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The basis of unified field theory and the direction of future development

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Abstract. Unified field theory is a physical theory that describes and reveals the common nature and intrinsic connections of fundamental interactions in a unified way, starting from the idea that interactions are transmitted by fields. This paper will start from the past of the unified field theory and use the literature research method to describe the problems encountered in completing the unified field theory and the possible solutions for the future. The result shows that unified field theory is a dynamic theory that is still being studied and has significant implications for the development of physics. This article argues that many of the shortcomings of this theory are due to the lack of mathematical theory. It is also pointed out that the creation of a new mathematical system is a feasible way. Finally, it is concluded that unified field theory is still a very difficult problem to explore.

Keywords: unified field theory, relativity, quantum mechanics, string theory, mathematical systems.

1. Introduction

Relativity, which is used to describe the macroscopic world, and quantum theory, which is used to describe the microscopic domain, are recognized as the greatest theories of the 20th century and have provided an important theoretical foundation for the development of the physics community and even the world. Since Einstein, people have been working on the unified field theory to unify the macroscopic and microscopic worlds. For example, Wu Yueming and others used physical methods to explore the unified field theory advocated by Einstein [1]. Until now, Einstein used relativity to unify time's and space. Yang and Mills proposed the Yang-Michel theory to carry out the unification of weak interaction and electromagnetic interaction [2]. Maxwell's electromagnetic field theory unified electromagnetic interaction, strong force and electroweak interaction were pieced together in a specific situation, while gravity was slow to unify with the other three interactions. There are still some theories in the research stage that can unify these fundamental interactions well such as super string theory. Although these theories have been studied and developed a lot up to now, there are still no experiments to show that these theories are correct. The methods to achieve unified field theory will be discussed in this paper. This paper is divided into five parts: quantum theory, relativity, unified field theory, string theory, and discussion. The completion of the unified field theory will provide the physics community with a perfect model to describe the existing theories and phenomena and provide sufficient theoretical support for the future development of physics and technology. This paper can provide a better understanding of the current state of unified field theory and facilitate physicists making more contributions to the field.

2. Introduction to quantum mechanics

In the old quantum era, that is, the industrial revolution in the 18th century, people did not have detectors to measure high temperatures, and steel makers could only control the temperature by observing the color of the steel with the naked eye. So at that time, people desperately needed a precise relationship between the frequency of the radiated photons and the temperature. Scientists used black bodies, which are ideal objects that absorb all light without reflection or transmission to study thermal radiation. Wien concluded from experience that Wien's formula $R_0(\lambda, T) = c_1\lambda^{-5}e^{-\frac{c_2}{\lambda T}}$ (1), which can effectively solve the high-frequency band of blackbody radiation; the Riley-Kings formula, $R_0(\lambda, T) = \frac{2\pi c}{\lambda^4}kT$ (2), well describes the low-frequency band of blackbody radiation [3][4]. But no formula can effectively cover all the bands of blackbody radiation, Riley-Kings formula in the high-frequency part even got the impossible case of infinite radiation energy, this was later known as the ultraviolet disaster. Then Planck was inspired one day to subtract 1 from the denominator of the Wien formula to obtain the Planck formula, $R_0(\lambda, T) = \frac{8\pi hc}{\lambda^5} \cdot \frac{1}{e^{\frac{hc}{\lambda kT}}-1}$ (3)[5]. This formula converges to the Wien formula in the high frequency part and to the Riley-Kings formula in the low frequency. That is, Planck's formula can be derived by introducing the concept of quantization of oscillator energy. Planck broke through the concept that classical energy is continuous and introduced the quantum, the smallest unit of energy, from which quantum mechanics was born. Then the photoelectric effect came. The photoelectric effect refers to the fact that when light hits the surface of a metal, electrons are struck from the surface of the metal. If this piece of metal is connected to a wire, then a current will be generated in the wire. Interestingly, only when the frequency of irradiated light is greater than this frequency will there be electron spillover. This frequency is called the cutoff frequency. The photoelectric effect is difficult to explain with the knowledge of classical physics, but in 1905, Einstein published his paper "An illuminating view of the production and transformation of light", which introduced the concept of the "quantum of light" as described by Planck and perfectly explained the photoelectric effect. Later, as he continued to study the composition of matter, Bohr proposed a quantum model of the atom, the atomic orbital theory. Bohr's model inspired countless physicists of later generations to study the atomic model from the perspective of quantization and eventually established the theory of quantum mechanics, including Heisenberg and Schrödinger. It is no exaggeration to say that Bohr's atomic model is the bridge to the theory of quantum mechanics. Then, Heisenberg invented a new quantum theory, Heisenberg matrix mechanics, which is essentially the quantum mechanics of energy representation in Heisenberg's picture, the operators of mechanical quantities change with time, and the "quantum states" do not change with time. He used the Bohr-Sommerfeld quantization condition and the Bohr correspondence principle to obtain the quantization condition of the coordinate matrix satisfying the Kramers dispersion formula or the Kuhn-Thomas summation formula, which leads to the diagonalized energy matrix and the time-varying coordinate matrix of the resonator [6]. Then comes Schrödinger's wave dynamics. Heisenberg's matrix mechanics was inspired by Ball's atomic model, and Schrödinger's wave dynamics was inspired by wave-particle duality, and he used the formula, $i\hbar\frac{\partial}{\partial_t}\Psi(r,t) = \mathrm{H}\Psi(\mathrm{r},\mathrm{t})$ (4). Schrödinger's wave dynamics was inspired by wave-particle duality, and he used the equation of motion, a wave function, to describe the trajectory of particles in quantum mechanics instead of the equation of motion [7]. The above is the approximate development of quantum mechanics.

3. Introduction to relativity

Experimental studies before 1905 have shown that three types of experiments contradict Newtonian classical physics: the first is that the Michelson Morley (rotating interferometer) experiment does not observe the motion of the Earth with respect to the "Ether"; the second is that the electromagnetic induction of moving objects shows relativity (whether it is the motion of a magnet, or the third is that the inertial mass of the electron becomes larger with the increase in the speed of the electron motion. At that time, to explain these phenomena, many hypotheses were introduced within the framework of Newtonian mechanics (including the Lorentzian length contraction hypothesis and the Larmor "clock slowdown" hypothesis), and various formulas were obtained that were consistent with the experimental results, and even the Lorentzian coordinate transformations were obtained. But these formulas and Lorentz transformations come from different hypotheses or different models rather than from the same physical theory. Moreover, conceptual difficulties are encountered when using the Newtonian view of absolute space-time to explain the Lorentz transformations and the implied vacuum speed of light. This incongruity signaled the need for a shift from the old to a new conception of physics. Einstein inspected that the key to solving this problem lay in the definition of simultaneity: in order to compare time at different locations, clocks at different locations had to be synchronized with each other beforehand. No one had studied time coordinates in the Newtonian-Galilean inertial system, in which time coordinates require instantaneous information propagation and assume that motion has no effect on time. But the reality is that the fastest known speed is the speed of light, which is also finite, and there are no experiments where surface motion has no effect on time. Therefore, Einstein proposed the famous special relativity theory to solve these problems. Special relativity is based on two basic axioms: one is the principle of special relativity: all inertial reference systems are affine, that is, the form of physical laws is the same in any inertial reference system; the other is the principle of in-variance of the speed of light: the speed of light in vacuum is invariant in any reference system. According to the Lorentz change (which is also an important theoretical basis of relativity), Einstein can obtain the relative factor of special relativity: $\gamma = \frac{1}{\sqrt{1-(\frac{V}{C})^2}}$ (5) [8]. Based on this relative factor, Einstein can consider objects moving at high speed and get some conclusions such as the ruler scaling effect, the effect of motion on time and the non-existence of superluminal signals. Most classical mechanics can be successfully rewritten in relativistic form so that it can be used to better describe objects moving at high speeds, but only Newton's theory of gravity cannot be rewritten in the framework of special relativity, which directly led Einstein to extend his theory of special relativity and obtain the general theory of relativity. The core of this theory is that there is an essential connection between space-time and matter, and the existence of momentum and energy will bend the four-dimensional space-time, while the bent space-time will in turn have an impact on the motion of matter [9].

4. Advances in unified field theory

After Einstein proposed the theory of relativity, he was amazed to find that physics had begun to shift to mathematics and that the concepts introduced by purely mathematical methods on the basis of physical perception were now considered correct. Then, according to mathematics, one could derive a universal formula to cover all phenomena, and Einstein proposed the geometric unified field theory. But unfortunately, when he tried to unify gravity and electromagnetism (the only two fundamental forces known at that time), he encountered big problems, which became more and more obvious with the establishment of quantum mechanics: classicality (relative to quantum properties), abstraction (almost all geometric) and deviation between theory and practice [10]. Later, it was realized that the fundamental interactions are not only gravitational and electromagnetic interactions, but also weak and strong interactions. So Heisenberg proposed a nonlinear spin-volume field equation to explain the interactions between elementary particles. Later, the canonical field theory emerged, which is a class of physical theories based on the idea that symmetry changes can be implemented locally as well as globally. The most common example of a canonical field theory for a noncommutative symmetry group is the Yang-Michel theory. Physical systems are often expressed in terms of Lagrangian quantities that are invariant under certain transformations, and they have global symmetries when the transformations are implemented simultaneously at each point in space-time. Normative field theory generalizes this idea by requiring that Lagrangian quantities must also have local symmetry — it should be possible to perform these symmetric transformations in a particular region of spacetime without affecting another region. This requirement is a generalization of the equivalence principle of general relativity. Back in the 1950s, Glashow used canonical field theory to study electroweak unification theory, and in 1961 he published his paper "Partial symmetries of weak actions", which won him the Nobel Prize in Physics in 1979 [11]. He introduced the weak neutral current, which is compatible with the present theory, but unfortunately, not much attention was paid to his theory at that time. The problem that emerged from the early studies of electroweak theory was that the masses of the intermediate bosons that transmit the weak force were all artificially placed, a process that was very difficult until the Heggs mechanism was proposed, which physicists could use to make canonical field particles gain mass and overcome the problem of artificial placement, and weak point unification theory made big progress because of this. By 1967, a true weak point unified canonical theory was established. The success of the weak point unified field theory stimulated people to explore the unification of more macroscopic interactions. In short, the current unified field theory is still in the exploratory stage.

5. Possible solutions

During the period 1968-1973, it was discovered that the high-energy behavior of the scattering amplitudes of strongly interacting particles could be described by the dynamics of a one-dimensional string. In string theory, what physicists usually call “particles” correspond to the different modes of vibration of the string. In other words, the particles that make up matter and transmit interactions in the usual sense can be unified by a single string, which implies that string theory should have the potential to unify the four interactions, including gravity, by the interactions between strings. The relation between string and mass is easier to understand, the more violent the string vibrates, the greater the capacity of the particle; the more moderate the vibration of the string, the less energy the particle has. Then in Einstein’s mass-energy principle, both mass and energy are two ways of expressing the same thing: big energy represents big mass and small energy represents small mass. So the more violent the vibration, the greater the mass of the string, and conversely the more moderate the vibration, the smaller the mass of the string. Then in looking at the wave-particle duality in quantum mechanics, the volatility of the particle may be generated by the fluctuations of the string. Strings can have two topologies: open strings and closed strings. An open string has two endpoints and evolves freely in space-time with time to give a two-dimensional leaflet of the world. A closed string is a closed circle without endpoints that evolves freely in space-time to give a two-dimensional surface that is topologically equivalent to a column surface [12]. Two different strings can also collide with each other to produce a new string. String theory is primarily an attempt to resolve the apparent incompatibility of the two major theories of physics — quantum mechanics and general relativity — and to create a “theory of everything ‘ that describes the entire universe. However, this theory is very difficult to test and requires some adjustments to our picture of the universe, i.e., there must be more dimensions of space-time than the four known. The mathematical equations required for the theory to hold are 9 dimensions, plus the time dimension, is 10 dimensions, and further research has shown that a more complete understanding given by superstring theory reveals the 10th dimensional spatial orientation of string theory, so the maximum dimensionality of the theory is 11 dimensions. Some recent developments also suggest that people may live on a low-dimensional membrane, but gravity is still 10-dimensional, and to obtain a realistic 3-dimensional gravity, it can be explained by introducing a “shadow membrane” or Randall-Sundrum mechanism, which is a new way to bind gravity. A new approach to gravity. Scientists believe that these hidden dimensions may be rolled up so small that we do not detect them. Superstring theory is currently the most likely theory to unify the four fundamental interactions, but it has encountered some problems. If the unified field theory does exist, it has been found that there are actually 5 self-consistent superstring theories in ten dimensions. They are two IIA and IIB, a heterotic string theory with norm Apin(32)/Z2, a heterotic string theory with norm group E8×E8 and a type I string theory with norm SO(32), and they are not much in the perturbative framework differ. Specifically, they are of the same importance for the surrounding framework, but the unique one cannot currently found and the other four cannot excluded. Possible solutions are: 1) they are different on the surface, but they are intrinsically equivalent; 2) they can both unify relativity and quantum mechanics, which means that they are not the lowest level theory, they are just an expression of the lowest level theory for different situations or different aspects of the currently unknown theory. The existence of a larger theory, currently called M-theory, is predicted by linking one-dimensional strings with other superfilms on the basis of the original unified quantum mechanics and general relativity of perturbative string theory, and also by unifying all superfilms in a single theoretical framework, with these superfilms as the fundamental dynamical objects of the theory, while the previously mentioned models are several extreme cases of M-theory.

6. Discussion

This paper argues that in order to complete the unification of field theory or to improve string theory, one should first have the ability to create a new and more comprehensive mathematical system that can help physicists solve their problems. Just like Newton's invention of calculus, before the invention of calculus, people could not solve the instantaneous velocity, the derivation process of elliptical orbits of planets, the problem of the fastest descending curve, the problem of the tangent of a curve, the extreme value of a function, the volume of a complex sphere, and so on. But after the invention of calculus, not only were these problems solved, but it also provided a good mathematical method for the development of other fields.

7. Conclusion

The unified field theory is a dynamic theory that is still under research and is important for the development of physics, and many of the flaws in the theory are considered in this paper to be due to the lack of mathematical theory. However, it is very difficult to explore a new mathematical field, so future research on unified field theory requires mathematicians and physicists to have a deeper understanding of the mathematical field to create a good mathematical tool to standardize and visualize the unified field theory. This article stays only at the level of theory and ideas, without experimental studies to practice these theories. So future research will make practical experiments to verify these ideas in the future.

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