TIME INVARIANCE OF THE FUNDAMENTAL PHISICAL CONSTANTS

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Abstract**.** This paper shows that the variation of certain fundamental constants is practically impossible in a physical time frame of reference. We can have as many time frames of reference we want but when we transform them all into physical time frames of reference, with time as a measure of movement, physical equations retain their form and meaning and values of certain physical quantities and fundamental constants are the same. Therefore the question of variation of certain fundamental constants is only possible for those frames of reference other than physical time.

Key words: fundamental constants, fine structure constant, physical time.

1. INTRODUCTION

Current attempts to unify all four fundamental forces of nature have undergone profound transformations, in substance and content within physics. In this effect is the embedding of general relativity theory in quantum mechanics. One way to achieve this goal is to develop a common set of axioms, the basic principles, from which we can build a solid theoretical edifice. This is the reason why we test the validity of the fundamental principles of the general relativity theory: the general principle of relativity and the principle of equivalence.

One way to solve this global problem is, now consecrated, to test if the variation of fundamental constants of nature exists. The validity of the general principle of relativity can be tested by varying all the fundamental constants of nature and the principle of equivalence only through the variation of gravitational constant. Although the first principle is from this point of view a general principle, however, this separation is preferred.

In general, specific fundamental constants of quantum mechanics are used to test the general principle of relativity. In this way an overview of the laboratory and astrophysics observations is found in [1]. In our view we will limit ourselves in the following to a criticism of the variation of fundamental constants. What they share all these experiments? First, many values for each constant proposed under consideration, from which it is difficult to discern even a credible range of variation. Each experiment's results are different from other experiment, and it is impossible to say that one is right and the other is not in the absence of common criteria for evaluation. Finding such criteria is arduous and that is because there is no common basis for discussion, for some fundamental constants, we have two types of observations, laboratory and astrophysical. Then it would be virtually impossible to detect and differentiate the errors of reasoning from those of measurement and calculation in all their diversity because they can always very easy to ignore our claim of objectivity. So, how credible are these results? It is hard to say which give precedence to them.

In this vein there are several errors of principle. First of all the results lose touch with reality and thus physics become again philosophy. Many times the fundamental constants of nature have been introduced for experimental reasons, as proportionality constants. Their circumvention causes virtually impossible the interpretation of quantitative experiments. We have only qualitative experiments and a general empiricism. The exact nature of this science is given only by the establishment of causal relations (deterministic in the relativity case and probabilistic in quantum mechanics case) between the physical quantities investigated in the experiment. This would be impossible without keeping in experimental framework some quantities constant and observe the variation of others. A variation of all physical quantities would make it virtually impossible to perceive a causal relationship, in the direct and the indirect sense; this fact involve other experiments designed according to other principles and theories which considered a preferred variation of quantities, while the rest of them remain constant. Logically “the laws of nature are the same in any non-inertial reference system, they have the same form and physical quantities involved had the same meaning" is respected if one constant varies or all constants and quantities vary simultaneously.

The second error of principle to invalidate the general principle of relativity by considering the variation of fundamental constants is to consider quantum mechanics strictly in the framework of general relativity. Quantum mechanics constants vary due to varying standards of space, time and mass, which must remain constant in relativity theory. This is a consequence of the fact that between the two theories there isn’t a set of axioms and common principles. A rigorous theory in this direction would be to conceive space-time like a whole whose sizes and dimensions to be the constants of quantum mechanics. However this theory does not exist yet, as I know.

A third error of principle to invalidate the general principle of relativity by the variation of fundamental constants is to ignore the principle of causality implied in the words included "the speed of light is the same in all reference systems; it is the speed limit that is found in nature." The general principle of relativity has no meaning without this first principle of special relativity. It's actually a consequence of it. Non-causality would entail the existence of other laws of physics, in any reference systems, inertial or non-inertial. In the absence of causality, the irony is that we cannot set those laws. There is no certainty of their validity. All measurements should fluctuate chaotically, without any sense, would appear new phenomena, impossible to correlate with some variant quantities. The information that we use to conceive our theories of fundamental constants variation arrive to a physical observatory with a finite speed, the speed of light, either from the stars or in the labs, it seems nonsense to talk about the invalidation of general principle of relativity. Nobody denies the existence of speeds greater than the speed of light, but we have only the speed of light to observe their effects. In this case we only have two options: either directly study what happens to the laws of physics at speeds greater than the speed of light, or more simply to study just a case in which the speed of light is exceeded. Because measured values are of the order of measurement errors, this matter is for the moment impossible. On the other hand, even if this is possible, we would obtain nothing: out of the causality we throw all physics into philosophy. We haven’t access to reliable information, space, time and mass were imaginary, if we forgot to mention the assumptions of the theoretical framework we are. If we don’t forget, then you should expect that the new theory in which we work to be validated by other results in order that our results to have credibility.

Last error, but not the least, in validation of the general principle of relativity by the variation of fundamental constants of nature is its paradoxical or illogical character. Sometimes it is assumed true the theory of relativity, but final findings show that it is not true. Sometimes the assumptions are accepted as true and that's not true, while the findings show that are not true. Typical errors that are made when we are trying to validate a theory by itself. In the case of relativity theory it is an impossible mission. If you do not follow the axioms of the theory it means that you do not use this theory; if you do not use this theory, what do you use instead? Some theory you try to formulate there and then. What do you get? What you expect. Is valid your new theory? Nobody knows, because it is being already formulated. Or maybe one already formulated the new theory which has no validation other than the one obtained by you. It means that the theory has been validated? No. It goes into a kind of vicious circle from which even the non-causal output cannot save you. Usually this is happening when we are working with theories that incorporate extrinsic or intrinsic relativity and which pretend to be an extension of it in the non-causality domain. Causality and therefore relativity are presumed valid at the initial moment, but at the final moment are not. There are attempts to validate such theories dependent, in one form or another, by relativity, by ignoring its results in the non-causality domain. Correct would be to work with theories independent of relativity, these theories to be validated by other results, and then the results about the variation of fundamental constants to be credible.

2. Different frames of space, time and variation of fundamental physical constants

The experiments mentioned above also have in common that some assumptions are based on somewhat paradoxical. It is simply assumed a completely arbitrary change of fundamental physical constants and is expected then, after removing all the errors, to discern this change in nature. Or according to an earlier work, [2], it would be absurd to expect any kind of experiment to be able to measure these consequences.

Firstly, each experiment in part by the assumptions that we make, consider the length and time standards different from the international standards. Because we deal with a problem that concerns the international system of units strictly an experiment would be ideal to use only the hyperfine transition frequency of cesium atoms for measurements involving time and the wavelength of the Kr-86 for the length. Many of the mentioned experiments do not consider the above standards as reference standards, which in principle is not correct. Basically speaking, if we want to measure a variation of a physical quantity we must leave from a fixed value of that quantity, calculated according to a reference standard. Otherwise, nothing makes sense. Some authors, [3], went a little further with this idea. To measure the real variations of them, we have to compare the behavior of these variations considering two or more independent standards reference, for more accurate results. Let now apply this idea to our problem, but from a general perspective.

Consider two different standards, time and length. The actual standard of time is, as mentioned before, given by the frequency of the hyperfine transition of Cs atoms. In fundamental physical constants it is:

$$\upsilon_1 = \boldsymbol{m_e} \frac{\boldsymbol{m_e}}{\boldsymbol{m_n}} \alpha^2 \boldsymbol{c}^2 \frac{1}{\boldsymbol{h}} \tag{1}$$

where the meaning of these constants is known.
Similarly, the standard of length is defined by the wavelength of the Kr-86 near to $\lambda = 605{,}78$ nm. In fundamental physical constants it is given by:

$$L_1 = \frac{1}{m_e} \frac{1}{\alpha^2} \frac{1}{c} h \tag{2}$$

If we consider (1) and (2) the time and length standards then they should be constant by definition. It's hard to imagine the possibility that some fundamental constants can vary now as a function of time and length. For example, no change of the quantity:

$$\frac{L_1}{T_1} = c\alpha^2 \frac{m_e}{m_n} \tag{3}$$

could not be measured with our standard because we get to make some judgments that seem childish. Considering each term in the right side of equations (1) and (2) a fundamental physical constant, we could imagine in (3) the situation, a bit absurd, in which the expression from the left side of the equation remains constant as a result of proportional variation of constants α. and m_e / m_n. We might ask then what bizarre correlation may exist between the electron and the neutron mass ratio and fine structure constant components. We would think at some point we somehow passed the strict physics and play only with some numbers.

Next step of our approach is to stop a little at the second pair of standards of length and time necessary for the course of what follows. We are, of course, free to choose any length and time we want as standards. We will adopt the second standard of time the Compton frequency of electron, that means:

$$\upsilon_2 = m_e c^2 \frac{1}{h} \tag{4}$$

Unlike (1) and (2) this expression is simpler, contains no constants in the form of ratio and no fine structure constant. That is an advantage because if we choose an expression for standard of length that contains about the same constants, when we do the ratio of the standards of length and time we can get a simpler expression than (3), which can work more easily. In this vein, we consider the standard of length, the radius in units of Bohr radius of hydrogen atom:

$$L_2 = \frac{1}{m_e} \frac{1}{c} \frac{1}{\alpha} h \tag{5}$$

If we ignore the standards (1) and (2) then the reference standards are expressions (4) and (5), they are constant by definition, and it would be very difficult to imagine a change in the quantity:

$$\frac{L_2}{T_2} = c\frac{1}{\alpha} \tag{6}$$

to be the result of variation of fundamental physical constants from it. The situation is changing if we try to compare the standards of the same type and how they vary according to which the fundamental constants they contain. The most convenient would be to consider the simple expression:

$$\frac{L_2}{L_1} = \alpha \tag{7}$$

Note that now one can easily imagine a variation of the fine structure constant, given that a standard length remains fixed reference and the other would vary inversely with the variation of the fine structure constant.

3. The consequences of introducing a single time reference, the physical time

This would be the situation in the case previously considered. We might be reasoning that it would contain some variation of fundamental physical constants. However, in practice, from experimental reasons we should issue a little differently. It's obvious that in our space-time frames (3) and (6) is missing something. That something is the condition of measurability, which is specific to quantum mechanics, not only to the theory of relativity. Time is measured only by space and space only by time. We cannot imagine an experiment in which to measure them simultaneously. We measured each other with the condition to be known the speed, at a time. Physical time, as we know it is only a measure of movement in a certain space with a known speed. On the other side space can be measured only like duration of the movement. Therefore, because our references for space and time (3) and (6) must be operational from the experimental point of view we must have a measurability condition, defined by:

$$\frac{nL}{pT} = c \tag{8}$$

where n and p are positive real numbers; they are required to define multiple elementary lengths and times determined in experiments. Velocity c is known, otherwise we could make any experimental determination, is a speed limit, the speed at which light travels. Of course, the relation (8) must be understood only from practical reasons. A direct interpretation would lead to some absurdities: it is clear that the Bohr radius of hydrogen is not measured by the Compton electron frequency, to give just one example. In practice we only use multiples of these standards and do not care where they came from, only we care to be exact. Then, a speed faster than the speed of light is unspecific to classical mechanics, while in the astrophysical observations is used only information that reaches us here on Earth with the speed of light, a specific speed of quantum mechanics. The speed of light must be understood only as a limitation of nature. If c could vary then we have not a space-time frame in which we can make reliable measurements.

So we have now the principles which can reconsider our problem. It is obvious that if one takes into account (8), in relation (6), since c is fixed, it can be concluded that α is a constant. Any variation of it, in a physical time frame, is null. If we consider now this very important intermediate result in relation (3), taking into account (8), it results that the electron to neutron mass ratio is a constant.

Now, if we apply a variation to the relation:

$$L_2 = \alpha L_1 \tag{7'}$$

and we consider that the fine structure constant variation is zero then we have:

$$\delta L_2 = \alpha \delta L_1 \tag{9}$$

If we apply now a variation to the relation (7), it will result after an elementary calculation:

$$L_1 \delta L_2 - L_2 \delta L_1 = 0 \tag{10}$$

From (9) and (10) follows:

$$\delta L_1 (\alpha L_1 - L_2) = 0 \tag{11}$$

it results the invariability of standard length (2). This result, which is introduced in relation (10), has as a consequence the invariability of standard length (5). And last but not least, from the invariability of standard length (2) can be easily deduced that the variations of the Planck constant and electron mass are simultaneously zero. Finally we conclude that the variations of all physical constants contained in (1), (2), (4) and (5) are simultaneously zero if we set the measurability condition (8).

4. Discussions

The consideration of the physical time is always necessary from experimental needs. What we measure in all cases is the physical time. Of course, we have to distinguish between the microscopic and macroscopic world. In the macroscopic world the physical time is not necessarily related to the speed of light , is related only to the extent that astrophysical observations that we receive from long distances travel through space with constant speed of light. When we are making measurements we measure the frequency or the wave length of light. Because we cannot simultaneously measure both in the same experiment we are virtually forced to maintain constant the speed of light. What we measured, for the mere reason that the speed of light is constant, it can't give us in any way a variation of fundamental physical constants as we implicitly assumed that we are in a physical time frame of reference. For this reason, we believe, all the results concerning the variation of fundamental physical constants obtained from some astrophysical observations are wrong. In a single experiment is impossible to discern more than a variation of a physical quantity in the equation that links frequency, length wave and the speed of light. The other variation is calculated by keeping constant the third quantity. And the third quantity in a physical time is just the speed. Otherwise we cannot have a physical time reference; we have some other frame of reference: not a space-time framework for discussion but a space-velocity or velocity-time frames of reference. But we work strictly on a physical space-time framework. Therefore in experiments related to the variation of fundamental physical constant the speed of light is an ultimate truth.

From the previous section is clear the need for uniqueness of the physical time. If we had more time references, equation (1), equation (4), as well as any other time references, and there is no criterion of their unification, this situation virtually create the possibility that we have some variations with respect to time (which time?) of the fundamental physical constants. Eventually it would be a hubbub, no quantitative relationship would be valid, the physics could not exist as we know it today to serve as a basis of comparison for those who want to change it without modify its fundamentals.

The existence of a unique time frame, however, put everything up. The equations hold their shape and the physical quantities significant content, regardless of physical time reference in which we work. The speed of light is constant, we know exactly what we measure, time or space, and we are entitled to use the current system of units. This system it is not by chance related to space and time and not to velocity and time or to velocity and space, because the units of measure for velocity are reducible to those of space and time. Therefore a change of physics in terms of variation of fundamental constants might feel the need for a change of the measurement units.

A physical time frame of reference implicitly assumes constancy of the speed of light. This leads to invariability of the constants mentioned above. This idea can be generalized to all fundamental physical constants. It's like we say that light speed invariance principle of relativity is valid in all physics. The general principle of relativity [4], also is valid in all physics, because it follows from this principle. The principle of causality, which also stems from the invariability of light speed, is also true in all physics. We cannot have both qualitative and quantitative experiments without the principle of causality. We cannot measure anything. We cannot get any quantitative relationship between the physical quantities involved in the experiments if we are not in a physical time. Therefore the relativity principles are not specific for the relativity theory; they are specific for quantum mechanics implicitly, more or less related to the deterministic-probabilistic nature of its results. If we want to invent a new physics we have to give up firstly to physical time, which, seen from the above, now seems impossible and meaningless.

5. Conclusions

By using two independent references of space and time and by maintaining a constant reference space, we can conclude that it is possible to study the fine structure constant variation. By introducing physical time, time as a measure of the movement required by the experimental measurability considerations, initial spatial and temporal references turn in that they contain invariable quantities. This invariableness cannot be questioned. All fundamental physical constants contained in equation (1), (2), (4) and (5) are invariant simultaneously.

The need to introduce physical time is a matter of principle. Firstly, the physical time is the time by which all other possible time references are unified. And finally, without physical time, time and space may not be as one, we are in a different frame than a physical one, and the measurements we make are questionable.

REFERENCES

[1] J. P. Uzan, Rev. Mod. Phys. **75**, 403-450, 2003.
[2] H. C. Ohanian, Found. Phys. **7**, 391, 1977.
[3] T. C. van Flandern, On the measurement of cosmological variations of the gravitational constant, L. Halpern, Univ. of Florida, 21, 1978.
[4] A. Einstein, Relativity: the special and general theory, Methuen & Co. Ltd, 1920.