Dirac's Large Number Hypothesis: Is it related to 40 Hz Gamma Oscillation or Consciousness?

Sisir Roy*, Samyadeb Bhattacharya†, B. V.Sreekantan‡

ABSTRACT

All physical theories depend on the values of few universal constants like Planck constant, speed of light and gravitational constant. These theories show us that, if the values of the constants were even slightly different, the world around us - from atom to universe, would also be completely different. Is it mere a chance or fine tuning of these universal constants made the existence of life possible in the present universe? Dirac Large Number hypothesis based on the precise values of these constants made a profound impact in this debate in twentieth century physics. The present authors found another large number which is of the order of Dirac large number 10^{40} in life sciences. This is the ratio of smallest time scale of 40 Hz oscillation in neuronal system of brain and the smallest timescale called Planck time in the present universe. Since 40 Hz oscillations dominate at awake and REM sleep states, our findings may shed new light on the issues of life and consciousness and the fine tuning of the fundamental constants in the present universe.

Key Words: Dirac large number, anthropic principle, 40 Hz oscillations, consciousness, universal constants

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I. Introduction

Starting from the smallest atom and the nucleus within, to the inconceivably great cosmic universe, nature supplies an enormous variety of physical structures. Some of them can be said to be more or less homogenously distributed throughout the universe with rather narrowly defined properties. We can take the comparative example of the atom and star in this context. The details of the structures and their differences will depend on the laws of motions and various boundary conditions they are subjected to. However, the gross features of both the structures - like their size, mass or lifetime can often be determined within an order of magnitude with certain relations incorporating some fundamental constants such as G, h, c, e, m_p etc. The structure of atom, which is essentially determined by the laws of electromagnetism and quantum theory, is quite heavily dependent on the fundamental constants like the Plank's constant (h) and the charge of the electron (e). On the other hand, the cosmological structures like stars, which are predominantly associated with gravity and electromagnetism, depends on the gravitational constant (G). Such examples can be found in each and every physical theory, where we find the structural dependence on these few fundamental constants. The intriguing aspect is that all of the physical theories depend remarkably on the values of few universal constants. The question arises whether if the numerical values of these constants were different, whether the world as we conceive would have been the same? The physical theories show us that, if the values of the constants were even slightly different, the world around us - from atom to universe, would also be completely

Corresponding author: Sisir Roy, National Institute of Advanced Studies, IISC campus, Bangaluru 560012, India.
Address: Samyadeb Bhattacharya, Quantum Information and Computation Group, Harish Chandra Research Institute, Allahabad, Uttar Pradesh 211019, India. **e-mail** ✉ sbh.phys@gmail.com
B.V.Sreekantan, Address: National Institute of Advanced Studies, IISC campus, Bangaluru 560012, India.
Phone: :+ 91-80-2218 5143 **Fax**: +91-80-2218 5028
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different. So is it only by a mere chance the fundamental constants have such values to make the universe as it is? Or the precise fine-tuning of the physical constants, that made the emergence of life possible in this universe is not just an accident, but has other precise reasons behind it?

Several publications (Carter, 1974; 1983; Davies, 1982; Rees, 2000; Gamow 1940) over the years which examine this very question. It has been asserted that if the physical constants had different values, then life could not have emerged. Even if it had emerged, it would not have been in its intelligible form as prevailing in our planet. Some authors (Carter, 1983; Davies, 1982; Rees, 2000; Gamow, 1940; Kafatos, 2005) in the above mentioned publications tried to justify this statement with reference to certain relations between various physical constants asserted by Paul Dirac in the "Large number hypothesis" (Kafatos, 2005). Relying on the coincidence of large dimensionless numbers arising out of the ratios of various fundamental constants, Dirac proposed a hypothesis that the gravitational constant (G) can vary inversely to the cosmic time scale (t_c). Based on this hypothesis, several authors have reviewed this area of research to make it a very influential proposition in the world of physics. The relevance of discussions on large numbers were highlighted further by Weyl (1917; 1919), who arrived at another large number 4×10^{42} by comparing the electron radius r_e with a hypothetical radius of a particle with the same charge of an electron and the electrostatic energy equal to the gravitational energy of the electron. With this initiation, it has been found that several other quantities, such as electron's electrostatic force (F_e) and it's gravitational counterpart (F_g), the energy of electron's coulomb field (E_o) and its self-energy (E_s) and many others have got the numerical value similar to the Weyl number as their ratio. Following Weyl's speculation Stewart later showed that (Stewart, 1931) the ratio of the radius of Universe and that of electron is of the order of 10^{40}, which is only two orders smaller than the Weyl's number. Later calculations done by various researchers showed that this order of 10^{40} comes surprisingly frequently in the ratio of many other physical quantities, which we will discuss in section II. Carter (1983) further elaborated the relevant timescale of biological evolution in Darwinian selection process in the light of Large Number of Hypothesis. So far as authors' knowledge goes no investigation has been reported yet regarding the evolution of nervous system of animals and its connection with the fundamental physical constants or their ratios.

In this paper we present our new results related to a dimensionless number similar to that found by Dirac. We find the number 10^{40} considering the ratio of quanta of time associated with gamma rhythm of the brain and the quanta of time in the physical universe called Planck time. Gamma rhythm is the dominant rhythm present during wake as well as in REM sleep (dream state). The conscious activity of the brain is associated with gamma rhythm. The quanta of time corresponding to gamma rhythm is shown to be (10^{-14}) ms (Joliot *et al.,* 1994) whereas the quanta of time in the physical universe i.e. Planck time is of the order of 10^{-43}s. Planck time is the smallest unit of time in the physical universe which is determined by the fundamental constants like *G, c, h* i.e.,

$$\tau_p = \sqrt{\frac{Gh}{c^5}} = 1.35x10^{-43}\ \text{s}.$$

No concept of time, space or causality exists beyond this Planck scale. The emergence of time, space or causality poses one of the most challenging questions in 21st century physics. The quantum of time associated with gamma rhythm indicates that brain or more specifically nervous system cannot resolve any two stimuli within this period of time. It is interesting to note that a quantum of time associated to gamma rhythm is not directly related to the above fundamental constants. Some authors (Carter, 1974; Carter, 1983; Davies, 1982) have speculated that the fine tuning of the fundamental constants is necessary for the existence of life or intelligent beings. Here, we find a ratio of two time scales (two quanta of time) as of the order of Dirac large number 10^{40}which is clear indication of a direct connection of the fine tuning of the fundamental constants in physical universe with the existence of conscious activity of life associated to gamma rhythm in the brain. This may shed new light on Dirac large number hypothesis and the biological evolution in particular to existence of intelligent being which will be discussed in section III. Finally possible implications are discussed in section IV.

II. Variation of Fundamental Constants and Anthropic Principle

As we have mentioned in the introduction, after Weyl's numerical estimation of the ratio of the electromagnetic and gravitational force between two electrons, many researchers have found various other estimations of fundamental physical quantities, which also puzzlingly lead to huge numbers of the order of 10^{40}. In the course of this development, Arthur Eddington said that it is possible to overcome this difficulty of the occurrence of such huge number, if the number can be connected to the total number of particles in the universe. Eddington estimated this number to be $N=10^{79}$. This is almost the square of the Weyl number. Later Dirac noticed that certain cosmic "coincidences" occur in nature linking microscopic with macroscopic quantities. A most unusual relationship is the ratio of the electric force to gravitational force (this ratio is presumably a constant in an expanding universe where the physics remains same);

$$\frac{e^2}{Gm_e m_p} = 10^{40} \qquad (2.1)$$

while the ratio of the observable size of the universe to the size of an elementary particle is

$$\frac{R}{\frac{e^2}{m_e c^2}} = 10^{40} \qquad (2.2)$$

Here, in this relationship, the numerator is changing as the universe expands because the scale of the universe R is constantly changing in an expanding universe. Dirac formulated the so-called Large Number Hypothesis which simply states that the above two ratios are in fact equal for all practical purposes and postulates that this is not a mere coincidence. Other ratios such as the ratio of the size associated to an elementary particle, like the electron, to the Planck length,

$$\frac{\frac{e^2}{m_e c^2}}{\frac{hG}{c^5}} \sim 10^{20} \qquad (2.3)$$

can also be constructed (Harrison, 1981) yielding the conclusion that fine tuning is prevalent in our universe. Many other interesting ratios have been found approximately relating some cosmological parameters and microscopic properties of the matter. The ratio of the electron mass and Hubble (mass) parameter H is $hH/c^2 \sim 10^{39}$ (Cetto *et al.*, 1986). Jordan (1947) noted that the mass ratio for a typical star and an electron is of the order of 10^{60}. The ratio of mass of the observable universe and Planck mass is of the order of 10^{61} (Shemi-zadeh, 2002). Peacock (1991) points out that the ratio of Hubble distance and Planck length is of the order of 10^{61}. Finally, the ratio of Planck density and recent critical density of the universe is found to be of the order of 10^{121} (Andreev and Komberg, 2000). Most of these large numbers are rough ratios of astrophysical parameters and microscopic properties of the matter determined with accuracy of the order of magnitude. These relationships may be indicating the existence of some deep, underlying harmonies involving the fundamental constants in linking the microcosm to the macrocosm. Physical theory has not, however, accounted for these in a self-consistent way, waiting perhaps for the anticipated unification of all physical forces at the quantum gravity or superstring levels.

In 1961, astrophysicist Dicke (1961) noticed that this dimensionless number should necessarily be large in order to make the lifetime of stars sufficient enough to generate heavy chemical elements like carbon. Knowing that carbon is the most essential element for organic material, this is the first assertion called "anthropic coincidence", which infers that the connection between the physical constants is necessary for the existence of life in the universe! There are many examples of large numbers of the order of 10^{40}having close relationship with the occurrence of life. We have already mentioned that the electromagnetic and gravitational force, between which the first is almost 10^{40} times stronger than the later. If they were comparable in magnitude, then the stars and planets would have collapse a long before and life would not have time to emerge and evolve. Based on these arguments, the anthropic coincidences were condensed into a form of a principle in the 1970s. Carter (1974), in his work mentioned two version of the principle- weak and strong. Subsequently in later times, many authors have given their own versions, of which we feel Barrow and Tipler's version (Barrow and Tipler, 1986) is relevant here for mentioning. Barrow and Tipler's weak anthropic principle can be quoted as;

The observed values of all physical and cosmological quantities are not equally probable but take on values restricted by the requirement that there exist sites where carbon based life can evolve and by the requirement that the Universe be old enough for it to have already do so.

It should be noted that Barrow and Tipler emphasized that a certain precision in the values of physical constants is needed for the creation and evolution of "carbon based life". Now their strong anthropic principle reads like:

The Universe must have those properties which allow life to develop within it at some stage in its history.

This strong version of anthropic principle is more suitable for our discussion in this paper. What our concern is to deal with a sub-division of this general phenomena of life i.e., the question of "conscious state of life".

III. Anthropic Principle, Biological evolution and 40 Hz oscillation

It is generally believed (Wald, 1954) that the existence of elements heavier than hydrogen is necessary for any kind of mechanism for life. Thermo nuclear combustion is necessary for the production of heavier elements from hydrogen. Again it requires several billion years for occurrence of this type of conversion in the interior of a star. According to general theory of relativity no universe can provide several billion years of time unless it is several light-years in extent. In this context Wheeler (1974) made a very pertinent statement "So why, in the "no-knower-no-world" view, is the universe as big as it is? Because we are here!"

In this context, it is relevant to mention a very important issue raised by Carter in his paper on biological evolution (Carter, 1983) that cosmologists would run a risk of error in the interpretation of astronomical and cosmological information unless due account is taken of biological restrains under which the information was acquired. Of course he put a warning to biologists too that they would also run a risk of the interpreting the evolutionary data unless they took into the account of astrophysical information.

Dicke noticed that the dimensionless number as discussed above should necessarily be large in order to make the lifetime of stars sufficient enough to generate heavy chemical elements like carbon. Knowing that carbon is the most essential element for organic material, this is the first assertion called "anthropic coincidence", which infers that the connection between the physical constants is necessary for the existence of life in the universe. This gives rise to the most challenging and profound question:

Is the initial adjustment to the structure of the universe made in such a way so as to render the possible existence of knower?

Severe criticism and reinterpretations have been made on the issue of Large Number Hypothesis and the existence of intelligent being or life. The dimensional large number or simply Dirac Large Number (10^{40}) is estimated by taking the ratio between quantities which are remotely related or quite unrelated. We emphasize that we find the same dimensionless Dirac number taking ratio of the two units of time: one the shortest time unit in the physical universe called Planck time and the other the smallest time unit require to cognize anything in the outside world through our brain.

Let t_B (quanta of time in brain) denotes the smallest unit of time related to 40 Hz gamma oscillation and t_p be the smallest unit of time called Planck time in the physical universe, then

$$\frac{t_B}{t_p} = \frac{(10-14)10^{-3}}{1.35x10} \sim 10^{40} \qquad (3.1)$$

Where Planck time

$$t_p = \sqrt{Gh}/c^5 = 1.35x10^{-43} \text{ seconds.}$$

Planck time depends on the fundamental constants in the physical universe whereas the time unit in brain does not apparently depend explicitly on any such fundamental constant. This is quite different from the other large numbers discovered so far in the following sense:

1. Whereas the previous numbers all depend on various constants of the physical universe the "quanta of time" in the brain is not directly related to any such constant.
2. The ratio is taken in our estimation between the two similar quantities.

Gamma oscillations have been described in several areas of the neocortex, entorhinal cortex, amygdale, hippocampus, striatum, olfactory bulb, and thalamus as well as in other areas. It is reasonable to assume that a key ingredient of gamma oscillations is $GABA_A$ receptor-mediated inhibition.

One of the most challenging issues in understanding consciousness is to figure out how information is synthesized to form our subjective experience. The widely accepted hypothesis is that synchronous gamma waves from many

places in the brain combine to create the unified subjective experience. In this way, neurons performing different tasks in separate regions of the brain share in a single activity instantaneously. In a recent review Buzsaki et al. (Buzsaki and Wang, 2012) elaborated the mechanism of synchronous gamma oscillations of neurons. Gamma rhythm is a pattern neuronal oscillation whose frequency ranges from 25 Hz to 100 Hz though 40 Hz is typical. Gamma frequency oscillations are present during waking and REM sleep.

The changes in the electric membrane potential generate action potentials of neurons. The multiple action potentials in sequence form the so-called spike trains. The oscillatory activity of neurons is associated with these spike trains. The oscillation of single neuron can be observed in sub-threshold fluctuations in membrane potential. However, it is not at all clear whether the value of quanta of time associated to synchronous gamma oscillation among neurons explicitly depends on the exact numerical value of any of the fundamental constants like *G, c, h* etc. Apart from the concept of quanta of time associated to gamma oscillations, various scales of timing as intrinsic property of neural network have drawn large attention to the community (Goel and Buonomanno, 2014). Mauk et al. (2004) studied the time scales of temporal processing for human starting from microsecond (sound localization, echolocalization) to Circadian rhythm (day, hour etc) over a scale of 12 orders of magnitude. Again the time scale associated to 40 Hz oscillations is not related to circadian rhythm. Frequency of gamma oscillation almost remain the same for all mammals and the frequency is little lower (20 - 30) Hz for insects (Buzsaki, 2010). Moreover, the evolutionary effect on gamma rhythm has not been observed so far (Buzsaki, 2013). Here, we consider the time scale associated to 40 Hz oscillation since this is predominant for conscious activities for human being.

The above analysis raises deeper questions regarding the anthropic principle and the existence of life. Planck time is dependent on the exact numerical values of various fundamental constants like *G, c, h*. Here, we would like to emphasize that the large number that we take found comparable to Dirac number is the ratio of identical quantities namely the Planck time and the time unit associated to synchronous activity in central nervous system or simply brain must be around millisecond range when Planck time is of the order of 10^{-43} s. So an observer or knower who can observe a universe finely tuned with the various fundamental constants must have a synchronous activity of gamma oscillations around 40 Hz in his or her nervous system. That is what we find from the experimental results in modern neuroscience.

IV. Conclusion

It is clear from the above analysis that we have found a ratio of two time scales: one related to the smallest time scale (Planck time) in the physical universe and the other related to quanta of time associated to rhythm of brain of living organism not only human being but also for almost all multicellular organisms. It is to be noted that the shortest time scale in physical domain or Planck time depends on fundamental constants like Planck constant, Gravitational constant and speed of light whereas it is not at clear whether shortest time scale in the brain explicitly also depend on these fundamental constants. However, the effect of gravity on synchronized oscillations in nervous system needs to be studied before any definite conclusion regarding this matter. It is worth mentioning that Hameroff and Penrose (1996) speculated about the relation between gravity and consciousness but from a different perspective. At certain stage of evolution of the universe life appears and hence the synchronous oscillation in brain. Before appearance of life the fine tuning of the fundamental constants occur so as to give rise to an environment for carbon based life. At the level of Planck scale quantum fluctuation prevails in contrast to any other kind of noise or fluctuation. Here we mean noise in the sense of unwanted variation. So the Planck time or the shortest time scale is intimately related to quantum fluctuation. Quantum fluctuation is ubiquitous over this universe and dominates at small scale like Planck scale. On the contrary we do not know what its effect at neuronal level is and hence on the synchronized oscillation of ensemble of neurons. It is amazing to learn that the universe originated due to quantum fluctuation though we do not know its effect on conscious activity or simply consciousness. It gives rise to the challenging issue whether consciousness is at all related to principle of quantum theory even though the quantum theory is considered to be most fundamental theory of nature.

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