Abstract: The notions of time in the theories of Newton and Einstein are reviewed so that certain of their assumptions are clarified. These assumptions will be seen as the causes of the incompatibility between the two different ways of understanding time, and seen to be philosophical hypotheses, rather than purely scientific ones. The conflict between quantum mechanics and (general) relativity is shown to be a consequence of retaining the Newtonian conception of time in the context of quantum mechanics. As a remedy for this conflict, an alternative definition of time – earlier presented in Kitada 1994a and 1994b – is reviewed with less mathematics and more emphasis on its philosophical aspects. Based on this revised understanding of time it is shown that quantum mechanics and general relativity are reconciled while preserving the current mathematical formulations of both theories.

Introduction

Previous papers of Kitada 1994a, 1994b proposed an approach to the problem of overcoming the apparent inconsistency of non-relativistic quantum mechanics and general relativity. The purpose of this paper is to explain the structure and background of that approach, with emphasis on a certain philosophical problem related with the notion of time.

The inconsistency of quantum mechanics and general relativity, when looked at mathematically, seems at first sight obvious and inescapable from the fact that the geometry of quantum mechanics is Euclidean, while general relativity employs a curved, Riemannian geometry.

The proposal of Kitada 1994a to overcome this apparent mathematical incommensurability of these two geometries is by “orthogonalizing” them; i.e. by expressing them as a direct product $X \times R^6$, where $X$ represents the curved Riemannian manifold associated with general relativity, and $R^6$ (or in the usual space-time context, $R^4$) denotes the Euclidean space of phase space coordinates $(x, v)$ of non-relativistic quantum mechanics. As two components of the orthogonalized total space $X \times R^6$, the Riemannian space $X$ and the Euclidean space $R^6$ are compatible with no contradiction.
General relativity and quantum mechanics are the two most important and comprehensive theories of contemporary physics. By “comprehensive” we mean that both theories claim to apply to everything. In practice it may seem as if these two theories applied to different physical domains, since the most striking applications of quantum mechanics occur when we consider things that are extremely tiny in relation to ourselves – things like electrons and photons – while the most striking applications of general relativity occur in connection with extremely large and dense concentrations of matter and enormous spatio-temporal magnitudes. But, in principle, every physical thing must be capable of being described adequately by both theories, at least this is what the theories claim. And there are certain cases – of particular interest in recent cosmology and astrophysics – where the extremes of density that are the particular province of general relativity coincide with the extremes of minuteness that are the special province of quantum mechanics. In those situations, the physicist is compelled to face a problem which is present in the background of science all the time but which can otherwise be evaded without practical consequence: the fact, namely, that these two comprehensive theoretical structures appear to be mutually incompatible, that they seem to involve different – and contradictory – assumptions about the nature of space, time and causality.

Our intention in this paper is to outline an approach to the understanding of general relativity and quantum mechanics in which these theories will appear as distinct but systematically coordinated perspectives on the same reality. The orthogonalization of the spatial foundations of the two theories allows us to speak of the two theories as distinct. To express the possibility of their systematic coordination will require a more extended analysis of the nature of time.

In brief, we can express our approach as follows:

1. We begin by distinguishing the notion of a local system consisting of a finite number of particles. Here we mean by “local” that the positions of all particles in a local system are understood as defined with respect to the same reference frame.

2. In so far as the particles comprised in this local system are understood locally, we note that these particles are describable only in terms of quantum mechanics. In other words, to the extent that we consider the particles solely within the local reference frame, these particles have only quantum mechanical properties, and cannot be described as classical particles in accordance with general relativity.

3. Next we consider the center of mass of a local system. Although the local system is considered as composed of particles which – as local – have only quantum mechanical properties, in our orthogonal approach we posit that each point \((t, x)\) in the Riemannian manifold \(X\) is correlated to the center of mass of some local system. Therefore, in our approach, the classical particles whose behavior is described by the general theory of relativity are not understood as identical with the “quantum mechanical” particles inhabiting the local system – rather the classical particles are understood as precisely correlated only with the centers of mass of the local systems.

4. It is important to recognize that the distinction we are making between local systems and classical particles which are the centers of mass of local systems is not a simple
distinction of inclusion/exclusion. For example, we may consider a local system containing some set of particles, and within that set of particles we may identify a number of subordinate “sublocal” systems. It would seem that the centers of mass of these sublocal systems must be “inside” the local system as originally defined, but the sublocal system is at the same time a local system, and we have said that the centers of mass of local systems are correlated with classical particles whose behavior is to be described in terms of relativity theory.

The paradox is avoided by noting that the distinction we are making is a distinction of reference frame, not a distinction of inclusion or exclusion. When we speak of classical particles (or centers of mass) we are speaking of the particle in terms of the observer’s time, which is understood as distinct from that of the particle observed. To the extent that the time of the system $L$ itself is adopted as the reference time, then we are speaking of the behavior of a local system whose development must be described in terms of quantum mechanics.

It is our contention that time necessarily has two quite different aspects, in relativity theory, on the one hand, and in quantum theory on the other, and the intention of this paper is to show that these two aspects of time are in fact complementary and that the notion of local time, which we have associated with the quantum mechanical local system, is not only the main ingredient of a unification of quantum and relativity theories, but that this actually is necessary to constituting the time of relativity theory.

The “orthogonalization” of the geometries of quantum mechanics and general relativity gives two ways of expressing the same reality so that it means that two aspects of quantum and relativity theories are complementary, but it does not immediately specify the relationship between quantum mechanics and general relativity as branches of physics. This relationship will come to light as we investigate the nature and conditions of observation.

We take the following stand on the property of observation, which gives a distinction between classical and quantum mechanical observations as well as a relation between two aspects of nature:

The quantum mechanical, non-relativistic effects are usually hiding themselves from the observer, and the observation usually reveals classical aspect of nature, if the observer observes the centers of mass of infinite number of local systems outside the observer in accordance with the observer’s own time $t_O$. The quantum mechanical nature of the local system $L$ appears, when the time $t_L$ of a fixed observed system $L$, consisting of finite number of particles, is adopted as a reference time. Then the observed values of physical quantities of $L$ are obtained by correcting the non-relativistic quantum mechanical values of $L$ in accordance with the relativistic transformation of coordinates from the coordinates of the system $L$ to the observer’s coordinates.

To state this in another way, our basic assumption is that there are two kinds of observation. Let us decompose the total universe, i.e. the set of all particles $\{1, 2, 3, \ldots\}$ into a disjoint sum of the subsets $L_j$ of $\{1, 2, 3, \ldots\}$. Some of the $L_j$ may be an infinite set,
but in that case we assume that such infinite $L_j$ does not constitute an observable local system. What we call local system is the system consisting of finite number of particles. Let $L_1, \ldots, L_\ell$ ($\ell$ may be infinite) be the totality of the observable local systems in the decomposition $\{L_j\}$ of $\{1, 2, 3, \ldots\}$. Suppose that $L = (L_1, \ldots, L_k)$ ($k(\leq \ell)$ being finite) constitutes a local system consisting of the particles which belong to some of $L_1, \ldots, L_k$. Then there are two kinds of observation.

The first kind of observation is the observation of the centers of mass of the local systems $L_1, \ldots, L_\ell$, when the sum of the sets $L_1, \ldots, L_\ell$ is equal to $\{1, 2, 3, \ldots\}$, hence $\ell$ is infinite. In this case, we assume by axioms 4 and 5 in section V below that the observer observes classical phenomena about the centers of mass of $L_1, \ldots, L_\ell$.

The second kind of observation is the observation of the inside of a local system $L = (L_1, \ldots, L_k)$ ($k$ is finite). In this case, $L$ follows quantum mechanics with respect to the local time $t_L$ of $L$. When the observer inquires into the inside of the quantum mechanical local system $L$, we assume by axiom 6 in section VI that the observer makes an “ideal” decomposition of $L$ into its sublocal systems $L_1, \ldots, L_k$, say, and makes an “ideal” observation on the ideal classical particles $L_1, \ldots, L_k$, i.e. the centers of mass of $L_1, \ldots, L_k$. We assume by axiom 6 that in this case, the quantum mechanical quantities of $L_1, \ldots, L_k$ are transformed to classical relativistic ones in observer’s coordinates, obeying the general relativistic transformations of coordinates. During this “ideal” observation, the Euclidean structure of $L$ disappears for the time being, and we consider the observation as an observation performed in an ideal Riemannian manifold associated to the centers of mass of $L_1, \ldots, L_k$ within the observer’s coordinate system. The quantum mechanical quantities of $L_1, \ldots, L_k$ transformed to classical relativistic ones, e.g., times, energies, and so on, of the local systems $L_1, \ldots, L_k$, then are used to reconstruct the Hamiltonian $H_L$ for the local system $L = (L_1, \ldots, L_k)$ so that the relativistic effect like gravitation is included in the resultant Hamiltonian $H_L$. This modified Hamiltonian $H_L$ explains the relativistic quantum mechanical phenomena about the local system $L = (L_1, \ldots, L_k)$, when they are observed in the observer’s coordinate system.

The first kind of observation explains the classical nature of the phenomena which are usually observed in daily activities, and the second kind of observation explains the relativistic quantum mechanical phenomena like the behavior of electrons accelerated near the speed of light. Several examples of these kinds of observations will be given in sections VI, VII, and VIII.

We call the time $t_L$ of a local system $L$ the local time of the system $L$. This notion of local time is a main ingredient of our consistent unification of quantum and relativity theories.

In this respect, the notion of time will be reflected first below, going back to its definition. We will recall the notions of time in Newton’s context and in Einstein’s context, and clarify philosophical difference between them. Then we will give an explanation of our definition of time, which is based on some philosophical assumptions stated in sections III and IV, assumptions intermediate between Newton’s and Einstein’s. We will see in sections V and VI how our notion of time works for the purpose of our unification of quantum mechanics and general relativity.
I. Assumptions of Newton and Einstein on the Notion of Time

Isaac Newton specifies the notion of time as follows in his *Principia*, Newton 1962, p.6:

Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration: relative, apparent, and common time, is some sensible and external (whether accurate or unequable) measure of duration by the means of motion, which is commonly used instead of true time; such as an hour, a day, a month, a year.

Also in pp.7-8, he states:

Absolute time, in astronomy, is distinguished from relative, by the equation or correction of the apparent time. For the natural days are truly unequal, though they are commonly considered as equal, and used for a measure of time; astronomers correct this inequality that they may measure the celestial motions by a more accurate time. It may be, that there is no such thing as an equable motion, whereby time may be accurately measured. All motions may be accelerated and retarded, but the flowing of absolute time is not liable to any change. The duration or perseverance of the existence of things remains the same, whether the motions are swift or slow, or none at all: and therefore this duration ought to be distinguished from what are only sensible measures thereof; and from which we deduce it, by means of the astronomical equation.

The main point of this famous passage is to assert the existence of an absolute, true time. However, it is important to note that Newton asserts the existence of his absolute time by means of a distinction. There is absolute time, which flows without reference to anything external, and then there is relative, apparent, or common time, which is a measure of duration made by comparison of motions. Not only that, but although there may be no absolutely regular motion by means of which absolute time may be accurately represented, absolute time is an ideal standard by means of which relative or common time is “corrected.”

Einstein’s theory of relativity, as is well-known, sharply contrasts with Newton precisely on the question of time and space: Einstein’s theory makes no reference to either absolute time or absolute space. Einstein retains the relative or common time which can be measured and determined by means of actual clocks associated with each local observer, but he completely jettisons Newton’s notion of an absolute time flowing equably for all observers.

For example, in Chapter IX of Einstein’s 1920 popular presentation of special relativity, Einstein has been exploring whether two events which are simultaneous with respect to an embankment next to a railway track are also simultaneous for an observer riding in the train that is moving on the track, and his analysis comes to the following conclusion:
Events which are simultaneous with reference to the embankment are not simultaneous with respect to the train, and vice versa (relativity of simultaneity). Every reference-body (co-ordinate system) has its own particular time; unless we are told the reference-body to which the statement of time refers, there is no meaning in a statement of the time of an event.

Now before the advent of the theory of relativity it had always tacitly been assumed in physics that the statement of time had an absolute significance, i.e. that it is independent of the state of motion of the body of reference. But we have just seen that this assumption is incompatible with the most natural definition of simultaneity; if we discard this assumption, then the conflict between the law of the propagation of light in vacuo and the principle of relativity (developed in Section VII) disappears.

In this passage it is clear that, with the advent of the special theory of relativity, Einstein has abandoned Newton’s notion of an absolute or true time.

According the Einstein, each observer observes within his own frame of reference – and with respect to time his time frame is his own clock. The theory of relativity gives us procedures for coordinating observations made in diverse reference frames, frames that are in relative motion or even, in the case of general relativity, mutually accelerated.

In the context of Einstein’s theories, the universe as a whole has no frame of reference of its own. Time of the entire universe is merely time observable by the observer. We may imagine a way to construct a frame of reference that is large enough to include all observers, at least all the observers we can think of. But no matter how inclusive this frame of reference, it is still an essentially local framework, or an extrapolation and coordination of local frameworks. Time for Einstein never ceases to be connected to the clocks of observers. It is never the “true time.” And time for Einstein can never be said to “flow equably” for all observers, no matter how situated with respect to one another. The observed universe may be said to exist, but its observation is always connected to the reference frames of its observers.

In either standpoint of Newton or Einstein, it is noticeable that they both made some assumptions on the absolute space and time. Newton assumed that they exist and assumed implicitly that they should coincide with the actual, common space and time when one deals with the motion of bodies. On the contrary, Einstein assumed that such absolute space and time do not exist, or at least need not be considered because they cannot be perceived actually by observation activities. Instead Einstein took the standpoint that what exist are the actual clocks and rules by which the observer can measure the motion of the observed systems or bodies.

It should be noticed that this sort of assumptions can be made in any other different ways from Newton’s or Einstein’s, whenever the assumption can be introduced, resulting no inconsistency to the physics theory. We will present one set of such assumptions in sections III and IV, and adopt them as our basic philosophical assumptions which replace the assumptions of Newton’s and Einstein’s.

II. Conflict between Quantum Mechanics and Relativity
The direct motivation of the introduction of the special theory of relativity by Einstein was the contradiction of Newtonian mechanics with electromagnetic theory, which was developed in 19th century. Einstein’s research of simultaneity quoted above solved the inconsistency with direct alteration of the basic notion of simultaneity and time. The theory was further extended by Einstein to the general theory of relativity to include the gravitational phenomena.

On the other hand, M. Planck introduced the notion of quantum in 1900 in relation with the explanation of blackbody spectrum. This led to the introduction of the quantum mechanics by Heisenberg 1925 and Schrödinger 1926. In quantum mechanics, time plays a special, absolute role as seen in Schrödinger equation:

$$\frac{\hbar}{i} \frac{\partial}{\partial t} \psi(x, t) + H\psi(x, t) = 0, \quad \psi(x, 0) = \psi_0(x),$$

where the Schrödinger operator or the Hamiltonian $H$ of the system is defined by

$$H\psi(x, t) = -\frac{\hbar^2}{2m} \sum_{j=1}^{3} \frac{\partial^2 \psi}{\partial x_j^2}(x, t) + V(x)\psi(x, t).$$

Thus the solution of the Schrödinger equation is given by

$$\psi(x, t) = \exp[-itH/\hbar]\psi_0.$$

In this context, the time $t$ is given a priori, and then the motion $\psi(x, t)$ of the system is derived from the Schrödinger equation by using the time evolution $\exp[-itH/\hbar]$ of the system.

The speciality of the role of time can be seen also by looking at the alternative formulation of quantum mechanics by Feynman 1948. See also Kitada 1980 for the relation between the classical mechanics and quantum mechanics researched along the line given by Feynman 1948.

Because the evolution in the framework of non-relativistic quantum mechanics is governed by the Schrödinger equation, the space and time are intrinsically Newtonian in quantum mechanics in the sense that the form of Schrödinger equation is not invariant with respect to the relativistic transformation of coordinates. Thus quantum mechanics is not consistent with either special or general relativity, even if one ignores the more fundamental problem of relating the quantized magnitudes of the one with the continuous magnitudes of the other. Further, the discrepancies found in experiments, such as the motion of electrons accelerated to a velocity close to the speed of light, indicate that the quantum mechanics may be imperfect.

Many attempts have been made to reconcile quantum mechanics with relativity theories, e.g. the Dirac equation, quantum field theories, quantum gravity, and so on. Except for the case of the Dirac equation, where the special relativistic space-time is successfully formulated in harmony with quantum mechanics while retaining the special role of the time parameter, all of these attempts suffer from inherent difficulties. See, e.g., the final
sentences in the last section 81 of Dirac 1958. See also Sachs 1986, Chap. 2, and 1988, Chap. 10, where a comprehensive list of discrepancies between quantum and relativity theories is presented.

These attempts have been continued until quite recently and have in general tended to disregard the fundamental discrepancy, mentioned above, between the Newtonian conception of time presupposed by Quantum Mechanics and the quite different notion of time presupposed by Einstein’s relativity theories. Recently some useful reflections have been made on this point (see Isham 1993 for some review, see also Unruh 1993, Hartle 1993). In general, however, it appears that most other researchers are approaching the problem of time as a problem of a technical nature whose solution is to be found by means of technical adjustments within the frameworks of quantum field theory, quantum gravity, etc.

III. What should be the Notion of Time?

We have stated that the cause of the conflict between quantum mechanics and relativity is in the choice of the notion of time: In quantum mechanics, time is an absolute notion that retains the Newtonian conception of time; while, in relativistic theories, time is a notion whose values are determined only relatively.

What then should be time, if one is given this conflict and cannot be satisfied with this situation of physics? One would agree that a certain notion of time must, at least, be able to reconcile quantum mechanics and general relativity, for both theories have overwhelming evidences and show the power of explanation of experimental and observational facts with outstanding accuracy.

There are several attempts presently such as quantum gravity (see, e.g., Ashtekar-Stachel 1991, Isham 1993 for these attempts) toward a reconciliation of quantum mechanics and general relativity, where the problem of time is recognized central. In many of these attempts, the problem is considered to be a technical one to find out how to identify time in relation with the quantization. There are even other approaches, where time does not play any fundamental roles at all. Several difficult problems remain unsolved in these attempts. Almost all of these attempts toward a unification of quantum mechanics and relativity have been engaged in their work with the expectation that the relativistic invariance under the group Diff($M$) of diffeomorphisms of the spacetime manifold $M$, is preserved in their final ‘quantized’ universe. There are several ways in getting the final quantized world; e.g., one way is to identify time before quantization, another is to identify time after quantization, and many others (see Isham 1993). These attempts go back to the invention of quantum field theory by Dirac in 1927. These attempts, however, have not been proved to be consistent (see, e.g., Fröhlich 1982 for the inconsistency proof of one of such theories), even though they can give partial explanations of some relativistic

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1This book contains an attempt at unifying the relativity and quantum theories from a standpoint that is quite different from the one that we have taken. He starts by taking his stand within the classical context, and develops a matter field theory of inertia, which tries to realize the Einstein’s ideal of a unified field theory.
quantum mechanical phenomena including Lamb shift.

These attempts seem to be overlooking the possibility that the problem may be at the more fundamental level, namely at the level of philosophical confrontation between Newton and Einstein in their attitudes toward the “absoluteness” of the total, entire universe and time. As we have stated, Newton holds the notion of absolute time so that it could be identified with the accurate measure of motions to control the total universe in a visible or observable manner. Einstein claims that what actually observable are the relative time and coordinates, and there is no necessity for such an absolute time to be dominating throughout the whole universe.

Seeing this, we notice that this conflict disappears, if we cease to adhere to the ‘visible’ absolute time of Newton, namely if we assume that the total absolute time exists but is unobservable to the observers, and that the observable facts are only the relative local motions, places, and times. Specifically, there is a room for reconciling this conflict, where we distinguish between the absolute time and the relative time so that they are, respectively, unobservable and observable, and have different values. Then we can hold the notion of absolute time for quantum mechanics, without contradicting the actually observable (general) relativistic time.

To state this assumption in other words:

What the observer can see is the local classical (general) relativistic phenomenon. On the contrary, the total universe is quantum mechanical, and its quantum mechanical nature cannot be seen directly by any observer.

This assumption or standpoint is one possibility by which one can avoid the above-mentioned philosophical discrepancy between Newton and Einstein. Even if one adopts this standpoint, there might be several passages to proceed. We here present one of the possible passages.

**IV. An Alternative Notion of Time**

In this and subsequent sections, we state an outline of our basic framework of one possible way to reconcile the quantum mechanics and general relativity. In doing so, we avoid the rigorous mathematical arguments as far as it is possible, except in some places where we need to clarify the precise meaning for those who might feel it necessary. We also avoid the logically firm formalism in order to make the meaning of our theory clear. It would be, however, helpful to the reader to remark that our stand of the following description is basically the mathematical formalism: Our framework consists of six axioms, axiom 1 through 6 stated in the followings in some implicit way, which are assumed as our basic postulates that must hold *a priori* in our physical world and none of which can be derived from the other axioms.

Our basic assumption as an alternative for Newton’s absolute time is that the total, entire universe has no time. Namely, contrary to Newton’s absolute time that flows equably throughout the entire universe, we assume that the total universe is static and
stationary. More specifically, the total universe is assumed to be a quantum mechanical bound state, i.e. an eigenstate of a Hamiltonian, denoted $H$, of infinite degrees of freedom, in a certain sense (see axiom 1 in Kitada 1994a, 1994b). (We should state that our notion of the eigenstate of $H$ with infinite degrees of freedom is a rather weak one than the usual meaning of eigenstate.)

Thus the universe itself does not change. However, inside itself, the universe can vary quantum mechanically, in any local region or in any local system consisting of a finite number of (quantum mechanical) particles. Therefore, we can define a local time in each local system as a measure or a clock of (quantum mechanical) motions in that local system.

In other words, for a local system $L$ with $N$ number of particles $1, 2, 3, ..., N$, there can be defined the position vectors $x_1, x_2, x_3, \cdots, x_N$ and momentum vectors $p_1 = m_1 v_1, p_2 = m_2 v_2, p_3 = m_3 v_3, \cdots, p_N = m_N v_N$, where $m_j$ is the mass of the $j$-th particle, so that the correspondent quantum mechanical selfadjoint operators $X_j = (X_{j1}, X_{j2}, X_{j3})$ and $P_j = (P_{j1}, P_{j2}, P_{j3})$ in a Hilbert space $\mathcal{H} = L^2(R^{3n})$ of $N = (n + 1)$ particles, satisfy the so-called canonical commutation relation. (This statement is axiom 2 of Kitada 1994a.)

Then the local time $t_L$ associated with the local system $L$ is defined as a quotient of position $x_j$ by velocity $v_j = p_j/m_j$

$$t_L = \frac{|x_j|}{|v_j|}. \quad (1)$$

Here we note that the right hand side of this definition looks depending on the number $j$. But it is known (Enss 1986) that it does not depend on $j$, if one defines the right hand side in a certain quantum mechanical way as in Kitada 1994a, sections 4-5 (see axiom 3, Theorem 1, and Definitions 1-3 there, and the paragraph after the formula (3) below for more precise descriptions). Thus local time is defined as a measure of motion inside each local system. This notion of local times is not contradictory with the nonexistence

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2If we try to be rigorous in philosophical sense, we should remark that the non-existence of time in our context should be interpreted as the “eternity” in Spinoza’s sense (Spinoza, The Ethics in Descartes, Spinoza, and Leibniz 1960) rather than as the conventional meaning of the eternal continuance that lasts forever without a beginning or end. In Definition VIII of The Ethics, Part I, Spinoza states

VIII. By eternity, I mean existence itself, in so far as it is conceived necessarily to follow solely from the definition of that which is eternal.

Explanation. — Existence of this kind is conceived as an eternal truth, like the essence of a thing, and, therefore, cannot be explained by means of continuance or time, though continuance may be conceived without a beginning or end.

Our axiom 1 which asserts that the total universe, which will be denoted $\phi$, is an eigenstate of a total Hamiltonian $H$, means that the universe $\phi$ is an eternal truth, which cannot be explained in terms of continuance or time. In fact, being an eigenstate contains no notion of time as seen from its definition: $H \phi = \lambda \phi$ for some real number $\lambda$. The reader might think that this definition just states that the entire universe $\phi$ is freezing at an instant which lasts forever without a beginning or end. However, as we will see, the total universe $\phi$ has an infinite degrees of freedom inside itself, as internal motion of finite and local systems, and never freezes. Therefore, as an existence itself, the universe $\phi$ does not change, however, at the same time, it is not freezing internally. These two seemingly contradicting aspects of the universe $\phi$ are possible by the quantum mechanical nature of the definition of eigenstates.
of the total time: The total universe of infinite number of particles is stationary as will be described in section V below. Any local system of finite number of particles, however, can be nonstationary, and can vary inside itself, as a consequence of the variation outside the local system, which compensates the change inside the local system, so that the stationary nature of the total universe is preserved.

We remark about the difference between our definition of local times and the conventional understanding of the notion of time. The common feature of the conventional understanding of time, including Newton’s definition of absolute time, is that the time is something existing or a one given a priori, independently of any of our activities, e.g. of observation activities. In our definition, time is not an a priori existence, but a convenient measure of motions inside each local system. Our definition of local times mentioned above at the end of the paragraph before formula (1) is that a local time is a clock — which measures, not time, but the motions of the local system. Differently from the conventional understanding where time is given a priori, the clock does not measure time, but it is time in our definition. Further, as we will state in section V in the paragraph after formula (3), the proper clock is the local system itself, and it is a necessary manifestation of that local system. In this sense, “clocking” is the natural activity of any local system. It follows from this that to be an existing thing in the world necessarily involves clocking, without which there is no interaction. In these senses, our stand is in complete contradiction to the conventional understanding of time measurement, where time is given a priori and clocks measure those times, therefore the measurement of time is an incidental activity. Contrary to the conventional understanding, our stand is that all beings are engaged in measuring and observing, and the activities of measuring and observing are not incidental, but pertain to the essence of all interactions. If we are permitted to express it somewhat boldly, we have turned things completely around: It is not that things exist and their duration is incidentally expressed by clocks. According to our formulation, clocks exist and their operation is necessarily expressed by duration.

We explain these in a more physical manner. As noted above, the formula (1) fortunately defines a common parameter $t_L$ associated to each local system $L$, because it is independent of the particular choice of the particle number $j$. This is exactly a magical fact which enables one to define time, as well as, that makes one believe that time is an existence which exists outside us a priori. However, the formula (1) holds only in an approximate sense as explained in p. 288 of Kitada 1994a, related with the uncertainty principle, and there is a possibility that the difference among the quotients $|x_j|/|v_j|$ ($j = 1, 2, \cdots, N$) can be detected by experiments (see Kitada 1994b). What looks a priori about the existence of the time coordinate is only a disguise in this sense. Instead, what exist a priori are positions and motions (velocities), through which the approximate values of time can be measured by taking the quotients $|x_j|/|v_j|$ in each local system $L$ consisting of $N$ particles $j = 1, 2, \cdots, N$. Time is, therefore, a quantity determined approximately by experiments by the use of formula (1), and is not an existence that is a priori. We will touch on this point again in section V.

Nevertheless, once a local time is identified by the formula (1), as a measure of motion, as $t = |x|/|v|$ in each local system, our definition of local times is a specification or a clarification of the ‘relative, apparent, and common time’ measured ‘by the means of
motion, which is used ‘instead of true time’ in Newton’s sense (see the first quotation from *Principia*, Newton 1962). It is a realization of Einstein’s local nature of time and coordinates, as well, in the sense that the local time is defined only for each local system consisting of a finite number of particles.

We next remark on the relation of our notion of time with those of Newton’s and Einstein’s. Newton’s assumption in *Principia* is the existence of ‘true time’ flowing equally throughout the universe to give an absolute and accurate meaning to the ‘usual, common time,’ by identifying his absolute time with an idealization of the common time. This assumption was necessary for the unified treatment of the motion of bodies which was considered common throughout the universe.

But we know from the proposal of Einstein’s special relativity that the absolute time flowing equably throughout the entire universe is unnecessary in constructing physics theory. We know, even more, from Einstein’s proposal that such a notion would do more harm than good in constructing a consistent physics theory.

In this point our choice is to follow Einstein in abandoning the notion of equally flowing time, controlling the entire universe, so that we adopt the local times for describing local motions, that will be shown to be consistent with the general relativity.

On the other hand, we also follow Newton in the point that it is necessary to consider the entire ‘true’ time in order to have a synthetic view to nature. For this purpose, we adopt, as our actual definition of the true time, the assumption that the entire, true time does not exist.

To sum up, we have localized Newton’s notion of time so that it will be shown to be consistent with the relativity. On the other hand, we adopted, as a substitute for Newton’s total, absolute time, a stationary static universe, instead of Newton’s dynamical universe changing linearly and equably forever.

We finally remark that the assumption that the total universe does not change, implies that there exists a quantum mechanical correlation among the local systems inside the universe. Namely if a local system changes, then the effect of that change propagates instantaneously to other local systems inside the universe in a quantum mechanical way, or in other words any change in any local region of the universe is compensated by the corresponding change of the rest of the total universe. In this sense, the total universe is inseparably related inside itself in quantum mechanical way.

V. Independence of local systems and the Relativity

Before introducing the relativity into our context, we first remark that, any two local systems $L_1, L_2$ inside the total universe are not correlated in classical way in their local

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3In this respect, our stand is quite similar to the one adopted in D. Bohm and B. J. Hiley 1993. They consider the universe as the one that cannot be divided, and is internally correlated. Also we remark that their notion of the “implicate order” (see Chap. 15 of Bohm-Hiley 1993) is essentially the same as our notion of “local systems.” Our local systems are determined by their outside and the total universe itself, to conclude the stationary nature of the universe. Vice versa, local systems and the stationary nature of the total universe determine the outside of the local systems. Bohm-Hiley’s implicate order is another expression of this statement.
times $t_{L_1}$ and $t_{L_2}$, although they are correlated inside the total universe in a quantum mechanical way. We note that this statement is not contradictory, because the quantum mechanical nature and classical nature of the universe are mutually independent aspects of the universe; therefore, these local times correlated in quantum mechanical way can be noncorrelated in classical manner, as two mutually independent aspects of nature. Namely the local times $t_{L_1}$ and $t_{L_2}$, and further the coordinates of $L_1$ and $L_2$, are mutually independent in any classical manner.

The verification of the last statement requires some definitions in Kitada 1994a or Kitada 1994b. We here mention only that this independence of $t_{L_1}$ and $t_{L_2}$ is a consequence of our choice of the Hilbert space

$$U = \{\phi\} = \bigoplus_{n=0}^{\infty} \left( \bigoplus_{\ell=0}^{n} H^n \right), \quad H^n = H \otimes \cdots \otimes H, \quad H = L^2(R^3),$$

(2)

of possible universes $\phi$. We briefly explain this definition. $\phi$ represents a possible ‘state’ of the total universe. The space $H$ of the state vectors can be regarded as representing a flat Euclidean space where one particle $j$ lies. For each particle $j$, there is a state space $H_j$, the tensor product $H^n = H \otimes \cdots \otimes H$ of whose $n$ copies represents the $N = n + 1$ particle Euclidean space. Noting that there are infinitely many different sets of particles with the same number $N = n + 1$ of particles, we get an infinite sum $\bigoplus_{\ell=0}^{\infty} H^n$ of the same space $H^n$. Then summing this space with respect to the number $n = N - 1 (\geq 0)$, we define the total Hilbert space $U$ of possible universes $\phi$ by $U = \bigoplus_{n=0}^{\infty} (\bigoplus_{\ell=0}^{n} H^n)$.

That the universe $\phi$ does not change, as described in section IV, means in this context that $H\phi = \lambda\phi$ for some real number $\lambda (\leq 0)$ in a certain sense, where $H$ is the total Hamiltonian defined on the space $U$ of possible universes as mentioned in section IV (see axiom 3 in Kitada 1994a for precise definition). In the definition of the above $U$, the subscript $n$ represents the number $N = n + 1$ of (quantum mechanical) particles of the local systems under consideration. (Therefore the total universe $\phi$ represents one possible state of the universe, consisting of infinite\footnote{To be precise in philosophical sense, the \textit{infinity} property of the universe $\phi$ here should be interpreted as the “absolutely infinite” in the sense of Spinoza, \textit{The Ethics}, Definition VI of Part I:

VI. By \textit{God}, I mean a being absolutely infinite — that is, a substance consisting in infinite attributes, of which each expresses eternal and infinite essentiality.

\textit{Explanation.} — I say absolutely infinite, not infinite after its kind: for, of a thing infinite only after its kind, infinite attributes may be denied; but that which is absolutely infinite, contains in its essence whatever expresses reality, and involves no negation.

Our total universe $\phi$ is a perfection in the sense that it has no outside, and everything is inside $\phi$. The infinite nature of $\phi$ is, therefore, not an infinity after its kind in the sense of the following Definition II of \textit{The Ethics}, Part I, and must be the absolute infinity.

II. A thing is called \textit{finite after its kind}, when it can be limited by another thing of the same nature; for instance, a body is called finite because we always conceive another greater body. So also, a thought is limited by another thought, but a body is not limited by thought, nor a thought by body.

In this sense, our universe $\phi$ is a perfection with no limits, as well, in the sense of Leibniz, \textit{The Monadology}, 

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ℓ in the double sum in \( \mathcal{U} \) represents the difference of the particles that belong to various systems with the same number of particles. Even if two local systems \( L_1, L_2 \) have a common part \( L_3 \) consisting of those particles which belong to both of \( L_1 \) and \( L_2 \), the two local Hilbert spaces \( \mathcal{H}_{L_1} \) and \( \mathcal{H}_{L_2} \) of the state functions for the particles in \( L_1 \) and \( L_2 \) are different spaces, say \( \mathcal{H}^{n_1} \) and \( \mathcal{H}^{n_2} \), where \( n_j + 1 \) is the number of particles in \( L_j \), hence \( \mathcal{H}_{L_1} \) and \( \mathcal{H}_{L_2} \) are mutually independent when considered in \( \mathcal{U} \), which is also the case even when \( n_1 = n_2 \) unless \( \ell_1 = \ell_2 \). This fact gives us an arbitrariness for the classical mechanical relation between the local times \( t_{L_1} \) and \( t_{L_2} \) (see also p. 289 of Kitada 1994a). Due to this arbitrariness, we have a complete freedom to make any assumption on the classical relation of \( t_{L_1} \) and \( t_{L_2} \), and also on the classical relation of the coordinate systems of \( L_1 \) and \( L_2 \), with keeping the quantum mechanical correlation inside the total universe, as a consequence of the relation \( H \phi = \lambda \phi \). We can therefore assume an arbitrarily fixed transformation:

\[
(t^2, x^2) = f_{21}(t^1, x^1)
\]

between the classical coordinate systems \((t^j, x^j)\) of any two local systems \( L_j \) \((j = 1, 2)\).

We summarize what we have described in a more precise manner. A local system \( L \) is a system consisting of a finite number, say \( N = n + 1 \), of particles. Let \( \phi \) be the universe chosen from the set \( \mathcal{U} \) of possible universes. Then the state vectors \( \psi_L = \psi_L(x_1, \ldots, x_n) \) of the local system \( L \) of \( N = (n + 1) \) number of particles are obtained from the universe \( \phi \) as \( \psi_L(x_1, \ldots, x_n) = \phi(x_1, \ldots, x_n, x_{n+1}, x_{n+2}, \ldots) \) with varying \( x_{n+1}, x_{n+2}, \ldots \) as the parameters that determine each state \( \psi_L \) of the local system \( L \), corresponding to each choice of the infinite number of coordinates \((x_{n+1}, x_{n+2}, \ldots)\). The totality of such \( \psi_L \) constitutes a local universe \( \mathcal{H}_L \) which represents a state space for the local system \( L \). The local Hamiltonian \( H_L \) for \( L \) is the restriction of \( H \) onto \( \mathcal{H}_L \). Then the proper or local clock for \( L \) is defined as the unitary group \( \exp[-itH_L] \) \((t \in \mathbb{R})\) on \( \mathcal{H}_L \), and the parameter \( t \) in the exponent of the group \( \exp[-itH_L] \) is called the proper time or local time of the local system \( L \). This is the precise definition of the local time of a local system, and gives rise to the definition (1) of the local time described above by the use of Enns’ result, 1986. We notice that this procedure is a reverse one to the usual procedure adopted in physics to describe the physical phenomena, the procedure stated in section II, where time \( t \) is given a priori, and only after \( t \) given, the motion of the local system is described by \( \psi(x, t) = \exp[-itH/\hbar] \psi_0 \), by utilizing the evolution \( \exp[-itH/\hbar] \), which in our case plays the role of the clock of the system. In this sense, our definition of local times reverses the conventional understanding of time, as stated in section IV.

To make the physical meaning implied by these assumptions and considerations clear, we introduce here two kinds of conventional coordinate systems associated with each local

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41 (Descartes, Spinoza, Leibniz 1960, p. 461):

41. Whence it follows that God is absolutely perfect, perfection being understood as the magnitude of positive reality in the strict sense, when the limitations or the bounds of those things which have them are removed. There where there are no limits, that is to say, in God, perfection is absolutely infinite.
system \( L \). One is the *proper coordinate system* of \( L \) which is the Euclidean coordinates describing the quantum mechanical world inside the local system \( L \). Another is the observer’s coordinate system, which emerges when the observer observes the outside in classical way and is the curved Riemannian coordinates associated with the local system \( L \), that measures, as an observer, the classical world, outside the observer’s local system, consisting of infinite number of classical particles. (We repeat that, by classical particles, we mean the *centers of mass* of local systems. On the other hand, the particles whose positions and momenta determine the local time (1) as described above, are quantum mechanical particles.) For convenience sake, we assume that, at the center of mass of a local system \( L \), the space coordinates \( x = 0 \) for both proper and observer’s coordinate systems.

In other words, the coordinate system \((t, x) \in \mathbb{R}^4\) of a local system \( L \), defined by using the local time parameter \( t = t_L = |x_j|/|v_j| \), plays double roles which are mutually independent: one role is the measurement of the inside of \( L \) itself, and another is the observation of the *centers of mass* of other local systems \( L' \), at least in a vicinity of the center of mass of \( L \). (In particular, \( L' \) can be equal to \( L \).) These two roles are distinguished from each other by the difference of their metrics \( g_{\mu \nu}(t, x) \): For Euclidean proper coordinates, \( g_{\mu \nu}(t, x) \equiv 1 \) for \( \mu = \nu = 0, 1, 2, 3 \) and \( \equiv 0 \) for \( \mu \neq \nu \), and for the curved Riemannian observer’s coordinates, \( g_{\mu \nu}(t, x) \) is a general metric tensor, under the assumption of the general principle of relativity adopted below. Namely \( g_{\mu \nu} \) satisfies the transformation rules:

\[
g_{\mu \nu}(y_1) = g_{\alpha \beta}^2(f_2(y_1)) \frac{\partial f_2^\alpha(y_1)}{\partial y_1^\alpha} \frac{\partial f_2^\beta(y_1)}{\partial y_1^\beta},
\]

where \( y_1 = (t^1, x^1) \); \( y_2 = f_2(y_1) \) is the transformation from the coordinates \( y_1 = (t^1, x^1) \) to \( y_2 = (t^2, x^2) \), which was fixed arbitrarily in (3) above; and \( g_{\mu \nu}(y_j) \) is the metric tensor expressed in the observer’s coordinates \( y_j = (t^j, x^j) \).

From the obvious fact that the center of mass of a local system \( L \) is independent of the inner relative coordinates of \( L \), these two roles of coordinate system of \( L \), i.e. the roles as the proper and observer’s coordinates, are independent mutually. Further, between the observers’ coordinate systems of any two local systems \( L_1 \) and \( L_2 \), there is complete arbitrariness in making any assumption on the classical relation, as mentioned above.

We repeat here our standpoint that the quantum mechanical world and classical world are mutually independent as two independent aspects of nature, expressed as a direct product \( X \times \mathbb{R}^6 \). This implies that the proper coordinate system of \( L \) does not contradict the observer’s coordinate system of \( L \). To state this difference in accurate manner, the classical observation is concerned with the infinite number of local systems \( L_1, \cdots, L_\ell \).}

5. We here remark that the *center of mass* of a local system \( L \) consisting of \( N \) number of particles \( 1, 2, \ldots, N \) with positions \( x_1, \cdots, x_N \) and masses \( m_1, \cdots, m_N \), is a position vector

\[
x = (m_1 x_1 + \cdots + m_N x_N) / (m_1 + \cdots + m_N).
\]

The center \( x \) of mass is the configuration part \( x \) of a point \((t, x)\) of the Riemannian manifold \( X \). This is the meaning of the correlation between the center \( x \) of mass and the point \((t, x)\) in \( X \), which was stated in the introduction.
which decompose the total universe \{1, 2, 3, \ldots\}, and the quantum mechanical observation
is with the inside of a local system \(L\) consisting of finite number of particles. Therefore
there is neither intersection nor overlapping between these two kinds of observation and
between the corresponding coordinate systems of proper and observer’s coordinate systems.

Therefore, we can assume, as have been anticipated, the principles of general relativity
(general principle of relativity, and the principle of equivalence) as a classical relation be-
tween the observers’ coordinate systems of \(L_1\) and \(L_2\). Explicitly, we assume the following
two postulates:

\textit{General Principle of Relativity} (axiom 4). Those laws of physics which control the
relative motions of the centers of mass of the observed local systems are expressed by the
classical equations which are covariant under the change of observers’ coordinate systems of \(R^4\).

\textit{Principle of Equivalence} (axiom 5). The coordinate system \((t^1, x^1)\) associated with
the local system \(L_1\) is the local Lorentz system of coordinates. Namely, the gravitational
potentials \(g_{\mu\nu}\) for the center of mass of the local system \(L_1\), observed in these coordinates
\((t^1, x^1)\), are equal to \(\eta_{\mu\nu}\). Here \(\eta_{\mu\nu} = 0 (\mu \neq \nu), = 1 (\mu = \nu = 1, 2, 3), \) and = \(-1
(\mu = \nu = 0)\).

Namely, we assume that the classical world outside an observer’s local system obeys
the general relativity with respect to that observer’s coordinate system.

On the other hand, we have been assuming, from the first stage of our definition of
local times, the quantum mechanics, for the relative motions of the particles inside every
local system. In other words, we assume that the world inside each local system obeys the
quantum mechanics with respect to the proper coordinate system of that local system.

We then have the following

\textbf{Theorem.} The additional postulates of general relativity for the outside of the ob-
server’s local system are consistent with the quantum mechanical postulates inside each
local system.

\textit{Proof:} The general relativity is postulated on the framework of the observer’s coordinate
system, and the quantum mechanics is postulated within the proper coordinate system.
These two kinds of coordinate systems are independent mutually. Therefore, these two
postulates (or any other kinds of postulates) are consistent, if these postulates are con-
sistent with the metrics of these coordinates.

In our case of general relativity and quantum mechanics, we first recall that the relation
of any two of the observers’ coordinate systems can be determined arbitrarily as stated
above. Thus the observer’s coordinate system can be chosen to be the curved Riemannian
coordinates, consistently with the general relativity. In other words, the postulates of
general relativity can determine the metric of the observer’s coordinate system. Namely,
recalling that \(x^2 = 0\) at the center of mass of a local system \(L_2\), we see that the principle
of equivalence (see axiom 5 above) implies for \(g_{\alpha\beta}(y_2)\) in (4) that \(g_{\alpha\beta}(t^2, 0) = \eta_{\alpha\beta}\), where
\( \eta_{\alpha\beta} = 0 \ (\alpha \neq \beta) = 1 \ (\alpha = \beta = 1, 2, 3) \), and \( = -1 \ (\alpha = \beta = 0) \). (The consistency of this axiom follows from the above-mentioned independence between the center of mass of a local system \( L \) and \( L \)'s inner proper coordinates. See Kitada 1994a, Theorem 2.) Thus the metric at the center of mass of the local system \( L_2 \), observed from the local system \( L_1 \), is determined by the above transformation rules (4) for \( g_{\mu\nu}^j \) as follows:

\[
g_{\mu\nu}^1(f_{21}^{-1}(t^2, 0)) = \eta_{\alpha\beta} \frac{\partial f_{21}^{\alpha}}{\partial y_1^{\mu}}(f_{21}^{-1}(t^2, 0)) \frac{\partial f_{21}^{\beta}}{\partial y_1^{\nu}}(f_{21}^{-1}(t^2, 0)).
\] (5)

For the quantum mechanics, it is obvious that the Euclidean proper coordinates of a local system naturally describe the quantum mechanics consistently. Q.E.D.

See Kitada 1994a, section 6, where another proof is given in Theorem 2. It utilizes the two sorts of independence mentioned above; the one between the observers’ coordinates of any two local systems, and another between the center of mass of a local system \( L \) and \( L \)’s inner proper space. See also Kitada 1994b, section 3, where a mathematical argument utilizing the notion of vector bundle is presented to show the above theorem.

We make a remark that the formula (4) or (5) above gives a relation of the metric \( g_{\mu\nu}^j \) \((j = 1, 2)\) between two local systems \( L_1 \) and \( L_2 \), but these formulae do not determine \( g_{\mu\nu}^j \) in any concrete sense. To determine \( g_{\mu\nu}^j \) requires another assumption like the Einstein field equation in the usual general relativity. We suggest another possibility on this point: The field equation can be chosen arbitrarily as far as it is consistent with the two principles of general relativity. We may choose the Einstein field equation itself as one candidate. We may also adopt the Hoyle-Narlikar field equation (see e.g., Narlikar 1977, Arp 1993). Both of Einstein’s and Hoyle-Narlikar’s are consistent with general relativity, or they are equivalent with each other in a certain mathematical sense (see Narlikar 1977). We will touch on this point again later in section VIII.

VI. Observation, that gives a connection between quantum mechanics and general relativity

In this way, we regard our world as a unity of the quantum mechanical world inside each local system and the classical world outside the observer’s local system.

As stated in section II, it is commonly considered that quantum mechanics (QM) and general relativity (GR) are incompatible with each other. For instance, QM requires Euclidean space as the base space and the QM laws are linear, while GR the curved Riemannian space and the GR laws nonlinear; QM is non-local and non-causal, while GR obeys the causality; and so on (see Sachs 1986, Chap. 2). This is the case if one sees the two theories as the same leveled theories, or the theories on the same plane.

We have, however, seen that these two theories becomes consistent with each other, if we orthogonalize them mutually: Set QM on a Euclidean space-time \( R^4 \) as an inner space tangent to the curved Riemannian space-time \( X \) of classical general relativity. Then in the total physics space, namely in the product \( X \times R^4 \) (or \( X \times R^6 \)) of these spaces, QM and GR are mutually independent, hence mutually consistent.
Then, are QM and GR non-interrelated entirely, if they are independent of each other? Quite contrarily, this independence is of completely logical nature and makes it possible to assume an arbitrary but fixed relation between these two aspects of nature. This relation is given by “observation” process, which will solve many fundamental incompatibilities between QM and GR as listed in Sachs 1986, Chap. 2.

In our theory, observation of the inside of a local system $L$ by an observer’s local system $O$ corrects the quantum mechanical values associated with the particles inside the system $L$, by a relativistic transformation of coordinates associated with observation, into a relativistic quantum mechanical values. The QM and GR are correlated in this sense.

We here make an important remark that all possible local systems exist $a$ priori by definition, i.e. all possible sets consisting of finite number of particles are local systems. When one observes other local systems the observer makes a choice of the local system under observation, but the existence of other local systems is a logical one and not affected. More precisely speaking, when an observer makes an observation, the observer makes or chooses one cluster decomposition of the total universe, i.e. it decomposes the set $\{1, 2, 3, \ldots\}$ of all particles into a disjoint sum of subsets $L_j$ of $\{1, 2, 3, \ldots\}$, where $L_j$ may be an infinite set while in that case the particles in $L_j$ do not constitute a local system, hence are not observable. Then the observer observes the centers of mass of those local systems $L_j$. Thus at each moment, the observer observes those specific local systems characterized by this decomposition. At another moment, the decomposition can be changed to another one. However at each moment in the time frame of the observer, it observes just one set of local systems corresponding to a decomposition of the total universe. Thus although all decompositions of the universe are possible logically, the actually observed decomposition is just one at each moment for each observer. Therefore, here is no problem of overlapping between different observations whether or not they are made by the same observer. Moreover this formulation explains the apparent inconsistency like the EPR paradox, as the confusion of different observations made based on different cluster decompositions of the universe. We give some other examples of this type of paradoxes in section VII.

Our theory can be further rephrased as an explanation of the daily observation activities. We do not try to explain, e.g., the observation $O_2$ of the observation activity $O_1$, which has been one of the observation problem. Instead, this we explain as an observation of a physical phenomenon that a local system of the observer of the observation $O_1$ interacts with the observed system. The observation in our theory is concerned with only the final stage of observation in this respect.

Another important remark on the term “observation” is that the term is an undefined one in the sense that it is defined in axiom 4 without specific definition. To clarify this some more, let us take the example above of the observation $O_2$ of an observation activity $O_1$. Usually people regards $O_2$ as an explanation of the observation $O_1$. Then they meet the problem of premeasurement and objectification (see Auyang 1995, section 4). In our framework, we regard $O_1$ merely an interaction process between the observer of the observation $O_1$ and the observed system, and see by the observation $O_2$ that $O_1$ follows Schrödinger equation with no inconveniences which the current views meet. As to the observation $O_2$, we thus need not worry about what it is or how it should be defined or
explained inside the theory. We just do the “observation,” which in the context of our daily activities has a position similar to the position that the undefined term “observation” has in our theory. In this sense, the term “observation” represents a final stage of observation, namely it is our actual deed of observation which cannot be analyzed any more.

Let us return to our problem of QM and GR. The actual relation which we impose between QM and GR can be described as an assumption about the observations of the inside of an observed local system, from an observer’s local system. We refer to axiom 6 in Kitada 1994a, 1994b for this assumption, which states that

*the actually observed values when observing the inside of a local system are the classical ones which are obtained by correcting the bare quantum mechanical values inside the observed system, in accord with the relativistic change of coordinates from the observed local system to the observer’s local system.*

We remark that what is actually observable is the scattering amplitude or differential cross section of the scattering experiment or observation. These are the quantities observed at the final stage of the observation activities. Other intermediate observation would change the process itself, hence must not be done during the experiment. Other quantities than the final scattering amplitudes, e.g., the intermediate position and velocity of the centers of mass are not observable directly. Nevertheless, we assume that these observation can be done in an “ideal” sense, and assume the above assumption also on this kind of observation as well as on the actual observation of scattering amplitudes.

To state more concretely this assumption:

**Axiom 6.** The momenta \( p_{Lj} = \frac{m_j x_{Lj}}{t_L} \) of the particles \( j \) with mass \( m_j \) in the observed local system \( L \) with coordinate system \((t_L, x_L)\), are observed, by the observer system \( O \) with coordinate system \((t_O, x_O)\), as \( p_{Oj} = \frac{m_j x_{Oj}}{t_O} \), where \( x_{Oj} \) is obtained from \( x_{Lj} \) by the relativistic transformation of coordinates: \((t_L, x_L)\) to \((t_O, x_O)\) as in axiom 4. The same is true for the observation of the energies of the particles: the energies of the particles in the observed local system are observed by the observer as the ones transformed in accordance with the relativity.

Namely, it is assumed that the quantum mechanical momenta \( p_{Lj} = \frac{m_j x_{Lj}}{t_L} \) of the particles within the system \( L \) are observed in actual or ideal experiments or observations by the observer system \( O \) with coordinate system \((t_O, x_O)\), as the classical quantities \( p_{Oj} = \frac{m_j x_{Oj}}{t_O} \) whose values are calculated or predicted by correcting the quantum mechanical values \( p_{Lj} \) with taking the relativistic effects of observation into account. A similar assumption is made for the energies of the particles. (See the examples below and in pp.296-297 of Kitada 1994a, where it is explained how to actually ‘apply’ these assumptions to treat the probabilistic nature of QM. In the latter example, the differential cross section \( d\sigma/d\Omega \) is the classically observed value when the energy \( E \) and the angle \( \theta \) are fixed, or if we state it in physical terminology, are ‘measured’ in the scattering experiment considered there. The bare quantum mechanical value for \( d\sigma/d\Omega \) in this case
is the formula (14) in Kitada 1994a, and the relativistically corrected value is the formulae (17) and (19).

**Proof** of the consistency of axiom 6: This axiom 6 is consistent with our former assumption of QM and GR, because axiom 6 is concerned entirely with how nature looks at the observer when one observes the inside of a local system, and is independent of the logical validity of our theory. Q.E.D.

This consistency guarantees us on the theoretical level that it is admissible to make this assumption, axiom 6, in our theory. The effectiveness of axiom 6 is solely checked through experiments and observations of actual physical phenomena. Some examples supporting this axiom on the experimental and observational level are given in Kitada 1994a, 1994b. We give below more comprehensive explanation of our idea about the effects of observations.

To explain our idea more clearly, let us consider an observation of a local system consisting of two electrically neutral particles (e.g., neutrons) 1 and 2 with mass $m_1, m_2$, interacting merely through gravitational force. In our theory, gravitation is generated by observation process through relativistic transformation of coordinates, and is not assumed a priori, e.g., to be a Newtonian gravitational potential as a term in the Hamiltonian of the local system under consideration. How can we then explain the gravitation between the two particles 1 and 2? We explain the gravitation as follows: Let the Hamiltonian of the local system of the two particles be

$$H_0 = h_{01} + h_{02},$$

with $h_{01}$ and $h_{02}$ being the free Hamiltonians for the particles 1 and 2 respectively. In this expression, there appears no gravitation. We decompose this system “ideally” into two subsystems $L_1$ and $L_2$ consisting of the particles 1 and 2 respectively.

In the next paragraph, we use the terminology “observation” as if it were done actually about the positions and velocities of the local systems $L_1$ and $L_2$. However, as remarked just before axiom 6, these quantities considered below are intermediate ones and are not observable directly. The following description of observations of such quantities should be interpreted as a description of a certain “ideal” procedure of observation for getting a quantum mechanical expression for gravitation. Therefore as a coordinate system of the observer’s local system, we adopt the observer’s coordinate system.

We suppose that we make an “ideal” observation on particles 1 and 2 intermediately before the final observation of the scattering amplitude. This ideal observation means that we make a relativistic transformation of coordinates from the systems $L_1, L_2$ of particle 1 and 2 to the observer’s coordinates. Thus a gravitational field appears in this ideal observation along with this relativistic transformation of coordinates. The classical general theory of relativity, namely axioms 4 and 5 together with an additional assumption as Einstein field equation, then yields that, in the first order approximation, the Newtonian gravitational potential $Gm_1m_2/r$ is working between the two particles or the two subsystems $L_1, L_2$, with distance $r$ moving with relative velocity $v$ at the time of this “ideal” observation. We assume that one of the particles, say particle 1, is stable with
respect to the observer. We transform this classical observation into quantum mechanical statement, \textit{i.e.} into a relativistically modified expression of the Hamiltonian $H$ above. The quantum mechanical evolution of the local system $L$ is given by

$$\exp[-itH]f = \exp[-ith_{01}] \exp[-ith_{02}]f \approx \exp[-ith_{01}]f_1 \exp[-ith_{02}]f_2$$

in the proper coordinate system of $L$, if we assume that $f \approx f_1 \otimes f_2$ with $f, f_1, f_2$ being the initial states of the local systems $L, L_1, L_2$ at the initial time $t = 0$. In this ideal observation, the local systems $L_1, L_2$ are observed as possessing different times $t_1, t_2$, respectively, in the observer’s coordinate system of the observer. These times $t_1, t_2$ are observed in accord with the relativistic transformation of coordinates in relation with the observer’s space-time coordinates. If we denote the observer’s local time by $t_O$, these times $t_1, t_2$ are expressed in terms of the observer’s time $t_O$ as follows according to the special theory of relativity:

$$t_1 = t_O, \quad t_2 = t_O \sqrt{1 - (v/c)^2},$$

where $c$ is the speed of light in vacuum. Thus, the evolution $\exp[-itH]f$ is transformed, in the observer’s coordinates, as follows:

$$\exp[-itH]f \mapsto \exp[-it_O h_{01}]f_1 \exp[-it_O \sqrt{1 - (v/c)^2} h_{02}]f_2 \approx \exp[-it_O \{h_{01} + \sqrt{1 - (v/c)^2} h_{02}\}]f.$$

Here the subsystem Hamiltonians $h_{0j}$ are approximated by the relativistic classical energy

$$h_{0j} \approx m_j c^2 + p_j^2/(2m_j) \approx m_j c^2.$$

The above evolution is, therefore, approximated by

$$\exp[-itH]f \approx \exp[-it_O \{H_0 - Gm_1 m_2/r\}]f$$

in actual observation, where we have used the classical energy conservation law to replace $p_j^2/(2m_j) = m_j v^2/2$ by $Gm_1 m_2/r$. This formula indicates that we can adopt the relativistic quantum mechanical Hamiltonian

$$H_0 - Gm_1 m_2/r \quad \text{(6)}$$

as an approximate relativistic Hamiltonian that is actually observed in the observation of the local system $L$ when looking into its sublocal systems $L_1, L_2$. This is a typical example of our explanation strategy of the quantum mechanical relativistic phenomena related with gravitation. We remark that this procedure consists of two processes: one is the \textit{decomposition} of the observed system $L$ into some sublocal systems that are inquired by the observation, and another is the \textit{relativistic transformation} of these subsystems’ coordinates into the observer’s coordinate[s].

\footnote{The author is indebted to Dr. Masashi Oogami for the idea to make the formulation of our treatment of gravity clear in this way by introducing these two steps. The author is grateful to him for his kind permission for me to refer to this formulation in this paper.}
A concrete application of this consideration is the example of the scattering of one neutron by two mirrors, which was considered in Kitada 1994b, section 5. In this example, the gravitational potential \(-\frac{Gm_1m_2}{r}\) above is replaced by a uniform gravitation \(gL/c^2\). In accord with the remark stated just before axiom 6 above, the actually observable quantity in this example is only the phase difference caused by the difference of the paths through which the two parts of the neutron pass. The distance \(r\) and the velocity \(v\) used in the above are nothing but theoretical apparatus, which are not observable directly.

If the phenomena are concerned with electrical or other forces than gravity, the treatment is different as shown in the example of section 9 of Kitada 1994a. In this example, no gravity is assumed and the pure electrical forces are treated. In the case, the decomposition of the observed system is not possible, because the total Hamiltonian \(H\) cannot be decomposed as a sum of mutually commuting \(h_{0j}\) as in the above. Instead, one has to treat the total Hamiltonian \(H\) to deduce the differential cross section (14) of Kitada 1994a from a purely quantum mechanical consideration. Only after this procedure, the relativistic effect of observation should be taken into the expression (14) to reach (17) and (19) in p.297 of Kitada 1994a.

If the observed system includes both of gravity and other forces, the order of treatment is as follows: First, consider the quantum mechanical Hamiltonian to deduce some formulae which explain the purely quantum mechanical phenomena about the system. Then, considering the relativistic effect of the observation, transform the coordinates of the system to the coordinates of the observer’s system. Then gravitation is automatically included in the final expression of the formulae.

These examples describe our idea of treating the relativistic phenomena like gravitation as the effect or the consequence of the observation. This will be discussed in more details elsewhere.

The above axiom 6 asserts, also, that the actually observed values of a quantum mechanical quantity must be classical. In other words, the quantum mechanical quantity is measured, in actual observation, as a classical quantity. Thus this axiom together with our other postulates resolves the fundamental problem of the consistency of the Copenhagen interpretation that the quantum mechanics must be tested through the experiments that are described by the use of classical physics (see Jammer 1974, section 4.2). This is another implication of our formulation. We also remark that the paradox presented by Einstein-Podolsky-Rosen 1935 can be resolved by our formulation (see Kitada 1994a, section 8), where the usual inconsistency between non-locality of quantum mechanics and local causality of relativistic theory is treated without contradiction, as mutually independent aspects of nature.

This axiom 6, by its nature, gives a certain relation between quantum mechanical and classical views so that the so-called relativistic quantum mechanical phenomena could be explained as in the above explanation. We repeat that, as far as we know, there is no theory that can explain relativistic quantum mechanical phenomena in any consistent way: The present quantum field theories, which look like successful at least in explaining some examples like Lamb shift, have not been constructed consistently or have never been proved to be consistent. See, e.g., Streater’s paper in Brown-Harré 1990, and Fröhlich
1982. See also Dyson 1953, Jaffe 1965, and Calan-Rivasseau 1982 for the proof that the series giving Lamb shift diverges. These results indicate a theoretical contradiction of quantum field theories which give predictions for the Lamb shift in ‘outstanding’ accuracy (see Kinoshita et al. 1983) by “theoretical” calculations based on the approximation up to the 6-th or 8-th order of the “divergent” series.

We conclude this section by remarking that if the state of a local system $L$ is a bound state of a local Hamiltonian $H_L$ corresponding to a local system $L$, then that state is not observable, insofar as the observer observes that local system. For if the state function $\psi_L$ of the system $L$ is a bound state of $H_L$, it cannot emit any light or information outside, hence cannot be observable by any observer. However, if the observer changes its view, e.g., if it observes a larger system $L'$ including the system $L$, then there is a possibility that the observer sees the system $L$, because the larger system $L'$ may be in a scattering state of the larger Hamiltonian $H_{L'}$, and as one of its subsystems, $L$ may be also observable. In general, what we see are dependent on what we intend to see, or in other words it is dependent on which part of the universe we are trying to see. We will try to clarify this point some more in the next section.

VII. Observation, which solves the current measurement problem

Let us begin with a seemingly contradictory example. When one is observing a stable hydrogen atom, why is it stable even if one is observing it? If the observer is inquiring into the hydrogen atom dividing it into an electron and a nucleus, they should obey classical physics by our axiom 4, hence the system has to decay according to the classical electromagnetic dynamics, with the electron going down into the nucleus, emitting photons. Would this not damage the quantum mechanical explanation of stability of atoms, getting the situation back to that of 19th century?

Our answer to this paradox is that, when one sees that the hydrogen atom is stable, the observer is observing the hydrogen atom as a local system consisting of the electron and the nucleus, but does not make any inquiry into its inside. In fact the stability of an atom is explained in QM as a property of the local Hamiltonian for the local system of the atom, precisely speaking as the semiboundedness property of that Hamiltonian, which is violated in classical mechanics. On the contrary, when one observes into the inside of the atom, the observer stimulates the atom by some method, e.g. by hitting the atom by other particles, to get some information on the internal structure of the atom, hence this observation would destroy the atom, if the observation would be successfully done to get the required information. In this case the objects of the observation, e.g. the electron, the nucleus, and the other particles used to make the observation, follow classical mechanics during the observation to result in the destruction of the atom along the scenario given by classical electromagnetic theory. This would give a first explanation of the decaying process of the atom in a classical mechanical way, which has been a mystery in the context of quantum mechanics.

We remark that the explanation given here is the same one as the ones given in sections 7 and 8 of Kitada 1994a, where we have treated, e.g., EPR paradox.
As another but more fundamental problem, which has been the crux of the current measurement problem, let us see the problem of the so-called “collapse” or “reduction” of wave functions, which is usually supposed to occur at the time of measurement. In the ordinary formulation of quantum mechanics, there is a gap between the quantum mechanical description as a wave function of the state under consideration and the actually observed values about the state. The former evolves according to an equation of motion, i.e. Shrödinger equation, but the actually observed values are considered as a result of “collapse” of the wave function to an eigenstate of the Hamiltonian which describes the system under consideration. We borrow an explanation of this problem from Auyang, 1995, section 4 The Quantum Measurement Problem (page 22), which describes the exact nature of the problem:

Quantum mechanics gives two descriptions that differ in nature, subject matter, and treatment. The characteristics described by state vectors are nonclassical; they are irreducibly complex and strangely entangled when expressed in classical terms. Besides its nonclassicality, the state-vector description is decorous; it is essentially of single systems evolving according to an equation of motion. The description offered by the statistics of eigenvalues is just the opposite. The characteristics it describes are classical and familiar. But besides its classicality, it has the appearance of bastard; it applies not to single systems but only to ensembles, and it is the result of “collapse” of nonclassical characteristics. The crux of the problem is that the quantum mechanics provides no substantive correlation between the two descriptions. The only relation between them is formal and abstract. It is provided by the observable, whose eigenstates contribute to the state description and whose eigenvalues to the statistical description.

The stepchild treatment accorded to the classical description by a theory that many interpreters claim to be universal and fundamental is regrettable, for from a broad perspective that includes but is not limited to quantum mechanics, these characteristics are objective. Classical characteristics are realized in the physical instruments used in quantum experiments, and they are subjected to the laws of classical physics. In the usual understanding, the classical and quantum descriptions are said to be connected in measurements. However, we do not have even a marginally satisfactory account of the measurement process. This is known as the quantum measurement problem.

As described in this quotation, the point of the problem is the lack of procedure which explains the collapse inside the framework of quantum mechanics. A rigorous theory of measurements developed by P. Busch, P. J. Lahti, and P. Mittelstaedt quoted in the same section of Auyang 1995 shows that the difficulty of the problem lies in objectification, which demands that the instrument realizes a definite eigenvalue at measurement. Many have tried to respond to this demand inside the framework of quantum mechanics. We repeat the words of P. Busch et. al quoted in Auyang 1995: “One would expect, and most researchers on the foundations of quantum mechanics have done so, that the problem of measurement should be solvable within quantum mechanics.”

Our stand to this problem is to leave the word “observation” or “measurement” as an
undefined term of our theory, as we have stated in section VI, so that the term cannot be analyzed and explained inside the framework of our theory. We do not give any explanation to the “collapse” and the measurement process within our theory, just similarly to Newton who left the term “gravity” as a mere name, to whose cause he did not give explanation. Instead we regard observation as an actual deed we do in usual life, and give a procedure of calculation of the scattering amplitudes which are only the quantities observable in actual quantum mechanical experiments.

What is important to know is that there are things which cannot be known to human beings. The modern science tends to think that it can explain everything in the universe, as the attempts to “Theory of Everything” indicate. However, we already know that there are things which cannot be known to human beings even in such a region of pure reason as mathematics, where K. Gödel 1931 showed that there are infinitely many number of propositions in a mathematical theory that includes natural numbers, the proofs of which and whose negation cannot be obtained in the framework of that theory. Those who are careful enough to be aware of that such a deep insight to the restriction of human ability of getting things has already been found at such an early stage of the 20th century, would agree with our stand that we do not try to explain everything around us and we leave the observation as actual activities of human beings which cannot be explored and analyzed any more.

Another point which should be stated about the current attempts to explain the measurement process is that these attempts have tried to explain that the instrument realizes a definite eigenvalue, but failed. This failure is not at all a problem from our standpoint. These attempts just explain the interaction between the instrument and the object in the framework of quantum mechanics. In our theory, this explanation is regarded as just an explanation of the quantum mechanical “scattering phenomenon” between the instrument and the object, and it is no wonder that it does not result in the “collapse” of wave function to give a definite eigenvalue.

These two examples show that there are two categories in the current measurement problems: One category arises from the misuse of the quantum mechanics and classical mechanics. In the stability problem of atoms, one is confused in the point where one should put a borderline between the quantum mechanical view and classical mechanical view. The problem is solved when one finds which local systems the observer is observing at each moment. Depending on the local systems that the observer observes, the view which the observer gets from nature is different. Even when one thinks that one is observing the same object, there are large possibility in which local systems are selected in each observation. According to this selection, the looks of things change from one to another. In the next section we will see another example of this kind.

Another category of problems has more deep root, which concerns with the human ability and inability of knowing things. This kind of borderline about our ability has already been set at the end of section III of the present paper. It is the statement of the unobservability of quantum mechanical nature of the universe. Although quantum mechanical nature of the universe is unobservable, we, as one of local systems inside the universe, can perceive it, since the change outside us influences us and vice versa,
so that the total universe is stationary. This is just the same situation as in Gödel’s incompleteness theorem, where although there are undecidable propositions whose proofs cannot be obtained by hands, the correctness of those propositions can be known from what they mean in the larger context. The universe is not an existence reachable by hands from human beings, but it tells itself to us by its eternal and total nature.

VIII. Hubble’s Law

As another example of the applicability of our framework to relativistic quantum mechanical phenomena, we give in this section some outline of the explanation of Hubble’s law, which was treated in Kitada 1994b. We will also touch on another possible explanation of the law.

Hubble’s law is a phenomenon which appears in observing the light emitted from astronomical existence such as stars, galaxies, etc. The emission of light is a quantum mechanical phenomenon which could be treated in our framework as in Kitada 1994a, section 11-(2). The observation on the earth of this emission of light from stars can be explained as a classical relativistic observation, by our assumption on observation stated in the previous section.

The mathematical treatment was given in Kitada 1994b, section 6. Here we explain why our stationary static universe admits an ‘expansion’ of this kind.

The ‘expansion’ in the large scale, as a result of our general principles of relativity and the additional assumption, i.e. the Einstein’s field equation, is an observational fact. This is no contradiction with our assumption of stationary universe, because the stationary nature of the universe is a quantum mechanical one and unobservable.

More specifically, in explaining the ‘expansion,’ one has to adopt a fixed observer’s space coordinates, which are in this case the ‘comoving, synchronous space coordinates,’ while, as the time coordinate, we assume that it ‘slices’ the spacetime by a one parameter family of spacelike surfaces (see, e.g., Misner-Thorne-Wheeler 1973, Chap.27). The ‘expansion’ appears only after these spacetime coordinates are fixed. This choice looks natural, but there are infinitely many other possibilities of the choice of coordinates. The fact that the Hubble’s law can be explained by the general relativity means no more than that our usual choice of coordinates accidentally coincides with this ‘natural’ choice of coordinate system of comoving, synchronous one. Or rather, reversely saying, the synchronous coordinates are chosen so that they coincide with our daily choice of coordinates in our astronomical observation.

This is no contradiction with our definition of stationary universe as a quantum mechanical eigenstate of a total Hamiltonian $H$. This Hamiltonian and therefore the total universe $\phi$ are hidden behind the observable phenomena. They appear only through some appropriately organized classical observations. Not all the quantum mechanical world can be observed, but only a few of them appear before our eyes through some well-designed experiments or measurements. One of them is Hubble’s law, which is a classical observation of the quantum mechanical emission of light from stars, though it mainly reveals the classical aspect of the universe, except for the spectrum structure of the light emitted.
from stars.

Observation and the true world can be different; which is not contradictory at all. The ‘big bang’ as claimed as a logical consequence of the Hubble’s law or expansion might be natural in its classical mechanical logic. However, the beginning of the universe is no more than an imagination, which cannot be seen actually, even if one had a ‘time machine,’ for the machine itself would contract at an initial point of the big bang when it goes back to the time of big bang, and it could not report the big bang phenomenon to the age when the machine started. Big bang cannot be an object of science in this sense of nonreproducibility of its phenomenon.

More precisely speaking, our assertion is as follows: What looks like the expansion depends on the choice of coordinates. A mathematical treatment in Kitada 1994b shows that the expansion is a one in a ‘virtual’ 4-dimensional Euclidean space, that is different from the one in the curved Riemannian manifold, in which we live according to the general relativity. This Euclidean space is borrowed from the outside of the Riemannian manifold in order to visualize the ‘expansion’ phenomenon. The mathematical fact is that the Robertson-Walker metric can be rewritten in a certain form, which can be ‘interpreted’ as this visualization of expansion. The actual result is a Riemannian geometry, whose interpretation as ‘expansion’ is only a convenient one.

Here we note that there is another possibility to explain the Hubble’s law, which fits the actual cosmological observations in more precise manner. As we have mentioned at the end of section V, one can assume another field equation than the Einstein’s, the Hoyle-Narlikar field equation which has a conformally equivalent solution to the Einstein field equation, whereas the interpretation given by Arp 1993 requires the creation of matters continuously at all points in the universe. This looks, at a first glance, contradicting our assumptions of quantum mechanics, but, as has been stated in section V, the Hoyle-Narlikar filed equation is a classical equation consistent with the two principles of general relativity which are concerned with the observed facts, hence, that field equation can be adopted as our basic field equation to determine the metric $g_{\mu\nu}$ without inconsistency with the constancy of the quantum mechanical masses of particles. The adoption of this type of field equation then gives a more preferable explanation than the usual ‘expansion’ explanation, of the astronomical observations, e.g., of quasars redshift, of the nearby stars redshift in and around the Milky Way, and so on (see Arp 1993).

In this way, our theory gives a flexible framework for the explanation of cosmological phenomena. The reader may, however, ask: If big bang is not an object of science, how can the stationary total universe in the present theory be justified without having the observability? The answer may be obvious from what we have mentioned, but we repeat it as a summary: if one assumes this universe, then one can explain some phenomena from cosmological size as Hubble’s law to the human size as the experiment of the interference of a neutron (see Kitada 1994b, section 5) with much flexibility. Also some microscopic phenomena can be explained (see Kitada 1994a, sections 7, 9). We emphasize that these are explained in one framework in a consistent way, differently from the existing explanations. We have also suggested a possibility of explanation of Lamb shift in Kitada 1994a, section 11-(2), in our framework, and a possibility of explaining the stability of galaxies, etc., as a quantum mechanical property of (approximate) eigenstates of local Hamiltoni-
ans associated with local systems, without appealing to the ‘dark matter’ which has not been observed or is considered as invisible matter. Our answer to the question above, therefore, is the unified manner of our framework that can explain some actual relativistic quantum mechanical phenomena as well as some fundamental cosmological problems, e.g., the recently noticed “cosmological conflict” between the ‘ages’ of the universe and the stars (see M. J. Pierce et al. 1994, W. L. Freedman et al. 1994, C. J. Hogan 1994, G. H. Jacoby 1994, B. Chaboyer et al. 1996).

IX. Discussions

1. Our leading principle of the construction of the theory has been the logical consistency of the theory. QM and GR has been introduced as mutually independent aspects of nature, by orthogonalizing these two theories. Then we have gotten a complete freedom to make an arbitrary assumption about the relation between these theories, as far as the assumption is consistent with QM and GR. We have chosen one possible assumption, axiom 6, so that it would explain the actual relativistic quantum mechanical phenomena. The validity of this axiom 6 can be checked by experiments and observations of actual physical phenomena. This requirement can be called again a requirement for consistency with the actual physical phenomena.

2. Our notion of time formulated in the above is an alternative for, or an intermediate notion between Newton’s and Einstein’s notions of time, in the following three points: 1) we define the local time as a measure of motion, as a substitute to Newton’s absolute time defined as a clock of the motion of bodies; 2) we can use the local time as the Einstein’s (general) relativistic proper time at the center of mass of a local system, so that we can recover the classical relativistic world; and 3) we can maintain the notion of absolute time dominating the total universe, although our notion of the absolute or total time works in quite a contrary manner to Newton’s absolute time.

Acknowledgements

The present work was started by the request from Mr. C. Roy Keys of Apeiron to write a paper which would be readable for non-specialists to understand Kitada 1994a. He helped us in various ways in the course of the preparation of the present version after H. K. wrote the first manuscript, which was given negative responses from some referees. He, nevertheless, finds certain meanings in the work, and has encouraged us ungrudgingly.

When H. K. wrote the first manuscript of “Theory of Local Times,” Kitada 1994a, which is the starting one of the present series of works, Dr. Izumi Ojima played an important role in the publication of the paper, without which the present work is not. He read thoroughly the first manuscript of “Theory of Local Times,” and gave H. K. a comprehensive list that contains his questions and criticisms. Owing to this list, H. K. could avoid unnecessary descriptions in the first manuscript of “Theory of Local Times.”
which might have led the reader to the out of context of the paper.

H. K. is also indebted to Dr. Masashi Oogami, who is a physicist and communicated with H. K. on line, discussing mainly the treatment of the relativistic phenomena including gravitational ones in the present framework. H. K. owes many points in section VI to the discussions with him.

H. K. had an opportunity at almost the final stage of the work to have Mr. Jacob Schach Møller at Dept. Math. Sci., Univ. Tokyo as a visitor from Aarhus Univ., Denmark, and to have had chances to discuss on the work. Section VII has been added owing to the discussion with him. H. K. expresses appreciation to him for the discussion.

We also thank Mr. Peter Unwin, who gave us a chance to discuss on CompuServe, and also encouraged H. K. at the early stage of the work.

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