FUNDAMENTAL FORCES AS DIFFERENT MANIFESTATIONS OF A SINGLE PARTICLE – A VIEWPOINT BASED ON AVAILABLE FACTS & RESEARCH

Mohit Naveen Issar

Research Scholar, Department of Physics, D.A.V. Postgraduate College, Sector - 10, Chandigarh – 160010, India

Paras Agrawal, Rohan Kaushal and Karan Singh Vinayak

Assistant Professors, Department of Physics, D.A.V. Postgraduate College, Sector - 10, Chandigarh – 160010, India

ABSTRACT

Till now, it is evident that all the interactions in the universe are precisely governed by four fundamental forces. The scientific community has a firm belief and understanding that these fundamental forces of interactions are - Strong force, Electromagnetic force, Weak interactions, and Gravitational force. Over the years, physicists throughout the world tried to unify these forces into a single force of interaction. It has also been discovered that these interactions take place due to the exchange of some particles between the interacting objects. These particles are called mediators. In this paper, we will try to introspect the idea of unification of forces through new speculation on the basis of the mediators that are produced in these interactions. We shall discuss their related aspects as the mediators are the reason behind the four fundamental interactions. We will also attempt to combine the facts which showcase association between these different mediators. We shall also discuss if there is any possibility that these mediators can be different manifestations of a single particle behaving differently under different circumstances.

Keywords: Forces of nature, interactions, mediators.

INTRODUCTION

The idea of developing a theory in which all the forces can explain to be unified into a single one is not new. We here in this manuscript tend to bring forth and propose arguments based on fundamental concepts that provided the vision that these four basic forces of nature are very different from each other on many grounds but at the same time exhibit many similarities too. Even the concept of similarity could also be extended to such an extent that the theory of the existence of a single mediator or universal mediator or force field everywhere justifying all the forces behaving differently at different ranges and conditions cannot be ruled out. Nevertheless, a single particle or universal interacting force could be representing all four fundamental forces in different forms acting differently under different conditions. However, this idea has also been proposed in the past (Perkins 2000). We shall discuss this idea further and discuss the aspects based on fundamental concepts which converge to the same conclusion. It is believed that different material mediums interact by the means of the exchange of particles between them which are termed as mediators and these mediators are specific to the respective forces in nature. These mediators are gluons, photons, intermediate vector bosons (W and Z particles), and gravitons (a name given to the mediator for the gravitational force, for which investigations are still underway to extract credential evidence) for strong force, electromagnetic force, weak interactions, and gravitational force respectively. It is an astonishing fact these mediators based on their characteristics are quite like each other. Thus, one cannot overlook the possibility of these mediators behaving as different manifestations of a single particle. Grand unification theory (Georgi, Glashow 1974; Glashow et al. 1970; Salam 1968; Weinberg 1967) proposes that all the basic four forces could be shaped into a single force on the basis of theory of considering a single mediator for all the forces, which also sounds realistic. By linking the similarities of these particles to each other, there is a possibility of getting an in-depth picture that may showcase the unification of all fundamental forces together. These mediators could be interpreted and assumed to showcase the different interplay of a single particle subject to different environmental conditions. The basis on which we interpret the subject in this paper is the conditions (especially range) and properties of mediators in which the corresponding force has the maximum strength.

UNDERSTANDING ON BASIS OF AVAILABLE RESEARCH

As per the standard Model, there are supposed to be 12 fundamental particles in the Standard Model (6 quarks and 6 leptons) (Perkins 2000; Griffith 2008). In a new perspective which we discuss in this paper, we assume that these fundamental particles are the basis of a force field that depends on their physical properties like mass, charge, etc. Let's see how this field varies and interacts with the field of other particles keeping an observer inside a nucleus. In all, the central idea of this paper is to consider the facts and behaviour of mediators to stress upon the validity of an assumption that a field (consisting of all fundamental forces) interacts with the field of other particles behaving like a different force under different conditions from strong forces inside nucleus up-to gravitational force.

Some convincing facts and justifications indicate that the four fundamental forces of nature ought to be the same single universal force but manifests different properties (while interacting through different mediums) under different conditions. The four different manifestations of a single mediator or different properties possessed by a single particle owe to the particle behaving differently based on size (like quantum mechanics applicable on microscopic particles, whereas classical mechanic on non-microscopic particles) and different environmental conditions (especially range between the interacting bodies or particles) which are beyond the limits of space and time. It is worth mentioning that there are also some facts which also indicate the otherwise case. We hereby have provided an initial vision by raking up some facts to broaden the investigation domain of the scientific community. It needs to be investigated that what is the possibility that a single mediating particle (single force field) behaving differently due to the type and size of bodies interacting as well as other external environmental conditions (like distance). And does this theory stand a scientific logic?

FUNDAMENTAL PARTICLES AND FORCES

The fundamental particles of the universe are the particles that combine to create all the existing heavier particles. It is well known that there are six generations of fundamental particles, three of quarks and three of leptons. All the particles, atoms, nuclei, etc. are made up of a set composition of these fundamental particles. All the quarks combine to yield heavier particles termed as hadrons and leptons, on the other hand, are the very fundamental building units themselves. The generations of quarks (Perkins 2000; Griffith 2008) are given below:-

Generation	**Quarks**
First	Up, down
Second	Charm, Strange
Third	Top, Bottom

The generations of Leptons are as:

Generation	**Leptons**
First	Electron, Electron Neutrino
Second	Muon, Muon Neutrino
Third	Tau, Tau Neutrino

These fundamental particles, as stated, form a diverse range of heavier particles that experience the fundamental forces along with them. These forces have specific regions in which they are dominant in comparison to the others. Like strong force is dominant only inside a nucleus (under normal circumstances), electromagnetic forces are dominant in universe everywhere. We tend to understand the portrayal of these forces as the interactions between net fields of these particles and from the perspective of an observer inside the nucleus.

STRONG FORCE

The first fundamental force that we are going to deal with is the strong force because this is the first force that an observer sees from the inside of a nucleus. Now it can be a valid assumption that these fields during their origin lack symmetry but as time flows, they achieve symmetry. This force is the strongest interaction that exists inside the nucleus in comparison to all the other forces. It is this force that keeps a nucleus intact despite the repulsive force (comprising mainly of Coulomb energy due to protons and symmetry energy due to N/Z ratio) it experiences (Vinayak 2017). There are three generations of quarks each having a specific mass and charge, thus having a specific field associated with it (The kind of the field is the same, but their relative strengths depend on the physical properties of the quarks). Now, as we know that a nucleus is composed of protons and neutrons which are further composed of quarks. These quarks will produce fields inside the nucleons that will interfere with each other (Perkins 2000). Due to these interferences at some sites constructive interference takes place and at some sites, destructive interferences take place (Mazur 2015). According to quantum mechanics, a particle is defined as a localized entity that is produced by interfering waves in such a way that waves interfere constructively at the site of the particle and destructively elsewhere. Thus, from this interpretation of quantum mechanics, it can be stated that a particle is produced at the sites of constructive interferences due to the fields of these quarks. This particle could be responsible for the interaction of these fields and may behave as a mediator of the force. These mediators that mediate the strong force inside the nucleus and nucleons are called gluons. It is also observed that they are present only inside the nucleus, thus restricting the strong force only to the inside of the nucleus. These are massless particles and are highly effective in the range where strong forces are active, which is of the order 10-15 m.

Let us understand this with an example of an interference pattern observed in a system of two sources of the sound (Mazur 2015). Waves of these two sources superimpose and interference occurs. A crest of one source superimposes with the crest of the other source. As a result, constructive interference takes place and at this point, an anti-node is formed. On the other hand, the crest referring to source also superimposes over the trough of the other source. Here a different output evolves and a node is formed at the point of interaction. Due to the multiple interferences taking place, rather a line of nodes and antinodes are produced.

Analogous to this, the fields inside the nucleus produce gluons at the points of antinodes. The super-impose taking place inside the nucleus is in very close proximity to the source, thus the interaction of strong field lines takes place here.

EARLY UNDERSTANDING OF FORCE INSIDE THE NUCLEUS

With the advent of the liquid drop model (Gamov 1930), the stability of nuclei is a function of various attractive interactions and repulsive forces (especially coulomb forces). The binding energy is considerably affected by the symmetry energy (energy which represents the neutron-proton asymmetry in an isospin-asymmetric nucleus, i.e., N/Z ratio), odd-even arrangement, and Coulomb forces. Here nucleus is a drop of charged liquid, without any specific structure. Heavy and super heavy elements are said to be of extreme interest to explore the role of isospin (symmetry energy and Coulomb forces) in the structure of nuclei, reaction dynamics, and astrophysical phenomena such as giant dipole resonances (GDR), pygmy dipole resonances (PDR), nuclear magnetic resonances (NMR), formation of neutron stars and supernova explosions (Lattimer et al. 2001; Lattimer 2004; Steiner, Prakash and Lattimer 2005). Knowledge of the stability, properties, and structure of nuclei (either heavy or super heavy) is crucial to extract the information about symmetry energy as well as its density dependence part (Danielewicz, Lacey and Lynch 2002; Li, Chen and Ko 2008; Tsang et al. 1996). It is evident here that the physical quantity that helps us the most to understand a nuclear structure is the binding energy of the nucleus. The liquid drop model also referred to as the Semi-Empirical approach of a nucleus gives a detailed formula to evaluate the correct value of binding energy of most of the nuclei.

ELECTROMAGNETIC FORCE IN RELEVANCE WITH STRONG FORCE

In biology, it is known for a fact that when cells combine to yield a tissue, the behaviour of tissue does not resemble the behaviour of those cells, but showcases the dependence on the interactions between the cells. Similarly, the quarks produce a net field of nucleons and the fields due to nucleons combine to form a net field of the complete nucleus, which depends on the physical properties of the nucleus and not on its composite for someone looking at the nucleus from outside. But as these fields grow and expand, they become weak since the observer sees them be very far from their actual source. The fields become weak because some portion of the energy carried by these waves is used to cross the energy barrier of the nucleus. Thus, from the viewpoint of a layman from inside of the nucleus, the field has more strength but becomes weak when away from the nucleus. When the interactions outside the nucleus are observed, the influence of strong force starts to vanish, and electromagnetic forces occupy strength in this region. The standard size of an atom is of the order 10^{-10} m, which is 10^5 times the size of the nuclei. Even though the range of the electromagnetic forces is infinite, they only gain prominence when at a distance far away from the quarks. These forces also exist inside the nucleus, but they are suppressed due to the presence of strong forces (this suggests that both the photons and gluons exist inside the nucleus at the same time). When this nucleus field overlaps with the other nuclei fields or say an electron, a mediator is generated which is also stated in above discussion. The mediator of this force is called photons. It is important to note that both gluons and photons are mass-less and charge-less. Here, a similarity could be derived in these two forces as the interacting particles possess a kind of similarity.

The presence or absence of the produced mediator is the reason behind the existence of the force associated with it and the number of mediator's determine the strength of the force itself. Therefore, even though photons exist both inside and outside the nucleus, strong force is higher in strength inside the nucleus due high number of its mediator. Similarly, as gluons doesn't exist outside the nucleus, strong force is only restricted to the nucleus.

WEAK INTERACTIONS

In nuclear physics, there is a notion that a nucleus with its neutron to proton ratio approximately equal to 1 is more stable in comparison to the nuclei which do not have N/Z (neutron to the proton) ratio as unity.

If the ratio is compromised the nuclei start to undergo radioactive processes to release energy and achieve a stable configuration with an N/Z ratio close to 1. The interactions which govern these processes are called weak interactions. Consider this with the help of a beta decay process, in which a neutron is converted to proton and vice-versa to keep the ratio close to 1 in an unstable nucleus. The nuclear reaction for the release of beta decay is given as:

N → P + e- (Beta particle) + ΰ (anti neutrino) (Griffith 2008; Fermi 1934)

Does the question arise that what is happening here? The difference in other interactions and this interaction is that the field evolving from one of the composite structures of quarks is could be influencing the other. In this case, the net field due to one of the structures of quarks is larger. Even though the same quarks have a similar field, the net field of neutrons is different from the protons due to the difference in their compositions. Therefore, if one of the two nucleons is relatively more than the other in a nucleus it undergoes radioactive processes by the means of weak interaction to achieve a stable ratio N/Z. A nucleus tends to achieve a configuration where the field due to both the nucleons is symmetric and uniform (Vinayak 2017; Gamov 1930; Danielewicz, Lacey and Lynch 2002; Li, Chen and Ko 2008; Tsang et al. 1996).

A similar phenomenon takes place when a heavy nucleus collides with another heavy nucleus. A large number of hadrons under the influence of these weak interactions are produced. This is again because under these collisions the fields due to nucleons become asymmetric. When they collide the relative distance between the nucleons shifted which in turn alters the field. Thus, any change in the field of the fundamental particles can trigger these weak interactions. These interactions are highly active in the range 10-17m, which is less than the dimensions of the nucleus.

The mediator produced to carry along-with weak interactions are called intermediate vector bosons which are W and Z particles. Unlike other mediating particles, these mediators carry both fundamental aspects i.e. mass and charge. One of the interesting facts which are observed in weak interactions is that quarks conversion takes place. These interactions arise due to change in the uniformity of the field, thus it creates an excess of energy, which in turn is transported by the vector bosons so that the field can regain its original state of symmetry and uniformity. The ultimate goal of all the nuclear structures is to fall to a stable configuration and it is known that the lesser the energy more stable the structure.

GRAVITATIONAL FORCE

This force is the weakest of all the forces. Provided that fact that its range is unlimited which is exactly in similarity with the electromagnetic forces. Its behaviour is very much similar to electromagnetic interactions. They both are conservative forces that act along the line joining two objects on which they are acting. Both these interactions are carried by the transfer of mediators. The distinction between these forces is the mediator which is the sole reason due to which these interactive forces come into existence. Electromagnetic forces manifestation of evolving photons marking the interaction between the charge of different bodies and transfer of energy, whereas the gravitational forces due to gravitons leading to the interaction between the masses of the different bodies. Mediators of both the gravitational and electromagnetic forces i.e., gravitons and photons are considered mass-less and charge-less. Both gluons and photons mark their existence inside the nucleus, at the same time. Similarly, both photons and gravitons exist everywhere simultaneously. The strength of the gravitational force is extremely weak in comparison to the electromagnetic force, and although they both share the same range. The gravitons thus produced could be very low in number in comparison to photons. This could be one of the well-founded explanations that the gravitons are still not discovered with absolute conformity and evidence. Also, this could be the possible explanation for the gravitational forces to be weak than the electromagnetic forces.

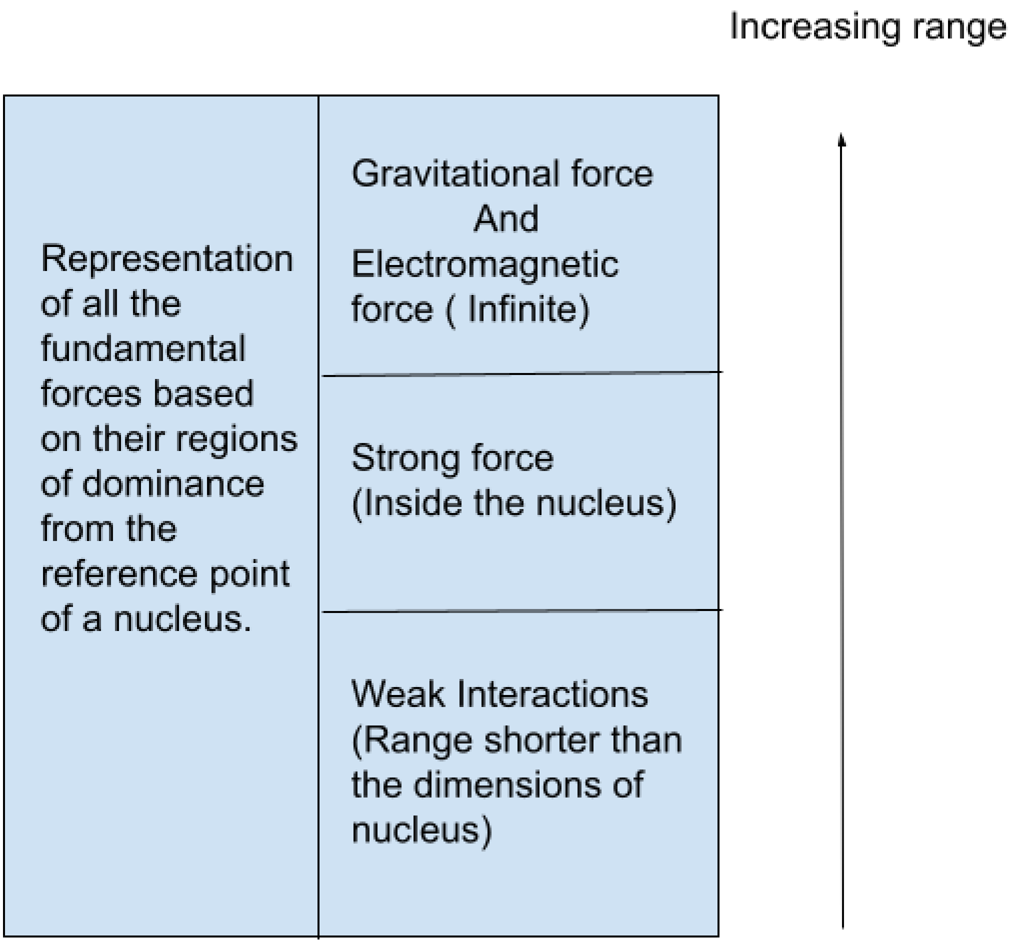

Figure 1: Pictorial illustration of perspective showing the idea of four different forces could be a manifestation of a single force

HOW DO ELECTROMAGNETIC FORCES ACT ALONG WITH AN ARRAY OF NUCLEI?

Consider a one-dimensional arrangement of the sources (coherent) say 100, arranged in such a way that one source is placed next to each other very closely (Mazur 2015). As the fields due to these sources superimpose with each other interference due to all the fields take place. Due to this arrangement of sources, the waves nearly cancel out everywhere except the direction perpendicular to the axis of sources. If a similar concept is applicable to the nuclei structures arranged side by side close to each other like in a 1-D structure, it can be extracted that mediators (photons) arise only in the direction perpendicular to the lattice. This supports the theory that electromagnetic force interplay is in the direction of the distance (minimum) between the two objects, which is perpendicular to the surface. Thus, a large number of photons are produced in this direction carrying energy and leading to the interaction between these two objects or structures of nuclei.

THE LINKAGE BETWEEN ELECTROMAGNETIC AND GRAVITATIONAL FORCE

A huge number of photons, preferably a line of photons are produced in a perpendicular direction when an array of nuclei interacts with another array of the nuclei. This photon exchange manifests the transfer of energy and hence the electromagnetic force arises. According to Einstein's mass relation, we know that energy and mass are inter-convertible. Thus, according to this relation, the mass of the photon is given as

$$M = E/c^2$$

The energy of photons in terms of the frequency of the photon is given as,

$$E = h\nu$$

From here, we get that as mass and energy are inter-convertible, there may be some possibility that mediators of forces (mass phase) are correlated to interacting force (energy phase).

It can be observed that the matter nature of the line of photons is weak in comparison to the energy (which is expressed by the frequency of the wave). Here is a possibility that the interacting line of photons which justify the presence of electromagnetic force between two material media, can add to the presence of graviton. A better way to say is that there is a single particle that behaves as both protons and gravitons under different environmental conditions like distance in this case. Since it is observed from the energy-mass relation that gravitational force is extremely weak as the mass nature is extremely weak in comparison to the energy, the life span of gravitons in the same beam must be drastically lower than the number of photons in the same beam. This could be the prominent reason due to which the scientific community is not able to track the gravitons with precision.

In classical understanding, the gravitational and electromagnetic interactions with huge range are conservative in nature. They have a similar kind of dependencies on the spatial distance between the interacting bodies. Hence, it can be a popular idea that both the interactions arise due to transfer of energy, with electromagnetic stronger due to a greater number of its mediators. Since, both the particles are completely mass-less and charge-less, it is difficult currently to distinguish between them.

We have attempted to showcase our perspective in Figure 1, in form of a pictorial illustration that different forces may be the manifestation of the same single universal interaction. We tend to propose an idea which may also need more investigations and justifications to provide much direction to the researchers for further exploration and investigation that how a single force (interaction) between bodies ranging from quarks, gluons to heavenly bodies could be interpreted as strong, electromagnetic, weak, gravitational, just due to condition (type of particles and distance between them). More in-depth investigations by experimentalists and theoretical analysis through models and simulations could address one of the most fundamental questions of forces of nature.

HIGGS BOSON AND UNIFICATION CONCEPT

Higgs Boson (Higgs 1964; Higgs 1966; Lawrence Berkeley National Laboratory 2019; Conseil Européen pour la Recherche Nucléaire (CERN); Strickland 2008) came into picture and provided clarity about the Unification concept. A mandatory requirement to develop a gauge-invariant theory for a particular force of interaction is the symmetry conservation which in turn can predict the mass of the mediators to be zero. When intermediate vector bosons were discovered, they were not mass-less which poses a great threat to the elegancy of the standard models. In 1964 an idea was proposed to explain the mass of the intermediate vector bosons by Robert Borut and François Englert and Peter Higgs separately. They introduced a universal field which is known as the Higgs field (Conseil Européen pour la Recherche Nucléaire (CERN); Strickland 2008; Hughes 1991) that gives the vector bosons their mass. The quantum particle associated with this field is known as the Higgs boson (Conseil Européen pour la Recherche Nucléaire (CERN); Strickland 2008). Many aspects of unification theory are available in (Salam 1980). As discussed above, symmetry breaks during weak interactions, and to re-establish the symmetry, the Higgs field distributes the mass accordingly. This in turn also suggests that the mediator for this field is also mass-less but it acquires mass due to the universal Higgs field. In 2012 Higgs particle was discovered and elegancy of the standard model remains intact (Higgs 1964; Higgs 1966).

SUMMARY

We here attempted to discuss a theory based on facts that bring forth an understanding that a single fundamental and universal force could be characterized or distinguished into four different forms when the distance between the interacting bodies/particles varies. Also, here the characteristics of interacting particles may play a role. This complete paper revolves around the idea of establishing similarities between different mediators of the four fundamental forces of nature. It has been concluded that three of these mediators are charge-less and mass-less. One of the mediators has both charge and mass. All the forces are dominant in specific regions even though all the mediators exist at the same time. These mediators come to the fore because of a supposed field present between or due to the fundamental particles. It is worth mentioning that the mediators with mass (W and Z particle) are influential because of the weak interactions in the range smaller than the nuclei. Mediators of electromagnetic force are dominant in the range greater than the nuclei and gluons (Lawrence Berkeley National Laboratory 2019) are dominant in the nuclei.

FUTURE CHALLENGES AND POSSIBILITIES

Over the years physicists have been exploring the facts and understanding the interactions to develop a unification theory to achieve a single force field that can explain the existence of all the forces. The four forces have one thing unique that they are governed by a specified mediator. Another point needs attention is that whether these mediators are the same or different. If these mediators are a single particle behaving differently, living multiple lives, existing as everything at the same time, then a comprehensive universal model could become a possibility. Thus, another viewpoint to address mediators is that they are only different manifestations converging to single particle but behaving differently under different conditions. Are these mediators fundamental or the force? This may be a new perspective or a distinct approach to investigate the idea of the unification of forces. If all the mediators are a single particle acting differently under different circumstances, then the understanding of all the forces being merged into one force will make Unification Theory a much feasible concept. Does the big question still loom that are there many mediators or just one? In-depth investigations in the theoretical and experimental domain may reveal the realistic picture of this viewpoint. The possibility of mediators being manifestations converging to a single particle seems very high. The idea of fields of a huge number of sources superimposing and producing constructive interferences perpendicular to its orientation supports the fact that field force acts along the line joining two involved bodies. The existence of force is due to the existence of mediators that is why gluons cannot be found outside a nucleus. Electromagnetic force and gravitational force both exist in the same range, but the former is far more dominant than the latter, therefore in the pool of photons, gravitons are still not detected. This might happen because the manifestation of the photon is dominant over the graviton in this region. Out of all the known cases, the gravitational source is supposed to be the most dominant in the vicinity of a black hole. Hence, the gravitons could be detected there. Even if it is possible, differentiating between a photon and graviton will be a great challenge. At the same time, more similarities between them will strengthen the theory of the existing single mediating particle or force field in-universe. The path to simplify the challenges is a new vision and viewpoint to decode the mystery behind the relationship between the four fundamental forces of nature. We have attempted to discuss such related aspects in this paper.

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