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HOW BEES CAN POSSIBLY EXPLAIN QUANTUM PARADOXES

Welcome to our “Yahoo!” - group to discuss hidden time

In the paper we briefly tell a story about what is quantum theory, quantum non-locality and delayed choice. Then we tell about most promising transactional interpretation of quantum mechanics, designed by John Cramer to explain these paradoxes, and how we introduce bees’ flights and hidden time into John Cramer’s approach.

What is quantum theory?

Quantum particles like atoms, molecules or electrons are known to have no smooth trajectories like bodies in classical mechanics. Instead such particles can be in so called *quantum states*, and make transitions between them. Say, an electron can be placed at some point. This is one kind of quantum state. Or, it can have some definite momentum (and thus no definite position).

Any transition has a probability which is calculated in quantum theory by some very strange formal mathematical procedure. This procedure provides a recipe to calculate a quantity called *amplitude*. The square of absolute value of this amplitude gives a probability of correspondent transition.

What is quantum non-locality?

Non-locality of quantum mechanics was widely spoken for the last decade due to quantum computations, quantum teleportation, EPR correlations. Still, non-locality of quantum behavior of particles is not necessarily connected to these exotic phenomena. Non-locality is present in *any* quantum transition.

Non-locality is intrinsic property of any quantum transition. It is most clearly seen if we use Feynman’s formulation of quantum mechanics. This formulation is popularly told by R. P. Feynman in his brilliant book “QED – a strange theory of light and matter” [1] (QED = quantum electrodynamics). More technical explanation is in his another book “Quantum mechanics and path integrals” [2]. See also

Main idea is that a particle, after leaving a source, reaches (in some sense) the detector by all possible paths. Each path provides a complex number, which is a value of some integral along the path. Total sum of such numbers over all paths gives the amplitude of transition. Being squared, this amplitude gives a probability of transition. From here we shall talk about states with definite position and transitions among them only.

So, here’s the real sense of quantum non-locality: amplitudes depend, generally speaking, on the *whole* Universe! To be true, only a small set of paths actually matters, while the income of others into total sum tends to be negligible.

Still, the paths that matter can be separated essentially. Here's the most illustrating classical example from classical paper of David Deutsch on quantum computations (Fig. 1).

If we suppose that a photon (a quantum of light) moves either this or that way after passing the beam splitter, then both of detectors *A* and *B* will work with equal probabilities at many runs of experiment. Still the detector *A* never works. In quantum mechanical language we say that path integrals at two paths sum to zero amplitude for that detector. In some way a photon "knows" about positions of *both* mirrors we use. It is true non-locality.

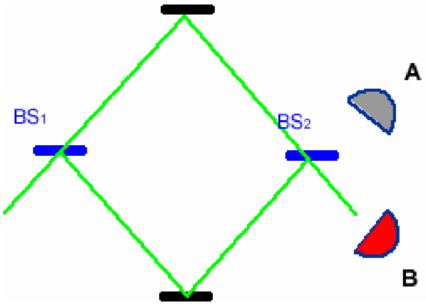

Fig.1

What is delayed choice?

Delayed choice [3] is a kind of analogue of non-locality for time dependence of quantum amplitudes, contrary to spatial dependence, as discussed above. Imagine the same classical experiment as at Fig. 1 (such an installation is known as Mach – Zehnder interferometer).

Let now all the distances between mirrors and detectors be so large that it takes essential time for a photon to travel across the arms of the interferometer. Let us also take off the beam splitter BS_2 at the moment just before the photons should come to it. In this case, according to predictions of quantum mechanics, the photon can hit either of detectors *A* and *B* with equal probabilities.

In the previous section we agreed that the photon travels both paths, i.e. arms of the interferometer. But it is not valid in current situation: hitting any of two detectors should be equivalent to traveling some single path only!

It looks as if the photon first moves both paths, but at the former place of BS_2 it decides to turn back and start his travel once more, this time one path only. In other words, the photon decides what a history he had at a final instant only. It is delayed choice paradox.

What is transactional interpretation of quantum theory?

Transactional interpretation of quantum mechanics (TIQM) is suggested by Prof. John Cramer of Washington University (Seattle, USA). It provides a very illustrative and comprehensive explanation of quantum non-locality and delayed choice.

Which is the difference between an *interpretation* and a full-value physical *theory*? It is normally assumed that an interpretation provides a *way of thinking* and no predictions. Instead, a full-value physical theory provides quantitative predictions that can be tested experimentally. Though, Afshar experiment seems to verify TIQM, as John Cramer supposes.

The core of TIQM is idea that a single act of a particle transition (consisting of both emitting and absorbing) should be treated as a single *transaction* between a source and a detector. Transaction is formed by two waves: a retarded *offering wave* (from past to future) from a source and an advanced (from future to past) *confirmation wave* from a detector. An illustrating space-time diagram is in John Cramer's paper. The two waves interfere in such an adjusted way, that there are no any waves *before* emitting and *after* detection.

Nature, according to TIQM, allows different transactions with probabilities, which correspond to quantum theory, but in each case only one happens. We could even formulate in the following way: do focus on transitions (= transactions) rather then emitting and detecting events separately; do view a transaction as a single physical phenomenon, a single event. To be true, such a formulation is our own "re-interpretation" of transactional interpretation☺.

In this case non-locality and delayed choice make no surprise. Say, in standard Mach – Zehnder experiment (Fig. 1) transaction is formed by waves in both arms of the interferometer (Fig. 2a).

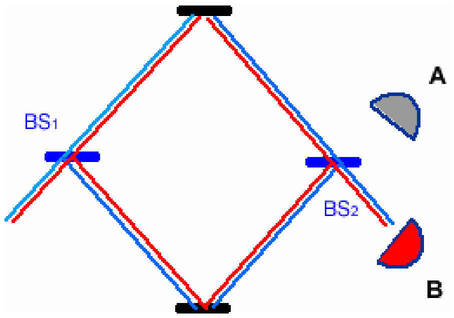

Fig. 2a

And in delayed-choice experiment one of two possible transactions happens, each within a single path (Fig. 2b, 2c).

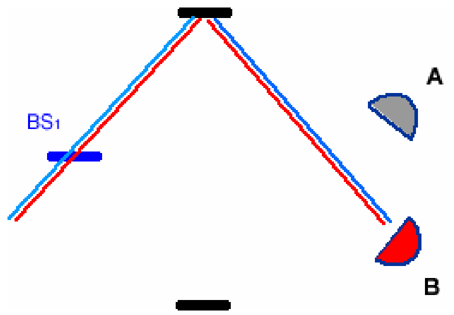

Fig. 2b

All figures 2a, 2b, 2c imply blue line for retarded offering wave, while red line means advanced confirmation wave.

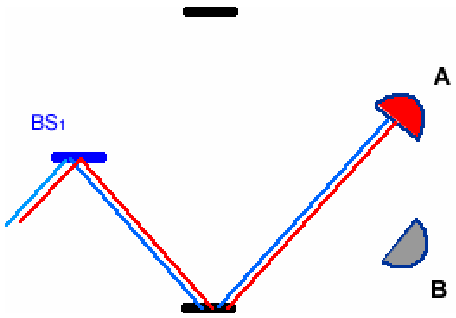

Fig. 2c

Why 2 waves in transactional interpretation?

What for the two waves are needed? In fact, John Cramer is not inventor of "backward – in - time" propagation. It is an idea of R. Feynman and J. Wheeler, which is explained in John Cramer's paper in detail.

Two waves are necessary to accomplish correlation of boundary conditions on both sides of transaction. This correlation takes place in many - particles effects like EPR, quantum teleportation, etc., which we do not examine here for simplicity, but which were the object of intense investigation and popularity for last decade. One can read a very good introduction by Prof. David Harrison of Toronto University.

Here's a very explaining citation from another paper by John Cramer:

"The process described above can also be thought of as the emitter sending out a "probe wave" in various allowed directions, seeking a transaction. An absorber, sensing one of these probe waves, sends a "verifying wave" back to the emitter confirming the transaction and arranging for the transfer of energy and momentum. This is very analogous to the "handshake" procedures that have been devised by the computer industry as a protocol for the communication between subsystems such as computers and their peripheral devices. It is also analogous to the way in which banks transfer money, requiring that a transaction is not considered complete until it is confirmed and verified".

What is hidden time model of quantum phenomena?

Explaining force of transactional interpretation is great indeed, but new questions arise, and they are obvious. As we pointed before, quantum transitions are probabilistic: one of many possible transitions (= transactions) can occur. Any particle can be either emitter or detector; it should emit retarded and advanced waves in all directions, to all possible "partners" in transaction. How it happens, that some definite transaction happens? Why this, not other?

We propose a simple idea of *how* some definite choice can be done. Our basic idea can be illustrated most clear by an analogy with *bees*. This analogy is proposed by Howard Bloom.

Imagine a beehive full of bees. They all have different jobs. Worker bees want to gather the harvest, by first they need a good decision about where to fly for most profit. Scout bees, (who are much less numerous than workers) fly in different directions to find a better lawn (Fig. 3a).

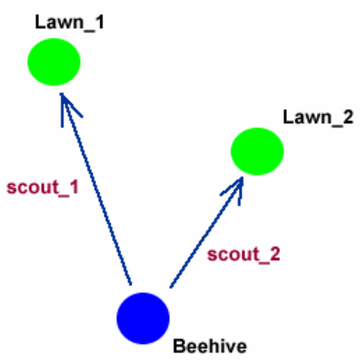

Fig. 3a

Each scout finds the best (in her opinion) lawn. Then she comes back home and starts agitating for her findings (Fig. 3b). As you might know, scout bees agitate by dancing special 8 – looking dances. Worker bees attentively "listen" to agitators. They wonder whose arguments are most convincing. Dances can take an essential time, especially if the deed is not about a good lawn, but about a new hive. At swarming the dances can long for several days, and agitating scouts can even die of emaciation!

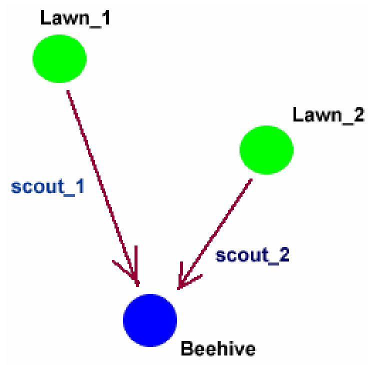

Fig. 3b

Finally worker bees make their joint decision and fly to some certain lawn (Fig 3.c).

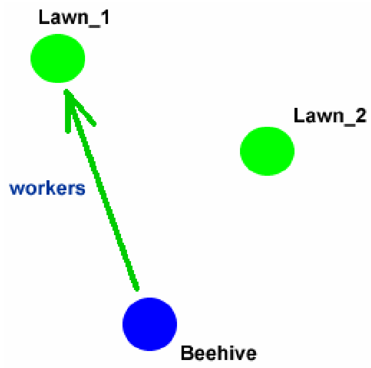

Fig. 3c

One can easily see that it looks very much like transactional interpretation. But instead of 2 waves, including *offer* and *confirmation*, we have 3 passes here. We add the third pass of, but it is a pay to explain why some certain transaction happens of many possible.

This also explains why in Feynman's formulation of quantum mechanics uses all paths to calculate quantum mechanical amplitude of a transition. In bees' language, scouts explore all lawns, but final collective decision is a single lawn.

So where is hidden time in bees' flights?

One can claim here: "Hay! It takes time for scouts to fly back and forth. What about speed of light? If we talk of a photon, it must reach the detector with the light speed! It can not jump back and forth 3 times between *all* possible detectors. It is crazy because it takes huge time!"

Yes! This is why we hide scout flights in *hidden time*. Physical time simply does not *tick* while scouts investigate the Universe. We suggest a very simple but original decision: physical time instants correspond to *completed* transitions, while such transitions correspond to *final* jumps only, like at Fig 3c. Scouts flights are simply *excluded* from the physical time☺.

More detailed arguments about why such a scheme is physically correct (including agreement with *special relativity*) are in our preprint and this article.

Another analogy: ants

Besides bees, there is another very promising, as we believe, analogy between quantum particles and living adaptive systems. These are ants. Whereas collective of bees in a hive is, in our opinion, an analogue to a single quantum particle, ant colony behaves much like a classical body which is a huge collective of particles.

Ant colony can perform optimization tasks like finding the shortest way from a nest to a food source. Ant algorithms are now very popular due to investigations by Marco Dorigo. Still, for the purposes of enlightening the analogy, main idea deserves at least a short description.

While different ants travel both short and long way from a nest to a food source (Fig. 4), they leave a smelling track of pheromones. At each of two crotches a traveling ant has a choice to go this way or that way. The probability of certain choice is proportional to intensity of smell, left by previous travelers.

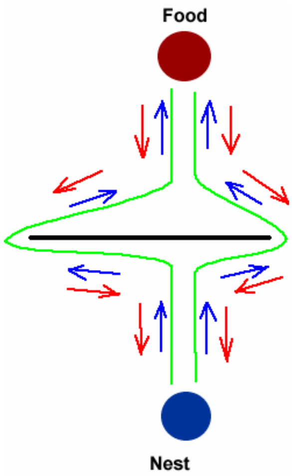

Fig. 4

Even implying equal parts of ants' choices at the 1st passage from the nest to food source we can estimate that the shorter way becomes more preferable very soon. The reason is that a longer way needs a longer time to pass and thus the smell of pheromone melts faster here than at a shorter way. As ants make many passes back and forth, more and more travelers prefer the shorter way, while the longer way becomes empty.

It is notable, that a single ant is rather random system, while a collective becomes a deterministic system. The same we have in physics: a single particle is random (according to laws of quantum mechanics), while a huge collective behaves in a deterministic manner.

Classical body (= a huge collective of particles) minimizes a physical quantity named *action*, while it moves. Say, a classical beam of light minimizes the length of propagation way (Fermat's principle). Doesn't it look too much like what an ant colony makes?

Many paths and **many passes**, as we believe, is a too strong analogy to ignore. We believe that Feynman's formulation of quantum mechanics ("many – paths formulation") paired with transactional interpretation (assuming passages back and forth) shows that elementary particles are complex adaptive systems very much like those we have in living nature.

The novelty of our approach at Keldysh Institute of Applied Mathematics in Moscow is to unite the two approaches and to put these passes into hidden time.

Which are the perspectives of hidden - time hypothesis?

We now want to point only 2 features of our hidden time program, which we believe will attract new generation of courage mathematicians and revolutionary physicists.

1st, 3 passes of signal, or, in other view, 3 kinds of signals (emit scout, send scout back and send final choice or final refusal) imply 3 kinds of elementary operations an electric charge can do (we mean that these are charged particles that emit and scatter photons).

These operations can be implemented by a single "device" using a unified algorithm; either 3 distinct algorithms, implemented by 3 distinct devices, can perform the whole procedure.

Thus we are courage to suggest that hidden time concept *implies by itself* existence of partial charges in addition to whole charges. In other words, hidden time concept "predicts" quarks. We are not confused by the fact that they are already opened☺, because nowadays quantum electrodynamics, which describes photons and electrons, and quantum chromodynamics, which describes quarks, are different theories. We suggest a unified approach.

2nd, we suggest that hidden time program can possibly lead to uniting quantum theory and gravity. In other words, we claim to compete to superstrings theory and quantum loop gravity theory at their home fields.

Our basic hypothesis here, which can quite be wrong, of course☺, is as follows. To be true, we don't talk about attraction of masses *yet*. Instead we suggest that the idea of exchanging signals in hidden time provides *for free* slowing of physical time.

Imagine that some particle develops scout signals from lots of other particles. The core of hidden time approach is that all queries stand in a queue until the "detector" fully develops the first query in this queue. "Fully" means sending the scout back and waiting until final confirmation or final refusal from corresponding has come (in hidden time, of course). See our preprint for technical details.

Imagine that the "detector" particle is inside a huge bulk of other particles. Although all the development of scout signals occurs in hidden time, a large number of queries (= scout signals) indirectly "stops for a while" physical time.

These two hypotheses are a qualitative estimation only. They can quite turn to be wrong! But we believe they deserve a more detailed analysis. Even if they are incorrect, it is very important *to test* that a very simple concept like hidden time *can* indeed or *cannot* unify quarks, light and gravity.

Our understanding of being *a scientist* tells us we have no right to pass by such a simple and possibly powerful concept. Because, even if proved to be wrong, it will provide us some very *fundamental* knowledge about what our Universe *cannot* be. Namely, a web of messaging agents☺.

References

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2. *R. P. Feynman, A. Hibbs*. "Quantum mechanics and path integrals". McGraw-Hill Book Company. New York 1965.
3. *Avshalom C. Elitzur, Shahar Dolev, Anton Zeilinger*. "Time – reversed EPR and Choice of Histories in Quantum Mechanics". ArXiv: quant-ph/0205182.