Problem of Time in Quantum Theory and General Relativity

A. A. Grib*
Instituto de Matemática, Estatistíca e Computação Científica
IMECC-UNICAMP CP6065
13081-970 Campinas, SP, Brazil

09/01/1999

Abstract

The problems of properties of time and its difference with space in Quantum Theory and Relativity are investigated.

1 Introduction.

The problem of time is one of the basic problems of modern physics. Despite the fact that time plays important role in any physical investigations there are some basic properties of it which are intuitively clear but don't have adequate expression in the physical theory. First of all this is the property of "becoming "! This property is totally absent in mathematical formulation as of classical physics as of the relativity theory. In relativity theory with its understanding of time as the fourth dimension of space-time one naturally comes to the idea of the "block Universe" when all events as well as worldlines are fourdimensionally "given" so that "becoming " is a totally subjective illusion of the human observer(see A .Grunbaum in [1] as the exponent of this idea).

Differently from relativity physics in quantum physics one finds the wave packet collapse procedure, showing that some version of "becoming" really

*e-mail: grib@ime.unicamp.br or grib@friedman.usr.lgu.spb.ru

can be found in Nature. Bell's theorem and breaking of Bell's inequalities in quantum physics strongly oppose any possibility of "preexisting "quantum properties as "beables" in fourdimensional spacetime (see A . A. Grib,W. A. Rodrigues, Jr. [2]). This can be considered as a serious blow to the "block Universe" point of view.

Nevertheless in some versions of quantum gravity when the Wheeler-DeWitt equation for the wave function of the Universe is written we again see "absence of time" problem, and some version of "block Universe" view is reconstructed when time is obtained in quasiclassical approximation. This occurs however because the measurement problem in quantum gravity is not even posited clearly.

In the works of the author [3,4,5] there was developed the quantum logical interpretation of quantum physics where time is introduced as the means for Boolean minded observer to conceive Non Boolean world of quantum physics. Here one finds some place for "becoming ". Time here looks like apriori form of human reason to conceive timeless quantum world. Some special properties of the early Friedmann Universe, for example causal disconnectedness, leading in quantum theory to absence of interferences for different parts of it, make space in early Universe looking like time with it's superselection rule. So one can use the same idea of "booleasation " of the non Boolean world for origination of space as well. This can somehow explain the spacetime unity despite of the ultimate difference between space and time. The other important place where time is seriously "needed " is quantum topology, because at it was shown by the present author in his works with Zapatrin[6,7] even the very existence of quantised topological degrees of freedom can be formulated adequately if one has as minimum two moments of time. So here one can speak about the object which can "exist "only if different moments of time are conceived. This is totally different from the standard situation in physics when usually the system "exists "at one fixed moment of time. This example moves us to another intuitively well known property of time— "duration".

Usually in relativity theory "duration " is misleadingly identified with the "length ", because it is measured by different kinds of "watches" for which some space length is used to measure "duration". But what are properties of "duration"making it different from length? In the so called "histories approach" to quantum physics there is an idea to develop probability theory not for "pointlike events" but for histories as random events. Despite of its advantages for understanding quantum physics are doubtful[2] the very possibility of such a generalisation of probability theory is interesting for our understanding of a history as some “duration”, not reducible to the sequence of events.

The third property of time making it different from space is its “direction” or irreversibility. It “flows” (the meaning of the “flow ” being unclear because of absence of the clear physical description of “becoming”) from the past to future. Intuitively we consider the possibility of “existence” of potentially many futures with one past.

But in histories approach or in the so called Everett-Wheeler interpretation of quantum physics as well as in modern speculations on the possibility of “time machines” one can speak also about “many pasts” existence.

The problem of time’s direction or the “time arrow ” was widely discussed in statistical physics, connected with the entropy behavior as well as in electrodynamics (the difference of advanced and retarded potentials) and cosmology-expansion of the Universe. Time machine problem puts the question of the difference of time from space on the new level. All these topics will be discussed in our research. We shall begin by a short philosophical review, because it seems that many of possible properties of time (if not all) on the verbal level were discussed by this or that philosopher.

2 Some Philosophical Speculations.

In ancient Greece as well as in ancient India time was usually conceived as cyclical. As summer periodically is changed on autumn,winter and spring so different events (but not all!) periodically occur. This idea came from identifying time itself with “measurable time ”. The best way to measure time was to use as watches movement of planets. Therefore an idea was developed that everything moves in time because these primordeal watches-planets periodically move...This idea became a basis for astrology—all events change because of the movement of planets. If planets stop all movement in the Universe will stop and “time itself ” will stop!

This identification of time with “measurable time” is popular in modern physics, first of all in relativity theory.

Today in speculations on quantum cosmolgy a popular idea is that time is a parameter needed to describe the connection between matter and the scale factor—the volume of the Universe. The volume of the Universe, playing the role of an ideal watch, can be identified with time.

Ancient Greeks as well as some Indian thinkers discussed also the possibility of the closed time. Differently from cyclical time here all events will again be realised after some time. This idea was criticised by Aristotelis in his "Politics ". Today we again discuss this idea in general relativity, speaking about closed time loops and the time machine problem.

Indian philosophers paid also much attention to the subjective time and claimed that time "exists " even if not measured by watches. For this they considered some duration perceived in the dream "without dream".

They discussed the idea of "duration " without events as it is experienced in some dreams...

Also in India, mainly in Buddhist schools, the idea of "time as subjective illusion" or illusive flow of karma was developed. Differently from Greeks (like later I. Kant in his philosophy) it was said that time is only some form of cognition of our reason and "objectively " does not exist.

In Judeo-Christian tradition some mixture of objective and subjective notion of time was developed. Differently from Greece and India the idea of linear time, flowing from some Beginning of the world to its End was developed. The idea of creation of the Universe from nothing together with creation of time itself was developed by St. Augustine in the 5-th century[8]. At the same time the idea of Original Sin sometimes is understood as "fallen age "so that the end of this "time "will be the beginning of the "new", not "fallen " age. The other world in Biblical tradition is conceived not as the other "space" but as "other time". This "falling" of time due to some modern Christian theologians (for example, Father Sergius Bulgakov[9]) occurs due to the Sin in our consciousness. This occurs because of the subjective origination of time as a priori form of our reason.

Some Buddhists (shunyavadin sect and some others) claimed that past and future events don't exist at all, only present exists, so that we live in the "flashing "Universe ". Every moment the Universe disappears into nothing and reappears looking similar to what disappeared. Past is nothing, future is nothing, we are surrounded by nothingness, our memories and hopes being illusions. Differently from this view St. Augustine conceived the idea of "existence on the same level of past, present and future", so that one can speak about three "presents"—present of past things, present of present things and present of future things. This idea today is the basis of the *block universe* of relativity theory.

The first man trying to formulate the idea of time in physical terms surely was Isaak Newton. His definition of time is very interesting because he was careful not to mix time with only "measurable time". He said: "Absolute, true and mathematical time or duration flows evenly and equally from its own nature and independant of anything external; relative, apparent and common time is some measure of duration by means of motion (as by the motion of a clock) which is commonly used instead of true time."

So Newton discriminated between absolute time and "common time" or measurable time. The important properties of time are "flow" and "duration". Nevertheless what we measure by watches is "common" time.

Let us discuss shortly some properties of common time. If one describes movement of some body in time one really compares two movements—of the body itself and another body called watches. There are different positions of the body in space; let it be some coordinate X, taking different values $x_{1,}$ x_2, x_3. There are different positions of the pointer Y, taking different values y_1, y_2, y_3. Experimentally we find some function $X(Y)$ and this is the description of the trajectory. But it is known from mathematics that any line can be written in the parametric form, i.e., $X = X(t), Y = Y(t)$ giving description of the same trajectory. So time here is just some parameter, which is not measured as itself. Nevertheless the great mystery is that taking different watches Z, W, etc. and describing movement of the same body comparing it with movements of these different watches one comes to the "unique" parameter t. This uniqueness is manifested in the same region of its definition , i.e., the real line, the same direction of change of values of t—from past to future! All this shows that parametric time as "common time" reflects some properties of the real or absolute time or shortly it proves "existence of time". Here one must make some remarks. What Newton meant, saying that time "flows evenly and equally from its own nature"?

A very important notion for Newton was the notion of the inertial frame, i.e., such complex of bodies forming lengths and watches such that the First law of inertia is valid. Movement of any body in this frame is inertial if there are no forces. This means that the acceleration $\frac{d^2X}{dt^2} = 0.$. Following Newton's idea about "even and equal flow" of time itself one can discriminate between "correct" watches and "incorrect" ones. Incorrect watches are such that the law of inertia is not valid, i.e., one has acceleration inspite of lack of forces. To give the idea let us have for some frame the inertia law, i.e.,

$$\frac{d^2X}{dt^2} = 0.$$

Then take other watches measuring new $T = f(t)$, such that

$$\frac{d^2T}{dt^2} \neq 0$$

Then,

$$\frac{d^2X}{dT^2} = \frac{d}{dT}(\frac{dX}{dT}) = \frac{dX}{dt}\frac{d^2t}{dT^2} + \frac{d^2X}{dt^2}(\frac{dt}{dT})^2$$

so that,

$$\frac{d^2X}{dT^2} = \frac{dX}{dt}\frac{d^2t}{dT^2},$$

i.e., new fictive forces occur because of use of "noncorrect" watches. But why are they incorrect? It seems that they don't simulate the property of "even and equal" flow. This property becomes very important in special and general relativity where time is very strongly identified with "measurable time ". Then if one compares two world lines—one straight, describing inertial observer, the other curved, describing movement with constant acceleration, using so called Rindler coordinates one can ask about "time flow" for these two. Proper time for the noninertial observer will correspond just to some $T(t)$ in our example. But according to Einstein's relativity "absolute" Newtonian time does not exist. Then for noninertial movement "noncorrect" watches become correct, describing correctly processes in proper time. When compared with inertial movement "fictitious" forces will lead to observable difference—so called Unruh effect—virtual particle creation which nevertheless can become real Rindler particles for the accelerated counter of particles. This shows "manyfaced" time of relativity, which differently from Newtonian can "flow" differently, not only "evenly and equally".

To end the part let us say some words about Leibnitz position who opposed the idea of existence of absolute time and claimed that time doesn't exist without objects and is the description of changes in objects.If it is so then there is no difference between "common "or "measurable "time and time itself.This was the first relativistic view on time.Time describes "relation "between objects and doesn 't exist without them.Must there be unique time ,describing relations between different objects? In modern relativity we see,that it is not the case.

Different "time flaws" for inertial and noninertial movements of objects are real on the same footing...

Newton's idea of time being put into the equations of mathematical physics led to progress in formulating deterministic mechanics and the so called Laplace determinism principle.Due to this principle,knowing Cauchy data at some moment of time and equations of motion one can predict properties of the system at any moment of time.From this point of view there is no "becoming ",all is given initially,or all information is given at the fixed moment of time.In a sense this looks as total neglect of real time which intuitively has to do with becoming and appearance of something "new "and after all new information which in principle can't be obtained without "existence" of different moments of time or "duration"!

The strong opponent of the relativistic— "spatial "and deterministic view on time was the French philosopher H.Bergson, who claimed that time is first of all duration and creation and that it is primary to matter, i.e.objectivistic, so that one must obtain material "objects" from time...Some neorealist intuitivistic philosophers, like Moore, S. Alexander and N. Lossky tried to connect time with "world consciousness" trying to explain cognition by participation of all conscious observers in the universal consiousness which is some property of time in which all objects exist and this is the reason why we can cognise them at all...

Differently from intuitivists adherents of I. Kant's critical realism claim time to be "a priori form" of the human reason and not existing without human beings at all!

3 Time in Classical Mechanics and Statistical Physics. The Problem of Irreversibility of Time.

The principles of Newtonian mechanics were realized in the equations of mechanics, and these are all totally reversible in time. In statistical mechanics putting the idea of probability for description of ensembles of particles governed by laws of reversible in time mechanics Boltzmann obtained irreversible in time Boltzmann equation and was one of the first to claim that the direction of time from past to future is governed by the Second Principle of thermodynamics.From this point of view the "past "is some ordered state,the future is more disordered state with larger value of the entropy.This point was criticised by the inventor of the idea of "arrow of time", A. Eddington. He said that our primitive idea "before "- "after " is not identical to "order"- "disorder" idea[10]. Often we have more order "after "... Loshmidt, Poincaré and others discussed the problem claiming that if the system is a closed one, then the most probable is the equilibrium disordered state with large entropy.The ordered state can occur only due to some fluctuation .But then, the system occurs like at the bottom of the canyon-both directions: to future and past lead to higher entropy! If direction of time is direction to higher entropy, then why we do not see in the world as many systems with one direction of time as with the other?

Even if one direction of time is chosen for some system due to the Poincaré reccurrence theorem the system after some recovery time will necessarily come to the same ordered state. Nevertheless this recovery time occurs very large for ensembles with large number of particles .Sometimes this is conceived as some answer, but as we explained before this does not answer the question of the preference of one direction in time to the other...

The proof of validity of irreversible in time Boltzmann's kinetic equation is based on the hypothesis of the "molecular chaos ", which puts time direction by hand to reversible in time equations of classical mechanics .One can put this hypothesis in backward in time direction and then we shall obtain other direction in time as the preferable one...All considerations using probability theory for ensembles, each particle of which is described by reversible in time equations,also put by hand the distinction between "unknown" future and "known" past , so supposing the time arrow.

There is also the so called "branching" idea, claiming that ordered initial state is obtained due to "intervention" of some external object to the system or branching of the system from the larger one. The system being "prepared" in the ordered state then evolves into more disordered one following the Second Law of thermodynamics. For example the stone was thrown to the pond-nonequilibrium state of water was formed, "after" water comes to equilibrium. A good question to this explanation of irreversibility in time is asked by Sklar[10]. Why for all observable branching systems we see "the same "direction in time, but not one for one system, the opposite for the other? The same "direction " is especially strange if the systems are on the spacelike distance one from the other...And we know from cosmology that in Friedmann Universe there were many causally disconnected parts:why time must have the same direction in them?

So we agree with Sklar and other researchers of the problem of time irreversibility that the problem is not solved neither in classical nor in statistical mechanics!

Let us discuss shortly properties of time in classical physics. Despite of Newton's discrimination between absolute and measurable time we have time as parameter in equations of classical physics. Such properties as "becoming", the difference between "before" and "after " are not described in this science at all. Time is understood as not connected with space, so that the time axis together with three space directions, being dimensions of the space, does not form any four dimensional space-time. It is possible even to consider here the "flash Universe " idea of buddhists-every moment the Universe disappears to nothing, but all information is contained at fixed "present moment" in Cauchy data and equations. There is no need for future for a "wise" mind who has all information about the Universe at present because nothing "new " can become in such a Universe.

The moving "now "in such a Universe does not lead to new information, because logically everything is contained at the fixed moment. Why not one but many different moments of time exist in the Universe? There is no answer to this question.

The other alternative, i.e., that of the "block Newtonian universe" is also possible. Present, past and future events exist equally and there is no substantial difference between them.

Maxwell equations as well as wave equation for the vector potential are also reversible in time. It is well known that Maxwell equations have two types of solutions—so called advanced and retarded potentials. Retarded potentials describe radiation coming from the source in the past while advanced potentials describe radiation coming from the future. Usually so called causality condition is put by hand, saying that only retarded potentials have physical sense. This leads to time irreversibility due to initial but not final conditions.

Unsatisfied by this "by hand " condition Wheeler an Feynman tried to formulate symmetric electrodynamics where both types of potentials are present[11]. They were lucky to show that if one considers a charge in the spherically symmetric cavity with absorbing surface then looking for radiation of this charge it occurs the phenomenon of destructive interference for advanced potentials produced by the surface and the charge itself. So in the result one can observe only retarded potentials which is really the case. So here we see the possibility to "explain" time asymmetry by space symmetry leading to mutual annihilation of some possible solutions in time symmetric electrodynamics. Nevertheless it is easy to see that any breaking of the spherical symmetry of the absorbing surface will lead to appearance of advanced potentials, their role being the larger,the larger is the breaking of symmetry (exact calculations for ellipsoidal surface were made by the pupil of the author V.Gutin (LFEI 1988, in Russian). However experimentally we do not see any effect of this type of actions from the future due to advanced waves (see [12]).

Following Wheeler and Feynman some authors tried to look for radiation of the charge in the spherically symmetric expanding Universe, claiming that "particle horizons " in such a Universe can play the role of Wheeler Feynman's absorbing sphere. But the results are not much convincing,the problem still is not quite solved.

4 Time in Special and General Relativity.

It seems as if in special and general Relativity theory one fully realized Leibnitz idea of relational time-absolute time does not exist, time is some relation between objects:one called the reference frame, the other—observed object. Then it is easy to understand that if one of the objects is described by the other measurable parameter-if one changed the velocity of the reference frame in special relativity or the acceleration of this frame in general relativity-time will behave differently! So Lorentz change of the time interval can be understood if time is relation! Nevertheless there is a principle of "existence " of absolute fourdimensional space-time which can exist without any objects, so here we still have Newtonian "empty " spacetime. Being just one of the dimensions of this universal spacetime time totally lacks its major property of "becoming" or "flow ". Its properties are not different from space dimensions. The only formal difference is the "wrong " sign in the signature of the metrical tensor, making the space pseudoeuclidean. One of the mathematical possibilities is describing time dimension by imaginary numbers. This possibility shows a very serious problem with time, because physically we cannot measure anything in imaginary numbers—such apparata do not exist! This again is the manifestation of some mystery about time—it can be measured by spatial watches, which really measure not *time* but the *space* interval.

However to have "watches "one must have one to one correspondence between "time" axis and space intervals for watches. If there was only one reference frame and objects were at rest in this frame one could not "see" any time—it could not be measured, being expressed only in imaginary numbers.Very important is the notion of "proper time ". In order to measure by watches such a time for some process in the system where the object is at rest the “pointer ” of watches must still move, in other case it will show nothing! For accelerated observer the “relation” which is time is measured by “spoiled” or “noncorrect” watches in the Newtonian sense.

Unfortunately it is impossible to express in the Relativity theory such properties of time as “becoming and duration” as well as “change”. Nevertheless if one has together with Newton the idea of existence of some “absolute ”time, different from “measurable ” time one can get from the Relativity theory some new insights on properties of time.

1. Such measurable property of time as “simultaneity ” is dependent on the reference frame. It is “changed” (the idea of “change” surely being connected with nonmeasurable absolute time)with the “change ”of the reference frame. Formally “change ”of the reference frame is described by the Lorentz rotation in space-time.

2. Time is “multifaced”—it manifests itself in many “measurable” times existence—there are as many different times as there are different reference frames. Nevertheless inertial reference frames have some preference to noninertial ones:noninertial reference frames are “incomplete” in Minkowski spacetime, one cannot describe consistently in them all events in spacetime .It is well known that in noninertial reference frames lines of simultaneity can intersect in Minkowski spacetime and one cannot unambiguously give some value for time in such cases. Noninertial reference frames however as it is believed can describe some parts of the whole spacetime and in any case proper time for the noninertially moving system describes correctly properties of the “absolute ” time. This is proved by the experiments with the “twin ” paradox, when it was shown that the radioactive nuclei being accelerated have different life-time than those unaccelerated.

3.One can say that “flow ”of time is different, because of different “measured ” time for different inertial frames, which is demonstrated by different life-time of elementary particles moving with different velocities.

This “flow ” of time is different in regions with different gravitational fields, manifested in the redshift on the Sun effect. One can revert the argument[13] and say that gravitational field itself is just the manifestation of different properties of time and its “flow ” in different points of “measurable” space and time. Well known Schwartzshild solution, as well as cosmological expansion, can be described in this language. In the latter case one must use so called conformal coordinates. If time “flows” differently in different points of space one describes all effects given by the first solution, if it “flows” differently at different moments of time, the difference being manifested through the time dependence of the scale factor, one describes cosmological expansion.

4. Lines of time can have "cuts", called singularities. These singularities occur inside black holes and in cosmology—at the beginning and probably at the end of the Universe. Also they can occur in "cosmic strings ".

These are properties of "measurable" time. General relativity also makes probable "end " of "measurable" time at any moment of time, the Big Crunch singularity being only the maximal solution [14].

However all these words about "flow " of time are metaphoric ones in Relativity theory. To express the "flow ", for example, in cosmology, one must use two different times— the conformal one and the synchronous other.

Write the interval for the Friedmann Universe as

$$ds^2 = a^2(\eta)(d\eta^2 - dl^2) = c^2dt^2 - a^2(t)dl^2.$$

To different values of η correspond different values of t and vice versa, the "flow " being described by the Hubble's constant

$$H = \frac{da(\eta)}{d\eta}/a^2(\eta) = \frac{da(t)}{dt}/a(t)$$

Nevertheless one of these times must "change " in order for the other to "flow " differently, but why it must "change"? Why we must "move" in time, if this movement is not described by geometry of the Relativity theory.

5 Time in Quantum Physics.

In quantum physics time is involved in two different ways; one is the same deterministic way as in classical physics using Schrödinger equation. The other is the totally *new* indeterministic wave packet collapse. It is the second type of change of the wave function which shows that quantum physics can say something new on time.

1.The time evolution of the state vector $|\Psi(t)>$which describes the state of the given system at time t is causal (and linear) if the system is not subjected to any measurement by some observer. More precisely, this means that from

$$|\Psi(t_0) = \sum_{i=1}^{n} c_i|\Psi_i(t_0)>,$$

we can calculate

$$|\Psi(t)>=\sum_{i=1}^{n} c_i|\Psi_i(t)>.$$

The evolution is given by the linear Schrödinger equation

$$H|\Psi(t)>=ih\frac{d|\Psi(t)>}{dt}$$

where H is an Hermitean operator called the Hamiltonian. When it does not depend on time we have,

$$|\Psi(t)>=\exp[\frac{-i}{h}H(t-t_0)]|\Psi(t_0)>.$$

The norm of the state vector $|\Psi(t)>$ is of course conserved for all time t because the evolution operator

$$U(t,t_0)=\exp[\frac{-i}{h}H(t-t_0)],$$

is unitary.

2. Postulate of wave function collapse (or reduction of the state vector).

When we measure a given observable A ,a system with state vector$|\Psi(t)>$jumps indeterministically into one of the eigenvectors of the operator A. If

$$A|u_{n>}=a_n|u_n>$$

then

$$|\Psi>\longrightarrow|u_{n>}$$

The probabilty for $|\Psi>=\sum c_m|u_m>\longrightarrow|u_n>$ is given by

$$W_n=|<u_n|\Psi>|^2=|c_n|^2$$

Following some ideas of his teacher—Professor V. A. Fock— the author developed in his works the so called quantum logical interpretation of quantum physics[3]. The departure point was Fock's idea that differently from Schrödinger evolution, describing some physical interactions, the wave packet collapse change of the wave function is a "logical operation". 'Trying to find a good description for this, the author came to the idea that this is a "translation " from one non Boolean logical structure to the other Boolean logical language. And this translation is possible only if different moments of time exist and the translater himself—observer using Boolean logic or classical language (as N. Bohr insisted)—is moving in time! So here, time plays crucially new role—without time, if only one fixed moment existed, it is impossible to conceive the quantum system with its complementary properties described by noncommuting operators in Hilbert space. Observer himself being the quantum system consisting of many atoms can realize himself as self-observing one only moving in time!

To do it formally let us follow the description given in our book with W. A. Rodrigues Jr [2]. Take the quantum system of spin 1 for which two noncommuting observables-projections on two different axises are measured and consider the so called Hasse diagram for it (see the book [2]) describing the quantum logical lattice of "yes-no "questions. There are six logical atoms for it corresponding to 6 values of possible spin projections—3 for one projection and 3 for the other. The corresponding "yes-no" properties are considered as exclusive, i.e., for "conjunction"$\wedge$ one has,

$$1 \wedge 2 = 1 \wedge 3... = 1 \wedge 6 = 2 \wedge 3 = .. = 5 \wedge 6 = 0,$$

where 0 is always the $false$ element. The structure of this quantum logical lattice is such that if one introduces "disjunction" $\vee$ the lattice consists of two parts corresponding to complementary properties of two different spin porojections, so that for any two from them one has

$$3 \vee 4 = 2 \vee 5 = 1 \vee 6 = ... = I,$$

where I is always $true$. It is easy to see that the lattice is nondistributive. Indeed,

$$1 \wedge (3 \vee 4) = 1 \wedge I = 1 \neq (1 \wedge 3) \vee (1 \wedge 4) = 0 \wedge 0 = 0.$$

It follows that for a nondistributive lattice we cannot define the classical probability measure. Instead, we must use the so called probability amplitude represented by the wave function. To each element of our lattice corresponds some projector P_L and if $|\Psi>$, the state vector is known, we can define

$$\mu(L) =< \Psi|P_L|\Psi >,$$

as giving the probabilities according to Born's rule for a yes answer concerning the property L.

As it is easy to see there are distributive triplets $(1,2,3),(4,5,6)$. For them it holds

$$\begin{aligned} 1 \wedge (2 \vee 3) &= (1 \wedge 2) \vee (1 \wedge 3), \\ 4 \wedge (5 \vee 6) &= (4 \wedge 5) \vee (4 \wedge 6). \end{aligned}$$

It is only if we take one of the atoms from the left side and the other from the right side, that we get nondistributivity. To the elements of sets for which the distributivity law does not hold there correspond noncommuting operators in the Hilbert space of the quantum system. To elements of the set for which distributivity law holds, there correspond commuting operators.To atoms 1,2,3 correspond $S_z = +1, 0, -1$, to the atoms 4,5,6 correspond $S_x = +1, 0, -1$.

The role of observer in quantum logical interpretation is inferred from the inadequacy between his Boolean distributive logic which is materialized in the measuring device used by him and the non Boolean logic of the quantum world.The result of this inadequacy is the wave packet collapse.

Indeed the non Boolean nondistributive lattice is not isomorphic to the Boolean logic of the observer.The conscious observer solved the problem of the adequation of the Boolean structure of his logic and the non Boolean logic of a large class of phenomena occuring outside his mind.How? By inventing a special relation for these phenomena—*time*.

Let us see how with invention of time any contradiction that an observer might find between his Boolean logic and the non Boolean world disappears.

Referring again to our very simple quantum system described by the Hasse diagram for spin 1 system we observe the following.

For the Boolean observer if 1 is true and due to the structure of the Hasse diagram it is equal to $1 \wedge (4 \vee 5 \vee 6) = 1$, then $(4 \vee 5 \vee 6)$, being true due to Boolean structure of his logic needs *either* 4 *or* 5 *or* 6, must be true. In non Boolean logic it is possible to have $4\ false, 5\ false, 6\ false$ but nevertheless $(4 \vee 5 \vee 6)\ true$.

But for the Boolean observer this is impossible! So he will say that at some $moment\ of\ time$ one of the 4,5,6 (totally undetermined, and this is the source of quantum indeterminism) *becomes* true!. So, becoming or $movement\ in\ time$ appears because of the difference of the two logics!

An observer always measures noncommuting observables at $different$ moments of time and it is impossible for him to get information about them simultaneously.

We can consider this profound difference in the logical structures of the quantum world and the logic of our consciousness as the reason why we as human beings always move in time to the future while in space we can be at rest in a given point.This happens only due to the fact that the observer can identify himself as some union of a Boolean consciousness and a material body due to the *principle of the psychophysical parallelism* only if he is *moving in time*!

To the Boolean sublattices of the non Boolean lattice the observer can give the interpretation in terms of events in Minkowski spacetime.

According to the quantum logical interpretation a quantum object is then to be identified with a nondistributive lattice of its properties (qualities) and it is not supposed as existing in spacetime. $Yes - no$ values are given to the elements of this lattice by a Boolean observer and they change in time according to the wave packet collapse rule. So the lattice itself describes only some *objective potentialities* which are actualized as *events* due to observation.The *birth of time* is a necessity for the observer if he desires to make his internal logic adequate for the logic of the phenomena that are outside of his mind. But in doing so, a *Boolean consciousness* duplicates the lattice or makes anothe r*copy* of it. It becomes necessary for it to construct a new Hilbert space with *superselection rule* due to time. For $t_1$we have the Hilbert space H_{t1}, for $t_2$we have H_{t2}.

Then one constructs the direct sum of Hilbert spaces $H_{t1} \oplus H_{t2}$. Now, it is easy to put in this direct sum one to one correspondence between noncommuting operators S_z, S_x and commuting operators S_z^1, S_x^2 acting nontrivially in $H_{t1,}H_{t2}$. Let us call this *doubling* or *copying* procedure *the Booleazation procedure.*

Time is not *operator of time* here but just some parameter to discriminate copies of the same quantum object as the quantum logical lattice.There are no superpositions of states for different moments of time and this is the meaning of the *superselection* rule.

Now let us make some remarks to this simple example.

1. As we said previously there are distributive triples in our lattice. That is why the observer in his use of time must consider at the next moment all possibilities forming as in standard probability theory the full set of events, i.e., if 1 *is true* for t_1, then for t_2 it is not only one or two potentialities from the other triple can become true, but all of them must be considered. This corresponds to taking complete set of eigenfunctions of the non commuting

operator measured at the next moment of time.

2. For the quantum object with infinite number of different nondistributive triples corresponding to infinite number of noncommuting operators (which is the case for the spin 1 system with all different projections of spin) Boolean observer must use infinite number of different values of the time parameter.

3. Let us go back to the ancient Greece idea about the existence of "ideal watches", movement of which is the reason for any other change in time. Remind that for Greeks it was rotation of planets which was the cause of all movement in the world.Now we can say that these ideal watches are quantum watches. This means that if one takes different values of different spin projections of the quantum system as meaning different moments of time, than any *movement* or change in time can be expressed as the dependence of the position of the body in space for example X on this parameter S_α, i.e $X(S_\alpha)$. As we explained before, Boolean observer must *move* in time in order to identify himself as consciousness and as the material body constituting one quantum object *having* all its properties *at once*. As in our previous discussion of the Newtonian time the dependence $X(S_\alpha)$ can be expressed in the parametric form $X = X(t)$, $S = S_\alpha(t)$.

4. One can ask the question: why our consciousness is Boolean and what can be the definition of apparatuses used by Boolean mind making them different from other quantum objects?

There are two basic features of consciousness which can somehow give an answer to this question . The first is its "introspection" feature, mentioned by London and Bauer in their investigation of the problem of measurement in quantum physics[15]. The second feature is the necessity of the division on the "subject" and "object"for any cognition which leads to the so called "decoherence" effect— to the appearance of the preferable basis of commutative observables for the observer, leading to his (her) classical behaviour.

a) F.London and E.Bauer in their book [15] described the process of measurement as getting information by some observer in the following manner.Consider a system composed from the quantum particle,macroscopic apparatus and conscious observer as described by some wave functions.During the measurement process one has some special evolution due to the von Neumann "measurement interaction Hamiltonian" so that the initial wave function develops in time as

$$\Psi_q(x)\Psi_{app.}(y)\Psi_0(z) \longrightarrow \Psi = \sum_n C_n u_n(x) v_n(y) w_n(z)$$

where $u_{n(}x), n = 0, 1, 2...,$ are eigenfunctions of the operator A so that

$$Au_n = \lambda_n u_n,$$

and

$$\Psi_q(x) = \sum_n C_n u_n(x).$$

Here $\Psi_q(x)$ is the wave function of the quantum system,$\Psi_{app.}(y)$ is the wave function of the apparatus, $\Psi_0(z)$ the wave function of the observer. Same interpretation is given for $u_n(x), v_n(y), w_n(z)$.

The observer in the result of evolution is described by some density matrix. This density matrix is nevertheless not a mixture of states, i.e., when the system with some probability is in some pure state. If the observer's density matrix was a mixture then the the wave function of the whole sysrem could not be in a pure state which is the case, but also in a mixture .But it is due to specific properties of consciousness that the pure state "becomes" a mixture. According to London and Bauer the main characteristic of consciousness is introspection—taking account of what one is conscious of. Being conscious means that "I know that I know "—I am conscious of my subjective state, discriminate between "true" and "false " (as we shall add here to London and Bauer). London and Bauer put the hypothesis that this means that a conscious observer go from the density matrix when nothing is certain to a mixture when some pure state and "certainty " due to it appears. Then the next feature of consciousness is manifested—it "recognises " this pure state giving "ignorance interpretation " to the mixture. All this according to our "quantum logical interpretation" means that it is consciousness which gives "yes-no" values to properties of the quantum object.

b) Much popular in all investigations on foundations of quantum physics is the so called "decoherence approach " of R. Feynman,W. Zurek, R. Omnes[57] and others. According to it, one can divide any quantum system on the "system itself " and "environment". If one chooses some special collective variables describing "the system itself",then tracing(i.e.doing a well specified mathematical procedure for averaging over properties of the "environment" which are not being observed) over “environment”one finds that for an environment large enough the density matrix for our “system” (subsystem of the whole—“our system + environment”) becomes diagonal in the chosen basis of collective variables very rapidly in time. Its diagonality is interpreted as the density matrix for a mixture.The adherents of the “decoherence” approach try to solve the problem of “classical apparutuses” without speaking about “consciousness” by this “ad hoc” identification of the diagonal density matrix with a mixture. The mistake here, noticed by many opponents of the approach is that it contradicts the pure state description of the whole system of which our apparatus is the subsystem. So one must agree with D 'Espagnat[16] who stressed the necessity of going from the density matrix of the subsystem to the mixture in the measurement process even if the density matrix is diagonal! And here we again must remember London and Bauer's introspection. So “apparatus” or the “system” described by collective variables must have contact with “consciousness ”.

Another criticism of the approach was due to J .Bell who said the following[17]: “What is it in the big system saying : please divide me on the *system itself* and *environment* and trace over *environment*”? ”

To this criticism of J. Bell we can answer: it is “me ” as an observer who makes the above decision. To “observe ” means that I “divide” the whole world on “me” as totally “distinct” from what I observe—my “environment”. This is the well known division on the “subject” and “object” of cognition. So decoherence effect can explain how consciousness can make a choice of a preferable basis in Hilbert space, i.e., that corresponding to collective variables of the body of the observer. The density matrix of the observer's body becomes diagonalised very rapidly in time and some pure state is identified as the state of consciousness. Interference terms due to diagonality of the matrix are not checked by consciousness, so deterministic classical evolution of collective variables becomes possible. Classical determinism is necessary for the existence of “memory” for consciousness. So only some commuting observables with classical description of their evolution become possible for direct observation and this solves the problem : why our consciousness is described by Boolean logic, while the whole world is not Boolean!

Now let us give the definition of the “apparutus” in quantum physics.

Definition: “Apparatu ” is a quantum system which gives to the observer the possibility to get information about some commutative set of observables of another system, called “quantum object ”. This implies the necessity of a special form of interaction between apparatus and the observed system—

measurement interaction of the von Neumann type and coupling to the collective observables of the observer body himself. Despite of the fact that apparatus being a quantum system is described by some nondistributive lattice, the observer uses only some distributive part of this systemsince he is interested to get information at the fixed moment of time about only one of the complementary properties of the quantum object. Apparatus can be as “large” as a bubble chamber, or as small as a atom of silver in a Stern-Gerlach experiment. It is not “largeness” or “macroscopicity ” of the system which makes quantum system an “apparatus” but its use by a concious observer that needs information expressed in terms of Boolean logic.

c) *Principle of the physico-psychological parallelism.* This principle in psychology and neuroscience says that to any psychological process corresponds some physical process in the body. Von Neumann proposed to formulate this principle in the theory of quantum measurement as the principle of the “moving frontier” between observer and the observed object. Despite of the idea that it is consciousness which makes the wave packet collapse of the wave function and gives “truth” values to observables it is always possible to include in “observer ” any apparatus used by him to get information about the quantum object. From this point of view any apparatus is some “extension” of the observer like spectacles are extension of the human eye...Observer giving truth values, gives them not only to properties “now” but also to the “past” if this “past ” by retrodiction is determined due to classical logic and classical determinism by the present. Due to von Neumann principle the whole description of getting information by the observer is organised in such a manner that it is always possible to put the frontier between the observer and the observed at any place. For example if the atom is observed by some microscope, then it is possible to describe the atom plus microscope as some quantum system with noncommutative observables and the frontier goes between the microscope and eyes of the observer, so that wave packet collapse occurs in the eye...But because in getting information only some special commuting properties of the microscope are used it is possible to have other description giving the same results for the observer, when wave packet collapse occurs in the microscope. One can also say that the eye is also the quantum system and then the frontier “observer-observed ” goes inside the brain, etc. It is important that the frontier can be moved as in space as in time—so it is always possible to say that our apparatuses showed something definite even “before” the human observer looked on them. This “before” is defined by the conscious observer due to the possibility to connect his “yes-no" values now with some properties in the past classically determined by retrodiction. That is why human observer can discuss quantum properties of objects many millions years before the appearance of the biological body of the observer himself!

Questions: *If consciousness plays so important role in the world, that it gives truth values to physical properties and without it only potentialities forming quantum logical lattice exist, is it only human consciousness or it is something more? Dogs also give truth values to potentialities?*

There can be different answers for these questions.

The first "idealistic" answer corresponds to the idea of the idealistic philosophy "that subject of cognition is always one and the notion of number don't work for the subject of cognition" (see for example A.Schopenhauer in his "*The World as Will and Representation*"). It is easy to see from this idea, why different observers give the same truth values to potentialities and we see "one"objective world. This is formulated as the so called *Wigner's friend paradox*.Why, if the quantum system is observed by two persons—one being Wigner and the other being his friend— both give the same truth values for potentialities and not different ones? Really, it is impossible to say that different persons see the same physical world because it is "objectively" the same...But if there is only one "ultimate subject" manifested in the cognising person surely there will be one world. Similar to this is the idea of "one" universal consciousness in which participate different human beings when cognising anything about the world. However we think there is another possibility to solve Wigner's friend paradox taking into account our idea of the role of time in quantum logic. For this, let us take into account that if "movement" in time is necessary to observe non Boolean structure for a Boolean minded observer, then quantum logical lattice can serve as "clocks". The system is "prepare " at one moment of time t_0 and after it some value of the noncommuting observable is obtained which corresponds to the other moment of time t_1. If Wigner's friend will see other value of the noncommuting observable he will give to it another value of the time parametert_2. Simultaneously both observers cannot see different values of the same observable. If they see it simultaneously they both give the observable the same truth value. If they give different values to it, then one must say that they will see it at different moments of time! Boolean logic, valid for commuting operators (classical determinism making possible prediction for its values at other time) and von Neumann's principle of measurements of the first kind, saying that if the system is in some eigenstate of the observable operator, then in the next moment of time one will see the same value of it if the same measurement is made, prevent the possibility for the second observer to have other value at the next moment of time than that of the first obsever. So the only possibility occurs when the same quantum system is copied as prepared at the other moment of time and then the second observer makes his measurement of the noncommuting observable with anothe value. But this does not contradict anything observed.

Concerning the question about animal consciousness, dogs in the degree that they get information also participate in using Boolean logic to comprehend non Boolean world.

Another idea is to speculate about the origin of life, and to understand the difference between inanimate object and an animate one as the difference between quantum objects and measuring apparatuses.What is general for alive creatures and measuring apparata in quantum physics?

1. A living object is "opposed" from everything else which is defined by him as the "environment ". It is due to this opposition that Darwinian evolution with its natural selection and struggle for existence occur...Nothing of this kind exists in the inanimate world (for example there is no Darwinian evolution for cristalls...).

2. A living object deals with "information" about the environment, being in this respect very close to the measuring apparatus in quantum physics. Important role is played by the information about the living creature itself which is the genetic code. For this, differently from everything else in Nature, the living creature uses three manipulations: (a) writing this information in symbolic form, (b) storing it, (c) reading it to reproduce the organism.

This information is written and symbolised in terms of Boolean logic, desspite the fact that of organic molecules are quantum objects.

3. If any living object is some "measuring apparatus " in the quantum sense one can understand "spontaneous" activity of this organism as well as the necessity of "movement in time" for it to exist. The phenomenon of the "free will" can be understood as identical with quantum indeterminism and from the point of view of our analogy the living organism is a "self measuring"quantum object !

4. The nonliving quantum Universe is defined relative to living creatures which use their Boolean logic to get, to store and to read information about it and other organisms in it. The definitions of space, time, irreversibility of time, etc., are given by these organisms and don't have or have totally different sense without them. If one speaks about something "before" origination

of life, this "before" has no other sense, than deterministically contained in the "present " of the living organism and prolonged to the "past " by classical physical laws. As we explained before in classical physics due to the Laplacian determinism all information is contained at any present moment.

Despite our idea that the living organism makes measurements of different noncommuting obsevables at different moments of time, it stores this information in some classically defined "memory". It is easy to understand that all information could be "erased" and no memory could exist at all , if quantum system with its noncommuting observables was used.

So, does Bohr's division of all objects in Nature on quantum objects and measuring apparatuses reflects the division of matter on the living and nonliving ones?

Can this form of Copenhagen interpretation in which consciousness plays an important role be useful for understanding other (different from the physical ones) phenomena?

We think that the answer is positive. As the author discussed it earlier[18,19]:

a) rare telepathic phenomena can be understood as realising *EPR* situation when consciousness itself like in London and Bauer example is described by the wave function. Absence of telepathy and information transfer in Aspect and others experiment occurs because of the necessity of using apparatuses as intermediate between consciousness of the observer and the quantum particle. If in "passive" (when no question about one state is asked) state just the wave function of consciousness is registrated as it is (without wave packet collapse which occurs in active relation to one's state), then it is trivial to see the possibility of telepathic communication.

b) Quantum teleportation effects, when the wave function of some external object is teleported to the other object, which can be located inside human brain or elsewhere inside the body can give new insights for the possibility of our cognition of external objects. In this case, one can claim that we cognise not only "images" external objects inside our brain (like on the TV screen). The idea is that due to teleportation properties of external objects a conscious observer perceive them as they "are ". Thus, it seems that the nonlocality of quantum physics can play a important role in the theory of cognition.

To finish this part, let us stress again that quantum physics, saying that "objectively" only potentialities exist, strongly opposes the view of "tenseless" existence of events in spacetime. This view, manifested by some philosophers of science as well as by some mathematical logicians supposes a relational theory of time where this concept is used just to express relations between events which exist objectively. A serious challenge to this view was made by the Gleason's theorem (see[2]), which shows nonexistence of "truth functions" for quantum properties. So it is wrong to speak about any existence of quantum events in future without relation to an observation!

5.1 The Problem of the Time Operator in Quantum Mechanics.

Differently from space, time in quantum physics is only a parameter or a coordinate. Space in quantum physics is represented in two different ways. One manifestation of space is the coordinate dependence. For example, in quantum field theory one can measure local observables—the operator of the stress-energy tensor, depending on the local quantised field $T_{\alpha\beta}(\varphi)$ and express these also as $T_{\alpha\beta}(x, y, z)$, $\varphi(x, y, z)$. Understanding these coordinates as describiing points belonging to some metrical space with a group of motion—rotation and translation groups, one can define the transformations of our operators, of the field and the tensor. These coordinates and group transformations can be understood as transformations of our classical apparatuses..

But there exist also operators for the space coordinates X, Y, Z, having well known commutation relations with the corresponding operators of projections of momenta. Understanding the momentum as the generator of translation in space (considering the Poincaré group) and the operator of coordinate, as a nonrelativistic approximation for the generator of Lorentz transformation—translation in momentum space, one can look on these commutation relations as the consequence of the Poincare group. But no operator for time arises from this procedure.

Commutation relations in quantum physics usually are understood as corresponding to Poisson brackets in the classical theory. But then, for Poisson brackets one has (using double brackets as notation for Poisson brackets),

$$\frac{dA}{dt} = [[A, H]]$$

From this one obtains

$$[[t, H]] = 1$$

So one can expect to have in quantum physics some operator T with,

$$[T, H] = i$$

However, it is easy to see that due to the specifity of the dynamics of quantum systems, leading to stability of these systems and to existence of low boundary for the energy, this "time operator " cannot exist!

Indeed, suppose that such operator exist. Then, take $|E'>$—an eigenstate of the energy operator H with E' as an eigenvalue.

Take

$$|E'>_\varepsilon = \exp i\varepsilon T \exp -i\varepsilon T(H) \exp i\varepsilon T|E'> = (E' + \varepsilon)|E'>_\varepsilon$$

So, for arbitrary values of ε not only do the eigenvalues of H form a continuum but they extend to negative infinity.

That is why, W. Pauli wrote in 1933: "We conclude that the introduction of an operator T must fundamentally be abandoned and that the time t in quantum mechanics has to be regarded as an ordinary number (c–number)".

Let us make some remarks on uncertainty relation for time. We have in quantum physics,

$$\frac{d < Q >}{dt} = i < [H, Q] >,$$

from which as usual, one gets

$$\Delta E \Delta Q \geq \frac{1}{2} |\frac{d < Q >}{dt}|.$$

Now measuring observable Q and its *change* one uses some clock to measure time interval t. One has,

$$t\Delta E \Delta Q \geq \frac{1}{2} t |\frac{d < Q >}{dt}| \geq \frac{1}{2} \Delta Q,$$

from where one obtains

$$t\Delta E \geq \frac{1}{2}.$$

Nevertheless, differently from the other uncertainty relations here it is not *dispersion* of time but the exact value of the time interval which appears in the formula .One can measure together the moment of time and the energy but energy can be non conserved in the limit given by the uncertainty relation..

6 Irreversibility of Time in Quantum Physics.

Can one have some new information on the problem of irreversibility of time from quantum physics? There are two points in quantum physics where this irreversibility is manifested.The first is in the wave packet collapse during measurements, the second—T noninvariance of the K^0-meson and probably B-meson *decays*.

Schrödinger equation in most cases is time inversion invariant, i.e., it mantains its form if one changes $t \to -t$ and simultaneously makes a complex conjugation so that the imaginary unit $i \to -i$. The exception is in the standard model of weak interactions where due to the existence of a special form of interactions between quarks and leptons the interaction term of the Lagrangian or Hamiltonian is not invariant under *T-inversion*, being invariant only on *CPT-inversion*, i.e.together with the change of the sign of *time* one must also change the sign for *space*—do space—inversion and also do *C-conjugation*, i.e., change all particles on antiparticles. It looks as if some new *unity* of space and time is manifested in these rather rare decays! Why after all together with going backwards in time one must also change *right* on *left* in space?

CPT-symmetry says that in Nature one must see equal number of processes with *particles* with one direction of *time* and processes with *antiparticles* in the other direction of *time* and *left* direction in *space* changed on *right* direction and vice versa. All this can have serious consequences for cosmology when one deals with apparent asymmetry between particle and antiparticles, created in the early Universe by the strong gravitational field of the expanding Universe. Nevertheless, it is totally unclear how this small asymmetry is connected with the total *arrow of time* manifested in the macroscopic world discussed by us previously.

Now let us discuss the second, more general, asymmetry due to the wave packet collapse. During measurement one has two processses—the first is of getting the mixture from the pure state, the second is registration by the observer of one of the members of the mixture. Surely this process is irreversible—if one tries to use Schrödinger equation to go back in time one does not receive the original wave function. Also, from the density matrix, one cannot by use of the Schrödinger evolution to come to the initial pure state.

However some critics notice that the situation here is similar to the *entropic* arrow of time.Why all observers define the *same* arrow of time and not a different one ?

This is somehow connected with the Wigner friend paradox. Only if all observers participate in one consciosness, one direction of time will be defined. From this, one can even try to prove the existence of only *one* consciousness (World consciousness) which may be due to the existence of the same direction of time for all observers.

The other problem is that due to measurement—wave packet collapse phenomenon—one can have a process where the density matrix becomes the pure state. Why not to have a symmetry in Nature when both types of processses take place? At some places the pure state becomes the density matrix, at the other the density matrx becomes a pure state?

In quantum statistical physics one begins by writing an equation for the density matrix which is reversible in time, and then using the so called Zwanzig's projector method one obtain *master equation* which is irreversible in time. This projector method plays the role of Boltzmann 's molecular chaos hypothesis. It corresponds to the idea of *measurement* of special macroscopic observables. So, one can say that irreversibility in time occurs as the consequence of some wave packet collapse procedure, as discussed by us previously, and we must say that we still have here the same problem—why all collapses define one and the same direction in time?

6.1 Time in Some Models of Quantum Gravity.

Despite the fact that a convincent quantum theory of gravity is still not formulated, there are some simple models based on the Wheeler-De Witt equation, which are used for so called minisuperspace case. For the general case, the theory is still not free from divergences. Also, some basic problems, like, e.g., the role of observer in the Copenhagen interpretation (or in some other interpretation, as e.g., the Everett interpretation etc.) are unsolved.

Quantum cosmology as a version of quantum gravity supposes quantization not only of matter but also of gravity, this meaning quantization of the space-time itself.

The complete theory is still not developed but there are some models thanks to Arnowitt, Deser, Misner, Hawking, Wheeler, De Witt etc.[20]

Take the signature of the four dimensional space-time as $(-,+,+,+)$.

Consider a compact spacelike *3-surface* Ω dividing the 4-manifold M into two parts, so that a time coordinate is defined, Ω corresponds to $t = const.$

Write the metric as

$$ds^2 = -(N^2 - N_\alpha N^\alpha)dt^2 + 2N_\alpha dx^\alpha dt + h_{\alpha\beta}dx^\alpha dx^\beta,$$

where N is called the *lapse* function measuring the proper time separation of the surfaces of constant t. N_α is called the *shift* vector measuring the deviation of lines of constant x^α from the normal to the surface Ω. Write the action for gravity and matter as

$$S = \int (L_g + L_m) d^3x dt,$$

where

$$L_g = \sqrt{-g}R.$$

After putting away some terms having the form of the divergence of some vector one has,

$$L_g = \frac{m_{pl}^2}{16\pi} n(G^{\alpha\beta\gamma\delta}K_{\alpha\beta}K_{\gamma\delta} + h^{\frac{1}{2}}R^{(3)}),$$

where $R^{(3)}$ is the three curvature, h is the determinant of the three metric tensor and

$$\begin{aligned} K_{\alpha\beta} &= \frac{1}{2N}(-\frac{\partial h_{\alpha\beta}}{\partial t} + 2N_{(\alpha|\beta)}), \\ G^{\alpha\beta\gamma\delta} &= \frac{1}{2}h^{\frac{1}{2}}(h^{\alpha\delta}h^{\beta\gamma} - 2h^{\alpha\beta}h^{\gamma\delta}). \end{aligned}$$

For a massive scalar field one can write,

$$L_m = \frac{1}{2}Nh^{\frac{1}{2}}[N^{-2}(\frac{\partial\varphi}{\partial t})^2 - 2\frac{N^\alpha}{N^2}\frac{\partial\varphi}{\partial t}\frac{\partial\varphi}{\partial x^\alpha} - [h^{\alpha\beta} - N^\alpha\frac{N^{\beta^\beta}}{N^2}]\frac{\partial\varphi}{\partial x^\alpha}\frac{\partial\varphi}{\partial x^\beta} - (m^2 + \xi R)\varphi^2].$$

In the Hamiltonian treatment of general relativity one regards the components $h_{\alpha\beta}$ of the 3-metric and the field φ as the canonical coordinates. The canonically conjugate momenta are

$$\pi_{\alpha\beta} = \frac{\partial L_g}{\partial h_{\alpha\beta}} = -\frac{h^{\frac{1}{2}}m_{pl}^2}{16\pi}(K^{\alpha\beta} - h^{\alpha\beta}K), K = g^{\alpha\beta}K_{\alpha\beta}, \pi_\varphi = \frac{\partial L_m}{\partial \varphi^\cdot}.$$

The Hamiltonian is

$$\begin{aligned} H &= \int (\pi^{\alpha\beta}h^\cdot_{\alpha\beta} + \pi_\varphi\varphi^\cdot - L_g - L)d^3x \\ &= \int (NH_0 + N_\alpha H_\alpha)d^3x \end{aligned}$$

where for $\xi = 0$ one has,

$$H_0 = 16 m_{pl}^{-2} G_{\alpha\beta\gamma\delta}\pi^{\alpha\beta}\pi^{\gamma\delta} - \frac{m_{pl}^2}{16\pi} h^{\frac{1}{2}} R^3 + \frac{1}{2} h^{\frac{1}{2}} (\frac{\pi_\varphi^2}{N} + h^{\alpha\beta}\frac{\partial\varphi}{\partial x^\alpha}\frac{\partial\varphi}{\partial x^\beta} + m^2\varphi^2),$$

and

$$G_{\alpha\beta\gamma\delta} = \frac{1}{2} h^{-\frac{1}{2}} (h_{\alpha\gamma}h_{\beta\delta} + h_{\alpha\delta}h_{\beta\gamma} - h_{\alpha\beta}h_{\gamma\delta}).$$

The quantities N and N_α are regarded as the *Lagrange multipliers*. Thus the solution obeys the momentum constraint,

$$H^\alpha = 0,$$

and the Hamiltonian constraint,

$$H_0 = 0.$$

This corresponds to the "absence of time " 'or the "frozen dynamics" in quantum gravity!

For given fields N and N^α on Ω the equations of motion are,

$$\dot{h}_{\alpha\beta} = \frac{\partial H}{\partial \pi^{\alpha\beta}}, \dot{\varphi} = \frac{\partial H}{\partial \pi_\varphi}, \dot{\pi}_{\alpha\beta} = -\frac{\partial H}{\partial h_{\alpha\beta}}, \dot{\pi}_\varphi = -\frac{\partial H}{\partial \varphi}$$

The quantum state of the Universe is described by a wavefunction Ψ which is a function on the "superspace" : W-infinite dimensional manifold of all 3-metrics $h_{\alpha\beta}$ and matter fields φ. Denote $\gamma_{\alpha\beta}$ a small change of the metric $h_{\alpha\beta}$ and μ a small change of φ. For each choice of $N > 0$ on Ω there is a natural metric $\Gamma(N)$ on W, namely

$$ds_w^2 = \int N^{-1}[\frac{m_{pl}^2}{32\pi} G^{\alpha\beta\gamma\delta}\gamma_{\alpha\beta}\gamma_{\gamma\delta} + \frac{1}{2} h^{\frac{1}{2}}\mu^2] d^3x.$$

The wave function does not depend on time t, because t can take arbitrary values under different choices of N and N_α.This means that

$$H\Psi = 0.$$

Taking

$$\pi^{\alpha\beta}(x) = -i\frac{\delta}{\delta h_{\alpha\beta}(x)}, \pi_\varphi(x) = -i\frac{\delta}{\delta\varphi(x)}$$

one obtains the *Wheeler-De Witt equation,*

$$(-\frac{1}{2}\triangle + \xi R + V)\Psi = 0$$

where $\triangle$ is the Laplacian in the metric Γ and R is the scalar curvature of this metric. Also, the potential is,

$$V = \int h^{\frac{1}{2}} N[-\frac{m_{pl}^2}{16\pi} R^{(3)} + \Lambda + u] d^3x,$$

where

$$u = T^{00} - \frac{1}{2}\pi_{\varphi}^2,$$

and Λ is the cosmological constant.

The Friedmann metrics correspond to the "minisuperspace " models, when

$$ds_w^2 = G^2(-N^2 dt^2 + a^2 dl^{\rightarrow 2}),$$

where, $G^2 = \frac{2}{3m_{pl}^2}$ has been included for convenience.

Then, the action for the minimal coupling is

$$S = -\frac{1}{2}\int dt N a^3 \{\frac{1}{N^2 a^2}(\frac{\partial a}{\partial t})^2 - \frac{k}{a^2} - \frac{1}{N^2}(\frac{\partial \varphi}{\partial t})^2 + m^2\varphi^2\},$$

where $k = 0, \pm 1$. Then, for closed spacetimes our action is finite.

The classical Hamiltonian is

$$H = \frac{1}{2}N(-a^{-1}\pi_a^2 + a^{-3}\pi_{\varphi}^2 - ka + a^3 m^2 \varphi^2),$$

where

$$\pi_a = -\frac{ada}{Ndt}, \pi_{\varphi} = \frac{a^3}{N}\frac{\partial \varphi}{\partial t}.$$

Then the Wheeler -De Witt equation results,

$$\frac{1}{2}N\exp(-3\alpha)[\frac{\partial^2}{\partial \alpha^2} - \frac{\partial^2}{\partial \varphi^2} + 2V]\Psi(\alpha, \varphi) = 0$$

where $\alpha = \ln a$ and

$$V = \frac{1}{2}(\exp(6\alpha)m^2\varphi^2 - \exp 4\alpha)$$

One can regard this equation as a hyperbolic equation for Ψ in flat space with coordinates (α, φ) with α as the "time"coordinate. Then there is a question for a boundary condition. Hartle and Hawking supposed that,

$$\lim_{\alpha \to -\infty} \Psi = 1.$$

Then, it can be shown that there exists a solution oscillating in the region $V > 0$, $|\varphi| > 1$. This is very important, because then there is a possibility to show how classical Friedmann closed spacetime originates from some quantum era. Let us represent the oscillatory component of the wave function in the WKB approximation. Write,

$$\Psi = \mathrm{Re}\,(C \exp iS),$$

where C is a slowly varying amplitude and S is a rapidly varying phase. S then, satisfies the Hamilton-Jacobi equation,

$$H(\pi_\alpha, \pi_\varphi, \alpha, \varphi) = 0, \pi_\varphi = \frac{\partial S}{\partial \varphi}, \pi_\alpha = \frac{\partial S}{\partial \alpha}.$$

Then the first equation can be written as

$$\frac{1}{2} f^{ab} \frac{\partial S}{\partial q^b} + \exp(-3\alpha) V = 0,$$

with

$$f^{ab} = \exp(-3\alpha) diag(-1, 1)$$

and q^bcorrespond to α, φ.

The wave function will sutisfy the Wheeler-De Witt equation if,

$$\Delta C + 2i f^{ab} \frac{\partial C}{\partial q^a} \frac{\partial C}{\partial q^b} + iC\Delta S = 0$$

where Δ is the Laplacian in the metric f^{ab}. Ignoring the first term in the previous equation, let us integrate it along the trajectories of the vector field

$$x^a = \frac{\partial q^a}{\partial t} = f^{ab} \frac{\partial S}{\partial q^b}$$

where a new parameter "time "t is introduced by definition. Now, following Hawking and Halliwell[20], let us proceed and investigate different regimes for small values of the scale factor and large ones.

The oscillating solution starts out at $V = 0, |\varphi| > 1$with $\frac{\partial\alpha}{\partial t} = \frac{\partial\varphi}{\partial t} = 0$, and grows exponentially with

$$\frac{\partial\alpha}{\partial t} = m|\varphi|, \frac{\partial\varphi}{\partial t} = -\frac{1}{3}m\exp(3\alpha).$$

Let us look for a solution of this equation in parametric form. As it is known, the line in the plane (α, φ) can be written in the form $\alpha = \alpha(t), \varphi = \varphi(t)$.

At first, for not large time one has the inflation regime—exponential growth of the scale factor a and then for a oscillating φ one obtains a closed Friedmann Universe(see [21]).

It is interesting to see that at the singularity when $a \to 0, \alpha \to -\infty$, nothing specific occurs because we have the boundary condition that $\Psi \to 1$. If one interprets 1 as a "vacuum " then the existence of the wave function with this boundary condition and quasiclassical asymptotics for large scale factor is called "*creation of the Universe from nothing*"

The "time" appears only for the quasiclassical region when a and φ are large enough. The "origination" of time can be described as a consequence of the quasiclassical form of the wave function: the wave function is such that $\Psi = \exp\{iS\}$ and S is extremal on some line in the plane (a, φ). This line, as we said before is written in the parametric form through a parameter t, but the most simple choice of the parameter is to identify it with the scale factor a itself! So, once one has a "larger" a , the "later " is the time! In this, we recognise the ancient Greek idea when time is identified with ideal watches which here—differently from the movement of the planets— is the expansion of the Universe!

Now let us make some remarks concerning this Wheeler-De Witt picture of quantum cosmology.

1. Time does not exist when gravity is really quantized. It appears only in the quasiclassical approximation, when due to the specific form of the wave function it is possible to speak about a big probabilty [1] of having some trajectory in the plane—with two axes, one being matter, introduced by some hypothetical massive scalar field, the other axis being the scale factor of space. Nevertheless, there is no need for "movement " in this time or "going " from one value of the scale factor to the other. In space one can

[1]Despite the fact that the word "probability " does not have a clear sense in this form of quantum cosmology when many words are used just on analogy with the standard quantum physics.

also have “lines”, but it is not always that one observes different points on this line “moving ”on it.

2. There was an attempt by Don Page to construct a model of the “quantum Universe ” for which due to “frozen dynamics” there is no time for the whole Universe, while if one looks for a given “subsystem” of it one obtains Schrödinger equation with time, and a Hamiltonian for the subsystem not commuting with the full Hamiltonian. This however lead us into the problem of the observer in a quantum Universe.

3. Putting canonical commutation relations in the *ADM* formalism in quantum cosmology, means that quantum cosmology is some nondistributive lattice and due to our idea of the Booleazation of non Boolean logic, time is introduced by observer. Surely, this is totally different from the quasiclassical time introduced through the quasiclassical wave function. It seems, as in the standard quantum physics, that quantum cosmology strengthens the fact that there are two different “times” in quantum physics—one due to Schrödinger equation, the other due to wave packet collapse and the observer measuring noncommuting observables. In quantum cosmology there is a possibility to speak about the “probability” of having “time” as the parametric time or the probabilty to have quasiclassical “clocks ”!

So, some observer defining time due to the Booleazation process has the possibility to define by his quasiclassical measurement parametric time which he can then use in his deterministic predictions or retrodictions. As we explained previously both times are needed for human observer to do Booleazation and to have Boolean memory in order to have all properties of information.

And now let us make some remarks on the “euclidean time ” idea much popularised by S. Hawking in his papers, and even in a popular book[22]. Euclidean spacetime has the signature of the Euclidean space, which is different from the pseudoeuclidean Minkowski spacetime. Writing the solution of the Wheeler-De Witt equation in the form of the functional integral over compact fourdimensional metrics Hawking tried to speculate on the physical sense of these euclidean compact four dimensional spaces. Time in such a space is totally identical to the space dimension. Pseudoeuclidean time is a feature of quasiclassical approximation as we explained before. S. Hawking even went so far as to claim that pseudoeuclidean time is “the illusion of the human mind” (private communication to the author) while really the spacetime of the Universe is a compact Euclidean one, with no singularities, so that singularities occur as artefacts of the erroneous quasiclassical reasoning, applied to the region where it does not work...

However no physically observable results were proposed to prove that the euclidean metric has some sense different from the mathematical trick to calculate the functional integral.

The main objection against euclidean physical spacetime is a deep connection between pseudoeuclidean time and quantum physics. Imaginary unit for time leads to the difference between Feynman functional integrals with imaginary unit in the exponent and Wiener integrals used in stochastic theories where instead one has the real value. This manifests the difference between quantum theory with the wave function as the probability amplitude and standard probabilistic theory. Another place where imaginary unit is present is in the commutation relations,e.g., the commutator of the coordinate and momentum operators is just equal to the imaginary unit. This as was mentioned by Schtukelberg makes imaginary unit very important for quantum physics with its complementarity of observables.

However let us discuss here the possibility of the classical signature change in general relativity.Let us write the following 4-dimensional element

$$ds^2 = -\sigma N^2 dt^2 + g_{ij}(dx^i + N^i dt)(dx^j + N^j dt)$$

where σ defines the signature as $\sigma = -1$ on some M^- and $\sigma = +1$on M^+ and g_{ij}, N, N^i are the standard 3-metric, lapse and shift functions discussed by us previously.Geometries with the signature change are characterised by certain *junction* conditions satisfied at the *junction* surface S. The first metrics of this kind were obtained in the models of creation of the Universe from nothing when one deals with solution of the Wheeler-DeWitt equation written as the Euclidean path integral having *WKB* asymptotics discussed by us previously here. This Euclidean form can be interpreted as describing some "tunnelling effect" which on the other language can be obtained by using "imaginary time ". So there is a temptation to look for some solutions of Einstein's equations with the change of signature for time. This temptation was realized in a series of papers devoted to classical solutions of Einstein's equations with the signature change. It was found that such solutions do exist—some of them satisfying *strong junction* conditions when the extrinsic curvature and the affine comoving parameter derivative of matter fields must vanish, i.e., $K_{ij}|_{S^\pm} = \partial_t \phi|_{S^\pm} = 0$ [23,24]. Some solutions satisfy *weak junction* conditions when all these values are continuous at the junction hypersurface[24]. As it was first mentioned by Teitelboim, the Hamiltonian approach does not determine the signature of the spacetime. There is no Einstein equation for the lapse function and being arbitrary it has any sign. So one can replace N^2 by some $N(t)$ in the expression for the ds^2. Then, we can find Friedmann solutions of the Einstein's equations with lapse function changing its sign at some t_0, but with finite density and pressure of matter at t_0. However, at t_0 some singularity, usually believed to be a kind of coordinate singularity, will occur. One will have $N(t) \to 0$, $t \to 0$, but the proper time $s = \int \sqrt{|N(t)|}dt$ is finite if elapsed from the surface t_0. Time measured by t "speeds up indefinitely" relative to proper time s as one approaches the surface. Classical realization of the quantum cosmology idea of Hartle- Hawking was made in [24]. For some "time "$-\frac{\pi}{2H} \leq t < 0$ one has the Euclidean compact four dimensional sphere, while for the positive time one has Lorentz metric and inflationary expansion.The Universe in the Euclidean phase "is " but does not "exist "[24], because one cannot perform experiments there. It has no "beginning " and is geodesically complete.

So, these examples show the possibility of the change of the signature in classical general relativity while the physical sense of such a change and what can be the "motivation" for it is not clear.

One can ask the following question: "If time arises according to our idea— due to the Booleazation of the non Boolean logical structure, what is the reason for it to be pseudoeuclidean and not Euclidean? ". The answer can be that it does not really exist, being a an ideal element like the imaginary unit and cannot be measured as something external to mind! Superselection rule for time and absence of the quantum observable as the selfconjugate operator for time, then can be interpreted as due to absence in "the objective world of nondistributive lattices" of such a "property"as time!

7 The Time Machine Problem.

The four dimensional point of view of Special and General Relativity theory naturally puts the problem of possible existence of closed timeloops in spacetime. Really, if time is just the fourth dimension of space-time and in space closed spacelike lines exist, why there are no closed timelike loops? The answer surely will be positive for the compact "euclidean " spacetime. But even if it is pseudoeuclidean, the success of the Special and General relativity treating time on the same level as space makes the problem open for discussion.

The idea of movement "back in time" was considered by Schtukelberg and Feynman in order to describe antiparticles. This idea is still not refutable in quantum field theory, where the standard interpretation uses the reinterpretation principle and makes always possible to call the electron moving back in time a *positron,* with a positive charge moving in usual direction of time. Vacuum loops for particle-antiparticle pairs form timelike loops in Minkowsky spacetime. However, these loops correspond to virtual particles and it is impossible to see any "movement" along them in any experiment. That is why they are considered as only some mathematical trick in quantum field theory.

The real problem of observable closed timelike loops originates in General Relativity.The first man to speak about timelike loops— "time machines" was K. Gödel[25] who in 1949 found a solution of Einstein's equations describing a rotating Universe with closed timelike lines. The stress-energy tensor for the rotating Gödel Universe has the form,

$$T^{ab} = \rho U^a U^b + \frac{\omega^2}{8\pi} g^{ab},$$

where ρ is the density of the dust and ω is the vorticity of matter, describing its rotation. Closed time like loops in Gödel Universe are not geodesics, and one must have acceleration in order to be on it. Oszvath [26] and De [27] generalized Gödel's Universe including electromagnetism and it occurred that it is possible to be on the closed timelike loop due to the Lorentz force acting on the charge. Even for the vacuum solution of Einstein's equations (so called Taub-NUT model) there exist closed timelike geodesics.

Then, for rotating black holes, described by the Kerr's metric it was found that for the angular momentum large enough so that

$$a^2 > m^2,$$

where a is the angular momentum, m is the mass of the black hole, closed time like loops occur.

Tipler found a solution of Einstein's equations for an infinite rotating cylinder source which similar to the Gödel case has closed timelike loops[14]. Tipler claims that the result can be valid for finite cylinder but with the large enough angular velocity.

Gott found that closed timelike loops occur in the spacetime of the two infinitely long cosmic strings.[28]

Another class of "time machines" was discovered by quantum field theorists using the possibility to break standard energy conditions—positivity of the energy density—for the vacuum polarization in the Casimir effect. Morris, Thorne,Yurtsever[29], Novikov[30] found solutions of Einstein's equations, describing *wormholes* and showed that relative movements of mouths of wormholes lead to closed timelike loops. So, the idea appeared to construct time machine using the Casimir effect. Despite of the technical realization of such a machine is far from possible, nevertheless the principal questions of time machine paradoxes discussed previously mainly by science fiction writers became the topic of serious scientific journals. Some authors calling themselves "the Consortium", led by K.Thorne, claim the possibility of time machine, others following S. Hawking believe in the cosmic censorship principle, forbidding the existence of time machines due to incompatibilty of its existence with the quantum field theory in curved spacetime[31]. So the problem is discussed today not only in the framework of classical general relativity but also in the quantum theory. In quantum theory time machine will correspond to a new type of nonlocality-nonlocality in time! Nonlocality in space is a general feature of quantum physics where so called entangled states play important role.Is nonlocality in time possible?Here again we ask about ultimate difference of space and time! By the way Kurt Gödel himself as it is known [31] considered his example of closed timelike loops leading to the so called "grandfather's paradox " as proving the ideal nature of time differently from space.

And now let us discuss some paradoxes arising in case of closed timelike loops for the classical and quantum cases.

However before discussing the problem, following[32] let us discriminate between "a time travel" and "time machine". Time travel is possible for example in the rotating Gödel Universe. But here the whole Universe acts as a "time machine ". It is not "constructed " by any engineer. Real "time machine" is something engineerly constructed, so that only "after" some moment of time one has it. This means that the usual science fiction scenario to travel to Middle ages, etc., is not possible. One can say that in spacetime there exists a time slice S so that to the past of it in $J^{-}(S)$, there are no time machines.This explains according to "time machine theorists" why our world is not full of "tourists " from the future...But if it will be constructed then those on closed timelike loops will go back in time...What paradoxes they will see.

1. The grandfather paradox. This paradox was first formulated in science

fiction literature. Can one go to the past and kill there one's grandfather so that to prevent to be born in the future? Surely the answer if using standard logic is negative. If there is a closed timelike loop not all acts are possible for the time traveller. This is called the consistency constraint. For the traveller this means some constraint on his "freedom of will". Mathematically, this means that differently from the standard situation in mathematical physics when any local solution can be extended to some global solution of the equation, in case of time machine not all local intial conditions (not contradicting physical laws) can be realised—global solution influences on local conditions. So, this is manifestation of nonlocality in time. In science fiction this is expressed as "the random policeman argument ". When the timetraveller will try to kill his grandfather a policeman suddenly occurs close to him and will prevent him from doing his act! In the physical context the problem was analysed by Echeverria et al[33] and Novikov[34] for the "double mouths wormhole time machine" and billiard balls going through it. For this case, the ball going into one mouth then arrives from the other mouth of the wormhole at the earlier time, so that then it can collide with his younger self. If the collision is such that, after it no ball can come to the first mouth, we have a contradiction which is the grandfather's paradox. However it is interesting that one can find infinite number of collision situations with different angles of scattering of one ball with respect to the other leading to the noncontradictory situation when one ball after all comes to the first mouth! Contradictory collisions are considered as impossible due to the selfconsistency condition. From this simple example one can make two important conclusions.

(a) Global selfconsistency condition prohibits for some locally possible situations to be realized (the "policeman" rule).

(b) If time machine will be constructed different possible selfconsistent situations can be realized and usual causality from the past (before the first meeting with the time machine) cannot give a principle for preference of one of these to the other—for example, one scattering angle of the billiard ball to the other— if both are consistent!

So a new kind of randomness due to some "branching " at the point of first meeting with the time machine arises. From this, some authors claimed that time machine has something to do with quantum physics with its probabilistic nature. However, in quantum physics we do not have trajectories, and as we shall see new problems like lack of unitarity of evolution arise for the time machine.

Now, recall a theorem of S.Hawking (here we follow.[32]). Hawking tries to investigate the problem—what it means to "switch" the time machine? He assumes the existence of a partial Cauchy surface S such that a null surface generated by null geodesics $H^+(S)$ separates the portion of spacetime with closed timelike curves from the portion without them.$H^+(S)$ is called a *chronology horizon*. If all the past generated generators of $H^+(S)$ are contained in the compact set, then $H^+(S)$ is compactly generated.

Theorem 1 *Let M, g_{ab}, T^{ab} be a cosmological model satisfying Einstein's equations .Suppose that M, g_{ab}admits a partial Cauchy surface S and that T^{ab}satisfies the null energy condition, i.e., $T^{ab}K^aK^b \geq 0$ for every null vector K^a. Then,*

(a) if S is non-compact,$H^+(S)$ cannot be non-empty and compactly generated, and

(b) if S is compact $H^+(S)$ can be compactly generated but matter cannot cross $H^+(S)$.

This theorem shows that the "engineer himself" constructing the machine cannot put himself into it!

And now let us discuss situation with the time machine in quantum theory.

2. First of all discuss the example in TaubNUT spacetime where the chronology horizon is compact and generated by a smoothly closed null geodesic. It is interesting that each time when the tangent vector of it is transported parallel to itself around a loop it is expanded by a factor of $\exp(h)$, $h>0$,indicating a blue shift.Making infinite number of circuits needed to reach $H^+(S)$ the blueshift diverges. This is interpreted as divergence of the energy density meaning instability of the time loop itself (or impossibility to have it in Nature). However the blue shift of light close to the timeloop is considered by some authors to be used in explanation of the sources of gamma-bursts in the Universe...

Hawking put the conjecture of the cosmical censorship for time machines claiming that due to quantum field theory effects the vacuum expectation value of the stress energy tensor for quantized field $< 0|T^{ab}|0 >$ diverges on the time loop.

However S. Krasnikov [35] and V. Sushkov [36] noticed that this divergence depends on the quantum state used as bra or ket vector. They showed that there exist states for which the expectation value is finite!

The next important feature of quantum theory with closed timeloops present is breaking of unitarity of evolution. At first it was shown in [37] for

Green functions calculated by using the path integral taking among the paths the closed timelike loop. Then, in [38] it was shown that the Hamiltonian for the situation with closed timelike loop is non Hermiteanone. Does it mean the impossibility to have a time machine? Or the opposite—breaking of unitarity occurs in measurement processes due to the wave packet collapse—so do time machines have something to do with the measurement problem?

Resuming, one can say that the problem of existence or nonexistence of time machine is today as controversial as the great philosophical question asked in this respect by Kurt Gödel: is time objective or ideal?

And now we will discuss the idea of origination of not only of time but also of classical space in the early Universe as due to the difference between Boolean logic of observer and non Boolean logic of the physical world.

8 General Remarks on Quantum Effects in the Early Universe.

Investigations of quantum effects in early Friedmann Universe made by us in the seventies [39,40] showed that the main physical effect in it is particle creation in the special era of the Compton time from the beginning. It was shown[20,41] that visible number of protons and electrons (Eddington-Dirac number) can be obtained due to creation of Grand Unification X bosons in the early Universe by the gravitational field of the expanding Universe with their subsequent decay on quarks and leptons with baryon and CP nonconservation. Nevertheless the main problem still unsolved was creation of entropy in the early Universe, leading to the large cosmological scale factor, esponsible for the process of particle creation. It occurred that because particles played a negligible role compared with radiation (entropy), the process of particle creation was described not as self consistent process when gravitational field itself was due to particles and vacuum polarization as their source. Instead, some external gravitational field with still unexplained source was needed. A self consistent model for the open case was found possible only for creation of particles with the mass of the order of the observable Universe, when change of the effective gravitational constant due to vacuum polarization effect is taken into account.[42]

Nevertheless if one considers only masses smaller than the Planckean ones an interesting fact of the connection of the number of particles(particle-antiparticle pairs) with the number of causally disconnected parts of the Friedmann Universe was discovered. Massive conformal coupled scalar particles, massive spinor and vector particles are created in such a manner as if all virtual pairs, existing on the Compton length at the Compton time from the beginning of the Universe, become "materialised " at later times moving in the quasiclassical limit along classical geodesics of the spacetime. But Compton length at the Compton time from the beginning is just the horizon distance for that time. So, a simple reasoning leads to the conclusion that particle creation is due to the "work of the tidal forces of gravity on the Compton length being equal to the mass of the particle ", so that the number of particles created in the early Universe is of the order of the number of causally disconnected parts in the volume of the Universe at that time.

Here the "volume" is that which will evolve in the modern visual Universe, so that the difference between open and closed model is not important. There is no particle creation in the De Sitter Universe differently from the Friedmann Universe which can be due to absence of a natural definition of time (the curvature is constant!) for this case. Only vacuum polarization effects due to quantum fields are present in the De Sitter Universe which is consistent with understanding it as originated from vacuum as its source. This connection of particle creation in early Friedmann Universe with causal disconnectedness seems to be some important fact about quantum physics in the early Universe. Surely, particle creation from the vacuum by the strong external field can occur even in Minkowski spacetime if this external field is an electromagnetic one. In this case, there are no causally disconnected parts and one can speak about wave functions extending on any distances, about symmetrised or antisymmetrised many particle states, etc. Nevertheless, in the case of a causally disconnected Universe, it is not possible to speak about overlapping wave functions for distances larger than the causal horizon at some time. So, the situation is like existence of many disconnected Universes and quantum physics for such case will be different from the standard description. Something like a superselection rule in Hilbert space formulation will arise due to absence of superpositions of states for disconnected parts. Nevertheless, differently from the "trouser Universe", in order to have a homogeneous and isotropic Friedmann spacetime one cannot have some "fixed frontiers" of causally disconnected parts. Depending on the positions of physical particles, these "frontiers" can be chosen arbitrarily up to indeterminacy of the Planckean length. This arbitrariness can be obtained if one can speak about different probabilities of localizing created particles in different subdivisions of the volume of expanding space on causally disconnected parts. One has the temptation to identify this probability measure with the entropy. So, in this case particle creation must be accompanied by the creation of entropy and an arrow of time arise. It is easy to understand the process of "thermalisation" of the Universe accompanying particle creation due to existence of horizons—causally disconnected parts. Really, vacuum of particles from which particles are created, similar to the well known Unruh effect [43] when we have the trivial example of causally disconnected parts of space—the left and the right edges ,is seen by the particles in one causally disconnected part as the "thermal bath" due to breaking of all correlations existing in the vacuum. Instead of the quantisation in full Friedmann space one must do quantisation in one (which can be any) such part .The boundary conditions for wave functions can be put on the frontiers of the causally disconnected part, i.e., on the horizon itself which is the light cone. Due to the property that the light cone is the characteristic surface of the wave equation in curved space-time[44] this boundary condition as in the case of Unruh effect does not mean introducing any "boundaries" or "frontiers" in space. So, one arrives to a situation similar to the quantum theory in Milne's Universe—particles move inside the light cone for some special time from the beginning of the Universe. It is well known[41] that similar to Unruh effect quantization in Milne's Universe leads to special vacuum polarisation effect described by the "thermal bath" with the temperature defined by the scale factor of the metric. For Compton time from the beginning this temperature will be just the Compton one. Nevertheless, in cosmology it is known that if one still has some temperature for the Compton time it is much larger than the Compton one. For example, for X-bosons the Compton temperature occurs for the time $t = 10^{-35}$ *sec* and not for the Compton time $t_0 = 10^{-39}$*sec.* This can have sense that Milne's approximation is not valid for the time close to the Compton one when the curvature of spacetime is not negligible inside the horizon, but existence of the horizon leads to some temperature as it is for the Milne's case. So, differently from the *inflation* models thermalization occurs not because of "interaction"of particles in some pre Friedmann era, but just the opposite—it occurs like in Unruh effect, due to "lack of interaction" between particles in causally disconnected parts. So, global vacuum appears as the density matrix for each causally disconnected part. This global vacuum can be prepared in Friedman space before particle creation due to special conformal properties of Friedmann space (it is conformally static and one can easily define vacuum in the static Universe) and conformal invariance of wave equations in Friedmann Universe for massless case.

An important question in cosmology is about origination of the classical space and time. In our paper [3] (see also [2]) there was proposed an idea that classical time is needed in order to make possible observation of different complementary properties of the quantum system described by noncommuting operators or observation of the non Boolean lattice of properties by the observer with Boolean mind getting information about it. Superselection rule for time can be used for making noncommuting operators commuting ones, taking different sections of Hilbert space divided by the superselection rule. The same idea can be used for space if for causally disconnected parts one uses superselection rule for space. Then, classical space is needed in order to make observable different complementary observables, the number of which can be made infinite (this can be an argument for infinite in space Universe[5]), so that again Booleazation of non Boolean lattice is made by making "copies" of the same system and measuring different observables for different copies.

This process of "copying" of the same quantum system can be understood as "particle creation" with accompanying it vacuum polarization due to which space-time arises in a self consistent way, so that one can "explain" particle creation by the nonstationary metric of arising space-time itself.

Some hint to correctness of this "Booleazation " idea or "making all Everett worlds realized" in the existing Universe can be taken from the well known observation (see Terazawa in [45]) that the number of protons in the Universe is equal to the ratio of the surface of the sphere with the radius of the observable Universe to the area of the Compton length of the proton. This can be understood as realising all possibilities for the direction of the spin of the proton in the modern era of evolution of the Universe.Universe is such that all quantum possibilities for spin projections of the proton are realised in it.And modern Universe is proton-electron (not quark, etc.) dominated. All this can be understood due to the *anthropic principle* in cosmology. We see the Universe as having this age, this size, this particle content due to consistency with existence of the observer with his proton-electron dominated body.

Our investigation here is organised as follows. First we discuss some facts on particle creation and entropy in the early Friedmann Universe.Then we investigate the possibility for understanding origination of classical spacetime due to the idea of the difference between non Boolean logic of the world and Boolean logic of the observer, realizing J. Wheeler's idea [46] of getting physics from logic.

8.1 Particle Creation in the Early Friedmann Universe.

Here we shall reproduce some known facts about particle (particle-antiparticle pairs) in the early Friedmann Universe.

The metric of the isotropic homogeneous Friedmann space-time,used in the Standard model in cosmology is taken in synchronous reference frame so,that the interval can be written in differential form as

$$ds^2 = cdt^2 - a^2(t)d\overrightarrow{l^2},$$

where the space interval can be defined for all three cases of the closed, open and quasieuclidean cases. The standard heuristic evaluation of the number of created particles in the early Universe is as follows. Let us write equations of geodesic deviation:

$$\frac{d^2n^i}{ds^2} = R^i_{jkl}u^j n^k u^l,$$

where $u^i$is 4-velocity, $n^k$is a spacelike vector of geodesic deviation and R^i_{jkl} is the Riemannian curvature tensor. Taking in some reference frame $u^0 = 1$, $u^\alpha = 0$, $\alpha = 1, 2, 3$, $n^0 = 0$, looking on $\frac{d^2n^i}{ds^2}$as on some "acceleration" and multiplying both sides of our equation by the mass one obtains the "tidal force". A condition for particle creation means that the work of the tidal force on the Compton length of a particle is of the order of m. To obtain this one must multiply both sides of our equation besides m by the Compton length $l_c = m^{-1}$, and equate this to m. In this way one obtains a condition for particle creation:

$$\mid R^\alpha_{0\beta 0} \mid l_c^{-2} = m^2.$$

For the usual Friedmann model of the Universe this value of $\mid R^\alpha_{0\beta 0} \mid$occurs for the time$t = m^{-1}$.

So, this shows that a pair of particles can be created on the Compton length at the Compton time from the beginning of Friedmann Universe .But what is the geometrical meaning of the Compton length at the Compton time of evolution of the Friedmann Universe? It is the size of a horizon at that time! The "volume" of the Universe at that time is evaluated as $a^3(t)$, so the amount of created particles is evaluated as the number of causally disconnected parts,

$$NN_h = \frac{a^3(t)}{(2ct)^3}, \text{ for } t = t_c.$$

The particles created in causally disconnected parts due to the expansion of the Universe "meet " in general space after disappearance of causal disconnectedness and today we can see all these particles inside the horizon distance for modern time.

Surely one can ask in what sense this heuristic evaluation is correct? Can one always say that the number of created particles can be obtained by dividing the volume in which external field has some critical value on the Compton volume?

The general answer is negative. Generally vacuum has some "correllations" for distances larger than the Compton ones. This can be easily seen from the general expression of the vacuum in terms of "pairs " using Bogoliubov's transformation describing a change of the vacuum due to dependence of the Hamiltonian on time and its nondiagonality in terms of creation and annihilation operators. It is "entangled" state like the ground state of the superconductor.

But for particle creation in Friedmann space exact calculations made by us previously without any euristic calculations confirm that the number of created particles in this causally disconnected space (which is totally different from causally connected Minkowski or De Sitter space) is of the order of the number of these parts. This can be confirmed by exact calculation of the correlation function for created pairs (see [41]). This function goes to zero for spacelike distances larger than the Compton's one .As to the number of created pairs for the X-boson of the grand Unification scale it is

$$N_{mx} = \frac{(10^{27}ct)^{\frac{3}{2}}}{(2ct)^3} \,|_{t=mx^{-1}}= 10^{84}.$$

Exact calculations [3[give some factor $b^{(s)}$, where s is the spin of the particle. For zero spin particle $b^{(0)} = 5 \cdot 10^{-4}$, and N_{mx} is of the order of Dirac-Eddington number of protons in the Universe. If these X bosons then decay with baryonic charge and CP violation on quarks and leptons one can obtain the observable numbers of protons and electrons. As it was said before, an interesting fact is that one can obtain the observable Eddington-Dirac number of protons in the visible Universe dividing the area of the surface with the radius of the Universe $R = 10^{28} cm$ on the surface $S = l_c^2$,where l_c is the Compton length of the proton. This can be interpreted in the sense that in the isotropic Friedmann space particles were created in such a manner that all potentialities for some degree of freedom, for example spin projection of the proton, are realised. At the same time this is just the consequence of the isotropic and homogeneos nature of the Friedmann metric itself. Really, to the proton corresponds some Compton area with some spin vector attached to it. And so it is not infinite but finite number of potentialities for spin directions that can be seen by some observer today as realized in the Universe with finite radius. In other words one can say that if something like a wave function of the Universe exists than it describes all different "Everett worlds" for proton as realized in it, which is different from what one sees as realized in the quantum particle experiment where only one potentiality is realized at the fixed moment.

Exact calculation of particle creation in the Friedmann Universe made by us previously was due to calculation of the vacuum expectation value of the stress-energy tensor of the quantised scalar, spinor and vector massive fields in curved spacetime $< 0| \hat{T}_{ik} |0 >$. This expression, which is finite after making three well known regularizations, has different forms for the time smaller then the Compton one and the time larger than that. For small time it is dominated by the so called vacuum polarization terms and for large time it describes created particles with the dust like equation of state so that created particles freely move in expanding space along geodesics of it. So the general structure is,

$$< 0|T_{ik}|0 >_{reg} = < T_{ik} >_c \delta_{\kappa,1} + < T_{ik} >_0 + < T_{ik} >_m,$$

where $\kappa = 1$ for the closed Friedmann space and the first term is the Casimir term for this case.The second term describes vacuum polarization present even for the massless case and leads to the conformal anomaly-it can be expressed through geometrical terms and does not depend on the choice of the vacuum state.The last term depends on mass—it describes particle creation as well as some geometrical terms depending on mass. For example, for $t \ll m^{-1}, m^2 \ll |R_i^k| \ll G^{-1}$ for conformal scalar particles one has

$$< T_{ik}^{(0)} >_m = \frac{m^2}{288\pi^2} G_{ik} + \frac{m^4}{128\pi^2} g_{ik} \ln(\frac{R^{\times}}{m^4})$$

where $R^{\times}$is some invariant composed of curvature tensors of dimension m^4. The first term being put into the right-hand side of Einstein 's equations leads to a change of the efective gravitational constant so that a new gravitational constant for very strong field is some G_{eff} and

$$(8\pi G_{eff})^{-1} = (8\pi G)^{-1} + \frac{m^2}{288\pi^2} = Z^{-1}(8\pi G)^{-1}.$$

Here G is the modern value of the gravitational constant.

For $t \gg m^{-1}$the leading term depends on the choice of the vacuum,it describes real particle creation and has the form,

$$< T_0^0 >_m = \frac{2b}{a^3}m, \mid < T_\alpha^\alpha >_m \mid \lll < T_0^0 >_m .$$

Here the constant b depends on the spin of the particle and on the behaviour in time of scale factor of the Friedmann model.For example calculations give $b = 5.10^{-4}$ for spin zero and $b = 3, 9.10^{-3}$ for spin one half particles and radiation dominated Universe.

So, these were results if one does not take into account causal disconnectedness of the early Friedmann Universe which necessarily will lead to change of the global pure vacuum state into some density matrix or mixture of states similar to the well known Unruh effect. For the Unruh effect, existence of the particle horizon is manifested in the change of the Minkowski vacuum into some heat bath with the density matrix. So,we claim that for $t \gg m^{-1}$one has

$$< T_0^0 >_m = \frac{2bm}{a^3} + T_{0pol}^0,$$

where T_{0pol}^0 describes vacuum polarization due do existence of particle horizons.It can be described by some temperature and entropy and it is this term which plays the main role in the early Universe and which accompanies particle creation term.

Let us discuss some important aspects of this calculation.

1. *The notion of particles in curved space-time.* Particles can be defined as point like objects moving along geodesics of the curved spacetime. It is well known that despite of all discussions about the definition of quantum particles in curved spacetime, experimentalists, measuring primordeal radiation or cosmic rays know well that their particles move in quasiclassical limit along geodesics arriving to the earth from other galaxies or the Big Bang itself. So, the main mathematical problem is to answer the question: to which

quasiclassical limit of what Fock quantization in curved spacetime do these particles correspond? One can think that particles in this classical sense can be defined in any space, be it isotropic or anisotropic. For Friedmann spacetime the answer was given by us using the principle of diagonalization of the Hamiltonian of quantized field in curved spactime. The main problem for particle creation is to show that if the stress-energy tensor-vacuum expectation value of the operator tensor of the quantized fields for some early time did not have the form of the dust of particles in curved space and could be understood as vacuum polarization, at the latest time it has the structure of the stress-energy of the dust. If it is the case (and our calculations show it is!) our theory "explains" particle creation. The results for particle density are finite for massive scalar conformal particles and spinor particles. For minimal coupled scalar particles as well as for longitudinal components of massive vector bosons and gravitons it is not finite.But as it is known minimal coupled particles in the clasical limit (as well as longitudinal components of vector bosons and gravitons) do not move along geodesics[46] and in this sense are pathological. Nevertheless, in our paper[47] it was shown that if one takes into account the nonlinear selfinteraction term, then due to change of the vacuum (spontaneous breaking of symmetry) physical particles become conformal coupled. So, one can use results for conformal particles for these particles too.

2. *The problem of vacuum.*There were no particles in the early Friedmann Universe. The simple argument is that due to causal disconnectedness when the size of the horizon is smaller than the Compton length there is no "place " for a particle to be located in the expanding space. In Friedmann spacetime, due to the property of conformal invariance of field equations for massless case one can go to quantum theory in static case where a conformal vacuum as the ground state of the Hamiltonian is well defined. Vacuum as the ground state of the Hamiltonian constructed via the metrical stress-energy tensor is defined also for the massive case. This vacuum coincides with the conformal vacuum in the massless case and was used by us in our calculations of particle creation. So, the results of our calculations show the rationality of our choice of the vacuum.

3. *Entropy problem.* Nevertheless, these calculations in no sense took into account the property of causal disconnectedness of the Friedmann Universe. Our idea now will be that causal disconnectedness leads to appearance of entropy. Really, if one has some volume defined by the scale factor of the model as $a^3(t)$, then one can divide it on many causally disconnected parts

by different ways. The number of different possibilities of the division of the fixed volume on causally disconnected parts can be evaluated by the dimensionless number $a^3(t)/l_{pl}^3$, where l_{pl} is the Planckean length as some “atom” of the length.The ratio of this number to the number of causally disconnected parts(which is of the order of the number of created particles) is for X-bosons $l_x^3/l_{pl}^3 \approx 10^{12} - 10^{10}$, which is not far from the experimentally observed entropy of the Universe. So, the idea for the particle creation will be to put instead of our vacuum, the density matrix of some temperature distribution leading to the observable entropy and to use the expectation value of the stress -energy tensor of the quantised X-boson field as the right hand side of Einstein's equation to produce the metric of the Friedmann's space-time metric. This leads to a new form for the stress-energy tensor for time larger than the Compton one. Due to heuristic considerations given before it seems natural to think that the main contribution for particle creation will be described by the same term, while for the vacuum polarisation the whole density matrix for virtual particles (like in Unruh effect) must be taken into account. The right value of the entropy garantees correct value of the stress-energy tensor and of the scale factor which now will have the cosmological order. The temperature arising due to the entropy also will be of the correct order. The structure of the T_{0pol}^0can be understood from the analogy with the structure of the stress-energy tensor for the Unruh effect and more closely in the Milne's Universe[41], describing the inside of the light cone in Minkowski spacetime. For massless particles (and if the effective temperature is larger than the mass one can always neglect the mass) one has a Planckean distribution of virtual particles with the radiation like equation of state $p = \epsilon/3$. The scale factor for the Milne's Universe is $a(t) = t$, and the temperature will be the Compton one for the Compton time which surely is not the case for cosmology. But early Universe is far from Milne's Universe even inside causal horizon,s o the temperature arising due to existence of particle horizon will depend on the real scale factor. If one can neglect mass for energies (temperatures) much larger than the mass one can use zero mass approximation and get just radiation dominated Universe with correct temperature if correct value of entropy is obtained. Here we put the hypothesis that the value of entropy due to existence of particle horizons and that obtained by counting the number of different possibilities to obtain causally disconnected Universe is the same number! This garantees the correct cosmological order of the temperature. Exact calculation of the T_{0pol}^0 can be made if one in analogy with the Unruh effect takes some global vacuum for the whole Universe evolving into the volume observed today. Then, one puts a boundary condition for the complete set of functions used in quantization inside one causally disconnected part at the Compton time.This boundary condition can be put outside of the fixed region. Different subdivisions of space on causally disconnected parts will lead to different boundary conditions. So, the density matrix will arise. Surely exact calculation here is more difficult than in the Unruh effect. Exact calculation of the T^0_{0pol} can be made if one puts the boundary conditions for the complete set of solutions inside one fixed causally disconnected part at the Compton time. In analogy with the Unruh effect this boundary condition can be put on the light cone out of the fixed region. Different subdivisions of space on causally disconnected parts lead to different boundary conditions. This leads to the density matrix. Vacuum state inside one causally disconnected part playing the role of Rindler vacuum for the Unruh effect will look as some thermal bath for the observer inside in terms of particle created . It is just nonzero expectation value of the stress-energy operator over this state that gives T^i_{kpol}.

And now let us discuss our next proposal to consider entropy creation, time arrow, particle creation and origination of space-time itself as one and the same process.

9 Origination of spacetime due to Booleasation of non Boolean Lattice.

Let us start this section by recalling some basic points of our quantum logical interpretation of quantum physics and the role of time in it. Taking the idea of the ultimate difference between the logic of consciousness as Boolean one and the logic of the world as the nonBoolean one, one comes to the idea of how mind "invents" time in order to "grasp" the non Boolean reality. In non Boolean logic it is possible that

$$a - true = a \wedge (b \vee c) - true,$$

despite the fact that

$$b - false, c - false,$$

which is a contradiction for Boolean mind. To be free from contradiction Boolean mind invents some parameter, called *time*, so that *either* "b" *or*

"c" becomes true at some other *moment* of time. These b, c are still incompatible with a because they occur at different moments of time. So, becoming and the so called wave packet collapse when noncommuting operators are measured at different moments of time are explained by one and the same cause. From this point of view, time is needed for observing different complementary observables, described by noncommuting operators in Hilbert space. Due to the so called "superselection rule" for time, meaning absence of interference terms for different moments of time Hilbert space can be understood as the direct sum of spaces $H = H_{t_1} \oplus H_{t_2} \oplus ...$ Then, to noncommuting operators A, B in the space H_{t_1} there correspond commuting operators for different moments A_{t_1}, B_{t_2}. Let us call *Booleazation of non Boolean* structure, this possibility of making noncommuting operators commuting for different sectors of one Hilbert space due to the superselection rule .

And now, let us discuss the generalization of this procedure to obtain *space*.

If we analyse our idea of origination of time we shall see that one makes many *copies* of the same system for different moments and this *copying* process one calls *evolution* in time. Generalization of this idea for *space* will mean that non Boolean structure existing *here and now* for Boolean mind will be copied in space as many *identical* particles or copies in different *points* of space which is just *invented* by mind for this reason. So, one solves the above mentioned paradox of the non Boolean logic by saying that *either b or c* is true at the other *point* separated from the previous one by a *spacelike* interval. Noncommuting operators at the same point become commuting if taken at different points of space separated by a spcaelike interval! This process of *copying*, leading to origination of space looks like *particle creation.*

So, from our point of view spacetime exists because of existence of the quantum systems (System}.This is close to Leibnitz point of view, where spacetime describes relations between "things" and do not exist without them. Also, similar to Kant's view, space and time are apriori forms of reason and arise due to the possibility for a Boolean mind to observe non Boolean world! From this point of view, there is no necessity for "quantization" of gravity, for if it is just the curvature of spacetime. Here, we agree with such relativists as L. Rosenfeld and L. Infeld who opposed the idea of quantization of gravity, understanding gravity as geometry but not some "material" object! Nevertheless, surely one can enlarge geometry for the noncommutative case and in this sense gravity can be understood more generally.

For space, usually if one has states of many-particles at different points, one uses as Hilbert space of the system, *not* the direct sum of Hilbert spaces associated to each one of the particles (as is the case for the Hilbert space resulting from time with superselection rule), *but* the tensor product. For tensor products one also has a Booleazation effect. Suppose, for simplicity that we have two identical particles, whose "individual" states are rays in the Hilbert spaces $H_1$and $H_2 \equiv H_1 = H$. Consider twof noncommuting operators A , B on the Hilbert spaces H_1 and H_2. In the Hilber space of the two particle system, $H_1\otimes H_2$ operators A and B, become the commuting operators $A \otimes 1, 1 \otimes B$. But, if there is no superselection rule for space one can also have superpositions of states at different points, so that the space is not really classical. The situation becomes different in the case of a causally disconnected space as is the case of the early Friedmann spacetime. Here, one can speak about superselection rule for space either!

At each causally disconnected part, some property of the non Boolean lattice, which can be described, e.g., as a toy model of X-boson observables or *superstring*, some *property* is realized. In the totality of all causally disconnected parts all properties of the non Boolean lattice are realized. Using Everett's conjecture, one can say that in infinite (open case Friedmann Universe) all potentialities are realized at the same moment of time in infinite space.This can be an argument for the open Universe and more deep— understanding of the meaning of its infinity as manifestation of the infinite dimensional Hilbert Space!

So we propose the following scenario of the origination of the Universe.

1. A Non Boolean lattice of properties defining some "universal " quantum system, of which all elementary particles with their properties are just some manifestations is realized for a Boolean observer "here and now "as many particle (particle-antiparticle) system, when one and the same lattice is "copied " many times in space and time used by the Boolean observer to form some Boolean system of commuting observables representing in this manner the original noncommutative system.

2. Taking as the toy model X-gauge meson with spin 1, it is possible to say that an infinite number of space-like intervals is needed in order to realize an infinite number of projections of its spin. For pairs of particles this corresponds to the EPR idea[49] of measuring noncommuting operators of one particle if one has a two-particle system with satisfies some *global* conservation law. Our non Boolean lattice of properties must contain such

a property as quantized particle-antiparticle field as well as the particle and antiparticle numbers.

3. The process of "observation " of the non Boolean lattice which is the same as creation of space and time together with particle creation is accompanied by entropy creation leading to origination of the *time arrow*. This entropy arises due to the existence of different possibilities to distribute the created particles in causally disconnected parts of the Universe evolving to the volume observable by modern observer. Up to the Planckean scale no space point is preferable to any other.

4. Copying in space understood as particle creation in a causally disconnected Universe is accompanied, due to Einstein's equations by origination of the curvature of evolving Friedmann space-time, so that in some *sense* energy conservation is valid if one understands this process as creation of particles by the gravitational field..

5. Future protons and electrons originate through the creation of X-bosons at the Compton time from vacuum due to gravitation field of the expanding Universe with baryon charge and CP nonconservation leading to the baryon asymmetry which we observe today.

6. Despite the fact that the real Universe belongs to the open type and is infinite, human observers can observe only a finite part of it! This part today is "proton and electron" dominated and is such that all "spin potentialities" of these particles are realised in it. Entropy is present in the modern Universe in the form of Primordeal radiation which in a sense is like Unruh radiation— just some property of vacuum in expanding Universe.

7. There is no need for gravity quantization in such a theory because space and time are understood as *artefacts* invented Boolean minds to observer a non Boolean structure.

8. Despite the fact that the idea of "Booleazation of the Non Boolean lattice" can explain the origination of space and time, there is a difference between space and time in the early Universe. Different points as centers of Compton intervals for the quantum system are not fixed and can be arbitrarily moved on the Planckean length leading to different possibilities realized in a fixed volume. This leads to a necessary connection of homogeneous space and existence of the entropy. Nothing of this kind occurs with time, which can be and really is inhomogenuous (as it must be in the Friedmann Universe).

Differently from the inflation's idea, $copying's$ idea of Booleazation of a Non Boolean lattice, can explain the homogeneoity of the Universe and thus solve the horizon paradox (same temperature for causally disconnected parts) without any *extra* hypotheses, like the inflaton field, etc., and leadis naturally to the open Friedmann Universe. Finally, let us recall that the *special role* of observer, which is manifest in our approach, can explain the validity of an anthropic principle in cosmology.

10 Time in Quantum Topology.

One of the important problems of modern quantum theory is the problem of *quantum topology.* Can one have some description for quantum topology, where the topology can be randomly changing? For quantum gravity as we said earlier one can have superspace, which has the structure of usual Boolean (distributive set) of different matrices. But, if the topology is stochastic, what is the structure, if any, of the appropriate set of events? Can one introduce a Kolmogorovian probability measure or probability amplitude (the wave function) for these stochastic topologies? The next question arises when the topology can change. Can one try to introduce some object, playing the role of the "conjugate momentum" for topology, so that an analogy of canonical quantization can be developed? Some steps in this direction were made by C. Isham and his coworkers[50].

Physically, this problem is important for modern superstring theory and there are views that some differences with the usual quantum theory breaking untarity of time evolution can arise. There is also an opinion that quantization of topology is necessary for Planckean scales of spacetime, when gravity must be quantized. Different topologies can lead to diffferent causality relations and there is an idea that quantization of topology must be at the foundation of any quantum theory of gravity if such a theory will be invented. At last, there is a possibility[51] that some aspects of the identity principle and Pauli principle can be understood in terms of nontrivial topology in configuration space for many particle system.

In our papers [6,7] we investigated a toy model of topologies for 3 points and showed that even on the initial level, before some quantization, without speaking about any Planck 's constant, one has something similar to a quantum structure, in the sense of absence of the Kolmogorovian probability measure for the lattice of topologies.

There are two important features for the topology-lattices of 3 and more points which make this system different either from the usual probabilistic space (as phase space in classical mechanics) or from the usual quantum system (quantum logical lattice). The first is the nondistributivity of this lattice, making it different from any classical system. The second is that it is not *orthomodular*, which means that it does not admit any definition of *logical negation*, which makes it different from any classical system.

In paper [7] we constructed some matrix representation of the lattice of topologies for 3 points and it occurred that contrary to quantum systems the arising operators are not self conjugate , being only idempotents. This leads to the *absence* of a wave function description for topologies.

So there is still the question, if topologies are stochastic, what mathematical formalism can describe this stochasticity? The answer was found in our paper[52]: in order to have natural definition of negation for any topology we must *double* the lattice of topologies! For our model, this is again the same "copying trick " which was used by us before, introducing time and space as resulting from to the difference between the Non Boolean structure of quantum systems and the Boolean structure of mind. But now, the difference is that *next moment of time* is *necessary* to introduce *negation*, so that one can say about some property not only what it *is*, but also what it is *not*! So, differently from the standard quantum logic, here *yes-no* values are given to properties for different moments of time. One can say that even the *existence* of the system itself as *this* and *not that* can be conceived only for two different moments of time. At the fixed moment of time one cannot characterize properly the system in logical terms.

So our doubling can correspond to the *new* role of time for the lattice of topologies .If any topology is defined at some moment of time, its negation will be defined at some different moment. Other interpretation would be the introducition of a new degree of freedom, dual to topological one. If a quantum object has "topological degree of freedom", in order to have *negation* one comes to the necessity of some other *dual* degree of freedom, described by the lattice, dual to the lattice of topologies. For the case of 3 points, this lattice is the same as the original topological one, but generally, for more points it is different. So, for the case of more points our doubling will not correspond to *copying* of the same system, but rather like for noncommuting coordinate and momentum, one measures coordinate at one moment of time, momentum at the other. Dual lattice can be called non topological lattice in analogy with J. Wheeler's *yes* and *no* geometries. Our idea of using time for interpreting the doubled lattice—when to the original lattice, the dual lattice is added with identification of the bottom 0-*element* and the up 1-*element*—

is based on the following observation. If the same collection of sets forming the topology is present in the lattice and the dual one and in the new lattice they intersect at the 0-*element*, then it is natural to interpret this as meaning that they are taken at different moments of time, being different due to different values of time parameter. It is not necessary that the dual lattice must be identical with the original one for this interpretation to be valid.

Investigation of the new structure made for our toy model for three points leads to a Hilbert space formulation, which is in some respect similar to "histories approach" of Gell-Mann, Hartle, Isham[54,55] . As a result, we obtain a Hilbert space formulation with wave functions for topologies and self conjugate operators for topologies with natural orthogonality. Differently from the usual quantum theory, a probabilistic interpretation will be possible only for some cases of vectors and observables. The most interesting new feature that arises is due to the new role of *time*—it is the breakdown of the superselection rule for time, resulting in appearance of superpositions of vectors for different moments of time!

And now let us proceed to more formal material.

10.1 The Topological Lattice for Three Points.

We begin with a brief review of principal definitions. Let X be an arbitrary set. A topology on X is a collection τ of subsets of X, called open, such that

$$\begin{aligned} T_1)\ 0,\ X &\in \tau, \\ T_2)\forall A,\ B &\in \tau \Rightarrow A \cap B \in \tau, \\ T_3)\ \forall\ A_{j,}\ j &\in J,\ \cup A_j \in \tau, \end{aligned}$$

where J is an arbitrary index set.

The topologies on X are partially ordered: σ is said to be weaker than τ (denoted $\sigma \leq \tau$) if any set $A \subseteq X$, open in σ is open in τ,

$$\forall A \subseteq X, A \in \sigma \Rightarrow A \in \tau.$$

Here we restrict ourselves to a case where the set X has only 3 elements . For topographical simplicity we use the following brief notation for topologies. Let $X = \{a, b, c\}$ then istead of $\{0, \{a\}, \{b\}, \{a, b\}, \{a, b, c\}\}$we shall write $ab(ab)$.

For instance,

$$a(ab) \text{ denotes } \{0, \{a\}, \{a, b\}, \{a, b, c\}\},$$
$$a(bc) \text{ denotes } \{0\{a\}, \{b, c\}, \{a, b, c\}\}$$

An important property of the lattice $\tau(3)$ (see Hasse diagramm in our publication [7]) is its nondistributivity. To see this, take three atoms $a, (ac), c$ of the lattice and consider

$$\begin{aligned}(a \vee c) \wedge (ac) &= ac(ac) \wedge (ac) = (ac), \\ (a \wedge (ac)) \vee (c \wedge (ac)) &= 0 \vee 0 = 0.\end{aligned}$$

In the sequel we shall work not only with atoms but also with coatoms of $\tau(3)$. There is another equivalent way to describe topologies on X which uses the notion of convergence .Namely, a sequence $x_1, ..., x_n$ of elements of X tends (or converges) to $x_0 \in X$ if and only if for any open set U containing x_0 there is a number N such that $x_k \in U$ for all $k > N$. When the set X is finite, the above definition becomes the following. Consider two elements $x_{1,}x_2 \in X$. Then, $x_1 \to x_2$ if $x_1$belongs to the smallest open set containing x_2. Therefore, we can specify a finite topology by listing all pairs of converging points. In particular coatomoic topologies are so strong that they contain only one pair of converging points. For example, $c \to a$ means that the topology is $bc(bc)(ac)$.

Another important feature of the topology lattice is the lack of *negation.* That means that no operation : $\tau \to \tau$ can be defined making the lattice τ orthocomplemented. For the lattice $\tau(3)$ this impossibility has a simple explanation—any finite ortholattice must have even number of elements while $\tau(3)$ contains 29 elements.

10.1.1 The Doubled Lattice

In order to introduce negation in our lattice we suggest the following construction. Double the lattice of topologies, understanding the initial one $\tau(3)$ as corresponding to one moment of time t_1 and the second copy, consisting of *negations* of the first one, corresponding to another moment t_2.

This new role of time means that "*yes*" and "*no*"-s must be considered at different moments of time for topologies!

In order to make the topology lattice a structure closer to the conventional quantum mechanical formalism, we introduce its elements by operators .In

[7] this was done by introducing a couple of linear spaces, rather than one Hilbert space as it is the case in standard quantum mechanics. Here we shall apply the duplication procedure to the lattice $\tau(3)$ in order to represent its elements by operators in a Hilbert space.

So, the doubled lattice L will have the form of the horizontal sum (for details see [52]) lattice $\tau(3)$ and $\tau(3)^{op}$ (where $(.)^{op}$means the order reversed lattice (see also [52]). Let us describe this procedure in more detail.The lattice $\tau(3)^{op}$is built from $\tau(3)$ by reverting it: the smallest element 0 becomes the greatest one and so on. To distinguish the elements of $\tau(3)$ and $\tau(3)^{op}$ we denote the elements of the latter as $a, (ab), (b \to c)$, and so on.

The next step is to form the horizontal sum $\tau(3) \oplus \tau(3)^{op}$. It is done by putting these lattices together (no pair of elements from different parts are comparable), and then identifying their greatest and least elements:

$0 = 1, 1 = 0$

There are atoms in the lattice (there is only 0 below them) and coatoms (there is only 1 above them). In $\tau(3)^{op}$, atoms are negations of coatoms and coatoms are negations of atoms. So, generally if the number of points is larger than 3 the lattice τ^{op} can have other number of atoms than τ and will be different from any lattice of topologies and can correspond to some degree of freedom "dual " to topological degree of freedom. The resulting lattice L now posseses the natural *negation* operation: $L \to L$ of orthocomplementation: for any $x, y \in L$,

$$\begin{aligned} (x \vee y) &= x \wedge y, \\ x \vee x &= 1, x \wedge x = 0. \end{aligned}$$

However in the case when $\tau(3)$ is the topology lattice ,L being orthocomplemented is not orthomodular.The orthomodularity law

$a \leq b \Rightarrow a \vee (a' \wedge b)$

is violated. Here the point is used for the complement.That is why $L = \tau(3) + \tau(3)^{op}$ is not a quantum logic.The structure of L can be visualised as two copies of the original Hasse digramm put together and having common greatest and least elements.

10.1.2 Some Basic Features of the Matrix Representation of the Doubled Topologies Lattice.

In our paper with R .R. Zapatrin[52] a formalism has been introduced, where the elements of the doubled lattice of topologies are representedby 12-dimensional matrices. As it is known, elements of the quantum logical lattice are represented by self conjugate projectors in Hilbert space. Similar construction was made by us for topologies. A 12-dimensional Hilbert space was constructed with the scalar product defined by the "sandwich matrix "of the doubled lattice. Each element of the lattice is then represented by some 12-dimensional Hermitean matrix. It was found the algorithm for lattice operations $\vee, \wedge$ which due to lack of modularity of the lattice is different from the case of quantum logical lattices.

Now, when the elements of the lattice L are represented as projectors in H one can investigate the well known quantum mechanical formula for transition probability,

$$\Pr(\phi, \psi) = | < \phi, \psi > |^2.$$

A new feature of the system was found: if u, v are orthogonal atomic properties, then the Kolmogorovian law for the probabilistic interpretation holds if and only if the state of the system is their superposition,

$$\psi = k_1 u + k_2 v.$$

But this superposition is a superposition of vectors taken at *different* moments of time! It follows that the superselection rule for time is broken for our system, which makes it different from standard quantum mechanical systems.

11 Everett-Wheeler-DeWitt and Histories Approach Interpretations of Quantum Physics

And now we shall briefly comment the problem of time in other than Copenhagen interpretation of quantum physics. Whe shall concentrate on the *Everett-Wheeler-De Witt* interpretation and in the *histories* approach.The original idea of Everett[56] was to use only one type of time evolution in quantum physics instead of the usual two kinds of evolution, the one due to measurement and the other due to Schrödinger evolution. For this, one uses the idea of "existence" of many Universes, where all potentialities for any quantum system are realized. This ensemble of infinite number of Universes evolves according to Schrödinger equation. However, the observer has relation with only one of the copies of his Universe. At different moments of time this observer can "identify " himself with different copies of himself existing in different worlds and this, he interprets as the collapse of the wave function and indeterminism.

Really, at the other moment he deals with a different "past " evolving due to Schrödinger evolution to his new present. As J. Bell once said[17] , in this interpretation one deals with a "many pasts" existence. However, as Everett himself was the first to see, an important role in this interpretation is played by the "memory" of the observer described by classical or quasiclassical physics. In other case, memory could be erazed when going from one "world" to the other. But in this we again, recognize the difference between the "clasical language " of the observer and the quantum world. Absence of the observable manifestation of "other worlds ", makes this interpretation rather disputable.However if our Universe is really infinite and in it all quantum potentialities are somewhere realized, than this interpretation probably can help us to find some unity between quantum physics and cosmology.

Another strategy to have only "one" evolution is the "histories " approach.

The main object of the approach is *history*, which is a time ordered $(t_1 < t_2 < ... < t_n)$ conjunction of properties defined by the observables $\{A_{1,}A_{2,...}A_n\}$. The properties do not need to be compatible. It is to histories that probabilities are asigned. To see how this is done, we first assume that:

a) the initial state of the quantum system at time $t_0(< t_1)$ is given by the density matrix ρ (in the Heisenberg representation) and

b) the spectrum of each observable A_i, represented by the operators $A_i(t_i)$ is divided into a complete family of disjoint sets $D_i^{\alpha_i}$.

Given the set $\{\alpha_i\}$ we define a history U by the time ordered sequence of properties,

$$U = \{P_1^{\alpha_1}(t_{1),}P_2^{\alpha_2}(t_2), ...P_n^{\alpha_n}(t_n)\}$$

The joint probabilty for finding all the properties in an appropriate sequence of measurements is called the*probability of the history* and is given by

$$p_U = Tr(P_n^{\alpha_n}(t_n)...P_2^{\alpha_2}(t_2)P_1^{\alpha_1}(t_1)\rho P_1^{\alpha_1}(t_1)...P_n^{\alpha_n}(t_n))$$

This equation is the well known Wigner's formula for the probabilities. By varying the set $\{\alpha_i\}$we obtain a *complete family* of histories.

The probabilities of histories are additive for disjoint properties occuring at the same time. The probabilities of a larger history is the sum of the probabilities for the more detailed ones entering it.

However ,additivity is not satisfied by all complete families of histories, since the probabilities for histories must be consistent with the quantum additivity of amplitudes. The condition is expressed by the so called *consistency conditions* first found by Griffits in 1984[]. Gell-Mann and Hartle presented the consistency conditions as

$$Tr\{P_{n-1}^{\alpha_{n-1}}(t_{n-1})...P_1^{\alpha_1}(t_1)\rho P_1^{\alpha'_1}(t_1)...P_{n-1}^{\alpha'_{n-1}}(t_{n-1})\} = 0,$$

where the sequence $\{\alpha_i\}$is different from the sequence $\{\alpha'_i\},(i = 1, ...n - 1)$.

These are sufficient conditions, the necessary conditions were found by Griffits[57] and Omnes[58]. Histories satisfying the consistency conditions are said to be *consistent* histories.All other histories are said to be *inconsistent*.

To consistent histories we can give $yes - no$ values and say that they are!

If properties are compatible, then they are consistent with respect to every initial state. This is the situation one has in classical physics. An interesting feature of the approach is that for special states there may be properties that are consistent but not compatible! An example of consistency is when the state is a probabilistic mixture of pure states $|\varphi_i >$ with weights w_i and one has projectors P_i on these states and arbitrary projectors Q_j. The probabilities of conjunctions, taken in order are

$$p(P_i Q_j P_i) = w_i < \varphi_i|Q_j|\varphi_i > .$$

However despite of some interesting and new insights "histories approach " is not equivalent to the standard quantum mechanics. This inequivalence from the point of view of our research, shows some properties of time due to “becoming ”, making impossible to treat real history as some “existing ” object! We recall here here the criticisms given in our book [2]. One of them, is the Kent’s result that for finite dimensional Hilbert space there always exists some finite number, such that qantum indeterminism disappears after making some finite number of measurements. After that, the determinism is restored. Surely for any spin system when infinite number of noncommuting observables can be measured freely and lead to random results such a property does not exist in standard quantum mechanics. So, histories approach in a sense presupposes some “tenseless” existence of either of events forming the history or history as a whole described by some “truth” function, but these assumptions contradict “potentiality ” existence of qantum properties in the standard quantum physics in its Copenhagen interpretation!

12 Conclusion.

And now let us present some conclusions .Our review of properties of time in Relativity and Quantum Physics is rather “inhomogeneous”. We resumed a lot, when dealing with well known features of time in classical and statistical mechanics, as well as in classical Special and General Relativity. The reason for that is that this material is described in many different books on time in physics. We only stressed some special points, especially those where *personal* opinion of the author was expressed. Much attention was given to the role of time in Quantum Physics based on the author’s quantum logical version of the Copenhagen interpretation of quantum physics. Quantum gravity and quantum topology as well as the time machine problem were discussed. Resuming one can say the following.

In classical physics time is present as parametric time, which is not much different from space. It is in quantum physics that time becomes present in its two manifestations:

1. In measurement process, when something “new ”and unpredictible can arise (or “become”).

2. In parametric form like in classical physics when Schrödinger evolution takes place.

3. “Movement in time ”occurs because of the difference between the Non Boolean structure of the physical world and Boolean logic of the observer.

4. Minisuperspace quantization of gravity leads to the idea that the “parametric time ” can be introduced only in the quasiclassical domain, and exists only for some special quasiclassical wave function of the Universe. However time due to “measurement process ” must exist even for this model, if noncommuting observables for quantum gravity in the canonical formalism are to be measured. However the parameter introduced by a Boolean observer for this case as time will not coincide with the classical time parameter. The last possibility leading to the identification of the “quantum measurement time ” and classical parametric time arises only in the quasiclassical limit.

5. Booleazation procedure of the non Boolean lattice can be used in cosmology of the early Universe to understand the origination of classical space due to particle creation. This is valid however, only if a superselection rule for space due to the causal disconnectedness of the early Universe is at work, this being the case for times close to the singularity of the Friedmann Universe.

6. The time machine problem with its paradoxes of time nonlocality in

classical physics and nonunitarity in the quantum domain shows some inconsistency between spatial parametrization of time and its intrinsic property of “becoming”. So, it seems that if a time machine is possible than “becoming ” as property of time will be not manifested on the timeloop at all!

7. In quantum topology one can find a new manifestation of time, when the necessity of existence of not one, but many moments of time occurs due to the property that the very definition of the system in terms of what it “is ” and what it is “ not ” *needs* at any rate two moments of time and is impossible for only one moment.

And to end, we want to claim that the old problem of “the time arrow ” is *still* with us!

Despite of the entropical quantum measurement, T-noninvariance, electrodynamical and cosmological “arrows ” define one and the same direction, the problem of the difference between “before ” and “after” as being the same for different observers is not completely solved, because we still do not understand the reason of this coincidence. .

Acknowledgements

The author is indebted to Prof. Waldyr A. Rodrigues Jr. for stimulating discussion of the topic, which interested the author from the time of his first publication in *Nature* [58] in 1974, and for the hospitality at the UNICAMP, Campinas, Brazil, making this work possible. Surely, much in the views of the author changed since 1974, specially, the new features of time in Quantum Physics became more clear, while some old problems are still unsolved. But, it is naive to think that the great problem of time in Nature, being a fundamental philosophical problem, can be exhausted easily!

The author is indebted to FAPESP, SP, Brazil, for financial support of the work.

13 References.

[1[Grunbaum A., *Philosophical Problems of Space and Time.* Dodrecht, Reidel 1973.

[2] Grib A. A. Rodrigues, W. A., Jr., *Nonlocality in Quantum Physics*, Kluwer-Plenum 1999

[3] Grib A. A., *Int. J . Theor.Phys.* **32** (12), 2389-2400 (1993).

[4] Grib A. A., *Breaking of Bell's inequalities and the problem of measurement in quantum theory*, Dubna JINR.(1992).

[5] Grib A. A., Proc. of the Fourth Alexander Friedmann Intern.Seminar on Gravity and Cosmology, St.Petersburg, Pulkovo, Campinas, pp.119-130 (1999).

[6] Grib A.A., Zapatrin R.R., *Int. J . Theor.Phys.* **32**, 238,(1993).

[7] Grib A.A., Zapatrin R.R. *Int. J . Theor.Phys.* **35**, 593,(1996).

[8] Augustine, *Confessions*, Middlesex:Penguin 1961.

[9] Grib A .A. , Quantum Cosmology, the Role of Observer, Quantum Logics, in Russell et al (eds.), *Quantum Cosmology and the Laws of Nature:Scientific Perspectives on Divine Action*, Rome and Notre Dame:Vatican Observatory and University of Notre Dame Press, 1993.

[10] Sklar L., Time in experience and in theoretical description of the world, in Savitt S. (ed.) *Time's Arrow Today*, Cambridge University Press 1997.

[11] Wheeler J.A., Feynman R.P., *Rev. Mod. Phys.***17**,157-181,(1945).

[12] Cramer, J., *Rev. Mod. Phys.* 5**8** (3),647-687 (1986).

[13] Unruh W., Time, Gravity and Quantum Mechanics, in Savitt S. (ed.), *Time's Arrow Today*, Cambridge University Press (1997).

[14] Tipler F.J., *The Physics of Eternity. Modern Cosmology, God and the Resurrection of the Dead*, Doubleday.

[15] London F., Bauer E., *La Theorie de l 'observation en Mecanique Quantique*, Paris 1939.

[16] D 'Espagnat B., *Conceptual Foundations of Quantum Mechanics*, W.A.Benjamin, Reading, MA.1976.

[17] Bell J., *Speakable and Unspeakable in Quantum Mechanics,* Cambridge University Press,Cambridge,(1987).

[18] Grib A. A., *EPR Paradox, Bell's Inequalities and Telepathic Communication*, IMECC-UNICAMP,RP 16/95..

[19] Grib A.A., *On the Problem of the Role of Consciousness in Quantum Physics*, IMECC-UNICAMP, RP11/99.

[20] Grib A.A., *Early Expanding Universe and Elementary Particles*, Friedmann Lab Publ., St.Petersburg, 1995.

[21] Halliwell J., Hawking S., *Proc. of the 3rd Seminar "Quantum Gravity"*, Moscow, p.509, World Scientific,1984.

[22] Hawking S., *A Brief History of Time*, New York, Bentam, 1988.

[23] Carlini A., Ishihara H., Nakamura K., Okamura T. , *Proc. of the Fourth Alexander Friedmann Intern.Seminar on Gravitation and Cosmology*, St.Petersburg, Pulkovo, IMECC, Campinas 1999.

[24] Ellis G.F.R., Sumeruk A., Coule D.H. and Hellaby C., *Class. Quantum Gravity.* **9**, 1535-1554 (1996).

[25] Gödel K., *Rev. Mod. Phys. 21*, 447-450 (1945).

[26] Oszvath I., *J. Math. Phys.* **8**, 326-344 (1967).

[27] De U.K., *J. Physics A* (Ser 2) **2**, 327-332.(1967).

[28] Gott J.R., *Phys.Rev.Lett.* **66**,1126-1129 (1991)

[29] Morris M., Thorne K.S.,Yurtsever U., *Phys.Rev. Lett.* **61**,1446-1449,(1988).

[30] Novikov. I.D., *Sov. JETP* **68**, 43-49 (1989).

[31] Savitt S., *Canad.J. Philosophy* **21**, 399-417,(1991).

[32] Earman J., Recent work on time travel , in Sawitt S. (ed.), *Time 's Arrow Today*, Cambridge Press, Cambridge ,1997.

[33] Echeverria F., Klimhammer G., Thorne K., *Phys. Rev. D* **44**,1077-99 (1991).

[34] Novikov I.D., *Phys. Rev.D* **45**,1989-94 (1992).

[35] Krasnikov S. V., *Phys .Rev. D* **54**, 7322 (1996)

[36] Sushkov S. V., *Class. Quantum Grav.* **14**, 523 (1997).

[37] Antonsen F., Bormann K., *Int. J . Theor.Phys.* **35**, 1223 (1996).

[38] Antonsen F., Bormann K., *Int. J . Theor.Phys.* **37**, 2383-2395.(1998)

[39] Grib A. A., Mamayev S .G., *Sov. J.Nucl.Phys.***10**, 722-725 (1972).

[40] Grib A. A., Mamayev S. G., Mostepanenko V.M., *Gen .Rel. Grav.***7**, 535-547 (1976).

[41] Grib A.A.,Mamayev S. G.,Mostepanenko V.M., *Quantum Effects in Intensive External Fields,* Moscow, Atmizdat, 1980.

[42] Grib A. A., Frolov V. M., *Proc. of 4 Seminar "Quantum Gravity "*, Moscow, p.875, World Scientific, 1987.

[43] Unruh W. G., Phys.Rev.D 10, 3194-205 (1974).

[44] Grib A. A., *JETP Lett.* **67**(1), 86-87,(1998).

[45] Terazawa H., *Proc.of 3rd Alexandre Friedmann Intern. Seminar on Gravitation and Cosmology*, p.116, St.Petersburg, 1995.

[46] Misner C., Thorne K., Wheeler J.A., *Gravitation*, Freeman, 1972.

[47] Chernikov N.A., Tagirov E.A., *Ann. Inst .H. Poincaré A* **9**,109 (1968).

[48] Grib A. A., Poberii E.A., *Helv.Phys.Acta* **68**, 380-395 (1995).

[49] Einstein A., Podolski B., and Rosen N., *Phys. Rev .* **47**, 777-780 (1935)

[50] Isham C. J., *Clas. Quantum Gravity* **6**, 1509 (1989).

[51] Leinaas.J., Myrheim R., *J. Mod. Phys. B* **5**, 2573 (1991).

[52] Grib A. A., Zapatrin R. R., *In Search of Quantum Topology*, RP 72/96, IMECC-UNICAMP (1996).

[53] Gell-Mann M., Hartle J., *Phys. Rev. D* **47**(8), 3345-3386 (1993).

[54] Isham C. J., Linden N., *J. Math. Phys.* **36**, 5392 (1995).

[55] Everett H., *Rev. Mod. Phys.* **29**(3) 454-462 (1957).

[56} Griffits R.B., *J. Stat. Phys.* **36** (1-2) 219-272 (1984).

[57] Omnes R., *The Interpretation of Quantum Mechanics,* Princeton University Press, Princeton, NJ,1994.

[58] Grib A .A., Is Movement Backwards in Time Possible?, *Nature* (Moscow) **4**, 14 (1974), .