Amidst Rocky Peaks, Physicists Ponder The Universe

August 10, 2012

For fifty years, physicists have flocked to the Aspen Center for Physics to ponder their ideas amidst the serenity of the Rocky Mountains. The string theory revolution started there, and over the years the center has hosted 10,000 theoretical physicists—53 of whom are Nobel laureates.

IRA FLATOW, HOST:

This is SCIENCE FRIDAY from NPR. I'm Ira Flatow. How many pictures have you seen of Einstein in front of a blackboard, you know, scribbling equations, working through the math? That's how theoretical physicists spend their time, right? Either that or cooped up alone in their university offices with pencil and paper.

Well, in the late 1950s, a physicist named George Stranahan at a grad school in Pittsburgh at the time, he thought: Well, well, wouldn't it be nice to do all of those calculations with the Colorado Rockies, yeah, the Colorado Rockies as your backdrop? In his own words he said part of the theory was that since paper and pencil are the same in Aspen as Pittsburgh, and Aspen's a nicer environment, my work in theory would improve with this arrangement.

And so a few years later, in 1962, the Aspen Center for Physics was born, a place for physicists to rub elbows, to relax, do a little fishing, hiking, biking in the mountains and work on a Nobel Prize-winning idea. In the last 50 years, the center has hosted some 10,00 theoretical physicists, including 53 Nobel laureates, and my next guests are part of this year's flock of physicists, one of whom may have had too much fun in that Rocky Mountain high.

Michael Turner is a cosmologist and professor of astrophysics at the University of Chicago. He joins us from the campus. Welcome back to SCIENCE FRIDAY.

MICHAEL TURNER: It's a pleasure to be here.

FLATOW: Did I hear you had too much fun up there?

TURNER: I was having an awful lot of fun and crashed my bicycle and went to the hospital, and I'm now almost fully recovered.

FLATOW: Well, I hope you're doing well, Michael. I'm glad to hear that you're doing OK. Lisa Randall is author of "Higgs Discovery: The Power of Empty Space." She's also professor of theoretical physics at Harvard, and she joins us from the studios of Aspen Public Radio. Welcome back to SCIENCE FRIDAY, Dr. Randall.

DR. LISA RANDALL: Thank you, it's a pleasure to be here.

FLATOW: Well, you're there. For those of us who are not there, set the scene for us. What's it like there at the Aspen Center? What do you folks do all day there?

RANDALL: Well, it's a rather busy place to be because there's a lot of activities going on. You can make it as busy or not busy as you want. But there's a lot of physicists around. There are generally several talks a week. We have two different days where there's two seminars just in our program, the group of people interested in what we are interested in, and there's other talks, as well.

Then there's also public lectures, I gave one last night. Then there's also, of course, the necessary talking to your colleagues, which is really why you're there, to be able to catch up on what's going on but also to work on new projects. And then there's talking to your colleagues over lunch but also over a nice bike ride, which I'm actually missing the group doing the bike ride, so I took my bike ride this morning before they could make it because I'm here.

FLATOW: Michael Turner did a little bike riding, too, obviously. Glad he's feeling better. Michael, is it true that big ideas get started there, like string theory got its start at Aspen?

TURNER: Yeah, I think we've got a pretty good track record. String theory is one of the best examples. One of the key features of string theory today is super-symmetry, the symmetry between particles of half-integer and integer spin. And that aspect of super-symmetry started one summer in 1970 when Pierre Ramond came - got away from the usual distractions and was able to think.

String theory, in 1974, at a workshop in Aspen, at that time it was meant to be a theory of how the quarks were held together, and it got declared dead as a theory of the strong interactions. And at that workshop, John Schwarz said, you know, maybe it's a theory of everything.

And then for the next 10 years, the small number of people who were working on string theory used the physics center as their headquarters, and then in 1984 came a very big breakthrough when Green and Schwarz showed that the theory was mathematically consistent. And that really got things going.

So I think the formula of removing people, as Walter Paepcke, one of the founders of Aspen said, lifting us out of our usual lives. I think that formula has really worked in physics.

RANDALL: I also think that just being in a beautiful environment, it's calming, and you don't mind sitting still for long periods of time, talking to your colleagues, writing on a piece of paper and working. It's very comforting to be in a beautiful environment, to know that you could step outside and see beautiful things. And then you can go back into your head, and it's kind of very comforting.

FLATOW: Is it really a solitary job, thinking those things and writing them down?

RANDALL: It's not solitary, and that's why it's really great to have - we have workshops here. So a number of physicists with common interests, not exactly the same but related interests, will come at the same time. And there's plenty of opportunities to share ideas, to actually work together on projects, as well.

FLATOW: Well, a lot of people would like to talk about physics and schmooze with you about this. So I'm going to give the number out again, 1-800-989-8255. You can also tweet us, @scifri, @-S-C-I-F-R-I. And let me kick off the conversation.

Michael, are you - you talk a lot about dark matter. I know that's one of your great interests. And one of my questions is: If dark matter - if all we see, visible matter, is only four percent of the universe, and dark matter - and please correct me if I'm wrong - is like 20 percent, so the visible matter is all in the minority? I mean, most of the universe I dark. Why are things not made out of dark matter, then?

TURNER: Well, so it's even more interesting than that. So you've got the numbers right, but the - you can paint a sharper story here. So that four percent is the matter in atoms. We've done a very good accounting of how many atoms there are in the universe. Of that four percent, only a half a percent of that is in stars that we can see. The rest is still in hot gas that's more difficult to see. In fact, we typically only see it in the X-ray emission. And then you got it right with the 23 percent is the dark matter whose gravity holds together our galaxy, clusters of galaxies, and this puzzle goes back to Fritz Zwicky in the 1930s.

And we've worked ourselves into a very interesting point, which is there's not enough atoms in the universe. We have a good accounting of the atoms, and they account for only four percent of the universe, whereas the dark matter is more like 23 percent. So we've worked ourselves into this corner where we believe that the dark matter is a new form of matter.

And that's an idea that I believe we are on the verge of testing. The LHC, the Large Hadron Collider, will play a role. The dark matter particle could be directly produced there, very sensitive experiments that are placed underground to shield them from the cosmic rays are achieving the sensitivities necessary to detect the dark matter particles that hold together our galaxy.

And then occasionally, if our galaxy really is held together by dark matter, occasionally these dark matter particles bump into one another, annihilate into particles that are much easier to see, like gamma rays or positrons, and those techniques are very powerful. And right now, one indication that we might be on the verge of finishing off this puzzle is what I like to call is all the chatter.

So, you know, there was a paper a few months ago that maybe the dark matter annihilations in the halo of our galaxy had been seen in gamma rays. And the year before that, it was positrons. And some of the direct detection experiments have seen a signal.

But none of these yet have risen to the Sagan standard, that is if you make an extraordinary claim, you require extraordinary evidence. But we feel we're really on the cusp of solving the dark matter puzzle.

RANDALL: So Ira, can I make a few comments about this to you?

FLATOW: Sure, please.

RANDALL: So first of all, stuff is made of dark matter. The universe as a whole, in galaxies there's a lot of dark matter there. It's not true that we as human beings, we need light, we interact with light, and that's what makes a lot of our properties special, that's what makes us these huge processing machines.

But the galaxy as a whole does have dark matter around it. And actually one of the really interesting questions isn't just why aren't we made up of dark matter if there's so much of it but really why is the amount of dark matter, the energy stored in dark matter so similar to the energy density in ordinary matter?

You know, in principle, they could be very, very different. And so I think that's perhaps one clue to actually the nature of dark matter, to really understand that even though it's not interacting a lot, somehow there is a relationship, which gives us hope along the lines of what Mike Turner was saying that we can actually find it because maybe there is more of a connection than you would naively think.

And actually in terms of what he was saying at the end, that's actually the sort of thing that gets discussed even at the conference I'm at right now. We have a workshop that's mostly dedicated to Large Hadron Collider and particle physics, but there have been some interesting hints of evidence of dark matter from what's known as the Fermi Experiment.

And basically we all want to get together and really understand in detail what's going on, really get the nitty-gritty details that you wouldn't get otherwise, and so that's one of the reasons it's really nice to have this large group of people together.

FLATOW: Lisa Randall, author of "Higgs Discovery: The Power of Empty Space." Also talking with Michael Turner, professor of astrophysics at The University of Chicago. Our number, 1-800-989-8255. Gary in Washington, D.C. Hi, Gary.

GARY: Hi. I'm calling from the District of Columbia, and I have a question about physics in general. And do you feel that that your field is dealing in absolute true truths or in provisional truths? Because when I was a child I learned about Newton's law of gravity, which, of course, turned out to be a provisional truth and not a true truth.

RANDALL: So can I take that question because that's actually something I talk a lot about?

GARY: Well, (unintelligible) but I just want to, you know, when I see a lot of things that are frequently overturned, and it seems to me that that science mostly deals in what's utilitarian, because everything we discover that doesn't seem to have any utilitarian use, 20 years later, you know, we're developing something out of it that's very useful. But it doesn't seem to be any end-of-the-line truth that we get out of the science, but yet, it's very interesting and very utilitarian.

FLATOW: All right, Gary, thanks for calling.

RANDALL: That's right. And I think I'd like to turn that around because that's actually one of the virtues of the way we do physics. And one of the important themes that I talk about in the book that came out last fall, "Knocking on Heaven's Door," is the notion of scale and the notion of what we call an effective theory, which exactly addresses the question you're talking about. The fact is that at any given moment in time, there is uncertainty. We've measured things over a given range of parameters - distances, energies - to a certain accuracy.

Now, that means, though, whatever theory anyone comes up with has room for improvement. That is to say it's not necessarily the final answer. It doesn't mean it's wrong. Newton's laws are still correct. We still use Newton's laws to figure out the trajectory of a ball when we throw it, to figure out how to send things to the moon or to Mars. But, that doesn't mean that there isn't a more precise underlying theory. We wouldn't need it when we're calculating the trajectory of a ball because it doesn't give us any more accurate answer at the level at which we can make measurements.

But, if we look inside an atom, we get to these small scales where, for example, quantum mechanics is essential. If you get to high speeds, relativity is essential. So basically, that is the virtue of physics, and it's - I think, this is a really important point. It's actually one of the points that I emphasize, the - what uncertain - the role of uncertainty, the role of scale, in doing not just science, but basically any statement about truth is in some sense provisional. It covers the regions that you've studied, but that is why there's always room for new ideas and new theories. And I think that's great.

FLATOW: This is SCIENCE FRIDAY from NPR. I'm Ira Flatow talking with Lisa Randall and Michael Turner. Michael, can you define for us the difference between a cosmologist and an astrophysicist?

TURNER: Oh, that's a tough one.

(LAUGHTER)

TURNER: You get a lot of argument about that. So I think astrophysics has to do with the physics of the universe and the things in it, and a subspecialty has to do with cosmology - how the universe began, how it evolved, how it's going to end. And if I can make it even more complicated here, I like to divide cosmology into, sort of, two halves. One is sort of the reconstructing the history of the universe from, you know, dark matter and gas and atoms to stars and planets and galaxies and so on and so forth.

And then the other half - the half that Lisa and I are more interested in - has to do with the fundamental framework - so how did the universe begin, the questions that Lisa was asking. We now know the universe is made of a bunch of different components - dark energy, dark matter, photons, different kinds of matter - and trying to piece together the meaning of that, can we understand, you know, why we got the universe we got and what are the fundamental features of it.

FLATOW: Lisa, how does the Higgs discovery - it's sort of quieted down now, but it's certainly still being talked about - changed our idea of empty space? I mean, it's not really empty if it's permeated by the Higgs field, right?

RANDALL: That's right. In some sense, we knew that because we knew about dark energy. And I think it's a question of what we mean by empty - does empty mean no matter, or does it mean nothing? Because even if there is no actual matter, there can be energy present. There can be essentially charge present. And that's actually what's going on with the Higgs field. It's a very abstract concept. It's funny one of the most difficult things when writing the first book was describing this Higgs mechanism because it is so abstract, because it doesn't involve actual particles.

But nonetheless, in the presence of a Higgs field, which is basically something that permeates the universe, it's there everywhere, and it's effectively something like a charge. And particles have to travel through that charge-like stuff, and when it does, they acquire their masses. You might say why didn't they have masses right from the beginning, and that's because it actually would be inconsistent. You would make nonsensical predictions, like probabilities of interactions greater than one.

So you need a mechanism for these particles to get their masses. And in fact, the Higgs mechanism is the only way we know to do this consistently. So a lot of us were fairly confident the Higgs mechanism is right, this idea of having empty space full of this charged-like stuff. But the question is, first of all, is there real experimental evidence, and second, how did it happen. And that's why finding this Higgs boson is so important, because, first of all, it tells us the Higgs mechanism is right, and it also lets us go beyond the standard model, somewhat in the sense of your previous caller - how do we get beyond what we know now to see what underlies it, sort of look under the hood and see what's really going on.

FLATOW: Thomas Hogan(ph) on Facebook wants to know, is there an anti-Higgs boson?

RANDALL: Actually, the Higgs boson is its own antiparticle. It's a little bit confusing because there could be a more complicated, what we would call, Higgs sector. And in fact, in the early universe, there are sort of in some sense different types of Higgs particles. And so you can talk about antiparticles, but the Higgs boson itself, the one that's discovered in the experiment, is its own antiparticle.

FLATOW: It's the vanilla kind then, as they - I've heard it described that was discovered.

RANDALL: Yes. It's vanilla because it's the simplest model, and it's there by itself. And we really believe that there should be other structure along with it, which is one of the reasons, at least, I am so excited that they're going to run a little bit longer and measure its properties more precisely to see really is it this vanilla Higgs or is it something more exciting.

FLATOW: All right. We'll keep those fires and lights turned on, though. We're talking with Lisa Randall, author of "Higgs Discovery: The Power of Empty Space," professor of theoretical physics at Harvard. Also, Michael Turner, a proudly wearing cosmologist and a professor of astrophysics at The University of Chicago. Our number, 1-800-989-8255. You can also tweet us, @scifri. And we'll be right back after this break and schmooze a bit more about physics, so stay with us.

(SOUNDBITE OF MUSIC)

FLATOW: I'm Ira Flatow. This is SCIENCE FRIDAY from NPR.

This is SCIENCE FRIDAY. I'm Ira Flatow. We're talking about physics this hour and especially about dark matter and the Higgs boson with my guests. Lisa Randall, author of "Higgs Discovery: The Power of Empty Space," she also wrote "Knocking on Heaven's Door: How Physics and Scientific Thinking Illuminate the Universe and the Modern World." Michael Turner is a cosmologist and professor of astrophysics at The University of Chicago. Michael, we were talking about adding all those numbers up and a bunch of tweets came in, doing your arithmetic and said, well, if we've got 4 percent visible matter, dark matter is 23, what's the other 73 percent made of?

TURNER: Well, that's my favorite subject - dark energy.

FLATOW: Go for it.

TURNER: And so, you know, just when we were starting to think we could see the light at the end of the tunnel with dark matter and getting our heads around that most of the matter in the universe is not what we're made out of. All of a sudden comes along the fact that the expansion of the universe is speeding up, not slowing down. Of course, we would have expected it. For years, 70 years, cosmologists expect that gravity would be slowing down the universe, and instead, we find that the universe is speeding up.

And we can sort of understand that because within Einstein's theory of general relativity, gravity can be repulsive, very strange stuff has repulsive gravity, stuff that's very, very elastic. And we give it the name dark energy. It accounts for most of the universe. And what's sort of fascinating about this is this illustrates how science works. This discovery came along in 1998. This past December, Adam Riess and Saul Perlmutter and Brian Schmidt got the Nobel Prize for this discovery.

This discovery kind of completed our current level of understanding of cosmology and then gave us a brand-new puzzle to work on, which was so what is this weird stuff that has repulsive gravity? And so far, we have not made that much progress on what it is. It could be yet another example of empty space not being so empty. It could just be the energy of empty space having to do with quantum fluctuations, or it could be something as exotic as the influence of unseen extra dimensions, or it could be that it involves having to modify Einstein's theory of gravity.

Again, along the lines of what Lisa said, is that all of our theories are provisional. They described nature as best as we can, but when we get - when new facts come in, they often change the way we describe nature.

FLATOW: Einstein said - described gravity as geometry, didn't he? He said the mass of bodies actually warps space, and experiments we've done showed that to be true. How would you have to modify Einstein's theory of gravity to make it fit this sort of antigravity idea as expansion?

TURNER: Well, we can...

RANDALL: Actually, the - I'm sorry.

FLATOW: Go ahead.

TURNER: Well, we can - Einstein found an elegant way to describe gravity as the bending of space but we - it's often useful to use the alternative language. I'm thinking in Newtonian way. And so when I was saying that the gravity of this stuff is repulsive, I was thinking more in a Newtonian way, but it fits right into general relativity. And general relativity can accommodate it. But the big question is, does it really accommodate it, or do we have to go beyond general relativity to understand this.

For example, I'll give you one idea that doesn't seem to be panning out. I was involved in this idea. And the idea is that when the universe becomes very, very empty, it starts accelerating. And so we spent some time looking for a theory of gravity that would do that. We found a theory of gravity that would do that. Unfortunately, that theory of gravity didn't do a good job of describing the solar system.

FLATOW: I hate it when that happens.

RANDALL: So actually, one of the real problems of dark energy is, surprisingly, not just why is it there, but as Michael said, quantum fluctuations provide dark energy. It's there. The question is, why does it take the value that it does? In fact, if you put together quantum mechanics and special relativity and just try to predict what you'd expect. You'd expect the energy to be enormously bigger than we actually measure it to be. So the real question isn't just why is dark energy there? But why does it take this value it does?

And getting back to the point I made earlier, why is its energy at all comparable to the energy that we have in dark matter and ordinary matter today? That's part of the big mystery that we have. And since we're talking about the Aspen Center for Physics, I just want to mention that tomorrow I'll be moderating the panel. And actually, Adam will be one of the people speaking about his Nobel Prize-winning discovery.

FLATOW: Adam Riess. 1-800-989-8255 is our number. Lots of people want to talk about physics. Let's go to...

actually Adam will be one of the people speaking about his Nobel Prize-winning discovery.

Adam Riess. 1-800-989-8255 is our number. Lots of people want to talk about physics. Let's go to Greg in Boise, Idaho. Hi, Greg.

GREG: Hi. How are you doing?

FLATOW: Hi there. Go ahead.

GREG: So my question is regarding gravity. And I'm wondering whether it's causal rather than particulate, and I'll cite a couple of the things that I've seen recently as far as gravity seeming to affect things like molasses, where as the Earth moves through space, the gravity seems to be an inch short on the incoming side and an inch long on the outgoing side. It's like gravity doesn't immediately affect something and takes a second to quit affecting it. And then a number of the other experiments that seem to show the speed of light being a variable depending on the environment that it's in, i.e. high energy, high density environments can, in some cases, cause the speed of light to be a little bit higher and low energy, low density situations seem to have the possibility like a Bois-Einstein condensate to be able to slow light down. And I'm wondering...

FLATOW: Yeah. Quickly.

GREG: ...if gravity is purely because you have energy in particles that are effectively limiting that point in space to specific features that you are then causing the adjacent areas in space to also be limited, which is what is causing gravity because you cause kind of an inward force because of those limitations.

FLATOW: Thanks, Greg. Any reaction to that, Michael or Lisa?

TURNER: Well...

RANDALL: Well...

TURNER: ...Greg has a couple...

RANDALL: Go ahead, Michael.

TURNER: Greg has a couple of questions in there, and so I'll pick at one of them, which has to do with the speed of light. So the apparent speed at which light moves through materials, glass or water, can be less than or even, in some cases, greater than the speed of light in vacuum. And we understand how that works. That's called the phase velocity. A very interesting question that has to do with this grander idea about the laws of physics is are the laws of physics the same everywhere and constant with time? And are things like the speed of light constant or do they change?

And remarkably, the universe provides us a laboratory where we can address those questions of whether or not the laws of physics are the same here and across the universe. And to date, with a couple of tantalizing hints, remarkably enough, the laws of physics do seem to be the same everywhere and not changing with time. So there's a couple of hints, one of which could involve the speed of light that maybe some of the constants of nature change with time. But right now, the evidence is not very strong. But the question is a very interesting one about the laws of physics - are they always the same and are the constants of nature always the same?

FLATOW: Lisa?

RANDALL: Right. And I think the connection between the speed of light and causality was also a really important one. We - in order to write down our physics theories, we need to be able to make causal structures. And when we lose that, we have no idea what we're doing. And that's one of the reasons that...

FLATOW: What do you mean by making a causal structure?

RANDALL: Well, in the sense that if I do something here predicts what happens in the future. And if you have things in the past that can affect you, then all the laws of physics would break down. Now we don't know for sure that this is necessarily true, but certainly in the way we've done physics, that's the only way we can make sense of it. And that's one of the reason that - and that is connected with this maximum speed of light.

So it is true that, in principle, the speed of light could have changed over time. There's no evidence for that now. And it is true in principle. It could even have been different in different places. But if that's true, again, that would be a really big deal. That would break symmetries of the universe, the idea that things don't look the same in every direction, that they're the same in every place. And when we do physics, that's a basic underlying assumption we have. Yes, it's true that we can have different forms of matter, different objects that break that symmetry, but underlying it all, we have these laws of physics which are the same everywhere. And if that turns out not to be true, that would be a very radical development.

FLATOW: Does that mean new physics? We need new ideas in physics?

RANDALL: That certainly would be new ideas, yes.

TURNER: Well, we know we need a few new ideas. Coming back to cosmology, dark matter, dark energy, inflation, those seem to be aspects of the universe, and they're not in the standard model that Lisa was talking about. And so while the Higgs completes the standard model, I think everybody hopes that there will be some clues at the Large Hadron Collider, maybe even in the properties of the Higgs itself, that tell us what this grander theory looks like that incorporates dark matter, dark energy and inflation.

RANDALL: We should keep in mind, though, that in the context of the kinds of ideas we do in particle physics, there are many possible candidates for dark matter. It doesn't mean we know what dark matter is, but in the context of the kind of particle physics we do, we can come up with ideas of what they should look and what it could possible be. Dark energy is, in fact, much more mysterious. It's much harder to come up with a consistent theory where dark energy takes this particular value. So it really is on a different footing from the point of view, at least of those us there at the conference.

FLATOW: That would require really new physics to figure out what the dark energy is.

RANDALL: Well, again, why does it take the value it does? I mean, that is the mystery.

FLATOW: And why did it start at a certain time? Why did it kick in after a certain number of billion years of the universe?

RANDALL: Well, that we do understand because the dark energy, as we understand it, I mean, it's defined by its gravitation properties , and it's been there all the time. But it's just been too small for anyone to notice it. But as the universe expands, radiation dilutes, matter dilutes. Radiation actually dilutes faster than matter. So, in the beginning, the universe was dominated by radiation energy, then it's dominated by matter energy. But all of that stuff does - it's historic energy. It's like the tortoise. It just stays there, so it doesn't dilute. So eventually it has to take over.

TURNER: Although there was a deeper question that Ira had there also, which is let's suppose that the dark energy had been bigger and had kicked in earlier. Then if it kicked in too earlier, too much earlier, galaxies wouldn't have formed. And so that is a bit of a mystery. It's got many mysteries within it.

FLATOW: Yeah. We love talking about mysteries, and then - here on SCIENCE FRIDAY. And I want to thank you both for joining us. Michael Turner, cosmologist, professor of astrophysics, University of Chicago. Lisa Randall, author of "Higgs Discovery: The Power of Empty Space" and "Knocking on Heaven's Door." Have a great summer, and then keep thinking those big thoughts for us.

RANDALL: Thank you very much.

TURNER: Thanks, Ira.

FLATOW: You're welcome. I'm Ira Flatow. This is SCIENCE FRIDAY from NPR.

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