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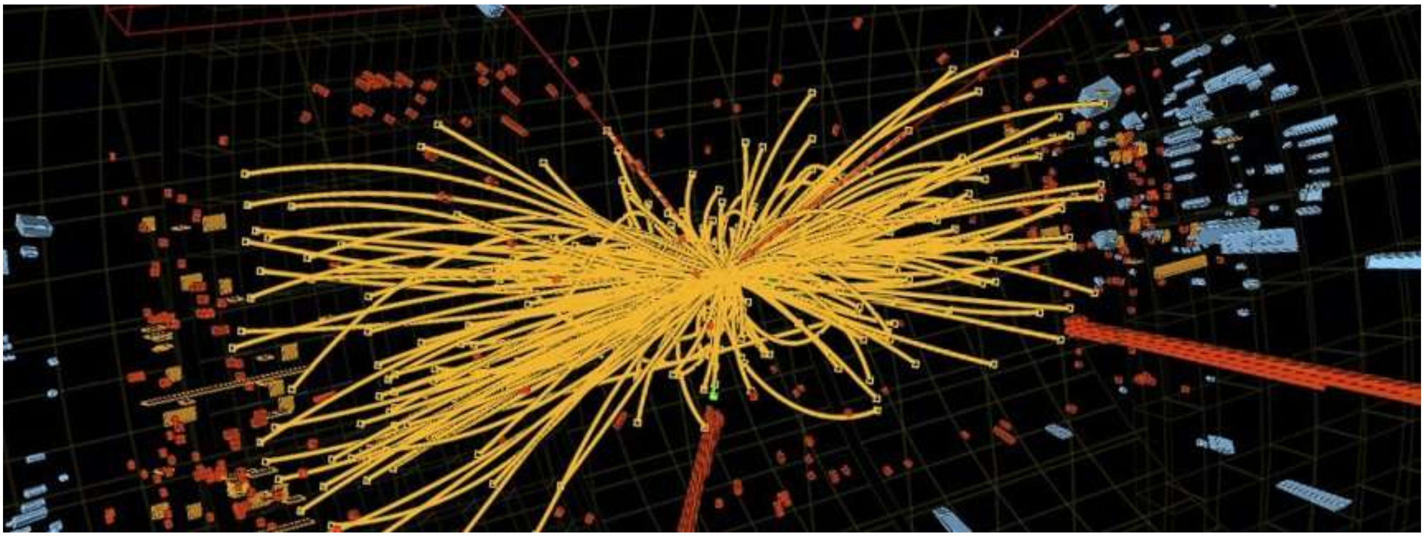
Nobel Physicist Frank Wilczek:
'The World is a Piece of Art'

Interview Conducted By Johann Grolle



AFP/ CERN A representation of traces of a proton-proto collision in the search for the Higgs particle.

Nobel Prize-winner Frank Wilczek talks to SPIEGEL about the universe's extraordinary symmetry, the overlap between beauty and physics and why we may be on the verge of a bigger discovery than the Higgs particle.

SPIEGEL: Professor Wilczek, Goethe once said one should hear a little music, read a little poetry and look at a beautiful picture every day so that worldly cares don't obliterate one's sense of beauty. Have you already had your daily bit of beauty today?

Wilczek: More than just a bit today. I've been reading books about art history and looking at pictures. I also have a very ambitious summer reading program. Today I read a science fiction book, "Starmaker" by Olaf Stapledon. It may not be a literary masterpiece, but it's full of inspiring visions. Normally I also play the piano quite a bit, but our piano has gotten out of tune while we were abroad.

SPIEGEL: In your new book, "A Beautiful Question," you write that physics also appeals to our sense of beauty. Does art inspire you when you're studying the laws of nature?

Wilczek: It would be hard to say it is directly inspiring, but I'm convinced that art and science activate the same parts of the brain. The brain rewards us for interacting with beautiful things. In this way, evolution wants to encourage us to do what is good for us. This applies to many things of course, but one of them is the understanding of how things are going to behave.

SPIEGEL: We try to make sense of things …

Wilczek: … yes. And when we succeed, we perceive it as beauty.

SPIEGEL: What is "beautiful" about physics?

Wilczek: Don't you find it compelling, for example, that the equations that have been developed to describe musical instruments are very nearly the same as the equations that govern how atoms work? In a violin or a piano, sounds are produced by the vibrations of sounding boards or strings. In atoms, the things that vibrate are more abstract: They are associated with the colors of light that a particular kind of atom likes to emit or absorb. And this, by the way, is very much the same idea that Pythagoras was groping towards when he associated the movement of the planets with music of the spheres. Electrons do in fact go around the atomic nucleus much the same as planets go around the sun. We can think of atoms as musical instruments that produce a very real and very perfect music of the spheres.

SPIEGEL: But are these similarities between music, atoms and planetary orbits more than just a coincidence?

Wilczek: If it is a coincidence, it is a gorgeous one. It is a gift.

SPIEGEL: Every artist has his or her own style. When you are investigating the laws of nature, do you feel that nature has its own style, too?

Wilczek: Absolutely. The world is a piece of art, produced according to a very peculiar style. What I find particularly striking is the outstanding role of symmetry.

SPIEGEL: Could you explain that?

Wilczek: Sure. The principle of symmetry as we use it in physics and mathematics can be described as "change without change." While this may sound mystical or bizarre, it actually means something quite simple. What, for instance, makes a circle such a symmetrical object? It's that you can rotate it around its center and it will remain a circle. In the case of an equilateral triangle, small rotations will change it, but if you rotate it by 120 degrees it comes back to itself. It thus has some symmetry, though less than a circle. This concept of symmetry as "change without change" can easily be generalized to laws of physics, or to the equations that express them.

SPIEGEL: And this helps you to understand the world?

Wilczek: Very much so. A key assumption of the theory of relativity, for instance, is that if you view the world from a moving train, things may look different but the same laws of physics apply. In electrodynamics, you can make a number of transformations on electric and magnetic fields, but the equations remain valid. Now you can look for the perfect equations whose consequences remain unchanged under a whole lot of transformations. These are, so to speak, the circles among the equations. And it turns out that those are the ones that govern the world.

SPIEGEL: The paintings of Expressionists and 12-tone music have been denounced by many people as very ugly. There is often much debate about which art deserves to be called "beautiful." Is there more agreement among scientists?

Wilczek: No. Just as in the arts, agreement often exists more in retrospect. Take quantum physics for instance: Many of its founders -- Planck, Einstein, Schrödinger -- struggled with it until their death. Until it is appreciated, the concept of beauty has to be enforced by an extensive dialogue with nature.

SPIEGEL: When did physicists discover the particular importance of symmetry?

Wilczek: In its modern form, it is an idea of the 20th century. But uncannily, Plato seems to have foreseen it. He put forward a system in which the four elements -- earth, air, fire and water -- consisted of building blocks which had the shape of four ideally symmetrical platonic solids. That brilliant vision anticipated, in a broad sense, the modern idea that nature uses symmetry to construct the world -- even though in detail his model was hopelessly misguided, of course.

SPIEGEL: When did you become aware of the beauty of the laws of nature?

Wilczek: Well, as a conscious thing, it was quite recent. I only started thinking in these terms five years ago when I was asked to give a lecture on quantum beauty.

SPIEGEL: Before that, beauty didn't guide you in your work?

Wilczek: Implicitly it certainly did. Looking back, I realize that I have always been looking for the simplest, most beautiful and most symmetrical description. But I didn't focus on that aspect explicitly. I was immersed in the day to day work of trying to advance things.

SPIEGEL: Your most famous work, that later earned you a Nobel prize, was done in 1972 and 1973 ...

Wilczek: … yes, I was pretty young at the time, 21 or 22 years old. In order to understand what we did, you have to know that there are four basic forces of nature: gravity and electromagnetism, which are the classic forces, then two more forces that physicists became aware of when they started to study atomic nuclei in the twentieth century. These are the strong force which basically holds the nuclei together and the weak force that has to do with various decay processes. What I did in collaboration with David Gross was figure out the equations of the strong force. We correctly guessed them because we intuitively looked for particularly beautiful and symmetrical equations.

SPIEGEL: Did you know at the time that you were unveiling a deep truth of nature?

Wilczek: Oh yes. I said to David: "If the experiments turn out the way we predict, we are going to get a Nobel Prize for this." And this is exactly what happened.

SPIEGEL: Did you experience a moment of deep revelation?

Wilczek: There have been moments like that, but they were not like what you're imagining. The experimental situation was pretty murky, so I couldn't say: "Ok, we explained this fact and that fact and everything fits perfectly." The basic building blocks in our theory, the quarks and gluons, had never been observed. Only in late 1974 were there new experiments and did the picture become much clearer.

SPIEGEL: Heinrich Hertz once said that the equations of electromagnetism are very intelligent, more intelligent even than the people who figured them out.

Wilczek: Well, this is definitely true in the case of quantum chromodynamics, as the theory of the strong force is called. We started with a few assumptions about beauty, symmetry and consistency and all the phenomena of nuclear physics are supposed to come out. So you get out much, much more than you put in.

SPIEGEL: Nowadays the theory you developed is part of the Standard Model, which describes our world in a fascinatingly precise way. But you and your colleagues are still not satisfied.

Wilczek: No. The Standard Model has significant aesthetic shortcomings. The last word of nature should be more beautiful.

SPIEGEL: What bothers you about it?

Wilczek: The Standard Model has loose ends. There are four different forces that go into it. But one would rather have just one unified description of all the forces. There are also different materials going in, and there, again, you would rather have them reduced to just one. What's so exciting about the current situation is that there are proposals for addressing many of these shortcomings.

SPIEGEL: What do these proposals look like?

Wilczek: The basic idea is that the principles that we use to formulate the modern theory of electromagnetism, the weak and the strong force are all uncannily similar. They are sort of begging to be united in one overarching theory. Mathematically this can easily be accomplished. But when you do that, the intrinsic strength of all the forces should be equal. When we observe them, they are not. So it first looked as if we were stuck in a dead end, but then we realized that at very small distances you must include quantum effects. And when you take them into account, the three forces become more and more similar -- just as a unified theory predicts.

SPIEGEL: So you do have a unified theory of all three forces?

Wilczek: Wait a minute. The three forces become almost the same, but not quite. They only do once you make still another symmetry assumption, which is called supersymmetry or Susy. As with the other symmetries, it is based on the principle "change without change." It's just that in this case you can exchange particles and forces with each other without changing the laws. This is a rather bold step, but once you take it, the theory works: At very short distances the strength of all three forces becomes exactly the same.

SPIEGEL: This sounds too good not to be true.

Wilczek: You said it. Or otherwise nature has pulled a terrible joke on us.

SPIEGEL: How can you be sure it's not a joke?

Wilczek: We need to find some of the additional particles that are predicted by supersymmetry. That could happen next week at CERN, but a year or two, or maybe five, is more likely. According to our theory these particles can't be too heavy, which means that there is a very good chance the accelerator at CERN will find them.

SPIEGEL: Have you placed any bets on it?

Wilczek: Yes, I did. I bet 100 Nobel chocolate coins on the prediction that they will find Susy particles by 2020.

SPIEGEL: Nobel chocolate coins?

Wilczek: Yes. These are chocolate coins coated with golden wrapping they offer at the ceremony in Stockholm. I have a few spare ones left. But if I lose the bet I will have to ask friends to gather some more at the ceremony. You can scoop them up and smuggle them out.

SPIEGEL: Would the discovery of these Susy particles be even more spectacular than was the discovery of the Higgs particle?

Wilczek: Well, to me it would. The Higgs particle is a glorious thing, but in some sense it is just like dotting the i's and crossing the t's on the theory of the Standard Model. The discovery of Susy particles, on the other hand, would be a profound step beyond it.

SPIEGEL: Are you astonished that nature obeys laws that we humans are able to understand?

Wilczek: This fact has deep meaning, and is not at all guaranteed. As a thought experiment, let us assume that the whole world is just a simulation on a gigantic supercomputer, where we are also just part of this simulation. So, roughly speaking, we are talking about a world in which Super Mario thinks that his Super Mario world is real. The laws in such a world wouldn't necessarily be beautiful or symmetric. They would be whatever the programmer put in there, which means these laws could be arbitrary, they could suddenly change or be different from place to place. And there would be no simpler description of these laws than a very long computer program. Such a world is logically possible, but our world is different. It is a glorious fact that in our world, when we go really deep, we can understand it.

SPIEGEL: A glorious fact, you say. But this cannot be a satisfying statement for physicists. Aren't you looking for an explanation for this very fact?

Wilczek: I'm not sure what that kind of explanation would look like. We hit rock bottom in our description of the world. The only highly speculative explanation I could think of might be that there is a star maker, some engineer that is responsible for this design.

SPIEGEL: Some call it "God" -- a word physicists use remarkably often.

Wilczek: Don't forget: Many of my heroes, like Galileo, Maxwell, Newton and, less explicitly, Einstein thought what they were doing was finding out what God is. All of them had this inspiration that if you want to find out what God is, you have to look at his work.

SPIEGEL: How about you? Are you also looking for God?

Wilczek: Well, I want to find out what reality is and then you call it what you will.

SPIEGEL: Professor Wilczek, we thank you for this interview.

About Frank Wilczek

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Wilczek, 64, is a professor at MIT, in Cambridge near Boston. He was awarded the 2004 Nobel Prize in physics. To this day, Wilczek is searching for a unified theory of matter. He has now written a book, "A Beautiful Question," in which he examines the secrets of nature.