MICHAEL KACHELRIESS

Professor of Physics at the Norwegian University of Science and Technology.

Kachelriess_particles1_nothing1_evolution1_reality1_calculation1
Of what is the matter of the universe composed? What are the highest energy particles in the Universe and how are they equated?

Kachelriess_time1_evolution2_system1_complex1
The concept of time evolution is one of the main topics of physics. One tries to describe the evolution of a system from initial to final state, if one is able to do this then one has solved the problem. In the simplest case it is linear evolution, but unfortunately this is only an approximation and therefore most of the work of particle physicists is to improve on this… Alright, so linear is in some sense trivial… So if I have one cause, I know the evolution… If I add another one, I just get some kind of superposition, that is somehow trivial. But in reality the world is more complicated.

Kachelriess_time2_evolution3_system2_complex2
Particle physics looks for the time-evolution of the simple systems, and then you think that everything else is composed out of the simple systems. If we understand how the single electron behaves then you know how the sum of the electrones behaves, if it would be really linear. But unfortunately it is not. In that sense there are still some more complex topics if you know how the single states behave, the universe is then composed of everything and this is a nonlinear thing, so once again this kind of nonlinearity makes the things complicated.

Kachelriess_time3_energy1_system3_quantum1
The time-evolution in the quantum mechanical systems is described by a unitary operator. And this simple fact essentially tells us that time-evolution does not change the probabilities. The sum of all probabilities is one, so this is constant in time. Therefore this evolution operator is unitary. The second thing is that it forms a group which means also something simple… If you move from one time to another one, you could do this in two steps, and you could make it arbitrary. This is a simple mathematical property.

Kachelriess_quantum2_time4_space1_gravity1
If one goes to quantum field theory it is somehow simpler that one says space-time is a classical label. And on space-time there are some quantum processes going on. Alright, so this is an inherent problem; if one would like to talk about quantised gravity then you also have to find a quantisation picture of space and time, and this is not yet possible in a consistent theory. So in that sense, this fact that time is special is one of the very fundamental problems in physics.

Kachelriess_reality2
From my point of view, I do not think so… That we will reach this, I mean it might be that there is just one unique theory which is consistent, but it does not look like this.

Kachelriess_reality3_energy2
We will construct better theories, but how can you be sure that it is the final one?
It is like saying that what was an elementary particle one hundred years ago is now a composite particle. You just look closer at higher energies and then you realise that your atom is not an elementary particle et cetera.

Kachelriess_calculation2_quantum3_evolution4
If you know the laws of physics, then essentially, if we know the initial state, we can calculate what is happening. Even though it is quantum processes, we can describe in average what is happening. So in that sense there is no arbitrariness.

Kachelriess_evolution5_time5_nothing2
If we have a very good idea of what the initial state of the Universe at a very, very early time was, then you can calculate the evolution. There are some unknown things, obviously, but the general behaviour you can calculate. Just from the Universe starts from where you homogeneously expand at some point, galaxies

form and so on and so on… And somehow this is so… if you put in the right theory then you should figure out the picture of the Universe today.

Kachelriess_being1_system4
Well, in the end, human life, or the creation of life, is just part of the whole puzzle. So essentially the fact that we consist of carbon and so on, depends, in the end, on some funny details in nuclear physics and what kind of elements you create. Even though this is a big step, you would have to go from biology to chemistry to physics - in the end everything boils down to the fundamental laws.

Kachelriess_open1_closed1_system5_energy3_movement1
An open system refers to the fact that we receive energy from the outside, so essentially we take energy from the sun, and this allows us our life in luxury, right? While in the system, if we take the universe as a total, obviously does not receive anything from the outside and is in that sense a closed system and moves, in some sense, only in one direction: downwards! Things become less and less bright in the future.

Kachelriess_calculation3_meaning1_nothing3
If you do calculations in quantum field theory then you often encounter the problem that you should sum or integrate over some quantities and they are infinite. So you would expect a well defined number, but instead you get you get an infinity, so from a mathematical point of view these theories are not consistent and as a physicist one does not hesitate to make sense of this, even if the mathematics is not there. So there is a whole kind of mission; how one extracts sense out of mathematical nonsense.

Kachelriess_reality4_nothing3
If one describes something like the scattering process; an experiment where one has a initial particle prepared, and then one detects some final particles, then you use some kind of mathematical picture to describe what happens in between. Which by definition, because it happened in between, is not observed.

Kachelriess_nothing4_reality5
Virtual particles - though one draws diagrams and so forth - are in the end just …. you could say, it is a fiction. It is a kind of tool which we use to describe it. We like to talk about virtual particles which are popping out of the vacuum and elating again, but all this stuff is not observed, really. So it depends on your philosophical mood… You could say they are just some kind of nice tool to have an intuitive picture, and it helps you to do calculations - or you could take it more serious, because it works so well, then after some time you really think that these particles are there… But in practice they are something which is not observable.

Kachelriess_reality6_nothing5
They are not observable by definition. So your tool is something that describes the scattering process between a sum stated minus infinity and a sum stated plus infinity and that is what is measured. And you then use some language to describe this by mathematics and we are happy if it describes the result, but this does not mean that you could conclude that your picture is correct. You can always only prove that your picture is wrong. So you can exclude that Newtonian gravity works at high velocities etc., but you can never prove that this theory and this picture is correct. You can just compare it to a number of experimental results and you can say it does not contradict to anything, but again this does not mean that it is a fact, you see, it is not a finite theory. It is just a picture which is valid within a certain range.

Kachelriess_technology1_reality7
With technology there will be improvement and we will see an increase in the validity of our theories and so on. But this kind of fundamental distinction that some stuff is not observable by definition, it is just part of our thinking, so our thinking is independent of reality… No, that is too much. Our thinking is… it might not be the only way to think about reality.

Kachelriess_nothing6_movement2_energy4_quantum4_oscillation1
A free particle in quantum field theory you associate with an harmonic oscillator, so it is just… essentially

nothing is happening. You could excite it and it would move, but even if it's not moving at all, there would still be an energy associated, and this is what is called zero-point-energy. So it is very specific connected to this harmonic oscillator picture.

Kachelriess_nothing7_energy5
Nothingness in the sense that I have no excitation, so it is really the lowest state, but still there is some energy associated with it.

Kachelriess_time6_evolution6_complex1
All this is based on perturbation theory. With our linear time-evolution everything is simple.
But now, in general, it is not like this. It is not linear, it is non-linear, and then to do calculations we use perturbation theory. We start with some small quantity and we make a series of expansions of this small quantity. And then by doing this series of expansions all these pictures come up with the virtual particles and so on. So this is just an approximate description we introduce to do some kind of calculation.

Kachelriess_nothing8_evolution7_force1
We think that the Universe started from nothingness, very close to vacuum state, then it was expanding very fast. Everything that was before was diluted and in the end of this process the universe was empty except the vacuum energy. There is very good evidence of all this and we know roughly when it happened. But this process essentially cuts us off from what was before. Because essentially, information was also diluted, so probably it makes it impossible to go beyond.

Kachelriess_nothing9_meaning2
There was zero, and then space and time was created. The question is then; What was before? This question is not allowed. It makes no sense. Because in the whole process, before time and space was not existing, so there is nothing to ask.

Kachelriess_nothing10_meaning3_reality9
I don´t think that philosophy really helps. If we take the question if there is a fundamental theory of everything, you could take a glass of red wine and discuss it, but in the end physics is about experiments. You need to have an experimental proof. And philosophy will adjust afterwards.

Kachelriess_space2_time7_reality10
In early times you could declare that space and time are absolute and it is a preconception that we have, and so on - then you realize our conceptions are wrong - and you have to adjust philosophy.

Kachelriess_reality11
I would not even ask a question to a philosopher!

Kachelriess_being2_communication1
But still the distances are enormous and the other thing is that the life of each civilization is short. So you have some small spikes somewhere in the galaxy - there, there, and there - so very likely there are some people out there, but we will not have communication with them, so it is a bit theoretical.

Kachelriess_movement2_nothing11
In the simple approximation one calculates the flux of nucleons by knowing what is the decay spectrum in the decay from one single super heavy dark matter particle and then essentially one just sums up the flux of each around the earth, and takes the propagation into account.