The possibility of a hidden variable in time

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Abstract: The aim of this paper is to explain why objects decay or change their structure and why these processes have distributions in time. In a search for the above, we suggest to look for a correlation between the objects’ internal information and its possible decay. This leads us to a new definition of existence time which will be defined in detail in the text and later on illustrated in the context of spatial variables. However, here we suggest it only in the context of spatial variables. However here we suggest it only in the context of spatial variables. Therefore we could argue that the information held in the objects affects the flow of time. Also therefore one should ask how much time has passed in, for example t =5 s for two different objects. The idea of time defined in a nonabsolute way will be applied to the case of elementary particles and a hidden variable associated with time will be presented in this context. The concept of a hidden variable was suggested in EPR (Ref. 1) in the context of spatial variables. However here we suggest it only in the context of time. Following the above a particular correlation between sequential particles existence time will be suggested which, if it exists suggest a hidden variable in time. However, even a different correlation than the one suggested or any correlation at all will present a big breakthrough in particle and quantum physics making it worthwhile to search for in any scenario. © 2010 Physics Essays Publication. [DOI: 10.4006/1.3504889]

Résumé: Cet article vise à expliquer pourquoi les objets se désintègrent ou modifient leur structure, et pourquoi ces processus présentent des distributions temporelles. Dans ce but, nous suggérons de chercher une corrélation entre les données internes d’un objet et ses potentialités de désintégration. Cela nous conduit à une nouvelle définition de la durée de vie, qui sera précisée dans l’article, puis illustrée dans le cas d’une particule élémentaire. Cette définition de la durée de vie a pour effet de suggérer une variable temporelle cachée. Différentes possibilités de mesurer l’effet d’une variable cachée sur la durée de vie sont discutées en suggérant une corrélation particulière entre les durées de vie des particules successives. Une telle corrélation pourrait apparaître dans plusieurs processus, l’accent étant mis ici sur la chaîne de désintégration d’un tau en muon puis en électron. Dans le cas général néanmoins, nous suggérons non seulement de rechercher les corrélations ci-dessus, mais toute corrélation entre durées de vies dans les chaînes de désintégration de toutes les particules. Si elles existent, ces correlations amèneront une percée remarquable en physique quantique et nucléaire, motivant leur recherche dans tout scénario.

Key words: Existence Time; Hidden Variable; Correlated Particles Decay Times.

I. INTRODUCTION

The aim of this paper is to explain why objects decay or change their structure and what is the source of distributions in time of decay and structure changes. In order to do that we need to examine the concept of time. Time is a central quantity in human life and in science in general. Time is used to plan the near and far future, it is used to describe the length of existence of a particle, a body, or a human being. We have gained important insight on time from the theory of special relativity where it was shown that time is not an absolute property in nature and in fact it is a quantity that changes with regard to its specific observer. In this paper, we furthermore elaborate about time’s definition and nature and will develop further the concept of time’s nonabsolute value. The fundamental experimental observation, which is the starting point of this paper, is the fact that different objects have different decay times. In a search for an explanation to this observation, we suggest to look for a correlation between the objects’ internal information and its possible decay. If the above is true than we can argue that time does not flow uniformly in objects of detailed structure which means that time in n seconds does not pass uniformly on two different objects. Therefore we could argue that the information held in the objects affects the flow of time. Also therefore one should ask how much time has passed in, for example t =5 s for two different objects. The idea of time defined in a nonabsolute way will be applied to the case of elementary particles and a hidden variable associated with time will be presented in this context. The concept of a hidden variable was suggested in EPR (Ref. 1) in the context of spatial variables. However here we suggest it only in the context of time. Following the above a particular correlation between sequential particles existence time will be suggested which, if it exists suggest a hidden variable in time. However, even a different correlation than the one suggested or any correlation at all will present a big breakthrough in particle and quantum physics. Therefore the experimental effort for detecting this possible correlation is worthwhile in any scenario.

References:

This paper is organized as follows. Section II discusses the current definition of time and the questions and problems that arise. Consequently, a new definition for existence time will be presented. Section III discusses time in the elementary particle case. Section IV discusses possible ways on which one may measure existence time and the conclusions are presented in Sec. V.

II. THE DEFINITION OF TIME

The starting point for defining time is by movement through the equation $X=V \cdot T$, where $V$ is the velocity of an object and $X$ is the distance it passed.

In the past, time was defined by the movement of the earth around the sun. This was a circular periodic movement, however you could extract $X=V \cdot T$ from it. Nowadays it is defined by using an atomic clock which also uses movement in the form of the duration of 9 192 631 770 periods of the radiation corresponding to the transition between two hyperfine levels of the atomic ground state of the caesium 133 atom. From this process one could also, in principle, extract $X=V \cdot T$.

In the current definition of time we use the length of a movement. We evaluate the length of a movement using a specific process in nature (usually a periodic process) that is continuous and we can measure accurately, define the unit of second, and then define all the other processes happening in the world with respect to it. The second is used as a scale to all other processes. This is valid for our everyday life but also when we perform physical measurements.

The difficulties in using various types of periodic processes to quantify time are discussed in detail in Ref. 2.

The current definition of time is adequate to describe a world of identical structureless objects, their actions, and relations. It is useful for comparing the length of any movement with any velocity by the division of the movement into seconds. In such a structureless world, if an object is at rest, it is not affected by time and also in such a world the concept of existence time of an object is irrelevant. However the world is more complicated and as we know is composed of objects with detailed structure and the different information held in the different objects may also affect time and, in particular, the existence time. In such a world, the current definition is useful for setting up a time for a date but it is suggested here that it may not describe properly the length of existence of objects. This may be so due to the lack of inclusion of internal information, where $Sn$ seconds may not pass uniformly on two objects with different internal information. This may be reflected in the different existence time of objects. This idea may be applied to macroscopic objects but also to elementary particles and we may ask if elementary particles carry more information than we are currently aware of and whether this information governs their decay.

If we take for example the lifetime of a muon according to quantum field theory (QFT), it decays simply because it can, i.e., there exist an appropriate Feynman diagram that allows the decay. The downfall of this explanation is that it does not explain specifically the distribution in decay times. Therefore, as a more detailed explanation it is being suggested here that the muon’s range of decay times implies that there is some internal information within the muon that dictates its existence time and that the unit of second does not describe properly its existence time. The above leads us to a new definition for existence time for an object which is motivated by the range of decay times and also gives a reason for the decay:

Existence time is the sum of the internal changes that the object experiences during a period throughout which it keeps its internal structure/properties.

Where the period is defined using external time in our usual definition of time. A somewhat related idea regarding the rate of time was suggested in Ref. 3. However, there it was not related to objects and to existence time of objects and decay in particular. In Ref. 3, there was also no conclusion about the nonuniform flow of time.

It is being suggested here that the information that governs the existence time is the number of internal changes within the object. In order to define the object’s existence time, we should use also the external time. We should treat external time as a scale for internal changes within the object and it is suggested that the correlation between the internal changes and external time dictates the object’s existence time. This means that if the object experiences a large number of internal changes per second, its existence time may be shorter than that of an object that experienced a small number of internal changes per second. Therefore, for any object, the amount of internal changes provides a reason for the object to decay or change its structure. Also, from this we may suggest that since different objects have different internal changes, time does not flow uniformly.

In the above definition of time, we describe the total number of internal changes that an object experiences. In fact, an object may experience two kinds of internal changes: periodic changes and nonperiodic or random changes, both of which should be considered with respect to the unit of second. In the periodic case, the same process repeats itself within the object while keeping the object’s original structure intact, while in the nonperiodic case, the changes are random and may cause a change in the objects’ structure or decay.

When we look at the concept of time, we realize that the more significant types of changes are the ones that cause structural changes to the object, i.e., the nonperiodic changes. Since these changes may affect the objects’ existence time.

In the following, we will look at both types of changes but put more focusing on the nonperiodic ones. We will argue that the nonperiodic changes are the reason that objects’ decay or change their structure. Furthermore, we will argue that the range in the time for decay and structural changes is due to different magnitudes per second of nonperiodic changes in the objects. We may also suggest from the above that the object’s nonperiodic internal changes for a short period of external time may also provide some predictive information about the object’s total existence time.

We will demonstrate these changes in the case of an elementary particle because in this case the existence time and initial conditions can be clearly defined but in principle it could apply to other physical objects.
III. EXISTENCE TIME OF ELEMENTARY PARTICLE

The sum of internal changes can be defined for any fundamental particle: stable or unstable. However, the existence time could be clearly demonstrated in the case of an unstable particles, as will be shown in the following discussion.

Let us consider the process $e^+e^- \rightarrow \mu^+\mu^-$. If we look at the $\mu^-$ and measure its mean external lifetime, we get in its rest frame: $2.197 \times 10^{-6}$ s. Also in this case there is some internal information we can include in the time definition as suggested in Sec. II. The muon satisfies the following equation:

$$h \cdot f_p^\mu = M_\mu \cdot c^2,$$

where $c$ is the speed of light, $h$ is Planck constant, $M_\mu$ is the muon mass, and $f_p^\mu$ is the muon’s periodic phase frequency.

From this, we can learn that there is an internal movement in the muon at rest in the form of phase change, where $f_p^\mu$ is the number of phase periods per second. Therefore, we can define the number of periods for a muon mean lifetime as $f_p^\mu \cdot 2.197 \times 10^{-6}$ which gives the number of internal changes during the muon lifetime. Of course, in this case, we cannot change $f_p^\mu$ in the $\mu$ rest frame by any external force and also $f_p^\mu$ does not change the muon’s existence time.

The number of changes defined above represents the periodic changes within particles. As it was explained in Sec. II, we do not expect these changes to affect the particle structure or existence time and we are particularly interested in the nonperiodic or random changes. Therefore, by applying this to the elementary particle case, we should also look here for nonperiodic changes. In doing so let us discuss the muon lifetime from a different aspect. The mean muon lifetime, $2.197 \times 10^{-6}$ s, in fact, represents a distribution of values for the muon lifetime. This distribution falls exponentially, where most of the muons decay early on. This distribution represents a range of lifetimes for the muon. When we perform an experiment and reconstruct these lifetimes, the order in which this distribution is filled is purely random. The question this randomness and range of values presents is how come all these identically born muons have different lifetimes. This seems to contradict the logic that physical laws should repeat themselves under identical conditions. This contradiction can imply that there is some variable in the particles that produced the pair of muons, in this case the electron and positron, that is responsible for these differences in lifetime and for the apparent randomness in the order in which the distribution is created. This variable should present a correlation between the electron and muon which are nonidentical, nonspatially entangled particles, and, in particular, particles of different mass. One may suggest that these particles exhibit some kind of an entanglement in time. This additional hidden variable is suggested here only in the context of the particle decay process and may not be linked to the wider range of randomness of phenomena in quantum mechanics and their possible explanation. That is, it is related to QFT but does not expected to explain all spatial randomness phenomena. In particular, this additional variable associated with time should not be linked to any angular distribution caused by randomness since, as it is suggested here the source of randomness for angles and for decay times is different. As an example we can look at $e^+e^- \rightarrow \tau^+\tau^-$ and argue that there should not be any relationship between the distribution of the production angles of the tau and the distribution of the tau’s decay times. In the above example we suggest a hidden variable that only concerns the tau decay and which is not related to the tau production angle.

By combining the above with the definition of existence time given in Sec. II, one may argue that the additional variable is the number of internal random changes within the muon that is responsible for its sooner or later decay. In the view of this, one may speculate that behind each muon lifetime stands a different random frequency $f_r$, which describes the number of random changes that the muon experienced per second. Therefore, one may analyze the muon lifetime distribution, such as the muons that decay early on experience very large number of random changes per second and the muon that survive longer experience less number of random changes per second. Therefore, the sum of internal random changes may be given by

$$T_{int(r)} = f_r \cdot t,$$

where $t$ is our usual external time and $f_r$ is the number of random changes per second for particle $j$. Note that $T_{int, r}$ is dimensionless, and its role to dictate the decay time.

The question is now what are these random changes? A possible candidate for them may be the virtual emission and absorption of photons by a charged particle. In this process, a photon with a range of momentum is emitted of a charged particle. The origin of randomness in this process comes from QFT such that although we know that small momentum emissions are more probable than large ones, the order in which they are emitted is purely random and this aspect is what makes it a suitable candidate for the random frequency $f_r$. As QFT does not have any specific interpretation for this process, one may take the freedom to speculate about its role as the random changes within charged particles. It is being suggested here that charged particles come with different values of random frequencies, $f_r$, for the virtual photon emission. The random frequencies should depend on the particles mass for its strength and its range of frequencies. The general expression for it may be given by

$$f_r = f(M, W(M)),$$

where $M$ is the particle mass and $W(M)$ is the width of the frequency spectrum that the particles have, which also needs to depend on the value of the mass. We now have to find the exact expression for the value of $f_r$. For this let us look at the decay of the $\mu$ particle. After giving all the above demands for $f_r$, one may suggest the following expression as a candidate for $f_r$ distribution, for example, in the $\mu$ case, in units where $\hbar = c = 1$:

$$f_r(M_\mu, j = 0 \rightarrow t) = M_\mu \cdot e^{-j^2/\mu},$$

where $M_\mu$ is the muon mass, $\tau_\mu$ is the muon mean lifetime, and $t$ is our usual external time. Here $j$ represents the range of muons with different frequencies where each $j$ corresponds to a different existence time of the muon. In the
above expression the values of \( t \) in which \( f_r \) is nonzero replaces \( W(M) \) from Eq. (3) as the range of frequencies that the particle has. It is being argued here that the time \( t \) after the particle was born is the relevant time to expose the \( \mu \) random frequency, \( f_{r(\mu)} \) by using Eq. (4) and that \( \tau_p \) should be treated as a shape variable that dictates the shape of the muons exponential decay distribution. It is also being suggested that \( f_{r(\mu)} \) is encoded in the \( \mu \) by the virtual photon emission process.

### IV. POSSIBLE MEASUREMENT OF EXISTENCE TIME

Consider now the interaction \( e^+e^- \rightarrow \tau^+\tau^- \) and let one of the \( \tau \)’s decay into a \( \mu \). This decay chain is illustrated in Fig. 1. Assuming that each \( \tau \) has a particular \( f_{r(\mu)} \), one may ask what happens to it in the decay into a \( \mu \).

According to Eq. (4) the \( \tau \)’s \( f_{r(\mu)} \) should be greater than that of the \( \mu \) so it cannot be conserved in the interaction. It is being suggested here that what is, in fact, being conserved is the ratio between the random and periodical frequencies \( f_{r(\mu)}/f_{r(\mu)} \), where \( f_{r(\mu)} \) is defined in Eq. (1) and so, therefore, the factor \( e^{i\theta/r_{\tau}} = e^{-i\theta/r_{\tau}} \) is conserved and provides the relationship between the two particle lifetimes since creation \( \tau \) and \( \tau \). This relationship reduces of course to

\[
\frac{t_{\mu}}{t_\tau} = \frac{\tau_\mu}{\tau_\tau}
\]

and therefore allows you to predict what would be the \( \mu \) lifetime after it was born given the \( \tau \) lifetime after it was born. Therefore, if, for example, the exponential factor has the value of 0.8 for the \( \tau \), the same value of the exponential factor will be conserved also in the \( \mu \) case but will of course correspond to a different existence time since the shape of the exponential decay distribution is different in the two cases.

This correlation was never looked for in the past and it is not clear what would be the best way to attempt to measure it. Since the additional variable, \( f_{r(\mu)} \), is related to the particle mass, which is an internal property of the particle, it is not clear if one needs to use weak measurement or strong/regular measurement.

If we choose to be conservative we would attempt to measure this by using weak measurements which require building a dedicated detector. Alternatively it is possible that this correlation would not be destroyed by a strong/regular measurement and in this case one may use regular detectors and even existing data.

For the regular measurement case, this correlation between the tau and the muon lifetimes cannot be measured with detectors that were used, for example, in LEP (Ref. 6) or the B factory, due to the long distance that the muon would pass before decaying but requires a dedicated detector with the desired properties. For example, it would be possible to build a detector that attempts to stop the muons after the \( \tau \) decay in a thick material that would slow them down. This would allow the size of the detector to be reasonable.

It is also possible that the above correlation as written in Eq. (5), will be conserved with the appropriate particles widths in different processes and we can use LEP or B factory data for processes as listed below: for example, \( e^+e^- \rightarrow \tau^+\tau^- \) and to choose one of the tau’s to decay into a state containing a kaon or a pion. This kaon or pion lifetime after creation can be measured and then one may look for a correlation between their lifetimes and the tau lifetime. Since we look for correlation between particles, it would also be interesting to check if the possible correlation causes a deviation from the exponential decay distribution after the kaon or pion are produced by their father tau. In this case we look for a correlation between an elementary particle and a meson and it is not clear what the possible correlation would be in this case as it is different between the originally suggested correlation between the tau and the muon decays. This is due to the possible different decay mechanisms in elementary particles and mesons or a possible Zeno-like effect that may take place inside the meson which do not prevent the mesons decay but destroys or changes the original correlation.

However, it is possible that the random information is conserved in the same way as suggested between the \( \tau \) and the \( \mu \) or there is still some correlation also in this case and it would be interesting to look for it. Another possibility would be to look for correlation in the \( b \rightarrow c \) quark decay chain. This could be done, for example, in any LEP or B factory experiments, where \( b \) events are produced and than decay into \( c \) particles. Yet another possibility would be to look at \( e^+e^- \rightarrow c^+c^- \) events where we can look at one of the \( c \) mesons and its decay into kaon and its counterparts. Yet another possibility would be to look for a correlation between the lifetime after creation of a charged pion or a kaon and its decay into a final state containing a muon and its subsequent decay. All the above correlations could be measured, in the strong/regular scenario, very accurately using very large ex-
existing data sets under the limitations of a possible Zeno Like effect as explained earlier. If no correlation is found these tests could be equivalent to a test of bell inequalities\(^9\) for the case of time.

This kind of correlations between chain decay times may be evident in other systems such as atoms (atomic levels) and nuclei and one may look for them there as well.

Even a different correlation than the specific one suggested here or any correlation at all in the above or similar processes would imply the existence of a hidden variable in these interactions and would present a big breakthrough in the field of particle and quantum physics making it worthwhile to search for in any scenario.

The sum of internal changes is difficult to define for what we call a fundamental particle as we may not understand at the moment its exact structure well enough and even if it indeed has any.

The frequencies, \(f_p, f_r\) that were defined above for the muon and tau is just one way to treat the possible nonfundamental nature of fundamental particle and are by no means the only way.

One of the questions that arises is what is the elementary particles’ inner structure, how we can get information about it if indeed there is internal structure, and what is the relation between the internal structure and the particles length of existence.

V. CONCLUSIONS

The problem of defining existence time for nonfundamental objects was discussed. In contrast to the conventional notion of time that depends only on reference frame, we define here a different sort of time, existence time, as the sum of all internal changes, and apply it to elementary particles. The new definition provides a reason for the objects’ decay or structural change and also gives a reason for the distribution in decay times. Therefore, the object decays after it passes a certain amount of internal changes and the differences in decay times of objects is due to the different internal changes that the objects experience. Possible ways in which one may prove or disprove that indeed internal information governs elementary particle decays were discussed and it was shown that it is in principle possible. The suggestion was to consequently look for a particular correlation between the decay chain of a tau to a muon and than to an electron and to make a more general search for correlation between chains of decay times of particles.


\(^4\)Particle Data Group (PDG) booklet.


\(^9\)J. S. Bell, Physics (Long Island City, N.Y.) 1, 195 (1964).