Basic paradoxes of statistical classical physics and quantum mechanics

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Abstract: Both statistical classical mechanics and quantum mechanics are developed and well-known theories. They represent a basis of modern physics. Statistical classical mechanics allows deriving properties of big bodies investigating movements of the smallest atoms and molecules of which these bodies consist, using Newton's classical laws. Quantum mechanics defines laws of movement of the smallest particles at small atomic distances considering them as probability waves. Laws of quantum mechanics are described by Schrödinger equation. Laws of such movement are much more different from laws of movement of large bodies, such as planets or stones. The described two theories are known and well studied for a long time. Nevertheless, they contain a number of paradoxes. It forces many scientists to doubt about internal consistency of these theories. However, the given paradoxes can be resolved within the framework of the existing physics, without introduction of new laws. To make the paper clear even for the inexperienced reader, we enter in this paper some necessary basic concepts of statistical physics and quantum mechanics without use of formulas. Necessary exact formulas and explanations to them can be found in Appendices. For better understanding of the text, it is supplemented by illustrations. Further in the paper the paradoxes underlying thermodynamics and quantum mechanics are discussed. The approaches to solution of these paradoxes are suggested. The first one relies on the influence of the external observer (environment) which disrupts the correlations in the system. The second one is based on the limits of self-knowledge of the system for the case when both the external observer and the environment are included in the considered system. The concepts of **Observable Dynamics, Ideal Dynamics, and Unpredictable dynamics** are introduced. The phenomenon of complex (living) systems is contemplated from the point of view of these Dynamics.

Keywords: Schrodinger’s Cat, Observable Dynamics, Ideal Dynamics, Unpredictable Dynamics, self-knowledge, correlations

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1. Introduction

At the very beginning of this paper it is necessary to make a number of extremely important notes.

1) This paper **is not** a philosophical paper on physics, unlike some other papers about paradoxes of quantum mechanics. We use scientific methods to consider a solution of these paradoxes. We also construct the physics excluding these paradoxes and find requirements at which it is possible.

Misunderstanding of physics, leading to these paradoxes, gives set of physical, but not philosophical, errors.

2) This paper **is not** an attempt to give some new interpretation of quantum mechanics. All interpretations (for example, multi-world interpretation, Copenhagen etc.) just try to give more or less evident explanation of quantum mechanics. These interpretations do not solve any paradoxes and do not introduce any new appearance in the physics. The author considers all the existing reasonable interpretations being admissible. A paradox solution in this paper is not related to some interpretation, and is based on general physics.

3) This paper **is not** a popular scientific paper and includes new, original ideas. The paper is designed to a very wide set of specialists including biologists, physicists (in quantum mechanics, statistical physics, thermodynamics, non-linear dynamics) and computer science specialists. Therefore we have given the popular review of physics base. Though it can seem trivial for one expert, but, nevertheless, will be very useful to another expert. Besides, there are no formulas, only figures and text. All formulas are contained in Appendixs. The author is not a pioneer of such style. Examples are books of Penrose **[1,2],** Hofstadter **[3],** Mensky **[4],** Licata **[85] .** These books are not popular books despite their "easy" style. The author hopes that he also will be allowed to use this nice style.

4) This paper is not just a review of papers being already completed (though many references are given thereto), it also includes original ideas of the author.

5) The author **does not try** to find new laws of physics[1]. All reviewing is within framework of already existing physics. The motivation to write this paper was the fact (paradox!) that the author has not encountered **any** paper or the physics textbook where the full and clear explanation of these paradoxes of physics and its consequences is given. Moreover, in many papers these paradoxes are ignored. In other papers the explanation is not full or not correct. In many papers the solution is based on just some one interpretation of physics (usually multi-world). Sometimes some new (but not necessary!) laws of physics are used for explanation there.

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[1] *Peierls **[7],** Mensky **[4]** assume that resolving of quantum mechanics measurement paradox is possible by change of quantum physics laws and introduction concept of "consciousness" in physics. **Penrose [1, 2]**, Leggett **[8]** assume that laws of quantum mechanics are broken for large enough macroscopical systems. However, many other physics problems have already been successfully solved without introduction of new laws. Examples are Gibbs paradox **[9]** or interpretation of spin as own rotation moment of Dirac electron wave function **[10]**. Broken symmetries of the Life or the Universe (such as symmetry of time direction or symmetry of right and left) can be explained by help of fundamental weak interaction. Weak interaction breaks these symmetries. Full explanation can be found in Elitzur paper **[11]**. However, in the current paper we neglect these small effects and search for some other reasons for asymmetry of time.*

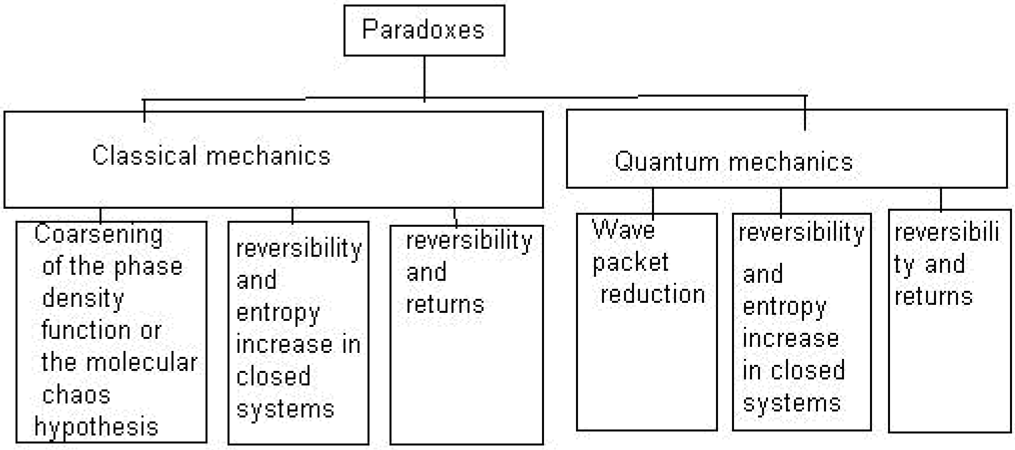

Figure 1. Paradoxes in Classical and Quantum mechanics

2. Principal paradoxes of classical statistical physics.

2.1 Macroscopic and microscopic parameters of physical systems [5, 6].

Let's begin our discussion from statistical physics. We will look at the gas outflow from a jet engine nozzle.

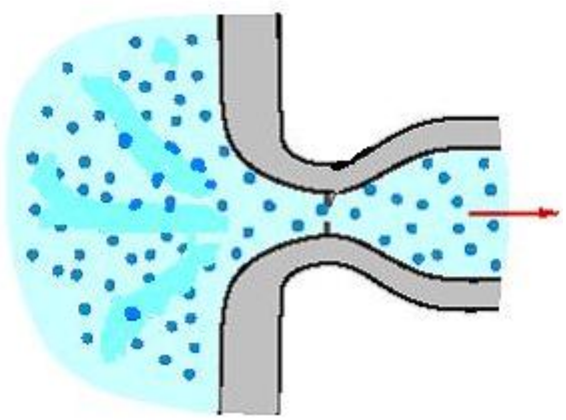

Figure 2. The outflow of gas from a nozzle. Shown (with magnification) are molecules of gas invisible by naked eye.

We will see distribution of density and velocity of flowing gas, but for large volumes only. These volumes include enormous number of invisible molecules. These easily observable density and velocity distribution of flowing gas are defined **as macroscopic parameters** of the system. They give incomplete description of the system. The full set of its parameters is given by velocities and positions of all gas molecules. Such parameters are defined **as microscopic parameters**. Flowing gas is defined as an observable **system.** The system is termed **isolated** if it does not interact with its environment. The system **internal energy** is the sum of all its molecules energies.

Further on (unless the contrary is stated), we will consider isolated systems with the defined internal energy and finite volume.

2.2 Phase spaces and phase trajectories. [5, 6]

Let's introduce the multi-dimensional space. Coordinates and velocities of all molecules of the system will define the axes of this space. Then, the system will be figured by a point of this space. The position of this point will give the full microscopic description of the system. This space is defined as a system **phase space**. The system state change is featured by the point moving in this space and defined **as a phase trajectory**.

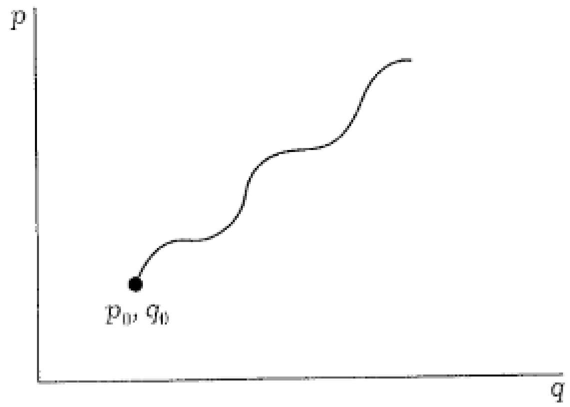

Figure 3. Trajectory in the phase space. The current state of the system described by the point in phase space p, q. Time evolution is described by a trajectory beginning in the initial state point p_0, q_0. (Fig. from [17])

Let us assume that only macroscopic parameters are known, and microscopic parameters are unknown. Then the system can be described in phase space by a continuous set of points corresponding to these macroscopic parameters. It is the **phase volume ("cloud") of the system** or, otherwise, **ensemble of Gibbs**. All points of this volume have equal probability and correspond to different microscopic (but identical macroscopic) parameters. (Look **Appendix A) [5, 6]**

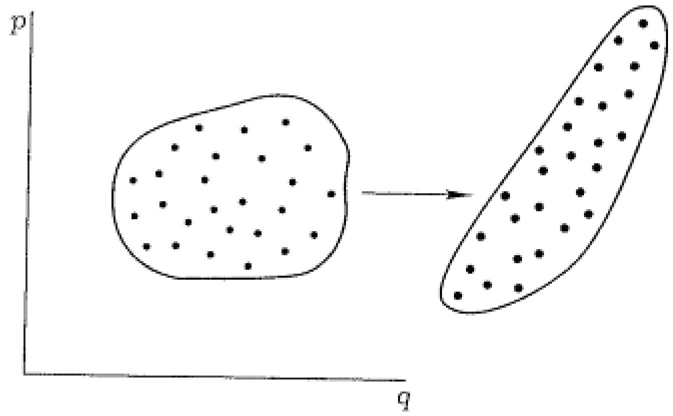

Figure 4. Ensembles in the phase space. Gibbs ensemble is described by a cloud of points with different initial condition. Form of the cloud changes during evolution. (Fig. from [17])

For each set of macroscopic parameters (**a macroscopic state**) it is possible to discover the correspondent **ensemble** of microscopic parameters sets. To make this **ensemble** finite, we will divide the phase space into separate very small meshes. Such method is defined **as discretization** of the continuous space. By such reviewing, the system with finite volume and given internal energy can be featured by a very major, but **a finite ensemble** of states. For each macroscopic state it can be found the corresponding major, but **a finite ensemble** of microscopic states. The majority of systems have property that huge part of its possible microscopic states correspond to only one principal macroscopic state. It is **the equilibrium state**. For example, for gas in given volume, it corresponds to uniform distribution of molecules in the volume.

(Look **Appendix E.**) **[5, 6].**

2.3 Ergodicity and intermixing. [12-14]

The majority of real systems possess property **of ergodicity [13, 14]**: almost any phase trajectory should visit eventually all microstates meshes, possible for given energy of a system. The system should stay for approximately equal periods of time in each microstate mesh. Ergodic systems possess the remarkable property. The average value on time of any macroparameter over a trajectory will be identical for all trajectories. It coincides with the average value over the ensemble of systems featuring thermodynamic equilibrium. (This ensemble (named microcanonical) is distributed over a constant energy surface). The majority of real systems possesses property named **chaos** or **intermixing (**So-called **КАМ theorem) [13, 14]:** in neighborhood of any point of a phase space there is always such another point that the phase trajectories of these two points diverge exponentially fast **[12, 14]**.

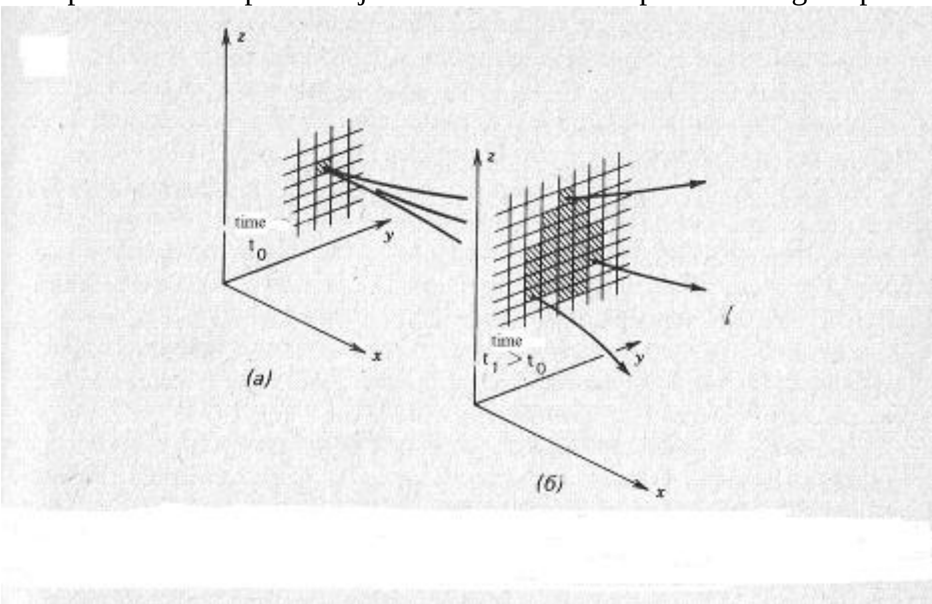

Figure 5. Illustration of uncertainty increasing or information loss in a dynamic system. Shaded square at the moment of time t_0 describes uncertainty of initial condition knowledge. (Fig. from [12])

Exponential speed is defined as follows: if after 1 second trajectories diverge twice from initial magnitude as after the next second they will diverge already in 4 times from initial magnitude. After the next second they diverge in 8 times from initial magnitude etc. It is very fast type of divergence. The systems possessing property of intermixing always are ergodic.

2.4 Reversibility and Poincare's theorem.

Microstate evolution is **reversible**. For each trajectory in phase space there is the inverse trajectory obtained by inversion of all velocities of molecules into opposite values. It is equivalent to reverse demonstration of a film about the process. Almost any trajectories after some time (probably very large) should return to its initial microstate. This statement is named **Poincare's theorem** about returns. (See **Appendix C) [6]** Most of real systems are chaotic and unstable, and phase trajectories from previously neighboring microstates are fast divergent. Therefore at such systems the return time is unequal for even previously neighboring microstates. It strongly depends on an exact position of the initial trajectory point in a mesh that phase space is divided. But for a very small class called **integrable systems,** this return time is approximately identical for all initial points of phase mesh. These returns occur periodically or almost periodically.

2.5 Entropy. [5, 6, 15]

Let's introduce the basis concept for ~~the~~ statistical mechanics **- macroscopic entropy**. Suppose that some macroscopic state corresponds to 16 microstates. How many questions that can be answered just «yes» or «no» should be asked in order to understand in what one from these 16 microscopic states the system exists? If we ask about each microstate we need to ask 15 questions to do it. But it is possible to do it in a smarter way. We will divide all microscopic states into two groups, with 8 microstates in each group. The first question will be, to what group does microstate concern? Then, the specified group will be divided into two subgroups with 4 microstates in every one of them, and we will ask the same question. We will continue this procedure until obtaining the single microstate of the system. It is easy to calculate that only four such questions for the current case shall be required. It will be the minimal number of questions for the current case. This minimal necessary number of question can be defined **as macroscopic entropy of macrostate. [5, 6, 15] (**See **Appendix B)** It is easy to calculate that entropy is logarithm with basis 2 of microstate number and increases with increasing of a microstate number. Accordingly, the equilibrium state has maximum entropy, because it corresponds to maximal number of microstate. It is often told that entropy is a measure of disorder. Indeed, the more disorder in the system the more questions are necessary to be asked to find the microstate of system. Therefore, entropy also increases. Why do we need to introduce such "abstruse" conception like entropy? It seems like easier to use the number of microstates instead! But entropy possesses remarkable property. Let us assume that we have the system consisting of two disconnected subsystems. Entropy of a complete system is the sum of two entropies of its subsystems. (Really, full number of questions correspond to full system is sum of questions for each of subsystems). But the numbers of microstates are multiplied. To make sum is easier than to multiply!

The statistical mechanics states some the important properties of physical systems:

Let the initial macroscopic state correspond to some volume in phase space. The theorem exists that during reversible Newtonian evolution of the system, the value of this phase volume is conserved (See **Appendix F.) [6]**. Therefore, the number of microstates corresponding to it also conserves. The entropy corresponding to this set of microstates is defined **as entropy of ensemble**. From conserving of phase volume follows that entropy of ensemble is constant in time.

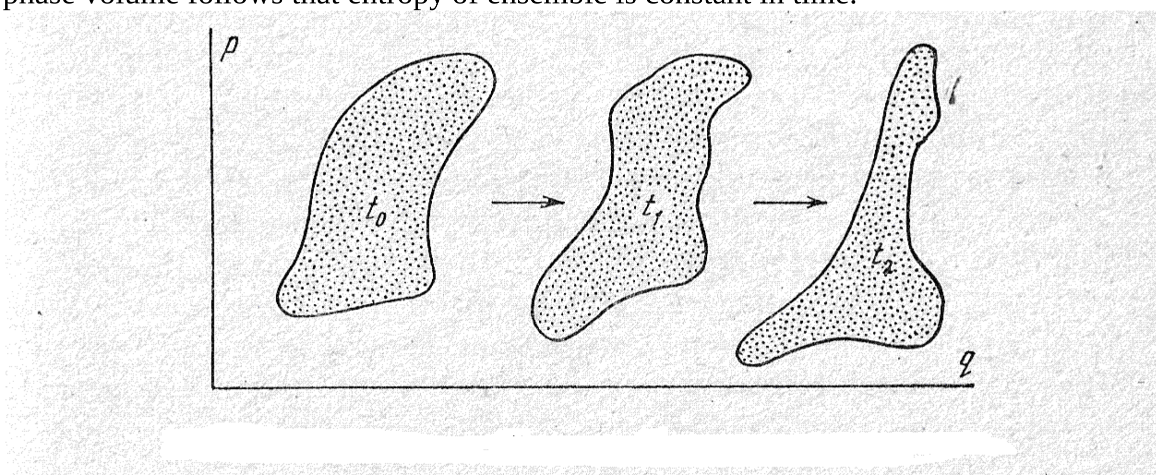

Figure 6. Conservation of volume in phase space. (Fig. from [14])

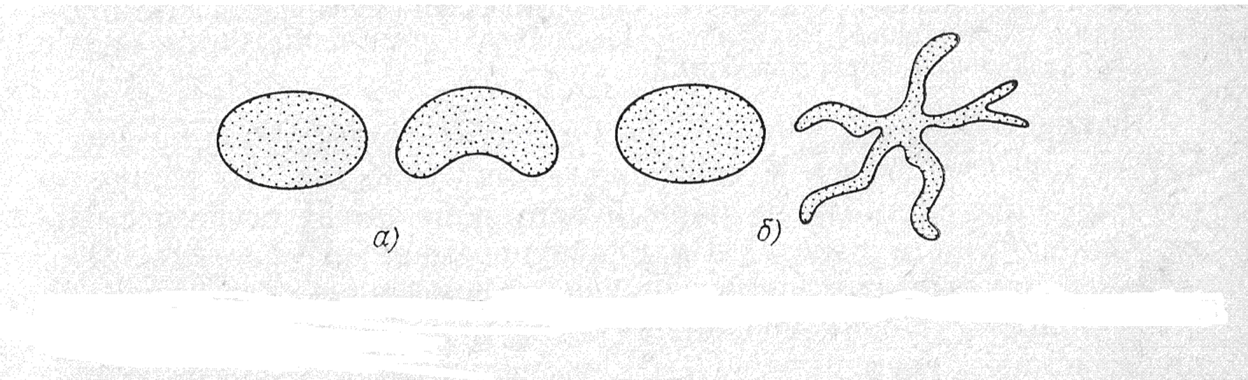

Figure 7. Change of phase volume element in stable a) and unstable b) cases. (Fig. from [13])

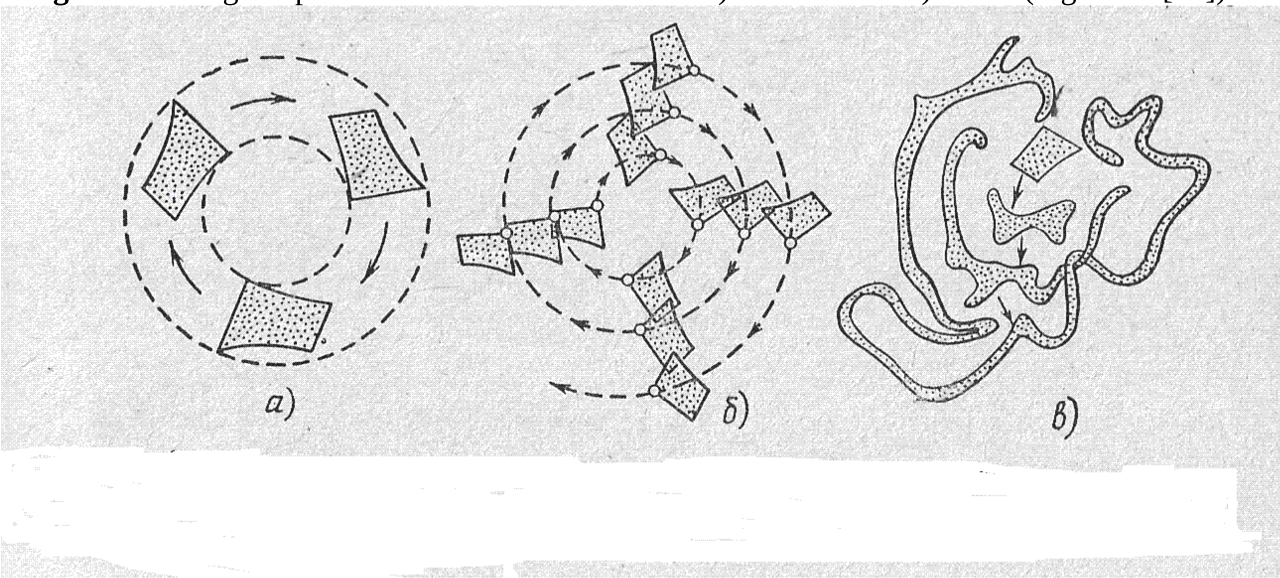

Figure 8. Different types of flows in phase space: a) nonergodic flow b) ergodic flow without intermixing c) ergodic flow with intermixing. (Fig. from [14])

2.6 Evolution of macroscopic entropy for chaotic systems.

From properties of ergodicity follows that the system, from almost any initial microstate, will transfer after a while to equilibrium state, and there will be in this state a *majority of time*. It so happens because the most of transiting microstates during evolution of system ~~are~~ correspond to equilibrium state. Indeed, the equilibrium state has maximum macroscopic entropy. Even if **macroscopic entropy** of initial state was small, after converging to thermodynamic equilibrium it would increase very strongly. This property is opposite to the property **of ensemble entropy** which remains to a constant value during evolution. Indeed, **entropy of ensemble** is defined by a number of microstates that does not change during evolution. It is constant and equal to the initial number of microstates. Whereas, **macroscopic entropy** is defined by a number of microstates which corresponds **to a current macroscopic state**. For thermodynamic equilibrium this number of microstates is very large.

For chaotic systems (systems with intermixing) the following theorem is true:

Processes of *macroparameters evolution* with macroscopic entropy decreasing are strongly unstable with respect to small external noise. By contrast to this processes of *macroparameters evolution* with macroscopic entropy growth are stable[2].

Let's prove it. We will consider a process with entropy growth. The initial state of the system is featured by some macroscopic state far from thermodynamic equilibrium. Such state is characterized as compact (closed and limited) and convex (containing a straight segment connected its any two points) in phase volume. As the system is chaotic, in a neighborhood of each point there will be also another one with exponentially diverging distance between them. Because of phase volume conservation (See **Appendix F**) in a neighborhood of each phase point always there will be also another one, such what these two points exponentially converge, and not just diverge. As a result of intermixing initially compact small phase volume will spread over constant energy surface in phase space completely and is not so convex. y. It possesses a large quantity of "sleeves" or "branches". But the full volume of phase "drop" is conserved in any case. "Sleeves" exponentially expend over their lengths and exponentially shrinking over width. Eventually the number of "sleeves" or "branches" grows; they are fancifully incurvate and cover by its “net” at phase energy surface completely. This process is named as a **spreading of phase "drop" [13, 14]**. Let’s assume that some small external noise has thrown out a phase point from "sleeve" of a phase drop. But shrinking goes perpendicularly to "sleeve" and the phase point will come nearer to "sleeve", not to go away from it. It means that process of phase drop spreading is stable with respect to noise.

Therewith, noise can strongly influence microstate, but not macrostate. Macrostate is correspondent to an enormous number of molecules microstates. Though external noise can strongly change a state of every individual molecule, full contribution of all molecules to macrostate remains unchanged. It is related to “law of large numbers” in the probability theory **[16].** Most of microstates, corresponding to some current macrostate, evolve in entropy growth direction, because probability of such evolution is much more. When the phase drop almost spread along the whole constant energy surface, its macrostate would correspond to usual thermodynamic equilibrium. Thus even not small noise cannot affect noticeably its macrostate because the most of microstates in system correspond to equilibrium.

Now we will consider an inverse process going with entropy decreasing. The initial state is defined by points set in phase space gotten from direct process («a phase drop» spreading) final state by molecules velocities reversion**.** At a reversion of velocities the initial shape of «a phase drop» does not change. But shrinking direction because of velocities reversion is not so perpendicularly, but in parallel to its "branches". Instead of phase drop spreading there will be its shrinkage. Suppose some small external noise has thrown out a phase point from a "sleeve" of a phase drop. But shrinking goes in parallel and the spreading goes perpendicularly to the “sleeve” so the phase point will go away from

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[2] *Actually, we will consider a simple example of ideal gas entropy growth. Gas expands from small volume of a box filling this box. Expansion process is clearly stable with respect to small noise. Thereagainst, the inverse process is easily prevented by such small external noise because of molecules scattering.*

the "sleeve", instead of coming nearer. It means that process of phase drop shrinkage is unstable to noise

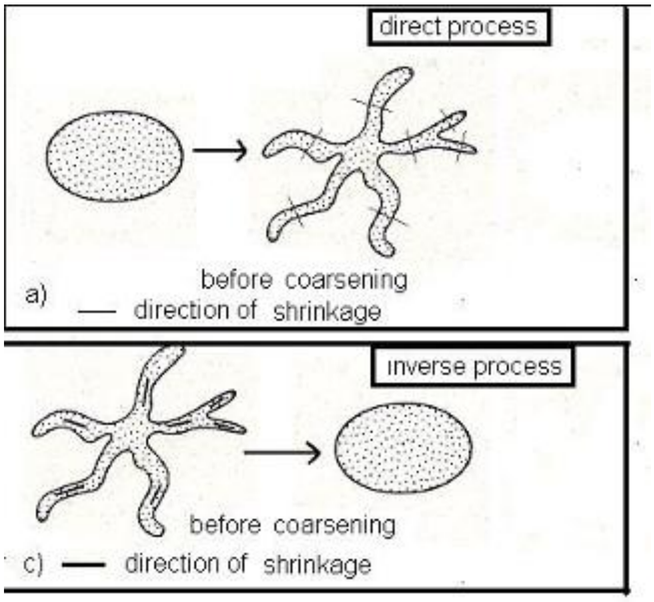

Figure 9. Direct process with macroscopic entropy increasing and its inverse process. Directions of shrinkage are denoted.

2.7 The second law of thermodynamics and the paradoxes related to it.

So, we are ready to discuss the second law of thermodynamics and paradoxes related to it. The second law states:

In the isolated finite volume systems macroscopic entropy cannot decrease, and can just increase or leave constant. Finally macroscopic entropy reaches the maximum in a thermodynamic equilibrium state [5, 6].

The principal paradox consists in inconsistency of this entropy growth law with the basis properties of a statistical physics featured above. Really, from reversibility follows that for each process with entropy increasing there is an inverse process with its decreasing. It is **paradox of Loschmidt**. Besides, from Poincare's theorem of returns follows that the system must return to initial state. Hence, and its entropy also will return to initial value! It is **paradox of Poincare.**

The concept of molecules **correlations** of velocities and positions is closely related to these two paradoxes.

2.8 Additional unstable microscopic correlations and their connection with paradoxes of a statistical physics.

Correlation is a measure of mutual dependence of variables. (In our case it is a measure of mutual dependence of molecules velocities and positions). **Pearson's correlation** is the most known one. It is a measure of linear relation of two variables (See **Appendix D).** It is obvious that there are much more complex dependencies and corresponding thereto more complex correlations. Correlations between various variables lead **to restrictions** on possibility of selection of some values of these variables.

The knowledge of a macroscopic state of system is one of sources of correlations. Really, not all but just some microstates can already correspond to the given macroscopic state. Thus, their set is already restricted. It will lead to restriction on possible molecules velocities and positions, i.e. restriction on possible microstate of the system. It is worth noting that all such correlations are macroscopic and are manifested in dependence between macroscopic parameters of the system. For macroscopic states with small entropy the restriction on a select of possible microstates are great and, accordingly, the number of macroscopic parameters and correlations between them is great. For system being at thermodynamic equilibrium entropy reaches the maximum, and the number of macroscopic parameters and correlations between them is small.

Additional or microscopic unstable correlations [17] are defined not just by knowledge of the current macroscopic state, but also by that of previous macroscopic history of system. Suppose that the physical system evolved from an initial macroscopic state into some another current macroscopic state. Thus, not all microscopic states conforming to a current macroscopic state are possible. Only such states which at reversion of velocities of molecules lead to an initial state can be considered (property of reversibility of motion.). It superimposes additional restrictions (correlation) on a set of the microstates corresponding to a current macroscopic state. **Additional unstable correlation** can be spotted in another way, not via knowledge of the past, and via knowledge of the future. According to Poincare's theorem, the system should return to a known initial macroscopic initial state in some known time. Knowing a certain current macroscopic state and knowing when in the future there will be a return, we can superimpose additional restrictions (correlation) on a set of the microstates corresponding to this current macroscopic state. These correlations are named unstable because they are very unstable with respect to external noise (as we will see below). From definition of these **additional unstable correlations** it can be seen that they are close related to Poincare and Loschmidt paradoxes.

These correlations are named additional with respect to **the macroscopic correlations**. **(**The macroscopic correlations are correspondent to the macrostate representation). It is existence of these **additional correlations** that leads to violation of the second law of thermodynamics and ensures a possibility of returns and the reversibility, i.e. appearances observed in Poincares and Loschmidt paradoxes.

One of the basic properties of **additional or microscopic correlations** is **instability**. Interaction of different parts of observable system or interaction of the system with environmental systems (including the observer) leads to additional disappearing of correlations. To be more exact, these additional correlations "spread" between parts of the system and/or between the system and surrounding systems. Suppose there is some initial state with small entropy. After some short time the first collisions between molecules shall occur. Their positions and velocity become correlated (Indeed, it can be checked up by velocities converting. Finally we again obtain the initial state). Meanwhile, only close pair of the molecules at collision are correlated. However, in the process of increase of number of the collisions, arising correlations will include larger and larger number of molecules. Finally the correlations will be spread over the entire increasing volume of the system. There is "spreading" of correlations in the system **[17]**.

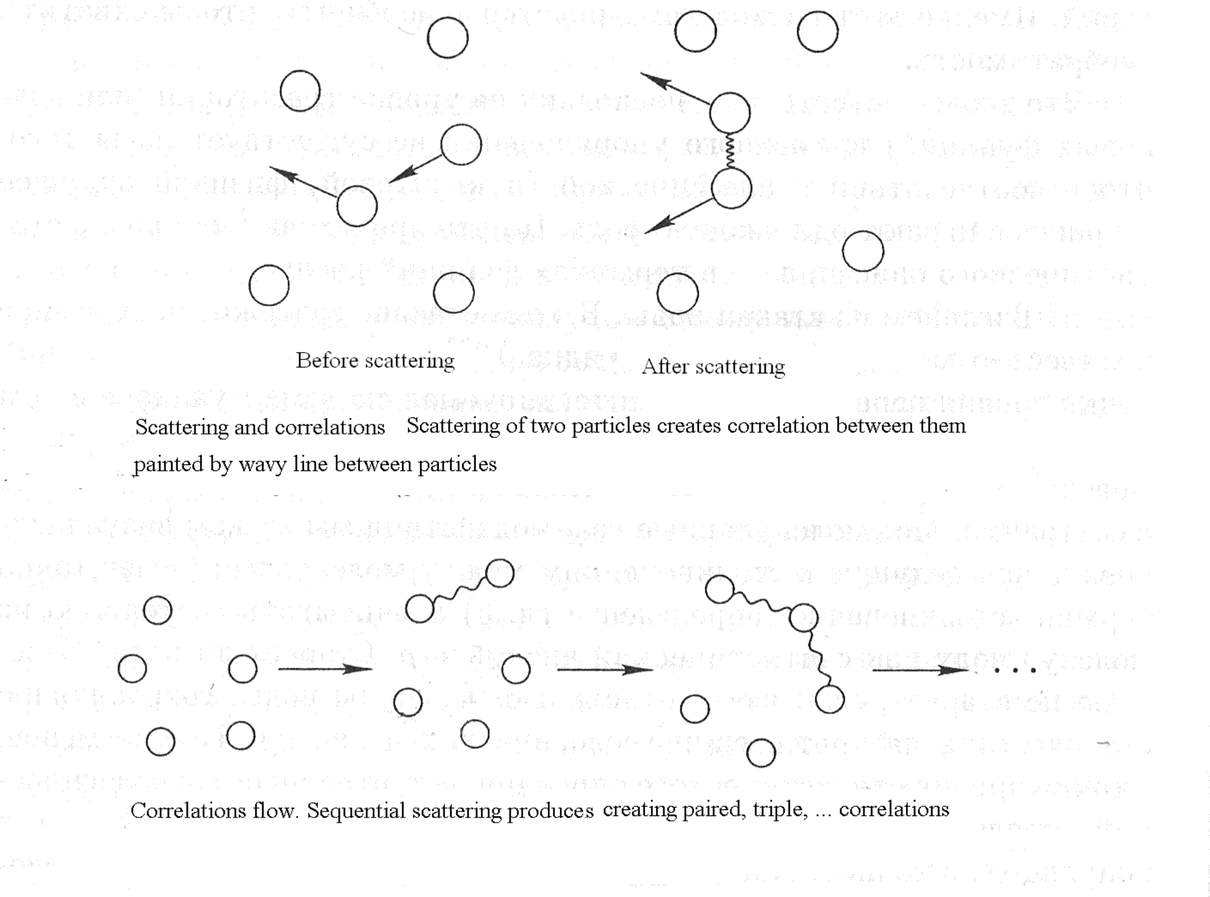

Figure 10. Scattering and correlations. Correlations flow. (Fig. from [17])

Similarly, if the system consists of two non-interacting systems, correlations will exist only inside each system. Returns and reversibility are possible for each of such subsystems. Suppose there is at least a small interaction between these subsystems. Then correlations "will flow" from one subsystem into another, and these two systems become dependent. Accordingly, olny their joint return or reversibility will be possible.

3. Principal paradoxes of quantum mechanics

3.1 Basic concepts of quantum mechanics - the wave function, Schrodinger equations, probability amplitude, measurands, indeterminacy principle of Heisenberg [18, 19].

For clarity of presentation, we will give at first **the basic concepts of a quantum mechanics.**

Motion in quantum mechanics is featured not by a trajectory, but by **a wave function**. It is a probability wave, to be more exact, a "probability amplitude" wave. It means that the quadrate of amplitude module of the wave function in some point gives probability to detect a particle in this point. Change in time of this probability wave is defined **by Schrodinger equation [19]**. This is a linear equation, i.e. the sum of its two solutions is also the solution. Thus, amplitudes of probabilities are summed, but not probabilities themselves. Indeed, the probability is defined by the quadrate of amplitude. It imports **nonlinearity** to a wave function evolution process.

Any **measurand** (for example, momentum) is featured by an orthonormal, full set of functions (**a set of eigenfunctions of a measurand**). The wave function can be expended to this set of eigenfunctions. Each of eigenfunctions set corresponds to some value of a measurand (eigenvalue). **Expansion coefficients** give **probability amplitude** for each such value. If the wave function is equal to some eigenfunction of the measurand set so the value of the measurand in this case is equal to the correspondent eigenvalue. If it is not the case, we can specify just probabilities for various eigenvalues.

The concept of a particle velocity has no explicit physical sense because there is no well defined trajectory of particle and there is just «**a probability wave» [19]**. Momentum is defined now not via a product of velocity and mass, but through wave function expansion coefficients over momentum eigenfunctions. This set of eignfunctions is similar to an orthonormal, full set of Fourier functions used in Fourier analysis.

Coordinate eigenfunctions are proportional to Dirac delta functions. The coefficients of wave function expansion over Dirac delta functions are given by value of a wave function in an infinite point of Dirac delta function. It corresponds to the above defined sense of a wave function as probability amplitudes.

Both momentum and coordinate correspond **to various** sets **of the eigenfunctions [19]**. Therefore, no wave function **can correspond simultaneously to both a single momentum eigenvalue and a single coordinate eigenvalue**, contrary to the classical mechanics. There it is the well-known **uncertainty of Heisenberg [19]. (**See **Appendix G.**). The reason is related to difference of its definitions in the quantum and classical mechanics.

3.2 Pure and mixed states. Density matrix [15,18, 20].

Quantum mechanics is most completely described by its wave function. This is the so-called **pure state**. For classical mechanics it was a point in a phase space. What is analogue in quantum mechanics to a classical statistical ensemble of systems (a cloud of points in a phase space)? It is a set of wave functions where to each function there corresponds its probability (instead of "probability amplitude" for expansion of pure state over eigenfinctions). It is definition of **the mixed state**.

Suppose that some system is a part of some large systems. Then, even if the large system is featured by a pure state, the smaller subsystem must be featured by the mixed state in general case. Exception is the case when the pure state of the large system can be described as a product of the small system wave function and its environment wave function. Let’s suppose, for example, that the small quantum system interacts with the device which is in a pure state. Although the large system (including the device and small quantum system) can be featured by a pure state, the small quantum system after measurement in general case is already featured by the mixed state.

For the equivalent representations of mixed and pure states **density matrix** is used **[20].** Let us choose some measurand and the corresponding set of eigenfunctions. As the density matrix representation in basis of these egenfunctions is featured by a square matrix. Every such function corresponds to a **diagonal element** of a density matrix. The value of the element is equal to probability to detect the corresponding eigenvalue during measurement of the measurand.

Nondiagonal elements of a density matrix define correlations between correspondent pairs of eigenfunctions. Nondiagonal elements have maximum value in a pure state, but for the mixed states their magnitude decreases and can become equal to zero. The density matrix always can be rewritten over a different set of eigenfunctions corresponding to some different measurand. Density matrix gives maximally full description of state of the system. Consequently, evolution of density matrix gives full description of evolution of the system. (See **Appendix I.)**

3.3 Properties of the isolated quantum system with finite volume and a finite number of particles [15].

Similar to classical systems, we will consider properties of the isolated (closed) quantum system with finite volume and finite number of particles.

1) Such quantum systems evolve over reversible equations of motion (Schrodinger equation)

2) Poincare's theorem is also correct for such systems. Moreover, quantum systems properties are similar to classical integrable systems properties. (Integrable systems are a very small part of all possible classical systems.) As follows, their returns occur in a nearly periodic fashion. Besides, the period of these returns depends on initial conditions very weakly.

3) For quantum systems it is also possible to define **entropy of ensemble**. Entropy is a measure of uncertainty knowledge about system state. Pure state gives maximally full description of quantum system. Therefore for any pure state entropy is equal to zero by definition. For the mixed state case, the system corresponds to a set of pure states. Therefore, entropy is already above zero. Suppose that the probability one of the pure states is close to 1 (one). Then this mixed state is almost pure and its entropy is almost equal to zero. When all pure states of the mixed state have equality probability, entropy reaches its maximum.

4) During evolution of a quantum system the pure state can evolve just to the pure one. In the mixed state the probabilities of its pure states also leave unchanged. So entropy of ensemble does not change during the quantum system evolution.

5) We can feature large quantum system by a small number of parameters named **macroscopic parameters**. To such mixed macroscopic state there corresponds the large set of pure states defined by microscopic parameters. Accordingly, on the basis of this pure set it is possible to calculate entropy of

a macroscopic state. We will define this entropy as **macroscopic entropy**. Contrary to entropy of ensemble the macroscopic entropy should not conserve during evolution of quantum system.

6) While measuring a quantum system, it will cease to be considered as an isolated system because of interaction with the measuring device. Accordingly, its initially pure state evolves to mixed one, and its microscopic entropy increases. Such evolution can not be reversed just by inversion of measured system. Inversion of the measuring device is necessary too.

3.4 Theory of measuring in quantum mechanics [15, 18] (Appendix J, O, P).

To check a scientific theory, it is necessary to make measuring by means of measuring devices. It is, at least, two measurings: for the initial and final state. If we know the initial state we can compare the measured final state with the state predicted by theory. So, in such a way we can check correctness of the theory.

In the classical mechanics measuring is a simple process of finding current parameters of the system not influencing its dynamics. In this case the full description of system given by all microparameters yields to the unique result of measuring.

In quantum mechanics situation is much more complicated. Measuring influences dynamics of a quantum system. Besides, in quantum mechanics, for a general case, we can predict just some probability of measurement result despite the fullest knowledge of its state (i.e. measured system is in a pure state).

Let's feature measuring process in quantum mechanics more in detail. Let the system in the beginning is featured by some wave function. Measuring of some measurand leads to the situation when the wave function transfers to one of eigenfunctions of a measurand with some probability. This eigenfunction corresponds to measured value of measurand which is equal to its eigenvalue. As it is written above, the probability of such measuring is proportional to the quadrate of wave function amplitude. It is obtained by expansion to eigenfunctions. Thus, after measuring, the system transfers from pure state to mixed state. It is ensemble of these possible measurement results with correspondent probabilities. This process is named **reduction of wave function**. It is not described by Schrodinger equation. Indeed, the Schrodinger equation describes just evolution from a pure state in the pure one. But a result of a reduction is a mixed state obtained from an initial pure state. Besides, the Schrodinger equation is reversible. But the process of reduction is nonreversible. The second type of quantum evolution is possible because during measuring the quantum system is not isolated - it interacts with the **macroscopic classical device**.

The macroscopic device, in order to be consistently featured by quantum mechanics, should be actually **ideally macroscopic**, i.e. either to be in infinite space, or to consist of infinite number of particles. The ideal macroscopic device does not obey Poincare's theorem of returns and has quite certain macroscopic state during all moments of measuring. For the ideal macroscopic device, quantum laws during any finite time yield the same results as classical laws. It ought to be remarked that the real measuring device (i.e. in the finite volume with finite particles number) is macroscopic but approximately. This note is very essential to our future analysis. It is the main source of paradoxes considered below. Thus, evolution of quantum system is divided into two aspects. The first is reversible Schrodinger evolution. The second is the nonreversible reduction of wave function occurring at interaction with the macroscopic classical device.

We explicitly observe classical devices only, not small quantum systems. So there is no necessity to represent in mind these "mysterious" quantum objects. Indeed, we can consider quantum objects just as some mathematical abstracts, allowing finding connections between results of observations obtained by means of measuring devices. Measuring devices are quite classical and representable. They do not have, for example, parameters which cannot be measured simultaneously, like coordinate and momentum in quantum mechanics. "Evident", "physical", "intuitive" representation of quantum mechanics is necessary just for simplification of understanding of the most complex mathematical models of quantum mechanics. Such understanding can not be completely possible, because our mind intuition is based on the classical world around us. But as it is written above, there is no such practical necessity. However, this impossibility is a real source of well known **"magic" and "mysteriousness" of a quantum mechanics**. Actually, there is no such “mysteriousness”.

3.5 Complexity of attempt of "classical" interpretation of quantum mechanics: introduction of hidden parameters and paradox EPR [18].

Quantum mechanics laws have probabilistic nature, and many measurands cannot be measured simultaneously. However, many laws of classical statistical mechanics are also probabilistic. There their probabilistic nature is caused by the hidden microscopic parameters **(Appendix U)**: velocities and positions of all molecules. Any classical macroscopic state is featured by a set of possible corresponding microstates. Similarly, we can try to interpret the quantum probability by introducing the **hidden parameters**. The knowledge of all these hidden parameters allows to uniquely determinate all variables in the quantum system. Similarly to the macroscopic classical state, in quantum mechanics some observed state corresponds to a set of possible values of the hidden parameters. However, in quantum mechanics existence of such hidden parameters is possible only under the following assumptions:

1) Measurement (except for special cases when one of measurand eigenfunctions is equal to wave function of the observed system) changes the state of the observed system. In a classical case it is possible (at least in principle) to make any measurement without perturbation of the observed system.

2) All hidden parameters cannot be measured simultaneously. Let us remind Heisenberg uncertainty principle. Measuring changes a system state (a wave function reduction), and, hence, all hidden parameters cannot be also measured by a set of sequential measurements. All hidden parameters have some well defined values. However, there is no such *real and observable* physical state in which all hidden parameters have these well defined values, but just some probability distribution of them exists. In any real experiment we can measure only a part from these parameters**.** Simultaneously this measuring will lead to uncontrollable perturbation for the rest of parameters.

3) **Existence of the hidden parameters in quantum theory is impossible without introduction of long-range interaction between them [18]**. This long-range interaction acts instantaneously across

even an infinite distance. However, there is no contradiction with the relativity theory maximal velocity limit, because this interaction can not transfer any information or a mass. Really, the parameters are hidden so the interaction between them is also hidden and not observed. The *observed* appearances can be explained by usual correlation of random values.

This necessity of introduction of unobserved long-range interaction is a **too high price for classical "presentation"**. So the hidden parameters interpretation usually are not used in literature on quantum mechanics. It is easier to consider quantum mechanics laws just as some mathematical method to calculate usual random correlation of observable macroscopic parameters for measuring devices.

This necessity of introduction of long-range interaction of the hidden parameters is illustrated by well-known Einstein-Podolsky-Rozen "Paradox" **(EPR) [18], (Appendix R).** This "paradox" is actually fictitious. It arises just when somebody wants to make classical interpretation (i.e. hidden parameters interpretation) of quantum mechanics by "the small price" (without long-range interaction).

It is based on the analysis of electron-positron pair states. In the beginning the particles were together, and then scattered over large distance.

An electron (or a positron) has intrinsic angular momentum which is defined as spin. Classical analogue of the intrinsic angular momentum is the angular momentum of the rotating round intrinsic axis. Unlike the classical intrinsic angular momentum, the absolute value of a spin projection has invariable magnitude (1/2), and its projection to any axis has only two possible values: along the axis and across the axis (+1/2 and-1/2). If we choose the other axis it will possess the same property. However, projections to two different axes cannot be measured simultaneously. There is no quantum state in which spin projections to two different axes have certain values. Suppose that the electron-positron pair is conceived with the total spin equal to zero. The electron and the positron will move in opposite directions and up to large distance between them. Exact values of their spins are unknown. Suppose we have measured a spin +1/2 of an electron along ~~a~~ some axis (we will designate it as axis Z). From the conservation law of the full spin the positron spin projection on the same axis is equal to-1/2. We may also measure the positron spin projection along any other axis. If this axis is perpendicular to axes Z we can measure both +1/2 and-1/2 with equal probability. For some different axis, provisions of quantum mechanics also allow to calculate precisely the mutual probabilities of positron-electron spin projections.

Let's assume that spin projections have "classical" interpretation as hidden parameters. Measurement just makes known formerly the hidden value. Then why does some dependence of measured spin projections of an electron and a positron exist? Are these usual random correlations? Or does some long-distance interaction between hidden parametres really exist? With the help of so-called **Bell's inequality (Appendix T)** it is possible to prove the following theorem: **There is no set of hidden parameters and its probability distributions that can explain mutual probabilities calculated from quantum mechanics without introducing some long-distance interaction between these hidden parameters.** So long-distance spins interaction exists in hidden spins theory.

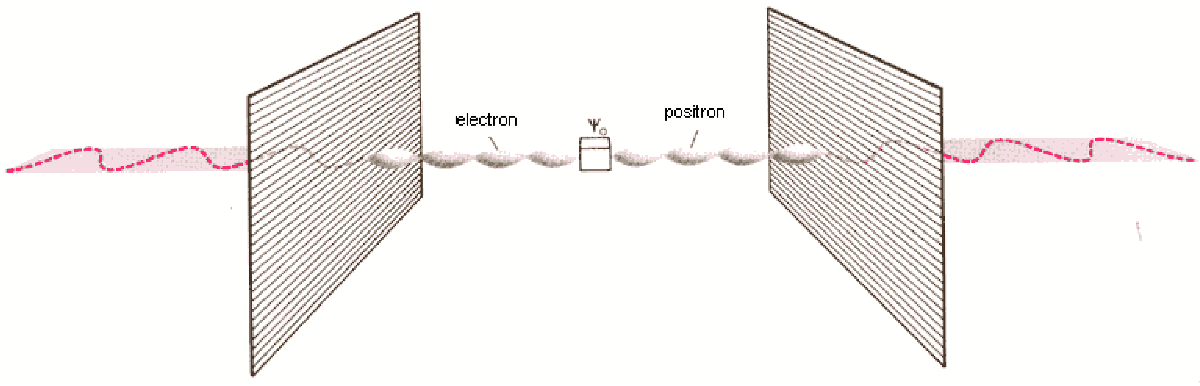

Figure 11. EPR experiment.

However, it is possible to consider not all hidden parameters but just results of measuring. In this case dependence between electron and positron spins can be easily explained by using usual random correlations between the measured parameters. It is result of the fact that we are capable to measure simultaneously only two projections of a spin (one for an electron and one for a proton) from large list of all possible hidden parameters.

The dependence between long-range objects is defined as **quantum correlation,** if introduction of hidden parameters for explaining this correlation is impossible without long-range interaction of these hidden parameters. For **classical correlations** it is always possible**.** After measuring the quantum correlations transform to usual classical ones.

Let's sum up. Introduction of hidden parameters in quantum mechanics is impossible without long-range interaction between these parameters. It is possible to refuse hidden parameters and to consider quantum mechanics just as some mathematical apparatus giving random dependence between measured properties of large classical devices. In this case, any long-range interaction is not required. Dependence between observed values can be explained by usual random correlation. Correlation exists because the measured quantum objects were initially together.

3.6 Problem of two slots as an illustration of quantum mechanics complexity

Because of impossibility of "easy" classical interpretation of quantum mechanics, a well-known American physicist Richard Feynman supposed that nobody understands quantum mechanics. Once he noted that «the single secret of quantum mechanics can be expressed by just one experiment that with a double slot and electrons. It is a modern version of the classical experience made in 1801 by an English scientist Thomas Young for demonstrating of the wave nature of light». This experiment was very simple. In Young’s experiment light from a source (a narrow slot *S*) illuminates a screen with two closely positioned slots S_1 and S_2. While transiting through each of slots, the light is scattered by diffraction, therefore on white screen E the light beams which have transited through slots S_1 and S_2, were overlapped. In the field of overlapping of light beams a number of alternating light and dark bands is formed - that we define now as an interference pattern. Young interpreted the dark lines as places where "crests" of light waves from one slot meet "troughs" of waves from the other slot, quenching each other. The bright lines occur in places where crests or troughs from both slots coincide, making light amplification. During almost two hundred years varied variants of two-slot-hole Young experiments were considered as a proof of wave nature of waves on water, radio signals, X-rays, sound and thermal radiation.

We will define a concept of **path difference** of waves from slots. Suppose there is some point on the final screen. The difference of distances from the two slots to this point, measured in wave length units, is named as **path difference** for this point. If it is an integer we have wave the maximum in this point. If it is an integer and half we have the minimum.

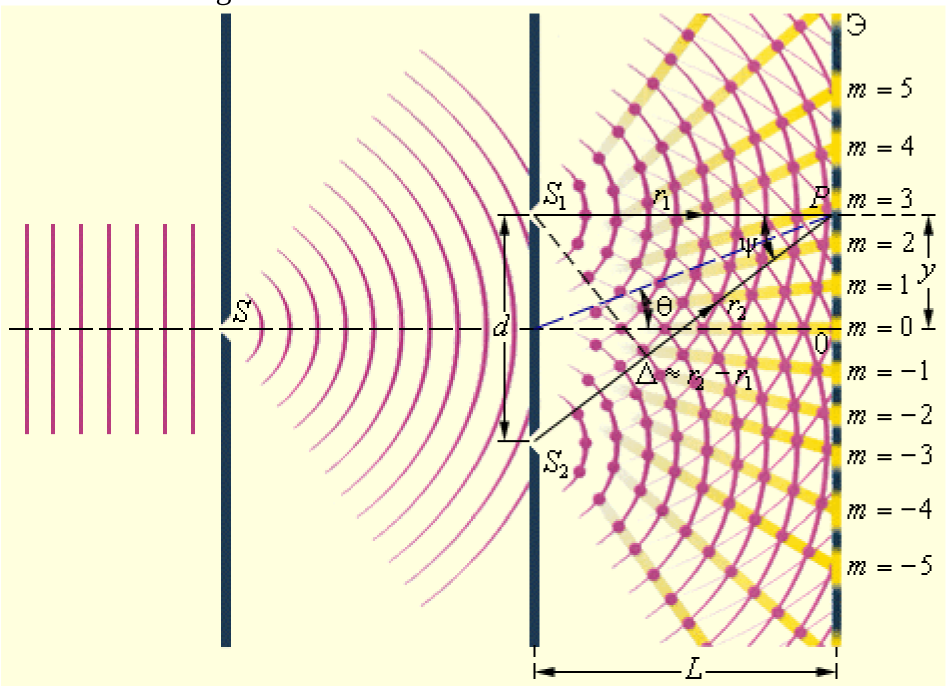

Figure 12. Young's experiment with light. (Fig. from [96])

It's remarkable that Young's experiment can be made with electrons too. Instead of sunlight beam, a beam of electrons transits through parallel slots. The screen plate is coated with a luminophor (similar to the screen of a television tube). Each electron colliding with the luminophor leaves an illuminating point, thus registering its arrival in form of a usual particle. But the image generated by all electrons makes surprising impression. It gives an interference pattern similar to that which is obtained in case of light. It is absolutely unlike to that we would obtain by throwing balls in a fence with two boards taken out (it is similar to two slots). The two-slot-hole experiment with electrons demonstrates that these particles can behave as a wave.

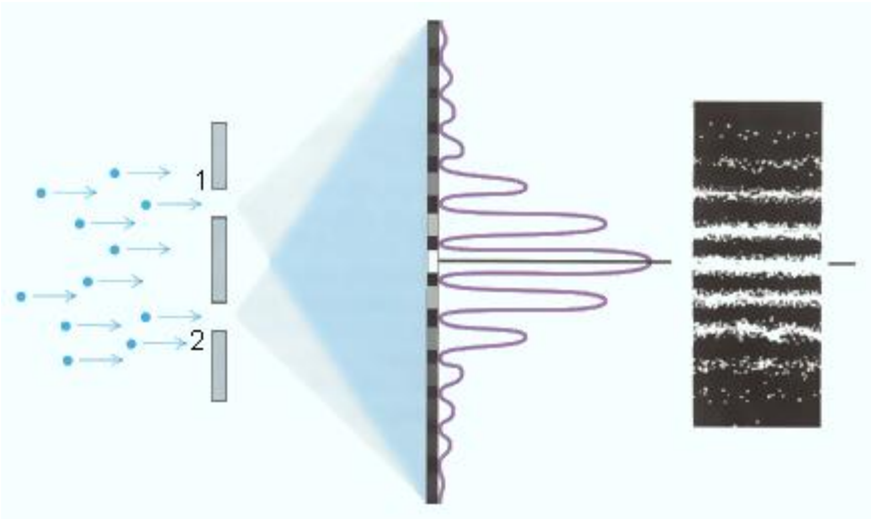

Figure 13. Young's experiment with electrons. (Fig. from [97])

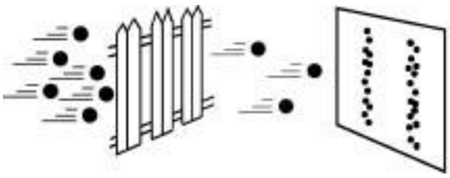

Figure 14. Young's experiment with balls and fence.

If one of slots is closed in two slots electrons diffraction experiment then an interference pattern disappears. The band of the electrons is registered instead. Hereupon we open the second slot and close the first one. In such a way we obtain the second band. The final pattern is similar to the pattern obtained by the balls game described above, i.e. a simple sum of these two bands. But if the both slots are opened simultaneously we observe a complex interference pattern instead. The results of this experiment can not be explained by interaction of electrons - the same result is obtained by emitting of electrons one after one. The reason is that electron position is not defined by a certain trajectory, by wave of probabilities. Two waves from two slots summarize and give an interference pattern. The quadrate of amplitude of sum of these two waves on the screen gives probability to find an electron there.

Let's assume that we arrange a detector which shows through what of slots an electron transits. The final pattern in this case is similar to results of the experiment with alternately closed slots. I.e., the interference pattern disappears. This result is explained by influence of the measuring device - the detector. There is reduction of wave function and its pure state transfers to the mixed one. Thus, instead of the sum of wave amplitudes from two slots, the probabilities summarize, and the interference pattern disappears.

This experiment shows two main properties of quantum mechanics. At first, **we cannot predict an exact final position of an electron in the screen**, and we can discover just probability for all point. Only a large number of electrons gives a quite certain and predictable distribution pattern on the screen**.** In the classical case the result was predictable for even a single particle. Secondly, **we cannot perform *any* measuring of the intermediate state of an electron, without perturbation of this intermediate state causing change of further measuring results**. So, having checked up through what of the slots the electron has transited, we will destroy the further interference pattern. In classical mechanics it was always possible, at least in principle, to make measuring without perturbation of the system dynamics. In quantum mechanics such measurement is possible only if wave function of the measured system is identical to some eigenfunction of a measurand.

The experiment with two slots also allows explaining the mechanism **vanishing of quantum interference effects for macroscopic systems.** It occurs under following three requirements:

1) Coherent**,** "monochromatic" wave considering in the experiment interacts with its environment or its source. This interaction leads **to transformation** of its **pure state to the mixed state**. As consequence, the probability wave is not an infinite sine curve, but set of sine curve segments. Such segment of the sine curve is named a wave packet. A phase of some wave packet is random value. Length of a wave packet is about 10-20 wave lengths. It has the order of wave-atom interaction radius. The atoms correspond to the surrounding medium or the source.

2) Consideration system with **macroscopic sizes**. The distances between slots (D) are much larger than lengths of a wave packet (n λ) and distances from the slots to the screen (L). More precisely: $D \gg \sqrt{(L \cdot n\lambda)}$, where λ is a wave length.

3) Introduction of **macroscopic parameters** (averaging wave intensity on a length much larger than lengths of a wave packet, and during the period of time much longer than the time of the wave packet transiting through some point).

As the distance between slots increases (at constant value L), the **path difference** becomes much larger than a wave packet length for the most of points of the screen. As result, phases of the waves coming from the slots become random. Hence, it's not amplitudes of wave that are summarized but coarsen macroscopic intensities. Therefore, the interference disappears for the most of points on the screen. As the distance between slots becomes larger than the distance to the screen, the interference remains just in the small neighborhood of a screen point which would be precisely in the middle between slots. The size of an interference range gets equal to a wave packet. At the further increasing of distances between slots, wave intensity in this interference range starts to decrease and converges to zero without decreasing its size[3]. So, small interference effects are not observed at coarsened (i.e. macroscopic) description.

All these effects of vanishing of interference are caused by macroscopic nature of the system and its parameters and also by the mixed nature of initial state. Such transformation of a wave from pure

[3] *It must be mentioned that this system has **infinite size** in wave propagation direction and the wave is not reflected by the screen. Therefore, unlike the finite systems considered below, if the interference disappears it does not appear again. On the other hand, when the distance between slots **converges to infinity** (at constant value L) quantum interference effects converge to zero (for any finite wave packet length and for any finite degree of macroparametres coarsening.*

coherent state to mixed state because of interaction (entangling) with its environment is named **decoherence** (from Latin *cohaerentio* - connection) **[21-25]**, (**Appendix P**). The system is intermixed or entangling with a surrounding medium. For macroscopic (i.e. very large) systems **decoherence** leads to vanishing of quantum interference, as discussed above in the experiments with two slots. The **decoherence** theory has an important consequence: for the macrostate quantum theory predictions are almost coincide with predictions of the classical theory. But the price for this coincidence is irreversibility as we will see further.

3.7 Schrodinger's cat paradox [26] and spontaneous reduction [18].

The complete violation of the wave superposition principle (i.e. the full vanishing of interference) and the wave function reduction would occur only during interaction of quantum system with an ideal macroscopic object or a device. The ideal macroscopic object either has infinite volume, or consists of infinite number of particles. Such an ideal macroscopic object can be consistently described both by quantum and classical mechanics[4].

Further on (unless the other is assumed) we consider, similarly to the classical case, only systems with finite volume with a finite number of particles. Such devices or objects can be considered as macroscopic just approximately[5].

Nevertheless, a real experiment shows that even for such non ideal macroscopic objects the destruction of superposition and correspondent wave function reduction may occur. We will define such reduction of imperfect macroscopic objects **as spontaneous reduction**. The spontaneous reduction leads to paradoxes which force to doubt completeness of quantum mechanics, despite all its tremendous successes. We will reduce the most impressive paradox from this series - Schrodinger's cat paradox (Schrodinger 1935) **[26].**

It is a thought experiment which clarifies the principle of superposition and wave function reductions. A cat is put in a box. Except for the cat, there is a capsule with poisonous gas (or a bomb) in the box which can blow up with 50 percent probability because of radioactive decay of plutonium atom or casually illuminated light quantum. After a while the box is opened and one gets to know whether the cat is alive or not. Until the box is opened (measuring is not performed), the Cat stays in a very strange superposition of two states: "alive" and "dead". For macroobjects such situation looks very

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[4] *Thus, observing light of a remote star, we study it, but we do not influence as it could have been expected on basis of quantum measuring theory. We change only a state of star photons reaching us. This is because we consider the Universe space as infinite. So, illuminated photons have no chance to return to the star and to change its state. In the case of the finite Universe, observable photons can return to a star and influence it. However, for a very large Universe, a very long time may be needed.*

[5] *For example, the above described star-observer system in a very large finite Universe would behavior similar to an infinite Universe during a very long, but finite time only*.

mysterious[6]. (Thereagainst, for quantum particles superposition of two different states is very natural.) Nevertheless, no basic prohibition for quantum superposition of macrostates exists.

The reduction of these states at opening the box by an external observer does not lead to any inconsistency with quantum mechanics. It is easily explained by interaction of the external observer with the cat during measuring of the cat's state.

But the paradox arises at the closed box when the observer is the Cat itself. Really, the Cat possesses consciousness and it is capable to observe both itself and the environment. At real introspection the cat cannot be simultaneously alive and dead, but is just in one of these two states. Experience shows, that any consciousness creature or feels itself live, or it is dead. Simultaneously both such situation does not exist. Therefore, spontaneous reduction to two possible states (alive and dead) really occurs[7]. The cat, even together with all contents of the box, is not an *ideal* macroscopic object. So such observable and nonreversible spontaneous reduction contradicts to reversible Schrodinger quantum dynamics. In current case it can not be explained by some external influence, because the system is isolated. **[18, 27, 7].**

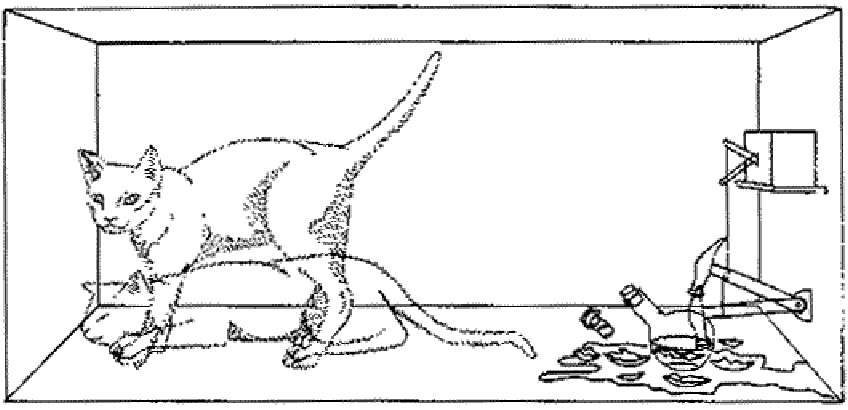

Figure 15. Experiment with Schrodinger Cat. (Fig. from [98])

There are many problems related to a spontaneous reduction. Whether does it actually contradict to Schrodinger quantum dynamics? When the system is enough macroscopic that the spontaneous reduction can happen? Whether must such almost macroscopic system have consciousness like a Cat? What are time moments when a spontaneous reduction can occur?

3.8 Zeno Paradox or «paradox of a kettle which never will begin to boil».

The "paradox of a kettle which never will begin to boil" is related to the last of the above mentioned problems. Actually, here are two paradoxes, but not just one.

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[6] *Sometimes there try to describe such situations with help of art through "paradoxical" images* ***[3, 28], (Appendix V).***

[7] *Though there are some exotic attempts to understand how the consciousness can perceive such exotic states of macroobjects* ***[3, 28], (Appendix V).*** *See also the previous reference.*

Let us assume that there is some quantum process. For example, decay of a particle or transmission of a particle from one energy level on another one.

The first paradox is as follows. **If time intervals between acts of registering converge to zero, then the specified process generally never happens during any chosen finite time interval**! It can be explained by influence of quantum measuring. Measuring leads to reduction to the mixed state (broken and not broken particle). Besides, relative process rate (over one particle) converges to zero when measurement time interval converges to zero. These two facts lead to process stoppage for frequent measurements.

The second paradox is as follows. In real life decay of the substance containing large number of particles is always featured by the exponential law. It is not casual. The relative velocity of such decay is constant in time. Accordingly, it is impossible to find observationally "age" of such substance if we do not know an initial number of not broken particles, and broken particles taking away from the system. But quantum decay, according to the quantum mechanics equations, is featured **not by the exponential** law. Therefore, the relative rate of decay at the beginning of the process is equal to zero, and then increases. We can make paradoxical conclusion that it is possible to introduce non-physical concept of the system "age". "Age" can be easily found through the current relative rate of system decay.

We will resolve this second paradox in the part of the paper concerned to Observable Dynamics.

3.9 Quantum correlations of system states and their connection with paradox of the Schrodinger cat.

The concept **of quantum correlation of system states** is closely related to the paradox of Schrodinger cat. Suppose there is some spontaneous reduction of states of the alive or dead cat. Any further measuring then will depend on the previous Cat's state. It can be either "alive cat", or "dead cat". Observed data can be divided into two non-overlapping groups: one group will correspond to “alive cat”, the other one to "dead cat". But if Cat is in quantum superposition of these two states the results of the further measurements will depend on the both states of Cat. So it cannot be divided already into two non-overlapping groups. This connection between the initial states, expressed in impossibility to divide further results of measuring into independent non-overlapping groups corresponding to such initial states, is named "quantum correlation of system states".

In mathematical language, this fact is explained by nonlinearity of connection between probability of an observed data and a wave function. In other words, the quadrate of sum is not equal to sum of the quadrates. Appearing additional terms (or the interference terms) are the measure of quantum correlations.

Quantum correlations are corresponding also to nondiagonal elements of a density matrix. For the mixed state obtained as a result of measuring, all nondiagonal terms are equal to zero.

Let's express the paradox of Schrodinger cat in the language of quantum correlations: on the one hand, the cat introspection gives only one from two possible results: or "alive cat", or "dead cat". Thus there is some spontaneous reduction, and quantum correlation between these states disappears. It means that further results of measuring **can be divided** into two independent non- overlapping groups corresponding to initial states.

On the other hand, according to Schrodinger equations, quantum correlation cannot disappear itself, without presence of external forces. It means that further measuring results **can *not* be divided** into two independent non- overlapping groups corresponding to initial states.

This inconsistency between Schrodinger dynamics and the observable spontaneous reduction will lead to the paradox.

4. Quantum mechanics interpretations. Their failure to solve the paradoxes

One of the problems that we wrote of above is difficulty of understanding of quantum mechanics on the basis of our classical intuition based on the real word experience. There are various interpretations of quantum mechanics **[18]** that can also serve for simplification of such understanding. It is necessary to specially emphasize that neither of interpretations of quantum mechanics would lead to solving the above mentioned paradoxes, they just allow understanding of quantum mechanics in visual and clear way for our intuition. We will restrict ourselves by only three of the wide list of possible interpretations. The most popular for today and also a very evident one is multi-world interpretation.

4.1 Multi-world interpretation. [29, 30, 18].

Let's describe it in more detail. From the example of Schrodinger cat we can see that quantum evolution can lead to various and macroscopically distinguishable conditions. We really observe only one of them. Multi-world interpretation states that all these states exist simultaneously in certain “parallel worlds”, but we (or a cat in our mental experiment) can observe only one of macroscopic alternatives.

The similar approach illustrates the concept of spontaneous reduction by the following. As all the worlds exist simultaneously, all of them can influence results of some measuring. Generally, results of measuring cannot be divided into two disconnected groups related to the alive and dead cat. It means that these worlds correlate with each other and each of them influences the results of measuring. Presence of spontaneous reduction at measuring will lead to losses of this correlation. Results of measuring will break up into independent groups corresponding to various worlds.

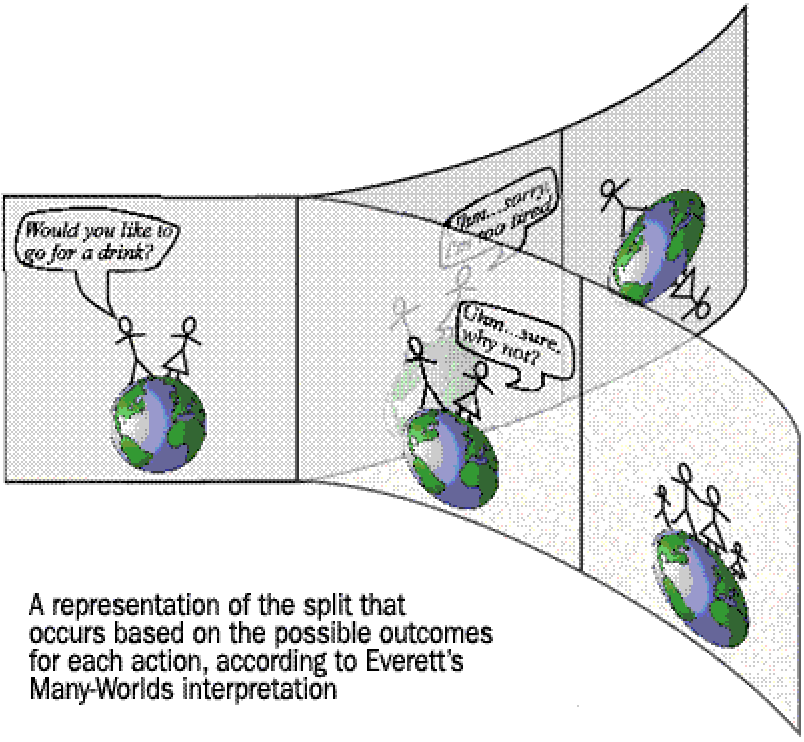

Figure 16. Multi-world interpretation. (Fig. of Max Tegmark from [99])

The multi-world interpretation as such does not explain Schrodinger cat paradox. Really, the Cat observes only one of the existing worlds. Results of the further measurings depend on correlations between the worlds. But neither these worlds nor these correlations are observed. «Parallel worlds» that we know nothing about can always exist. But these worlds can really affect results of some future experiment of ours. I.e. the knowledge of the current state only (in our "world") and quantum mechanics laws does not allow us to predict the future even probabilistically! But it was just such predictions the quantum mechanics has been developed for! Just on basis of spontaneous reduction that destroys quantum correlations between the worlds, we can predict the future using knowledge of only current (and really observed) states of our "world". The paradox of Schrodinger cat returns but just having its shape changed.

It is not clear also how to define the macroscopic states corresponding to “separation” on “the parallel worlds”. (Really, wave function expansion is ambiguous, and different sets of orthogonal functions can be used for this purpose.) It is not clear how to find the exact moments of time when this "separation" happens. But solving the paradoxes (contrary to a very widespread mistake) is not the purpose of quantum mechanics interpretations.

4.2 Copenhagen interpretation.

Another interpretation is the Copenhagen interpretation. It is used in today’s papers and is standard for most usual book and papers in quantum mechanics field. It states that at the moment of observation of macroscopic states, spontaneous reduction occurs and quantum correlations disappear. So it results in the paradoxes described above.

It is necessary to score that the reduction in the Copenhagen interpretation happens just for a chosen *final* observer in the sequence of measurings. From his point of view, the experiment should be described. The reduction, like velocity of the system, depends on the choice of the observation system.

Let's suppose that some external observer investigates some other observer, for example the external observer (scientist) investigates the Schrodinger Cat. No spontaneous reduction, really observed by the Cat himself, happens for the external observer.

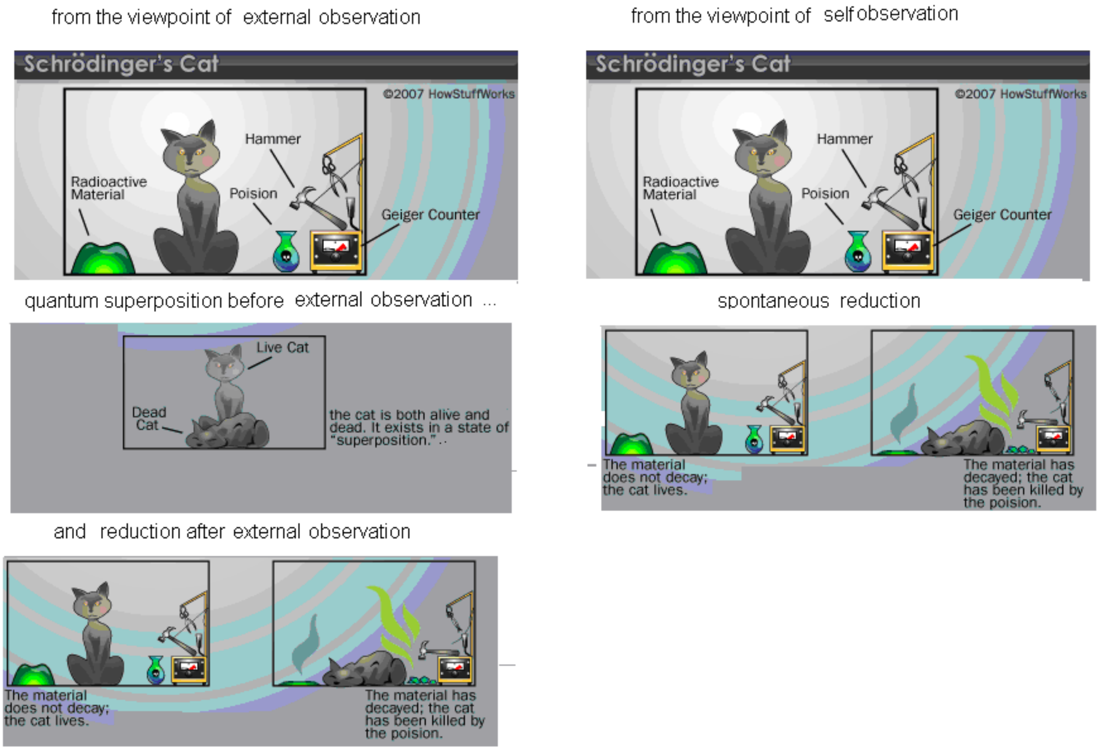

Figure 17. Schrodinger cat experiment from the viewpoint of external observer (experimenter) and self observation (the Cat itself) (Fig. from [100])

From external observer point of view the reduction happens just when the external experimenter opens the box and consequently interacts with the Cat and results in the reduction. It means that there is no paradox for the external observer.

Only when the Cat is regarded as the final observer, there is spontaneous reduction, and consequently there would be the paradox described above. Really, the Cat can feel itself only alive or dead, but not in these two states simultaneously!

This note is very important, as its misunderstanding leads to absolutely erroneous statements **[29, 30],** that the Copenhagen interpretation is incompatible with the multi-world interpretation. Actually, as we will see further, the difference between these interpretations is not observable and so both interpretations can be used.

4.3 Interpretation via hidden parameters. [18], (Appendix S,T,U)

Introduction of the hidden parameters defines one more interpretation related to EPR paradox. It is, for example, the wave-pilot theory of de Broglie - Bohm **[18].** This theory includes coordinates, velocities, spins and wave function (wave- pilot) being changed in time according to Schrodinger equations, as hidden parameters. Thus, quantum correlations (as we saw above during discussion of EPR paradox) led to locality violation, i.e. long-range interaction between the hidden parameters. For explanation of connection between actually measured (not hidden) parameters such long-range interactions are not necessary. These connections are perfectly described by usual correlation of variables. Thus, the reduction of a macroscopic state (or happening at measuring, or spontaneous) leads to vanishing of quantum correlations which become classical ones.

Difference between quantum correlations and the classical correlations, appearing after reduction, is expressed not only in the existing long-range interaction. Let the correlated long distance parts of the system (these parts was together in a pure state in the beginning) again appear together after some, may be, and long time. Thus in a quantum case we obtain pure state again, but in the classical case accompanied by reduction (or happening at measuring, or spontaneous) - the mixed one. In the case of spontaneous reduction it leads to inconsistency with Schrodinger evolution. Paradoxes do not disappear but just acquire some different appearance.

5. Definition of complete physical system in the theory of measuring.

In measurement theory it is necessary to include both the observer and a surrounding medium into the complete system because in many cases even their small influence cannot be neglected. As it will be clear later on it is true not only for quantum but also for classical mechanics. Generally the complete system consists of three parts: the **observable system**, **the surrounding medium**, and the **observer**. The observer also consists of three parts: **the measuring device**, the **person of the observer** and **the memory** of the observer. The memory is necessary for keeping the sequence of observation. This observation sequence can be used for comparison with the theory. It is necessary for memory to **be isolated from its entire environment**, except for the channel of receiving information. If some external factors can influence it, changing or erasing its contents, no experiments for the theory verification are possible. It is a very important statement. It helps to resolve many paradoxes, including those considered below.

The final point of the complete physical system is the observer's memory. The system includes only one observer. Certainly, many observers can exist, but we should choose a point of view of only one of them. The rest ones would be considered as just parts of the observable system or the environment. But which one must be chosen? The problem is solved similarly to relativity theory - it is possible to choose any one. But it is important to interpret all facts from the point of view of the single chosen observer. For Schrodinger Cat paradox case the observer can be either the Cat, or the external observer-experimenter. (But not the both together!)

6. Solution of the paradox of Schrodinger cat.

Let's remind that the paradox of the Schrodinger cat consists in inconsistency between the spontaneous reduction observed by a cat and Schrodinger evolution forbidding such reduction. To correctly understand the paradox of Schrodinger cat it is necessary to consider it from the point of view of two observers: the external observer-experimenter or the Cat, i.e. **introspection**.

In case of the external observer-experimenter the paradox does not arise. If the experimenter tries to see whether the cat is alive or not, it influences inevitably the observable system (in agreement with quantum mechanics) that leads to reduction. The system is not isolated and, hence, cannot be featured by a Schrodinger equation. The reducing role of the observer can also be played by the surrounding medium instead. This case is defined as decoherence. Here the role of the observer is more natural and is reduced just to fixing decoherence. In both cases there is entangling of measured system with the environment or the observer, i.e. there are correlations of the measured system with the environment or the observer.

What will be if we consider the closed complete physical system including the observer, observed system and environment? It is Cat's introspection case. The system includes the Cat and his box environment. It ought to be noted that **the full introspection (full in the sense of quantum mechanics) and the full verification of quantum mechanics laws is impossible in the isolated system including the observer himself**. Really, we can measure and analyze a state of external system precisely in principal. But if we include ourselves as well in consideration there are the natural restrictions. It related to possibility to keep in memory and to analyze states of molecules by means of these molecules themselves. Such assumption leads to inconsistencies (**Appendix M**). Therefore, the possibility to find experimentally inconsistency between Schrodinger evolution and spontaneous reduction by help of introspection in an isolate system is also restricted.

Nevertheless, let's try to find some mental experiments leading to inconsistency between Schrodinger evolution and spontaneous reduction.

1) The first example is related to reversibility of quantum evolution. Suppose we have introduced a Hamiltonian capable to reverse quantum evolution of the Cat-box system **[29, 30].** Though practically it is almost impossible, theoretically no problem exists. If the spontaneous reduction happens the process would be nonreversible. If the spontaneous reduction is not present the Cat-box system will return to an initial pure state. However, only external observer can make such checkout. The Cat cannot make it by introspection because Cat’s memory will be erased after returning in an initial state.

From the point of view of the external observer, no paradox exists because he does not observe spontaneous reduction that really can lead to a paradox.

2) The second example is related to necessity of Poincare's return of quantum system to an initial state. Suppose the initial state was pure. If spontaneous reduction really exists in the case of Cat

introspection, it leads to the mixed state. Then return would be already impossible - the mixed state cannot transfer in a pure state according to a Schrodinger equations. Thus, if the Cat has fixed return, it would come to inconsistency with spontaneous reduction. But the Cat cannot fix return (in the case of quantum mechanics fidelity), because return will erase Cat's memory. So, there is no paradox.

The exterior observer actually can observe this return by measuring an initial and final state of this system. But there also no paradox exists, because he does not observe any spontaneous reduction that really can lead to a paradox.

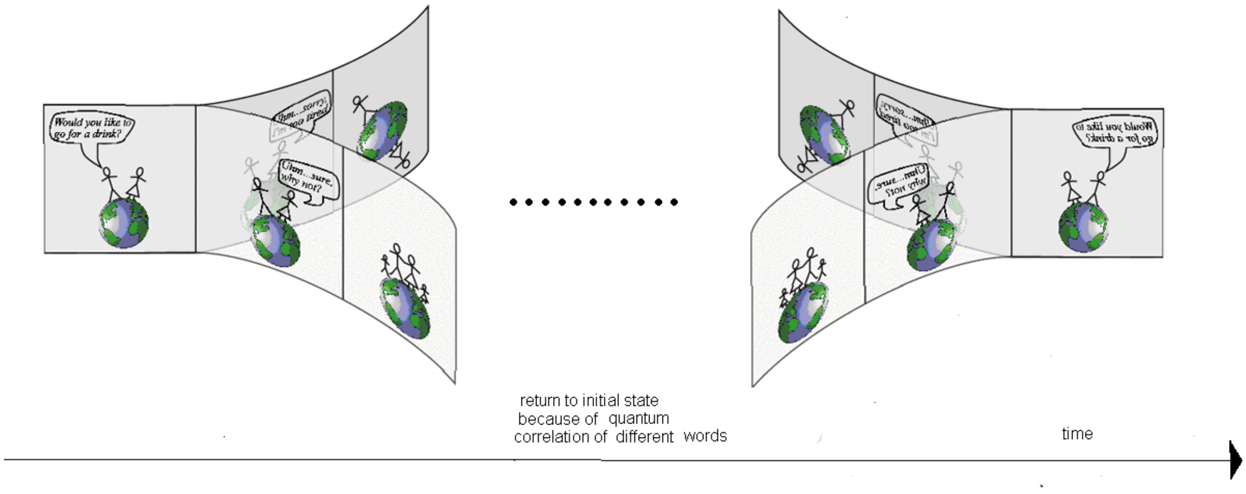

Figure 18. Poincare's return close to initial state due to quantum correlations.

It is worth to note that the inconsistency between spontaneous reduction and Schrodinger evolution can be experimentally observable only when the spontaneous reduction is kept in memory of the observer and this memory is not erased and not damaged. All experiments described above are not covered by this requirement. Thus, these examples clearly show that though the spontaneous reduction really can lead to violation of Schrodinger evolution, this violation experimentally is not observed.

3) The third example. Quantum mechanics gives superposition of a live and dead cat in a box. Theoretically, an exterior observer can always measure this superposition *exactly* if it would be one of measurement eignfunctions. Such measuring would not destroy superposition, contrary to the case when the live and dead cat are eignfunctions of measurement. Having informed the cat about the result of measuring we will enter into inconsistency with spontaneous reduction observed by the cat **[31, 32]**. Such argumentation would hold a double error.

At first, this experiment is used for *verification* of Cat's spontaneous reduction existence when the observer is the Cat itself. The external observer does not influence Cat's memory only when the spontaneous reduction is not present, and the Cat's state is superposition of live and dead states. But it does influence and can destroy Cat's memory in spontaneous reduction case. So such experiment is not legitimate for verification of spontaneous reduction existence.

So, no contradiction with the past exists.

Secondly, the data transmitted to the Cat is kept in his memory. Thus this transmission changes both the state, and all further evolution of the Cat, i.e. the system can not be considered as isolated in the following. So, no contradiction with the future exists.

The external observer does not see spontaneous reduction and, hence, does not observe the paradox. So, from the external observer’s point of view, such verification is quite possible and legitimate. It does not influence the external observer's memory. Moreover, such verification, which does not break evolution of the observable system, allows measuring not just an initial and final state of system but also all intermediate states. I.e. it implements continuous non-perturbative observation!

It ought to be noted that the external observer can observe the superposition of an alive and dead cat just theoretically. Practically it is almost impossible. In contrast for small quantum systems, the superposition is quite observable. It results in the fact that quantum mechanics is considered usually as the theory of small systems. But for small macroscopic (**mesoscopic**) objects such observation is possible too. The large set of particles at low temperatures or some photons states **[33]** can be an example.

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7. Solution of paradoxes of Loschmidt and Poincare in classical mechanics. Explanation of law of increasing of macroscopic entropy

Let us also consider two cases here – when an observer is included into the observable system, and when he is outside of it.

The basic inconsistency of classical statistical mechanics is inconsistency between the law of increasing of entropy and reversible classical motion laws. It is expressed by Poincare and Loschmidt paradoxes.

In case of classical mechanics, unlike quantum mechanics, a more simple case is that when the observer is included into the observable system. Poincare's return of the system to an initial state leads to memory erasing, similarly to the previous chapter argumentation. It makes Poincare paradox experimental observation impossible. The reversion of velocities really leads to entropy decreasing. However, the time direction is relative and not absolute. So we should define positive direction of the time arrow. It is reasonable to choose the time arrow in the direction of entropy growth. We will define such time arrow as the proper time arrow of the system. With respect to this **proper time arrow,** Loschmidt paradox disappears. It ought to be noted that in both paradoxes solutions there is both memory erasing in final system state, and entropy growth in direction of proper system time arrow. Close to the final state, the direction of proper system time arrow reverses with respect to initial state direction. The main reason of impossibility of paradoxes observation is caused **by impossibility of complete system state knowledge with the help of introspection**.

For the external observer, the situation is more difficult. Theoretically, interaction between the observer and observable system can be made by an arbitrarily small in the classical mechanics. Hence, nothing prevents to observe entropy decreasing. In this case directions of the proper time arrow of the observer and the observable system are opposite. Is it really possible? Theoretically yes, but practically it is almost impossible. Most of real physical systems are intermixing (chaotic) systems. It means that their phase trajectories are exponentially diverges in presence of small noise. Small interaction of the observer with the observable system or a surrounding medium with observable system is inevitably present almost in all cases. We remind that for chaotic systems the following theorem is true:

Processes of *macroparameters evolution* with macroscopic entropy decreasing are strongly unstable with respect to small external noise. By contrast to this processes of *macroparameters evolution* with macroscopic entropy growth are stable.

Therefore, inevitable small interaction leads to destroying of entropy decreasing processes and to observer's and observable system's proper time arrows synchronization. Hence the system can not be considered as isolated, and classical mechanics paradoxes for isolated systems are not relevant. Small interaction of a surrounding medium with the observer and with observable system will have the same effect, as interaction of the observer with observable system - proper time arrows synchronization for all subsystems. In this case the role of the observer is more passive and is natural.

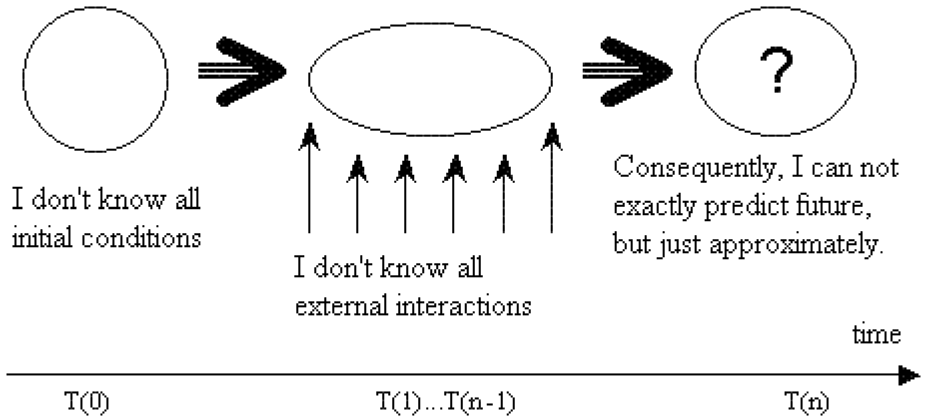

Figure 19. Reasons explaining causes of unpredictability in classical mechanics.

In the works **[1, 2, 6, 34]** synchronism of all proper time arrows in the surround world is considered as big mystery. Why do we never meet processes with entropy decreasing though their probability is equal to probability of entropy increasing processes? Attempts are made to find explanation in the origin of our Universe[8] **[1, 2, 6, 34].** Nothing of the kind is necessary. Simple, inevitable, small interaction always exists between systems. It leads to visible synchronizing of all proper time arrows.

Thus, the trajectories causing entropy decreasing are not stable with respect to small noise from the external observer. In the case of quantum mechanics such noise is even theoretically inevitable during measuring if we do not know the true initial state of the measured system. State

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[8] *Why our present low entropy Universe has not been created from Chaos by some time reversal process* ***[1, 2]?*** *It would look like some large fluctuation! Why its origin is very low entropy state lead to Big Band? The answer is given by Elitzur's paper* ***[35].*** *There it is shown that the optimal process for desirable low entropy states creation there is creation of initial state with much more lower entropy than the desirable one. This method was named «the sky lift» by him. It is because of analogy with using sky lift for further descent of the mountain.*

measuring leads to inevitable violation of this measured state. In classical mechanics measuring can be made at least theoretically precisely. Therefore we should introduce some small external noise and/or initial state errors "manually" in order to explain entropy growth for the observer.

In actual measuring such small external noise is always present. The enormous efforts, causing environment entropy growth, are necessary to prevent this noise influence. Such environment entropy growth is much larger than entropy decreasing obtained by this observable system isolation. Thus, the entropy increasing law will be fulfilled again. Here there is an analogy to paradox resolution about Maxwell's Demon **[37-38]** which uses sorting of molecules for entropy decreasing. Acquiring information for sorting leads to entropy increasing much more than correspondent entropy decreasing.

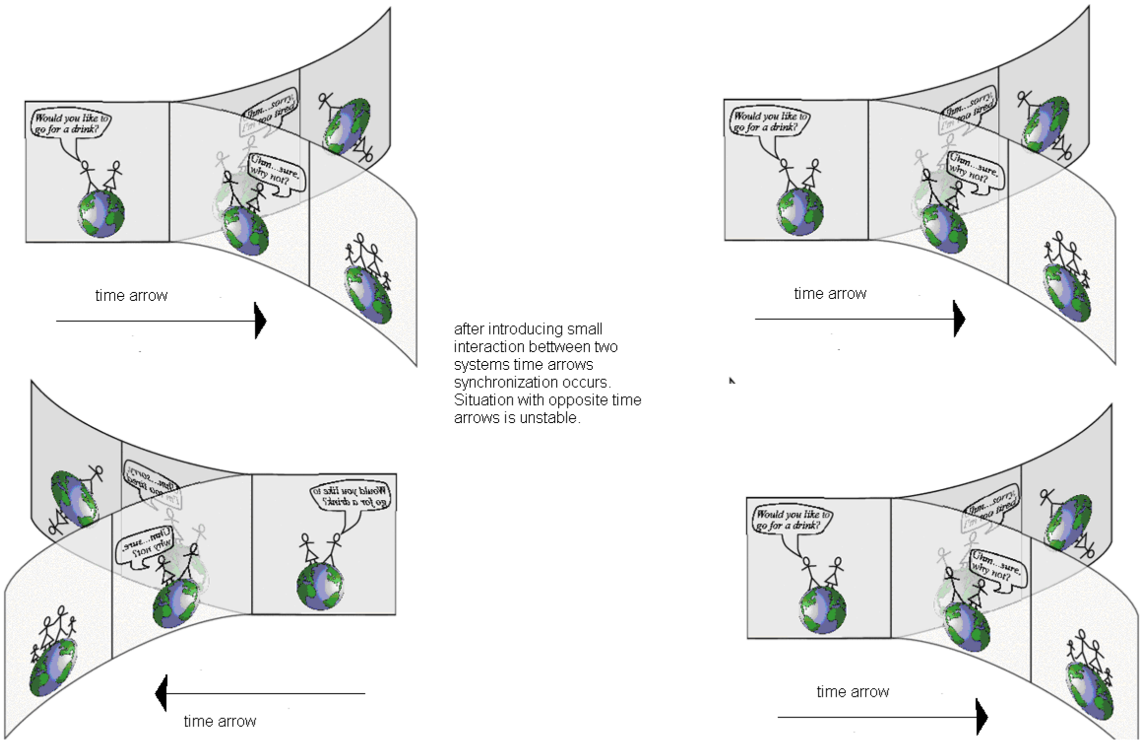

Figure 20. Synchronization of time arrows.

Though prevention of small and all-pervading interaction between systems is a very difficult problem for macroscopic system, for very small systems it is easily executable. Actually, we can observe everywhere small fluctuations which correspond to violations from entropy increasing law. If we neglect a very small friction, reversible processes are easily observable in gravitational astronomy too.

8. Deep analogy between quantum mechanics (QM) and classical statistical mechanics (CM) (see also Appendix N)

From the above described reasons it is possible to guess that there is almost full analogy between properties and paradoxes of CM and QM and also between methods of their solution. We will describe these analogies in more details.

1) The both mechanics are reversible in time.

2) For the both mechanics Poincare's theorem of returns is applicable. However, if for CM **almost-periodic** systems are very small class of systems, for QM all systems in finite volume are **almost-periodic.**

3) In CM there are correlations correspondent to macrostate knowledge and the **additional** hidden microscopic **correlations** related to knowledge of its "history". In QM two types of correlation are also possible: the classical correlations described by density matrix diagonal elements, conserving during measuring reduction, and **hidden quantum correlations**, described by density matrix nondiagonal elements, leading to paradoxes. **Small external noise** from the observer or the environment destroys **additional correlations** in CM and leads to coarsening of phase density function. Similarly in QM, **entangling** of observable system with observer (inevitable interaction during measuring) or **entangling** of observable system with environment (decohernce) lead to vanishing of quantum correlations (density matrix nondiagonal elements vanishing) and wave function **reduction**.

4) In case of introspection observation of Poincare or Loschmidt returns is impossible because of memory erasing. As a result, at introspection observation of additional correlations (in CM) or quantum correlations (in QM) leading to paradoxes is also impossible.

5) In QM and CM it is possible to define two kind of entropy - entropy of ensembles (phase density function) and macroscopic entropy. Entropy of ensembles conserves during reversible evolution, macroscopic entropy can both increase and decrease. At introspection entropy decrease becomes unobservable. For the external observer small interaction of this observer with observable system or observable systems with the environment also makes entropy decrease impossible (or very hard-achievable). Let's try to isolate from an environment noise and to observe some entropy decreasing system. Yet very large entropy increasing is necessary for it. This entropy increasing is much larger than entropy decreasing obtained with the help of isolation. Actually, no completely isolated and impenetrable cavities exist in our real world, no ideal infinitely light-weighted particles. But small and all-pervading interaction does exist.

6) Process of spontaneous reduction in QM is related to neglecting by quantum correlations and transition from a pure state to mixed one, thus, leading to increasing of macroscopic entropy. It is interesting that macroscopic entropy increasing can be found by similar way for Boltzmann equation in CM. It is achieved by introduction of **“molecular chaos hypothesis”.** It is related to neglecting by correlations between particles (i.e. their momentums and coordinates are assumed as independent). Thus the two particles distribution function is considered as the product of one-particle functions. Thus, introduction of spontaneous reduction in the QM equations is very similar to introduction entropy increasing law in CM equations.

7) Laws of QM are statistical. In QM observation of unknown state inevitably results in changing observable system evolution. The most of systems in CM are intermixing, so in reality their behavior also is casual. It is related, firstly, to small interaction of an observable system with an observer or

environment. Secondly, our knowledge of initial state is not full. However, theoretically, for very exact accuracy of initial state measuring and full isolation, behavior of the system can be predicted as precisely as we want. However, for reaching such accuracy in reality, enormous entropy increasing of environment shall be needed.

8) In both cases paradoxes arise only for macrosystems. Laws of behavior of microsystems are not applicable because of small external noise and finite accuracy knowledge of the initial state. The single serious difference between QM and CM is the following. In CM small, but finite interaction during measuring (observation) or small errors of the initial state knowledge should be introduced "manually", but in QM it arises naturally because of theoretically inevitable interaction during measuring of unknown quantum state[9].

In conclusion, we come to an unexpected deduction: the paradox of the Schrodinger Cat in QM is the quantum analogue of entropy increasing law in CM. In QM microsystems are usually investigated, and in CM macrosystems. So these actually equivalent paradoxes possess so different forms. But the main sense of them is the same.

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[9] *Very often there are examples of "purely quantum paradoxes", ostensibly not having analogy in the classical statistical mechanics. An example is Elitzur - Vaidman paradox **[36]** about the bomb which can be discovered without explosion:*

1) Let the wave function of one photon branches to two possible channels of some devices. In the end these channels again unite, and there is an interference of two probability waves. Entering bomb into one of the channels will break process of interference and will allow discovering the bomb even if the photon will not detonate it. (The photon is capable to detonate the bomb)

2) The full analogy is the following experiment in CM. In one of the channels where there is no bomb, we throw in a macroscopic beam of many lightweight particles. In other channel where the bomb is present only one lightweight particle travels. This particle is not capable to detonate the bomb, but the bomb can throws it back. This particle is undetectable macroscopically because of finite sensitivity of devices. But if the beam of particles in the end of the channel has unstable dynamics, even presence of one undetectable additional particle can strongly change this dynamics (so-called «effect of the butterfly»). It will allow registering a new particle which will transit through the second channel if bombs are not present. It is the full analogy between QM and CM paradoxes!

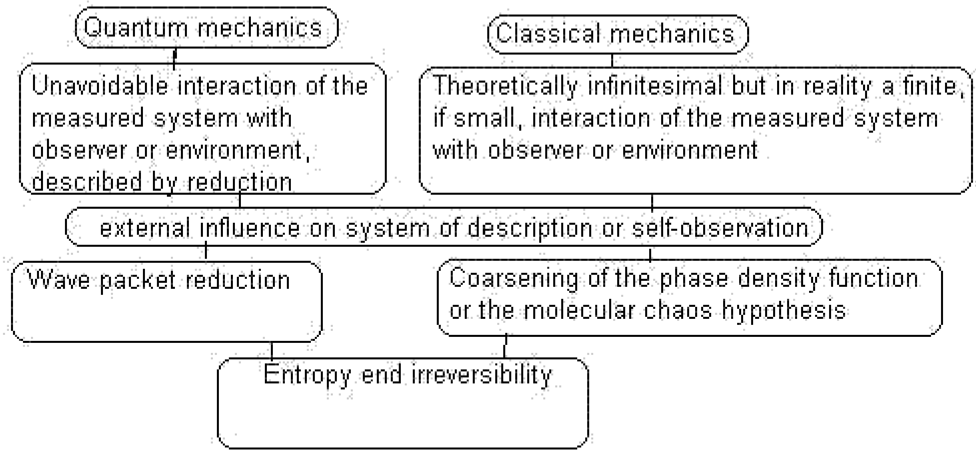

Figure 21. Sources of irreversibility and entropy in physics.

9. Time arrows synchronization/decoherence [88-94].

The follow question can appear. Assume that there exists a process in which the entropy decreases. For definiteness, let us take this process to be a spontaneous reconstruction of a house (previously destroyed in an earthquake).

Let us also take a simple example of the gas expanding from a small region of space into a large volume. If, after some time, all the velocities are reversed, the gas will end up in the starting small volume. If we turn on the camera to take a series of snapshots recording different stages of spontaneous house building/ (gas shrinking), we expect that the camera will record this spontaneous process. Why will the camera not be able to record it? What exactly will prevent the camera to record these snapshots?

The answer this question is following: even a very small interaction between the camera and the observed system destroys the inverse entropy decrease process and results in the time arrow directions synchronization of the observer and the observed system. (A time arrow direction is defined in the direction of the entropy increase.) This very small interaction appears because of light, eliminated by the observed object and reflected by the camera (and also because of light eliminated by camera). In absence of the camera the role of the observer can play environment, eliminating and reflecting the light. (Any process without a observer has no sense. He must appear at some stage of the process. But his influence is much smaller than the environment influence.) External noise (interaction) from the observer/the environment destroys correlation between molecules of the observed system. It results in preventing the inverse process with the entropy decrease. In the quantum mechanics such process is defined as "decoherence". The house reconstruction/(the gas shrinking) will be stopped, i.e., that the house will not really be reconstructed/(the gas will not shrink). In contrast the entropy increase processes are stable.

Decoherence (time arrows synchronization and “entangling”) and relaxation (during the relaxation a system achieves its equilibrium) are absolutely different processes! During the relaxation macroscpical variables (entropy, temperature, pressure) strongly change to its equilibrium values and invisible microscopical correlations between parts of the system increase. During the decoherence the macroscpical variables (entropy, temperature, pressure) are almost constant. Invisible microscopical correlations inside the subsystems (environment, observer, observed system) are strongly destroyed, but new correlations appear between the subsystems. It is named “entangling” in the quantum mechanics. During this process the time arrows synchronization happens also. Time of the relaxation is much larger than time of the decoherence.

Let us take a simple example of the gas expanding from a small region of space into a large volume. In this entropy-increasing process the time evolution of macroscopic parameters is stable to small external perturbations. If, after some time, all the molecular velocities are reversed, the gas will end up in the starting small volume; this is true in the absence of any perturbation. This entropy-decreasing process is clearly unstable and a small external perturbation would trigger a continuous entropy growth. Thus the entropy-increasing processes are stable, but the decreasing ones are not.

The following example is a citation from Maccone's paper **[39, 40]:**

"However, an observer is macroscopic by definition, and all remotely interacting macroscopic systems become correlated very rapidly (e.g. Borel famously calculated that moving a gram of material on the star Sirius by 1 m can influence the trajectories of the particles in a gas on earth on a time scale of s **[41]**)"

But no problem exists to reverse together the observer (the camera) and the observed system. Because of the Poincare return theorem for closed system (including the observer and the observed system) it must happen automatically after very large time. But the memory erasing of observer doesn't allow register this process.

The most real systems are *chaotic* – a weak perturbation may lead to an exponential divergence of trajectories, and also there is always a non-negligible interaction between an observed system and an observer/environment. But *in principle* both in the quantum mechanics and in the classical mechanics we can make unperturbative observation of the entropy decrease process. The good example of such mesoscopic device is a quantum computer: no entropy increase law exists for such system. This device is very well isolated from the environment and the observer. But *in practice* unperturbative observation is almost impossible for macroscopical systems. We can conclude that the entropy increase law is *FAPP* (for all practical purposes) *law*.

Let us consider time arrows synchronization for two non-interacting (before some initial moment) systems. The systems had initially the opposite time arrows. It means that there exist two non-interacting systems, such that in one of them time flows (i.e., entropy increases) in one direction, while in the other time flows in another (opposite) direction. However, when they come into an interaction with each other, then one of them (the "stronger" one) will drag the other ("weaker") one to flow in his ("stronger") direction, so that eventually they will both have time flowing in the same direction.

What exactly it means to be "stronger? Is it something that increases with the number of degrees of freedom of the system? It is not correct. "Stronger" or "weaker" does not depend on the number of degrees of freedom of the systems. For the first system the interaction appears in its *future* after initial moment (In initial moment the systems have opposite time arrows). For the second system the interaction was in its *past.* So situation is *not symmetric in time* and the first system is always "stronger". It happens because of the instability of the entropy decrease processes and stability of the entropy increase processes described above.

Indeed, suppose we have two initially isolated vessels with gas. In the first one gas expends (the entropy increase). In the second one gas shrinks (the entropy decrease).

In the first vessel the gas expends from small volume in the center of a vessel. Velocities of molecules are directed from the center of the vessel to its boundary. It is physically clear that a small perturbation of the velocities can not stop gas expending. Indeed, velocities after a random small perturbation will continue to be directed from the center of the vessel to its boundary. The noise can even increase expending. So, the expending process is stable.

In the second vessel gas shrinks from the full volume of a vessel to its center. Velocities of all molecules are directed to the center of the vessel. It is physically clear that a small random perturbation of the velocities can easily stop gas shrinking. Indeed, the velocities even after a small perturbation will not be directed to center of vessel. Thus, the shrinking process is stopped. So we can conclude that the shrinking process is unstable. This shrinking process can be obtained by reversing gas expanding. If we reverse the molecules velocities of the expending gas *before* the collisions of the molecules with each other and the vessel boundary such instability is linear and not strong. But for reversing *after* collisions this instability is exponential and much stronger.

Both directions of time have equal roles. But a small random noisy interaction breaks this symmetry for the described above two systems because of the instability of the entropy decrease processes. The symmetry of time exists only for *full* system including the two defined above subsystems. But the time arrows of the interacting subsystems must be the same.

In reality, the interaction with infinite time can be replaced by large finite time T, which is chosen to be much smaller than Poincare return time. So in the first system we have the interaction during [0, T] and in the second one during [-T, 0]. Can our argument be still applied? Instead of the asymmetry of the forces in this case we obtain a asymmetry of the initial conditions: At initial moment 0 for the first coordinate system [0,T] the two vessels have the different eigen time arrows. However, at initial moment -T for the second coordinate system [-T,0] the two vessels have the same eigen time arrows in negative direction. Only if T is exactly equal to Poincare return time the situation will be indeed symmetric. For such situation the two eigen time arrows is also different in moment T, but everyone is opposite its initial direction in time 0. Again the “stronger” system has the interacting forces in its future with respect to its eigen time arrow.

This theory can explain the same direction of entropy growth in all parts of Universe. But it can not explain a low entropy initial condition of the Universe. It is probably a result of the anthropic principle **[42].**

10. The law of entropy increase and "synchronization of time arrows"/decoherence in the gravitation theory.

In Einstein's general relativity theory motion is reversible similarly to the classical mechanics. But an important difference also exists between the general relativity and the classical mechanics. The general relativity is ambiguous theory. Indeed, in the general relativity two various initial states can give infinitesimally close states after *finite* time interval. It happens, for example, during formation of a black hole as a result of a collapse. Let us consider the inverse process describing a white hole. In this process the infinitesimally close initial states after the *finite* time interval can give the different final states. It means, that an observer/environment can affect considerably on its evolution during *finite* time interval even when the observer/environment infinitesimally weakly interacts with the white hole. As a result of this property the law of the entropy increase turns to be an exact law, but not FAPP (for all practical purposes). So the entropy becomes fundamental concept. Really, there is such fundamental concept, as the entropy of a black hole. Also it is possible to explain existence of this entropy by the perturbation created by the observer. This perturbation may be now even infinitesimal weak unlike the classical mechanics. During the formation of the black hole the entropy increases. Time reversion leads to appearance of the white hole and the entropy decrease.

The white hole cannot exist in reality because of the entropy decrease. The entropy decrease is prohibited in the general relativity because of the same reasons that it is prohibited in the classical mechanics. It is instability of the entropy decrease processes which much stronger in the general relativity, than in the classical mechanics. This instability results in synchronization of the eigen time arrows of the white hole and the observer/environment. The direction of the eigen time arrow of the white hole changes on opposite one, coinciding with the eigen time arrow of the observer/environment. The white hole transforms to the black hole.

Here is also the well-known black hole information paradox **[43]:** the information (which in classical and a quantum mechanics is conserved) disappears in a black hole for ever. It would seem that there is no problem: probably the information is stored inside of the black hole in some form. However chaotic Hawking radiation makes explicit this process of information losses: the black hole evaporates, but the information is not recovered.

The Hawking radiation concerns to semiclassical gravitation. However the paradox can be formulated also within the frameworks of the general relativity theory. The spherical black hole can be "changed" into a white hole at some moment.[95] Thus process is converted in time. But the information can not be recovered because of the ambiguity (the infinitely strong instability) of the evolution of the white hole.

Usually only two solutions for this problem are considered. Or the information really disappears, or because of interior correlations of the Hawking radiation (or exact reversion of the black hole process after its transmutation to the white hole) the information is conserved. But, most likely, the third solution is true. Because of inevitable influence of the observer/environment it is impossible to distinguish these two situations experimentally! But if it is impossible to check experimentally, it is not a subject of the science

Both for the general relativity theory and for semiclassical gravitation the paradox can be resolved by means of influence of the observer/environment. Really, let us suppose that the Hawking radiation is correlated, not chaotic (or the white hole would be inversed to the black hole exactly). As the infinitesimal influence of the observer/environment leads to the inevitable losses of these correlations (and the correspondent information) during the finite time interval. It is senseless to include the observer into the described system: the complete self-description and introspection is not impossible. The information conservation law can not be checked experimentally for such a case even if it is really correct.

We have now no general theory of quantum gravitation. However for a special case of a 5-dimentional anti-de-Sitter space this paradox is considered by many scientists to be resolved. The information is supposed to be conserved, because a hypothesis about AdS/CFT dualities, i.e. hypotheses that quantum gravitation in the 5-dimensional anti-de-Sitter space (that is with the negative cosmological term) is equivalent mathematically to a conformal field theory on a 4-surface of this world. It was checked in some special cases, but not proved yet in a general case. Suppose that if this hypothesis is really true, as it automatically solves the information problem. The fact of the matter is that the conformal field theory is unitary. If it is really dual to quantum gravitation then the corresponding quantum gravitation theory is unitary too. So, the information in this case is not lost. But we suppose, that it not correct. The process of the formation of a black hole and its subsequent evaporation happens on *all surface* of the anti-de-Sitter space (described by the conformal quantum theory). It includes as well the observer/environment. But the observer can not precisely know an initial state and can not analyze the system behavior because he is a part of this system! So his influence on the system can not be neglected. Thus, the experimental verification of the information paradox again becomes impossible!

Let's consider from the point of view of the entropy increase law such a paradoxical object of the general relativity theory, as a wormhole **[44].** We will consider Morris-Thorne wormhole **[45].** By a very simple procedure (we put one of the wormhole mouths on a spaceship, then the spaceship moves with relativistic_velocity over closed loop and returns the mouth to its initial place) the wormhole traversing space can be transformed into one traversing time. After this transform the wormhole can be used as a time machine, leading to the well-known paradox of a grandfather. How this paradox can be resolved?

For macroscopic wormholes the solution can be found by means of entropy increase law. The realization of this law is ensured by the instability of entropy decrease processes, resulting in time arrows synchronization.

Really, the wormhole traversing space does not lead to the paradox. If an object go into one mouth at some time moment then it go out from the other mouth after some later time moment. Thus the object travels from a initial high-order low entropy environment to the future low-order high entropy environment. During the trip along the wormhole the object entropy also increases. Thus, the directions of the time arrows of the object and the environment are the same. The same conclusions are correct for travelling from the past to the futre into a wormhole traversing time

However for travelling from the future to the past the directions of the time arrows of the object and the environment will be already opposite. Really, the object travels from the initial low-order high entropy environment to the future high-order low entropy environment. But its entropy increases and does not decrease! As we spoke earlier, such process is unstable and will be prevented or forcedly converted by a process of synchronization of the time arrows. It must happen at the moment that moving mouth of wormhole returns to its initial state.

"Free will" allows us to initiate only irreversible processes with the entropy increase, but not with its decrease. Thus, we can not send the object from the future to the past. Process of synchronization of the time arrows (and the correspondent entropy growth law) forbids the initial conditions which are necessary for the travelling of the macroscopic object to the past (and realization of conditions for the paradox of a grandfather).

In paper **[46]** it is demonstrated, that for the thermodynamic time arrow it is impossible to have identical orientation with the coordinate time arrow over closed timelike curve because of the entropy growth law. The described here process of synchronization of the time arrows (concerned with infinitely large instability and ambiguity of the entropy decrease processes) is that *physical mechanism* which actually ensures both this impossibility and realization of the entropy growth law over the same thermodynamic time arrow.

For microscopic wormholes a situation is absolutely different. If initial conditions are compatible to travelling to the past over a wormhole, there are no reasons which can prevent it. If some small (even infinitesimally small!) perturbation of initial conditions leads to an inconsistency with the wormhole existence, the wormhole can be always easily destroyed **[47].** Really, there appears the mentioned above property of the general relativity: infinitely large instability (ambiguity). It means that the infinitesimal perturbation of initial conditions can result in finite changing the final state during finite time!

However, it is not a solution of the grandfather paradox which is a macroscopic, not microscopic phenomenon. Really, suppose that there are two processes with opposite time arrow directions: a cosmonaut and the surrounding Universe. The cosmonaut travels over a wormhole from the Universe's future to the Universe's past. But for the eigen time arrow direction of the cosmonaut it will be travelling from its past in its future. For the general relativity theory the situation described above is impossible even in principle (in contrast with the classical mechanics): even infinitesimal interaction leads to synchronization of time arrow directions because of infinitely large instability (ambiguity) of processes with entropy decrease (in this case "process with entropy decrease" is the cosmonaut travelling from the future in the past). This synchronization of the time arrow directions can be accompanied both destroying the wormholes **[47],** and conservation of the wormhole and a modification of only initial conditions **[46].** But actually the entropy growth law (and the corresponding synchronization of time arrow directions) *does not allow even occurrence* of such situations with an inconsistency between macroscopic initial conditions and a initially defined (unchanging and invariable) macroscopical space-time topology (including a set of wormholes) **[46]** Let us formulate a final conclusion: *for macroscopic processes* the infinitely large instability (ambiguity) of processes with the entropy decrease (and the correspondent synchronization of time arrow directions) does impossible occurrence of initial conditions incompatible with existence of the given wormholes. This instability also prevents both wormholes destroying, and traveling macroscopic objects to the past (resulting in "the grandfather paradox") Let us conclude. We see a wonderful situation. The same reasons (which allowed us to resolve the reduction paradox, the Loshmidt and Poincare paradoxes) allow also resolve the information paradox of black holes and the grandfather paradox for wormholes. It is remarkable universality!

11. Ideal and Observable Dynamics

11.1 Definition of Ideal and Observable Dynamics. Why is Observable Dynamics necessary?

We see that the exact equations of quantum and classical mechanics describe **IDEAL** dynamics which is reversible and lead to Poincare's returns. On the other hand, the equations of physics describe **OBSERVABLE** dynamics, for example, of a hydrodynamic equation of viscous fluid, Boltzmann equation in thermodynamics, the law of growth of entropy in the isolated systems (***master equations***) - are nonreversible and are excluded by Poincare's returns to an initial state.

Let's give definition of Observable and Ideal Dynamics, and also explain necessity of introduction of Observable Dynamics. **Ideal Dynamics** is described by exact laws of quantum or classical mechanics. Why do we use the word "ideal" for our definition? Because really observed laws (entropy increase law and spontaneous reduction) contradict to Ideal Dynamics laws. This violation of Ideal Dynamics is explained or by interaction of measured systems with environment or/and an observer, or by limits of self-knowledge of the system obtained by introspection in case of both the external observer and the environment is included in the considered system. So real systems are either open or do not have full description, i.e. ideal dynamics is impossible.

Can we conclude that using physics laws is impossible in these cases? Absolutely no! The most of such systems can be described by equations of exact (or probability) dynamics, despite their non-isolation or incompleteness. We define this dynamics as **Observable Dynamics**. The most of the equations in physics named ***master equations*** (such as, for example, as hydrodynamic equations of viscous fluid, Boltzmann equation in thermodynamics, the law of growth of entropy for isolated systems) are the equations of Observable Dynamics.

In order to possess the property described above, Observable Dynamics should meet certain requirements. It cannot be operated with the full set **of microvariables**. In Observable Dynamics we use just much smaller number **of macrovariables** which are some functions of microvariables. So Observable Dynamics is much more stable with respect to initial condition errors and to external noise. Really, the microstate change does not lead inevitably to a macrostate change because one macrostate is correspondent to large set of microstates. For gas, for example, macrovariables are density, pressure, temperature and entropy. Microvariables are velocities and coordinates of all its molecules.

How can the Observable Dynamics be derived from the Ideal Dynamics? It is derived either by introduction in the Ideal Dynamics of small but finite external noise or by introduction of errors into initial state. These noise or initial state errors always exist in real experiments, but don’t occur in ideal models. What is the meaning of small but finite noise? Noise or errors should be large enough to prevent non-observed appearances (inverse processes with entropy decreasing or Poincare's returns). On the other hand, noise or initial state errors should be small enough to keep dynamics of macroparameters to be unchanged for processes with entropy growth.

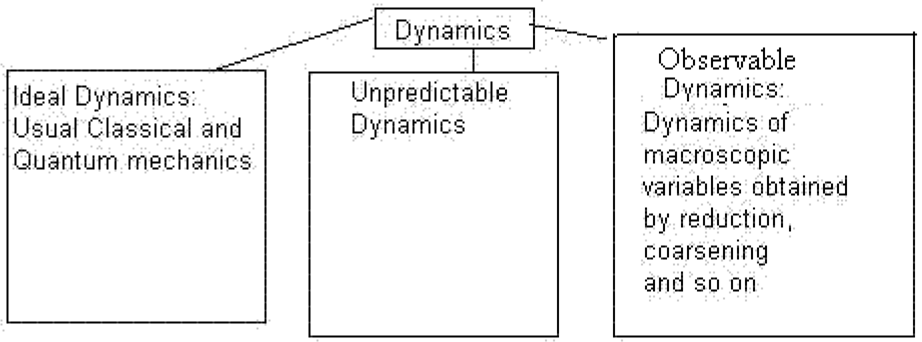

Figure 22. Three types of Dynamics.

Observable Dynamics for processes with entropy growth yields results coinciding with Ideal Dynamics. However, the inverse processes going with entropy decreasing and Poincare's returns are impossible in Observable Dynamics.

The possibility of introduction of Observable Dynamics is related to the above specified stability of the processes going with entropy growth with respect to initial conditions errors and to external noise. On the other hand, **the entropy decreasing processes**, and Poincare's returns **are unstable** even for small noise and small initial conditions errors. But these appearances also are not observed in real experiments.

What it is the reason of entropy growth processes stability in Observable Dynamics with respect to noise (under appropriate selection of macrovariables)? Two main reasons were defined by Schrodinger **[48].**

The first one has been already described above. Actually, macrostate is correspondent to enormous number of molecules states. Though external noise can strongly change a state of every single molecule the full contribution of all molecules to macrostate remains unchanged. It is related to “law of large numbers” in the probability theory **[16].** An example of correspondent law can be macroscopic fluid or gas motion laws.

The second reason is related to discretization of states in quantum mechanics. As different quantum states are discrete and have strongly different energy, small noise cannot change them. It is the reason for stability of a chemical bond and allows considering macromolecule thermodynamics.

What for is it necessary to use Observed Dynamics, instead of Ideal dynamics if the two yield to identical results in all important observational situations related to entropy growth? Because **Observable Dynamics description is much simpler than that of Ideal Dynamics.** Observable Dynamics throws away unobservable processes (like inverse processes with decrease of entropy or Poincare returns) out of consideration, uses smaller number of variables and simpler equations. Besides, it allows abstracting away from small external noise or incompleteness of initial condition of the system, allowing making description of the system exact or probable.

We know that the true theory is Ideal Dynamics. Observable Dynamics yields different results. Whether it is possible to discover experimentally this difference between these two theories, provided that Ideal Dynamics is really true? Theory can be considered as either correct or not correct just if some real experiment can reject the theory. Such theory is named **falsifiable** in sense of **Karl Popper [49].** Suppose that Ideal Dynamics is correct. Is Observable Dynamics falsifiable in the sense defined above?

For the complete physical system including the observer, observable system and a surrounding medium Observable Dynamics is not falsifiable in Popper's sense (under condition of *fidelity of Ideal Dynamics*). I.e. the difference between Ideal and Observable Dynamics in this case cannot be observed in experiment[10].

For the system being only measured, without inclusion of an observer and an environment, Observable Dynamics basically is falsifiable. For this purpose it is necessary to exclude any influence from the surrounding medium or observer of the measured system, to prepare some known initial state, to measure final one and then to compare the obtained result with the theory. There appears temptation to ask: May be some Observable, but not Ideal Dynamics is really true? **[1, 2, 8]** For example, suppose that the spontaneous reduction really occurs for macroscopic systems which are large enough. I.e., the spontaneous reduction is observed not just by introspection, but for the external observer at the full isolation of a macrosystem from environment noise too. However, in the case of isolated systems being not large, when Ideal Dynamics can be observationally checked, it always appears to be really true.[11]

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[10] *Nevertheless, it can be useful. Some calculation can be made easier in its framework. It can be simpler for understanding. For example, in the framework of Galileo related to the sun we can calculate planets dynamics much easier and much more precisely than in that of Ptolemy related to the Earth. Although, principally we may choose any one. Accordingly, the selection between «the Earth rotates around the Sun» and «the Sun rotates around the Earth» remains free and arbitrary. It is defined only by beauty of description and our convenience.*

Similarly, in mathematical science the selection of some definitions and axioms is bounded only by our convenience and the requirement of axioms consistency. The theory explaining how to make selection is absent (unlike Göde's theorem of incompleteness). Usually, arguments of "beauty" and theorems "generality" are used to explain some choice. However, these things need more exact definitions. ***[50]***

[11] *Such experiments do exist and are performed for systems of the intermediate size between macro and micro, so-called mesoscopic systems. All these experiments confirm Ideal, not Observable Dynamics. In these*

However, for macroscopic systems exclusion of any perturbation from surrounding medium or observer on measured system is a very difficult problem, so **practical unfalsifiability** of Observable Dynamics exists. I.e. theoretically it is possible to reject it, but in real experiment it is very difficult to make it.

Let's make here very important note. Some cases are possible when Observable Dynamics can not be formulated correctly. So the system stays unpredictable because of non-isolation or initial state incompleteness. It is the case of the **Unpredictable Dynamics** examined in the following chapter.

11.2 What is the selection of Observable Dynamics macroscopic variables restricted by?

It is of great importance that **the selection of macroparameters cannot be arbitrary**. Observable Dynamics should lead to entropy increasing law and irreversibility. For correct macrovariables definition entropy increasing processes should be stable and equivalent both for Ideal and for Observable Dynamics. On the contrary, the entropy decreasing processes should be unstable in Ideal Dynamics and impossible in Observable Dynamics. This requirement superimposes serious restrictions on selection of possible macroscopic states. So in classical statistical mechanics set of microstates, corresponding to some macrostate, look like a compact, convex drop in phase space.

This macrostate and its entropy increasing dynamics are stable with respect to small external noise. Let's consider set of the phase space points corresponding to the spreaded phase drop with set of narrow branches ("sleeves") and reverse velocities of all molecules. Such ensemble can not be correspondent to any macrostate, although the ensemble is corresponding to initial states of processes with entropy decrease. The impossibility of the correspondent macrostate is explained by instability of such set with respect to small noise. By the same reason it is impossible to select microparameters, i.e. velocities and co-ordinates of all molecules, for system decryption (even as some limiting case). In chaotic system such microstate is strongly unstable. Certainly, additional reason is also the enormous number of such parameters.

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experiments the quantum interference is observed (in the absence of a spontaneous reduction) and there are entropy fluctuations ***. [3, 8].***

However, for really large macroscopic systems similar experiments will not be possible in the foreseeable future. In the fundamental physics the similar situation exists for String Theories and Great Unifications. Experiment which can confirm or reject them will not be possible in the foreseeable future except for some unexpected miracle. But in the Einstein theory of gravitation which is checked up precisely only for not too large gravitation forces, the situation is similar. (We will remind here, for example, mysterious dark substance and energy, and also new gravitation theories of Milgrom ***[51]*** *and Logunov* ***[52-53]****).*

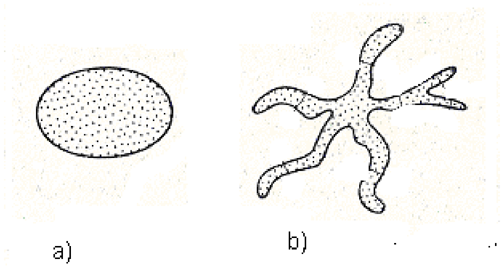

Figure 23. Possible a) and impossible b) distributions for macrostate.

Similarly, in QM there is a problem: for example, why for the basic macrostates of the Schrodinger cat do we choose two basic states defined by live or dead cat, but not two basic stats defined by their difference and the sum **[54]**? From point of view of QM it is also possible. The reason in that an alive or dead cat is stable with respect to environment perturbations. Contrarily, their sum or difference are entangled with an environment and transfer in a mixture of an alive and dead cat during very short time. We named this process as decoherence previously. It finishes much faster than all other thermodynamic relaxational processes **[20, 23-25].** I.e. selection of two states to be exactly the alive or dead cat is dictated by necessity of stability to external noise.

Which property of the Ideal Dynamics equations leads to a priority of such states? This property is **locality of interaction**. Only molecules close in space are strongly interacting. Really, states of live and dead cat are strongly separated in space. So their superposition (sum or difference) is easily reduced to their mixture by interaction with surround medium molecules. **Definition of such priority macroscopic states (named *pointer states*) in case of a quantum mechanics is featured in Zurek papers [21, 22].** Suppose that interaction between molecules would be defined not by closeness of molecules positions but by closeness of its momentums, for example. So in this case the priority macroscopic states (pointer states) would be absolutely different.

For system closed to thermodynamic equilibrium priority macroscopic states (pointer states) correspond to energy eigenfunctions. In energy representation at thermodynamic equilibrium a density matrix is diagonal.

Let's mention here that the selection, both macrovariables set and correspondent Observable Dynamics equations, is ambiguous. There is a large set of possible Observable Dynamicses. As a matter of fact, all thermodynamics **master equations** (for example, hydrodynamic equations of viscous fluid, Boltzmann equation in thermodynamics, the entropy growth law in the isolated systems) are Observable Dynamics equations. Various Observed Dynamics differ by their degree of «macroscopicity», and by choice of a proper macrovariables set.

Let consider an ensemble which is in equilibrium with a thermostat. in QM such ensemble is represented by energy representation of density matrix. Its nondiagonal elements, corresponding to correlations, are zero. Similarly, in the CM, in equilibrium no correlations between the molecules exist. Two kinds of nonequilibrium exist. The first one is defined by macroscopic correlations of macroparameters. They are expressed in QM by diagonal elements, with the values different from equilibrium, for density matrix in energy representation. These correlations disappear during process named as **relaxation** to equilibrium state. The second one defined by microscopic correlations (It is quantum correlations in QM or additional unstable correlations in CM). Quantum correlations correspond to nonzero nondiagonal elements of density matrix in energy representation. These microscopic correlations are much more unstable and much faster damp than macroscopic ones. Process of their vanishing is named above as decoherence. Decoherence time is much less than relaxation time.

11.3 Two main methods for Observable Dynamics (Master equations) deriving.

Let's consider methods of Observable Dynamics deriving. According to two principal causes leading to necessity of Observable Dynamics application (i.e. external noise for external observer or incompleteness of system state knowledge for introspection), we can divide all methods of deriving of Observable Dynamics into two groups.

The first method is related to introduction of small uncontrollable noise from an external large thermostat (for example, the vacuum is thermostat with zero temperature). **[20]** This noise destroys the additional microscopic correlations leading to returns and reversibility.

The second method is related to incompleteness of full system state knowledge for introspection. It allows implementing coarsening ("spreading") of the function featuring system states **[6, 13]** (**Appendix K**). For CM such function is the phase density function, for QM it is a density matrix. If we consider CM case coarsening is flattening (averaging) phase density function in a neighborhood of each point over some time period. Between flattening evolution is featured by the usual equations of Ideal Dynamics. For QM similar procedure is related to a periodic reduction of a wave function **[18]** and Schrodinger equations uses between reductions. Similar methods of coarsening destroy the additional correlations leading to returns and convertibility. As we already above scored above, these correlations experimentally are not observed for an introspection case.

Observable dynamics (at introspection) should feature behavior of the system (with entropy growth) and should produce results coinciding with Ideal Dynamics, just during some finite time interval. This time is much smaller than Poincare return time. Indeed, the system cannot be observed experimentally during larger time interval because of observer memory erasing at returns.

11.4 Solution of Zeno paradox from the point of view of Observable Dynamics. Exponential particle decay is a law of Observed instead of Ideal Dynamics.

Due to necessity of Observable Dynamics concept, we can remind the above mentioned quantum **Zeno paradox**. Here we give solution of the second part of this paradox (about non-exponential decay) within framework of Observable Dynamics.

Let choose a number of undecayed particles N (with a small possible error) which is the measured macroparameter. During the initial moment t_0 there were N_0 undecayed particles. Ideal quantum dynamics of the further decay is not exponential. But quantum measuring of decay inevitably imports perturbations to Ideal dynamics, doing its inapplicable. We can reduce perturbations imported by measuring, by increasing intervals between measurings. The time interval between measurings (reductions) on the one hand should be large enough in order not to influence essentially dynamics of decay. (**$\Delta t >> \hbar / \Delta E$** where Δt - between reductions, ħ a-constant lath, ΔE - an difference of energies between states the broken up and not broken up particles) On the other hand, the time interval must be less than an average lifetime of the decayed particle. (**$\hbar / \Delta E << \Delta t < \tau$**, where τ - a medial lifetime of decayed particle). The full time of decay process observation should be much less than Poincare's return time. Indeed, for isolated finite volume systems, including the observer, such returns are not observed because of observer memory erasing. (**$n \cdot \Delta t << T_{return}$** where n - number of observations [reductions], T_{return} - Poincare's return time) Suppose that time interval between measurings and full time of observation are chosen correctly, i.e. satisfy all these requirements. For such case the law of decay is already strictly exponential and does not depend on concrete exact value of the chosen time interval between measurings (reductions). This **exponential law of decay ($N=N_0 \cdot \exp(-(t-t_0) / \tau)$) is already the law of Observable, but not Ideal dynamics**, according to the Observable Dynamics definition.

11.5 Examples of various methods of deriving Observed Dynamics by help of «coarsening»: Boltzmann equation and Prigogine's New Dynamics.

An example of Observable Dynamics is **Boltzmann equation [5, 6].** Coarsening ("spreading") of phase density function (**Appendix K**) is produced over two stages. Over the first one, the phase density function is replaced by one particle function. It corresponds to the phase density function averaging over all particles except for one. The equation for a one-particle function is a reversible equation of Ideal Dynamics and depends on a two-particle function. The equation of Observable Dynamics is obtained by the next coarsening step. «Molecular chaos hypothesis» is introduced. It means that correlations between any two particles assume to be zero, so two-partial function is replaced by the product of two one-particle functions. Substituting such two-partial function in the equation described above we come to nonreversible and non-linear Boltzmann equation. It is very similar to QM reduction, when all correlations between possible measuring results (that is to say, nondiagonal density matrix elements) are forced to be zero.

As one more example of Observable dynamics deriving is a coarsening method used in Prigogine's «**New Dynamics» [14, 55], (Appendix L).** It is a very wonderful method. Both coarsening ("spreading") procedure and equations of motion (obtained by simple substitution of inverse to coarsened function in the equations of Ideal Dynamics) are linear. In CM non-isotropic coarsening of phase density function is used. As described above, for chaotic systems in a neighborhood of each phase space point there is such direction that trajectories diverge exponentially along (**a spreading direction**). Also there is a direction that trajectories converge exponentially along (**a shrinking direction**). Just along shrinking direction coarsening ("spreading") of phase function is yielded.

Let's consider a macroscopic state corresponding to some compact, convex «phase drop». This «phase drop», spreading on a phase space, gives many "branches". The shrinking direction is perpendicular to these "branches". Therefore function coarsening along them leads to increasing «phase drop» square, and, correspondingly, to increasing of microstates number and entropy.

Now we will consider an inverse process. The initial state is described by set of phase space points gotten from final state of direct process («phase drop» spreading) by reversion of all molecules velocities. Velocities reversion does not change the spreaded «phase drop» shape. Shrinking direction becomes not perpendicular but parallel to its "branches". Therefore, for this case coarsening along **spreading** direction almost does not change «phase drop» square. Accordingly, the number of microstates and entropy also do not vary almost in contrast with magnification of entropy spread «a phase drop» at direct process.

Thus, **non-isotropic coarsening breaks time direction symmetry.** Consequently, the correspondent equations appear nonreversible.

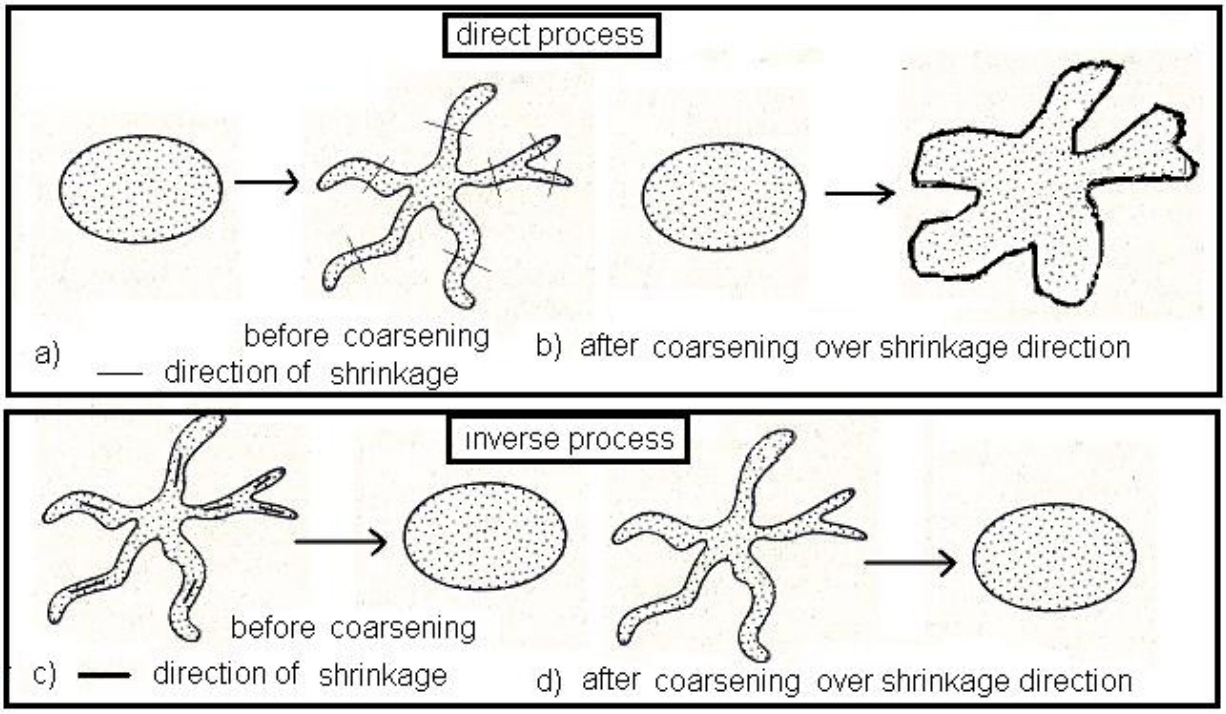

Figure 24. Direct process with macroscopic entropy increasing before coarsening **a)** and after coarsening **b).** Inverse process before coarsening **c)** and after coarsening **d).** Direction of shrinkage are denoted. Anisotropic coarsening is produced along direction of shrinkage in Prigogine "New Dynamics".

Let's consider «New Dynamics» for quantum systems. Similar linear non-isotropic coarsening procedure can be yielded also in QM case, but only for infinitely large quantum systems (the infinite volume or the infinite number of particles). Finite quantum systems with a finite number of particles are almost-periodic, and have a finite return time. For such cases «New Dynamics» is not applicable[12].

Prigogine suggests considering all real quantum systems as infinitely large. The solution, however, can be much easier. Observable Dynamics has sense just during time much less than return time. System cannot be observed experimentally during large time interval because of memory erasing at returns during introspection. But for small time intervals, large volume systems behaviors in a thermodynamic limit are very similar to infinite systems behavior. The thermodynamic limit is a limit when system volume moves to infinity, but the ratio of particles number to full system volume remains constant. If we have a system, for which the thermodynamic limit does not exist at all (for example, the macromolecule) it can be considered as surrounded by environment for which such limit does exist. All these methods allow us to use the equations of "New Dynamics" also for finite QM systems.

«New Dynamics» is often subjected to criticism **[34].** The basic argument against this theory is the following. "We can explain all paradoxes and problems of QM/CM without this «New Dynamics»". It is really true, and we indeed have done it in this paper. So, these critics conclude, «New Dynamics» is not necessary and redundant! But we must consider «New Dynamics» not as replacement of QM/CM (that, unfortunately, Prigogine really did), but just as one of the *useful and simple form* of its Observable Dynamics. It allows us to describe physical systems by *simpler and irreversible* laws, excepting unobservable experimentally reversibility and returns. It is its real and big advantage.

Let's consider now a situation when it is not possible to find any Observable Dynamics. This case was defined above as Unpredictable Dynamics.

12. Unpredictable Dynamics

It is not always when Ideal Dynamics, broken by exterior noise (or by incompleteness at introspection), can be replaced by predictable Observable Dynamics. For some systems its dynamics becomes unpredictable in principle. So we define dynamics of such system as **Unpredictable Dynamics**. As follows from the definition, for such systems it is impossible to introduce macroparameters typical of Observable Dynamics and to predict their behavior. Their dynamics is not featured and not predicted by scientific methods. Thus, **the science itself puts boundaries of its applicability.**

We do not doubt about fidelity and universality of basic laws of physics. But the impossibility of full knowledge of (system states)/(system dynamics laws) exists, because of interaction with the observer/environment or incompleteness at introspection. It makes impossible full experimental verification of these basic physical laws in some cases. It gives us some freedom to change these laws, without any inconsistency with experiment. When these modifications lead to predicted dynamics of system it is named as Observable Dynamics. For the other case when any predicted dynamics is not possible, it is already named as Unpredictable Dynamics.

Let's give some examples of Unpredictable Dynamics.

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[12] *Also New Dynamics is not applicable to almost-periodic systems of CM. However, the most of real CM systems is systems with intermixing (chaotic). Therefore for CM this problem is less important.*

1) Phase transition or bifurcation points. It is a place or *point* of branching or forking of a single macroscopic state, featured by Observable Dynamics, into some set of possible macroscopic states. This branching occurs by changing some regulated external parameter or by time evolution. In these points Observable Dynamics loses the unambiguity. There are huge macroscopic fluctuations and using macroparameters becomes senseless. Evolution also becomes unpredictable in these points, i.e. there is Unpredictable Dynamics.

2) In the modern cosmological models there are additional appearances, except for appearances already featured above. They are related to losses of the information and correspondent incompleteness of system state knowledge. It is Black Hole or unobservable Universe space existing out of observer light cone.

3) Case of uncontrollable unstable microscopic **quantum correlations for system isolated from decoherence** of environment. Suppose that some observer fixes the initial state of quantum system. He can predict and measure any future system state providing no interaction between observed system and environment or observer exists before this measurement. Let us consider another external observer who doesn't know the initial system state. Unlike for the first observer, system behavior is unpredictable for him principally. Really, any attempt of the second observer to measure system state unpredictably destroys system quantum correlations and correspondent evolution. I.e. from the point of view of the second observer there is Unpredictable Dynamics. Well-known examples of such systems are **quantum computers** and **quantum cryptographic transmitting systems [23-25]**.

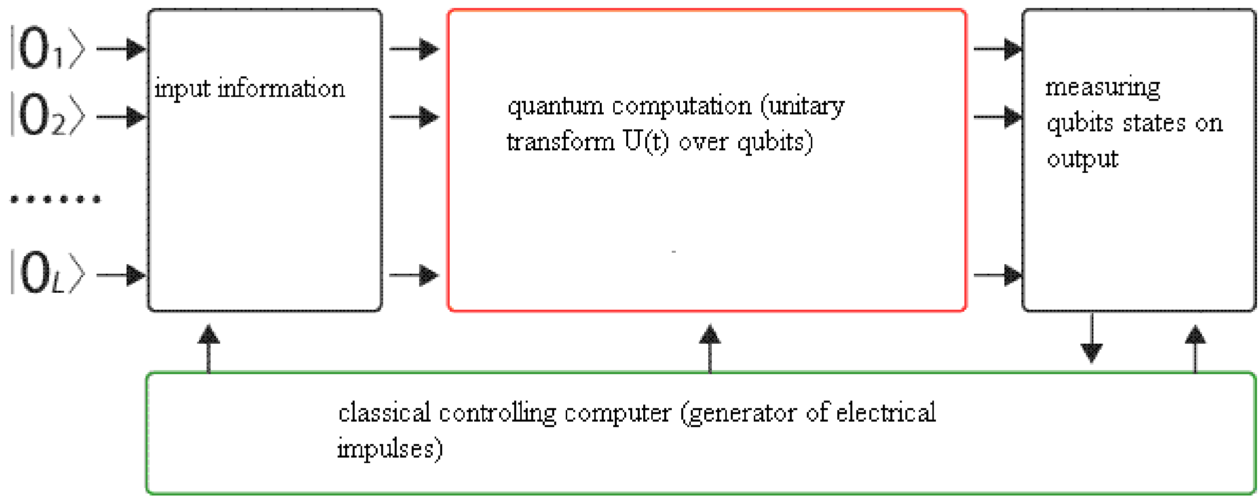

Figure 25. Quantum computer.

Quantum computer is unpredictable for any observer who does not know its state in the beginning of calculations. Any attempt of such observer to measure intermediate state of quantum computer during calculation destroys calculation process in unpredictable way. Its other important property is high parallelism of calculation. It is a consequence of QM laws linearity. Initial state can be chosen as the sum of many possible initial states of "quantum bits of the information". Because of QM laws linearity all components of this sum can evolve in independent way. This parallelism allows solving very quickly many important problems which usual computer can not solves over real time. It gives rise to large hopefulness about future practical use of quantum computers.

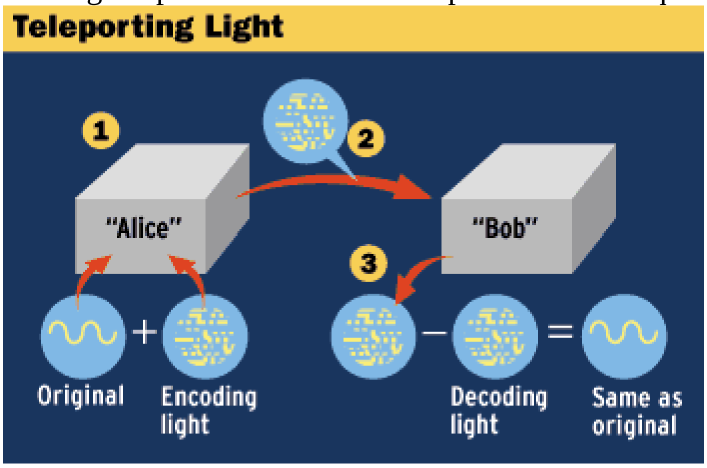

Figure 26. Quantum encoding and decoding. (Fig. from [102])

Quantum cryptographic transmitting systems use property of the unpredictability and unobservability of "messages" that can not be read during transmitting by any external observer. Really, these "messages" are usual quantum systems featured by quantum laws and quantum correlations. An external observer which has no information about its initial states and try make measuring (reading) of "message" over transmission inevitably destroy this transmission. Thus, message interception appears *principally* impossible under physics laws.

It should be emphasized, contrary to the widespread opinion, that both quantum computers and quantum cryptography **[23-25]** have classical analogues. Really, in classical systems, unlike in quantum systems measuring can be made precisely in principle without any measured state distorting. However, in classical chaotic systems as well there are the uncontrollable and unstable microscopic **additional correlations** resulting in reversibility and Poincare's returns. Introducing "by hands" some small finite perturbation or initial state errors destroys these correlations and erases this principal difference between classical and quantum system behavior. Such small external noise from environment always exists in any real system. By isolation of chaotic classical systems from this external noise we obtain **classical analogues of isolated quantum devices with quantum correlations [86-87].**

Analogues of quantum computers are the **molecular computers [56, 86-87]**. The huge number of molecules ensures parallelism of evaluations. The unstable microscopic additional correlations (resulting in reversibility and returns) ensure dynamics of intermediate states to be unpredictable for the external observer which is not informed about the computer initial state. He would destroy computer calculation during attempt to measure some intermediate state.   .

Similar arguments can be used for **classical cryptographic transmitting systems** using these classical unstable microscopic additional correlations for information transition. "Message" is some classical system that is chaotic in intermediate states. So any attempt to intercept it inevitably destroys it similarly to QM case.

4) Conservation of unstable microscopic correlations can be ensured not only by passive isolation from an environment and the observer but also by active dynamic mechanism of perturbations cancelling. It happens in so-called physical **stationary systems** in which steady state is supported by continuous **stream of energy or substance through system**. An example is a micromaser **[57]** – a small and well conducting cavity with electromagnetic radiation inside. The size of a cavity is so small that radiation is necessary to consider with the help of QM. Radiation damps because of interaction with conducting cavity walls. This system is well featured by density matrix in base energy eigenfunction. This eigenfunctions are Zurek's "pointer states" (similarly to any system of closed to equilibrium). Such set is the best choose for Observable Dynamics. Microscopic correlations correspond to nondiagonal elements of the density matrix. Nondiagonal elements converge to zero much faster than diagonal ones during radiation damping. In other words, decoherence time is much less than relaxation time. However, beam of excited particles, passing through a micromaser, leads to the strong damping deceleration of density matrix nondiagonal elements (microcorrelations). It also leads to non-zero radiation in steady state.

5) An example of very complex stationary systems is alive systems. Their states are very far from thermodynamic equilibrium and extremely complex. These systems are high ordered but their order is strongly different from an order of lifeless periodical crystal. Low entropy disequilibrium of the live is supported by entropy growth in environment[13]. It is metabolism - the continuous stream of substance and energy through a live organism. On the other hand, not only metabolism supports disequilibrium, this disequilibrium is himself catalytic agent of metabolic process, i.e. creates and supports it at necessary level. As the state of live systems is strongly nonequilibrium, it can support existing unstable microcorrelations, disturbing to decoherence. These correlations can be both between parts of live system, and between different live systems (or live systems with lifeless system). If it happens dynamics of live system can be referred to as Unpredictable Dynamics. Huge successes of the molecular biology allow describing very well dynamics of live systems. But there are no proof that we capable to feature completely all very complex processes in live system.

It is very difficult to analyze real live systems within framework of Ideal, Observed and Unpredictable Dynamics because of their huge complexity. But it is possible to construct mathematical models of much less difficult nonequilibrium stationary systems with a metabolism. We can really analyze such systems. This is important problem for the further job of physicists and mathematicians. Some steps to this direction are described below in chapter about synergetic systems.

Let us do some important remark. Unstable microcorrelations exist not only in quantum, but also in classical mechanics. For example, they exist in classical chaotic systems (with intermixing). Hence, such models should not be only quantum. They can be classical too! It is very frequent error supposing only the quantum mechanics can feature similar appearances **[1, 2]**. Above we specified already many times that introduction "by hands" of small but finite interaction or initial state errors erase unstable microcorrelations. Hence, principal difference between quantum and classical mechanics disappears.

6) The cases featured above do not describe all possible types of Unpredictable Dynamics. The exact requirements at which Ideal Dynamics transfers into Observable and Unpredictable Dynamics is the problem which is not solved completely yet by mathematics and physics. Another problem which is

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[13] *So, for example, entropy of epy Sun grows. It is an energy source for life on the Earth.*

not solved completely yet (and, apparently, related to the previous problem) is the important role of these three types of Dynamics in complex (live) systems. The solution of this problem will allow understanding more deeply the physical principles underlying the life. We will devote the following chapter to this problem.

13. Complex (live) systems.

Let's mention here that while the previous statements were strict and exact, statements in the current chapter are more hypothetical. Let's assume in this chapter that the life completely corresponds to laws of physics. The following problems should be considered below:

What is the life and death from the point of view of physics?

Are there some live organism properties that are not compatible to physics?

What are properties of live systems different from lifeless systems from the point of view of physics?

When live systems have consciousness and free will from the point of view of physics?

The life is defined, usually, as special high ordered form of organic molecules existence, possessing ability to metabolism, reproduction, adaptation, motion, and response for external irritants, ability to self-preservation or even to rise of self-organizing. This is a true but too narrow definition: many of live systems possess only a part from these properties, some of these properties also exist in lifeless substance, and inorganic form of life can exist too.

13.1 Life from the point of view of physics - the previous papers.

The first attempt to describe the life from the point of view of physics has given by Schrodinger **[48]**. In this book life has defined as an aperiodic crystal, i.e. the high ordered[14] form of substance but not based on simple repetition as normal crystals are. It also has given two reasons doing Observable Dynamics of live systems stable to interior and exterior noise: the statistical "law of large numbers" and the step-type behavior of quantum transitions ensuring a stability of chemical bonds. It has marked similarity of live organism and clock: for both cases there is «an order from the order» despite high temperature noise.

The following step to understanding of life was made by Bohr **[58].** He paid attention at the fact that according to QM full measuring of live system state inevitably perturbs its behavior. It results in unpredictability and incognizable character of life. The criticism of these sights of Bohr by Schrodinger **[59]** is not well-grounded. He writes that the full knowledge of quantum system state is probabilistic. So (unlike a classical case) the full quantum system state knowledge allows to predict the future just probably. The problem, however, consists in the fact that measuring creates *stronger* ambiguity than

[14] It means - possessing low entropy. The live system "eats" negoentropy from its environment. Thus, it is an essentially open system.

the probabilistic character defined by QM. I.e. it is impossible to predict its behavior even probably! In absence of measuring the behavior would be different, than at its presence **[41].** Measuring erases unstable classic (or quantum) correlations between system parts, changing its behavior. Thus, measuring makes behavior of system to be principally unpredictable, and not just probabilistic. It happens not just in QM, but also in CM where between real systems there is a small finite interaction destroying unstable additional microcorrelations.

In Bauer's[15] book **[60]** it was marked that high ordering (low entropy) are defined not only by nonequilibrium distribution of material in live organism but also by high-ordered (strongly unstable) structure of a live substance. This strongly unstable structure is not only supported by metabolism process but also it is catalytic agent for this metabolism. Seemingly, proteins or viruses have ordered structure also in the crystalline form. However, in a live substance it is possible to meet their much more high-ordered and low-entropy modifications. Eventually, nevertheless, there is degradation of structure in time. It leads to inevitability of death and necessity of reproduction for the conservation of life phenomena. I.e. metabolism process only very strongly decelerates decay of the complex live substance structure, instead of supporting them to be unchanged. The experiments described by Bauer confirm energy production and respective entropy increasing in autolysis. Autolysis is decay of a live substance because of lack of supporting metabolism. At the first stage of process energy is produced because of destruction of strongly unstable initial structure of live substance, and at the second stage of process - because of action of appearing or releasing protolytic (decomposing) enzymes. Bauer considered existence of this overmuch *structural* energy as an essential feature of life.

Most of the above-mentioned papers considered only individual live organisms, whereas in fact it is possible to define and describe life as the totality of the live organisms (biosphere). Here the issue of the origins of life arises. The most complete answer to these questions from the point of view of modern physics is given in the paper of Elitzur **[38].** The origin of life in this paper is considered as an ensemble of self-replicating molecules. Coming through the sieve of Darwinian natural selection, life accumulates the genetic information (or rather *useful* information (knowledge), in terms suggested by Elitzur) about the environment. This increases the level of the system's organization (negentropy) in agreement with the second law of thermodynamics. Lamarck's views in their too straightforward formulation were shown to contradict this law of physics. A wide range of issues is discussed in this paper. However, it has also the following drawbacks:

The description is true for life as a whole, i.e. as a phenomenon, but not so for an individual live organism.

The suggested reasoning disproves just the most simple and straightforward version of Lamarck's theory, whereas there is a number of hypotheses and experiments illustrating the possibility of realization of Lamarck's views in real life **[61].**

In Elitsur's view, the self-organizing dissipating systems suggested by Prigogine (e.g., Benard cells **[62]**), in contrast to the live organisms, are denied the adaptation capability. Naturally, the adaptability of Benard cells is incomparable with that of live systems, but still they do exist, even if in a very primitive form. Thus, Benard cells change their geometry or even disappear depending on the

[15] Bauer is a talented Soviet biophysicist who tragically perished in Stalin's prisons. He was considerably ahead of time.

temperature difference between the upper and lower layers of the fluid. This can be well considered a primitive form of adaptation.

13.2 Life as process of preventing relaxation and decoherence. Conservation of both macroscopic correlations and unstable classical (or quantum) microscopic correlations.

Bauer determines life as a highly unstable system of self-maintaining due to motion and metabolism. Live systems resist to transition from an unstable state to a more stable one. We can suppose that this instability is mostly due to strongly unstable (additional in CM or quantum in QM) microscopic correlations. Live systems tend to maintain these correlations and preserve them resisting to decoherence process. It must be mentioned that live systems can support such correlations both between their internal parts and with an environment.

Let's remind that we define two types of correlations in physical systems, the first one being stable to small external noise macroscopic correlations between system parameters. For example, it is connection between pressure, density and temperature for ideal gas. The second type is unstable microscopic correlations which lead to reversibility and Poincare's returns, both in quantum and in classical systems. Decoherence destroys these correlations, breaking reversibility and preventing returns. It leads to entropy increasing law. We assume that live systems possess ability to conserve these unstable correlations, slowing down or preventing decoherence.

Let's compare live and lifeless systems property to inhibit destroying and transformation to thermodynamic equilibrium. Systems can actively inhibit to relaxation process. Indeed, it is a case of live or lifeless stationary systems exchanging energy or substance with an environment. However, the system can inhibit not just to relaxation but also to decoherence. In lifeless systems it can be achieved by passive way, i.e. by isolation of the system from an environment. In live open systems it is reached by active interaction with environment, by external and internal motion, by metabolism.

Ability of life to support not only macroscopic but additional classic (or quantum) microscopic correlations makes life to be unpredictable, as it was assumed by Bohr. It is important that quantum mechanics is not necessary here; similar correlations exist also in classical mechanics. Analogue of quantum correlations are additional microscopic correlations in CM.

Successes of the molecular genetics do not contradict to influence of unstable and unpredictable correlations which may be essential for life. It is possible to create some type of Observable Dynamics for life. Really, live systems are open systems actively interacting with a casual environment. The exterior observer interacts with them usually much less and cannot change in their behavior considerably. However, an attempt to understand and to predict life too explicitly and in details can break the complex and thin correlations conserved by life. It can lead to Unpredictable Dynamics of live systems, resulting in effect predicted by Bohr.

13.3 Synergetic systems - models of physical properties of complex (living) systems.

Let's introduce concept of synergetic physical systems. We will define them as simple physical or mathematical systems illustrating some properties of complex (live) systems. First of all, we are interested in synergetic models of systems, capable to inhibit external noise (decoherence in QM). They conserve system correlations (quantum or classical), leading in reversibility or Poincare's to returns.

There are three methods to construct such systems:

1) The Passive method: it is creation of some "walls" impenetrable for noise. Examples are models of modern quantum computers.

2) The Active method, inverse to passive one: it is some kind of dissipative or live systems, conserving disequilibrium with the help of active interaction environment and also interchanging by energy and substance with environment (metabolism). It seems that the future models of quantum computers should be found in this field.

3) When correlations are considered for system including the whole Universe. The external noise is impossible here. Source of correlations for such system is Big Bang. We will define these correlations, correspondent to whole Universe, as **global correlations**.

Two factors ought to be noted here:

1) Many complex systems during their evolution pass dynamic bifurcation points (time moments). There is a set of possible future evolution ways after this moment of time but not just a single one. Selection of one of them depends on small perturbation of system state in bifurcation time moment **[63-65].** In this moment even very small correlations (which can be conserved with the help of methods, describe above) can make enormous influence on evolution of the system. Existence of such correlations restricts predictive capability of physical science but does not restrict our personal intuition. Nevertheless, since we are integral part of this Universe we can really be capable to "anticipate" these correlations at some subjective level in principle. Whereas these correlations are impossible for experimental scientific observation, no contradiction with scientific laws exists here.

2) Very powerful sources of negoentropy from an environment are necessary for both passive and active correlations conservation methods. Therefore full entropy of system and its environment can only increase. The entropy increasing law continues to be correct for full system including observable system, environment and observer, though it is not correct for observable system only. Entropy reduction in full system can happen in principle (in according with Ideal dynamics), but it is unobservable, as explained above. So we need not consider such unobservable situations.

Let's demonstrate some examples of synergetic models for physical processes.

So, crystals growth models ability of live systems reproduction. By the way, the analysis of these systems allows discovering a doubtful place **[66-67]** in Wigner's argumentation **[27]** about inconsistency between life organism reproduction ability and QM. Let's assume that interaction between reproducing **quantum** system and its environment **is random**. For such interaction Wigner really proves that reproduction probability is close to zero. However, actually this interaction is not casual but defined by a crystalline lattice of already existing crystal. In live organisms for protein synthesis process there crystalline lattice is replaced by existing DNA nucleotide sequence, so the interaction is not random too.

The active deceleration of decoherence, similar to active correlations conservation methods in live systems, exists in open systems like micromasers already described above **[57]**. They are a one more example of synergetic systems.

One more active mechanism of decoherence inhibition is so-called «**quantum teleportation**» **[24].** This process can reproduce the exact copy of any initial quantum state accompanied by destroying of this initial state. (To create copy of any quantum state accompanied by conservation of this state is impossible in QM **[24]**.) We can reproduce this copying over and over again with small time intervals. It is possible to conserve any initial quantum system state for a long time with the help of such a process inhibiting decoherence. This process is equivalent to conservation of the initial measured state in the described above paradox «kettle which never will begin to boil». It is observed at multiple and frequent measuring of a current state. But there exists difference between these two cases too. For «quantum teleportation» case the initial state remains not just unchanged like "kettle paradox" case but also unknown.

Dissipative systems are active synergetic systems too. They illustrate properties of open live systems to relaxation deceleration, conservation of low entropy and primitive form of adaptation to surrounding medium change.

The other example is the quantum isolated systems (for example, the modern quantum computers at low temperatures). They demonstrate the property to conserve unstable quantum correlations. It is similar to conservation of the strong instability in the live systems, related also to conservation of similar quantum or classical correlations. However, unlike live systems, this conservation is passive. Penrose gives example of such systems, probably used by a brain for thinking **[1, 2].** It is system of tubulin dimers serving as a basis for cytoskeleton microtubules of neurons (main cells of brain). The system of tubulin dimers is considered by Penrose as some quantum computer **[23-25].** Even if this hypothetical model is not true it would illustrate **principal possibility** of quantum correlations existence in brain. Analogue of quantum correlations in CM are additional unstable microcorrelations, and analogue of the quantum computer is the molecular computer with these additional correlations between molecules. Similar correlations appear in chaotic or almost chaotic classical systems (with intermixing). Probably it is possible to construct model of brain also on the basis of such classical (not quantum) chaotic systems. Thus they would have all properties of quantum computers - unpredictability, parallelism of calculations. Since Penrose wrongly considers classical chaotic systems as unsuitable for modeling of live systems, so he even does not consider such possibility.

Other example of synergetic systems illustrating properties of quantum correlations are the quantum oscillating systems almost isolated from an environment **[8].** Let suppose there is some superconducting ring. State "A" corresponds to clockwise current, and a state "B" counter-clockwise one. Then this oscillating quantum almost isolated system can change its states by following: A -> A+B -> B -> A-B -> A. Here "A+B" and "A-B" are quantum superposition of states A and B. Suppose we would like to measure current directions in the ring. Such measuring can destroy superposition state if system would exist in such state at the moment of measuring. Thus, it can change dynamics of system and destroy quantum correlations between states of superposition **[8].**

It is possible to construct another example of oscillation system sensitive to measuring, which may be interesting for biologists and chemists. It will have actively protection from external noise influence. Let we have a process consisting of three stages. At the first stage there appears enzyme with unstable conformation "A". At the second stage it catalyzes some chemical process. In turn, this process inhibits destroying of unstable conformation A. Let us consider more complex situation. Let suppose there are two unstable conformations "A" and "B" which are capable to catalyze process at the second stage. Enzyme has no fixed conformation "A" , but sequential set of unstable transitions from A to B, from B to A, and so forth. At third stage enzyme goes to the third chemical reaction. If at its initial moment enzyme was in conformation A it indeed would catalyze this reaction. Otherwise, no catalysis appears. Thus the third stage depends on finite enzyme conformation state at the end of the second stage. Let during the second stage (at some time moment) we decided to measure enzyme conformation state (by nuclear magnetic resonance, for example). As transition process from A to B (or B to A) is unstable, measuring can break phase of this process. As result, at third stage beginning enzyme can come at conformation B instead of A. Thus, the third stage reaction can not begin. So measuring intermediate enzyme state can destroy process, changing its result products. It can be true, both for quantum, and for the classical mechanics types of process.

With the help of synergetic “toy” models it is possible to understand synchronicity (simultaneity) not coupled casually processes and global correlations phenomena.

Example are nonstationary systems with "peaking" (blow up) **[63-65]** considered by Kurdyumov's school. In these processes some function is defined on plane. Its dynamics is featured by the non-linear equations, similar to the burning equation. Blowing up solution function can converge to infinity for *finite* time in single or several closed points on plane. It is interesting that function comes to infinity in all these points at the same moment of time, i.e. synchronously.

By means of such models we can illustrate population growth (or engineering level of civilizations) in megacities of our planet **[68].** Points of the infinity growth are megacities, and population density is a function value.

Let's complicate the problem. Suppose that during some initial time moment there is very fast expansion ("inflation") of the plane with blowing up process. Nevertheless, processes of converging to infinity in points set remain synchronous despite that these points already are not closed and lie at huge distance.

This more complex model can explain qualitatively synchronism of processes in very far parts of our Universe after fast expansion caused by Big Bang ("inflation"). These blowing up processes appear only at some narrow set of burning equation coefficients. It allows drawing analogy with «anthropic principle» **[69].** Anthropic principle states that fundamental constants have such values to allow our observed Universe to appear with anthropic entities inside, capable to observe it.

It is also interesting to illustrate the complex processes by means of "cellular" models. A good example is the discrete Hopfield model **[70, 71].** This system can be featured as a square two-dimensional lattice of meshes which can be either black or white. We will set some initial state of a lattice. Coefficients of the linear interaction between meshes are unequal. They can be chosen in such a way that during its discrete evolution the initial state transfers in one of possible terminating states from previously defined known set of states (attractors). Let these attractors be A or B letters.

There are such initial unstable states which differ just on one mesh (a critical element). Thus, one of them has attractor A, and another one - B. Such synergetic model is a good illustration of *global instability of* complex systems. It also shows that this instability features the system as a whole, but it is not feature of some its parts. Only an external observer can change critical element and thus change the system evolution. Внутренняя динамика самой системы сделать это не может. Internal dynamics of the system itself is not capable of it. *Global correlation* between meshes of unstable initial state define unambiguously which attractor must be chosen by this lattice (either A or B).

This model can be interpreted as a neural network with feedback or as a spin lattice (spin glass) with unequal interactions between spins. The system can be used for pattern recognition.

It is possible to complicate model. Let each mesh in the lattice featured above itself is a similar sub-lattice. Let assume that the process runs in two stages.

At the first stage, large meshes do not interact, interaction is only in sub-lattices which change under the usual method. Initial states of all sub-lattices can be chosen as unstable. We will associate the final state A of sub-lattices as a black mesh of the large lattice, and B - as a white one.

The second stage of evolution is defined as usual evolution of this large lattice already, without modifications in sub-lattices. Its initial state which appeared at the previous stage can be unstable too.

Let the total state of coarsened lattice be the letter A, and its each large mesh is A too. Let us name this state «A-A». Then appearance of this exact final state (but not some different one) is capable to explain correlations in unstable initial state by global meshes and by defined values of interaction coefficients between meshes.

Let's assume that before the featured above two stages process our coarsened lattice occupied a very small field of space but as a result of expansion ("inflation") was extended to enormous sizes. It was only thereafter when the process featured above had begun. So it is possible to explain existence of global correlations in unstable initial state (resulting in lattice attractor «A-A») by initial closeness of meshes (before "inflation"). A specific selection of interaction coefficients between meshes (also resulting in attractor «A-A») is possible to explain similarly to «anthropic principle».

Indeed, this coarsened lattice can be compared to our "Universe". Its big meshes (sub-lattice) can be compared to "live organisms", inhibiting (actively or passively) «decoherence». «Decoherence» is an influence of some big mesh "environment" (i.e. influence of other meshes) on processes existing inside this mesh. Then global correlations of unstable initial lattice states can serve as analogues of possible global correlations of unstable initial state of our Universe, and interaction coefficients of meshes correspond to fundamental constants. Initial process of lattice expansion corresponds to Big Bang.

13.4 Hypothetical consequences explaining life as a method for correlations conservation.

The definition of life as the totality of systems maintaining correlation in contrast to the external noise is a reasonable explanation of the mysterious silence of Cosmos, i.e. the absence of signals from other intelligent worlds. All parts of the universe, having the unique center of origin (Big Bang), are correlated, and life maintains these correlations which are at the base of its existence. Therefore the emergence of life in different parts of the Universe is correlated, so that all the civilizations have roughly the same level of development, and there are just no supercivilizations capable of somehow reaching Earth.

The effects of long-range correlations can explain at least a part of the truly wonderful phenomena of human intuition and parapsychological effects. A well-known psychiatrist Charles Jung wrote about it in his paper "On Synchronicity" **[72-75].** We will cite here the most interesting fragments from this paper. Here is a fragment defining “synchronicity”:

“*But I would rather approach the subject the other way and first give you a brief description of the facts which the concept of synchronicity is intended to cover. As its etymology shows, this term has something to do with time or, to be more accurate, with a kind of simultaneity. Instead of simultaneity we could also use the concept of a meaningful coincidence of two or more events, where something other than the probability of chance is involved. A statistical- that is, a probable concurrence of events, such as the "duplication of cases" found in hospitals, falls within the category of chance…*

…space and time, and hence causality, are factors that can be eliminated, with the result that acausal phenomena, otherwise called miracles, appear possible. All natural phenomena of this kind are unique and exceedingly curious combinations of chance, held together by the common meaning of their parts to form an unmistakable whole. Although meaningful coincidences are infinitely varied in their phenomenology, as acausal events they nevertheless form an element that is part of the scientific picture of the world. Causality is the way we explain the link between two successive events. Synchronicity designates the parallelism of time and meaning between psychic and psychophysical events, which scientific knowledge so far has been unable to reduce to a common principle. The term explains nothing, it simply formulates the occurrence of meaningful coincidences which, in themselves, are chance happenings, but are so improbable that we must assume them to be based on some kind of principle, or on some property of the empirical world. No reciprocal causal connection can be shown to obtain between parallel events, which are just what gives them their chance character. The only recognizable and demonstrable link between them is a common meaning, or equivalence. The old theory of correspondence, was based on the experience of such connections- a theory that reached its culminating point and also its provisional end in Leibniz' idea pre- established harmony, and was then replaced by causality. Synchronicity is a modern differentiation of the obsolete concept of correspondence, sympathy, and harmony. It is based not on philosophical assumptions but on empirical experience and experimentation.”

Here is citation giving an example of «synchronicity» from Jung’s personal experience:

“*I have therefore directed my attention to certain observations and experiences which, I can fairly say, have forced themselves upon me during the course of my long medical practice. They leave to do with spontaneous meaningful coincidences of so high a degree of probability as to appear flatly unbelievable. I shall therefore describe to you only one case of this kind, simply to give an example* *characteristic of a whole category of phenomena. It makes no difference whether you refuse to believe this particular case or whether you dispose of it with an ad hoc explanation. I could tell you a great many such stories, which are in principle no more surprising or incredible than the irrefutable result arrived at by Rhine, and you would soon see that almost every case calls for its own explanation. But the causal explanation the only possible one from the standpoint of natural science breaks down owing to the psychic relativization of space and time which together form the indispensable premises for the cause-and-effect relationship.*

My example concerns a young woman patient who, in spite of efforts made on both sides, proved to be psychologically inaccessible. The Difficulty lay in the fact that she always knew better about everything. Her excellent education had provided her with a weapon ideally suited to this purpose, namely a highly polished Cartesian rationalism with an impeccably "geometrical" idea of reality. After several fruitless attempts to sweeten her rationalism with a somewhat more human understanding, I had to confine myself to the hope that something unexpected and irrational would turn up, something that burst the intellectual retort into which she had sealed herself. Well, I was sitting opposite of her one day, with my back to the window, listening to her flow of rhetoric. She had an impressive dream the night before, in which someone had given her a golden scarab-a costly piece of jewellery. While she was still telling me this dream, I heard something behind me gently tapping on the window. I turned round and saw that it was a fairly large flying insect that was knocking against the window from outside in the obvious effort to get into the dark room. This seemed to me very strange. I opened the window and immediately caught the insect in the air as it flew in. It was a scarabaeid beetle, or common rose-chafer, whose golden green color most nearly resembles that of a golden scarab. I handed the beetle to my patient with the words "Here is your scarab." This broke the ice of her intellectual resistance. The treatment could now be continued with satisfactory results.

This story is meant only as a paradigm of the innumerable cases of meaningful coincidence that have been observed not only by me but by many others, and recorded in large collections. They include everything that goes by the name of clairvoyance, telepathy, etc., from Swedenborg's well-attested vision of the great fire in Stockholm to the recent report by Air Marshal Sir Victor Goddard about the dream of an unknown officer, which predicted the subsequent accident to Goddard's plane.

All the phenomena I have mentioned can be grouped under three categories:

1. The coincidence of a psychic state in the observer with a simultaneous, objective, external event that corresponds to the psychic state or content (e.g., the scarab), where there is no evidence of a causal connection between the psychic state and the external event, and where, considering the psychic relativity of space and time, such a connection is not even conceivable.

2. The coincidence of a psychic state with a corresponding (more or less simultaneous) external event taking place outside the observer's field of perception, i.e., at a distance, and only verifiable afterward (e.g., the Stockholm fire).

3. The coincidence of a psychic state with a corresponding, not yet existent, future event that is distant in time and can likewise only be verified afterward.

*In groups 2 and 3 the coinciding events are not yet present in the observer's field of perception, but have been anticipated in time in so far as they can only be verified afterward. For this reason I call such events **synchronistic**, which is not to be confused with **synchronous**.*"

This «synchronicity» described by Jung from the scientific point of view can be explained not just by accidental coincidence but also by unstable unobserved correlations existing between live organisms and environmental objects. As we already wrote above, metabolism processes can support such correlations and inhibit their «entangling» with an environment during decoherence. As these correlations are unstable, they are not observed (i.e. correspond to Unpredictable dynamics). This explanation does not necessarily require the use of quantum mechanics, since similar correlations can be found in classical mechanics that have analogues of the quantum correlations. Attribution of such correlations exclusively to quantum mechanics is a common mistake.

Unobservability of these correlations for the external observer does not mean that they can not be registered by our subjective experience in form of some «presentiments». Similarly, the external observer cannot measure or predict calculation result of quantum computer because any attempt of doing it would destroy this calculation. Let assume that the quantum computer has some "consciousness". Then he can have some "presentiment" of a future result of calculation, unlike the external observer who can not.

The above consideration **does not "prove",** however**,** that «synchronicity» is actually related to unstable correlations. We can just conclude that such assumption does not contradict to physics. Any observational verification of this hypothesis does not seem possible **in principle.** The reason is **principal unobservability of these correlations**.

For example, let's assume that some person had started two initially correlated quantum computers and knew their initial state. Further it got dead or disappeared. Then we never can predict future calculations results for these two computers. If we would see some correlations between its calculations results (for example, they are the same) we have not any way to choose between two possibilities: it is caused by initial conditions correlations or it can be explained by simple accidental coincidence. Indeed, any attempt to measure internal state of quantum computer during calculation process leads inevitably to destroying its correct operation! Similar reasonings are correct not only for quantum but also for chaotic classical systems with unstable additional microscopic correlations.

May be our real World of live entities actually is also a set of such correlated computers with unobservable unstable correlations between them? And the role of live substance consists just in conservation of these correlations? Only God can know their exact initial state if we suppose His existence. But existence of such correlations is quite possible, because our World has appeared from a single point as a result of «Big Band». And all live organisms on our planet, may be, can be a result of unique "protocell" evolution.

Large human insight and some parapsychological effects can lie in a narrow field, on the verge of comprehensibility by exact science. This is the field of Unpredictable Dynamics. Their basic elusiveness and instability does not allow for natural selection to increase these properties **[76, 77].** Because of instability and unpredictability it also is not possible to investigate these appearances by scientific methods. Though these appearances do not contradict to any physical laws and are quite possible from point of view of physics.

Mensky **[4]** in his book also tries to justify some fine points of human intuition and parapsychological effects through specific features of quantum mechanics. However, he makes some very typical errors.

1) For explanation of these effects there is no necessity of quantum mechanics laws "violations". For example, no transitions to other parallel Worlds (introduced by Multi-world interpretation) by means of "consciousness forces" of some "medium" are necessary. It is enough to assume some correlation between desires of "medium" and happening events. Because of these correlations the environment can “play along” our desires. In turn, the consciousness, because of these correlations can "have a presentiment" of the future. Attempt “to measure” or “to discover” these unstable quantum correlations will lead just to their vanishing and nonreversible changing further evolution. Any “violation” of usual quantum mechanics laws by "medium" is not necessary.

2) Effects, similar to quantum ones, can happen in classical chaotic systems too. Accordingly, all these effects can be modeled classically, without quantum mechanics.

3) Mensky writes about complexity and even impossibility of validation of individual system evolution from the scientific point of view. During such evolution we observe non-repeated events. Their probabilities are described by different probability distributions. Really, usually in a science for verification of some probabilistic theory, an ensemble of the same events is used with the help of «law of large numbers». **[16]** Nevertheless, there is the “law of large numbers” for events of different kinds too! (Generalized Chebyshev’s theorem, Markov’s theorem) **[16]** Hence, by means of these statements consistency in QM laws can be examined also for such a complex set of different events, correspondent to individual system evolution.

14. Conclusion.

Thus, **this paper is not** just a kind of **abstract philosophical discussion**. Lack of understanding of the principles discussed in this paper can lead to mistakes in solving physical problems. Most of the real systems cannot be described with ideal equations of quantum or classical mechanics. The influence of the measurement and environment on the system (which is inevitable in quantum mechanics and almost always present in classical mechanics) disturbs the evolution of the system. The attempt to include the observer and the environment into the system to be described leads to the paradox of the self-observing system (see **Appendix M**). Such system cannot measure and retain complete information on its own state. Even the approximate (self-) description in such system can only have applicability in time domain limited by times small enough to be much less than the return time for this system. After this return time is determined according to the Poincare's theorem all the information concerning the previous state of the system is inevitably erased. However, the description of the system in this case is possible in the frame of observable dynamics. The possibility of such description is explained by the independence of observable dynamics on the type and value of external noise for a wide range of noise types, thus observable dynamics is determined only by the properties of the system itself. Observable dynamics can be based on roughening of the distribution function or density matrix, because the initial state of the system is not defined precisely. The difference between the observable and the ideal dynamics cannot be experimentally verified even when observer and environment are included into the system to be described, because self-description is limited in precision and observation time domain. Thus the returns of the system to the initial state predicted by the Poincare's theorem for ideal dynamics cannot be observed by the self-observing system due to the effect of erasing of information concerning the previous states. Introduction of Observable Dynamics helps to solve all the known paradoxes of classical and quantum mechanics.

Lack of understanding of the principles discussed in this paper can lead to mistakes in solving physical problems. Given below are several examples of such mistakes, including the errors in the pole theory for the problems of flame front motion and the "finger" growth at the liquid/liquid interface.

Sivashinsky et al. **[78]** state that the Ideal Dynamics of poles causes an acceleration of the flame front propagation, and that this is not due to noise because the effect does not disappear with the decrease of noise, and depends purely on the properties of the system. However, the noise-connected Observable Dynamics does not depend on the noise over a wide range of its values.

Tanveer *et al.* **[79]** found a discrepancy between the theoretical predictions for "finger" growth in the problem of interfacial fluid flow and the results of numerical experiments. However, no understanding was reached in paper **[79]** of the connection of this discrepancy with the numerical noise, which leads to a new Observable Dynamics.

These are just two examples taken from the daily practice of the author of the present paper, and more such examples can be easily found.

The results of this paper are necessary for through understanding of the basics of nonlinear dynamics, thermodynamics, and quantum mechanics.

In usual problems of physics usually there is no necessity for the deep analysis of a situation made in this paper. It related to fact that usual considered physical systems are either systems with small number of particles, or systems of many particles closed to thermodynamic equilibrium. In such systems it is possible either to use precise Ideal Dynamics, or to use the simplified "approximate" methods for deriving Observable Dynamics. It is, for example, reduction in QM or Boltzmann equation in CM. Therefore, interest of physicists to papers similar to this one is small enough. However, many physical systems are not included into narrow class, featured by Ideal or simple Observable Dynamics. Their behavior basically is unpredictable, even probabilistically. We named their behavior as Unpredictable Dynamics. Quantum computer concerns to such systems from the point of view of the observer who did not observed its "start". Systems with Unpredictable Dynamics can include also some stationary systems far from thermodynamic equilibrium. Live organisms can be examples of such stationary systems. Even if such systems could be partially or completely featured by Observable Dynamics, its deriving is very nontrivial problem. If physics would try to feature such complex systems, then understanding of methods stated in this paper becomes necessary. Many such problems still wait for solution from physicists and mathematicians:

1) Which methods for deriving of Observable Dynamics of complex systems exist?

2) When deriving of Observable Dynamics is impossible and system can be featured just by Unpredictable Dynamics?

3) Whether is it possible to create «synergetic» systems «on paper» (for example, similar to Penrose's tubulins), which would illustrate **principal possibility** of appearance and existence of complex stationary systems (both classical, and quantum), featured by Unpredictable Dynamics? We will try to give here only some guesses about this possibility:

a) The systems featured by Unpredictable Dynamics, should be capable to inhibit decoherence and to conserve unstable additional classical (or quantum) correlations both inside complex systems, and between systems.

b) Such systems can have several unstable states and can transfer between them during evolution. The stream of negoentropy, substances or energies (i.e. metabolism) would allow to conserve these unstable states and process, without destroying it, and to protect them from external noise. On the other hand, unstable systems can serve itself as catalytic agents of this metabolism. In such systems would be possible both inverse processes, and Poincare's returns. Indeed, they are protected from external noise (decoherence) by the metabolism. External noise would be reduced and be incapable to destroy these process or states. But, any attempt to measure a current state or process in this unstable system would destroy its dynamics. Thus, this dynamics would be unobservable. Such systems can be not only quantum, but also classical.

c) In usual physics a macrostate is considered as some passive function its microstate. However, suppose that some system itself is capable to measure both the own macrostate, and its environment macrostates. In such a way, **feedback of macrostates through microstate appears. [3]** (**Appendixs M and V**)

d) It can be some kind of self-replicated **cellular automata**. **[80]**

Last years were published very interesting papers in the direction of building-up such «synergetic» systems, probably similar to live organisms **[81-83].** It must be mentioned that build-up of such models is a problem of physics and mathematics, not philosophy.

Appendix A. Phase density function. [5-6, 14]

The state of a system of N particles identical from the point of view of classical mechanics can be given by the coordinates $\mathbf{r}_1, \ldots, \mathbf{r}_N$ and momenta $\mathbf{p}_1, \ldots, \mathbf{p}_N$ of all the N particles of the system. For brevity's sake we shall further use the notation

$$x_i=(\mathbf{r}_i,\mathbf{p}_i) \quad (i=1, 2, \ldots, N)$$

to designate the set of coordinates and the momentum spatial components of a single particle, and the designation

$X = (x_1, \ldots, x_N) = (\mathbf{r}_1, \ldots, \mathbf{r}_N, \mathbf{p}_1, \ldots, \mathbf{p}_N)$

to denote the set of coordinates and momenta of all the particles of the system. The corresponding state of 6N variables is called 6N-dimensional phase space.

We shall consider a Gibbs ensemble, i.e. a set of identical macroscopic systems in order to define the concept of distribution function. The experimental conditions are similar for all these systems. However, since these conditions do not determine the state of the systems unambiguously, then different values of X shall correspond to different states of the ensemble at a given time *t*.

We select a volume dX in the vicinity of the point X. Assume that at a given time *t* this volume contains points characterizing the states of dM systems from the total number M of systems in the ensemble. Then the limit of the ratio of these values

$$\lim_{m\to\infty} dM/M = f_N(X,t)dX$$

defines the density function of the distribution in phase state at time *t*. This function is obviously normalized as follows:

$$\int f_N(X,t)dX = 1$$

The Liouville equation for the phase density function can be written in the form:

$$i\frac{\partial f_N}{\partial t} = Lf_N$$

where *L* is the following linear operator:

$$L = -i\frac{\partial H}{\partial p}\frac{\partial}{\partial x} + i\frac{\partial H}{\partial x}\frac{\partial}{\partial p}$$

where *H* is the energy of the system.

Appendix B. Definitions of entropy.

We can give the following definition of entropy:

$$S = -k\int_{(X)} f_N(X,t)\ln f_N(X,t)$$

In quantum mechanics entropy is defined via density matrix:

$S = -k\ \mathrm{tr}\ \rho \ln \rho$ **[15]**

where *tr* stands for matrix trace.

Entropy defined in such a way does not change in the course of reversible evolution. Coarsened values of f_N or ρ should be used to obtain the changing entropy.

Appendix C. Poincare's proof of the theorem of returns.

The number of the phase points which are leaving the given phase volume g during motion and not returned in it, will be eventually less any finite portion of the full number of phase points. We will prove this standing.

Let's consider the system having finite phase volume *G*. We will select inside this volume some *fixed* surface σ, restricting small volume *g*. We will consider the phase points flowing through a surface σ from volume *g*. The velocity of transition of a phase point on a phase trajectory depends only on phase coordinates, therefore number of the points flowing in a unit of time through the fixed surface σ, does not depend on time. We will designate through *g'* the volume occupied with phase points which flow in a unit of time from phase volume *g*, not being returned in it again. During *T g'T* volumes of a phase fluid flows from volume *g*. As the flowed out volume is *g'T*. Under the assumption, it is not returned more in volume *g* as it should fill a remaining part of the full phase volume *G*. A phase fluid is incompressible, therefore flowed out of *g* the volume *g'T* should not exceed volume in which it will flow out, i.e.

$Tg' < G - g < G$. (1)

Volume *G* is finite, therefore at finite *g '* this inequality can be satisfied only for finite T. For $T \to \infty$, the inequality (1) is satisfied only at $g' \to 0$, as it must be shown.

Appendix D. Correlation.

Let's consider the following problem. A series of measurings of two random variables *X* and *Y* has been carried out, and measurings were carried out pairwise: i.e. we got two values for one measuring - x_i and y_i. Having the sample consisting of pairs (x_i, y_i), we wish to check, whether there is dependence between these two variables. This dependence is named **correlation**. Correlation can exist not only between two, but also a larger number of magnitudes.

Dependence between random variables can have the functional character, i.e. to be the strictly functional ration linking their values. However, at handling of experimental data dependences of other sort are much more often - statistical dependences. Distinction between two aspects of dependences consists in the fact that that the functional connection establishes strict correlation between variables, and statistical dependence only speaks for the fact that distribution of random variable *Y* depends on what value is accepted by a random variable *X*.

Coefficient of Pearson's Correlation.

There are some various coefficients of correlation to each of which the above told will relate. Coefficient of Pearson's Correlation characterizing a degree of a linear relation between variables is most widely known. It is defined as

$$r = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2}\sqrt{\sum_i (y_i - \bar{y})^2}}$$

Appendix E. Thermodynamic equilibrium of the isolated system. Microcanonical distribution. [5, 14]

We will be interested in an *adiabatic system* – a system isolated from external bodies and having certain, strictly given energy E.

MICROCANONICAL distribution

Let's consider an adiabatic system, i.e. a system which cannot exchange energy with external bodies at invariable external parameters. For such a system, obviously,

$$H(X, a) = E = const \tag{1}$$

and phase density function φ (ε) should look like acute maxima since energy of the system can be practically precisely fixed and will not change eventually. But phase density φ (ε) in a limit at $\Delta E \to 0$ turns, up to a constant factor, to a Dirac delta function $\delta\{\varepsilon - E\}$. Thus, for an adiabatic isolated system it is possible to suppose:

$$\omega(X) = [1 / \Omega(E, \alpha)]\, \delta\{E - H(X, \alpha)\}, \tag{2}$$

Where $1 / \Omega(E, \alpha)$ is the norming factor that can be found from requirement of normalization, i.e.

$$\Omega(E, \alpha) = \int_{(X)} \delta\{E - H(X, \alpha)\} dX \tag{3}$$

Expression (2) is named as microcanonical Gibbs distribution. On basis of this distribution it is possible to calculate phase averages of any physical quantities for adiabatic isolated system with the help of formula

$$\overline{F} = \int_{(X)} F(X) \frac{1}{\Omega(E,a)} \delta\{E - H(X,a)\} dX \tag{4}$$

Magnitude $\Omega(E, \alpha)$ has visual geometrical meaning. $\Omega(E, \alpha)\, dE$ has sense of phase volume of lamina concluded between hypersurfaces $H(X,a) = E$ and $H(X, a) = E + dE$.

Appendix F. Theorem about invariance of phase "fluid" volume.

Let suppose that each mass point of system is featured by Cartesian coordinates x_k, y_k, z_k $(k = l, 2..., N)$.

We also sometimes will designate of these three coordinates vector $\vec{r}_k$. This system of *N* mass points can be featured also *3 N* by generalized coordinates:

$q_n (x_1..., z_N)$ (n=1, 2..., 3N).

Equations of motion of such conservative system are the equations of Lagrange

$$\frac{d}{dt}\frac{\partial L}{\partial \dot{q}_k} - \frac{\partial L}{\partial q_k} = 0 \qquad (\mathrm{k} = 1, 2, \ldots, 3\mathrm{N}) \tag{1}$$

Where *L=K-U*-function of Lagrange, or a Lagrangian; K - a kinetic energy; a system *U*-potential energy. However in a statistical physics it is more convenient to use equations of motion in the Hamilton shape:

$$\left.\begin{array}{l} \left.\begin{array}{l} \dot{q}_k = \dfrac{\partial H}{\partial p_k} \\ \dot{p}_k = -\dfrac{\partial H}{\partial q_k} \end{array}\right\} \quad k = 1,2,...,3N, \\ H = \sum\limits_{k=1}^{3N} p_k \dot{q}_k - L, \quad p_k = \dfrac{\partial L}{\partial \dot{q}_k} \end{array}\right\} \tag{2}$$

- A Hamiltonian function, or a Hamiltonian, a *(q_1, q_2..., q_{3N}; p_1, p_2..., p_{3N}) - a population of canonical variables.* In blanket deductions we will designate all canonical variables letter *X and,* supposing:

$q_k=X_k$, $p_k = X_{k+3N}$ *{k=1, 2..., 3 N).* (3)

For formulas transforming to compact form all population of variables (X_1, X_2..., X_{6N}) will be often designated by one letter (X), and product of all differentials dX_1 dX_2 ...dX_{6N} it will be designated through dX.

The equations of Hamilton represent system of the differential equations of the first order, so values of all variables X during the moment t are completely defined if values of these variables X0 during the moment t = 0 are known. This property of the Hamilton shape mechanically allows introducing geometrically the evident image of the system and its motion in a phase space. Driving of phase ensemble in a phase space can be considered as motion of a phase fluid, by analogy to motion of a usual fluid in three-dimensional space. In other words, phase space points are identified with points of the imaginary phase fluid filling space.

It is easy to prove, that for the systems, satisfying to the Hamiltonian equations, a phase fluid is incompressible. Really, the denseness of a usual three-dimensional incompressible fluid is constant. Hence, owing to the continuity equation

$$-\frac{\partial \rho}{\partial t} = div\ \vec{\upsilon}\ \rho = \rho\ div\ \vec{\upsilon} + \vec{\upsilon} \cdot \nabla \rho \tag{4}$$

And requirements ρ = const for an incompressible fluid, we have:

$$div\ \vec{\upsilon} = \frac{\partial \dot{x}}{\partial x} + \frac{\partial \dot{y}}{\partial y} + \frac{\partial \dot{z}}{\partial z} \tag{5}$$

This theorem can be easily extended for a fluid in many-dimensional space, and consequently, for an incompressible phase fluid the requirement of equality to zero of a multi-dimensional divergence should be satisfied, i.e.

$$\sum_{k=1}^{6N} \frac{\partial \dot{X}_k}{\partial X_k} = 0 \tag{6}$$

It can be seen easily, however, that owing to the equations of Hamilton (2)

$$\sum_{k=1}^{6N} \frac{\partial \dot{X}_k}{\partial X_k} = \sum_{k=1}^{6N} \left(\frac{\partial \dot{q}_k}{\partial q_k} + \frac{\partial \dot{p}_k}{\partial p_k} \right) = \sum_{k=1}^{6N} \left(\frac{\partial^2 H}{\partial q_k \partial p_k} - \frac{\partial^2 H}{\partial p_k \partial q_k} \right) \equiv 0 \tag{7}$$

, as it must be shown.

Since a phase fluid is incompressible so during its motion there is the invariable phase volume occupied with any part of this fluid.

Appendix G. The basic concepts of quantum mechanics. [18-20]

Wave function.

The basis of a mathematical apparatus of quantum mechanics is made by the statement that the system state can be described by (generally speaking, complex) function of coordinates $\Psi(q)$, and the quadrate of the module of this function defines a probability distribution of values of coordinate q: $|\Psi(q)|^2 dq$ is probability to find values of coordinates in $[q,q+dq]$ space interval for measuring produced over the system. Function Ψ is termed as a system *wave function*.

Observable variables.

Let's consider some physical quantity *f*, characterizing state of a quantum system. Strictly speaking, in the following discussion we should speak not about one variable, but about their full set at once. However, for simplicity we will speak below only about one physical quantity.

Values of some physical quantity are named as its *eigenvalues,* and their full set is named as *spectrum* of eigenvalues for this variable. In classical mechanics a set of all possible values of any variable is generally continuous. In a quantum mechanics also there are physical quantities (for example, coordinates) which eigenvalues fill the continuous number; in such cases it is *continuum spectrum of* eigenvalues. If all possible eigenvalues are some discrete set; in such cases it is *discrete spectrum.*

Let's consider at first for simplicity that considered variable *f* possesses a discrete spectrum. Variable eigenvalues *f* we will designate as f_n where the index *n* can have values 1, 2, 3, …. We will designate Ψ_n for system wave function of state correspondent to value f_n of variable *f*. Ψ_n is named *as eigenfunctions* of the given physical quantity *f*. Each of these functions is normalized, i.e.

$$\int |\Psi_n|^2 dq = 1. \tag{1}$$

If the system has some arbitrary state with some wave function Ψ the measuring of variable *f* will give one of eigenvalues f_n. According to a principle of superposition the wave function ψ should represent a linear combination of all eigenfunctions ψ_n correspondent to all values f_n that can be measured with nonzero probability. Therefore, generally any state function Ψ can be presented in the following form

$\Psi = \Sigma\, a_n \Psi_n,$ (2)

,where summation is yielded on all n, and a_n - some constant coefficients.

Thus, we can conclude that any wave function can be expanded to the set of eigenfunctions of some physical quantity. Such a set is named *complete set of functions*.

In expansion (2) the module quadrate $|a_n|^2$ defines probability to measure f_n of variable f for state with a wave function Ψ. Sum of all probabilities should be equal to one; in other words, the relation should take place

$$\sum_n |a_n|^2 = 1 \qquad (3)$$

Observable variable can be defined by means of the operators over function space. Result of operator action on function is also function. Then eigenfunctions ψk and its eigenvalues λ_k are simply a solution of the functional equation:

$$A\,\psi_k = \lambda_k \psi_k \qquad (4)$$

, where A is an operator of correspondent observable variable.

Label H is usually used for Hamiltonian - an energy operator.

For one particle in external field *U (x, y, z)* it is defined by the following formula:

$$H \equiv -\frac{\hbar^2}{2m}\Delta + U(x,y,z) \qquad (5)$$

, where $\Delta = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$ - an operator of Laplace

The matrix form of a quantum mechanics.

Let's expand some function under operator action, and the output function over eigenfunctions of some observable variable. Then both these functions can be noted as columns of these expansion coefficients. The operator of the observable variable can be noted in the form of a square matrix. Product of this matrix on a column of coefficients of expansion of the first function will give coefficients of expansion of the second function. This form of operators and functions is named **the matrix form of a quantum mechanics**.

Schrodinger equation.

Let's write out here a wave equation of motion for a particle in an external field.

$$i\hbar\frac{\partial\Psi}{\partial t} = -\frac{\hbar^2}{2m}\Delta\Psi + U(x,y,z)\Psi. \qquad (6)$$

The equation (6) has been found by Schrodinger in 1926 and is named *a Schrodinger equation.*

Uncertainty principle of Heisenberg.

If we characterize indeterminacies of coordinates and momentums by average quadratic fluctuations

$$\delta x = \sqrt{\overline{(x-\bar{x})^2}},\ \delta p_x = \sqrt{\overline{(p_x-\bar{p}_x)^2}},$$

it is possible to find the minimal possible value of their product.

Let's consider a one-dimensional case - a package with wave function ψ *(x),* depending only on one coordinate; we will guess for simplicity that medial values x and p_x in this state are equal to zero. We start with obvious inequality

$$\int_{-\infty}^{+\infty}\left|\alpha\ x\varphi + \frac{d\phi}{dx}\right|^2 dx \ge 0$$

Where α is any real constant.

Let's calculate this integral.

Using that

$$\int x^2|\varphi|^2\,dx = (\delta x)^2$$

$$\int \left(x\frac{d\varphi^*}{dx}\varphi + x\varphi^*\frac{d\varphi}{dx}\right)dx = \int x\frac{d|\varphi|^2}{dx}dx = -\int|\varphi|^2 dx = -1,$$

$$\int\frac{d\varphi^*}{dx}\frac{d\varphi}{dx}dx = -\int\varphi^*\frac{d^2\varphi}{dx^2}dx = \frac{1}{\hbar^2}\int\varphi^*\hat{p}_x^2\varphi\ dx = \frac{1}{\hbar^2}(\delta p_x)^2,$$

finally we obtain:

$$\alpha^2(\delta x)^2 - \alpha + \frac{(\delta p_x)^2}{\hbar^2} \ge 0$$

This quadratic trinomial (over α) is non-negative for any α, if its discriminant is non-positive. From this condition we can obtain inequality:

$$\delta x\ \delta p_x \ge \hbar/2 \qquad (7)$$

The minimal possible value of product is equal to ħ/2.

This *uncertainty principle* (7) was found *by Heisenberg* in 1927

We see that decreasing of coordinate uncertainty (i.e. δx*) results in increasing* uncertainty of momentum along the same axis(δp_x), and on the contrary. In particular case, when the particle is in some strictly certain point of space ($\delta x = \delta y = \delta z = 0$), so $\delta p_x = \delta p_y = = \delta p_z = \infty$. It means that all values of momentum have equality probability. On the contrary, if the particle has strictly certain momentum p all its positions in space have equal probability.

Appendix I. Density matrix.

Consider a beam of N_a particles prepared in state $|\chi_a\rangle$, and another beam of N_b particles in state $|\chi_b\rangle$ independent on the first one. To describe the combination of beams we introduce the mixed state operator ρ defined as follows:

$$\rho=W_a|\chi_a\rangle\langle\chi_a| + W_b|\chi_b\rangle\langle\chi_b|,$$

where $W_a=N_a/N$, $W_b=N_b/N$, $N=N_a+N_b$

Operator ρ is called a density operator or a statistical operator. It describes the way the beams were prepared and therefore contains complete information about the total beam. In this sense the mixture is completely defined by the density matrix. In the special case of a pure state $|\chi\rangle$ the density operator is given by the expression

$$\rho=|\chi\rangle\langle\chi|.$$

Operator ρ is usually convenient to write in matrix form. Therefore we choose a basic set of states (most commonly used are $|+1/2\rangle$ and $|-1/2\rangle$) and decompose the $|\chi_a\rangle$ and $|\chi_b\rangle$ states over this basic set as follows:

$$|\chi_a\rangle=a_1^{(a)}\,|+1/2\rangle+a_2^{(a)}\,|-1/2\rangle,$$
$$|\chi_b\rangle=a_1^{(b)}\,|+1/2\rangle+a_2^{(b)}\,|-1/2\rangle.$$

In the representation of $|\pm1/2\rangle$ states we have the relations for the kept states:

$$|\chi_a>=\begin{pmatrix} a_1^{(a)} \\ a_2^{(a)} \end{pmatrix}$$

$$|\chi_b>=\begin{pmatrix} a_1^{(b)} \\ a_2^{(b)} \end{pmatrix},$$

and for the conjugated states:

$$\langle\chi_a|=(a_1^{(a)*}\,,\ a_2^{(a)*}\,)\,,$$
$$\langle\chi_b|=(a_1^{(b)*}\,,\ a_2^{(b)*}\,)\,.$$

Using the matrix multiplication rules we obtain for the “external product”:

$$|\chi_a><\chi_a|=\begin{pmatrix} a_1^{(a)} \\ a_2^{(a)} \end{pmatrix}\begin{pmatrix} a_1^{(a)^*}, a_2^{(a)^*} \end{pmatrix}=\begin{pmatrix} |a_1^{(a)}|^2 & a_1^{(a)}a_2^{(a)*} \\ a_1^{(a)*}a_2^{(a)} & |a_2^{(a)}|^2 \end{pmatrix}$$

and a similar expression for the $|\chi_b\rangle\langle\chi_b|$ product. Substituting these expressions into the density operator, we obtain the density matrix.

$$\rho = \begin{pmatrix} W_a \left| a_1^{(a)} \right|^2 + W_b \left| a_1^{(b)} \right|^2 & W_a a_1^{(a)} a_2^{(a)*} + W_b a_1^{(b)} a_2^{(b)*} \\ W_a a_1^{(a)*} a_2^{(a)} + W_b a_1^{(b)*} a_2^{(b)} & W_a \left| a_2^{(a)} \right|^2 + W_b \left| a_2^{(b)} \right|^2 \end{pmatrix}$$

Since the |±1/2› states were used for the basic state, the obtained expression is called density matrix in {|±1/2›} representation.

Statistical density matrix P_0.

In conclusion, we make several notes concerning the statistical matrix P_0 which has remarkable properties. We know that all the possible macroscopic states of the system in classical statistical thermodynamics are considered *a priori* equiprobable. In other words, the states are considered equally probable, unless information is available concerning the total energy of the system, its contact with the thermostat ensuring the constant temperature of the system, etc. Similarly, in wave mechanics all the states of the system corresponding to the functions forming the complete system of orthonormalized functions can be *a priori* considered equiprobable. Let $\varphi_1,\ldots,\varphi_k$, is such a system of basis functions. Provided the system is characterized by a mixture of the φ_k states, in the absence of other relevant information we can assume that the statistical matrix of the system has the form

P_0= $\sum_k pP_{\varphi_k}$ **, where** $\sum_k p = 1$**,**

i.e. that P_0 is the statistical matrix of a mixed state with all equal statistical weights. Since φ_k are the basis functions, matrix P_0 can be represented as follows:

$(P_0)_{kl}=p\delta_{kl}$

If matrix P0 characterizes the statistical state of the ensemble of systems at the initial moment of time, and the same value A is measured in all the systems of the ensemble, then the statistical state of the ensemble would be still characterized by the P0 matrix.

The equations of motion for the density matrix.

The equations of motion for the density matrix ρ have the form:

$$i\frac{\partial \rho_N}{\partial t} = L\rho_N$$

where L is the linear operator:

Lρ=Hρ-ρH=[H,ρ],

where H is the energy operator of the system.

If A is the operator of a certain observable, then the average value of the observable can be found as follows:

$<A>=trA\rho$

Appendix J. Reduction of the density matrix and the theory of measurement

Assume that the states $\sigma^{(1)}$, $\sigma^{(2)}$, ... are "clearly discernible" in measuring a certain object. The measurement performed over the object in one of these states yields numbers λ_1, λ_2, ... The initial state of the measuring device is designated *a*. If the measured systems was initially in the state $\sigma^{(\nu)}$, then the state of the complete system "measured system plus the measuring device" before their interaction is determined by the direct product a X $\sigma^{(\nu)}$. After the measurement

$$a \, X \, \sigma^{(\nu)} \rightarrow a^{(\nu)} \, X \, \sigma^{(\nu)}$$

Assume now that initial state of the measured system is not clearly discernible, but is an arbitrary mixture: $\alpha_1 \sigma^{(1)} + \alpha_2 \sigma^{(2)} + ...$ of such states. In this case, due to the linearity of the quantum equations, we obtain:

$$a \, X \, [\Sigma\alpha_\nu\sigma^{(\nu)}] \rightarrow \Sigma\alpha_\nu[a^{(\nu)} \, X \, \sigma^{(\nu)}]$$

There is a statistical correlation between the state of the object and the state of the device in the final state resulting from the measurement. A simultaneous measurement of two values in the system "measured object and measuring system" (the first one is the measured characteristic of the studied object, and the second is the position of the measuring device indicator) always leads to correlating results. Therefore one of the measurements mentioned above is superfluous: a conclusion on the state of the measured object can always be made based on observing the measuring device.

The state vector obtained as the measurement result cannot be represented as a sum in the right hand part of the relation above. It is a so-called mixture, i.e. one of the state vectors having the form:

$$a^{(\nu)} \, X \, \sigma^{(\nu)},$$

and the probability of this state appearing as the result of interaction between the measured object and the measuring device is $|\alpha_\nu|^2$. This transition is called wave packet reduction. And corresponds to the transition of the density matrix from the non-diagonal form $\alpha_\nu\alpha_\mu^*$ to the diagonal form $|\alpha_\nu|^2 \delta_{\nu\mu}$. This transition is not described by the quantum mechanical equations of motion.

Appendix K. Coarsening of the phase density function and the molecular chaos hypothesis.

Coarsening of the density function is called its substitution with an approximate value, e.g.:

$f_N^*(X,t)=\int_{(Y)}g(X-Y)f_N(Y,t)dY$

where

$g(X)=1/\Delta\ D(X/\Delta)$

$D(x)= 1$ for $|X|<1$
$D(x)= 0$ for $|X|\geq 1$

Another example of coarsening is the "molecular chaos hypothesis". It implies substitution of a two-particle distribution function with a product of single-particle functions as follows:

$f\ (x_1,x_2,t) \text{ -> } f(x_1,t)f(x_2,t)$

Appendix L. Prigogine's New Dynamics.

The New dynamics introduced by Prigogine is often mentioned in the present paper. Given below is a brief introduction to this theory based on the monographs **[14, 55].**

A linear operator Λ is introduced, which acts on the phase density function or density matrix ρ so that:

$$\tilde{\rho} = \Lambda^{-1}\rho$$

$\Lambda^{-1}\ 1=1$

$$\int\tilde{\rho} = \int\rho$$

where Λ^{-1} remains positive. The requirement on the operator Λ is that the function Ω defined via the function $\tilde{\rho}$ as follows:

$$\Omega = tr\tilde{\rho}^{+}\tilde{\rho} \text{ or } \Omega = tr\tilde{\rho}\ln\tilde{\rho}$$

complies with the inequality $d\Omega/dt\leq 0$

The equation of motion for the transformed function $\tilde{\rho}$ is

$$\frac{\partial\tilde{\rho}}{\partial t} = \Phi\tilde{\rho}$$

where $\Phi= \Lambda^{-1} L\Lambda$

Φ is noninvertible markovian semigroup.

$\Lambda^{-1}(L)=\Lambda^{+}(-L)$

Operator Λ^{-1} for the phase density function corresponds to the coarsening in the direction of phase volume decrease. In quantum mechanics such operator can only be found for an infinite volume or an infinite number of particles. A projection operator P is introduced in quantum mechanics, which makes all the non-diagonal elements of the density matrix zero. Operator Φ and the basis vectors of the density matrix are chosen so that the operators Φ and P are permutable:

$$\frac{\partial P\tilde{\rho}}{\partial t} = P\Phi\tilde{\rho} = \Phi P\tilde{\rho}$$

Appendix M. Impossibility of self-prediction of evolution of the system.

Suppose there is a powerful computer capable of predicting its own future and that of its environment based on the calculation of motion of all the molecules. Suppose that the prediction is rolling of a black or white ball from a certain device, which is an integral part of the computer and is described by the machine. The device rolls out a white ball when the computer predicts a black one, and rolls out a black ball when the white one is predicted. It is clear that the predictions of the computer are always false. Since the choice of the environment is arbitrary, then this contrary instance proves the impossibility of exact self-observation and self-calculation. Since the device always contradicts the predictions of the computer, then complete self-prediction of the system including both the computer and the device is impossible.

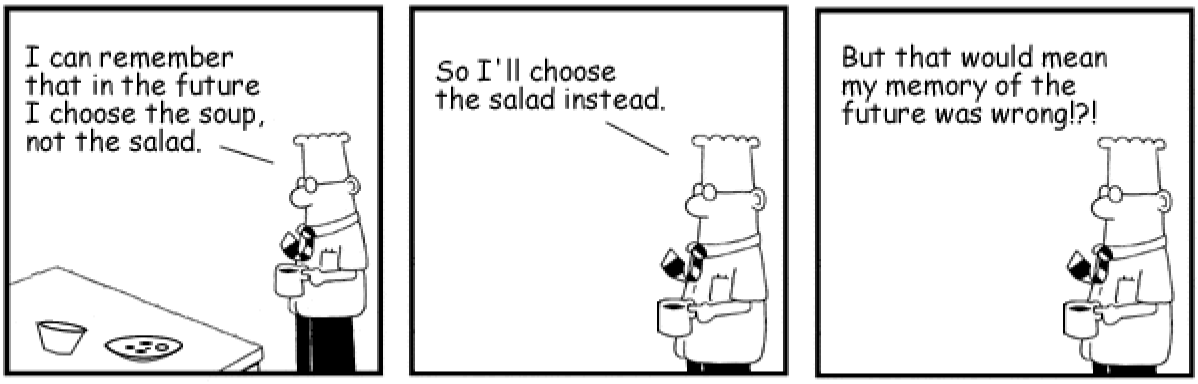

Figure 27. Impossibility of self-prediction. (Fig. from [101])

Appendix N. Tables of correspondence between the quantum and classical mechanics.

Table 1. Bsic Properties of quantum and classical mechanics

Quantum mechanics	Classical mechanics
Density matrix	Phase density function
Equation of motion for the density matrix	Liouville equation
Wave packet reduction	Coarsening of the phase density function or the molecular chaos hypothesis
Unavoidable interaction of the measured system with observer or environment, described by reduction	Theoretically infinitesimal but in reality a finite, if small, interaction of the measured system with observer or environment
Non-zero non-diagonal elements of the	Correlations between the velocities and

density matrix	positions of particles in different parts of the system

Table 2. Probability formulations in classical and quantum mechanics. **[18]**

	Classical mechanics	**Quantum mechanics**
Pure state	Point (q, ρ) *of* phase space	State vector $\|\psi >$
General state	Probability density $\rho(q, p)$	Positive hermitean operator ρ
Normalization condition	$\int \rho dqdp = l$	tr ρ = 1
condition for pure sate	ρ = δ-function	$\rho=\|\psi>\ <\psi\|$ (operator ρ rank is equal to 1)
Equation of motion	$\frac{\partial\rho}{\partial t} = \{H,\rho\}$	$i\hbar\frac{\partial\rho}{\partial t} = [H,\rho]$
Observable	Function $A(q, p)$	Hermitean operator *A*
Average value	$\int A\rho\, dq\, dp$	tr (Aρ)

Appendix O. A system reduction at measuring. [15, 18]

Let's consider a situation when the measuring device was at the beginning in state $|\alpha_0\rangle$, and the object was in superposition of states $|\psi\rangle = \sum c_i|\psi_i\rangle$,, where $|\psi_i\rangle$ - experiment eigenstates. The initial statistical operator is given by expression

$\rho_0=|\psi\rangle\ |\alpha_0\rangle\langle\alpha_0|\ \langle\psi|$ (1)

The partial track of this operator which is equal to statistical operator of system, including the object only, looks like

$tr_A(\rho_0)=\sum_n\langle\varphi_n|\rho_0|\varphi_n\rangle$

where $| \varphi_n \rangle$- any complete set of device eigenstates. Thus,

$$tr_A(\rho_0)=\sum |\psi\rangle \langle\varphi_n|\alpha_0\rangle\langle\alpha_0|\varphi_n\rangle\langle\psi|=|\psi\rangle\langle\psi|, \quad (2)$$

Where the relation $\sum | \varphi_n \rangle\langle \varphi_n | = 1$ and normalization condition for $| \alpha_0 \rangle$ are used. We have statistical operator correspondent to object state $| \psi\rangle$. After measuring there is a correlations between device and object states so the state of full system including device and object, is featured by a state vector

$$|\Psi\rangle=\sum c_i e^{i\theta i}|\psi_i\rangle|\alpha_0\rangle|. \quad (3)$$

And the statistical operator is given by expression

$$\rho_0=|\Psi\rangle \langle\Psi|=\sum c_i c_j^* e^{i(\theta i-\theta j)}|\psi_i\rangle|\alpha_i\rangle\langle\alpha_j|\psi_j\rangle. \quad (4)$$

The partial track of this operator is equal

$$tr_A(\rho)=\sum_n\langle\varphi_n| \rho |\varphi_n\rangle |=$$
$$=\sum_{(ij)}c_i c_j^* e^{i(\theta i-\theta j)} |\psi_i\rangle\langle\varphi_n |\alpha_i\rangle\langle\alpha_j|\varphi_n\rangle\langle\psi_j|=$$
$$=\sum_{(ij)}c_i c_j^* \delta_{ij} |\psi_i\rangle\langle\psi_j| \quad (5)$$

(Since various states $| \alpha_i \rangle$ of device are orthogonal each other); thus,

$$tr_A(\rho)=\sum|c_i|^2|\psi_i\rangle\langle\psi_i|. \quad (6)$$

We have obtained statistical operator including object only, featuring probabilities $|c_i|^2$ for object states $| \psi_i \rangle$. So we come to formulation of the following theorem.

The theorem 5.5 (about measuring). If two systems *S* and *A* interact in such a manner that to each state $| \psi_i \rangle$ systems *S* there corresponds a certain state $| \alpha_i\rangle$ of systems *A* the statistical operator $tr_A (\rho)$ over full systems *(S* and *A)* reproduces wave packet reduction for measuring, yielded over system *S*, which was before measuring in a state $| \psi \rangle= \sum_i c_i | \psi_i\rangle$.

Suppose that some subsystem is in mixed state, but full system including this subsystem is in pure state. Such mixed state is named *as improper mixed state.*

Appendix P. The theorem about decoherence at interaction with the macroscopic device. [18, 84]

Let's consider now that the device is a macroscopic system. It means that each distinguishable configuration of the device (for example, position of its arrow) is not pure quantum state. It states nothing about a state of each separate arrow molecule. Thus, in the above-stated reasoning the initial state of the device $| \alpha_0 \rangle$ should be described by some statistical distribution on microscopic quantum states $| \alpha_{0, s}\rangle$; the initial statistical operator is not given by expression (1), and is equal

$$\rho_0 = \sum_s p_s | \psi \rangle| \alpha_{0, s}\rangle \langle\alpha_{0, s} |\langle \psi |. \quad (7)$$

Each state of the device $| \alpha_{0, s} \rangle$ will interact with each object eigenstate $| \psi_i\rangle$. So it will transform to some other state $| \alpha_{i, s} \rangle$. It is one of the quantum states of set with macroscopic description correspondent to arrow in position i; more precisely we have the formula

$$e^{iH\tau/\hbar}(| \psi \rangle| \alpha_{0, s}\rangle) =e^{i\theta i, s}| \psi \rangle| \alpha_{i, s}\rangle. \quad (8)$$

Let's pay attention at appearance of phase factor depending on index *s*. Differences of energies for quantum states $| \alpha_{0, s} \rangle$ should have such values that phases $\theta_{i, s}$ (mod 2 π) after time τ have been randomly distributed between 0 and 2 π.

From formulas (7) and (8) follows, that at $| \psi \rangle = \sum_i c_i | \psi_i \rangle$ the statistical operator after measuring will be given by following expression:

$$\rho = \sum_{(s, i, j)} p_s c_i c_j^* e^{i (\theta i, S - \theta j, s)} | \psi_i \rangle | \alpha_{i, s} \rangle \langle \alpha_{j, s} | \langle \psi_j | \quad (9)$$

As from (9) the same result (6) can be concluding. So we see that the statistical operator (9) reproduces an operation of reduction applied to given object. It also practically reproduces an operation of reduction applied to device only ("practically" in the sense that it is a question about "macroscopic" observable variable). Such observable variable does not distinguish the different quantum states of the device corresponding to the same macroscopic description, i.e. matrix elements of this observable variable correspondent to states $| \psi_i \rangle | \alpha_{i, s} \rangle$ and $| \psi_j \rangle | \alpha_{j, s} \rangle$ do not depend on *r* and *s*. Average value of such macroscopic observable variable *A* is equal

$$\mathrm{tr}\,(\rho A) = \sum_{(s, i, j)} p_s c_i c_j^* e^{i (\theta i, S - \theta j, s)} \langle \alpha_{j, s} | \langle \psi_j | A | \psi_i \rangle | \alpha_{i, s} \rangle =$$
$$= \sum_{(i, j)} c_i c_j^* a_{i, j} \sum_s p_s e^{i (\theta i, S - \theta j, s)} \quad (10)$$

As phases $\theta_{i, s}$ are distributed randomly, the sum over s are zero at $i \neq j$; hence,

$$\mathrm{tr}\,(\rho A) = \sum |c_i|^2 a_{ii} = \mathrm{tr}\,(\rho' A). \quad (11)$$

where

$$\rho' = \sum |c_i|^2 p_s | \psi_i \rangle | \alpha_{i, s} \rangle \langle \alpha_{j, s} | \langle \psi_j | \quad (12)$$

We obtain statistical operator which reproduces operation of reduction on the device. If the device arrow is observed in position i, the device state for some s will be $| \alpha_{i, s} \rangle$. The probability to find state $| \alpha_{i, s} \rangle$ is equal to probability of that before measuring its state was $| \alpha_{i, s} \rangle$. Thus, we come to following theorem.

The theorem 5.6. About decoherence of the macroscopic device. Suppose that the quantum system interacts with the macroscopic device in such a manner that there is a chaotic distribution of device states phases. Let ρ - a statistical operator of the device after the measuring, calculated with the help of Schrodinger equations, and ρ' - the statistical operator obtained as a result of reduction application to an operator ρ. Then it is impossible to yield such experiment with the macroscopic device which would register difference between ρ and ρ '.

For a wide class of devices it is proved that the chaotic character in distribution of phases formulated in the theorem 5.6 really takes place, if the device evolves nonreversibly at measuring. It is so-called Daneri-Loinger-Prosperi theorem **[84].**

Appendix R. Zeno Paradox. The theorem of continuously observable kettle which does not begin to boil in any way. [18]

Theorem:

Let *A* is an observable variable of the quantum system, having eigenvalues 0 and 1. Assume, that measurings observable variable A are yielded in instants $t_0 = 0, t_1..., t_N = T$ on a time interval [0, *T*] and the reduction is applied after each such measuring. Let p_n - probability of that measuring during the moment t_n yields result 0. Then, if $N \to \infty$, and so, that max $(p_{n+1} - p_n) \to 0$,

$$p_N - p_0 \to 0 \qquad (13)$$

(So, if the system was some value of observable variable A at instant $t = 0$, it will have the same value of A also at instant $t = T$).

The proof:

Let P_0 be projection operator on characteristic space of observable variable A, corresponding to an eigenvalue 0, and let $P_1 = 1 - P_0$ the projection operator on characteristic space with an eigenvalue 1. Let ρ_n be the statistical operator characterizing the state of the system immediately before measuring at instant t_n. Then, the statistical operator after measuring is given by expression

$$\rho_n' = P_0\, \rho_n\, P_0 + P_1\, \rho_n\, P_1 \qquad (14)$$

So the statistical operator characterizing the state of the system state immediately before measuring at instant t_{n+1}, will be equal

$$\rho_{n+1} = e^{-iH\tau n}\, \rho_n'\, e^{iH\tau n} \qquad (15)$$

Where H - a system Hamiltonian, and $\tau_n = t_{n+1} - t_n$. We note here, that if the operator ρ_n is equal to sum of k terms of type $| \psi\rangle \langle\psi |$, the operator ρ_{n+1} would be sum no more than $2k$ such terms; since $\rho_n = | \psi_0\rangle \langle\psi_0 |$, it is follows, that the operator ρ_n is the sum of finite number of such terms. According to (15), we have

$$\rho_{n+1} = \rho_n' - i\tau_n [H, \rho_n'] + O(\tau_n^2). \qquad (16)$$

Since $P_0^2 = P_0$, $P_0\, P_1 = 0$, so

$$P_0\, \rho_{n+1}\, P_0 = P_0\, \rho_n\, P_0 - i\tau_n [P_0\, H\, P_0, P_0\, \rho_n\, P_0] + O(\tau_n^2). \qquad (17)$$

Hence, the probability of that measuring at instant t_n would yield result 0, is equal

$$p_{n+1} = \mathrm{tr}\,(\rho_{n+1}\, P_0) = \mathrm{tr}\,(P_0\, \rho_{n+1}\, P_0) =$$
$$= \mathrm{tr}\,(P_0\, \rho_n\, P_0) - i\tau_n\, \mathrm{tr}\, [P_0\, H\, P_0, P_0\, \rho_n P_0] + O(\tau_n^2). \qquad (18)$$

The second equality is valid because $P_0^2 = P_0$. We will consider now that the operator $P_0\rho_n P_0$ is equal to the sum of finite number of terms of type $| \psi\rangle \langle\psi |$ and for any operator X the relation is valid:

$$\mathrm{tr}\,(X| \psi\rangle \langle\psi |) = \langle\psi | X | \psi\rangle = \mathrm{tr}\,(| \psi\rangle \langle\psi | X). \qquad (19)$$

Hence, the commutator track in (18) is equal to zero, therefore

$$p_{n+1} = p_n + O(\tau_n^2). \qquad (20)$$

Let's designate maximum value τ_n by τ ($\tau = \max \tau_n$); then there is such constant value k, that

$$p_{n+1} - p_n \le k\tau_n^{\,2} \le k\tau\tau_n \qquad (21)$$

Therefore

$$p_N - p_0 = \sum_{n=0}^{N-1} (p_{n+1} - p_n) \le k\tau \sum_{n=0}^{N-1} \tau_n = k\tau T \to 0$$

At $\tau \to 0$.

Appendix S. Einstein-Podolsky-Rosen paradox [18].

Such point of view may be possible that difficulties considered in quantum mechanics are related exclusively by that the quantum mechanics vector of a state. It does not give full information about a system state: really there are other variables hidden from us, named as hidden variables. Its values completely characterize a state of system and predict its future behavior more in details, than the quantum mechanics. Serious argument of existence of such additional hidden variables has advanced by Einstein, Podolsky and Rosen in 1935. We will consider an electron and a positron pair born simultaneously in a state with the full spin 0. This spin state represents an antisymmetric combination of spin states of two particles with a spin 1/2, i.e. it looks like

$$|\Psi\rangle = \frac{1}{\sqrt{2}}\left(|\uparrow\rangle\,|\downarrow\rangle - |\downarrow\rangle\,|\uparrow\rangle\right) \qquad (22)$$

where $|\uparrow\rangle$ and $|\downarrow\rangle$ - the one-particle eigenstates of a component of a spin s_z with eigenvalues +1/2 and-1/2 accordingly, and in a two-particle spin state (22) spin state of an electron is noted by the first factor.

As the state with the zero angular moment is invariant with respect to rotations, it should look like (22) independently on axis direction. Thus, it is possible to note also

$$|\Psi\rangle = \frac{1}{\sqrt{2}}\left(|\rightarrow\rangle\,|\leftarrow\rangle - |\leftarrow\rangle\,|\rightarrow\rangle\right) \qquad (23)$$

Where $|\leftarrow\rangle$ and $|\rightarrow\rangle$ are the one-particle eigenstates of a component of a spin s_x.

Let's assume that the electron and a positron move in opposite directions and achieve very large distance between each other. Then measuring z component of electron is yielded. Thus, measured observable variable is $s_z(e^-)$ of full system; after such measuring the system state will be projected on some correspondent eigenstate of this observable variable: if measuring gives value +1/2 after measuring the system would transfer in a state $|\uparrow\rangle|\downarrow\rangle$. It means that the positron will be in a state $|\downarrow\rangle$ and measuring z-component of his spin $s_z(e^+)$ with the full definiteness will give value -1/2. We can note that this information about positron is obtained by means of the experiment yielded over electron. It is at great distance from positron and, consequently, can not influence it. Einstein, Podolsky and Rosen concluded therefore that the result of the experiment about the positron state (namely that $s_z(e^+) = -1/2$) should be a real fact which took place also before experiment with the electron.

Let's assume that electron spin is measured not for z-axis, but x-axis. Then from

(23) it follows that the system state will be projected either on state $|\leftarrow\rangle|\rightarrow\rangle$ or on a state $|\rightarrow\rangle|\leftarrow\rangle$. So the positron would have some certain value for its x-component.

$s_x(e^+)$. Such state of positron also should exist before last experiment. Hence, before the experiment the positron had certain values both $s_z(e^+)$ and $s_x(e^+)$. But they are incompatible observable variables, and they haven't simultaneous eigenstates: no such quantum mechanics state exists where both of them could have certain values. Einstein, Podolsky and Rosen made from here conclusion that quantum mechanics description is incomplete and there are "elements of realities" which the quantum mechanics does not consider. Let's consider quantum mechanics explanation of EPR paradox. After the experiment over electron, full system has really transferred to eigenstate $|\uparrow\rangle|\downarrow\rangle$ if it was measured value +1/2 for $s_z(e^-)$, or to eigenstate $|\rightarrow\rangle|\leftarrow\rangle$ if it was measured value +1/2 for

$s_x(e^-)$. It means that after experiment the positron is in certain state, either | ↓ › or | ←› accordingly, and this state is different from positron state before experiment. But it does not mean, that the positron state has been changed by the experiment over electron as the positron at all had no any certain state before experiment carrying out. If nevertheless to insist that the positron should be featured somehow separately it is necessary to be converted to its statistical operator. According to (22) and (23), this operator (before experiment) is given by expression

$$\rho_{e^+} = tr_{e^+} |\Psi\rangle\langle\Psi| = \tfrac{1}{2}\left(|\uparrow\rangle\langle\uparrow| + |\downarrow\rangle\langle\downarrow|\right) = \quad (24)$$

$$= \tfrac{1}{2}\left(|\rightarrow\rangle\langle\rightarrow| + |\leftarrow\rangle\langle\leftarrow|\right) \quad (25)$$

I.e. it is equal to unit operator in two-dimensional positron spin space multiplied by 1/2. We will consider now a statistical operator of a positron immediately after experiment but before the information about its result can reach positron. If the component measured in experiment with electron was s_z then the positron state would be or | ↑ ›, or | ↓› with equal probability, and the statistical operator would have an appearance (24). If the component measured in experiment with electron was s_x the positron state would be or | → ›, or | ←› with equal probability, and the statistical operator would have an appearance (25), i.e. the same, that in the previous case and before experiment with an electron. Though these three situations (before experiment, after experiment on measuring s_z and after experiment on measuring s_x) are differently featured with use of positron states, all of them correspond to the same statistical operator, and between them there is no experimentally observable difference. Thus, there is no experimentally observed interaction between electron and far positron, i.e. EPR experiment cannot be used for information transfer with velocity more than light velocity.

Appendix T. Bell's inequality. [18]

We will show now that the instantaneous interaction is inevitable for any theory with hidden variables which leads to the same consequences as quantum mechanics does.

Let's consider a situation in which experiments are carried out over two particles separated in space, and we will deduce consequences from an assumption, that results of experiment carried out over one of particles, are depend just on this experiment. They do not depend on results of any experiment carried out over other particle. This property is named *locality*. It will be shown below that the locality requirement results in such restrictions on correlations between results of experiments over different particles which contradict quantum mechanics predictions.

Basically between a locality and determinism no connection exists. Let's assume that probabilities are defined by some set of variables. We will designate this set by symbol λ (in case of two particles separated in space these variables can consist of the variables featuring individually both particles, and the variables featuring general devices, influencing simultaneous on both particles). Then for each experiment E it is possible to specify probability $p_E(\alpha \mid \lambda)$ of measuring α when variables have values λ. The theory will be *local* if experiments *E* and *F*, which are separated in space, are independent in sense of probability theory. From here we conclude that

$$p_{E\oplus F}(\alpha\oplus\beta\,|\,\lambda)=p_E(\alpha\,|\,\lambda)p_F(\beta\,|\,\lambda) \quad (26)$$

Any local theory which reproduces all predictions of quantum mechanics concerning EPR experiment for two separated particles with a spin 1/2, will be equivalent to the deterministic theory. Let's suppose that electron and positron are separated by a very large distance. Also let in experiment *E* the component of electron spin is measured in some direction, and in experiment *F* the component of positron spin is measured in the same direction. We will designate arrows ↑ and ↓ two possible observed dates. Then, as the full spin is equal to zero, we know, that experiments *E* and *F* will always yield opposite results; according to probability theory,

$$p_{E\oplus F}(\uparrow\oplus\uparrow)=p_{E\oplus F}(\downarrow\oplus\downarrow)=0 \quad (27)$$

Let ρ (λ) be the probability density characterizing probability that variables have values λ; then the composite probability (27) is equal to

$$p_{E\oplus F}(\uparrow\oplus\uparrow)=\int p_{E\oplus F}(\uparrow\oplus\uparrow)\rho(\lambda)d\lambda=$$

$$=\int p_E(\uparrow|\,\lambda)p_F(\uparrow|\,\lambda)\rho(\lambda)d\lambda \quad (28)$$

Since full probability is equal to zero, an integrand, being nonnegative, should be zero everywhere. Hence,

either $\rho(\lambda)=0$ or $p_E(\uparrow|\lambda)=0$ or $p_F(\uparrow|\lambda)=0$. (29)

Similarly we conclude, that

either $\rho(\lambda)=0$, or $p_E(\downarrow|\lambda)=0$, or $p_F(\downarrow|\lambda)=0$ (30)

As experiment *E* has only two results ↓ and ↑, we have the equivalent statements

$$p_E(\uparrow|\,\lambda)=0\Leftrightarrow p_E(\downarrow|\,\lambda)=1 \quad (31)$$

From (29) - (31) follows, that if $\rho(\lambda)\neq 0$ all four probabilities should be equal either 0, or 1. Hence, for all values λ which are possible actually, results of experiments are completely defined by value λ.

Thus, if we assume that the probability distribution of hidden variables is not influenced by type of experiment yielded over particles we can conclude that just deterministic theories should be considered.

Let's assume that each of two separated particles can be subjected by one of three experiments *A, B,* C, each of which can give only two results ("yes" or "no"). Then in the deterministic local theory the result of experiment *A* with a particle 1 is defined by property of system which we will designate a_1: it is a variable which can take values + and -. We have also similar variables b_1, c_1, a_2, b_2, c_2. We assume now that experiment *A* always gives opposite values for two particles; then $a_1=-a_2$. We will similarly assume that experiments *B* and *C* yield opposite results too for both particles, i.e. $b_1=-b_2$ and $c_1=-c_2$.

Let's consider now particles which are prepared with the fixed probability of values sets *a, b* and *c.*

Suppose *P (a* =1, *b* =1) designates probability that the particle has the specified values *a* and *b*. Then

$$P(b=1, c=-1)=P(a=1, b=1, c=-1)+P(a=-1, b=1, c=-1)\leq P(a=1, b=1)+P(a=-1, c=-1) \quad (32)$$

Hence, when pairs of particles are prepared with opposite values *a, b* and c, we have

P (b_1 = 1, c_2 = 1) ≤ P (a_1=1, b_2 =-1) + P (a_1 =-1, c_2 = 1). (33)

Each item in the right part of this inequality gives probability of result of experiment carried out over various particles; therefore the inequality can be checked even in case when A, B, C experiments cannot be carried out simultaneously over a single particle.

The probabilities calculated according to rules of quantum mechanics in the following case do not satisfy inequality (33). Indeed, we assume that two particles (an electron and a positron) with spin 1/2 are prepared in state with full spin equal to 0; then we know that measuring of a component of a spin in any given direction will yield opposite results for both particles. Let *A*, *B*, *C* designate experiments on measuring of components of a spin along three axes laying in one plane, and let the angle between axes *A* and *B* is equal θ, and the angle between axes *B* and *C* is equal *φ.* We will calculate probability *P* (b_1 *= 1,* c_2 = 1) entering into the left part of the inequality (33); it should be interpreted as probability that both measurings of components of spins of particles 1 and 2 along axes, the angle between which is equal to *φ,* will yield the same outcome +1/2. We take as an axis for a particle 1 axis z; Then if at measuring of a component of a spin of a particle 1 along the specified axis we would obtain value 1/2 after measuring the particle 1 will transfer in an eigenstate | ↑>, and a particle 2 - in an eigenstate | ↓>. Eigenstates of the measuring yielded over a particle 2, are obtained by rotational displacement of states | ↑> and | ↓> on an angle *φ* (we will tell round an axis x); thus, the eigenstate corresponding to an eigenvalue + 1/2, looks like

$$|+(\varphi)\rangle = e^{-i\varphi J_x}\,|\uparrow\rangle = [\cos\left(\tfrac{1}{2}\varphi\right) + 2iJ_x\sin\left(\tfrac{1}{2}\varphi\right)]\,|\uparrow\rangle =$$
$$= \cos\left(\tfrac{1}{2}\varphi\right)|\uparrow\rangle + i\sin\left(\tfrac{1}{2}\varphi\right)|\downarrow\rangle \quad (34)$$

Hence, the required probability is equal to

$P\,(b_1 = 1,\ c_2 = 1) = \frac{1}{2}\,|\langle + (\varphi)\,|\downarrow\rangle|^2 = \frac{1}{2}\sin^2(\frac{1}{2}\varphi)$ (35)

(Since probability of +1/2 for a particle 1 is equal 1/2). It is similarly possible to calculate entering into (33) probabilities

$P\,(a_1 = 1,\ b_2 = -1) = \frac{1}{2}\cos^2(\frac{1}{2}\theta)$

And

$P\,(a_1 = -1,\ c_2 = 1) = \frac{1}{2}\cos^2[\frac{1}{2}(\theta + \varphi)]$.

Thus, the inequality (33) is reduced to an inequality

$\sin^2(\frac{1}{2}\varphi) \le \cos^2(\frac{1}{2}\theta) + \cos^2[\frac{1}{2}(\theta + \varphi)]$,

Or to an inequality

$\cos\theta + \cos\varphi + \cos(\theta + \varphi) \ge -1$, (36)

Which are not fulfilled at $\theta = \varphi = 3\pi/4$. As a result we come to the following theorem.

The theorem 5.8 (Bell's theorem). Let's assume that two separated particle can be subject to one of three two-valued experiments. The same experiment yielded over both particles always yields opposite results. If particles are featured by local theory and experiments does not influence particles properties probability distributions then experiments results probabilities satisfy to an inequality (33).

This inequality is not fulfilled in quantum mechanics for a system of two particles with a spin 1/2, having the full spin equal 0.

Appendix U. de Broglie - Bohm theory of wave-pilot [18].

Typical features of quantum mechanics (in particular, the interference effects) make building-up theory of hidden variables to be a very hard problem. Some time ago the theorem (J. von Neumann) **[15]** seemed to be proved that no theory of such type can reproduce all consequences of quantum mechanics. But this proof appeared erroneous as the following counterexample shows. We will consider a separate simple particle, moving in the potential of V (***r***). We assume, that the particle is featured in an instant *t* not only a wave function ψ (***r***, *t)*, but also some vector q (t), and the wave function satisfies to a usual Schrodinger equations

$$i\hbar\frac{\partial\Psi}{\partial t}=-\frac{\hbar^2}{2m}\Delta\Psi+U(x,y,z)\Psi. \qquad (37)$$

And the vector q satisfies to the equation

$$\frac{dq}{dt}=\frac{j(q,t)}{\rho(q,t)}$$

where j and ρ are density of probability current and probability density:

$$j=\frac{\hbar}{m}\mathrm{Im}\left[\overline{\psi}\nabla\psi\right], \quad \rho=|\psi|^2. \qquad (38)$$

Let's assume now that in instant $t = 0$ it is large number of such particles exists, each of which is featured by the same wave function $\psi\,(r, 0)$, but the different vector q.

Let portion of particles for which value of this vector is in volume dV, containing a point q, is equal to σ(q, 0)dV; let this portion in instant *t* is equal σ (q, *t) dV.* Then, considering q as the particle coordinate, it is possible to consider all collective of particles as fluid with density *σ* and a field of velocities u = j/p according to (37). The last values should satisfy to the equation of continuity

$$\frac{\partial\sigma}{\partial t}+\nabla\cdot(\sigma u)=0 \qquad (39)$$

i.e.

$$\frac{\partial\sigma}{\partial t}=-\nabla\cdot\left(\frac{\sigma j}{\rho}\right) \qquad (40)$$

The equation of continuity has the single solution $\sigma\,(r, t)$ for given $\sigma\,(r, 0)$, $j\,(r, t)$ and $\rho(r, t)$. This equation have solution $\sigma = \rho$. Thus the equation (40) is equation of continuity. It has been shown, that this equation is a consequence of a Schrodinger equations (37). Hence, if distribution of values *q* for particles is featured at $t = 0$ by function ρ it would be characterized by this function at all future instants.

Thus, we can conclude that each particle with wave function satisfied to Schrodinger equations (37) has certain coordinate q in space and any our observational device creating particles with wave function *ψ,* yields particles with certain distribution of their coordinates; the portion of these particles $|\psi(q)|^2dV$ is in volume *dV* near point *q*. It is valid if the observational device creating particles with a wave function ψ, with probability $|\psi(q)|^2dV$ yields particles in volume *dV.* As values ψ and q evolve in time, according to the deterministic equations (37), (38), such distribution will be correct for all instants if it was correct during the initial moment.

It is possible to extend also such theory on systems from several particles, but thus there is one obvious difficulty. We will consider, for example, system of two particles. Variables will be q_1 and q_2, and the two-particle wave function looks like $\psi(r_1, r_2)$. As equations of motion it is necessary to consider a two-particle Schrodinger equation and two equations

$$\frac{dq_1}{dt} = \frac{j_1}{\rho}, \qquad \frac{dq_2}{dt} = \frac{j_2}{\rho},$$

Where

$$j = \frac{\hbar}{m}\mathrm{Im}\left[\overline{\psi}\nabla_1\psi\right], \; j = \frac{\hbar}{m}\mathrm{Im}\left[\overline{\psi}\nabla_2\psi\right], \rho = |\psi|^2.$$

Here j_1 and, consequently, dq_1/dt can be function q_2: motion of the first particle depends on position of the second particle. Thus, there is the instantaneous interaction between two particles, and it should be observed even in that case, when there will be no potential $V(r_1, r_2)$ for interaction between particles. It is the result of correlations between the particles, arising in the formalism of a quantum mechanics operating with wave functions. In particular, wave EPR function shows such correlations between separated particles.

Appendix V. Escher swirl where all levels are crossed. [3]

Figure 28. “Picture gallery” Escher M.K. (lithography 1956)

Extremely beautiful and at the same time strange disturbing illustration of a cyclone "eye" generated by Entangled Hierarchy is given by Escher in his "Picture gallery" (fig. 28). On this lithograph the picture gallery where a young man is figured, looking at a ship pattern in harbour of a small town, maybe Maltese, judging by the architecture, with its turrets, calottes and flat immovable roofs, on one of which a boy sits on the sun; and two floors down some woman - may be mother of this boy - looks from a window of the apartment arranged directly over the picture gallery where there is a young man, looking on a ship pattern in harbour of small town, maybe, Maltese - But that is it!? We have returned again to the same level with which began, though logically it could not happen in any way. Let's draw the diagram of that we see on this pattern (fig. 29):

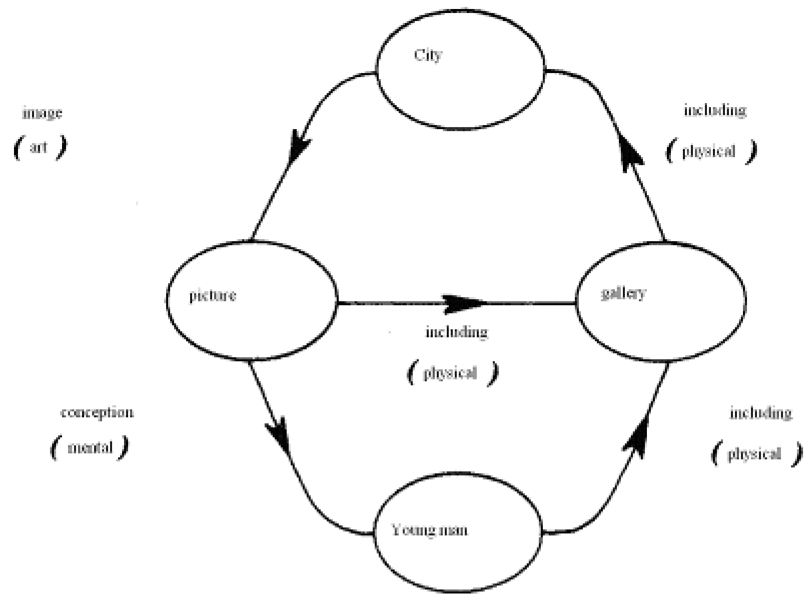

Figure 29. An abstract diagram of Escher's "Picture gallery" (Fig. from [3])

On this diagram three aspects of insertion are shown. The gallery is physically included in a city ("insertion"); the city is artly included in a pattern ("image"); the pattern mentally is included in the person ("representation"). Though this diagram can seem exact, actually it is arbitrary, because amount of the levels shown on it is arbitrary. Other variant of the upper half of diagram (**figure 30**) is presented below:

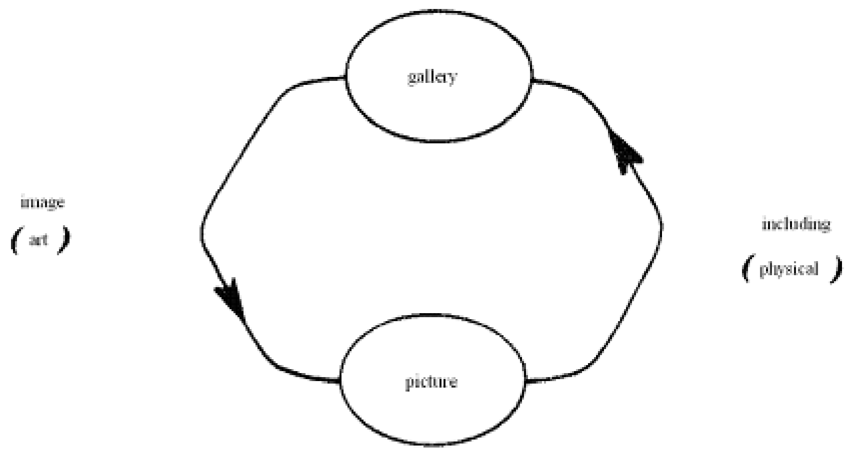

Figure 30. A short version of the previous diagram. (Fig. from [3])

We have cleaned the city level: though conceptually it is useful it is possible not to use it. The Fig. 30 looks the same as the diagram "Drawing hands": it is a two-stage Strange Loop. Dividing signs are arbitrary, though they seem us natural. It is visible more clearly from even more simplified diagram of "Picture gallery":

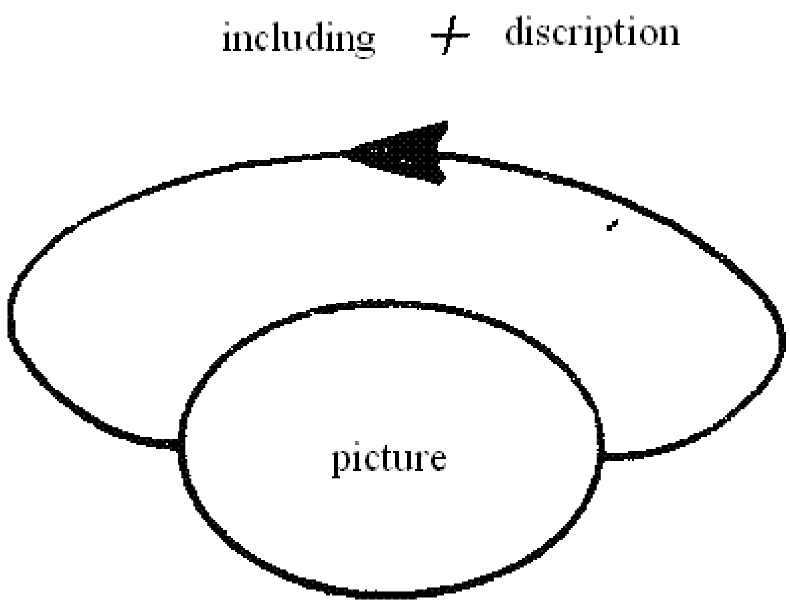

Figure 31. Following shorting of the previous diagram in **figure 29**. (Fig. from [3])

The paradox of a pattern is expressed here in the extremely form. But if the pattern “is included in itself” is the young man “included in itself” too? This problem is answered with **fig. 32**.

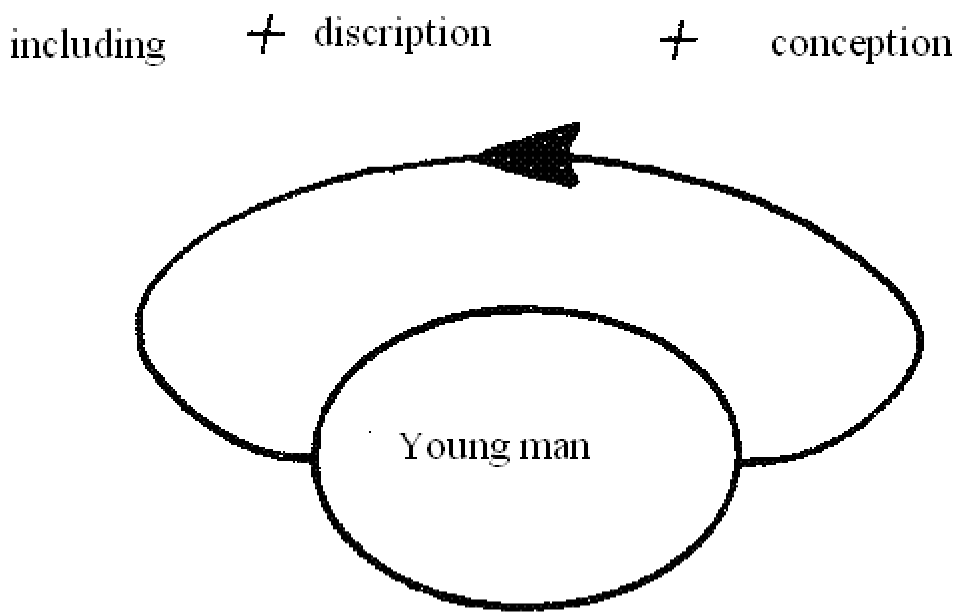

Figure 32. Different shorting of the previous diagram in figure 29. (Fig. from [3])

Here we see the young man in himself, in that sense what is obtained from connection of three aspects of "interior".

Whether there are viewers looking at “Picture gallery”, tightened "in themselves"? Actually, it does not happen. We can avoid this swirl because we are out of system. Looking at the pattern we see things imperceptible for the young man, - for example, Escher’s subscript “MCE” in the central "blind stain". Though this stain seems imperfection, most likely, the imperfection consists in our expectations, as Escher could not finish this fragment of the pattern to conflicting to rules on which he created it. The swirl centre remains - and should remain - incomplete. Escher could make its arbitrarily small, but it could not be saved of it absolutely. Thus, we, while looking outside, see that "Picture gallery" is incomplete, that the young man on the pattern can not see. Here Escher gave an art metaphor of the Gödel Theorem about incompleteness. Therefore Escher and Gödel are so tightly interlaced in my book.

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