Some Reflection on Time and Universe

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I want to say some words about the general direction of our work, some very general statements.

I was always interested in the problem of time. So I'm very happy that you have taken time as the main subject of your conference. I have been studying time since a long time. In fact I am interested in the problem of time since the 40-ties, so nearly 60 years ago. When I decided to be interested in the problem of time, people said to me generally, why was I interested in strange problem, it has been solved by Newton, and improved by Einstein, and there is no much to hope studying the problem of time. That is seems no more to be easy position today. Every month some book treating some aspects of time appears. Some people claim, that time is an illusion, like Einstein said about the direction (arrow) of time. Other people speak about travel in time, other speak again about multidimensional time, so there is certainly much interest in the problem of time. Probably this interest is partly due to our conviction that our Universe has a history. We speak about Big Bang. In every science we discover an evolving Universe. Therefore time plays an important role. Now, the paradoxes that the laws of nature seeing by classical physics are time — reversible and deterministic. The quantum mechanics on the level of Shrödinger equation is also deterministic in wave functions and time-reversable.

However, for important classes of dynamical systems the behaviour, which we see, is quite different. It is neither reversible, neither deterministic. An example is, of course, kinetic theory with probabilities and irreversible description. Then this is a controversy, which goes on since hundred years. What is origin of kinetic equations? And the majority of people claim that the new aspects of kinetic theory are due to ignorance, essentially to approximations which we make. I think, this is very difficult to accept. For example, Boltzman theory leads to the predictions on heat conductivity and viscosity which are in exellent agreement with experiments. Do you think that if we did not make any approximations there would be no viscosity. That would be very difficult to believe. Also, I think, existence of thermodynamics has already shown that something else may play an important role, because in thermodynamics, we know that far from equilibrium the new structure will appear, which have been studied in the laboratory, and the famous example was the Belousov–Zhabotinsky reaction.

Therefore it is again difficult to believe that this is due to our ignorance, to our approximations. That was essentially the conclusion very many years ago. And I want now to go beyond the identification of classical quantum mechanics, with time-reversable and deterministic description. And what is the classical description? The classical description is diagonalization of the Hamiltonian both in classical mechanics and in quantum mechanics. That means that we go to stable unchanging units, like the monads of Leibnitz. This is in the contradiction with the evolutionary nature of the Universe, which we observe. Therefore the first thing is to know how can we overcome this contradiction. We know since work of Kupmann and others, that when we have description in Hilbert space, we have time-reversable and deterministic description. But can we go beyond? For this thing, start with the Liouville equation, and this is important to understand, why we start with the Liouville equation, because our ambition is to combine or relate dynamics with kinetic theory and with thermodynamics. Now it is very well known since a long time that kinetic theory and thermodynamics are theories which need statistical ensembles, and this was, of course, the main contribution of Einstein and Gibbs. But again the ideal statistical ensembles are due to our ignorance.

We have now to understand why there are statistical ensembles which we can not reduce to trajectories or to wave functions. That corresponds to situations, which are, in general, not so simple. For example, thermodynamic situation, if the number of particles goes to infinity, the volume goes to infinity, concentration being finite and one can show, and this has been done by Professor Petroski, that for this, so called, thermodynamical limit, the interactions, in general, kick out the system from the Hilbert space. It's only when we are out of the Hilbert space, we obtain intensive and extensive quantities. Then the probability becomes irreducible. We can not go beyond the probabilistic description. And this probabilistic description is irreducible, we could say, because there are large number, practically, infinite number of degrees of freedom, which all interact, and in addition the interaction has to be nonlinear in some sense. So this characteristics of nonlinearity, infinite number of degrees of freedom are very important characteristics of our Universe. And we have to study the dynamics of this type of systems. It is clear that this type of systems is relatively complicated one, but I shall say now, I think, it indicates the right direction, but much has still to be done. By the way, kicking out from the Hilbert space is something which Dirac has described in field theory many years ago. I would say, that there is another difficulty, which I like to call Hamiltonian paradox. In classical mechanics once we diagonalize the Hamiltonian as I said, we obtain the static description, and the description of independent degrees of freedom, each unit, each, say, elementary particle, as we see as a free field, is independent of anything else than mechanics declared by Dirac equation or Klein–Gordon equation. But in fact, we see particles only because we see their interaction. We see the electron because it jumps from excited states to the ground states and emits a photon. Therefore we can not consider the electron alone, we have to see electron embedded in other interactions.

And that leads to a different description. Essentially we need to have particles, but particles, which are still embedded, like in macroscopic systems. For example, we know there is a town, but the town exist only because it is embedded in a medium. It is not like a crystal, a crystal could be isolated system. Town can not be isolated, life can not be isolated, it exists in interaction with matter, the isolated life is not possible it is not for a long time. Therefore we need the description which both leads to units, that are still units, but these units are interacting in time.

It is very convenient to start with I have called the dynamics of correlations. In dynamics of correlations on the statistical level you go from two particle correlation to three particle correlation, you create or destroy correlations, you have creating and destructing operators. This is the usual classical quantum description. The main problem is to find a unitary operator which leads from the initial representation of canonical variables to the representation with the Hamiltonian is diagonal. When the Hamiltonian is diagonal there are no more correlations. Correlations in the diagonal Hamiltonian, you could say, there is only through kinetic energy of independent particle. Therefore the problem of integrating systems or going to the representation which has no correlations is an equivalent problem. Now how to go outside, how to go to kinetic equations or thermodynamic description? Then, of course, correlations should not be destroyed. But it should be generalized to include dissipative processes. It means, essentially, that we now introduce analytic continuation because for these systems, we have resonances. There are resonances which according to Poincaré to create nonintegrable systems. We need resonances, and to cure divergent denominators corresponding to resonances we need to introduce analytical continuation, that is of course, not the first time, that it is used, and theory of nonlinear mechanics which has been much progress thanks to Russian mathematicians and physicists like Bogolubov. It is very well known that we have to correct divergent denominators, and once we deal with distributions, we have no more a Hilbert space, and the theorem of Kupmann on the equavalence between ensembles and trajectories is no more valid.

So essentially we have a method with correlation, which starting from the same formalism, leads to usual methods of classical dynamics like Hamilton–Jacobi and other line leads to dissipative systems. Therefore we have some kind of unification, because we now have the method which is valid for larger class of dynamical systems, dissipative or not, and which is essentially the same for classical and quantum mechanics. Quantum mechanics has its own problems how to deal with Fermi–Dirac and Bose–Einstein statistics, but there is no any big difference. Now when we go from classical mechanics of integrable systems, we go to dissipative systems, the essential point, which can be explained in more details by G. Ordonez, is that this introduces a new operator in place of unitary operator U. And this new operator, which is not unitary, but it was unitary for integrable system. This is more general determination of the operator which we call star-unitarity. But it changes very much the mathematics of dissipative systems, because this operator is not distributive. For example, this operator, which we call $\bar{\Lambda}$, acting on the square of energy is not the square of energy. Its action on the square of energy is different from the action on the energy squared. In other words, $(\widehat{H^2})$ and $\hat{H}^2$ play different roles. And that case is in a sense, beyond the algebra of quantum mechanics, there we know, we have noncommutative operators. Here we have an operator which destroy the distributivity. This is not a new discovery, because some years ago with Professors Misra and Courbage from France we have introduced the time operator about which Dr.Karpov will speak in more details. And the time operator is also a nondistributive operator which introduces fluctuation in the duration and leads also to uncertainty relation in time and energy, like the uncertainty relation, which we have in momentum and coordinate.

Thermodynamic systems are very close to field systems, fields are also formed by infinite number of degrees of freedom and, in general, the interaction means nonlinearity. And the theorems which we used for thermodynamical systems can be to some extent transposed to fields, and here we find again an essential difference between free fields which are described by Hilbert space and interacting fields which are kicked out from the Hilbert space.

It is interesting, because it shows that at very early stage we probably have already breaking of time symmetry, because, generally, what people think is that the beginning of the Universe, one way or another, would be differentiating, and differentiating would mean the interacting fields.

In differentiation you could have non linear field theory. But anyway, at the moment many people believe that there was a fuse related to string theory which is different, but from the point of view of the field theory the beginning of the Universe is the creation of matter fields or electromagnetic fields and so on.

So, let me conclude.

I think we see a different Universe, our classical Universe was as an example of what philosophers called being, now we see the Universe as becoming and in which the arrow of time plays an essential role starting with cosmology and going to biology and human history. The Universe is more complex, than we thought. The classical Universe was based on the idea of analogy with planetary motion and simple Newtonian laws.

This is only a very special and simplified view, view of the Universe as immersion of systems with an infinite number of degrees of freedom and nonlinear interactions. I think it would be the role of next generations to study these systems in more detailes than my generation could do.