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Spatial Attributes of Particles and Quantum Fields

Yougang Feng

College of Physics, Guizhou University, Guiyang, China
Email: ygfeng45@aliyun.com

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Abstract

According to the characteristics of manifold and the double helix structure of spacetime, four coordinate systems are established as reference frames. The grand parity principle and the general exclusion principle are proposed. The minimum action distance of electromagnetic force is obtained and the structure of intrinsic space of particle is studied. The stability of particle reaction, the reason for only three generations of leptons and the spatial significance of the electroweak equivalence are discussed by using the two principles and the four coordinate systems. The behavior of boson including condensation is described in terms of spatial structure. Finally, we suggest that symmetry between the field excited by charge and the field excited by mass should be further investigated.

Keywords

Spatial, Parity, Coordinate, Exclusion, Spin, Chirality

1. Introduction

There are two trends in the exploration of microscopic laws: One is to use more advanced symmetry groups to analyze quantum fields, and the other is to find new expression forms by adding spatial dimensions. We believe that because all physical phenomena appear in four-dimensional spacetime, rather than in virtual parameter space or high-dimensional space, the properties of particles can only be the manifestation of the 4D spacetime. The properties of symmetry groups must be properly represented in appropriate space, so the space properties are the fundamental ones.

There are three kinds of space: The first is the real world where matter exists, and there is no coordinate system. The second is metric space in mathematical sense describing the matter space, it can be chosen as a reference frame where position and time are absolute in Newtonian mechanics and relatively variable in relativity. The third is a test system which spatial resolution is limited by the capability of measuring instruments, including people. The uncertainty principle reflects the relationship between the second space and the third space [1], and the properties of quantum field manifest the attributes of the second space. In order to observe the motion of the target people set up a variety of coordinate systems as a reference system. However, the observer cannot arbitrarily choose the reference frame. It has been argued that as long as a particle has mass we cannot think of counterclockwise and clockwise particle separately, because different ways of looking at them (behind or in front of them) would turn clockwise spin into counterclockwise spin, thus breaking the chiral symmetry of the spin. That doesn't make sense. In fact, the reference frame itself represents the observer's point of view, which doesn't allow the additional observation methods. Here, it is necessary to introduce the concept of manifold. Manifold is a generalization of Euclidean space. Roughly speaking, a manifold is homeomorphic at every point near and an open set of Euclidean space. A manifold is just a space where pieces of Euclidean space are glued together. Therefore, the local coordinate system can be introduced near each point [2]. The characteristics of manifold allow different coordinate systems at different points occupied by different particles, which provides with a very effective tool for analyzing the properties of space. However, we should also understand that all discussion of the properties of particles treats the coordinate system as real space, sometimes it works, and sometimes it doesn't.

Field is a mathematical form, it and coordinate system cannot be independent of each other, the properties of the field determine the coordinate system, and *vice versa*.

Chirality is a helicity that doesn't change according to the subjective opinion of the observer because it is an inherent nature of coordinate space. The observer cannot change it since the system has been established. For example, we establish a right-handed system for the field related to charge and a left-handed system for the field related to mass [3]. Once determined, it never changes. The spin of particle embodies the chirality of the field, it's also a property of space. In addition to spin, the chirality of the field is also reflected in the positive and negative signs of the operator. The two fields show double helix property of vacuum.

In this paper, we try to explore and interpret the properties of particles and quantum fields by analyzing the attributes of space where they exist. In Section 2, we introduce four coordinate systems and their representation symbols, describe the structure of intrinsic space and the behavior of boson including condensation, then proposed grand parity principle and general exclusion principle. We obtain the minimum action distance of electromagnetic force. In Section 3, we discuss stability of particle reaction and the reason for only three generations of leptons, explain a possibility of existence of charm quarks in proton and spatial meaning of electroweak equivalence. Section 4 is conclusion.

2. Theory

2.1. Four Kinds of Coordinate Systems

There are four kinds of coordinate systems: 1) Time positive direction $t > 0$, x, y and z right-handed system $\{t > 0, R\}$. 2) Time positive direction $t > 0$, x, y and z left-handed system $\{t > 0, L\}$. 3) Time reverse direction $t < 0$, x, y and z right-handed system $\{t < 0, R\}$. 4) Time reverse direction $t < 0$, x, y and z left-handed system $\{t < 0, L\}$. They are all local coordinates, and under certain condition they can coexist at different points. The coordinate system for a charged particle is $\{t > 0, R\}$, if it gains mass, it also can have $\{t > 0, L\}$. At a certain point, it can only have one or the other. The $\{t > 0, R\}$ means its spin is right handed, the $\{t > 0, L\}$ means left handed spin. Its antiparticle coordinates correspond to $\{t < 0, L\}$ and $\{t < 0, R\}$, respectively. A neutrino's coordinate is $\{t > 0, L\}$, and the antiparticle's, $\{t < 0, R\}$.

The so-called vacuum is the space without charge and mass, in which there exist local left-handed coordinate system and right-handed coordinate system. When the time is disorder, the system with $t > 0$ and the system with $t < 0$ are equally likely to appear, that is, all the above four local systems can describe the vacuum, and they coexist. In presence of macroscopic time direction, there is local reversibility of microscopic time, which allow a few number of antiparticles to appear occasionally in the process of reaction, they are suitable to $\{t < 0, L\}$ and $\{t < 0, R\}$.

2.2. Grand Parity Principle

The grand parity principle: The four-dimensional spatiotemporal coordinate systems of two fermions generated in the same reaction must maintain parity.

For example, the coordinate system symbols of two particles are respectively $\{t > 0, L\}$ and $\{t < 0, R\}$, they comply with this principle and can be expressed as

$$\{t > 0,\ L\} + \{t < 0,\ R\} = \{0\} \tag{1}$$

where the symbol $\{0\}$ means the grand parity conservation. An electron with left-handed spin and an antineutrino with right-handed spin obey Equation (1), a neutrino with left-handed spin and a positron with right-handed spin also obey the equation.

The field interaction resulted from mass can be ignored, but the parity property of the space related to the mass must be taken into account. The grand parity principle is proposed on this point of view. In addition, the principle only pays attention to structural symmetry, regardless of energy. The parity in configuration space is a special example of the grand parity, for example, two electrons have left and right spins, respectively, they obey the following equation

$$\{t > 0, L\} + \{t > 0, R\} = \{t > 0, 0\} \tag{2}$$

If an unobservable quantity is changed into an observable quantity, there may be some symmetry breaking and new particles may be discovered. Because the parity of configuration space is broken, the weak force characteristics are found [4]. However, the nature of the weak force in the 4D spacetime is not found, since the grand parity conserved. As the basis and background of physical space, vacuum is always presents, thus, the grand parity is the basic symmetry in structure.

Electron has the same left-handed spin as neutrino, one with an electric charge and one without. In this sense, they constitute lepton duality,

$$\Psi = \begin{pmatrix} \nu \\ e \end{pmatrix}, \quad \bar{\Psi} = \begin{pmatrix} \bar{\nu} & \bar{e} \end{pmatrix} \tag{3}$$

and there exists a SU (2) local gauge field, which interaction terms with fermion field can be given by [5]

$$\frac{1}{2} g\left[\bar{\nu}\gamma^{\mu} A_{\mu}^{3}\nu + \sqrt{2}\bar{\nu}\gamma^{\mu} w_{\mu}^{+} e + \sqrt{2}\bar{e}\gamma^{\mu} w_{\mu}^{-}\nu - \bar{e}\gamma^{\mu} A_{\mu}^{3} e\right] \tag{4}$$

where g is the coupling constant. Comparing Equations (1) and (4), we know that one function of weak force is to maintain grand parity, which reflects its spatial property, that's why it often involves neutrinos and antineutrinos.

2.3. Spatial Limitation on Electromagnetic Force

The charge excites the right-handed system of vacuum to produce electromagnetic field [3]. The force has an infinite distance, so what is its minimum effective distance? Let's say that there is a positive charge $Ne > 0$, N is a natural number, that generates an electrostatic field. And then, you put in an electron in the field and the minimum distance that it can get to the positive charge is the minimum effective range of the field. Less than this range can be considered to have no electromagnetic field, that is, no electromagnetic force. In fact, that's the ground state of the hydrogen atom if $N = 1$. The orbit radius r_0 corresponding to the ground state is the minimum effective distance of the force. Since the electromagnetic field is a vacuum exited state, it must have the basic properties of material space, in which the uncertainty relation plays a key role [1]. $rp = \hbar$ can be obtained from the minimum uncertainty relation between moment p and the position r, and the energy E is given by

$$E = p^{2}/(2m) - Ne^{2} p/(4\pi\varepsilon_{0}\hbar) \tag{5}$$

According to the minimum energy condition, if $N = 1$ we obtain

$$r_{0} = \hbar/p = (4\pi\varepsilon_{0}\hbar^{2})/(me^{2}) = 5.3\times10^{-9}\ \text{cm} \tag{6}$$

r_0 is the minimum action distance (Bohr radius), at least, on this order of magnitude. At a distance $r < r_0$, the charge cannot excite vacuum field, which means that the charged particle no longer has the right-handed spin, but only has the mass-dependent left-handed spin. The maximum distance of the weak force and the maximum distance of the strong force are much smaller than r_0, and the charged particle (its antiparticle) exhibits only left-handed spin (right-handed spin) when the effects of these two forces are considered.

2.4. The Intrinsic Space of Particle

It is conceivable that a 4D spacetime consists of a set of points, where two points that are distinguishable by their nearest neighbors have disjoint domains [6]. Obviously, the spatiotemporal characteristics of the neighborhood constitute the local spacetime characteristics. Since the domain of a point is a part of the spacetime, it must be chiral. If a particle resides in a point, the domain is the intrinsic space of the particle, it is the chirality of this intrinsic space that determines the chirality of the particle spin. Therefore, we say that the chirality of a particle's spin is a property of local spacetime. For a given chirality, the 3-dimensional configuration space only allows three independent spin degree of freedom. In general, the three rotation axes are orthogonal to each other, but not parallel to the coordinate axes.

An electron only has one spin axis, which can be right handed or left handed, and it has to be one or the other. A neutrino only has a left-handed spin axis. For a particle, an axis of rotation can accommodate two states with opposite spins at the same time.

For composite particles such as proton and neutron, as there is no electromagnetic force in the intrinsic space and there are three spin axes, each of which can hold a quark (left-handed spin) and an antiquark (right-handed spin). There are three planes orthogonal to the three spin axes. The colors of the three planes with the left-handed spins axes as normal are red, blue and green, respectively. And the colors of the other side of the same planes with the right-handed spin axes as normal are respectively anti-red, anti-blue and anti-green. The color of the charge carried by a quark (antiquark) is the color of the plane perpendicular to its spin axis. The intrinsic space can be divided into eight parts by the three color planes: up, down, left, right, front and back. Each part is parallel to or intersects the coloered planes. So each part is a trichromatic combination. These eight parts are respectively equivalent to eight gluons. Since there is no length definition, the eight parts can be considered subjectively the same size regardless of their shapes. The important thing is that the color of each plane can be changed, as long as the three colors are balanced (colorless), so the colors of the eight parts changed. This is sustained by strong force.

The diameter in mathematics sense of intrinsic space for proton or neutron is equal to the distance between two nearest neighbors. So points in the intrinsic space are not distinguishable. This is why there are no independent quarks. And then, we see that the function of strong force is to preserve the basic resolution of the metric space. Moreover, the magnitude of spin is not a measure of configuration space, thus we can specify that the total spin magnitude of intrinsic space is 1/2, that is, the magnitude of a fermion spin is 1/2.

In fact, the size of the domain of a point is not uniform, and it is clear that a neutrino occupies less territory than a nucleus which is a collection of intrinsic space. We have seen that the strong force can also concentrate several protons and neutrons in a nucleus. However, when the number of these fermions in the nucleus is large, the size of the nucleus becomes large, the domain occupied by the nucleus becomes too large, so that the strong force cannot hold on to stability, and nuclear decay occurs under the participation of the weak force, such as beta decay. From this, we realize the dual character of the weak force: it can both cause heavy nuclear decay and maintain the conservation of grand parity.

The boson only moves at the boundary of the intrinsic space of the fermion (the space is an open set) and doesn't occupy the intrinsic space. It behaves like a free electron traveling through a crystal and can move without occupying the lattice. This property allows bosons to condense at the same energy state. When bosons occupy the boundary of two fermion neighborhoods, the three are in a connected region, which makes the fermions interact with each other. In this process, the bosons play a prominent role in transmitting force.

2.5. General Exclusion Principle

The principle says: Under the action of the same force (electromagnetic force, weak force or strong force) it is impossible for two or more particles of the whole fermions to be in the same single-state at the same time.

This principle is applied to fermions under electromagnetic force and leads to the same conclusion as the Pauli exclusion principle.

3. Discussion

3.1. Stability of Particle Reaction

There is a particle, there is its coordinate system symbol and there is a local space. Since non-fermion doesn't construct matter, when it occupies a point and has a symbol, which means that the local space structure is destroyed. Obviously, this non-fermion must decay to ensure the stability of the spatial structure. Thus, for a reaction, in addition to meeting the grand parity principle, the number of coordinate system symbols before and after the reaction must be the same (the two coordinate symbols obeying the grand parity are not included). Having a very short lifetime is a common feature of all unstable particles, non of which are fermions. Let's check the following reactions and relevant symbols,

$$\pi^- + \mathrm{p} \to \mathrm{n} + \pi^0 \tag{7}$$

The symbol of π^- is $\{t > 0, 0\}$, π^0 is $\{t = 0, 0\}$, there are no these two local coordinate systems.

$$\pi^+ \to \mu^+ + \nu_\mu \tag{8}$$

The relevant symbols reaction is shown as

$$\{t < 0, 0\} \to \{t < 0, R\} + \{t > 0, L\} \tag{9}$$

On one hand, there is no point with $\{t < 0, 0\}$ in the configuration space, on the other hand, the μ^+ (it is an antiparticle and there is no electromagnetic force, see subsection 2.3) and ν_μ obey the grand parity and the number of coordinate system symbols before and after the reaction is not conserved. It is true that the mesons are unstable particles with short lifetime. Consider the decay of a free neutrino

$$\mathrm{n} \to \mathrm{p} + \pi^{-} \tag{10}$$

π^{-} is unstable, it can decay

$$\pi^{-} \to \mathrm{e}^{-} + \bar{\nu}_e \tag{11}$$

The two reactions merge to form a stable reaction

$$\mathrm{n} \to \mathrm{p} + \mathrm{e}^{-} + \bar{\nu}_e \tag{12}$$

The symbols change as

$$\{t>0,L\} \to \{t>0,L\} + \{t>0,L\} + \{t<0,R\} \tag{13}$$

where the grand parity is conserved for the electron and the anti-electroneutrino,

$$\{t>0,L\} + \{t<0,R\} = \{0\} \tag{14}$$

Note that the charge doesn't excite the right-handed system, the electron's symbol is $\{t > 0, L\}$, which spin comes from its mass. The symbols before and after the decay are the same under the condition of grand parity. It must be pointed out that in the beta decay, if there is a local magnetic field such as the earth's in the nature or the artificially applied magnetic field in the laboratory, which means there is electromagnetic force, there are electrons with right-handed spins and electroneutrinos, obeying the principle.

With the same reason, we can discuss other reactions with unstable particles.

3.2. Reason for Only Three Generations of Leptons

The spin s of the charged particle with charge e and mass m constitutes the intrinsic magnetic moment: $M \propto (es)/m$. According to the general exclusion principle, since e^{-}, μ^{-} and τ^{-} have different masses, their spin magnetic moments are different, they cannot share the same spin axis. There are three independent spin axes (three degree of freedoms), only three kinds of independent leptons with the same charge and different masses are allowed to exist. A neutrino that can appear in the same reaction (the same force is applied) as a lepton is of the same generation as the lepton. It follows that the dimensionality of configuration space makes leptons only three generations old. The same applies to quarks, which are in the same generation as leptons that participate in the same reaction.

3.3. Charm Quarks in Proton

The charm coordinate system symbol is $\{t > 0, L\}$ and its antiparticle's is $\{t < 0, R\}$, thus

$$\{t>0,L\} + \{t<0,R\} = \{0\} \tag{15}$$

This pair can reside in the intersection of the three spin axes in the intrinsic space, which is not a violation of the general exclusion principle, and the pair has no charge [7].

3.4. Electroweak Equivalence

Each point in configuration space has a time direction. When the number of points in the positive direction of time is equal to the number of points in the negative direction of time, and these points are evenly distributed in the whole space, the whole space shows time disorder. At this moment, fermions have no masses, the symbols {t > 0, R} and {t < 0, L} exist together, the former for particles (electrons), the latter for anti-particles (positron), and they are only related to the charges. Because there is no mass, the electromagnetic force may not be constrained by the minimum action distance r_0, that is, the force can have the same action distance as the weak force. For the two particles, grand parity is given by

$$\{t>0,R\}+\{t<0,L\}=\{0\} \tag{16}$$

It indicates there is weak force. However, it can also be interpreted as electroneutral condition caused by electromagnetic force. These two descriptions are completely equivalent, which means that the two force can be considered as the same.

Once the overall space is time ordered, all fermions gain masses, with the symbol {t > 0, L} related to the electron mass, and {t < 0, R} related to the positron mass. We have

$$\{t>0,L\}+\{t<0,R\}=\{0\} \tag{17}$$

Equation (17) also conforms to the fourth term of Equation (4), which is caused by the weak force, and the charges only obey the classical superposion rule. There is no electromagnetic force due to the interaction distance is much smaller than r_0. And so the electroweak equivalence ended.

4. Conclusion

Real physical space has no coordinate system. We use metric space to describe the properties of fermions and fields. Such space has the characteristics of manifold. The behavior of all fermions and fields reflects the basic properties of spacetime, and they comply with the grand parity principle and the general exclusion principle. Since the charge excites the right hand system of vacuum and mass excites its left hand system, it seems that there should be symmetry between the two excited quantum fields. This is a secret of nature that deserves our exploration.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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