Zeitschrift: Trans : Publikationsreihe des Fachvereins der Studierenden am Departement Architektur der ETH Zürich

Herausgeber: Departement Architektur der ETH Zürich

Band: - (2014)

Heft: 25

Artikel: Parallels in the zeptospace

Autor: Giudice, Gian Francesco

DOI: https://doi.org/10.5169/seals-919446

PARALLELS IN THE ZEPTOSPACE

Gian Francesco Giudice

020

Gian Francesco Giudice (gg): As a theoretical physicist, I am of course wondering how I fit into the ‹trans› magazine.

transRedaktion (tr): Mr. Giudice, in your book ‹A Zeptospace Odyssey› you mention that what is fascinating about the Large Hadron Collider, is the journey into the unknown. Your work is speculative, explorative, which is the topic of our issue. Already with the title of your book, you draw parallels to the odyssey of Homer. You are exploring space, not on a human scale as we architects do but on a scale of 1000^{-7}. We were fascinated by this so-called Zeptospace. So we were wondering if we could find similarities between our fields and our approaches. Have you every talked to architects before?

gg: Not with architects, but artists visit CERN quite often. They are interested in understanding what we do in order to find new ideas and inspiration. And I think that there are a lot of similarities with architecture too, in the context of creativity. The actual work in theoretical physics is very much like that of an artist, in the sense of finding an idea and then developing it. You as architects need to find the material of how to translate an intention into a building. For us it is about finding the right mathematics. So unsurprisingly, even though we work with different tools, both are human intellectual processes and are therefore very much related.

tr: In order to understand your work better, could you tell us about your first project at CERN?

gg: The first project was related to the process that could have given rise to the ‹Baryon asymmetry›, which is one of the big issues in physics and cosmology: Why is our universe made of matter and not of anti-matter. The equations yield a perfect symmetry, so you would expect, just because of simplicity, that both are distributed equally in the universe. As matter and anti-matter annihilate each other over time, there must have been a really small quantitative difference in order to explain what we observe today. When you have such peculiar initial conditions there needs to be a reason. The explanation, we think, is that the universe really started perfectly symmetric and that some process developed the small difference. There are various speculations on how this could have happened and at the time I was working on one of them with a Russian colleague.

tr: So, how do you actually approach your speculations as a creative process?

gg: That is the hard part. While it of course involves a lot of studies to know your field and to locate room for new developments, most of us are able to solve but not to find a problem.

tr: Are all the people you work with theoretical physicists?

gg: When we talk about the field of particle physics, it's the people who are interested in the dynamics of particles; of how they interact with the fundamental forces and of how this affected the evolution of the universe. There is both a theoretical and an experimental part. At CERN, the experimental part outweighs due to the development of the accelerator and the detectors. And there is a huge separation between the two fields. Because of technicalities, the people who develop a machine need to be super-experts on how to construct magnets or silicon strips in order to observe various particles. Theoretical physicists know about the mathematics. While I converse with experimental physicists because, of course, there is a common interest in the final results, I don't work with them. It would be like you working with a medical doctor.

In general, the world is becoming more and more technical and everybody has his own expertise. Personally, I also see disadvantages in this development. While it is fantastic that young experimentalists, working on the particle detector for example, share their knowledge only with a handful of people in the world, they are so absorbed in their research that they end up ignoring the goal of the actual experiment.

tr: We have been very interested in this duality of theory and experiment and thought that interaction was necessary, in order to confirm experimentally what theory has stated.

gg: No, this interaction certainly exists, but in my everyday work I only interact with theorists. Imagine a painter and a sculptor. They can talk to each other, they can discuss. But at the moment when one needs to paint, he can't ask the sculptor for help. They use different tools. But they can discuss about ideas of how to approach a problem. This is a better analogy than the one of the medical doctor and the architect, I was exaggerating. While the activity is different, the final goal is the same. That's why this exchange of the two communities is very important.

Some of the theoretical activity has always been accused of being too mathematical, too separated from the experiments. While that sometimes is true, it is also necessary. In science you cannot set rules; if you do so, you are bound to lose. It is important to let creativity flow. It is a very wasteful process and it has to be wasteful. If you try to be efficient, it will not work. Setting off in one direction with a destination in mind, will bring you to that goal but not beyond. But science is about reaching unexpected goals. So the method is to set 100 people on different tracks, of which 99 completely fail but one will find something important. But we should probably not tell this to someone who is funding science. (laughs) These days, there is a preference for applied science, where a more direct approach is used. While you are able to achieve more short-term goals, it is a very blind way of proceeding and you are not going to get too far.

tr: Then we have already found one similarity with architecture, in a sense our process also needs to be wasteful. The two ingredients of intuition and simplicity also seem to be important to you. Now, looking at the equation of the Standard Model of Particles (fig. a), it might not seem simple.

gg: That's a good point. Is it simple or not? We need to go beyond appearances in order to understand. I was giving a talk once where I mentioned that particle physics proceeded to more and more simple things. But then this mathematician interrupted by asking if quantum mechanics were actually simpler than classical mechanics. In his opinion, at every step, physics became more complicated. The point is to tell the difference between mathematics and principle. Is the principle of the Standard Model of Particles simpler or not? So even though ‹$f=ma^2$› is very simple, it only describes very few processes. It can for example not describe electromagnetism. Isn't it striking that with a simple principle, by defining a symmetry, you can describe the entire universe? While Supersymmetry is more complicated because there are more particles, the principle is much cleaner. In general, when developing a theory, the argument was very often the one of simplicity, beauty. And nature usually chose the beautiful one, not the ugly, complicated one. So, the problem is to understand what is ugly and complicated and what is not. The point is not to look at the equations. Even if the mathematics are more complicated, it is only the language. It might actually be possible to rearrange the terms, to define a new quantity so that the equation becomes very simple.

tr: During our studies, we try to train our spatial senses. The more time we spend with observing, the easier it becomes to see relations. Is there something similar in what you are dealing with at this completely different scale of the Zeptospace?

gg: Yes I think so. It is the way you visualize things that makes the difference between a good physicist and an excellent physicist. Very often you work with the equation, and try to solve it, find a solution. The truly great physicist just looks at the blackboard and

$$-\frac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \frac{1}{4}g_s^2 f^{abc}f^{ade} g^b_\mu g^c_\nu g^d_\mu g^e_\nu +$$
$$\frac{1}{2}ig_s^2(\bar q^\sigma_i \gamma^\mu q^\sigma_j)g^a_\mu + \bar G^a\partial^2 G^a + g_s f^{abc}\partial_\mu \bar G^a G^b g^c_\mu - \partial_\nu W^+_\mu \partial_\nu W^-_\mu -$$
$$M^2 W^+_\mu W^-_\mu - \frac{1}{2}\partial_\nu Z^0_\mu\partial_\nu Z^0_\mu - \frac{1}{2c_w^2}M^2 Z^0_\mu Z^0_\mu - \frac{1}{2}\partial_\mu A_\nu\partial_\mu A_\nu - \frac{1}{2}\partial_\mu H\partial_m uH -$$
$$\frac{1}{2}m_h^2 H^2 - \partial_\mu\phi^+\partial_\mu\phi^- - M^2\phi^+\phi^- - \frac{1}{2}\partial_\mu\phi^0\partial_\mu\phi^0 - \frac{1}{2c_w^2}M\phi^0\phi^0 - \beta_h[\frac{2M^2}{g^2} +$$
$$\frac{2M}{g}H + \frac{1}{2}(H^2+\phi^0\phi^0+2\phi^+\phi^-)] + \frac{2M^4}{g^2}\alpha_h - igc_w[\partial_\nu Z^0_\mu(W^+_\mu W^-_\nu -$$
$$W^+_\nu W^-_\mu) - Z^0_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + Z^0_\mu(W^+_\nu\partial_\nu W^-_\mu -$$
$$W^-_\nu\partial_\nu W^+_\mu] - igs_w[\partial_\nu A_\mu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu(W^+_\mu\partial_\nu W^-_\mu -$$
$$W^-_\mu\partial_\nu W^+_\mu) + A_\mu(W^+_\nu\partial_\nu W^-_\mu - W^-_\nu\partial_\nu W^+_\mu)] - \frac{1}{2}g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu +$$
$$\frac{1}{2}g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2 c_w^2(Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) +$$
$$g^2 s_w^2(A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + g^2 s_w c_w[A_\mu Z^0_\nu(W^+_\mu W^-_\nu -$$
$$W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha[H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-] -$$
$$\frac{1}{8}g^2\alpha_h[H^4 + (\phi^0)^4 + 4(\phi^+\phi^-)^2 + 4(\phi^0)^2\phi^+\phi^- + 4H^2\phi^+\phi^- + 2(\phi^0)^2H^2] -$$
$$gMW^+_\mu W^-_\mu H - \frac{1}{2}g\frac{M}{c_w^2}Z^0_\mu Z^0_\mu H - \frac{1}{2}ig[W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) -$$
$$W^-_\mu(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)] + \frac{1}{2}g[W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) - W^-_\mu(H\partial_\mu\phi^+ -$$
$$\phi^+\partial_\mu H)] + \frac{1}{2}g\frac{1}{c_w}(Z^0_\mu(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) - ig\frac{s_w^2}{c_w}MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) +$$
$$igs_w MA_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) - ig\frac{1-2c_w^2}{2c_w}Z^0_\mu(\phi^+\partial_\mu\phi^+ - \phi^-\partial_\mu\phi^+) +$$
$$igs_w A_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) - \frac{1}{4}g^2 W^+_\mu W^-_\mu[H^2 + (\phi^0)^2 + 2\phi^+\phi^-] -$$
$$\frac{1}{4}g^2\frac{1}{c_w^2}Z^0_\mu Z^0_\mu[H^2 + (\phi^0)^2 + 2(2s_w^2-1)^2\phi^+\phi^-] - \frac{1}{2}g^2\frac{s_w^2}{c_w}Z^0_\mu\phi^0(W^+_\mu\phi^- +$$
$$W^-_\mu\phi^+) - \frac{1}{2}ig^2\frac{s_w^2}{c_w}Z^0_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) + \frac{1}{2}g^2 s_w A_\mu\phi^0(W^+_\mu\phi^- +$$
$$W^-_\mu\phi^+) + \frac{1}{2}ig^2 s_w A_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) - g^2\frac{s_w}{c_w}(2c_w^2-1)Z^0_\mu A_\mu\phi^+\phi^- -$$
$$g^1 s_w^2 A_\mu A_\mu\phi^+\phi^- - \bar e^\lambda(\gamma\partial + m_e^\lambda)e^\lambda - \bar\nu^\lambda\gamma\partial\nu^\lambda - \bar u_j^\lambda(\gamma\partial + m_u^\lambda)u_j^\lambda -$$
$$\bar d_j^\lambda(\gamma\partial + m_d^\lambda)d_j^\lambda + igs_w A_\mu[-(\bar e^\lambda\gamma^\mu e^\lambda) + \frac{2}{3}(\bar u_j^\lambda\gamma^\mu u_j^\lambda) - \frac{1}{3}(\bar d_j^\lambda\gamma^\mu d_j^\lambda)] +$$
$$\frac{ig}{4c_w}Z^0_\mu[\bar\nu^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar e^\lambda\gamma^\mu(4s_w^2 - 1 - \gamma^5)e^\lambda) + (\bar u_j^\lambda\gamma^\mu(\frac{4}{3}s_w^2 -$$
$$1-\gamma^5)u_j^\lambda) + (\bar d_j^\lambda\gamma^\mu(1 - \frac{8}{3}s_w^2 - \gamma^5)d_j^\lambda)] + \frac{ig}{2\sqrt{2}}W^+_\mu[(\bar\nu^\lambda\gamma^\mu(1+\gamma^5)e^\lambda) +$$
$$(\bar u_j^\lambda\gamma^\mu(1+\gamma^5)C_{\lambda\kappa}d_j^\kappa)] + \frac{ig}{2\sqrt{2}}W^-_\mu[(\bar e^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar d_j^\kappa C^\dagger_{\lambda\kappa}\gamma^\mu(1+$$
$$\gamma^5)u_j^\lambda)] + \frac{ig}{2\sqrt{2}}\frac{m_e^\lambda}{M}[-\phi^+(\bar\nu^\lambda(1-\gamma^5)e^\lambda) + \phi^-(\bar e^\lambda(1+\gamma^5)\nu^\lambda)] -$$
$$\frac{g}{2}\frac{m_e^\lambda}{M}[H(\bar e^\lambda e^\lambda) + i\phi^0(\bar e^\lambda\gamma^5 e^\lambda)] + \frac{ig}{2M\sqrt{2}}\phi^+[-m_d^\kappa(\bar u_j^\lambda C_{\lambda\kappa}(1-\gamma^5)d_j^\kappa) +$$
$$m_u^\lambda(\bar u_j^\lambda C_{\lambda\kappa}(1+\gamma^5)d_j^\kappa] + \frac{ig}{2M\sqrt{2}}\phi^-[m_d^\lambda(\bar d_j^\lambda C^\dagger_{\lambda\kappa}(1+\gamma^5)u_j^\kappa) - m_u^\kappa(\bar d_j^\lambda C^\dagger_{\lambda\kappa}(1-$$
$$\gamma^5)u_j^\kappa] - \frac{g}{2}\frac{m_u^\lambda}{M}H(\bar u_j^\lambda u_j^\lambda) - \frac{g}{2}\frac{m_d^\lambda}{M}H(\bar d_j^\lambda d_j^\lambda) + \frac{ig}{2}\frac{m_u^\lambda}{M}\phi^0(\bar u_j^\lambda\gamma^5 u_j^\lambda) -$$
$$\frac{ig}{2}\frac{m_d^\lambda}{M}\phi^0(\bar d_j^\lambda\gamma^5 d_j^\gamma) + \bar X^+(\partial^2 - M^2)X^+ + \bar X^-(\partial^2 - M^2)X^- + \bar X^0(\partial^2 -$$
$$\frac{M^2}{c_w^2})X^0 + \bar Y\partial^2 Y + igc_w W^+_\mu(\partial_\mu\bar X^0 X^- - \partial_\mu\bar X^+ X^0) + igs_w W^+_\mu(\partial_\mu\bar Y X^- -$$
$$\partial_\mu\bar X^+ Y) + igc_w W^-_\mu(\partial_\mu\bar X^- X^0 - \partial_\mu\bar X^0 X^+) + igs_w W^-_\mu(\partial_\mu\bar X^- Y -$$
$$\partial_\mu\bar Y X^+) + igc_w Z^0_\mu(\partial_\mu\bar X^+ X^+ - \partial_\mu\bar X^- X^-) + igs_w A_\mu(\partial_\mu\bar X^+ X^+ -$$
$$\partial_\mu\bar X^- X^-) - \frac{1}{2}gM[\bar X^+ X^+ H + \bar X^- X^- H + \frac{1}{c_w^2}\bar X^0 X^0 H] +$$
$$\frac{1-2c_w^2}{2c_w}igM[\bar X^+ X^0\phi^+ - \bar X^- X^0\phi^-] + \frac{1}{2c_w}igM[\bar X^0 X^-\phi^+ - \bar X^0 X^+\phi^-] +$$
$$igMs_w[\bar X^0 X^-\phi^+ - \bar X^0 X^+\phi^-] + \frac{1}{2}igM[\bar X^+ X^+\phi^0 - \bar X^- X^-\phi^0]$$

fig. a
Mathematical Equation describing the Standard Model of Particles.

fig. b
Joseph Mallord William Turner, ‹The Vision of Jacob's Ladder›, ca. 1830.
Image: Turner Bequest, Tate Gallery, London.

perceives the equation. He visualizes it in a different way which helps him to go beyond just developing the mathematics. There is a big difference for me between physics and mathematics. Mathematics develops certain formalisms, in physics you have to get a vision of what you want to do and then in a sense, language is secondary. Einstein for example had this vision. It was very clear for him what general relativity should be. And then he spent years and years in trying to develop the mathematics, in which by the way he wasn't the strongest in the world. He actually had to discuss with many mathematicians in order to find an expression. But he really was the one with the vision. It is about trying to visualize in other terms, find analogies which are simple and well known. You need to find the vocabulary that translates a concept from a messy problem to a simple and known concept. Once you know this you know what to expect and how to develop your story further.

tr: So this would be similar to this architectural sketch by Oscar Niemeyer? The freehand sketch as an abstraction to convey a vision without immediately knowing how the building will stand up?

gg: Even in physics, there are theoreticians who are incredible. They are having visions of buildings without knowing how it all comes together. In mathematics they are a disaster. If you give them a quadratic equation, they wouldn't know how to solve it. But they have these visions. Other people are very strong in mathematics, but they never have this kind of idea.

tr: That is where for us the engineer would come in. But, do you think that the people who can conceptualize are at the forefront?

gg: Yes, I had a name in mind actually. He is a friend of mine, who is amazing. A few years ago, I wanted to work with him as he was a famous professor who had tremendous ideas in the past, but after a week of discussions I was starting to get the feeling, I really might be talking to the wrong person. I was shocked, he didn't seem to know about a lot of things. So I was wondering if I was wasting my time, drifting off to discussions about Sharon Stone for example. But then, suddenly, an idea came through and it was a breakthrough. I had never even thought about it. Afterwards, I spent my nights working out the details. So there are people who have this incredible vision but are not very strong technically.

tr: Do they need this mathematical support?

gg: Yes, they do because without it they wouldn't be able to carry out the details. But the hard part of course is to have the idea and these are the kind of people who can do it.

tr: It seems important that our system makes it possible for people who have these visions to get into positions where they can have a positive influence. Is this in general the case at CERN?

gg: In that respect theoretical physics is very healthy. It recognizes people immediately even if they are very young, which is not true in every field. After all we are also a concrete science. It is easier to decide if an idea is good or bad. Maybe in architecture, it is more delicate.

tr: In your book, you mention Jacob's Ladder as a metaphor for order. By moving up the steps of the ladder, the chaos of the human scale gains an increasing sense of order up to the scale of the Zeptospace. Processes that we are unable to explain on a certain scale, become clear by moving one step up. While our endeavors seem very different, we could link them through the common goal of creating order or making sense of our environment. Are you able to read our architectural language or are you as perplexed as we are when looking at the equation of the Standard Model of Particles?

gg: As we were saying before, if you show me your project with all its details, I will get lost. But if you show me the picture of your building, I will be able to appreciate it. Probably it is the same here for physics. If I show you the equation, you will get a headache. But if I explain what is behind and what are the principles, maybe you will be able to like it. And I think the same is true for all human activities. Yes, we are in a very specialized world, so we can't expect people to understand everything. But as humans we get pleasure when seeing something beautiful. The challenge is to develop the taste to understand when something is beautiful. Have you ever visited CERN?

tr: No, unfortunately not yet.

gg: Many artists are struck by the beauty of it. If you go into the tunnel and visit the open detectors, they seem like fascinating buildings. They are as tall as buildings, they are colorful; there are intertwined cables, fiber optics, magnetics, electronics and huge devices. They give you a feeling of the beauty of the underlying ideas. As a human being, I can enjoy architecture. I don't know if being a physicist really matters. Maybe people who are spending their life with creative processes can better appreciate other

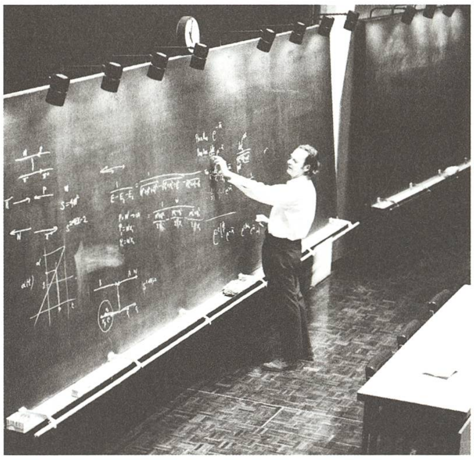

fig. c
Richard P. Feynman giving a talk at CERN in January 1970 on inelastic hadron collisions.
Photography: CERN.

kinds of creative processes. This could be something that makes you interested in science and me in architecture for this common human intellectual endeavor towards creating something.

I think in your ideas, you also have nature in mind. We are trying to second-guess nature. In order for an idea to be successful, it is in your case probably the judgment of the public, while for us the experiment shows if nature likes the theory or not.

tr: While we keep climbing Jacob's ladder, understanding more and more how our world functions, will science at some point make spirituality obsolete?

gg: I don't think so. As an individual, I don't think that the word obsolete is correct. Nobody would now say that the earth was created in seven days some thousand years ago. At the time of Galileo there was a conflict. Because they were trying to address the same questions. But the borders between a spiritual and a more rational vision of the world have changed. I don't think in that respect, that science has replaced religion: we are not dealing with the same kind of questions. So I get furious when religious fanatics start questioning science, stating that there is no proof. But I also get extremely nervous when people who talk like scientists say that religion is obviously wrong because we have replaced it by science. I am not trying to defend religious feelings, but think it is a bad service to science when you are saying that science has proved that God cannot exist. Claiming that there is a scientific proof for atheism is just a wrong interpretation of science. The spiritual is another sphere that has nothing to do with science. I could perfectly imagine that scientists could be believers or atheists. The problem arises when people claim that you can answer the same questions.

tr: Maybe we could go back to CERN. Do you know this book called ‹Inside CERN› by Andri Pol? (The book is a photographic essay that presents CERN as a very human story.)

gg: (Leafs through the book) No, I have never seen the book but CERN really looks like this: these are the corridors to my office, this is Lynn Evans, and there is a guy in theory. Some journalists expect, when coming to CERN, to find futuristic science fiction. The buildings, however – there is another friend of mine – are ugly, full of asbestos and with old furniture. You find the opposite of what you would expect.

tr: Is there anything you appreciate about the space that was created?

gg: No, I actually like it! For instance, there is the theory auditorium with wooden benches from the 60s. At some point the director-general proposed to refurbish it. They wanted to eliminate all of it and make it look a little bit like hotels today, with new chairs and a special modern white board. We decided that it was horrible and rejected the design. Instead we proposed to revarnish the wood of the benches and repaint the walls while leaving the old blackboard in place.

tr: Do you still also prefer the old chalkboards to the computer?

gg: Absolutely. In the main auditorium, there was a beautiful chalkboard too, filling a complete wall. There are these old photographs of Richard Feynman giving lectures there. They have renewed that auditorium without asking the theorists and threw the chalkboard away, saying that it broke during the renovation work. The naive wooden substitute bearing a logo of CERN, can of course not even remotely replace the idea of Feynman giving lectures at the blackboard…

tr: CERN seems to be a noble institution, defending absolute knowledge as a part of human culture, bringing together so many different member states that pull on the same strings. How is it to work at CERN?

gg: For me it's wonderful, both in a human and scientific way. Every day, I can feel the spirit of developing pure science as the final goal. What is important is that people recognize your work. The idea to set up a laboratory, which is very costly, with different nations, different interests, different economic situations, political situations gives a large amount of freedom to the scientists. Compared to particle physics research in the US, the idea of CERN worked much better, the successful ideas being openly collaborated and independent of any political decisions. It is really a model for how to manage science well beyond the particle physics. Science is changing very quickly and in order to develop such large projects, we need structures. The idea of having a scientist working alone could become more and more obsolete.

tr: Architecture has had an eventful, if not stormy journey in the 20th century. More or less at the same time when, in physics, the old ideal of the impartible atom was discarded with Thompson's discovery at the turn of the 19th century, architecture called for a radical new approach. Would you agree that physics has experienced something similar?

gg: Absolutely, I think this is true, even beyond physics and architecture. The beginning of the 20th century was really an incredible point, in most of the disciplines. In physics, electromagnetism, mechanics, we seemed to know everything. A cycle was complete and then everything shattered together. Music and literature were reinvented and then one wonders: is this just a coincidence that everything happened in all these fields or did it all come together because there was some interplay? And I believe that the second of these is probably true. It brings us back to this incredible interplay that exists between any kind of human intellectual activity. Of course, you may say that the idea of the impartible atom became obsolete because of a certain experiment. But I think this was not by accident, but was probably influenced by the uncertainty principle that made philosophers rethink reality. This new paradigm affected artists, musicians and went back to science, and then also psychoanalysis emerged. I think it can't be a coincidence that everything happened within 20–30 years. The world was completely revolutionized and that is a measure of how interconnected all these things are that seem unrelated.

tr: When your are talking about the goal that you share between experimental and theoretical physicists, how would you describe that goal?

gg: To understand nature, really, to understand its fundamental principles. Particle physics seems to mean that we want to understand particles. But that is just a name. The actual idea is to go after the fundamental principles, the rules of the universe. That wasn't clear in the beginning of the century when we were first confronted with quantum mechanics. Then, we wanted to understand this particular phenomenon. We had no clue that these common principles were hidden behind. Over the last century, the more we have understood the small scale, the more we have actually been able to see. We found a very simple underlying scheme. So now we have gone back to the simple/simplicity, and it is shockingly simple. This is the difference between the physics of the 19th century and now. Before, these theories were like separated islands that couldn't be connected. Now, we are seeing that by working on the small scale, the whole comes together as a simple principle. This is the fascination and why we are continuing this process. It is not about understanding yet another particle, the path is not just leading us to understand something about the small world, but it is giving us a clear vision of what are the roots of the universe at large.

It wasn't obvious in the beginning, and it is not obvious that we will continue. This is the other point, it could be that we will continue our search and at some point become confused. Actually, we are maybe already getting confused, because there does not seem to be a clear next step. We have actually reached the end of the ladder, not because there is an end but because there is no next step. So at a certain point, we need to change perspectives. We have been playing this game because it works and at every step we have learned something more fundamental.

tr: Then we could draw the parallel that, in architecture as well as in physics, it was about dematerialization, of atoms, of space. As you just mentioned, there might be no next step in increasing the resolution of our vision in order to understand the big picture. Has the cycle that was begun in physics at the beginning of the 20th century come to an end?

gg: I am not saying that we have reached that point, I am only saying that it could be.

tr: Do you think that this could again influence other fields?

gg: I wish! But then, these periods of great change were also disturbed by wars and fascist governments coming to power. But it would be extremely inspiring if there really were another similar revolution at hand. I don't know where it would come from. Certainly we had our revolution in terms of information, which has been remarkable. It has already had a huge impact on everything. But will it have the same impact as the one at the beginning of the century? Maybe in the future they will say that we hadn't recognized it at the time.

I wish, as a physicist, that physics could again be revolutionized and that I could be part of it. I am already lucky that I can spend my active years in the wake of the results of the LHC. But also in the 60s and 70s, it was very exciting in terms of physics, the difference was the time scale of the experiment. Back then, you could get results within six months. Now, an experiment takes 30 years, which means from the moment you plan it to the moment you get the result there is more than one generation of physicists. So this is one problem that we are facing now. It's not a scientific problem, but a sociological one. The time scale of the experiment is becoming so vast that it hinders science from being dynamic unless someone reinvents the way we do experiments so that we do not need to build bigger and bigger accelerators.

tr: In general, do you have solutions that we could maybe transport from your scale to our scale in order to perceive our problems differently?

gg: I don't know if I have the answer, but I think it is beautiful to try to find them. That is why I sometimes talk to artists. They are trying to represent some of these ideas. I think it is unavoidable that you are influenced by what is happening in science and vice-versa. The idea that the universe should be organized like a computer exists because we are developing the computer. The idea of the multiverse is now influencing a lot of artists and was probably itself influenced by art. The influence is mutual. But I am not sure that I would be able to help you with an idea. There is however a lot of taste in what kind of problems that you approach, or the way you want to approach them.

Gian Francesco Giudice, born 1961, is an Italian theoretical physicist working at CERN in particle physics and cosmology since 1993. His research focuses on the construction of new theories beyond the Standard Model of particle interactions and on their implications for the early history of our universe. He is the author of ‹A Zeptospace Odyssey›, a popular-science book on the physics of the Large Hadron Collider.

The interview was conducted and recorded by Samuel Aebersold, Janina Flückiger, Lex Schaul and Matthew Tovstiga in Zurich in May 2014.