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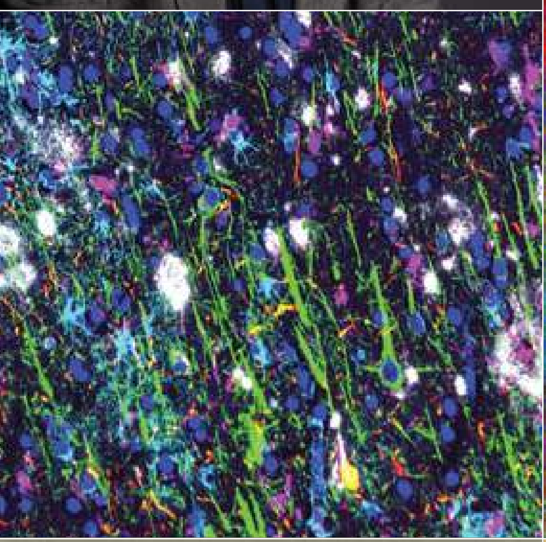
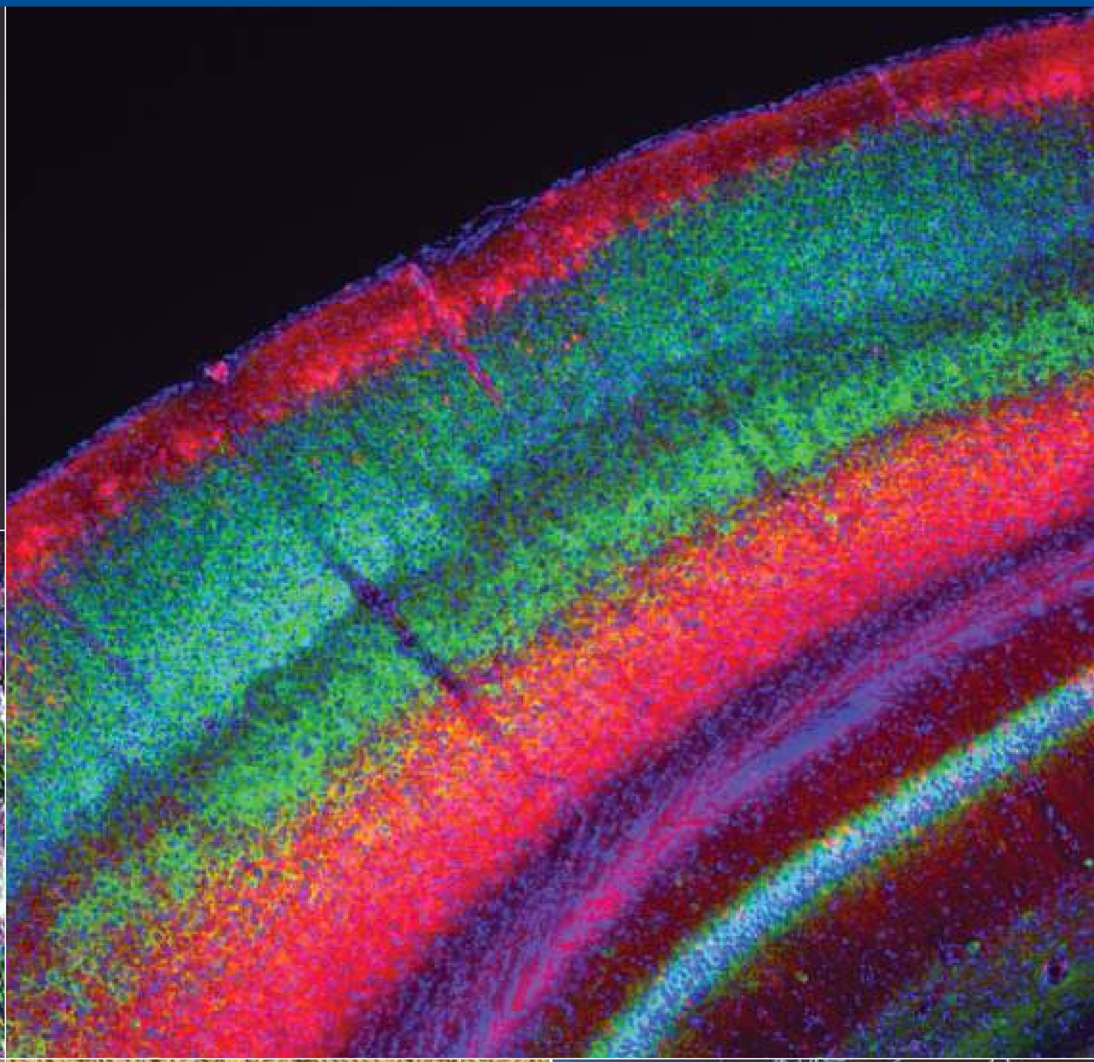
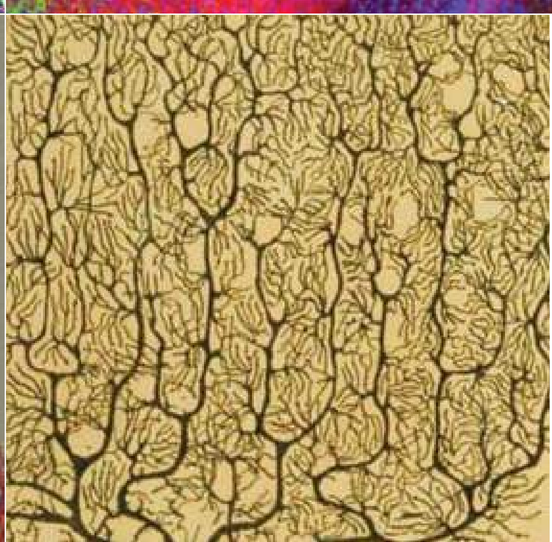






Timeless and Borderless Adventure

Conversation with Cumrun Vafa
Professor of Physics, Harvard University
Chairman of the SCGP Board of Trustees

Interview by Maria Shtilmark

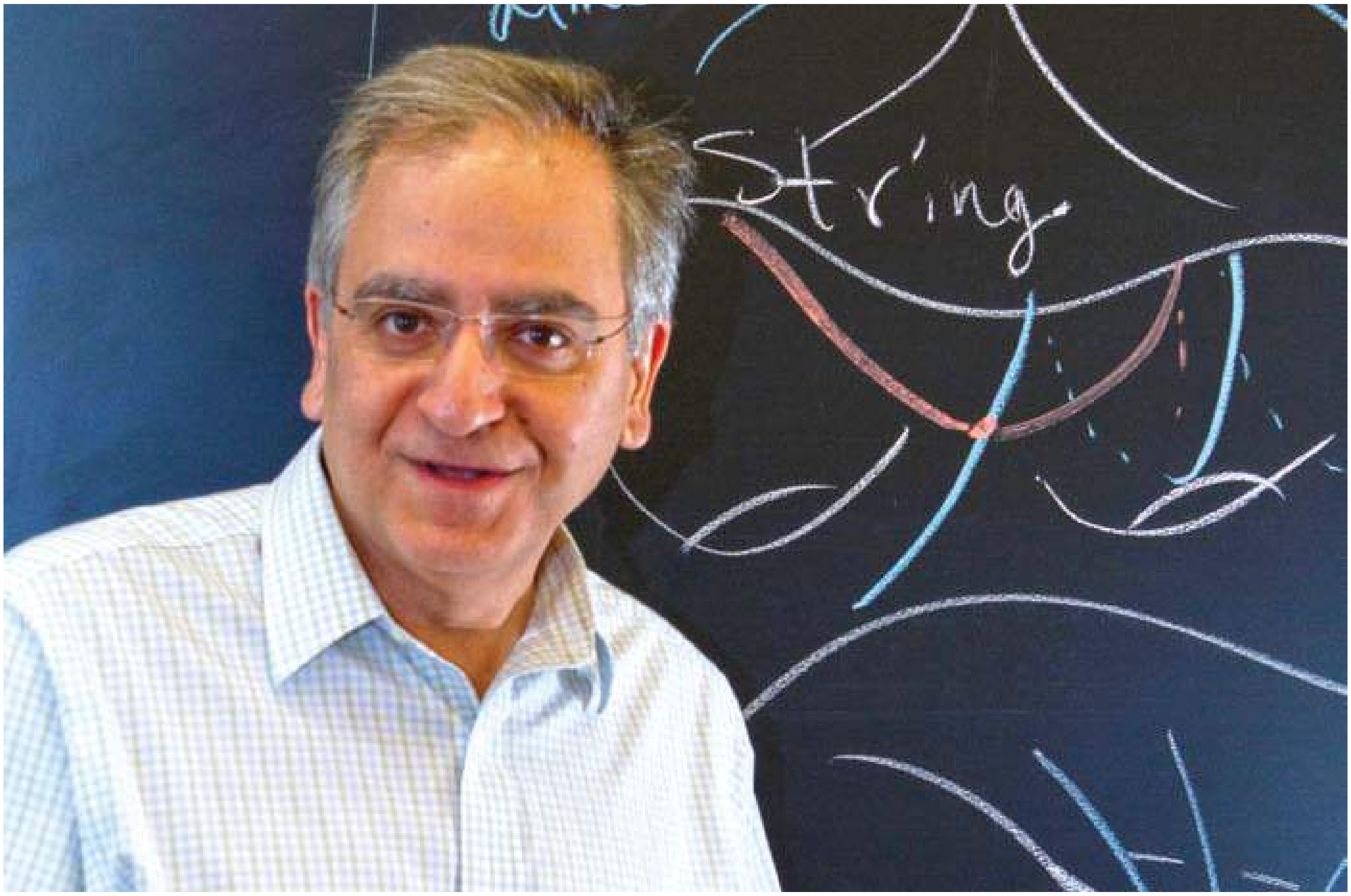


Photo: Hayward Photography, Milton, MA

The recipients of the 2017 Breakthrough Prizes were announced on December 4th, 2016, marking the organization's fifth anniversary recognizing top achievements in Life Sciences, Fundamental Physics and Mathematics. Dr. Cumrun Vafa, along with Drs. Joseph Polchinski and Andrew Strominger, was awarded the 2017 Breakthrough Prize In Fundamental Physics for his research in transformative advances in quantum field theory, string theory, and quantum gravity. Dr. Vafa has a rich history with the Simons Center. He joined our Board of Trustees in 2005 and has served as its Chair since 2009. He has also served as the Scientific Director of the annual Simons Summer Workshop since 2003, and visits the Center regularly. The Simons Center is pleased to formally congratulate Dr. Cumrun Vafa and all of the winners of the 2017 Breakthrough Prize In Fundamental Physics. Our heartfelt congratulations to all!

Congratulations on becoming a laureate of the 2017 Breakthrough Prize in Fundamental Physics "for transformative advances in quantum field theory, string theory, and quantum gravity." As this definition is a bit broad, what do you consider your main contribution?

Thank you. I don't take the credit personally and view this as recognition of not only my own work, but the work I've been doing with many people, with many different ideas. I've had over 150 collaborators, close to 170 now, written over 250 papers, and I can't say that one particular paper was the reason. It may have been the combination of them. I feel part of the group, where there is camaraderie between colleagues. The fact that they have chosen my two colleagues and me is kind of them, but I view this as not just us.

As to my work in general, the overarching theme has always been the connection between physics and mathematics, particularly in the context of geometry. How can we learn physical facts from geometry, and how we can learn geometry from physical facts? Many of my works are at the interplay between these two subjects, which cover a wide range of topics in physics, quantum field theory, quantum gravity and string theory. It seems to me that the bulk of progress in string theory lies in these relations between geometry and physics.

You graciously acknowledged all your collaborators on the Breakthrough Prize web page and thanked them. Not everyone does that!

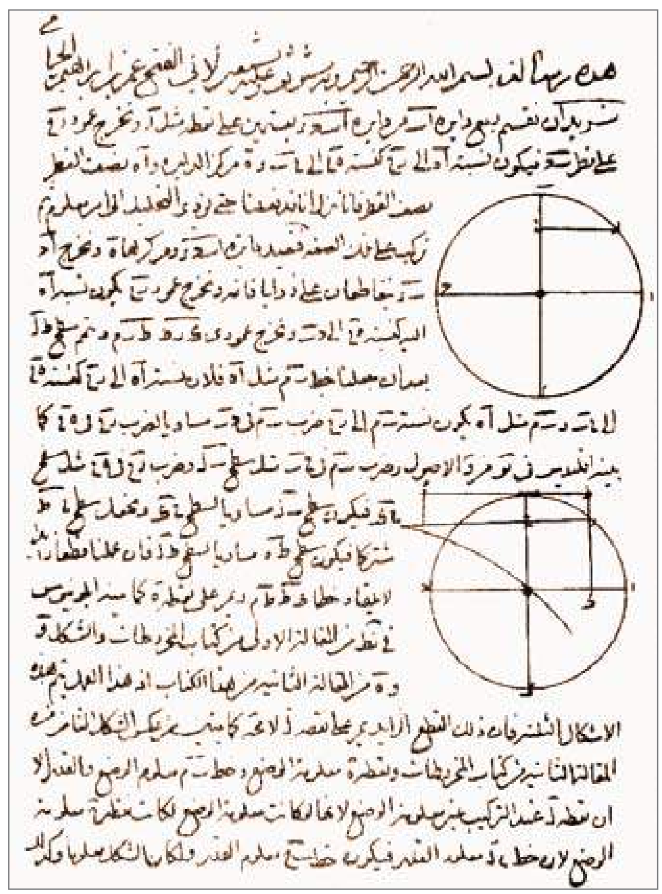
Thank you. I specifically contacted the InSpire and asked if they could help me collect the names, which was at the time when we were not supposed to let the news get out, so I couldn't tell them why I needed it. Unfortunately, in the InSpire's database, they can only list the collaborators up to a hundred. And I knew I had more than a hundred, so I asked them to find a way to actually increase the number and give me the names of all my collaborators. So, after a couple of weeks, they kindly forwarded to me the full list. Thanks go to them!

In your beautiful acceptance speech you thanked your parents, your sons, and dedicated this prize to your "wife and best friend," Afarin, whose unwavering support and love has been a steady pillar in your life.

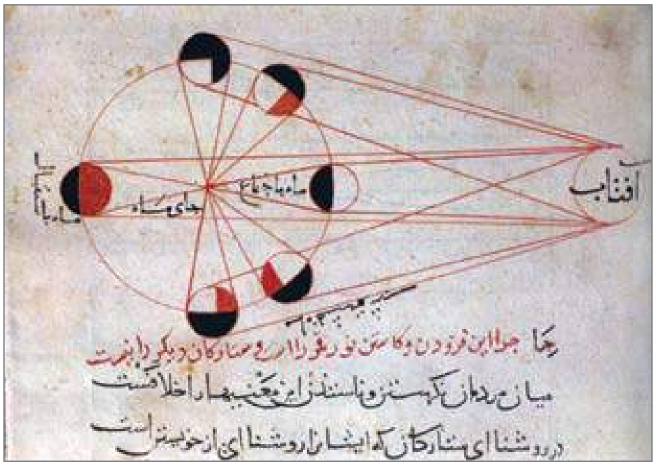
That's correct. I think my family (my wife Afarin and my kids, Farzan, Keyon, and Neekon) has played a special role in bringing inspiration and happiness to my life. I remember working on concrete physics projects and being inspired by the interactions with my sons when they were very young. "What is the relation?" you might say. I don't quite understand it, but I certainly owe them a lot of my inspiration.

You also mentioned Iran, "home of many eminent scientists, such as Khayyam and Biruni." Could you perhaps remark on the impact these two have had on your perception of the world?

I think in my acceptance speech I mentioned that science is a timeless, borderless adventure. If we take a snapshot of science today we'll see various centers of excellence, and some places that may be relatively quiet, but we should view this as not the property of science, but as transient phenomena. Sometimes science is strong in one place, sometimes in the other. It is not a territory of a particular area, and it's not a territory of a particular people, it's an adventure for the entire human kind. In this sense, I want to emphasize the fact that it's timeless — in different times, different cultures contributed more to the development of science and math. And it's borderless — it doesn't mat-



"Cubic equation and intersection of conic sections." Khayyam manuscript.



Al-Biruni (973-1048). The different phases of the moon.

ter where knowledge originates. People from different parts of the world can contribute, and do contribute. This open culture of science — the fact that it's borderless — is one of the main reasons science makes advances, and interacting with all these different people from different cultures and different backgrounds is one of the most fun parts of being a scientist.

As far as the names you mentioned, they are two among many ancient Persian mathematicians and scientists. Khayyam worked in geometry and math, trying to geometrize algebraic equations, among other things. That was one of his talents, in addition to being a philosopher and a poet. That to me defined that he was multifaceted, but deeply interested in the connection between geometry and algebra. The other person you mentioned was Biruni, who was a very perceptive physicist, in today's language. He knew deep math, but he applied it with precision to the world around us. For example, he used some simple and beautiful ideas from geometry to measure the radius of the Earth with unprecedented accuracy for his time. And this is late 10th — early 11th century! The fact that he actually applied geometrical ideas to the real world is what I found fascinating and inspiring.

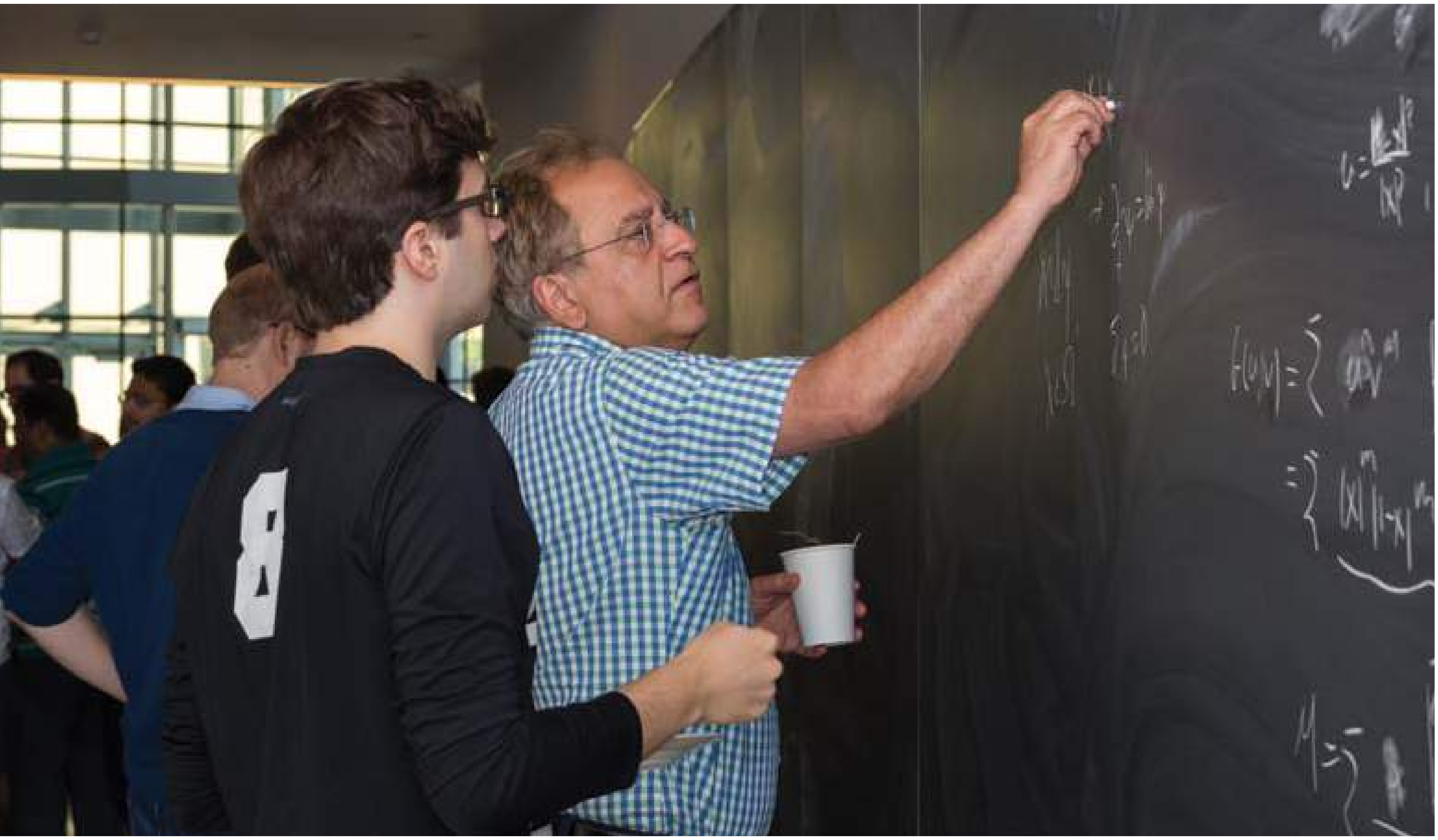
As someone who was born in Iran, could you tell us a little about how sciences were proportioned with other subjects in your school, and the system of education in general?

Yes, I was born in Tehran in 1960. I had the fortune of attending a very good school, the Alborz high school. But the education we were getting was not necessarily at the same level as in the Western countries, and in particular, we were behind in science education. Some parts of math were covered well; we had excellent classes on Euclidian geometry and appreciation of proofs. Understanding what mathematical proof meant helped me when I was learning more modern math. But at that time there was one textbook for the whole country, and that textbook wasn't that great in science. I was studying a little on my own, learning things like Einstein's theory of special relativity. I was so eager to go to college in the US that I applied one year early, so I started MIT in 1977. I was planning to study engineering and economics, but I took courses in both subjects and didn't like them. I was taking math and physics courses at the same time and those I loved, so by the second year I decided to switch. I graduated from MIT in 1981 with a double major in math and physics, and went to Princeton for a PhD in physics. Edward Witten was my advisor. I completed my PhD in 1985 and came to Harvard, becoming junior faculty in 1988, and senior faculty in 1990. I have been at the Harvard Physics Department since then.

I love going back to Iran. I enjoy visiting my relatives and giving lectures on physics and math. Scientific life has improved quite a bit since I was growing up; they have good groups working on string theory and modern aspects of mathematics. They may not be the leaders of the subject, but they have people following recent developments and writing good papers.

Talking about string theory, you mention mysteries (of confinement of quarks inside atomic nuclei) and enigmatic properties (of astrophysical objects, such as black holes). Is solving puzzles and uncovering mysteries your driving force?

Perhaps what summarizes my interest is the word magic. The very simple things we see around us, like this big moon out there in the sky which is not falling down — that's magical. It doesn't mean there is no nice and simple explanation to it. What I like about the beauty of science is taking this magical reality and making it understandable. Magic exists, even if we understand it. The way it is put together, the presentation of the reality in the form we see it, is magical. So trying to decipher the magic and understand how it comes to be so beautifully presented to us, combined with the rational explanation, often based on elegant mathematics, be it in the form of geometry or other ideas in mathematics, is very attractive to me.



Cumrun Vafa at the annual Simons Summer Workshop.
Photo: Natalia Ilina

> Perhaps what summarizes my interest is the word magic. The very simple things we see around us, like this big moon out there in the sky which is not falling down — that's magical.

We are curious as human beings. It is natural to be asking questions. But why we would direct our innate curiosity towards something like string theory, that will have no application in our lifetime, is a question that some people may ask. How can we be spending so much time on a subject so disconnected from physical observation of day-to-day life? It is a good question, and it is our sense of aesthetics that tells us that there is truth behind this theory that attracts us, and some of the application of it comes secondary. Because, after all, we are trying to understand how the truth of nature works. We also know that we will not finally understand it, as science only works in increments. In terms of the amount, we know the amount we can learn is very tiny, and we know that from looking backward. Also, it is a little disappointing that the human lifespan is so tiny compared to the age of the universe and all the beautiful reality. The maximum distance we travel is a distance on the globe; compared to the vast scale of the universe it is almost nothing. Connecting ourselves to sets of reality, which transcend space and time, gives us some kind of satisfaction of going beyond the reality of our finite lifetime. It is a minor satisfaction in view of the fact that we are not going to be able to visit everywhere and be around all the time.

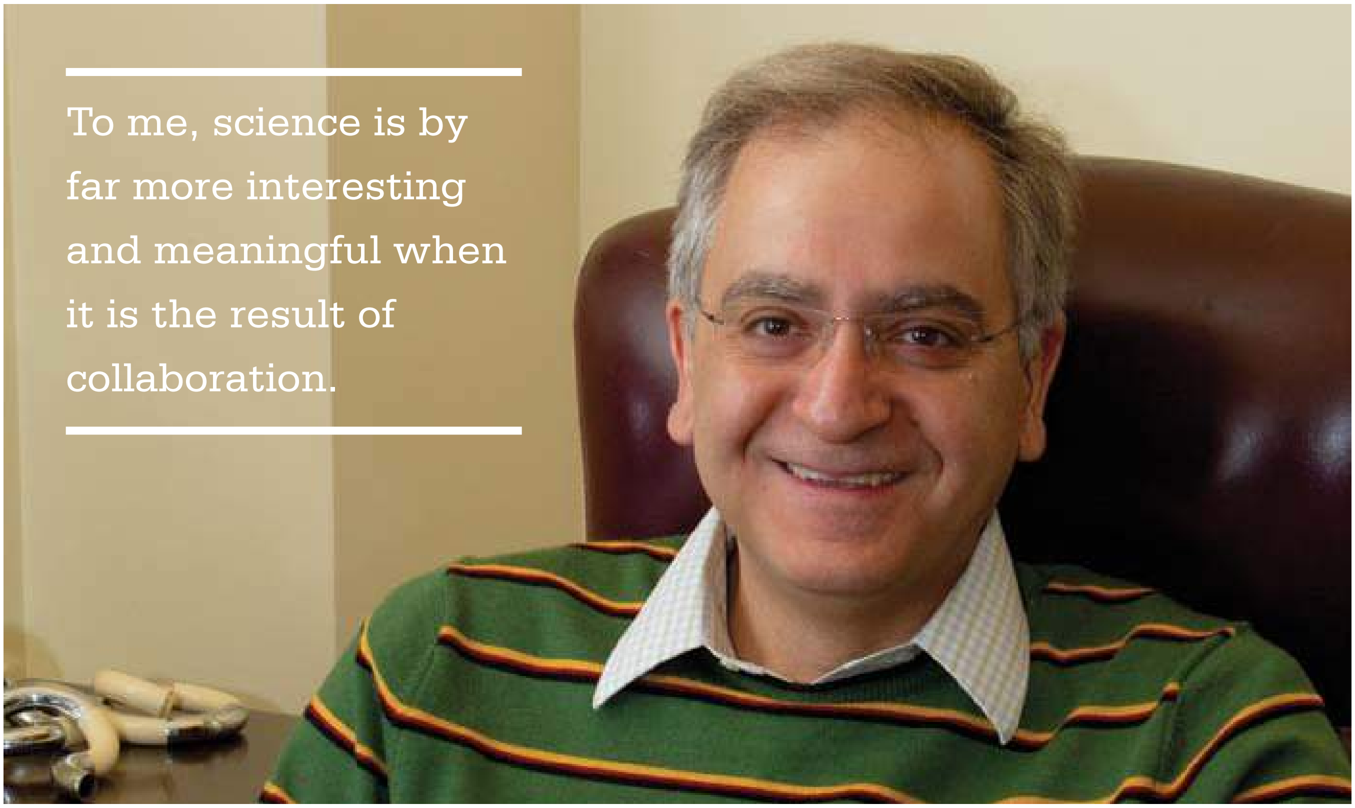
That is why I am attracted to fundamental science, though I know and I appreciate the fact that the contribution that I am going to make is going to be very tiny, compared to the portion of the unknown.

We started this conversation in 2014, when the discovery of the Higgs particle was a big topic, and I asked you if it answers major questions, or if you expect more to come? What do you predict CERN can bring in the future to the type of research you do?

If the Higgs boson discovery is the only discovery of the Large Hadron Collider, then this situation is very unfortunate. It means that whatever has been going on for the past 40 years is useless in the context of experiments. Of course, it is great that such a fantastic machine was able to discover the truth. It is a remarkable achievement, and the scientists who did it should be congratulated to the max. But nature could have given us more hints about string theory. We have not been as lucky as we wished. There still is room, though, as LHC has 5-10 more years before we can be sure if there is new physics at LHC.

Is there a question that you wish you were asked, but you were not?

I think there might be forums where a person who is not a physicist, and is not interested in forces and particles per se, could ask a scientist "so, what does it all mean for regular people?" Not so much explaining the laws of physics, or how forces of elementary particles work but "how does it affect my life?" or "how do you think about this?" or "does the way you look at the whole universe change your daily life?" In my opinion, these kinds of questions are not raised as much. Perhaps scientists are also a bit shy to venture into these areas because they don't consider it their area. Perhaps it is philosophy, or poetry; these domains are some that scientists don't



Cumrun Vafa

Photo: Hayward Photography

wander around, and people don't expect them to. They usually focus on matter of fact things, such as types of particles and kinds of forces, and it's a little too mechanical, or too technical, in my opinion. That's just my taste.

What I find a little bit strange in the attitude of scientists of this century, or of the past few decades that I have been working, is that in some sense it's not only not philosophical, it is sometimes anti-philosophical despite the fact that the foundation of science is philosophy. Many scientists do not recognize the underpinning of their own ideas as philosophical. They don't venture into those areas. Whenever this discussion arises, they dismiss it as useless and just put it off the discussion table. I think that's neither faithful to how science is being developed, nor good for the development of science. For example, during the early days of quantum mechanics, or relativity, there were discussions that were mixed with as much ideas of science as ideas of philosophy, and I think that aspect of science is missing today.

If we could return to collaborations — the majority of your work is in collaboration, but every 2 or 3 years you write a sole author article. Is that intentional or incidental, and what conceptual difference do you see in your papers alone vs. with collaborators?

I love collaborations. To me, science is about understanding things, and therefore getting help from other people and collaborating with them is perfectly good. Trying to build the "I did it!" kind of attitude is not good, and to me there is no loss in trying to get into collaborations. I like the diversity of talent that is brought in through other people and collaborations, so I enjoy that human aspect of trying to deal with different people, as well as the ideas they bring to the table. I come up with one idea, and my collaborator suggests another, and it makes it far more exciting. Occasionally, though, there is an idea that starts in my own head and gets finished in my own head. I didn't need collaboration; there is a case of a sole author paper. But it's not like I design it like I have to do this by myself. If it happens when somebody else contributes, then it's collaboration. So, to me, that is the nature of science.

Often in science, we see this unfortunate view that we are after heroes. Human sight goes into the direction of hero building, in political scene or other areas of human endeavor, like art, music or film. Somehow it gets translated to an idea that a sole author paper means you have a hero. I don't subscribe to this view of science. To me science is by far more interesting and meaningful when it is the result of collaboration. This is what I like about the Summer Workshop that we run at the Center. Many of the people I like to collaborate with are here. I use this opportunity to start or continue collaborations, and it is fantastic in that respect and fits very well with my attitude about science.

This year marks the 15th annual Simons Summer Workshop that you have directed. What are you especially proud of?

Yes, this is the 15th year of the Summer Workshop, and with every year it becomes even smoother and more effortless. It is by now well-recognized in our field that at the Workshop there is an atmosphere of discussion, collaboration, and top-notch people, as well as eager students and researchers, all gathered in one place. So not a specific topic, but that atmosphere is what drives us forward. The Center does an amazing job in making this a friendly environment. Every time I get feedback from the participants, they are always amazed how smoothly things run.

And we must thank you for that! How do you see the future of the SCGP? How will it and should it develop in 10 years?

String theory is under a great amount of pressure in terms of funding. Since it has not been connected to any experiments, there is tension for this field to be supported indefinitely by physics departments (which are supposedly based on physics experiments). On the other hand, mathematicians have seen that this subject is useful to the development of pure mathematics. A lot of them like to see the continuation of the development of string theory research, except they feel that a lot of things that are going on in string theory are not rigorous enough to be called mathematics. Therefore, many mathematicians view this as a good activity by the physics departments. So, subjects like string theory fall into the crack between two areas, and do not get supported.

This is where the Simons Center and similar institutes come in, playing a critical role in filling this void by the amazing workshops that take place here. The diverse group of people that come and interact here at the Simons Center has already brought a lot of impact into the joint area between physics and math, and I hope it continues to increase the number of activities and interactions in the future. I am very optimistic about that! ♦