Nature of Universal Forces, leading to a Modified Atomic Structure including Dirac's Ideas and Satisfying de Broglie's Restriction

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ABSTRACT

Forces operative in the universe have so long been considered to be pull of particles towards their own both in small and long range. From the properties of short-range nuclear attractions, characteristics such as *particle independence*, *saturation*, *pair* and *pairs of pair formation* have been developed.

Consideration of scattering of atoms by different types of projectiles show that Rutherford's atomic structure which was modified by Bohr imposing quantum condition does not satisfy known facts. Thus, photons can scatter extranuclear electrons but not powerful enough to scatter nucleons. Although, α- particles and slow neutrons are able to scatter nucleons leading to β^+ and β^- emission, the neutron- β-neutrino scattering proposed by Fermi poses some difficulties. To cap all these, there is the restriction imposed by de Broglie's hypothesis that nucleus is neither a repository nor a manufacturer of electrons. To account for all these restrictions, it was found that Dirac's suggestion of particles and anti-particles in which nucleons are embedded may be fruitfully utilized. Thus, an atomic structure based on modification of Rutherford-Bohr model has been put forward.

Triggering impulse of β- emission may be related to the gluon field which holds the binding energy till the point of overstretching of the mass of the quark involved.

Key-words: Universal Forces, Short- and Long-range Forces, Characteristics of Nuclear Forces, Modified Atomic Structure including Dirac's and de Broglie's Ideas

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Introduction

Careful consideration of the forces and interactions existing in the universe may be divided into 'Pull' and 'Push' [1] operating as 'short' and 'long' range forces, respectively. Like Coulombic attraction, short-range forces arising from the exchange of π-mesons in a nucleus is strongly attractive. The Coulombic interaction along with magnetic interaction can act as an attractive force in the log-range. Gravitation has been recognized as both strong and weak pushing force in the long-range.

So long, it was considered that the natural interactions are all pulling in nature. But recent analysis has shown that contrary to all other forces, gravitation is a force pushing from outside and that too operates both as inter-planetary and intra-planetary attraction [1]. A summary of the characteristics of all the forces are presented in Table I.

TABLE I: Characteristics of universal forces

Force	Nature	Coupling Constant	Relative Magnitude	Range/m	Arising from
Strong nuclear	Pull	$f^2/\hbar c$	1	10^{-15}	π-meson
Weak nuclear	Pull	$g^2/\hbar c$	$10^{-24} - 10^{-13}$	10^{-10}	β^-- neutrino
Electromagnetic	Pull	$e^2/\hbar c$	$1/137 - 10^{-2}$	Infinity	Coulombic
Weak Gravitational	Push	$G^2/\hbar c$	$\sim 10^{-40}$	Infinity	Centrifugal force
Strong Gravitational	Push	$g^2/\hbar c$	$\sim 10^{-30}$	Infinity	Centripetal force (Terrestrial)

Nature and characteristics of strong nuclear forces at short-range

At the outset, it is absolutely necessary to understand that according to de Broglie's hypothesis, a nucleus is neither a repository nor a manufacturer of electrons. It is not a case of either/or (wave or particle), rather it is a case for both (wave and particle). Following Heisenberg's uncertainty principle, the wave vector of the electron can neither be accommodated inside the nucleus nor the momentum of the electron is sufficient to act as a scatterer of the nucleus (however, even high energy electrons are used as a scatterer in determining the radius of the nucleus). Thus, the concept of electron capture (EC) by the nucleus is a direct contravention to the de Broglie's hypothesis. Originally put forward as a hypothesis, de Brogli's proposal with the support of Max Born's theory and Heisenberg's uncertainty principle has now become a compulsory nonfailing restriction.

The interconversion of neutron to proton and vice-versa inside the nucleus is, therefore, attributed to the exchange of an electron. Alternatively, it may be considered as the change of a u- to a d- quark and vice-versa. Thus, in that case the nucleon reduces to a pack of protons and quarks with little difference in producing attractive influence on one another to prove *charge independence* of the nucleons. The protons in the nucleus forms a spherical ball-like structure but the Coulombic interaction between protons and π- meson adduces an electrical quadrupole moment to change the sphericality of the nucleus (either prolate or oblate). The resulting quadrupole moment supplies an additional attractive interaction.

According to Yukawa [2], interaction of nucleons by π- meson (273 electrons) is strongest of all the cohesive forces. Thus, the nucleus is composed of only protons (spherical entity) and these might fill the nucleus as if forming a close-packed structure in which the balls are affected by the nearest neighbour giving the *saturation of forces*.

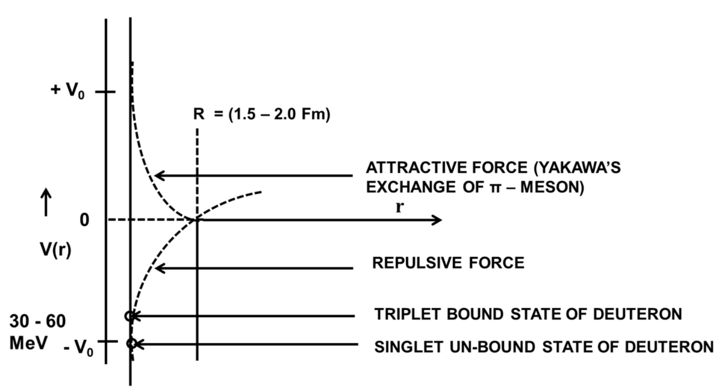

Fig. I. Nuclear force in terms of square-wave potential

The nuclear force can be represented in terms of a simple plot of potential energy as a function of distance from the centre (Fig. I). A square well potential ($V = -V_0$ when $r < R$, and $V = +V_0$ when $r > R$) is used in preference to Yukawa or Woods – Saxon potential for simplicity.

The binding energy of deuteron arises from one proton and one neutron or 2 protons and 1 d-quark. The two protons are attracted by the π- meson so strongly that they will coalesce into one entity. There must be a repulsive force so that the nucleons do not condense into one. This will explain the triplet state of deuteron to be bound by 1.1 MeV per nucleon. The singlet state which is theoretically shown to be bound by 77 KeV [3] indicates an unbound state. However, this singlet state has the spins in opposite direction and is suitable for the formation of a boson and can explain a *pair formation*. Thus, two singlet states will form a boson again and lead to a virtual α- particle (*pair of pairs*) formation [3]. Triplet deuteron is not able to form zero spin boson. The singlet form of deuteron is transient and passed into an unbound state after performing its duty in the initial nucleosynthetic process and passed into oblivion without any chance for a repetition of the process in the life time of the present universe.

In the nucleus consisting of protons and quarks, the repulsive force of the protons is compensated by the attractive force of the π- meson (139.5 MeV) among nucleons. We consider the nucleons as hard sphere in contact similar to ionic crystals or moving as ball bearings. This gives the idea of *saturation* of attractive force in *hcp* (hexagonal close packed) or *ccp* (cubic close packed) arrangement of spheres which shows a maximum of 12 hard spheres in contact occupying 74% of space. The saturation of force from 12 nearest neighbours gives rise to 139.5/12= 11.625 MeV per nucleon while the average experimental value is 7.328 MeV per nucleon due to repulsive forces. The repulsive forces are of two types.1). The repulsion of proton which increases asymptotically to a very high value with increase of A. 2). The interconversion of quarks which also increases with increase of A. It is possible that attractive and repulsive forces balance each other showing the average value of B/A.

Beta decay

1. Before developing Fermi's theory of β^- emission as a result of weak nuclear force described as β- neutrino force, it was Irine and Joliot Curie [4] who repeated Rutherford's scattering experiment with high energy α- rays from Polonium and identified some radioactive species by following the reactions which are β^+ active:

$$^{27}Al_{13} + {}^{4}He_{2} \longrightarrow {}^{1}n_{0} + {}^{30}P^{*}_{15} \longrightarrow {}^{30}Si_{14} + \beta^{+} \quad \ldots \quad (1)$$

$$^{24}Mg_{12} + (\alpha\, n) \longrightarrow {}^{27}Si^{*}_{14} \longrightarrow {}^{27}Al_{13} + \beta^{+} \quad \ldots\ldots \quad (2)$$

$$^{10}B_{5} + (\alpha\, n) \longrightarrow {}^{13}N^{*}_{7} \longrightarrow {}^{13}C_{6} + \beta^{+} \quad \ldots\ldots \quad (3)$$

* = Radioactive

Bohr's theory of nuclear reactions predicted the formation of compound nucleus, the subsequent decay of which are independent of the parentage. This was proved to be the case as shown by Ghosal [5].

$$\left.\begin{matrix} ^{60}Ni + \alpha \\ \\ ^{63}Cu + p \end{matrix}\right\} \longrightarrow {}^{64}Zn^{*} \longrightarrow \left\{\begin{matrix} n + {}^{63}Zn \\ 2n + {}^{62}Zn \\ p + n + {}^{62}Cu \end{matrix}\right. \quad \ldots\ldots \quad (4)$$

Target + Projectile ⟶ Compound nucleus ⟶ Decay Product with isotropic emission

Alexzander and Simanoff [6,7] also got similar result using other targets and projectiles.

$$\left.\begin{array}{l} ^{139}La + ^{16}O \\ ^{140}Ce + ^{15}N \\ ^{44}Nd + ^{11}B \end{array}\right\} \longrightarrow ^{155}Tb^{*} \longrightarrow 6n + ^{149}Tb \quad \ldots.. \quad \ldots\ldots.. (5)$$

2. Just after the discovery of α - n reaction by Curies, Fermi [8] and his collaborators subjected many elements to bombardment by slow neutrons and succeeded in producing compound nuclei which are radioactive. These are easy to obtain as neutrons are uncharged and no difficulty was faced in penetrating through positively charged nucleus. Absorption of neutron by the nucleus of an atom does not change the chemical properties but produces an isotope which may well be radioactive and may emit β^- rays [8].

$$^{27}Al + ^{1}n \longrightarrow ^{28}Al^{*} \longrightarrow ^{28}Si + \beta^{-} \quad \ldots.. \quad \ldots.. \quad \ldots\ldots.. (6)$$

In these two examples we see that β^- and β^+ emissions from radioisotopes are completely independent of each other and are free from the influence of the parent nuclei.

The nucleon- β^-- neutrino interaction of Fermi (weak interaction)

3. In order to account for the n – p conversion in a nucleus, Fermi proposed a hypothetical weak nuclear interaction. It was suggested that the conversion takes place according to the equation

$$^{1}n_{0} \longrightarrow ^{1}p_{1}^{+} + ^{0}e_{-1}^{-} + \text{energy} \quad \ldots \quad \ldots \ldots\ldots \quad \ldots\ldots.. \quad (7)$$

However, this equation is not supported by the laws of conservation. At both sides of the equation, mass/energy, charge, spin and statistical laws must be balanced. These were overcome by proposing the equation:

$$^{1}n_{0} \longrightarrow ^{1}p_{1}^{+} + ^{0}e_{-1}^{-} + \bar{\upsilon}_{c} + q_{p} \quad (\bar{\upsilon}_{c} = \text{antineutrino}) \quad \ldots \quad \ldots\ldots (8)$$

and the general form for heavy parent nucleus ^{A}Z

$$^{A}Z_{N} \longrightarrow {}^{A}(Z+1)^{+}_{N-1} + e^{-} + \bar{\upsilon}_{c} + q_{p} \quad \ldots \ldots \quad \ldots\ldots \quad \ldots\ldots \ldots \quad (9)$$

where q_p may be taken as $M[^{A}Z] - M[^{A}(Z+1)]$ $(M\,\bar{\upsilon}_c \approx 0)$

but even then, it does violate de Broglie hypothesis because a nucleus is neither a repository nor a manufacturer of electrons.

4. The reverse reaction that is proton to neutron conversation may be written as:

$$^{A}Z_{N} \rightarrow {}^{A}(Z-1)^{-}_{N+1} + e^{+} + \upsilon_{c} + q_{\beta+} \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots (10)$$

Where $q_{\beta+} = M[^{A}Z] - (M[^{A}(Z-1)] + 2m_e c^2)$ (m_e = mass of the electron)

If we examine the simple reverse reaction process

$$p^{+} \longrightarrow n^{0} + e^{+} + \bar{\upsilon} + q$$

or, $$p^{+} + \upsilon = n^{0} + e^{+} \quad \ldots\ldots\ldots \quad \ldots\ldots \quad \ldots\ldots \quad \ldots\ldots \quad (11)$$

This pumping of mass is theoretically possible but its probability is very small. It is made possible only by bringing together the protons and neutrinos in as high a concentration as possible. This was the procedure by which Cowen *et.al* [9,10] proved the existence of neutrinos by placing water (H^{+}) to react with neutrinos from a reactor and identified neutron and positron produced therefrom (Eq. 11).

It is to be noted that this reaction produces only positron and no electron and is independent of the Fermi β- neutrino hypothesis. However, formation of positron in the reaction is not supported by de Broglie's hypothesis.

5. An alternative process of the conversion of proton to neutron was suggested as capture of an orbital electron by the proton in a nucleus. The reaction can be written as

$$^{A}Z_{N} \rightarrow {}^{A}(Z\text{-}1)_{N+1} + \upsilon_{c} + q_{ec} \quad \ldots\ldots\ldots \quad \ldots\ldots\ldots \quad \ldots\ldots \quad (12)$$

Thus, two products are formed and therefore, it does not require the presence of an anti-particle. However, this process is in direct contravention of de Broglie hypothesis. It also shows that the emitted positron is not related with β^- emission proposed by Fermi.

In all the processes it is seen that the emission of positron (β^+) is not at all governed by β^- emission.

Modified atomic structure

In order to fit the scattering processes by projectiles of different energies on the extra nuclear electrons and nucleus of the atom, we propose a modified atomic structure consistent with all known principles and theories.

Rutherford showed that atoms consist of positively charged core in a central nucleus with extranuclear electrons revolving in orbits. This was modified by Bohr by imposing quantum conditions for electrons moving in orbits which do not emit energy during revolution. The nucleus contains protons and neutrons but there is no place for either electrons or positrons according to de Broglie's theory. To adjust with this view, we include Dirac's suggestion that the nucleus is imbedded in particles and anti-particles (e^+, e^-, υ, $\bar{\upsilon}$, p^+, p^-, n, n^- etc) and these energetic particles may convert a neutron to a proton and vice-versa to eject electrons or positrons as the case may be.

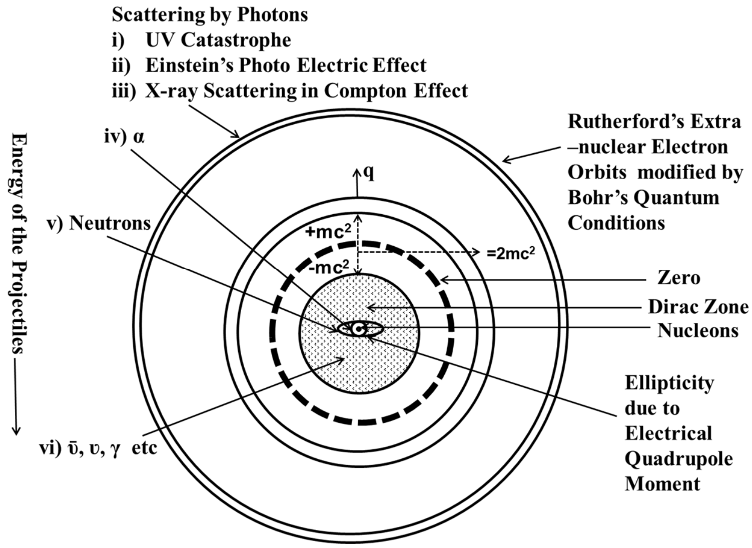

Fig. II: Rutherford-Bohr Model of Atomic structure modified by Dirac's proposal and de Broglie's restrictions (Schematic representation in two dimension)

The proposed atomic structure is shown in Fig. II in which the projectiles are arranged in left side in order of increasing energy (ordinate) namely photon, α, n, ῡ, υ, e^+ etc. On the right-hand side, different parts of the atomic structure are shown. The positively charged nucleus is not perfectly spherical but of an elliptical shape resulting from electrical quadrupole moment.

Quantum theory of radiant energy first proposed by Max Planck in the form of $E = h\upsilon$ was applied to account for a few unexplained parameters arising from interaction of light rays with extranuclear electrons of an atom.

i. The first of these was Black Body radiation from which a perilous ultraviolet catastrophe was predicted. This was circumvented by the proposal of Max Planck which assumed that probability distribution in which vibration frequencies are of high demand has very little chance of satisfaction and the opposite holds for low frequency demands.
ii. The puzzle of the photoelectric effect was resolved by Einstein by applying the quantum theory of Max Planck in which no emission was considered to take place

until a threshold frequency for a particular metal is reached. When the threshold frequency is exceeded, kinetic energy of the photoelectrons shows uniform increase.

iii. The Planck and Einstein picture of light quanta colliding with electrons inspired Compton to consider energy rich high frequency X-rays for scattering experiments which confirmed the theoretical expectations and proved decisively the quantum nature of radiant energy.

This energy quantum (photon) in these cases is not powerful enough for scattering nucleons (protons and neutrons) from a nucleus for which more powerful projectiles are required. These are α- rays, neutrons, particles and anti-particles. The scattering process by α-rays and by slow neutrons has already been described (v*ide supra*).

Neutron – β – neutrino weak interaction proposed by Fermi is described in this modified atomic structure as in Fig. III (a) where an antineutrino from the Dirac zone converts a neutron to a proton in nuclear core and the energy is sufficient to eject an electron from the Dirac zone along with any extra energy.

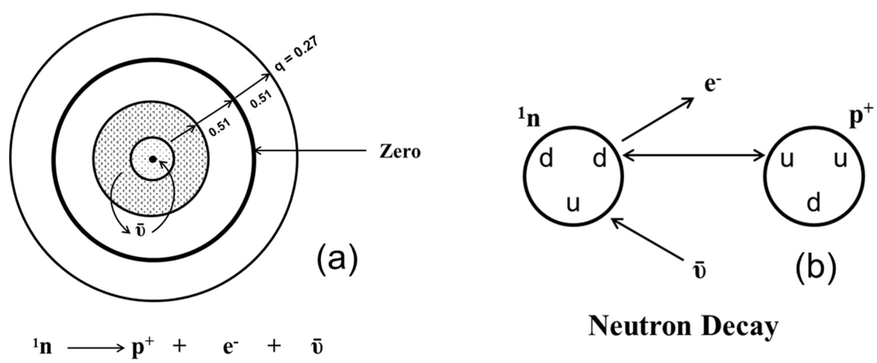

Fig. III: (a) An antineutrino converts a neutron to a proton and (b) Decay of a neutron to a proton

This could be looked upon as the process of nuclear decay whereby a neutron quark with ddu- mass of 939.55 MeV/c^2 is converted to a proton quark with uud- mass of 938.26

MeV/c^2. The energy released in the process is 1.29 MeV/c^2 (the difference between above two). Out of this, 1.02 MeV/c^2 the quantity ($2mc^2$) is utilized for expelling an electron from the Dirac zone and the rest 0.27 MeV/c^2 is released as excess energy. This is shown in Fig. III (b). The process may better be termed as Fermi – Dirac process of weak interaction.

The reverse of this process i.e., conversion of a proton to a neutron in the nucleus is shown in Fig. IV which is the process of Cowens to prove the existence of neutrino as described earlier. Here υ from the Dirac zone is pumping energy to produce a neutron in the nucleus and the released energy knock out a positron from the Dirac zone.

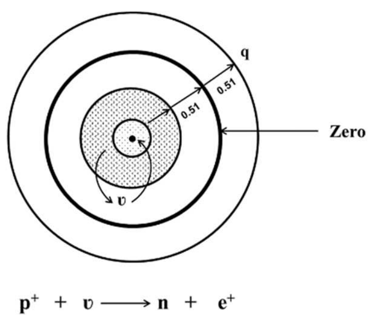

Fig. IV: Proton to neutron conversion

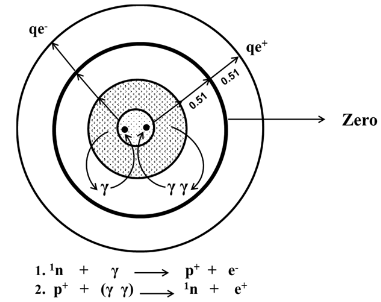

Fig. V: γ- rays from Dirac's zone knocks out electrons and positrons

The electron capture phenomenon is shown in Fig V. γ rays (single or multiple) from the Dirac zone will knock out either e^- or e^+ as the case may be.

Thus, we see that the expulsion of electron or positron from the system may be explained without violating the principle of de Broglie. Moreover, by the adoption of Dirac's ideas the concept of atomic physics can be smoothly extended to those of nuclear physics.

Possible role of the charge and mass of the quarks

According to the theory of quantum chromodynamics, the charge of the u- and d-quarks have +⅔ and -⅓ of electronic charge, respectively. A neutron is composed of udd- i.e.,

$+^2/_3 - ⅓ - ⅓ = 0$ electronic charge and a proton is composed of udu- i.e., $+⅔ + ⅔ - ⅓ = 1$ electronic charge.

But when it comes to the question of mass of the quarks, the situation becomes problematic. Quarks cannot be assigned with a definite mass. A quark may have a mass as low as a few MeV/c^2 (~10^{-30} kg) or as high as a few GeV/c^2 (~10^{-27} kg). This is because the entire mass of the quark is hidden or remain confined as super high binding energy in the Gluon field.

When quark charges are separated from one another, their interaction is governed by the Coulomb's law of inverse square. But when the mass of quarks is considered, quark-quark-gluon interaction involves adjustment of binding energy of gluon field. Thus, interaction between charges of quarks and the mass of quarks cannot be judged by the same parlance. The fact that at very short distance ($r < 2 \times 10^{-16}$ m), the statical gluon field is almost zero which is not surprising. At very short-range, gluon field has nothing to do on the action of the quarks (short-range freedom). The infrared confinement (long-range slavery) is due to the stretch of the binding energy of quarks to keep their identity intact. The overstretching of the gluon field will produce a reverse force so as to check the distance.

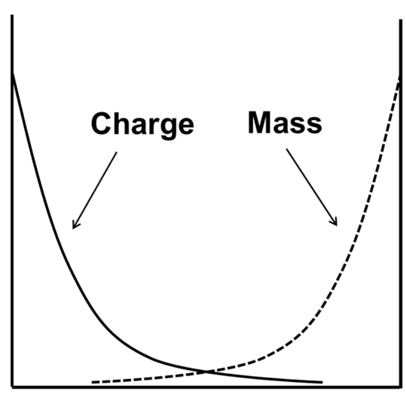

Fig. VI: Charge separation of quarks governed by inverse square law while mass separation is controlled by attractive gluon field

This gives an idea as to the remote control or the triggering impetus of the particle and anti-particle to eject a β^+ and β^- from the nucleus. As the quark-gluon-quark interaction increases, the gluon field allows as much binding energy as possible to the quarks but when a limit is reached, the opposing force starts acting and in this way the gluon field controls the β- emission.

Long-range forces of the universe (force at a distance)

As shown in Table I, the long-range universal forces are Coulombic, electromagnetic and gravitational. Coulombic forces act between positive and negative charges and exhibit both short- and long-range activities. It is effective inside the nucleus as short-range force and outside the nucleus it effects combination of atoms and molecules. The very long-range force comes down as "bolt from the blue" (depending on potential difference and the presence of polarizing atmospheric medium). Electromagnetic interaction shows a much larger effect of action at a distance as is observed by the effect of terrestrial magnetism on a compass needle along the globe. The mechanism of terrestrial magnetism is not yet completely resolved. The idea of a huge permanent magnet deep within the earth is not acceptable. However, there is the possibility that the magnetic field is produced from some sort of electric current circulating the earth.

The investigation of magnetic minerals in old rocks indicate that earth's magnetic field strength is not constant. Rocks are in general of two types. The *sedimentary rocks* are mainly formed by erosion of sandstone and the magnetite which is the common oxide of iron is deposited parallel to the magnetic field. These are slowly condensed into sandstone again and align themselves in the direction of the earth's field. In the *igneous rocks* which are solidified from the molten lava in a volcanic eruption, a similar magnetic material crystallizes during cooling down. These also contribute to the magnetic field of the earth.

Gravitational force which was earlier believed to be attractive in nature according to the theory of universal gravitation of Newton is shown to be a pushing force from outside [1]. The gravitational force is a long-range force but the action-at-a-distance is of two types – one is a stronger interaction which is operational in intra-planetary system when there is no centrifugal force and the second type is the inter-planetary system where the force is weaker due to the presence of centrifugal force. This long-range force is actually responsible for binding of the universe. In comparison to the short-range nuclear force (the magnitude of which is 1), the celestial force is of the order of 10^{-40} whereas the intra-planetary terrestrial force is found to be of the order of 10^{-30}. Thus, in general while the inter-planetary force is weaker in comparison, the intra-planetary force of interaction depends on the mass of the planet and becomes stronger the heavier the mass of the planet is.

Concluding Remarks

Classification of the universal forces and interactions have been done in terms of their properties and characteristics as far as their ranges and strengths are concerned. They can ultimately be distinguished by the contribution from three independent basic concepts viz., time, space and energy as shown in Fig. VII.

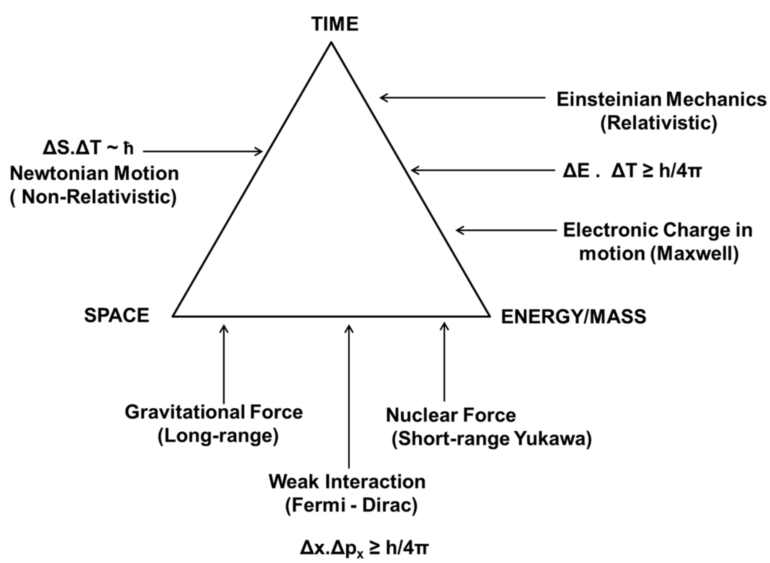

FIG. VII: Interrelation of universal forces and interactions in terms of space, time and energy

In the left of the diagram, the domain of Newtonian mechanics is shown which is guided by Galilean transformation and is valid only when the velocity of the particle is negligible in comparison to that of light. The mathematical uncertainty relationship between space and time is given by $\Delta s.\ \Delta t = \sim\hbar$ which is the quantum uncertainty relation which means that the interval $\Delta x = 10^{-33}$ cm and $\Delta t = 10^{-43}$ sec are the minimum length and duration respectively with which space and time participate in physical processes [11]. The possible closing of the space and time for macroscopic systems seems to be doubtful.

On the right of the diagram is shown the mass and charge which are in motion and the mathematical relation is the Heisenberg's uncertainty principle $\Delta E.\ \Delta t \geq h/4\pi$. When the mass is in motion and the velocity is comparable to the velocity of light, Einsteinian mechanics guided by Lorentz transformation equation is valid and the motion is relativistic. But the chief application of the idea of relativistic motion is in cosmological investigation of universal structure and in the evolution of stars. This type of motion is not relevant for atomic or nuclear phenomena at short distance.

Electromagnetic field arises when charge is in motion which varies with time. A time varying magnetic field acts as a source of electric field (Faraday's Law) and similarly a changing electric field gives rise to a magnetic field (Ampere's Law). Thus, when either of the field changes with time, electromagnetic field is produced in space which may propagate even in the absence of matter in the intervening region. The characteristics of these fields are compiled in the fundamental Maxwell's equations. This electromagnetic force acts as a short-range force (inside the nucleus) and as long-range force (outside the nucleus).

At the bottom of the of the figure is the domain guided by space and energy and is represented by Heisenberg's uncertainty principle i.e., $\Delta x.\Delta p_x \geq h/4\pi$. This includes the short-range nuclear force of Yukawa, the weak interaction of β-neutrino by Fermi – Dirac mechanism and the two types of long-range forces of gravitation – inter-planetary of magnitude ~10^{-40} and intra-planetary of magnitude ~10^{-30} (terrestrial). All these forces are independent of time.

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