Discussion on fundamental charge and fine structure constants

summary

In order to reveal the deep physical nature of the fundamental charge e and the fine structure constant and the internal relationship between electromagnetism and gravity, the quantitative relationship between the ψ field and the mass density and electromagnetic parameters is constructed by solving the electromagnetic field tensor equation and analyzing the symmetry breaking mechanism with the ψ field describing the spatio-temporal properties as the core α，The expressions of key proportional coefficients k_3 and eigenquantities A_0 are derived，It also clarifies that the quantization of fundamental charges stems from the spontaneous breaking of spatio-temporal symmetry. Research has shown that：The dimensionless form of the ψ field is equivalent to the fine structure constant $\psi_0 = \frac{e^2}{4\pi\varepsilon_0\hbar c} = \alpha$；Feature quantities A_0 are not only consistent with values α，The coupling relationship between electromagnetic and gravitational action can also be established by the gravitational constant G。This paper provides some new suggestions for understanding the quantized nature of fundamental charges and the physical significance of fine structure constants from the perspective of field theory。

Key words: basic charge; fine structure constant; $\psi$is a wave-like function; symmetry breaking; electromagnetic field tensor; Gravitational coupling

引言

The fundamental charge (e) is the smallest quantum unit of the amount of charge, and its existence and quantization properties were directly verified for the first time by the Milligan oil droplet experiment [1]；Fine structure constants $\alpha \approx \frac{1}{137}$ as a dimensionless constant，Connect quantum mechanics（Reduce Planck's constant $\hbar$）、relativity（光速 c）and electromagnetism（Basic charge e、Vacuum dielectric constant ε_0），It is the core physical quantity that describes the coupling strength of electromagnetic interactions [2]。However, traditional research focuses on the experimental measurement and phenomenological application of the two, and the theoretical exploration of their deep physical nature (such as the relationship with space-time structure and gravity) is still insufficient。

This article redefines $\psi_{(r,t)}$ the meaning of wave function，It is directly related to the mass density and electromagnetic field tensor, and the electromagnetic field tensor equation under the condition of angular and spherical symmetry is solved，Combined with the symmetry breaking mechanism, the internal relationship between the fundamental charge and the fine structure constant is derived, and the spatiotemporal geometric root of charge generation is revealed，The quantitative coupling relationship between the fine structure constant and the gravitational constant G is established，It provides theoretical support for the unified study of electromagnetic and gravitational effects。

1 理论基础与基本假设

1.1 $\psi_{(r,\theta,\phi,t)}$ It is a space-time geometric structure field，Definition of mass in a unit volume： $\rho_{(r,t)}$ The relationship is defined as:：

$\rho_{(r,t)} = \left(\frac{\psi_{(r,\theta,\phi,t)}}{c}\right)^2 D_0$

$\psi_{(r,\theta,\phi,t)}$ The dimension is: Asm^{-2}

D_0 It is a dimensional matching number: $D_0 = \mathrm{k}_g \mathrm{m}^3 \mathrm{s}^{-4} A^{-2}$

1.2 Electromagnetic field-like tensors $F^{\mu v}$ are antisymmetric tensors that describe electromagnetic fields, and their matrix form is [4]:

$$F^{\mu v} = \begin{pmatrix} 0 & -\psi_x/c & -\psi_y/c & -\psi_z/c \\ \psi_x/c & 0 & -\mathrm{B}_z & \mathrm{B}_y \\ \psi_y/c & \mathrm{B}_z & 0 & -\mathrm{B}_x \\ \psi_z/c & -\mathrm{B}_y & \mathrm{B}_x & 0 \end{pmatrix}$$

dielectric constant, and permeability: $\varepsilon = \frac{1}{c}\frac{\psi}{B}$, $\mu = \frac{1}{c}\frac{B}{\psi}$

1.3 Basic equations:

$$\nabla_\mu \left(\frac{1}{\mu_{(r)}} F^{\mu v}\right) = 0$$

1.4 Under the spherical coordinate system, the 4 dimensions unfold:

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \cdot \frac{1}{\mu_{(r)}} F^{0r}\right) + \text{Angular term} = 0 \qquad (1)$$

1.3 Definition and value of core physical constants

The key physical constants involved in this article are as follows:

- Basic charge: e = $1.602176634 \times 10^{-19}$C (After the 2019 reform of the International System of Units, e was defined as a fixed constant [5]);
- Vacuum dielectric constant: ε_0= 8.8541878128 $\times$ 10^{-12} F/m;
- Reduce Planck's constant: $\hbar = \frac{h}{2\pi}$ = 1.054571817 $\times$ 10^{-34} J·s (h It is Planck's constant);
- Gravitational constant: G = 6.67430 $\times$ 10^{-11} $kg^{-1}.m^3\, s^{-2}$;
- Coupling constant: k= 2.226×10^{-19} s $kg^{-1}.m^2$ (It is derived from the coupling characteristics of gravity and electromagnetism [3])。

2. ψ Solution of tensor equations for field and electromagnetic field

The time-radial component of the "electric field-like" ψ with the electromagnetic field tensor F^{0r} is satisfied:

$$F^{0r} = \frac{\psi}{c}$$

2.1 ψ field solution with angular terms

in the equation: $\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \cdot \frac{1}{\mu_{(r)}} F^{0r}\right) + \text{Angular term} = 0$

If $\text{Angular term} \neq 0$, The simplest solution is: $\boldsymbol{\psi}_{(r,\emptyset)} = \frac{A\,sin(n\phi)}{r}$

where A is the amplitude constant, n is a positive integer (represents the number of angular patterns), $\boldsymbol{\phi} \in [0, 2\pi)$ It is the angular coordinate。

2.1.1The value of angular coordinates $\boldsymbol{\psi}_{(r,\emptyset)}$

Since $\boldsymbol{A\,sin(n\phi)}$ is a periodic function, its value range is [-1, 1]。

At this time, the angular coordinates are satisfied:

$\phi = \frac{\pi}{2n} + \frac{k_8\pi}{n}$ $(k_8 \in z, \phi \in [0,2\pi))$

In previous articles, we have already given:

$\mu = \frac{1}{c}\frac{B}{\psi}$ ，知 $\mu_{(r)} = -\frac{1}{c}\frac{B(r)}{\psi(r)}$ ， $B_{(r)} = c\psi(r)\mu_{(r)} = \frac{kC^2}{r^2}\,\mu_{(r)}^2$

composed: $\lambda = \frac{1}{2\mu_{(r)}}(B^2 - \frac{\psi^2}{C^2}) = k_3\,\frac{G_A}{C^4}$ (k_3 is the proportional coefficient, G_AGravitational coupling coefficient)

$\frac{1}{2\mu_{(r)}}(B^2 - \frac{\psi^2}{C^2}) = \frac{\psi^2(1-\varepsilon^2)}{2\varepsilon} = k_3\,\frac{G_A}{C^4}$

$k_3 = \frac{\psi^2(1-\varepsilon^2)}{2\varepsilon} \cdot \frac{c^4}{G_A} = \left(\frac{A\,sin(n\phi)}{r}\right)^2 \frac{(1-\varepsilon^2)}{2\varepsilon} \cdot \frac{c^4}{G_A}$

$k_5 = \frac{(1-\varepsilon^2)}{2\varepsilon} \cdot \frac{c^4}{G_A}$

$k_3 = \left(\frac{A\,sin(n\phi)}{r}\right)^2 k_5$

Now k_3 and k_5 are constants, to make $\left(\frac{A\,sin(n\phi)}{r}\right)^2$ with constant $k_3/\ k_5$ match, $\boldsymbol{sin(n\phi)}$ Extreme value is required (namely $sin(n\phi) = \pm 1$)。$sin(n\phi)$ is locked。At this time: $\phi = \frac{\pi}{2n} + \frac{k_8\pi}{n}$ $(k_8 \in z, \phi \in [0,2\pi))$

$k_3 = \left(\frac{A}{r}\right)^2 k_5 = \left(\frac{A}{r}\right)^2 \frac{(1-\varepsilon^2)}{2\varepsilon} \cdot \frac{c^4}{G_A} \approx \left(\frac{A}{r}\right)^2 \frac{1}{2\varepsilon} \cdot \frac{c^4}{G_A}$

And A = $A_0 r$ must be necessary to ensure that the above equation is always equal: $k_3 = \frac{{A_0}^2}{2\varepsilon} \cdot \frac{c^4}{G_A}$

2.2field solution in spherical symmetrical space-time$\boldsymbol{\psi}$

When $\phi \neq \frac{\pi}{2n} + \frac{k_8\pi}{n}$ $(k_8 \in z, \phi \in [0,2\pi))$, The equation is no longer satisfied: $\boldsymbol{\psi}_{(r,\emptyset)} = \frac{A\,sin(n\phi)}{r}$, The simplest assumption is spherical symmetric spacetime:

In spherically symmetrical spacetime (only related to radial r)., Expand it to the conservation of radial components (using ν = r, as an example, to describe the conservation of radial "electromagnetic flow"):

$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \cdot \frac{1}{\mu_{(r)}} F^{0r}\right) + \text{Angular term} = 0$

Due to the symmetry of the sphere, Angular term = 0, Therefore, the core equation is:

$\frac{\partial}{\partial r}\left(r^2 \cdot \frac{1}{\mu_{(r)}} F^{0r}\right) = 0$

To distinguish it from the previous ψ one , we will rewrite ψ as: ψ_2

$\frac{\partial}{\partial r}\left(r^2 \cdot \frac{1}{\mu_{(r)}} \frac{\psi_2}{c}\right) = 0$

Since the derivative is 0, the items in parentheses are constants(set to),if k then $k = r^2 \cdot \frac{1}{\mu_{(r)}} \frac{\psi_2}{c}$ where $\mu_{(r)}$ the permeability is:

$\psi_2(r) = \frac{kC\mu_{(r)}}{r^2}$ (4.1)

$\frac{1}{2\mu_{(r)}}\left(\left(\frac{kC^2}{r^2}\mu_{(r)}{}^2\right)^2 - \frac{1}{C^2}\left(\frac{kC\mu_{(r)}}{r^2}\right)^2\right) = k_3 \frac{G_A}{C^4}$ (where k_3 is a constant)

$\frac{1}{2\mu_{(r)}}\left(\frac{k^2C^4}{r^4}\mu_{(r)}^4 - \frac{1}{C^2}\frac{k^2C^4\mu_{(r)}^2}{r^4}\right) = k_3 \frac{G_A}{C^4}$ (4.1)

Write the (4.1) form transformation as: $\psi_2(r) = \frac{kC\mu_0}{r^2} = \frac{k}{r^2\varepsilon_0 c} = \frac{4\pi\hbar k/r^2}{4\pi\varepsilon_0\hbar c}$

Let $k_1 = 4\pi\hbar k$ we get: $\psi_2(r) = \frac{k_1/r^2}{4\pi\varepsilon_0\hbar c}$

Consider the following formula:

$q = -k_2\frac{d\Omega}{d\tau} / \Omega^2$ (Ω is the three-dimensional angle of rotation in space)。

Integrate it: $Q = \int q\, d\tau = \frac{k_2}{\Omega}$ Then .Q can be understood as the number of spatial displacement vectors per unit solid angle in a specified time (t_0, t)

$\psi_2 = \psi_{2(r,\theta,\phi,t)}$, If the spherical area is S, then $\Omega = \frac{S}{r^2}$

$\psi_2(r) = \frac{k_1/r^2}{4\pi\varepsilon_0\hbar c} = \frac{k_1\frac{1}{S}Q}{4\pi\varepsilon_0\hbar c}$

This $k_1\frac{1}{S}Q = 4\pi\hbar k\frac{1}{S}Q$ can be understood as the number of spatial displacement vectors per unit area in a specified time (t_0, t) per unit solid angle, and we tentatively define this thing as ${e_a}^2$:

${e_a}^2 = 4\pi\hbar k\frac{1}{S}Q$ At this time $\psi_2(r)$ It can be rewritten as:

$\psi_2(r) = \frac{{e_a}^2}{4\pi\varepsilon_0\hbar c}$

Relationship between Ω solid angle ϕ and azimuth: (Spherical symmetry scene).

$\Omega = \int_{\theta_1}^{\theta_2}\int_{\phi_1}^{\phi_2} \sin\theta\, d\phi\, d_\theta$

$\Omega_{(\tau)} = \left(1 - \cos\left(\Theta_{(\tau)}\right)\right) \cdot \phi_{(\tau)}$ When $\Theta_{(\tau)} = \Theta$ it has nothing to do with τ, $\Omega_{(\tau)} = (1 - \cos(\Theta)) \cdot \phi_{(\tau)}$ The smallest rotating unit of the space-time spiral structure, completely composed of ϕ。

As mentioned earlier:$\phi = \frac{\pi}{2n} + \frac{k_8\pi}{n}$ $(k_8 \in z, \phi \in [0,2\pi))$, So $\Omega_{(\tau)}$ it is also discrete。

2.2Comparison of the two situations:

Now let's take a look, compare ψ and ψ_2 match, They are in: $\phi = \frac{\pi}{2n} + \frac{k_8\pi}{n}$ $(k_8 \in z, \phi \in [0,2\pi))$ Just switch once:

$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \cdot \frac{1}{\mu_{(r)}} F^{0r}\right) + \text{Angular term} = 0$ (Angular term $\neq 0$, $\psi_{(r,\emptyset)} = \frac{A\, sin(n\phi)}{r}$)

to: $\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \cdot \frac{1}{\mu_{(r)}} F^{0r}\right) = 0$ (Angular term $= 0$, $\psi_2(r) = \frac{kC\mu_{(r)}}{r^2}$)

The reason why the values before and after the transformation are equal is that $\psi_{(r,\emptyset)}$ it is used to describe the points in space-time and the definition of mass in a unit volume: $\rho_{(r,t)} = \left(\frac{\psi_{(r,t)}}{c}\right)^2$

After transformation: $\rho_{(r,t)} = \left(\frac{\psi_{2(r,t)}}{c}\right)^2$

So in terms of values: $|\psi_{(r,t)}| = |\psi_{2(r,t)}|$, The following is not a distinction between ψ and ψ_2 in the case of discussing values alone。

The number of switches per unit time is directly determined by the sizee_a。"One switch corresponds to one displacement vector" , For example, when ϕ from $\frac{\pi}{2n}$ to $\frac{\pi}{2n} + \frac{\pi}{2}$, The spatiotemporal structure completes one discrete change, corresponding to one displacement vector。

The number of switches in a unit time is n (this n is 0 or a positive integer)., In the function $sin(n\phi)$: the greater n, The smaller the switching step $\frac{\pi}{2n}$ of ϕ, The more switches per unit angle (i.e., the more frequent the switching)

On the unit area S, the total number of spatial displacement vectors n can be written as on Ω the unit solid angle per unit time:

n $D_1 = e_a D_2 = \left(4\pi\hbar k \frac{1}{S} Q\right)^{\frac{1}{2}}$

where D_1, D_2 is dimensional matching.

D_1: Corresponding to "linear density of the space-time spiral", the dimension m^{-1} is described as "the number of switching units distributed on the space-time spiral per unit length", ensuring that the dimension of nD_1 is ((switching frequency × linear density) $S^{-1}m^{-1}$

D_2: Corresponding to the "coupling coefficient of charge and space-time switching unit", the dimension is: ASm, and the dimension of the make is $e_a D_2$: ASm (charge × coupling coefficient).

And "unit area S, the number of spatial displacement vector bars passing through per unit time and per unit solid angle"

$n^2 D_1^2 = {e_a}^2 D_2^2 = 4\pi\hbar k \frac{1}{S} Q$

When n = 1:

$$\text{Number of displacement vectors} = \text{n} = 1$$

$$e_a = \text{Number of displacement vectors} = \text{n}$$

So we guess that this charge should be the smallest charge$\mathrm{n} = 1$, Without this switch, n=0, There will be no charge, which is commonly referred to as "symmetry breaking"。So we can define e_a the value of this as:: $e_a = 1$

In the case of ball symmetry, the angular term is 0, and it does not change over time, $\psi(r)$ It has nothing to do with r,

We get: $\psi = \frac{e_a{}^2}{4\pi\varepsilon_0\hbar c}$

That is to say, when the symmetry of the system is broken and transitions from the state with angular structure to the spherical symmetry state, φ it is frozen in the discrete direction of $\sin(n\varphi) = \pm 1$, at which point the angular degree of freedom disappears and the effective charge appears.

3. Notes on the basic charge e:

However, we have said that this smallest charge has long been defined in physics, called the fundamental charge, and its value is determined by Ampere's law, and he makes numerical provisions in order to harmonize with the existing physical quantity:

Reforms after 2019:To make the unit definition more stable (away from physical standards), the SI redefines amperes as "Based on fundamental charge (e) and Planck's constant (h)"。Specifically, 1 amp is defined as "the current when the base charge e flows at a rate of 1.602176634 C× 10^{-19}."

Current at 1/e through conductor cross-section in 1 second"(i.e., 1 A = 1 $\frac{C}{s}$, and 1 C = 1/e × 10^{19} of the amount of basic charge.))

The essence of this association is that humans have redefined the unit of current (amperes) by using the "current-charge relationship" described by Ampere's Law to make it linked to a fixed value of the fundamental charge. During the whole process, the physical value of the basic charge remains unchanged, and only the "standard" for human quantification of macroscopic electromagnetic quantities changes, so that the values of the two have a direct and fixed connection. That is, this value is not calculated but prescribed, so we can use this value directly.

Moreover, the Milligan oil droplet experiment illustrates the physical significance of the basic charge, and also implies that the value of the charge should be countable.

4. The result is obtained by connecting the above conditions:

So the above $e_a = 1$ is changed to: $e_a = \mathrm{e}$

Set ψ_0 = $\frac{e^2}{4\pi\varepsilon_0\hbar c}$ = α (Here ψ_0 is a dimensionless constant, α is a fine structure constant), n = $kg^{\frac{1}{2}}m^{-\frac{1}{2}}s^{-1}$ (Here n is the dimensional matching number)

We get: $\psi = \frac{e_a{}^2}{4\pi\varepsilon_0\hbar c}\,\mathrm{n} = \frac{e^2}{4\pi\varepsilon_0\hbar c}$ n = ψ_0 n

The "solid angle (Ω)" and "rotational angular velocity $\frac{d\Omega}{d\tau}$ " here are essentially quantitative descriptions of the spatial geometry (angular distribution of spiral motion) - that is, the physical meaning of e is directly determined by the structural parameters of the spiral motion in space.

Then = $\psi_0 = \frac{e^2}{4\pi\varepsilon_0\hbar c}\alpha = \frac{1}{137.036}$ This is the fine structure constant.

Compare the following formula:

$G_{\mu\nu} = \frac{8\pi G}{C^4} T_{\mu\nu}$

Unify the constants:

$G = kG_A = kc$ (kIt is a constant) $k = \frac{G}{c} = 2.226 \times 10^{-19}$ s $kg^{-1}.m^2$

Now by: $\frac{\psi^2(1-\varepsilon^2)}{2\varepsilon} = k_3 \frac{G_A}{C^4}$ get:

$$k_3 = \frac{e^4 c(1-\varepsilon_0{}^2)}{32\pi^2\varepsilon_0{}^3\hbar^2} \approx \frac{e^4 c}{32\pi^2\varepsilon_0{}^3\hbar^2} \approx 8.12 \times 10^{31} \quad (k_g m^6 / (c^2 \cdot s^5))$$

$\frac{k_3}{c^3} = \frac{\alpha^2}{2\varepsilon}$

$\frac{k_3}{c^3} = \frac{A_0^2}{2\varepsilon}$

get: $\alpha = A_0 n_0 = \left(2\varepsilon_0 k_3 \frac{G}{C^4 k}\right)^{\frac{1}{2}}$ The appearance of this formula is a bit unfamiliar to people, we can substitute the value of k and k_3 calculate it:

molecule: $2\varepsilon_0 k_3 G = 9.61 \times 10^{10}$

denominator: $C^4 k = 1.803 \times 10^{15}$

$A_0 = 7.3 \times 10^{-3}$

n_0 It is a dimensional matching number: $n_0 = m^{-1}$

Under the assumption of isotropy of the electromagnetic field, high symmetry in space-time, and weak/uniform field, the following can be approximately obtained:

$R_{\mu\nu} = \lambda g_{\mu\nu}$ Result: R = 4 λ (R is the radius of curvature)

$\lambda = \frac{\psi^2(1-\varepsilon^2)}{2\varepsilon} = k_3 \frac{G_A}{C^4}$

$\frac{A_0^2 n_0^2}{2\varepsilon} = \frac{\alpha^2}{2\varepsilon}$

$\alpha^2 = 2\,\varepsilon_0\,\lambda\,n_1 = \frac{1}{2}\,\varepsilon_0$ R n_1 (n_1 is a dimensional match, $n_1 = kg^{-1}m^{-2}s^3A^2$)

$\alpha^2 = \frac{1}{2}\,\varepsilon_0$ R n_1

n_1It can be understood as "isotropic source density dimension related to the coupling of space-time geometric fields and magnetic fields". The $\boldsymbol{\lambda}$ isotropic energy density of the electromagnetic field can also be understood as a "measure of curvature strength". So α^2it is related to the vacuum dielectric constant ε_0 and the radius of curvature R.

$\psi_{(r,\emptyset)} = \frac{A\,sin(n\phi)}{r} = \alpha\,sin(n\phi) \quad \phi = \frac{\pi}{2n} + \frac{k_8\pi}{n} \;\; (k_8 \in z, \phi \in [0,2\pi))$

$\psi(r) = \frac{kC\mu_{(r)}}{r^2} \quad \phi \neq \frac{\pi}{2n} + \frac{k_8\pi}{n} \;\; (k_8 \in z, \phi \in [0,2\pi))$

4.1 The symmetry breaking mechanism of the fundamental charge is described

The quantization of fundamental charges arises from the spontaneous symmetry of the space-time field from "non-spherical symmetry" to "spherical symmetry":

1. **Aspherical symmetry phase**: ψ is $\psi_{(r,\emptyset)} = \frac{A\,sin(n\phi)}{r}$, Angular degrees of freedom exist, but the charge correlation e_a is not quantized;

2. Symmetry breaking trigger: when $\phi = \frac{\pi}{2n} + \frac{k_8\pi}{n}$ $(k_8 \in z, \phi \in [0,2\pi))$时, $sin(n\phi) = \pm 1$, The angular degrees of freedom are frozen, space-time turns into spherical symmetry, and the ψ field is fixed $\psi = A_0 = \alpha$);
3. Charge quantization: spherical symmetry stage $\psi_0 = \frac{e^2}{4\pi\varepsilon_0\hbar c} = \alpha$, The charge correlation e_a amount degrades to the basic charge e, And it satisfies the quantization characteristic of "the amount of charge is an integer multiple of e", which is consistent with the observation results of the Milliken oil droplet experiment [1]。

conclusion:

The generation of electric charge is made by:: $\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \cdot \frac{1}{\mu_{(r)}} F^{0r}\right) + \text{Angular term} = 0 \quad (\text{Angular term} \neq 0)$

and: $\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \cdot \frac{1}{\mu_{(r)}} F^{0r}\right) = 0 \quad (\text{Angular term} = 0)$

$\psi_0 = \frac{e^2}{4\pi\varepsilon_0\hbar c} = \alpha$ It emphasizes the relationship between fine structure constants and (e, ε_0, $\hbar$, c).。

$A_0 = \alpha = \left(2\varepsilon_0 k_3 \frac{G}{C^4 k}\right)^{\frac{1}{2}}$ The relationship between the fine structure constant and the gravitational constant G is emphasized。

The quantization of fundamental charges stems from the spontaneous symmetry of space-time from non-spherical symmetry to spherical symmetry, and the freezing of angular degrees of freedom is the direct cause of charge quantization, and the "immobilization" of its values is the result of the coordination of macroscopic electromagnetic units and microscopic quantum quantums, without changing its physical essence.