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Mohamed El Naschie and the geometrical interpretation of quantum physics

Mohamed, first of all let me offer you my warmest congratulations on your 60th birthday. All my good wishes for you, for your very good health, for success and satisfaction in your work, for happiness in your life, and for our friendship.

It always was, and it still is a great pleasure for me to discuss with you fundamental questions concerning the interpretation of physics in general and quantum mechanics in particular. There are physicists who claim that one should not loose ones time by trying to interpret physics, it is sufficient that we have a quantitative description of a great deal of the universe and that using this knowledge we are able to understand and even to predict present and future developments in nature and in technology. There are other scientists who would like to gain an intuitive insight into the working mechanisms of nature besides being able to handle the mathematical apparatus describing it. I think both of us belong to the second group?

That brings me to your idea to regard spacetime as a hierarchal infinite dimensional Cantor set. It was a fascinating idea for me right from the beginning. It is a beautiful new approach for our understanding of basic physics. You did work out in detail that the set of fractal dimensions of the Cantor set constitutes a set of data which is basic for the fundamental constants in science. This is an important step forward in the long history of debating the origin of the fundamental constants. Deriving the mass spectrum of the elementary particles was essentially an experimental proof for the power and applicability of your theory. But I must say, what is most impressive for me, is the way you link quite different branches of science into one vision, applying topology to the understanding of spacetime as well as applying nonlinear dynamics to elementary particle physics. Your theory really is the vision of a universalist. That may explain your love to Goethe and Leonardo da Vinci.

Mohamed, how often did we discuss Thomas Young's optical double-slit interference experiment? I think it is one of the basic experiments in physics. You know, Richard Feynman wrote, it manifests the mystery of quantum physics. You just told me that you are going to prepare a new paper on it in which you emphasize the role of the double-slit interference in elementary particle physics.

Let me recall with you some of the wonders of quantum optics. The question is: What really is the mystery in quantum optics? Paul Dirac said, it is the wave function, Erwin Schrödinger said, it is the entangled state. Many people claim it is the wave-particle dualism.

There is a great deal of literature on the wave-particle dualism, much more literature than there is on Dirac's and also on Schrödinger's statement. Everybody feels compelled to contribute somehow to the wave-particle dualism.

Don't you think that this is going too far? The wave-particle dualism is, for me, a rather familiar phenomenon, well known in classical physics. It is actually the statement: When you have a physical object you might study the existence of the object in spacetime, but you also could shift your view point to the state of the object in spacetime.

The wave-particle dualism in quantum physics says that a quantum physical object, say a photon under certain conditions appears as being a particle, under other conditions appears as a wave.

What do we mean by saying it appears as a particle? With that we mean there is a way to detect the existence of the object in a well-defined interval in spacetime; in short, we can localize the object in spacetime. Simple detectors absorb the object in detecting it. In that case we can say only: The object has been detected in that and that spacetime interval.

What do we mean by saying the object appears as a wave? We mean that setting up an interference equipment we are able to observe interferences of the object with itself; that is: When the object can travel from one point to another along different, indistinguishable ways, then the probability amplitudes, determined by the wave function, to travel along the different ways, interfere with one another and might generate an "interference pattern" on the screen.

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That is: A photon—using appropriate detection instruments—can be localized in spacetime as an existing object, similar to a macroscopic object. The state of the photon, on the other hand, is described by a wave function. We can analyse the state of the object by studying interferences of the wave function and by doing so, we learn something for example about the energy or about the momentum of the object. Energy and momentum are properties of the state of the object.

It appears quite natural that asking about the existence of the object in spacetime and asking about the state of the object in spacetime are two different questions. Therefore you also need different experimental set-ups. You have to do different experiments in order to observe the one or the other property. There is no necessity at all, however, to say the object behaves as a particle or as a wave, depending on the way of observation; or as it is sometimes expressed, to say even the object *might be a particle*, but is also *might be a wave*. The fact is, the object is a localizable entity in spacetime and it has a measurable state which is represented by its wave function.

It is quite the same in classical physics. Assume we observe a macroscopic material object, a ball made out of plastic, to give an example. You, of course, have the possibility to detect the existence of the ball in some interval in spacetime, for example by looking at it. You also might determine the momentum of the ball, by using a momentum-measuring device. You would not expect that the localization of the ball in spacetime can be performed by the same facility which you use to measure its state, here its momentum. You will need different facilities for the different properties and certainly, you would not claim from the two observations that the ball mysteriously can behave either as a classical body or as its state or its momentum. It wouldn't make any sense.

In short: The wave-particle dualism is not a mystery for me. If there is a mystery, then it lies in the fact that you can describe the state of a quantum object by a wave function—as P. Dirac emphasized it. It is the way to describe the state of an object which is so different in classical and in quantum physics.

The same unjustified debate also takes place for the "collapse" of the wave function. Take the same classical example. The state of the ball might have inner degrees of freedom: If the ball is in thermal equilibrium, it might have a pressure inside and also a volume, it also might have a temperature inside and an entropy. If somebody has taken the ball away, would you say that there happened to be a "collapse" of the state of the ball or even a "collapse" of its volume or its entropy? You would certainly say if the ball is no longer there then its state is also no longer there. Isn't that quite naturally?

Schrödinger claims that—as shown in the EPR paradoxon—the most exciting difference between classical and quantum physics lies in the existence of the entangled state in quantum physics. There is no entangled state in classical physics.

What is an entangled state? The Pauli principle is a well-known example for the phenomenon of particle-correlations. But apart of such basic correlations between elementary particles there is also the possibility to generate additional correlations between two or more particles by preparing an entire ensemble of particles in a well-determined overall state: particular physical variables of the whole ensemble might then be more sharply defined than the same variables of the single members in the ensemble. The state of such an ensemble is what we call an entangled state. The members of the ensemble in such a state are related to one another by correlations although there might be no interaction between the particles.

Interactions between particles take place in spacetime; they are interpreted intuitively by the assumption of a force between the particles or a field at the positions of the particles in spacetime. Correlations seem to exist outside spacetime; they do not rely on forces, the particles are just related to one another by the overall state in which they were prepared. Neither does distance between the particles play any role in correlations, nor does it seem that any temporal processes of information exchange between the particles are necessary to generate correlated behaviour. Correlated behaviour appears as "eine spukhafte Fernwirkung", as Einstein put it. He could not believe in it. Experiments, however, have shown much later that entangled particles behave exactly as quantum physics predicted they would.

Schrödinger, I think, might be right. In our sense, up to now, we do not really understand the correlations in the quantum world. And it appears that there is a severe difference between the quantum world and the classical world.

I hope we will have many years of hard work to clarify all these epistemological questions. In the meantime Mohamed, I wish you and your new theory all the best. I also wish you and your beloved family all the happiness in the world.

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