Physical Science International Journal

24(9): 28-33, 2020; Article no.PSIJ.62600
ISSN: 2348-0130

Reinterpretation of Electric Field with Quantum Fluctuations: The Mechanism of Electrostatic Force of Attraction and Repulsion Between Two Point Charges

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/PSIJ/2020/v24i930214
Editor(s):
(1) Dr. Humaira Yasmin, King Faisal University, Saudi Arabia.
(2) Dr. Thomas F. George, University of Missouri, USA.
Reviewers:
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(4) Rero Marques Rubinger, Federal University of Itajuba, Brazil.
Complete Peer review History: http://www.sdiarticle4.com/review-history/62600

Original Research Article

Received 25 August 2020
Accepted 31 October 2020
Published 21 November 2020

ABSTRACT

Vacuum polarization rearranges virtual e^+e^- pairs. This causes the virtual e^+e^- pairs to rigidify in vacuum, reducing the quantum fluctuation energy. The quantum fluctuation energy is a fundamental force of vacuum, as evidenced by the Casimir effect. The change in quantum fluctuation energy was simulated in the superposition of the electric fields. The results show that the increase and decrease of the quantum fluctuation energy between the two point charges is related to the repulsive force and attraction in Coulomb's law.

Keywords: Electrostatic force; electric field; quantum fluctuation; vacuum polarization; annihilation; creation; Casimir.

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1. INTRODUCTION

The cosmic constant in Einstein's general theory of relativity is cosmic repulsion, which has a force equal to gravity in a static universe [1]. The repulsive force of the quantum vacuum was known to no one until the discovery of the Dirac sea [2-4] in 1930. The quantum field became widely known, and the empty space is not really empty and is filled with virtual particles [5,6] and the fluctuation of these particles has made it known that they have a high energy density of repulsive force [7,8]. This repulsive force is clearly confirmed in modern physics, such as the Casimir effect [9-11]. Therefore, if the quantum fluctuation decreases in a space in the universe, it is exposed to repulsive force from the outside.

The electrostatic force can be attractive or repulsive. It makes a repulsive force with the same charges and an attraction with different charges. In quantum electrodynamics, it is known that electromagnetic forces are mediated by photons, but there are no studies on the mechanisms of why and how they produce attraction or repulsion. This study is on the mechanism of electrostatic force based on the quantum fluctuation energy of a quantum field, and it is based on two assumptions. The first is that the fundamental forces of nature originate from the imbalance of the quantum fluctuation energy. Second, the quantum fluctuation is suppressed by vacuum polarization and the fluctuation energy is reduced. The first assumption is suggested by several theoretical researchers as the cause of gravity [12,13], but it will be more reliable if electrostatic force is also explained. The second assumption is that vacuum polarization clearly suppresses quantum fluctuation due to the rearrangement or rigidity of the virtual $\boldsymbol{e^+e^-}$ pairs [14,15].

In this study, annihilating or strengthening in the superposition of the vectors of virtual $\boldsymbol{e^+e^-}$ pairs was investigated when two point charges face each other. The changes of the quantum fluctuation energy are simulated. The mechanism of generating electrostatic force is explained through the unbalanced distribution of the magnitude of the quantum fluctuation energy around the two point charges.

2. VACUUM POLARIZATION AND QUANTUM FLUCTUATION

When point charge appears in a space, an electric field is made. In addition, vacuum polarization occurs around point charge. The flux density of the electric field not only has the same property as the density of the virtual $\boldsymbol{e^+e^-}$ pairs created by electric polarization, but the direction of the electric field line coincides with the direction of the vector of the virtual $\boldsymbol{e^+e^-}$ pairs. The rearrangement of virtual $\boldsymbol{e^+e^-}$ pair is a vector field like electric field. Fig. 1 shows the similarity between the vectors of the virtual $\boldsymbol{e^+e^-}$ pairs and electric field lines by point charge. This means that the rearrangement of virtual $\boldsymbol{e^+e^-}$ pairs vectors may be the substance of the electric field lines.

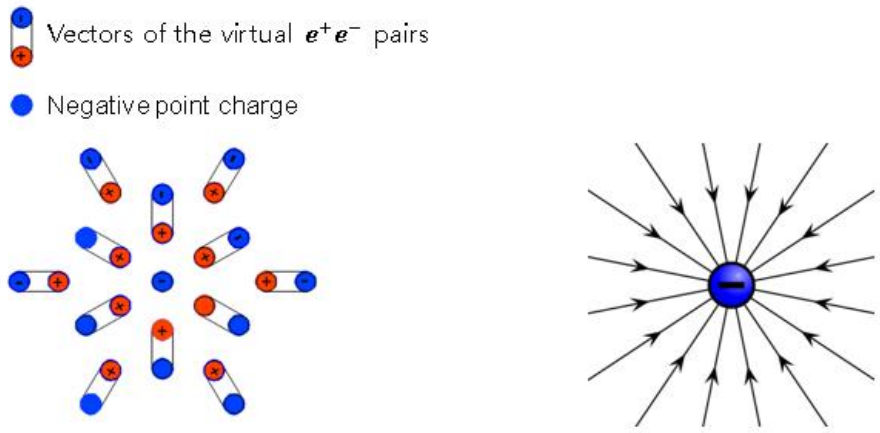
In the quantum field, a number of particles such as virtual electrons and positrons as well as virtual quark and gluon particles are fluctuating in pair production and pair annihilation as Feynman diagram shown in Fig. 2 [16]. Vacuum polarization due to electric charges rigidifies the fluctuation of the virtual $\boldsymbol{e^+e^-}$ pair among them. Therefore, if the quantum fluctuation energy is proportional to the number of virtual particles participating in the fluctuation, the quantum fluctuation energy decreases in proportion to the number of polarized virtual $\boldsymbol{e^+e^-}$ pairs. That is, the magnitude of quantum fluctuation energy reduction change $\Delta\mathrm{E}$ is proportional to the density of the polarized virtual $\boldsymbol{e^+e^-}$ pairs or the strength of the electric field. If the quantum fluctuation energy in the steady state is E_0, the fluctuation energy $\mathrm{E(r)}$ at a distance r from the point charge q can be expressed by the following equations (1), (2) and (3).

$$\Delta\mathrm{E} = \alpha(k_e \frac{q}{r^2}) \tag{1}$$

$$\mathrm{E(r)} = E_0 - \Delta\mathrm{E} \tag{2}$$

$$\mathrm{E(r)} = E_0 - \alpha(k_e \frac{q}{r^2}) \tag{3}$$

Here, k_e is Coulomb's constant and α is a correlation constant between electric field strength and quantum fluctuation energy.



(a) Vacuum polarization of negative point charge (b) Electric field lines of negative point charge

Fig. 1. Conceptual diagram for comparing vacuum polarization and electric field lines

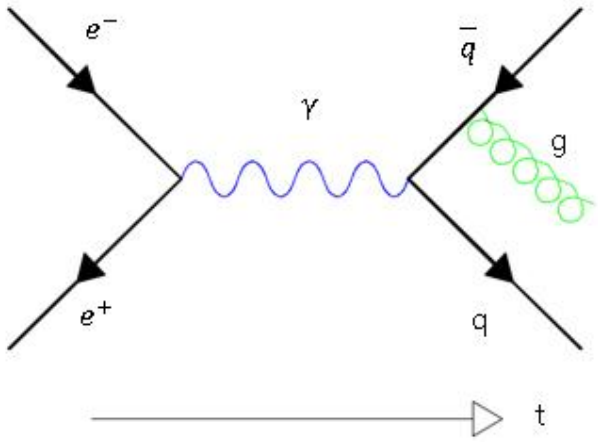


Fig. 2. Feynman diagram, an electron and a positron annihilate, producing a photon (γ, represented by the blue sine wave) that becomes a quark–antiquark pair (quark q, antiquark q̄), after which the antiquark radiates a gluon (g, represented by the green helix [16,17]

3. THE CHANGES OF QUANTUM FLUCTUATION ENERGY IN THE SUPERPOSITION OF ELECTRIC FIELDS

When the two point charges are close, the superposition principle is applied to the virtual e^+e^- pairs. Fig. 3 shows the superposition of the virtual e^+e^- pairs vectors when two negative point charges are close. Here, like the superposition of the electric field, when two virtual e^+e^- pairs vectors whose directions are perfectly opposite to each other meet, the two vectors of virtual e^+e^- pairs are forcibly annihilated. In addition, if the direction of the two virtual e^+e^- pairs vectors is partially opposite, then the sum of the two vectors of the virtual e^+e^- pairs create partial decay.

The annihilated virtual e^+e^- pairs vectors appear to have disappeared or deformed in the electric field lines as shown in Fig. 4. It can be seen that the virtual e^+e^- pairs vectors act like electric field lines. As mentioned earlier, the virtual e^+e^- pairs

vectors may be the substance of the electric field line. In the process of forcibly annihilating virtual e^+e^- pairs, some forced virtual e^+e^- fluctuations are additionally added, and as a result, the vacuum has greater quantum fluctuation energy than the quantum fluctuation energy of the steady state. The increased quantum fluctuation energy between the two negative point charges appears as a repulsive force between the two point charges. To be precise, the sum of the absolute values of y-directional scalar of the virtual e^+e^- pairs vectors that are annihilating in the superposition is engaged in the repulsive force of the two point charges. Fig. 4 shows two dimensional simulation results producing repulsive force.

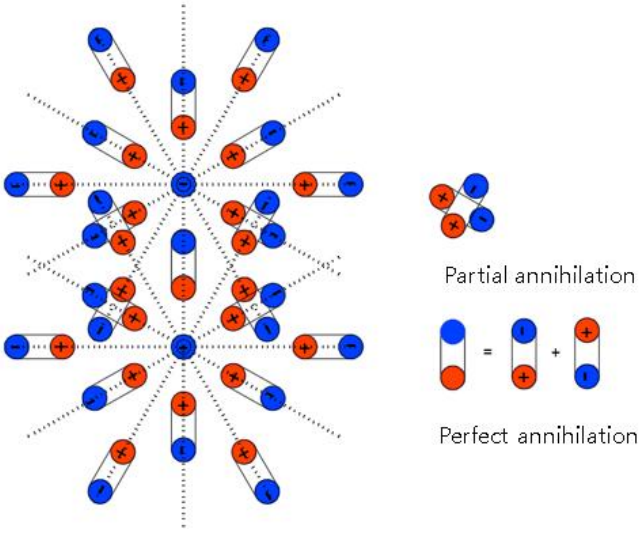


Fig. 3. Annihilation of the virtual e^+e^- pairs vectors in superposition of the two electric fields.

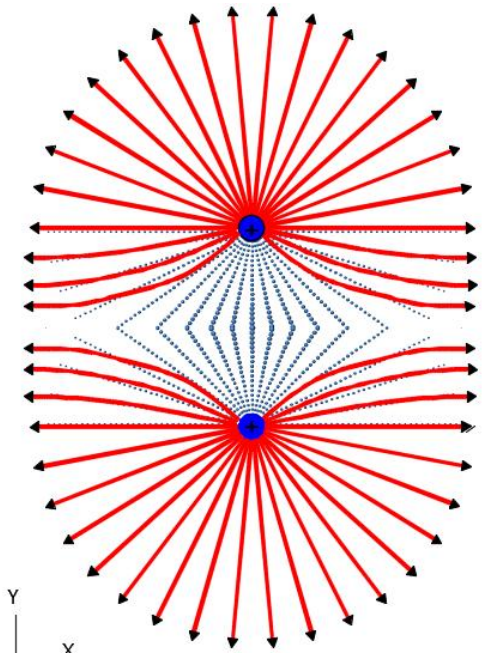


Fig. 4. A conceptual diagram of the increased quantum fluctuation energy between the two negative point charges (red arrows: electric field lines, blue dot: the sum of the absolute values of y-directional scalar of the virtual e^+e^- pairs vectors)

The mechanism of the repulsive force between the two positive point charges can be easily understood by the magnitude distribution of dot in Fig.4. Considering the size of the dot, it is the largest in the center and decreases as it moves toward the periphery. Therefore, as suggested in the introduction, considering that all fundamental forces of nature are caused by quantum fluctuation energy imbalance, the relationship between the repulsive force F and the increases of quantum fluctuation energy $\delta\mathrm{E}$ by the superposition can be expressed by equation (4).

$$\mathrm{F} \propto \delta\mathrm{E} \tag{4}$$

Here, F is replusive force and $\delta\mathrm{E}$ is the total sum of absolute values of y-directional scalars of virtual $\boldsymbol{e}^{+}\boldsymbol{e}^{-}$ pairs vectors that get smaller in the superposition of two positive point charges

If two point charges having different charge are facing each other, the virtual $\boldsymbol{e}^{+}\boldsymbol{e}^{-}$ pairs vectors between two point charges get bigger, rather than forced annihilation in the superposition. This further reduces the quantum fluctuation energy between the two point charges. The reduced quantum fluctuation energy creates attractive force between the two point charges. To be precise, the sum of the absolute values of y-directional scalar of the virtual $\boldsymbol{e}^{+}\boldsymbol{e}^{-}$ pairs vectors that get bigger in the superposition is engaged in the attraction force of the two point charges in equation (4).

4. REINTERPRETATION OF COULOMB'S LAW

In Coulomb's law, the repulsive force F created from two point charges with charges q_1 and q_2 separated by r distance is made by equation (5).

$$\mathrm{F} = k_e\left(\frac{q_1\, q_2}{r^2}\right) \tag{5}$$

Here, k_e is Coulomb's constant.

On the other hand, reinterpreting electrostatic forces from the perspective of quantum fluctuation energy, the strength of electrostatic force will be relied on the equations (1) and (4). First, as the distance increases, the density of virtual $\boldsymbol{e}^{+}\boldsymbol{e}^{-}$ pairs vectors becomes inversely proportional to the square of the distance. The distance between the two charges causes a change in the density of the virtual $\boldsymbol{e}^{+}\boldsymbol{e}^{-}$ pairs vectors, which also affects the number of virtual $\boldsymbol{e}^{+}\boldsymbol{e}^{-}$ pairs engaged in the superposition, which in turn contributes proportionally to the change in quantum fluctuation energy. Second, the magnitude of the charge q contributes to the absolute strength of the electric field, and ultimately directly affects the absolute number of virtual $\boldsymbol{e}^{+}\boldsymbol{e}^{-}$ pairs vectors. That is, as the magnitude of the charge q increases, the virtual $\boldsymbol{e}^{+}\boldsymbol{e}^{-}$ pairs vectors participating in the superposition increase in proportion. Third, the changes of quantum fluctuating energy $\delta\mathrm{E}$ in the superposition are related with the electrostatic forces.

5. DISCUSSION

It was determined that the quantum fluctuation energy increased in the superposition of the same two point charges. On the basis of this, the rearranged $\boldsymbol{e}^{+}\boldsymbol{e}^{-}$ pairs in electric field are vectors each of which has a magnitude and direction as shown in Fig.3. A rearranged $\boldsymbol{e}^{+}\boldsymbol{e}^{-}$ pair vector is simultaneously influenced by the two electric fields. In the superposition, it results in losses in the magnitude and direction of the vector. Finally, a rearranged $\boldsymbol{e}^{+}\boldsymbol{e}^{-}$ vector produced shortly in the electric field and annihilated partially or perfectly simultaneously. This compulsive production-annihilation mechanism does not occur in the steady state vacuum.

As suggested in the introduction, if the unknown fundamental forces of nature originate from the imbalance of the quantum fluctuation energy, it is correct to interpret the electromagnetic force followed by the gravitational force as quantum fluctuation energy. However, unlike electromagnetic force, gravity exists only in attractive force and no repulsive force. Although further research is required, By the 2000s, research revealed that most of the mass of protons was the field energy of the color charge contained in quarks and gluons, not quarks particles [18-20]. In other words, mass does not come from particles, but from the color charge field. Finally, the mass is mostly composed of color charges, not particles. These findings predict another phenomenon of vacuum polarization by mass. If the electric field is a vacuum polarization phenomenon caused by electric charges, the gravitational field is explained as a vacuum polarization phenomenon caused by color charges. However, why the repulsive force cannot occur in gravity? It seems to be related the eight combinations of color charges. This is because electric charges are two types of negative and positive, which are

mutually canceled and annihilated completely, whereas the combination of 8 types of color charges annihilated only a very small part, and most of them will be maintained in a vacuum polarization state. Therefore, the color charges of the eight combinations of vacuum polarization around the two masses are hardly annihilated in the superposition, which in turn strengthens the vacuum polarization between the two masses. The enhanced vacuum polarization leads to a decrease in the quantum fluctuation energy and is believed to be the cause of the universal gravitation between the two masses. Another reason is the analogy between Coulomb's law and Newton's law of gravity. This is because the density of all rearranged e^+e^- pairs is based on being inversely proportional to the square of the distance from the point source.

6. CONCLUSIONS

In quantum electrodynamics, it has been found that photons mediate the electromagnetic force, but the mechanism of attraction or repulsion between two point charges is not yet known. As a result of simulating the change in quantum fluctuation energy between two point charges, an imbalance in the distribution of quantum fluctuation energy was found. The quantum fluctuation energy increased between the same two point charges, and the quantum fluctuation energy decreased between the two different point charges. This is the cause of creating electrostatic repulsion and attraction between two point charges. The mechanism for electrostatic force considered only the vacuum polarization due to electric charge, but considering the vacuum polarization due to color charge, it is expected that the mechanism of gravity could be included.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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