immediately.

Tu: I certainly am not in a position to defend your Chinese friend's challenge to modern cosmology. He may very well be right. There are a lot of incarnations even in cosmology. That's, of course, his own belief. But I was a little bit worried when the moderator talked about the Dark Age and the beginning of the 17th century, the Enlightenment, and, of course now, in the last 10 or 15 years, and that we have totally radically different conceptions of the cosmos. Because what I have been doing for a long, long time is really working on the Dark Age. I find that the Dark Age itself is something that may become very relevant to many of the problems and issues we'll be exploring here. This reminds me that about 10 years ago, Piet Hut and I spent about a week in Dharamsala and engaged in a five-hour-per-day conversation with the Dalai Lama for five days. Originally, I thought these eminent scientists—the five leading physicists—were there simply to educate the Dalai Lama about the modern universe. But what I really learned in that conversation is that it's a fascinating dialog between science and religion, both in a very broadly, conceptualized way.

So I will begin with the notion of the so-called Axial Age civilizations. There's a notion that the German philosopher Karl Jaspers used after the Second World War. Jaspers conceptualized human history in terms of some of the great spiritual civilizations in South Asia, such as Hinduism and Buddhism; in East Asia, Confucianism and Daoism; in the Middle East, Judaism, which evolved into Christianity and, of course, Islam. So these civilizations, from his point of view, after the Second World War were still very relevant to our conceptualization of our world, and especially our personal experience.

And then he identified four of what he called the “paradigmatic personalities”: Socrates, Confucius, Buddha, and Jesus. Of course, now the list would have to include Mohammed and maybe Lao Tse and other people. So the question that I have with this new vision of the world—and we’re going to have a radical new conception of the cosmos—why are all these people, for centuries considered wise voices—the wisdom of the elders—totally relegated to the background? Or is there some way in which the communication between enlightened, more scientific, thinking, and this cumulative wisdom is still very much a part of our own universe? The enlightenment since the 17th century has been so powerful. There is an underlying assumption that the more we know, the light source will shine forth and darkness will be expelled. So the notion—almost like the evolution from the superstition of religion to metaphysical reflection—is that now we are in the age of science and experimentation. We know for sure what’s going on. The assumption is that as our knowledge extends, our darkness and ignorance will be reduced. But I think that most of us now agree that the more we know, the more we are hungry to know more, and the more we become aware of how little we really know. Like Leibniz trying to find the monad, we try to find that small thing that will help us to construct the universe. The more we try to look for that, the assumption that if it’s small, then it can be simple; and the simpler you get, the closer you will get to the material reality of things. But now we know that if it is small, it doesn’t mean that it’s simple. It can turn out to be extremely complex.

So we have a situation where the more we know, the more we are aware of how our ignorance is extended. In this particular situation, I think it is not at all unusual for some scientists like my colleague Gingrich to talk about God’s Universe. I think that part of the conversation should also be continuous dialog between the most advanced understanding of cosmology on the one hand, and some of these other forms of knowledge.

Hilary Putnam once characterized some of these forms of knowledge as non-scientific, but it doesn’t mean they’re not meaningful, important and absolutely transformative. How do we deal with something which is not quantifiable, which is often intangible, which may be extremely elusive or ineffable and yet profoundly meaningful, not just for our daily experience, but for our understanding of the universe and especially of our own planet?

I will end with one short note: probably in December of 1968, for the first time, the naked human eye was able to see our planet Earth, which is, of course, much smaller than the expansiveness of the cosmos. For the first time we realized how vulnerable this particular habitat of the humans is—not just the minerals, soil, water, and air. I think it’s very difficult for us to imagine. To me, it’s just as fundamental as some of the great scientific discoveries since the 17th century. I think maybe Wittgenstein made a remark, “If you haven’t died, you never know the meaning of life.” If you have never left the Earth, you never know the meaning of Earth. Now, in a strange way, thanks to great science and technology, we manage to get out of the world and look at it. And we had a vision—even high school students and primary school students—that was totally unimaginable before the ‘60s, let alone the earlier period. And that certainly helps us to change the world, to change our understanding of our Earth and so forth. Maybe what has happened in the last 10 years or so—this incredible discovery of the cosmos—will also, through a certain kind of trickling down process, help us to re-conceptualize not only our relationship to the cosmos, but to human relationships, our relationship to our own planet, and our relationship to history and to some of the great minds of the past.

Nanopoulos: I agree with some of the remarks that Professor Tu made here. One thing I have to make sure I've not misspoken: when I referred to the Dark Ages, I was referring to the Western type. Secondly, I believe that we may have a paradigm shift in our thinking about how we think about science. I don't buy this thing—we have it for many, many years now, especially with the post-modern philosophers—we have this attack on science. Scientists keep changing their minds. One Monday morning they change and say the universe is doing this. The other morning it's doing that, and stuff like that. You have to start all this business and it takes time to understand things better and to reach some conclusions.

Now, we have to put in our minds the following thing: we're getting photographs or "ways," in quotation marks, of the universe as it was 380,000 years after its appearance. I like to use the word appearance, not origin, because we don't even know if it was an origin. Eventually—I think within the next 50-100 years or something like that—we'll be able to have an even closer picture of the beginning of the universe. Why am I saying this? There is irrefutable evidence for what is happening, and corresponding theories that are going to support this. We have quantum physics for these things, which is almost, now, 100 years old. We're all using it in our house every day. It is strange to us; it is strange even to the scientists for these things. The universe is expanding—that means in the beginning it has to be very, very small, even smaller than an atom. So it has to obey these quantum rules. So that brings us the idea of the probability and chance for how all these things have appeared. But we have experimental and observational evidence. When I was a student, they didn't even know—they didn't even want to quote numbers. Then we had this number: 10 billion to 15 billion years. Now we go to 1% degree of accuracy. And that means that now cosmology has become a precise part of the scientific community, and is going to have a lot of answers.

Now, this will be the scientific concept. This has been addressed now, to see how the communications are going to be with sociologists, psychologists, and philosophers. And I believe that a new kind of dialog will come out of this, where everybody is going to participate. I'm not saying that the scientist is going to go. The scientists are going to do what they're supposed to do for this thing. The only thing I'm getting a little bit upset about is this kind of thinking that scientists keep changing their minds every Monday morning. I don't think we're changing our minds every Monday morning for this thing. I think things are being settled now, and it took years and years and years and years, because it's an evolutionary process of how we learn. We have the technology now, and that's why all these things are happening at this moment.

Of course we're sitting on the shoulders of giants, and the next generation is going to do the same thing. Already we have things that are going to change our view about the universe. That's what I'd like to stress. As Janna said, we know even today, as of this moment, not only that we are not the center of the universe, which we knew from Copernicus, but we know also that we are not made from the same stuff that most of the universe is made from. Now we know that 73% of the energy balance of the universe is pure energy. It is not even matter within the definition that the scientists have given to these things. And from this 27%, 24% or 23% is what we call "dark matter." And protons and neutrons and electrons—what you learn in high school—is about 4%. We are made only from 4% of what the whole universe is made of. All of these things have to come down and we have to absorb all of this stuff. This is experimental, observational stuff. It doesn't matter if we do not have a theoretical explanation for these things—this will come with time, right? But definitely all of these things are going to change our views about the whole structure of the universe.

Lavin: I really agree with you. There is this idea—and I've heard it a lot in discussion—that science is this totally relative thing, and that eventually we change our minds. Now Newton was totally wrong. It's not like that at all. Obviously, we are never going to go back to the day when we thought that the sun revolves around the earth. That is never going to happen. We really don't backtrack. We know when we're on a road—and even that the universe is accelerating. We're nowhere. We know we're in a touchy time, and that we're going to know a lot more in 10 years than we know now, and we might have to backtrack on some of the things we're saying today, but we're aware of that. We know the difference, I think, between stuff that is really solid and the stuff that is still being developed. But I think it's an interesting question when you bring up the great minds of previous centuries to say, "These are brilliant people who are as framed by their context as anybody." Maybe they're more visionary, maybe they see ahead, but they're also framed by their religion, by their culture and by the sate of science at the time. I think it's interesting to wonder how their minds would have been different and how their teachings would have been different in a different culture or in a different bed of knowledge.

I was recently reading some quote from Abraham Lincoln, who was an extremely progressive, enlightened human being and truly a fascinating person, but it was an incredibly racist quote. It's not that he was a horrible racist, it's that it was a racist time, and he was a product of that time. Had he been alive today, he never, we imagine, would have dreamt of saying some of the things he said in this quote. So we are very much shaped by the things we know at a given time, even the great minds. So I think this is part of what we say and it changes us. I think it's fascinating to wonder how it sloshes back and forth—how will science change culture? How are these great minds that are not scientists changed by the climate of what we know when we know it? Like you said: we know the job that we're doing. We're measuring things, we're making theories, and we have our parts to play in that. Our part to play is not to necessarily make huge cultural declarations. We do what we do regardless of whose sensibilities it might offend, including our own.

You described Einstein not wanting to believe that the universe was expanding and that it had a beginning, or at least it was not infinite and static. This was horrible to him, and he went so far as to change his own theory. That's a beautiful example of where one person's cultural noting interfered with their scientific vision. And he calls it his greatest blunder, not because it was the biggest mistake he ever made—he's not the greatest mathematician, he often made mistakes. His greatest blunder was, in some way, one of belief, and I personally think that's why he called it that.

I was drawn to science precisely because I have to change my belief system when confronted with certain data. I might believe that 70% of the universe is dark matter, or dark energy, but if an experiment comes along that's different, I'll happily change my mind. I feel the same way about psychic powers or telekinesis: if somebody would just show it to me once, I will happily change my mind. Your belief system, in science, is beautifully unimportant, and there's something about that that I find very gratifying.

Tu: I think we should make a distinction between progress and progressivism as an ideology, as a belief. There is no question about the progress of science, and the more we know and we verify things, we move ahead. We don't make the same mistakes people made before. But that's true in many other areas as well. Sociologists used to have a rather limited understanding of how societies worked. As they become more progressive in their thinking, they will be able to expand that. But progressivism is a belief very deeply rooted in the Enlightenment. I think perhaps the most powerful ideology in human history is the Enlightenment mentality. I use the term "mentality" very advisedly. It's not the Enlightenment movement. It's not what Hegel, Marx and others say—the Enlightenment project that still needs to be realized. It's a particular mentality, especially in China, because it's not science, but it's scientism. It is the belief in social engineering. It's the belief that we know the engineers are not actually scientists in terms of basic research. It's this technocratic mentality that we know what's going on and, in fact, we are now in this Age of Enlightenment. Anyone who still believes in something like religion, or a Christian or a Jew or a Buddhist—there must be something wrong with them. There's this insensitivity to many other areas of human concern. In an advanced course in philosophy at some leading university, these most brilliant minds, together with a teacher, try to struggle to understand Plato—two or three lines sometimes—or Socrates or, for that matter, Sanskrit texts in order to understand a Buddhist idea. That kind of cumulative wisdom is also a form of understanding if we believe that when we move with the progress of science or the other domains of human experience, human wisdom will naturally follow. That is not the case. I think sometimes we have this incredible problem of educated incapacity: the more we focus on what we know, the more narrowly professional we become and the less we're able to understand other dimensions.

Lavin: I in no way find them at all mutually exclusive. I even find it surprising that that would be on the table: the idea that by looking at, say, cosmology, which is the topic for today, in a scientific way that that would somehow exclude the study of Sanskrit lines or the humanistic importance of literature or art—quite the opposite. I do a lot of dealings with art.

Hut: There are many things I would love to respond to in what you said—for example, the fact that ethics and aesthetics are still completely outside science, and it's one of the most important areas in our lives on a daily basis. Whether they will become part of science in a very distant future, who knows? But what I would like to focus on is how young science is. Science got started in a modern form, say with Galileo, only 400 years ago. And the oldest expressions of art—the oldest expressions of depicting something outside ourselves—are in cave paintings of 40,000 years ago. So again, there's the 1%. For 99% of human history there was art and religion, and for only the last 1% there is science. So science often sounds like a teenager—like an adolescent, rebellious and arrogant. But it's because it's so young. And in another 400 years, if we could speak again, I think science will shape up quite a bit.

Nanopoulos: The thing that really bothers a lot of scientists in relation with the society is that a lot of people—I mean, read today's *New York Times* or something on what happened in Texas—some statements about what has happened today, the 17th of February, 2007. What I'm referring to is the following thing: that people are betting their lives on some beliefs that have been decided for them for the last 2,000, 3,000—I don't know how many years—and again, I'm speaking about Western societies, with which I have a lot of experience.

Tu: Eastern societies may be worse.

Nanopoulos: Could be, but I speak about the experience that I have seen in my neighborhood. And then you see people, because of these beliefs—they spend their lives in ways that you really cannot believe. And I believe that in the whole society something very wrong is happening. That's why I believe science, beyond all the spin-offs about the applications—I'm not referring to this kind of thing—conceptually can change a little bit the way that we're looking at the world and it will be better. I agree completely with you when you were saying that it is much more than religion or making religion be the whole opposite or complementary to science. There's so much other stuff there that we can combine together in a satisfactory way.

Hut: The idea of science being so young—I think the most interesting aspect of that, concretely speaking, is that science wants to be empirical. It is based on experience: on experiments in the laboratory, experience using a telescope. So that is science's greatest pride, but if you actually look at what has happened—every time I have an experience you can see it already in the language. "I see a table." There is a subject, there is an object, and there is an interaction. Everyday experiences like that—every scientific experience is like that. But science started by taking the easy path: it focused on the object pole of experience. It did not want to say much about the subject pole; it did not want to say much about the interaction. But if different subjects, in different ways, agree on the same object pole, then that is something about which we say, "This is empirical." This is really what empirical methods have established. That was a great way to get started. In 400 years we have been able to build up an enormous body of knowledge about objects. But still, if you go back to the source—where these empirical methods come from—we still have had only this one pole of experience. We still have very little to say about the subject pole, very little to say about what conscious experience is. And the hope is that studying brains would be one inroad. The unwritten hope in science is that by taking empirical methods, taking only one pole, studying that in great detail, you can go to the back door—to the pole door and the empirical attitude—and try to reconstruct everything. But that is, at the moment, a hypothesis. It may or may not be true. It may not even be clear whether or not we can find the criterion to say that that is true. But at least that is the attitude at the moment.
But while scientists will continue doing that, I think there is room for philosophers and people from other ways of knowing—certainly also psychology. It will be interesting to try other approaches as well. Scientists will do what they will do, and they will try not to be affected by their contextual situation, which is a good thing.

My prediction for science is that in the next few hundred years there will be a much better understanding of the subject pole of experience. We have seen in quantum mechanics that the way you measure something already influences what there actually is in matter. It's a very surprising thing. We have neuroscience, where you translate subjective and objective experience effectively. We have robotics—robotics is a very interesting thing, where, basically, we make a tool which is a subject and not an object. If you go back 50 years and you read science fiction stories, everybody predicted that there would be robots in every household. Nobody predicted computers in every household. But the computer is an object and a robot is a subject, and we have at least 100,000 years of experience in building objects; we have only a few decades of experience building subjects. This is also why software is such a problem. Hardware we can make, but software—it acts like a subject. I think in the next few hundred years science will grow into the whole empirical realm, talking about consciousness as subject as well as object. And the current scientific world picture is a picture of only objects, and often when I reflect on that, I feel like the person who, for the first time, went to the moon and looked back at the earth. If you become aware of the fact that you are not only an object, but really qualitatively something different, at least in your own experience as a subject, then if you look at the scientific world picture, it looks like you're looking at the world at arm's length. Since you are so used—especially young people—to identifying yourself with your brain, with your hormones, with all the objective constituents in your bodies, you forget that, in the most direct, empirical way, what is given here for each of you in this room—everything you see is being painted in your experience, in your consciousness. That is the first tool you use to study everything else. It is like a blind man who uses a stick to walk around. With the stick he can feel the whole room, but if you ask what he is really feeling, it's only the stick and the vibrations in the stick. So, yes, we have a very good scientific, objective, empirical method, but everything we are experiencing is given in our experience—that is our stick. And in that sense, we are blind. And yet, we can understand a lot of what is going on around us.

Liu: What I'm starting to hear here is confusion between scientific knowledge and unscientific knowledge. You're talking about what we would consider consciousness, which we're just beginning to understand the science of—seeing things which are empirical, which Galileo, as you rightly pointed out, defined as being empirical and scientific. But, you know, the schism between non-scientific and scientific information came with Galileo when he declared—I wish I remembered the actual work that he wrote this in—that he could no longer say whether or not it was beautiful that a falling object falls. Because he could not relate the two, he said, "I'm just going to deal with the empirical now. I'm going to let other people deal with the philosophy of beauty and aesthetics and so forth." Over the past 400 years, things have split so far that we no longer remember which is which. The intelligent design controversy is precisely this; I deal with this all the time in introductory astronomy classes: "Well, how do we know that the universe was a big bang thing? Couldn't some flying monster have just reached his tendrils down and created the universe?" And I say, "Sure, no problem, but what's the difference between these two knowledges? Each one has value, but which one do we consider science?" It's the one that we have made predictions about and hypotheses that have been confirmed. The hypothesis that has not been confirmed is not scientific knowledge, but it could be just as valuable.

So perhaps, Professor Tu, we are coming back to the place, now, where it is appropriate to start knitting together that knowledge which is scientific and that which is non-scientific, valuing them roughly equally, which has not been the case in the past century of our civilization, and in that way gaining some greater understanding. Nowhere—in science, anyway—do I see that linking together more beautifully than in cosmology, where humans have always wondered where we came from. Now, in the past few centuries, we've figured out where we come from. But we really haven't, from the actual consciousness, scientific point of view. We still don't know whether or not the cosmological concept is beautiful. I come back to this because when we were putting the Rose Center together back in 1999—Piet, you probably remember some of these conversations—that was just around the time that this dark energy thing was starting to be confirmed with the various observations of Cepheid variables locally and also the cosmic microwave background having its sorts of things—supernova cosmology changing—and the cosmological constant became important in all our cosmological ideas, scientifically. But we had to put this cosmic pathway together and say how old the universe was. So to figure the age of the universe, we needed to know what cosmology we wanted to use: how much was dark matter, how much was dark energy, and how much was real matter? And we had to send an email out to our scientific advisory committee saying, "Folks, we need to make a decision now about how old the universe is so we can put it in this stainless steel pathway."

Tu: What do we use?

Liu: Yeah, "What do we use? What are we going to say?" And I actually, from my observer's perspective, said, "You know what? Let's make the age about 13.5 billion, but let's leave the cosmological constant out, because it's kind of ugly. Sticking that thing in there makes our conception of the world not the beautiful matter-only thing—then space is uncontaminated with this extra stuff that shows up just because space is there. And a very brilliant cosmologist sent back an email almost immediately saying, "No, bad call, bad call. As aesthetically and theoretically abhorrent as I find the cosmological constant to be, that is what the observations say, and thus it must be there." So is the universe now uglier because it's got this extra contaminant in the beautiful pristine-ness of space?

Lavin: I was going to say, we're the contamination.

Liu: I agree.

Lavin: We're the bit of grit.

Liu: That's right. We're the junk that causes space time to bend. It's our fault. But isn't that a shift?

Hut: We are the contamination within the contamination.

Lavin: We're the ash.

Liu: Remember, eight years ago, that was still not 100% certain. We weren't clear yet.

Lavin: I'm still not sure it is 100% certain.

Liu: That's a good point.

Lavin: I think we could argue about whether or not it's 100% certain now.

Nanopoulos: But we're getting too technical now. Even the word "cosmological constant" I want to talk about, because we don't know if it's a cosmological constant.

Audience: Can you explain that? What about it is not beautiful?

Nanopoulos: This one I don't understand—about the beauty of the cosmological constant.

Lavin: Who wants to try the cosmological constant?

Liu: Go ahead. What is the constant?

Lavin: Do you want to try it?

Liu: The cosmological constant is just a little bit of energy that exists in every cubic foot of space.

Lavin: It's basically the energy of the vacuum. If you took a vacuum—literally a vacuum—and you evacuated everything inside of it—all the atoms, everything you could possibly think of to get out of there, all the light, everything, so it was just this dark, totally empty vacuum—it turns out that in Einstein's general theory of relativity, that that could have an energy associated with it even though it's empty. It's totally empty—no particles—and as far as we know, no normal forms of energy. But according to the general theory of relativity, that might actually have an energy associated with it, and we've become accustomed to calling that energy the cosmological constant because it was the term, as Piet was discussing, that Einstein introduced to try to render the universe static. He introduced this term, and it was called the "cosmological constant," so that's the terminology we carry on, but what it really means is the energy of empty space. Is that a fair description?

Liu: Perfect.

Lavin: It was simply a mathematical term that Einstein stuck into his equations. Somebody told him, "Do you realize your equations predict that the universe is expanding?" Someone just took them and calculated some things and said, "Oh, this predicts that the universe is expanding." Einstein refused to believe it, so he literally stuck a term in. It was the only possible term he could stick in that would be consistent with things like causality and certain essential, simple principals that he originally didn't introduce because he thought it was ugly.

Liu: Right. And there was no physical reason to put it in there. It was purely for aesthetic purposes. That's why it's ugly.

Hut: Just to make the picture clear: you had the original explosion; space expands very rapidly; then space slows down because of the gravity and everything attracts each other, so you have this fast expansion and then it slows down. But then, while things are slowing down, more and more space is created. The Big Bang is not an explosion within space, like when we create an explosion, but it is an explosion *of* space. Space is created in the Big Bang, and probably time, also. So it may not make sense to say, "What was there before the Big Bang," because time and space, as far as we know, were created in the Big Bang. They occurred; they appeared. These are dangerous words to use—loaded words. So that was the origin of space and time. While it was slowing down it was still expanding, but with more and more space appearing, the energy in the space appearing then turned out to be repulsive. So after a while, the slowing down stopped and the speed remained constant and then started to expand faster. So you have this very complicated situation of the very fast expansion, the slowing down of the expansion, and then the increasing speed of the expansion. We are now in an accelerating phase, and whether in the future it will slow down again and maybe fall back, nobody knows. It depends. Maybe there is another contribution to the cosmological constant. Maybe the constant is not quite constant; there are still many open questions.

Tu: Let me offer an ignorant point. Sometimes, if beauty is understood in terms of aesthetic structure—let's say geometric form—everything is predictable. You can see it and you can see that it's very appealing, that's it's the pristine picture of something that is beautiful. But we also associate beauty with dynamic process—it's not just static structure, it's a dynamic process. And dynamic process involves unpredictability, it involves fuzzy areas, involves chaotic situations you cannot control. In fact, from the Chinese aesthetic point of view, that's really the most marvelous thing for a creator. For example, a calligrapher is going to develop a vision about his own understanding of the world—the ability to show the dynamic change in the process, the unpredictability of how he's going to finish it, and sometimes imagination. All these features become part of it, and so it becomes aesthetic or aesthetically appealing precisely because it has violated our rather conventional knowledge about what is pristine, what is clear, what is precise, or what is aesthetic structure.

Liu: So the universe is becoming more beautiful as it becomes increasingly complex.

Tu: More beautiful in the following sense: it challenges our rather limited conceptions about what's going on.

Lavin: I think what you say is really interesting because we have to remember that, of course, the scientific endeavor is a human process. What you say about separating object and subject, I think, is very relevant because we're in a time where we've made a kind of cultural agreement to study the object. But we are asking questions that we find important for human reasons. Why is it interesting to me that the universe had an origin? I mean, these are human questions, and I think that shapes the flow of science. We were both discussing before the panel started that we study chaos and complexity, and that is a shift, especially in fundamental physics.

Tu: Thomas Barry, a great thinker, and also very much involved in the whole question of ecology, made the following observation: he said that for years and years we just assumed the world outside is a collection of objects—we look at them, study them. But, he said, is it possible for us to also imagine nature is not a collection of objects, but possibility a communion of subjects? On the surface, the notion is totally unscientific. If we follow Piet's notion about the importance of not just the subjective but the inner process of human understanding, that kind of interaction is an attitudinal question. It's not whether you are scientific or not scientific; it's how you consider your own scientific work in the broader context—the human context. So in that sense, even the idea of relating to the cosmos as you describe it, as a communion of subjects, is not simply a non-scientific utterance. It has some deeper meaning. I remember a number of years ago, a group of scientists—Carl Sagan was involved—sent a letter to religious leaders arguing that it is very important for these religious leaders to begin to appreciate the cosmos, to appreciate the world as sacred, because the scientists discover the beauty and the dynamism in it. So these spiritual leaders would try to teach a lot of people how to appreciate the whole cosmos, and how to appreciate nature as sacred. Many of the religious leaders not at all seasoned in scientific inquiry become wired in their attacking science. And therefore, people develop totally unrealistic views about nature and so forth.

Hut: In scientific terms, you can talk about it as a choice of coordinated systems. We find ourselves, empirically, in a situation where we are part of this world, and the world is given to us in consciousness. So there is a mind/world circle. That is the empirical basis, and from that we conclude that the most reasonable way of sharing all our knowledge, and the most reasonable way of organizing our knowledge, is to say that it is a world in which we appear, and we have knowledge of the world. But purely empirically, we start in the mind/world circle, and just like the map of the earth can never be precise because it depends on the prediction you use, we generally take the materialistic, or realistic as it is called, projection of the world rather than the idealist projection. But we have to remember that we are talking about particular coordinated systems.

Nanopoulos: Maybe it's time to open the discussion to the audience.

Audience: Okay, I'll put myself in context. First of all, I'm an atheist, indoctrinated as an atheist from childhood.

Liu: Is it possible to indoctrinate atheism?

Audience: Absolutely, yes.

Liu: I learned something.

Audience: I'm not a creationist in any sense of the word. However, the Confucian among you is the man who resonates most with me in this conversation. To start with the notion of beauty, as far as I'm concerned, has nothing to do with science or the scientific approach. It's art; it's the preoccupation of the subject. And I'm glad that you brought the subject/object issue to the table. Quantum theory confirms that the subject informs the observation as much as the object that is being observed. Therefore, I find any conclusive attitude among the physics community unacceptable to me on scientific terms.

Liu: Conclusions about what? About beauty?

Audience: No, not about beauty. I mean, everyone's entitled to their conclusions about beauty; that's private and subjective.

Nanopoulos: You want to say that the scientific evidence we provide somehow is random, because of this quantum mechanics stuff?

Audience: I'm not denying that the scientific community has accumulated gobs and gobs of observational information in the last 400 years. However, that information, nevertheless, is being observed through a subjective lens. Therefore, my opinion is that this community needs to recognize that no matter how much it observes, it is starting from a subjective place.

Nanopoulos: Okay, I'm very keen on this. I would like to express a thought because it sounds to me a little like relativism and because quantum theory is so much misused, so much misplaced, so much abused by people that have nothing to do with science. You see, there are people that are hearing the uncertainty principal, and then they say like these relativists—I don't mean Einstein—these philosophers.

Hut: His relativity theory was also misused.

Nanopoulos: The uncertainty principal—what are these guys talking about? We're never going to know. There is what these great holy fathers—Heisenberg and Bohr and Schrödinger, etcetera—told us about. It is that we are caricatures of reality. That the fundamental laws of physics, it is the physics of the microstructures. We are classical structures. And because we are classical objects, we have built in us these notions that we would like to know if the electron goes from here to here—like the bus outside on Madison Avenue. This is a wrong conception. The real world is the world of particle physics. We know this is the fundamental notion and that tells us about the way that this thing is working. It looks very strange to us and we introduce the notion of probability in science. But the equations that these things are telling us, that mean if you have an electron and it goes from here to here, there are probabilities. And if you ask me, I cannot answer your questions that we as a classical object, because these are the wrong questions. But the notion of science is, if you give me 100 electrons in one specific state, any time you give me this specific state, I can give you probabilities about what they're going to do within the next few seconds or something like that. You will find that any time you put these 100 electrons together, the probabilities are going to be the same. So the classical notion of the world—a static kind of thing—has been changed. But that is the way that nature is working. So it is not true that this uncertainty principal destroys the way that we understand the world—that we cannot predict things. The language has changed. So this notion that somehow because of quantum mechanics we don't know what we're doing is very, very wrong. I'm not talking to you, but this is how it comes to pass, because if you go to any book shop around here, I think they should be in prison—what they put out, these books about all this. I just see this and I become red in the face. I don't know how they allow these things to go before the public—such misuse. So what I'm saying—I would like to conclude with this: quantum physics—and I repeat again, because I see it all the time—I see the newspapers and I see it everywhere—this is the most strong notion that we have about this. This is as good a science as everything else, and it is as predictive as everything else.

Lavin: More so.

Nanopoulos: The only thing is that it is not immediately understandable by us if you are not inside this kind of thing because, I repeat, we are classical objects ourselves. Classical objects—classical physics, right?

Hut: To the extent that we are objects, we are classical.

Nanopoulos: Right, for this we are micro-objects, and that's why we have a very different logical system. But we know that the real thing—there's a difference in the particle physics. If you were an electron, you would think much differently.

Audience: I was glad to hear the conversation about the subject and the object polarities, rather than a kind of sharp demarcation between the inner and outer life. This is a kind of subjectivist way of thinking about the world, but I'm not sure what modern cosmology is after this conversation. I still don't know exactly. I heard a lot about beauty and other things, but I'm not really sure what the new cosmology is. What I'd like to know is whether you think there are any regularities or laws of nature that can inform our concepts of psychology. For example, in the early 1900s, Whitehead's thinking in terms of a process-led physics informed psychology, and so the notion of the subjective and objective pole and compressing the sort of actualization and so on are important concepts in process theory. So I'm wondering what the modern cosmologist would have to say to that kind of approach and what we could learn. Whitehead took metaphysics and tried to draw the psychology. Some of you are looking to the cognitive sciences for computation and mechanistic approaches to the nature of the mind and expect that maybe we can fix it with the laws of physics. I'm not sure that that kind of static, mechanistic approach is going to work. So I'd just like to know what your comments might be about subject/object, process-based thought.

Liu: Let me make a 30 second point about this and then let my colleagues answer this. The large-scale structure of the universe—the way that dark matter and matter are distributed—is not exactly uniform on small scales. Rather the filaments in the web and the structure are very similar to a fractal pattern. Mathematically, it follows fractal patterns. And neuroscientist colleagues of mine tell me that the way that human neurons are put together, when you look at the dendrites and the axons and so forth and mathematically describe their structure, also follows a fractal pattern. So from cosmology down to the human brain, there actually is a structural, objective similarity in that one respect.

Audience: But you're still dealing with the physical realm. In talking about human thought, you're not just talking about the human brain.

Nanopoulos: Do you want to say that beyond brain—what we have here is 1.3 kilograms or whatever it is for this thing—that everything comes from there? Is there is something else there?

Audience: No, that would be as reductionist as anyone. But you can't just simply eliminate the problems of mind and put them in the hands of future neuroscientists and say, "Neuroscience is going to solve that problem in 50 or 100 years." I think you need to deal with the problems of cognition, the nature of an active thought or an act of cognition—what is the mental state, for example? And I think it's cyclical and there's a constant replacement of mental states. So I wonder whether there are any cosmological principals, for example, that might map on to that.

Lavin: I don't think I'm going to say anything that's going to be satisfying to you, but just two random things came into my head: one is, when you say you don't know what modern cosmology is, I think what we'd probably all agree is that modern cosmology is based on the four fundamental forces.

Audience: Which are?

Lavin: We believe the entire universe can be reduced, thus far, to four, and actually to less than four. Let's just start with four: electromagnetism, from Maxwell; the Weak Force, which was awarded the Nobel Prize in the '70s; and the Strong Force, which dictates the behavior of subatomic particles inside the nucleus.

Nanopoulos: Nobel Prize in 2004, that one.

Lavin: That's right. And there's the recent Nobel Prize in 2006 for the Microwave Background. But the fourth force being gravity, for detection of the radiation left over from the Big Bang.

Hut: Gravity will be the Nobel Prize in 2020.

Lavin: So those are the four. Gravity is the fourth. So really, in some sense, we've unified three of them: all the matter forces, weak, strong and electromagnetic. We have not yet unified gravity with the other three, and that's the great ambition from theoretical physics. Now we're all here talking about cosmology, but we're all coming from slightly different angles. I think we'd all agree that modern cosmology is an attempt to apply that short list to understand how the universe was created, how it's evolved since then and what it's made of. Is that the short list?

Nanopoulos: How it appeared, not how it was created.

Lavin: Appeared, not created. Particles, too—

Liu: And quarks and lepton?

Lavin: Right, so how structure is formed and what it's made of.

Nanopoulos: Also a very short footnote here: you were talking about 100 years after. You see, the thing is that we can sit here now here and discuss this and that's because we have this development over 100 years. We're using quantum mechanics and there was a lot of development. Now, I believe that neuroscience is like physics in the beginning of the century or something like that. This thing is maybe the most complicated object in the universe, and it's going to take some time, I think, to really come to satisfy your appetite.

Audience: Neuroscience is a theory just like anything else.

Nanopoulos: Though I believe from there we understand questions we were discussing before. It is clear to a lot of us that studying this object with the new techniques is going to give us answers to a lot of these things that you're asking. But we are, admittedly, far behind.

Audience: You started out by saying this is going to change our view of the world and the self, so I'm trying to understand what, in the four principals, is going to impact human thought.

Nanopoulos: Well, let me tell you something. A lot of my colleagues—physicists—will say to you that the universe just appeared by chance. It's just a fluctuation from nothing. Quantify this statement and suppose I have all the experimental observational support that I have to say this statement: I believe this statement should change your mind on a lot of things.

Audience: My question is—there seems to be a basic tension here between what Professor Tu is saying and the context of the Dark Ages and this modern view of science. So I guess my simple question is—I'll give you the simple question and then the background—is science ready for Prime Time as a world-view? What I mean by that is, if you bring up a question like the intelligent design debate, we know that if we're here in New York, people are very dismissive of superstitious people. But if we put it in the context of, like, the war in Iraq, on the one hand, there is a context—a frame out there—of modern democracy being used to free the poor believers in Iraq and replacing the old system.

Nanopoulos: Oh, boy, that's a bad example.

Audience: They use the believers in the Midwest and say like, "Our boys are eating sand so that they might have freedom." They use the old Judeo-Christian beliefs within the country to send poor Midwesterners to war. So this has real implications, and it seems that science wants it both ways.

Nanopoulos: You are not identifying modern science with the present White House, right?

Audience: I'm just explaining how the concept of science is being used both ways.

Liu: Science itself is used and abused by people just as easily as religion or philosophy or anything else is.

Audience: Do you think science ever abuses believers?

Liu: No. Science itself does not abuse believers. Those who wish to abuse believers will use science to abuse them.

Hut: Exactly.

Liu: Science itself is noble and straightforward. It has never attempted to co-opt anybody's non-scientific beliefs. It is those who choose to use science to co-opt other people's beliefs. That's why the question is not a problem: science has always been ready for Prime Time. It's a teenager. But those who wish to use science to abuse—I have no faith or sympathy for them regardless. The anger is misplaced under those circumstances. It is misplaced not toward science, but toward those who would abuse science, just as those who would abuse Islam or those who would abuse Christianity or those who would abuse, literally, anything.

Audience: I'd like to make an observation and a question on the physics part of the discussion. The whole sequence—the expansion, the Big Bang and momentum and the slowing down because the gravitational attraction came to a point of null and then enough space was created, as you were saying, and dark force caused expansion again. Doesn't that seem entirely too convenient that just at the time it is needed, it appears. Maybe it's a similar question, but could it not be a different manifestation of the same thing? It seems so perfectly sequential. No one knows where gravity comes from or what carries it or what the dark force is, either. They so perfectly fit in. Just when it was needed, it came.

Liu: I would just say that it wasn't needed. It was one of the things we observed and we were surprised because it wasn't needed to explain anything.

Audience: Really? It sounds like—it's almost like a sine wave. Just when it hit the null, it went the other way. It sounds like something rebounding.

Lavin: It wasn't clear that we were at the point of the null as you describe it, by which I think you mean that the universe was about to re-collapse. We were not near that. So it was even stranger. We agree. It's strange for the opposite reason: it's strange because we don't need it for anything. It's almost: "What is it doing there?" The universe tends to be very economical; it tends to do things that are what we would call "natural." And if you study, basically, all of physics, mathematically, it can be reduced down to the idea of the path of least action. Take the simplest path and that's the correct path, mathematically. That's literally how we do the math. So this is surprising because it seems to be something unnecessary and unnatural.

Audience: It almost seems like a positive gravity and a negative gravity.

Lavin: Well, no, probably what's happening is we don't realize that it's the simplest path in a much more complicated system. Maybe the universe isn't three-dimensional; maybe it's ten-dimensional. Maybe the extra dimensions are doing something and that's why it's showing up. So absolutely we try to use a similar intuition to the one you're getting at, which is: what would be natural? What would be more holistic as an idea, and simplest and cleanest? And in that sense, we're using aesthetics to try to discover what we think is going to be a fact about the world.

Liu: It's amazing.

Audience: I'm Steven Casslin, I'm an editor with *Discover Magazine*. I just wanted to ask a question following off your previous comments in terms of the use and abuse of science. Consider that someone like Richard Dawkins, who feels very, very strongly that his science compels him to his belief and has therefore made attacks on the religious establishment based on science, is also abusing science, however much we might applaud his ability to attack intelligent design.

Liu: Richard Dawkins, I believe, is abusing science to a degree, though not, perhaps, to as great a degree as those who wish to deny that the world's climate is changing. But nonetheless, the problem is that it is relative. Its effect on science is profound. I feel that it is no longer necessary to have scientific knowledge and non-scientific knowledge at conflict with one another. The holistic understanding is extremely important. I listened to a very compelling radio show by, actually, a chaplain for the United States Army, if we dare to wander into political environments again. He tried as ardently as possible to tell his military superiors that the war in Iraq cannot be won by kinetic energy alone. It cannot be won by physics. If you try to say, "Well, we can blow up more things than the enemy, thus we can win," that's wrong because the non-scientific motivations of those who are in Iraq and are not happy with the Americans there. Those are very strong, and perhaps even stronger than the amount of physics we can induce in that part of the world. We must take all of this together as carefully as possible, and it's a shame that we all can't. But it is a very difficult question. Even the wise men of our civilizations have struggled with this question, just as we struggle with it today.

Nanopoulos: I have a little different answer for this one. I don't know Dawkins. I know the book, but I have not read the book. I don't need to read the book.

Liu: You need to read the book, Dimitri.

Nanopoulos: What I mean is—in a matter of time I would love to have time to read the book. But what I'm saying is that we live in the world that you are describing, in an idealistic world. That's the world, maybe, eventually we will live in. I mean, we're not living in such a world. And I think that Dawkins, who is a premier scientist in biology, took the time to write such a kind of book because we're living in a very extreme, hostile environment against science, right? You have to keep in mind that someone should answer—I'll be careful with my words now—to intelligent design and all these things that are going around. And all of us, we sit in our offices and we do our jobs, and we stop smiling for this kind of thing. But a lot of people there don't have the same kind of data that we have, right? Again, I have not read the book—maybe he is overdoing it, I don't know. But I have a lot of respect for him as a scientist. I have heard him speak, and I really have respect for him. But someone has to do a few things like that. There's a French author, also, who has done the same thing. I don't believe that the world has to be hostile. I would love to have a world in which all these things could coexist.

Liu: No, Dimitri, you're right. You're right. We do not live in an ideal world, and we have to have, I guess, soldiers on both sides fighting the bad fight in order that the truth comes out. But yes, I agree with you that if we use the blunt instrument of, "You know, you guys are superstitious, bang, bang, bang," we're going to have a problem. As we all know, the truth is complicated, and we must not assume that people we're trying to educate are too stupid to understand that. We must come and explain to them, in my opinion, that intelligent design is an idea, and evolution by natural selection, shall we say, is an idea. What are the differences between the two of them? One is a scientific theory whose hypotheses have been confirmed over and over again. One is a non-scientific hypothesis that either has never been proven or can never be proven by the basic premises of its hypothesis.

It's okay to have both kinds of knowledge, but when you are making a decision about how you're going to run your country, or how you're going to run your life, or how you're going to raise your kids, you must know the difference and decide accordingly. And I am willing to go that extra mile, take those extra minutes or hours or years to give folks that enlightened—better not use "enlightened"—that additionally educated opinion or educated knowledge—so that they can make that decision for themselves. It's not for me to make it for them.

Nanopoulos: I'm in 100% agreement, but they should know what kind of alternative is there. I'm not going to tell them what to do, but at least to know what is on the table.

Audience: Given the expertise in the room, I wonder if you could talk more concretely about some of the revolutionary observations that you referred to in the beginning within cosmology in the last ten years so we can be enlightened. And I do use that term enough to know what the latest debates are.

Nanopoulos: I would start with the observation that they found that the universe is not only expanding, but is accelerating. That came out about '98. And then what they saw is this object that they call supernova. And we take light from there with telescopes and what they found is that these objects were a little further than they would be in a normal, so-called "universe" for this thing. Now we have a lot of evidence that we're living in a universe that is not only expanding—because usually you would expect the universe to expand with deceleration, right? We had this big push in the beginning: gravity is attractive, as we know from when we were kids and we were falling down, right? We would expect that the universe not only expands, but it accelerates. In order to see that it is accelerating, there must be a new force somewhere there to help it to fight against gravity. And that's the force that in the beginning the journalists were calling "dark force." She was calling it "dark energy"—I mean, we all call it the "dark energy." So that was something that was unexpected. I have to say it was cold water. I was in this meeting in Marina Del Rey in California in February of '98, and it was really cold water. It was a good group from Berkley and from Harvard, so we knew that was no funny business there—it was real. It was cold water. We were really surprised, and we still are, but we've gotten used to it.

Audience: Is that hypothesized, or has it been proven?

Nanopoulos: It's proven—it's experimentally proven.

Lavin: We're measuring a form of energy, essentially.

Audience: I didn't get what the new force is doing.

Nanopoulos: The new force is somehow against gravity. Gravity tries to pull the whole thing back, but this thing is a little bit bigger. We have one force that way, one force the other way, right? And this force is not one of the usual forces.

Lavin: It's definitely gravitational, but we still don't know exactly.

Nanopoulos: While we have the framework of what is happening, we don't have at this moment the model. But it is a well-accepted model that they put on the table, saying, "This is the model—the Hut-Lavin model or whatever it's going to be, right?" The other thing was, which I think is also fantastically interesting, is that we have this WMAP which is a kind of NASA satellite that observed that in the beginning, we have the universe that was expanding, and we have a lot of energy, and the universe is—the temperatures were very, very high. As the universe is expanding it's cooling down. And still we have what we call the cosmic background radiation. This has been measured not very far from here—'65 Penzias and Wilson—and they found out that it's something like 2.73 degrees Kelvin. That means if you go somewhere in the universe, if there's nothing there, it's going to be 2.73 degrees Kelvin. Now, we're living in a universe that was homogeneous and exotropic—that means that everything is in perfection—you would expect for this thing when you look around, and everywhere you look it would look the same. So it was imperative that when they make better technology at some stage, if they look at this part of the universe and this part of the universe, to see a little bit of difference in the temperatures. So what is happening is that they measured these kinds of differences which—we're talking about almost one per million. That means a one-per-million difference in degrees Kelvin, right? And it's because of these differences that we are living here today. And it's an amazing kind of measurement. The precision is beyond any expectations, and also, because people in the beginning of the '80s had predicted what kind of fluctuations we were going to see, and this fluctuation—if you see the curves the experimenters produces, and the theoretical predictions, you cannot see the difference from there. That confirms that we have a kind of picture that we know what they're doing, and that's why I was saying in the beginning, it goes back—I mean, the measurements that they take, they look at the universe as it was 380,000 years after the Big Bang. Of course, the reason that we can do this is because the light has a finite velocity. Now, if you go further back and you have the technology that we have now, we can go and see these things as far as we can, and today we've reached the point of 380,000 years after the Big Bang, which is fantastic. It never happened before.

Liu: If I can mention two real quick scientific discoveries within the past 12 months. One is called the discovery of the Baryon Acoustic Peak—the Big Bang. This means that basically a bunch of people mapped millions of galaxies and tried to see if there was a pattern, and sure enough, they're like ripples in a cosmic pond, which suggests, indeed, that something actually happened, like a Big Bang. We'll get more detailed technically if you want. The other—and this is building on what Dimitri is saying—is the discovery of the polarization signal of the cosmic microwave background, which means that early on in the history of the universe, there was an interaction between the expansion of the universe and something called the "hyper inflationary expansion" of the universe—something that is necessary to make our universe the way it is today. There has never been any experimental suggestion that this hyperinflation actually happened, but this is the first time that it might have. These are just two simple things that happened in the past year. We can talk in greater detail later.

Audience: I guess I can direct this to Mr. Tu. It's the notion that politics is not scientific. And yet it can be, and must be, in order to recognize where these theories are coming from in terms of cosmology. Why? Where? We have to understand these things. When you started talking about how the universe is expanding, and that it's finite—I was taught that it wasn't. From a political point of view, I went along with it. But now you're saying it and I accept it. Who am I? I don't know science. But this is so important about this whole scientific question because there's no other way most of us are going to learn these things. And it's because of the political question—at least to understand the scientific factors that prevent progress of all of our minds, or most people's minds. So this thing has to be taken very seriously. You all seem very unified on this.

Nanopoulos: It's not politics if it's Republicans or Democrats. It is the politics of how science is going through the people. Because if we miss this thing and if we lose out of that, then why are we doing this? I mean, will we become a kind of sect like the ancient Egyptian sects, and we'll speak to ourselves. We'll take our Nobel Prizes and go home and we're happy, and society will pay no attention. We will come to an end like that, right?

Liu: Professor Tu, I am very interested in what you have to say about this, especially in your comment of scientism—the way that, for example, current Mainland China is really following a scientistic religion, almost. Please talk to us about that.

Tu: It's a fascinating question, and it's an important one. I totally agree with your description of what a good scientist is doing. Once the good scientist begins to address questions that are not directly related to the scientific work, the person, in fact, can simply be falling into a certain kind of ideological struggle, or actually plays the role of a public intellectual of the scientific community. For any professionalized work—the humanities or psychoanalysis—you have people who are dedicated to very specialized inquiries, and you find the truth, the structure that actually works, and you don't have time to deal with the non-scientific community, because that's how you become a first-rate scientist. Yet the scientific community itself has such power, influence and authority. And so a lot of people, as you pointed out, misuse science, abuse science, in order to advance their agendas. Now, the scientific community—these first-rate scientists doing work very, very well—not only well-conceived, but very detailed experiments—are also important intellectuals in the community, and they have to play the role—some of them, not all. You know Steve Weinberg—you may not accept his view. I think you like him.

Nanopoulos: Yes, I like him.

Tu: A lot of people believe that he's a missionary, right? He's atheist; he's a missionary. And then you have Professor Gingrich.

Liu: Owen Gingrich.

Tu: You take him seriously in the following sense: he would not talk about the intelligent design in terms of capitals. He used the small letters. So he opens a new area for some kind of communication. Now, you may consider that totally unacceptable within the scientific community, and that's fine. But the question is important. The question raised here: how to deal with this particular issue.

Audience: I'm synthesizing an earlier question—the very good question you asked about advances. How does this affect our view of man? I mean, man is prized as a creature both of sexuality and consciousness. I can think of two ingredients that you can ascribe to man—sexuality and consciousness. Well, the sexuality part you can put to the side.

Audience: It cannot be put aside.

Audience: But consciousness seems to be able to, for instance, exist without corporeal essence. If you talk about the creation of robotic creatures, that means we could have consciousness existing without Man as we know it.

Lavin: I'm inclined to address the Turing machines.

Nanopoulos: That's right. I disagree on many points with Penrose, but maybe here is a point where I would agree with him: I don't know if artificial intelligence is going to give the whole consciousness kind of thing. From the point of view that we have it now goes to Gödel's incompleteness theorem, with a meaning that maybe it is this algorithm that we're talking about. She has it in her book on this, also—that algorithm that we're talking about, because a robot is going to have an algorithm to make it work. Maybe that's not enough, finally, to give the whole thing. By saying this, I'm not saying that humans are something special from the other parts of the evolutionary process. But maybe I believe that the robotic stuff—we will have to be a little bit careful if it is going to ever correspond to the kind of thinking we have. I'm talking about from a materialistic point-of-view. The involvement may be that the quantum comes into play. Now, if it is possible to copy, completely, our brain, then we'll be fine for this thing. But then you have a complete copy, and that would be a different kind of thing. But with algorithms—to do programs—I think we're going to have a problem there.

Lavin: If I could just touch this quickly—Alan Turing is the great mathematician, famous code breaker, really amazing person, who was the first person to realize that, in some sense, thought could be mechanized. He's the first one to sit down and say, "I can write a simple program that could teach"—well, he didn't say it this way, but—"could teach a machine to think." He really is the father, therefore, of software and computers. So after Turing has this leap that he could make a simple algorithm to get a machine to add or divide or multiply, you have the whole world of artificial intelligence, saying, "Well, then I can simply design a brain. If I can make an algorithm, then I can get a brain to do what the human mind can do." The problem where that breaks down is that you can actually prove that you can't—the human mind is not capable of writing an algorithm complex enough to make a conscious brain. However, what you can also show is that since we evolved from simple algorithms, so to speak, maybe you could write a few simple algorithms and get them, numerically, on a computer, in some sense to evolve. And those algorithms could evolve a complexity that could be great enough for consciousness. So I can't design a conscious mind.

Audience: It's the emotions—is the robot going to develop subjective emotions?

Lavin: There's no reason not to think that they wouldn't also follow out of algorithms, and that the algorithms are just much more complicated than the kind of simple mechanistic one that I might be able to write. I can write an algorithm that gets two black holes to fall together under some force laws, but I can't get consciousness that way. But it doesn't mean it's not possible; it just means that I'm not complex enough to design something like that.

Audience: That's the way Freud theorized it: conflicts between different forces.

Nanopoulos: Don't forget a man called Gödel. This is a very, very important thing. He was a kind of—at the end of his life—a weirdo. But this theory that he proves, or the class of theorems that he proved—that somehow you need something more than an algorithm to decide between—because he was talking about the Turing machines and stuff like that. So this is going to be with us all the time—the axioms—you cannot prove the whole story. You feel that it is true, but you cannot prove it formally with the tools mathematicians are using. But I think we're so far behind getting to a point that—I'm sure that we're going to build robots. We have a long way to go with robots, and Piet was correct when he was saying that we are using objects not subjects for these things. It's not that I would like to push all this into the future, but, again, with respect to the units that he was talking about, we are very far behind in building subjects instead of objects. I think we are going to see—I don't know if this generation is going to see them—a fantastic robotics evolution for this kind of thing.

Audience: I liked the fractal idea as one kind of guiding principal. But I wanted to throw another kind of wrench into this. From the psychological point of view, there's a lot of discussion about myth and so on, and of course the truths that we hold to be true can be scientific truths. Those are the ones that we sort of all agree on as being true, but they're provisional. So there's really no clear relationship between truth and conviction. I say that because, from a psychological standpoint, both in normal subjects and in pathological cases—either psychopathology or organic brain pathology—false beliefs are held with much greater conviction than true ones. This is a really an interesting phenomenon: whether it's a delusion—a psychotic delusion. There's the debate between George Moore and Wittgenstein about rock bottom beliefs—I mean, Moore said, "This is my right hand. That's a rock bottom belief." And Wittgenstein did a monograph on certainty. Appealing that this is a rock bottom, a core fundamental belief: "This is my right hand." But Wittgenstein's brother, as you know, had lost his right arm and probably had phantom limb phenomenon. If he closed his eyes, he would have sworn that his right hand was still there.

Liu: To any given individual, conviction may not be distinguishable from truth. But to the universe, there's a big difference.

Nanopoulos: There is an objective reality, and this is what people with common brain or common mind put together as true.

Audience: As human beings, all of us know that we don't choose a reality, but for the self the objective reality—this chair has an objective quality. But your emotions and my emotions are very different from each other. There is a qualitative difference. And to make everything identical seems to be not to understand the complexity of reality. Of course, the history of human thought—

Nanopoulos: Science by definition is related with these objects that we all consider common, and we all have a common sense of them. Then, we have this other kind of thing like a poem, which different people may have different reactions to. I'm not saying that they're different kind of weights, but I'm saying that this is something that is definitely real and then we can discuss this kind of thing. I don't know—in the future the neuroscientists may explain all of this—what it means when I hear a kind of nice poem, why most of us consider it to be a nice poem, and what it does to our cells—what synapses are going up and down to give me this kind of esoteric euphoria. But again, we have a long way to go. But at least for the moment, science—and I am talking about physical science—is related with these things that we all perceive to be common.

Lavin: And I think most scientists—I was just going to say that most of us have an emotional reaction to the things that we discover. I think that's widely underestimated.

Nanopoulos: Scientists also are human beings, with all kinds of emotions. Of course you take this into account. We try as much as we can to leave these things and be as objective as we can.

Audience: Someone said earlier that human life is the contamination or the germ that causes space/time to bend. I was wondering if you could explain more what that means.

Nanopoulos: What it means is we're falling, I think. We were saying that we know now, within a few percent, what the stuff is that the universe is made of—the elemental stuff, the fundamental stuff. And this is dark energy, most of it—20 or 23% of what we call "dark matter"—and we more or less know what that's about. We're made up of 4% of this thing. So for the whole fundamental stuff, we're really contamination for this stuff. Why we say this is because of Einstein's relation between space and time and matter—the curvature of space and time is related with the energy content of the universe. If you look at Einstein's equation—we're going to deep water here—on one side it is just the geometrical notion, which are the space/time properties. On the other side, it is the energy material—the energy matter material of the universe.

Audience: How does that relate to the idea of the beauty of the universe?

Nanopoulos: Oh, the beautiful universe? I don't know. I think we cannot see—the universe is the universe, right? By definition it's beautiful, right? What can we say on this? It's not like a nice lady or a nice man—you change your opinion. I mean that's it.

Liu: You're speaking like Job: how do we know the will of God? How do we know it's beautiful? Because we say so.

Lavin: However, we do use aesthetic principals to solve problems and that's really strange. You have Murray Gell-Mann, a Nobel Prize winner, who comes along and says, "Oh, if I arrange things in this nice, symmetrical pattern, there's a particle missing that we've never discovered in the universe. I'm going to propose that that particle exists, because now it's a nice, beautiful symmetric." By beauty, here, he means symmetric—literally referring to symmetry. And low and behold, we discover this particle.

Liu: And we call it "Beauty."

Lavin: We call it "Beauty."

Nanopoulos: You recall that they asked Einstein about some equations that were not beautiful. Someone was making a joke on him, and Einstein took it very seriously, and turned to him and said, “I leave aesthetics to my tailor.”

Lavin: He had a tailor?

Audience: I had a question in response to the idea of patterns, and you also talked about fractals and observing how different elements form along similar structures. I know they’re also about these underlying principals of physics and how they reveal themselves in everyday life. People have talked about the way the stock market moves or traffic forms or sea growth patterns happen. I was wondering if you had much to offer about that.

Lavin: Well, the brain is an example of a fractal. Usually what happens with your brain—you need a large surface area to get more and more clever, progressively, as we evolve. It would be very bad if our brains also had to have a bigger volume to do that. We’d have to have these really big heads, and that would become unstable. So what the brain does is it folds; they make folds on the folds, and then there are more folds on those folds. That’s classic fractal patterning. What fractals do is, they have a large surface area because of all the folds, but a small volume. You can’t do that without a fractal, really. Eventually you have to go fractal if you want to do that. So the brain is an example of how we become clever enough, with small enough heads that we can lift them. The blood vessels and the lungs have this kind of fractal patterning for similar reasons: you want large surface area, small volume. So there are examples. Ultimately, the way we think about the world can be related to the laws of physics that we inherited, and also our experimentation. I have a six month-old baby who is testing everything. “Is this hard? Is this soft? What does this taste like?” She’s an experimentalist, essentially. And we all are born that way, and that’s how we develop this intuition about where to lay our feet, how hard to press, how high to step, and all these things we have acquired through experimentation.

Nanopoulos: Also, you see this part of evolutionary biology. Among some of the subclasses there they were trying to explain why we are—on the outside—the way we are. Of course, this is some random evolution that we have. For instance, for the head—if we had big heads, when the chimps were up in the trees there, the ones with such big heads would disappear. So the smaller heads would survive. There’s so much stuff that’s built into this that have physical processes.

Liu: Let me just give you a real simple example: I have this little bit of water in the cup. If I swirl it like this, you see little lines in it. That’s why those spiral arms are there: the same process—a fluid swirling, creating density waves that are spiral.

Nanopoulos: Is it always there, or is it accidental? The art?

Liu: It’s all connected.

Liu: From everyday things come cosmic things. The fractal stuff is just one of the most elegant and beautiful things I’ve seen, but I can do that with swirling water like this. That’s an example.

Audience: In your research in cosmology, do you ever think about the causality of the universe?

Lavin: That's interesting. We think about it only in the context of the possibility that the universe looks like a ginger root, so that we're like a plume off of this root, and our Big Bang is like the trunk of that plume, and all we see is this branch off the ginger root, and we think that's the whole universe. We simply cannot see past what we call the Big Bang event, but it's possible that it was just a plume off a larger space/time where there have been many plumes. In that sense, we are contiguous with one colossal—you might call it a "multiverse" or "megaverse." I think that's the terminology that's going around—a megaverse, a bigger universe, which has many plumes off of it, each of which looks like it had a Big Bang. It might have slightly different features than the one we happen to live in. That's a tenable possibility. So to distinguish between those possibilities, we'd like to have data. We don't have data. You described being able to see back to the time when the universe was a little over 300,000 years old, but I can't go back far enough to really penetrate the creation—I mean, appearance—event. But that doesn't mean that there won't be data, and that there won't be data that comes in surprising form—that comes in the form of accelerator experiments where we're smashing together subatomic particles. We might discover things that tell us about how the universe was created.
So by looking at the large, we discover things about particle physics—about physics on the smallest scales. We might now be looking at the smallest-scale physics experimentally and discover things about the universe on a large scale.

Nanopoulos: Because don't forget that the universe is now big, but at some stage in the beginning it was smaller. That's what we're concerned about: its origin. The $64,000 question is, what happened at the origin.

Lavin: You're almost trying to reproduce those conditions—when it was small.

Nanopoulos: That's why we build these accelerators that are going to be in Geneva, for instance—the supercollider and stuff like that. That's what we want to learn about. It's all related.

Audience: One last question. This is really for Professor Lavin. You were talking about the fractal nature of the brain and the folds. Doesn't that have a counterpart in string theory, and the idea of there being folds in the folds, possibly representing different dimensions?

Lavin: There are definitely analogies with physics and with biology that can be pursued. In fact, in the book that you reference, *How the Universe Got its Spots*, there's a direct analogy between how certain cosmic patterns are imprinted, and how, literally, the leopard got its spots. Turing, by some coincidence of conversation, was one of the people who realized things about the leopard getting its spots. That analogy in particular would be a tough one to pursue—the one you're going for between the brain and dimensions—because it would almost be as though if our brain could occupy another dimension, it wouldn't have to be fractal; it could fill itself out in that other direction, so to speak. It's because, for whatever strange reason that we don't understand, if there are extra dimensions, we can't occupy them. I don't know why I can't stick my hand in that other dimension. There are theories that it might be too small, that it's literally wrapped up like a straw, that, in a sense, I am sticking my hand in it but I don't notice because it's going round and round and round the space. Or there are theories that we're confined to something called a "brane": B-R-A-N-E. It's supposed to be a joke. It's bad physics humor: P-branes, D-branes, that sort of thing. So that analogy might be difficult to pursue, but it's interesting to think about.