ON QUANTUM MEASUREMENTS

Quantum, time, and space

I would like firstly to discuss the time-space relation universality problem. I will talk about the natural science only, more precisely – about physics. This one presents a science that is experimentally based on the measurements. As it is known, a measurement is a quantitative comparison of a variable with some etalon, which remains the same one between the different measurements. Because of that we can then compare the different measure results between themselves.

The basic measurements in physics present the time and space interval detections using some *drawing scale* and *clock*. So we need in the clear understanding, *why* we may hope that *each* object in the Universe is in fact *measurable in space and time*. Before quantum physics birth we had not any universal drawing scale and clock, hence this hypothesis was *a* declarative *measurement presumption* only, and it was revisited in the Special Relativity.

As I believe, quantum mechanics (QM) first pointed out to us "a light in the end of the tunnel". In fact, thanks to de Broglie, we understood that every quantum object is corresponding to some wave. The Lorentz's transformation correctness for the wave parameters is postulated, because of that *each* such object has some kind of *built* drawing scale (wavelength) and clock (wave period). Together all these objects present the gigantic population including in the Universe space-time relations community. The same manner, the some country economical community exists since all its participants have a sum of money. A subject without money (or any credit) is excluding from this community. If some object existed that had not the wave of de Broglie, it was disappeared from the Universe space-time relations system.

The frequency is inversely proportional to the wave period, and the wave vector is inversely proportional to the wavelength. The frequency and three spatial components of the wave vector present 4D-vector proportional to the de Broglie wave energy-momentum vector (the proportionality coefficient is equal to the Planck constant). If we postulate that this vector is invariant relative to the Lorentz's transformation, we may just deduce from here that for all physical objects the Special Relative is true since they contain the quantum "built" drawing scales and clocks!

Of course, we have to note the following fact. The both space and time can be specified with help of such feature as *extension* (length for space, duration for time). However, time has one more fundamental attribute that may be called "currency", or "time arrow". The evolution irreversibility is due to this feature, but it is independent on the wave's ones, as I believe. In my publications the time currency and time arrow I connect with the Universe expansion phenomena due to several external causes.

On "hidden variables" v. Neumann's theorem

As we know, a hard way brought Heisenberg to the QM's mathematical apparatus creation. It presents some formalism for that several commutations rules are used differing from these ones for usual numbers (physically this apparatus replaces a material point motion description by this one of several oscillators). Born identified these new rules with these ones for matrix. Then Dirac started to work, and saw that these rules are analogous to the known in classical mechanics Poisson's brackets. So, all this remains in QM as some kind of "exotic" differing it from classical mechanics.

The complex probabilistic wave function using to describe a quantum object also presents some exotic. For instance, the *mean* value *L* of some physical variable is given in QM by expression

$$L = \int \Psi^{*}\cdot\mathbf{L}\Psi\cdot dV$$

where **L** is the operator for this quantity. It is clear the *integration by volume* provides the *averaging over space*. So, physically the relationship $\psi^{*}\cdot\mathbf{L}\psi$ has to correspond with *the time averaging*.

In my book **[Shulman, 2004]** I told about a very effective way (in my opinion) to describe the classical osscilators (electrical, mechaninical, etc.) with help the standard mathematical tool used in electrotechnics. I prove there the following statements:

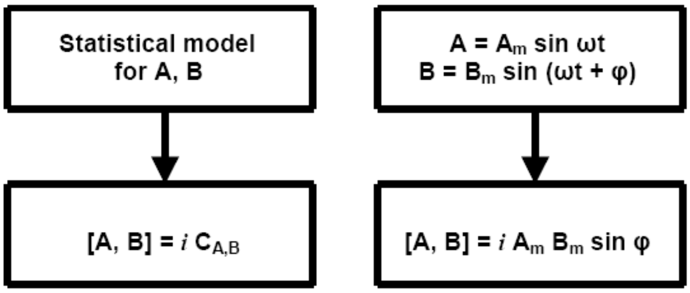
- The power, energy and action of an oscillator averaged over period can be presented as bilinear functions of the generalized coordinates and momentums, one of the each such pair factor should be taken in the complex conjugate form (like QM).
- For such bilinear form it is easy to introduce the commutator just like this one for quantum quantities. In particular, in such commutator for the classical mechanical oscillator coordinate and momentum at the right side there is the imaginary unit multiplied by action for this concrete oscillator (instead of the Planck constant for QM's commutator).
- For two-dimensional mechanical oscillators of two basic types the commutation relations may be deduced corresponding with the commutations rules for bosons and fermions in QM. A classical analogy of the quantum spin appears for the two-dimensional oscillator having the quarter-period phase shift between space axis. Since the three-dimensional oscillators with such shift between each pair of axis cannot be realized, the interdiction Pauli principle is accomplished for fermions (not for bosons).

Because the commutation rules for the *classical* and *absolutely deterministic* quantities are exactly analogous to the quantum commutators, the uncertainty relation is also correct for them (but the *concrete classical action* value is presented at the right side instead of the Planck constant). In the classical case such commutation rule tell us that we cannot synchronously measure the *maximal* values of an electrical current and tension, or of a coordinate and momentum of the mechanical oscillator. The micro-level analogy in this situation is presented by an *instant* value, and in macro-level we measure an effective one (RMS), an effective power in electrical line, etc.

John von Neumann profoundly analyzed the quantum measurement problems in his famous monograph **[Neumann, 1932].** In particular, he stated that uncertainty relation was just due to *the measurement process influence on its outcome*, so QM becomes in principle a statistical and non-causal one, introduces a non-zero dispersion into the quantum quantities distribution. From here v. Neumann deduces the determinism and some "hidden" variables impossibility. His logic is such. The measurement results *have a-priori a non-zero dispersion due to the QM statistical nature*. Because of that, when we connect with every physical quantity a *statistical* operator, we may deduce (as Kennard and Robertson showed) for two physical quantities that cannot be measured synchronously the operating relationship which is equivalent to the Heisenberg's uncertainty relation.

This v. Neumann's statement is usually interpreted as the proof of the impossibility to describe a quantum object with help any "hidden variable" theory, i.e. as the QM stochasticity in principle. *However, in fact the only sufficient condition is proved: if QM is a statistical theory, then the generalized uncertainty relation is accomplished*. But *the requirement* is more weaker: when *the uncertainty relation is accomplished*, the connection between two measured quantities *can be deterministic*, if this connection provides some *non-zero dispersion* during the synchronous measurement (we just have this case when try to measure synchronously the amplitudes of two oscillations with phase shift φ). So, in my opinion, the "hidden variables" interdiction is not generally proved.

Uncertainty relation and "hidden" variables



CONCLUSION: A statistical model leads [A, B] ≠ 0 , but [A, B] ≠ 0 does not necessarily leads a statiscal model!

The more, I state that, in fact, such hidden variable exists in QM, it presents a wave function phase angle. So, I put a logical finish to my hypothesis on the correspondence between the classical oscillators and the quantum ones. There is some explanation: we have very high frequencies in the quantum case (the electron rest energy having order 0.5 MeV corresonds to the wave frequency more than 10^{17} Hz). Hence, the QM probabilistic interpretation becomes the unnecessary one,althogh some reservations should be made due to a non-local nature of the quantum objects.

Remark: There is the profound difference between two theorems about "hidden variable". The v. Neumann's theorem is dedicated to the QM's *incompleteness*, and famous Bell's theorem treats the QM's *non-locality*.

v. Neumann's measurement model further critic

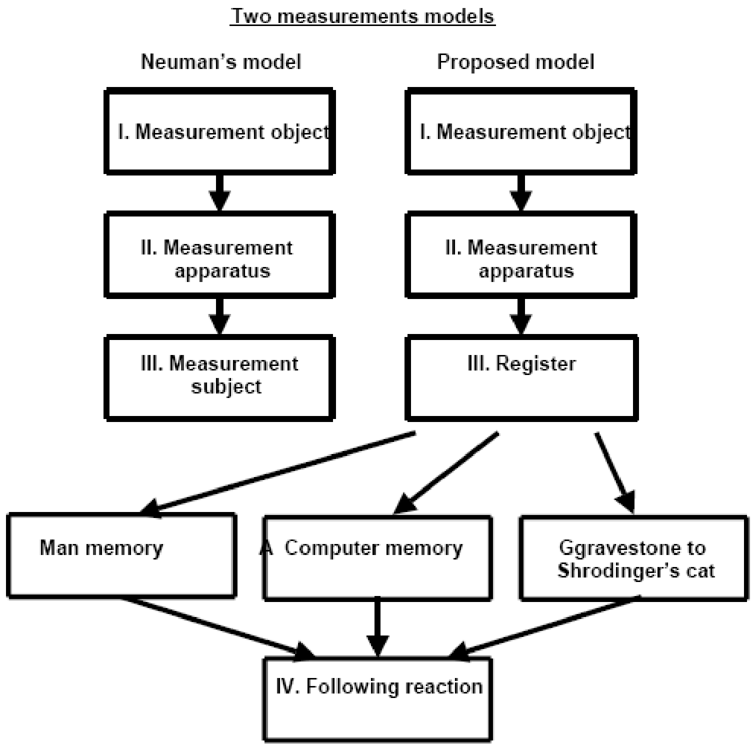
In QM the measurements play the role that cannot be ignored (not like classical physics). On the one hand, there are the systems having smallest own energy, so any measurement dramatically changes their state, and we *cannot know anything* about these states *between measurements*. On the other hand, there are situations, where an effective state monitoring (but without *direct* measurement) may prevent the particle radioactive decay (quantum Zeno effect). The same manner, the only fact of a detector presence can have a dramatic influence on the famous "Shrodinger's cat" fate.

The important question remains as a challenge to the scientific community: is the measurement role connected with the *consciousness* of any observer, or not. So, we have to carefully study, what namely does the measurement procedure present in general, and the measurement procedure in the experiments like two-slits ones in particular.

In the abovely cited monograf v. Neumann considered a quantum system evolution and defined two its possible types (I and II). The process II corresponds with an unitaire evolution and the reversible Srodinger's equation, Penrose called it "U-procedure". Contrary, the process I corresponds with an irreversible measurement process when *only one of the possible alternatives* must be realized, the non-unitaire wave function reduction happens. Such process type Penrose called "R-procedure", it is actively studying now experimentally, not only theoretically.

Neumann formulated famous measurement model consisting in *three* parts: a measurement *object*, a measurement *apparatus*, and a *subject* executing the measurement. Then, he connected with this subject any role that subject's *consciousness* plays in the measurement. He formulated so called physical "parallelism principle", according to which it may be possible to describe an extra-physical process of the subjective reception as if happened in the physical realm. The v. Neumann's purpose consisted in the studying, *what* and *how* varies when we change the whole model division into these three constituent parts, where the final part presents some subject having (very uncertain) non-physical features.

I think, the "parallelism principle" is here unnecessary one. I do not reject at all the wonderful features of the human *consciousness*, but I do not believe that a measurement or some process of the subjective perception presents a new essence that cannot be reduced to the physical world. Contrary, I state that, in fact, any (memory) register only has to follow the measurement device having arbitrary physical nature (may be, organical one). A subjective reception *may* conjugate with the registration act, however, that has not any influence on the measurement procedure and even does not present the necessity condition for any possible reaction, i.e. for a further events sequence. For instance, a computer or a simple automat may react to a dangerous parameter value and stop the industrial equipment working.



In fact, the quantum measurement role just consists in a final condition fixing when the measurement interaction energy is commensurable one with the measured system energy itself.

Conclusion

So, we came to the following statements:

- Namely the matter quantum level (thanks to de Broglie wave) allow us to measure space-time (as well as all the others physical) parameters.
- Contrary to the v.Neumann's "hidden variables" impossibility theorem, the Heisenberg's uncertainty relation *can* be due to a deterministic (not statistical) mechanism.
- The human consciousness does not determine the object evolution with help a quanum measurement and does not present a necessary component of the corresponding measurement procedure.

References

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[Shulman, 2004] M.H. Shulman *Variations on Quantum Theory* (in Russian). Moscow, Editorial URSS, 2004.

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