According to current views and experimental practice, all outgoing beams (Fig. 2 top) have the same intensity, which is $1/32$ of that of the initial beam (of course, real mirrors will not have exactly 50% transparency, and there will be some absorption, but this is not important).

Now we introduce into all the right-hand branches (corresponding, for example, to reflection by the mirrors) the 'informational cells' (shown by rectangles), which convey some information to the particles. These cells may be represented by the sets of glass plates in which the information is encoded in the thickness of the plates and the distance between them. The information conveyed by each subsequent row of cells is a continuation of the information conveyed by the previous row.

Real cells introduce some absorption, which can be taken into account in processing of the experimental data, or compensated by installing similar cells in the left-hand branches, which carry 'less interesting' information. For example, if each letter of our alphabet corresponds to a plate of certain thickness, then the left-hand cells may have the same plates arranged in alphabetical order.

According to the current views and practices, the introduction of informational and compensating cells will not affect the equal distribution of the intensity in the exit branches. If the particles have intelligence, however, they may take interest in the information presented to them. Trying out different paths, they will discover that the right-hand branches carry more information, and will prefer them to the left-hand branches. In other words, the particles will develop a conditioned reflex. This will alter the distribution of particles in the exit branches. Figure 2 shows an example of the probability of the particle occurring in different branches of the tree in the case of momentary formation of a conservative conditioned reflex — that is, when the particle after the first comparison of the right-hand and the left-hand branches immediately begins to give total preference to the right-hand ones.

The unequal distribution of particles in the exit branches may be detected by the experimenter, and can be rightly interpreted as an interest of the particles towards the information, and a manifestation of their intelligence. This important result does not even depend on the ability of particles to decipher information — it is sufficient that they are curious. It is like archaeologists traveling to remote places because of their curiosity for ancient hieroglyphs, long before they learned to read them.

The sum of information distributed in the cells may be a kind of a course teaching the particles a language for further dialogue. To measure the progress of learning, the experimenter from time to time may present the particles with the instruction "Please turn left". Since the particles, eager not to shirk the lessons, will tend to select the right-hand branches, the execution of this instruction will mean that the text was decoded, and we have moved to a higher level of information contact.

The scheme in Fig. 2 can do even more. By selecting a unique path, the particle may use the 'right – left' code ('0' – '1') to transmit a message. Since the detection of the particle in the exit branch corresponds to the unique path in the tree, we shall be able to read this message. For example, the leftmost branch in Fig. 2 corresponds to the message '00000', and the rightmost to '11111'.

This interpretation of QM is also developed in Refs [7 – 9].

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Reality and the main question of quantum information

A M Pilan

As a matter of fact, the main issue in M B Menskiĭ's "Quantum mechanics: new experiments, new applications and new formulations of old problems" is concerned with the information that is available in Nature for the (pre)determination of quantum histories.

After 75 years of debate many practical scientists do not believe in the expedience of discussing either the quantum paradoxes or the concept of information for physics. On pages 13 and 15 of *Physics Today* (February 1999) Anton Zeilinger cautiously observes that "after the success in demonstrating the entanglement, it will not be a big paradox if it turns out that quantum mechanics is about information", but is cut short by Goldstein: "does Zeilinger truly believe that information can simply and generally exist just by itself? — it always is about concrete things and events... — this is why it is interesting at all". So what is the quality and quantity of the determining information available in Nature?

The appeal to the multiplicity of parallel worlds constructed by the consciousness — which essentially is a turn to the philosophy of solipsism, presented in the review of M B Menskiĭ [1], might well be regarded as an indication that the situation is desperate. If we look at the role of 'God' from the cybernetical standpoint, however, we must admit that God will hardly take care of each of the alternative fates of all microsystems. As my contribution to the 'brainstorming' started by *Uspekhi Fizicheskikh Nauk* [*Physics – Uspekhi*] journal, allow me to share my conjectures about the form of presentation of quantum information.

We are living through the crisis of revision of QM from a mechanical machine to an information-cybernetic machine. If there is enough determinism in quantum mechanics to make

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feasible a 'quantum computer', then nothing prevents us from seeing the entire world as a quantum computer that calculates its own destiny as well as our fortunes. Regarding the role of consciousness of 'virtual little men' that try to guess how it works, the living brain seems to be made 'in the image and likeness' of inorganic nature — like a 'holographic computer' [11].

The existence of entanglement has been proved — EPR linkage that 'telepathically', across distance, limits the freedom of remote particles by 'mutual obligations', and such links essentially play the role of 'hidden parameters'. This means that the physical world is saturated with these links to some extent — but actually to what extent? Today it is still possible to express extreme views on this subject. As reasonably noted by M B Menskiĭ, one has to be ready that all this may turn out not to be physics after all. Here we encounter a fundamental methodological difficulty: by definition, physics deals with the universal prediction of outcomes of experiments for all kinds of observers — that is, physics is concerned with the invariants of the Poincare group and the group of internal charge symmetry, postulated by 'democratic principles' — the homogeneity of space and physics for all observers. Now the invariants of groups of physical symmetries are formulated with an accuracy not better than the amplitudes in the language of the functional of quantum states. At the same time, the individual history does not find its way into the quantum description. Matter itself, however, is an asymmetry in the symmetrical 'physical vacuum'. Then the vacuum, by the arrogant definition of physicists, renders itself to a trivial transform, while the "elementary particle is an irreducible transform of the Poincaré group" (up to a curved space, in which it is not known how to construct these transforms). Experience makes us admit that the maximum information *for a physicist* is the wave function, and that the wave function characterizes the method of preparation of a quantum ensemble — roughly speaking, it is a sequence of filters (made up of collimators and monochromators), after which the *physicist considers identical* the states of studied microsystems — but in no way are the individual microparticles or microsystems identical, because these filters are totally insensitive to the heritage of quantum histories of each particle in its individual EPR links.

The recognition of these individual links literally ruins all 'democratic' principles of physics — homogeneity and isotropy together with microscopic causality together with the equivalence of the observers. "Gentlemen, this is not physics after all", — argued the fathers of quantum mechanics, saying goodbye to determinism. Now is the time to part with indeterminism.

Since "God does not play dice", we should find out what information he has for consideration — that is, what is the quantity of information and how it is represented. 'God' for us is not that omnipotent moper, but the natural mechanism that defines the fates of physical processes, and information is not the 'Holy Spirit', but something comprehensible for theoretical physics.

In contrast to 'reality given to us through sensations', the presentation of information to 'god' we shall call 'actuality', assuming that the definitive invariant will be not the Minkowski interval, but the action which has Planck's natural measure. Planck's constant is not just a parameter for drawing a distinction between quantum and classical mechanics — it is a universal measure that answers for the distinguishability of physical states, or the natural measure of information. This role of Planck's constant became clear in the 1930s, when it was used for defining the entropy of an ideal gas.

Filling for once god's shoes, we come to the 'indeterminism' of quantum mechanics from the back door — through the negation of *quantum stochasticity*. If "*God does not play dice*", then he can only cope with finite information, and this is the reason why classical mechanics is too much for him. Quantum 'uncertainty', on the other hand, offers the greatest 'certainty' in the sense of the 'holographic principle' [1], according to which the amount of physical information available to 'god' in our world should have an invariantly defined quantitative measure ('on a spacelike 3-surface'), which is conserved with time from '3-layer to 3-layer'.

The role of 'god' becomes conceivable or calculable only if the *entire information contained in the physical world is finite*, because its carrier — the physical world (regarded for its definitive information as both the carrier and the channel) — has a limited capacity and throughput, which for any kind of carrier is limited by the classical Liouville measure of the available phase volume measured in quanta of action — Planck's constant raised to the power of the number of degrees of freedom. This volume increases with the energy and the 3-volume. Their resources in the observable Universe are limited. The limit of the amount of information transmitted by a physical system is the identification of the most pure state of the system, if the entire final list of its possible states is known.

All arguments about the finiteness of the total measure of information are in contradiction with the abstract quantum mechanics: after all, a simple system, such as the hydrogen atom, seems to have a countable number of distinct quantum states, while a 'boundless field' has a continuum of such. Nature, however, has set many limits to their availability, since a spatial continuum is an obvious mathematical artifact.

How can we discuss the spatial relationships of points in space without specifying the method for observing these relationships? A material point has long fell victim to quantum mechanics and (together with the 'world line') has been replaced by the vague 'wave packet'. In fact, the point is abandoned, the world line too, but the continuous space of events, described by the real 4-continuum, has stayed and remains the basis of the contemporary 'standard model' — locally — the micro-causal quantum field theory with its intermediate regularizations and final renormalizations. In the conventional quantum field theory the properties of geometric space enter the path integrals only through the specific form of the propagator. In the formal construction of field theory via the generating functionals, the form of the propagator can be left open up to the end — rather, one can try to extract the geometry of space in the form of a Green function from the properties of the graph of real relations as the parameter of order. Averages over the graph correspond to Green functions. The graph itself, however, it not too clear for mathematicians — homologies with cohomologies are synthesized without defining a smooth manifold, on which

[1] This principle initially emerged with the lower limit of entropy in black holes [9], but later, after the 'third superstring revolution', attempts have been made to extend it to our visible world (see Ref. [10]). The visible world is regarded as a closed system, rather than an open system, in contact with a heat buffer, like in the conventional treatment of information and entropy [11].

they would have been put in correspondence with chains and differential forms.

Geometry pretends that nothing has happened, and only admits its absurdity on Planck's scale. We are skeptical about the poetic image of boiling vacuum from the geometrodynamics of Wheeler, pending the discovery of gravitational waves or Higgs bosons. And if they are not discovered, like the absolute motion with respect to the ether, then it means that the phantom of ether (a continuous physical field as the continuous function of exactly defined space) has once again played a trick on physicists, like it had done before the Michelson – Morley experiments.

Observe that the metric tensor is seconded by the Lagrangian of the free field of particles: the wave function precisely ticks off the invariant world interval with its periods. "A straight line is a beam of light", only the beam is real, and in place of points we have 'sources' and 'detectors'. The world interval has swollen and dissolves in Feynman's integral. It would be good to abandon the spatial relations between the points of emptiness in favor of relations between material particles. Judge for yourself. Both the particles and the events are tied to points only by the amplitude of the wave function in our 'theater or shadows' — Minkowski's 'space of events', while the WF represents the *ensemble*. Because the quantum is unique and indivisible, this amplitude can be attributed by our 'defense' not to the particle but to the space, so that at the final triumph of justice at our 'court of law' the guilt for the unruly wave behavior would be shared equally between the particle and the space. In the spirit of relativity we say, "One cannot see without photons. Nor touch". It would be fair also to split between them the responsibility for the wave behavior not appropriate for the particle. Indeed, in case of collective behavior (for example, in a laser medium, the atom cannot be caught red-handed emitting the photon, and therefore the question of where and when the photon emission took place does not make sense. The world of quasi-particles is equivalent to the world of particles, and obeys the same laws with the same Planck's constant. The metric relations between points of empty space are replaced by dynamic distances in terms of action between the states of particles themselves, which are not necessarily localized at particular points in space. Elementary particles, if we look at them from the side of asymmetries that carry information, are ideal 'characters', (anti)-commutational abstract symbols, quantum-identical identifiers. Information is stored only in their arrangement in the text of the 'main book'. Needed: a natural way of representation of EPR links. There is one clue: action is the invariant metric between the states.

EPR links for conventional physics represent the laws of conservation of the total integrals of motion of the disintegrated system in the sums of these quantities over the fragments — hence the correlations of momenta, moments, positions relative to center of mass, etc. All these correlations in a proper quantum mechanical fashion are represented in Feynman diagrams and the corresponding integrals: the integrals of 'improper' processes away from the 'mass shell' — the classical path — are destroyed through the interference of paths. At the same time, the global Feynman integral over the entire Universe gives a scattering matrix uniformly the same everywhere. How then can the state of affairs in the world known to 'god' be represented?

The possibility of information interpretation of the measure of volume of the functional space of states for the Feynman integral seems to have been first indicated by Hans Bremerman [2], who also pointed out the possibility of interpreting the renormalizations (division by the vacuum bubble) as 'subtraction of the infinite *a priori* information'.

The sought measure of information should obviously correspond to some nonequilibrium extension of the Helmholtz free energy, which apparently can be made through the integral with respect to 'Euclidean' 'tunnel' paths in the spacelike cross section of the space of events. While in conventional statistical mechanics the equilibrium statistical path integral is taken between all periodic field configurations with the imaginary-time period equal to the inverse temperature [15], which is what corresponds to the state of equilibrium, in the calculation of the statistical sum of distinct states of the 'living' world and the measure of information contained therein, the sum of paths must be calculated not over all possible field configurations, but rather with respect to the concrete relations between the 'particles of matter', expressed in the actions of transitions between them. This generates a graph of (binary?) relations, which must be interpreted not as the combinatorial limit, but as a particular realization of Feynman's graph, solidified by fate. The prototype of this measure of information in the existing quantum field theory may be the logarithm of Feynman's integral (or, to be more precise, finite sum) of 'interaction' of all existing particles over the Euclidean space. The 'improbabilities' of current global states of the system that determine the information value may be defined (like in the theory of reliability) through the determinants of the matrix of intensities of transitions between its global states (with negative values for self-transitions on the main diagonal), if we replace the row and column for the selected state with unities, replace the probabilities with the real exponentials of action, and divide this partial determinant by the global determinant of the general normalization matrix. This is the analog of the major sum over states and the vacuum normalizing 'bubble' from the fermion and boson determinants of the field theory — not over all combinatorial vacuum diagrams, but over the actual reality. "Vacuum is the world". "Know vacuum — know theory". The major statistical sum ought to be regarded a naturally finite and preset quantity, and this sum is expressed in terms of action. Evolution takes the path of conservation of information, which should be equivalent to the principle of least action. There is the possibility of describing phase transitions upon cooling as storage of 'memory' with 'file compression', which frees the memory cells. Hence the 'time arrow', and such strange phenomena of physical world as biology with intelligence on top.

If the characters in the 'main book' are elements of the uniform space (in which some unified group acts transitively), then the elementary symbol reduces to Boolean unity, which marks the presence of something. All information predicates will reduce to the position of the symbol in the 'main book', the position being characterized only by the number of (half)-steps of action between symbols (recall the discreteness of the observed quantum states of compact systems). The symbols are arranged not in a line, like the binary code of a Turing machine, but in the nodes of a multiply connected graph. In other words, the 'beads on

[2] At the end of the appendix "Analytical representations, products of distributions" in book [12].

god's abacus' are not strung on a single rod, but are pierced by many entangled strings.

Ergo:

1. "God does not play dice", but only possesses finite information.

2. The 'Holographic principle' — all physical information in the causality-connected world has a finite measure and is conserved according to this measure.

3. Information is most likely available to god as a graph (matrix) of 'real' distances (relations) between elementary identifiers, or between distinct states of the world as a whole. The measure of action with respect to path is responsible for the distinction of states. This picture is compatible with Feynman diagrams, because probabilities, amplitudes and representations of Lee groups are all exponentials of action, while information is linked with action directly after taking the logarithm of these exponentials. In order to make information finite without the arbitrary component, one should try using a particular (half)-integer action.

In support we give an amorphous list of references which contain not too transparent analogies [11–14]. The transformation of a pure state into a density matrix in the measurement procedure is described by Zurek in Ref. [5], and presented in Ref. [6]. The conclusion of conservation of information follows if every time both the measuring device and the observer are included in the closed physical system concealed within the general unitary evolution operator — it is important that the information should not be pulled out or pushed in. The ways of a quantum system are inscrutable — God cannot gain more knowledge (after all, we also are in His hands).

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On the problem of selection of an alternative in quantum measurement

A D Panov

Two new closely related directions in quantum theory are currently actively being developed: quantum informatics and the theory of decoherence. A number of basic notions pertaining to this domain may be regarded today as well established. A sufficiently popular introduction without unnecessary simplification is given in the first three sections of the paper by M B Menskiĭ [1]. The fourth section deals with the role of the observer's consciousness in quantum measurement, and in our opinion is rather controversial.

The problem as we see it is the following. One can attempt to describe the process of measurement solely on the basis of unitary evolution in accordance with the Schrödinger equation, as first proposed by Everett [2]. Consistent application of the Schrödinger equation to a closed system that includes the studied microscopic object and its macroscopic environment (equipment, etc.) leads to a superposition of macroscopically distinct states describing the alternative outcomes of the measurement. The learned author notes that such a description does not provide for the mechanism of selection of any one alternative. Since in a real experiment the observer will only deal with a single alternative, such description of measurement is viewed as incomplete: it lacks the mechanism of selection of the alternative. Further on, the author claims that a theory that would describe such a mechanism must necessarily involve the consciousness, and proposes including the consciousness into the theory as the element that would logically complete the quantum description of measurement. Consciousness is charged with the *function* of selection of one of the alternatives from the coherent superposition of various possible outcomes of measurement, thus reconciling theoretical predictions and experimental results. As far as we understand, this implies that the consciousness is factored out from the framework of dynamic description, and appears as an explicit *metatheoretical element* for interpretation of the theory. There exists, however, a different view on the role and place of consciousness in quantum measurement, and fully acknowledging the importance of this issue we feel obliged to present it in this letter.

There are a number of works that give a consistent quantum treatment of the selection of an alternative by the consciousness of the observer in a quantum measurement. For example, the pivotal issue in the classical work of Everett [2] is the express inclusion of consciousness into the quantum description. Moreover, Everett maintains that such a descrip-

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