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Double Helix Wave-Particle Structures of Photon and ± Charged Elementary Particles. The Equation of Motion of the Particle with Both Intrinsic Spin and Double Helix Structure has the Same form as the Schrodinger Equation

Sennian Chen[1*]

[1]Department of Physics, National Huaqiao University, Fujian, P.R. China.

Author's contribution

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

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ABSTRACT

Photon and ± charged elementary particles have many commonalities like constant spin, duality, $\epsilon = h\nu$ etc. The purpose of this paper is trying to find out why such particles have the commonalities and how to make the commonalities. The first part of this paper is to derive and prove that the photon is consisted of an energy packet and a closely connected circular polarized EM wave with much smaller energy. The energy packet is a thin piece of circular polarized **EH** field wrapped by a cylindrical side membrane with helical distributed $\pm e$. Double helix structure of field **EH** in the energy packet plus intrinsic speed c being proved makes almost all the basic properties of photon in the paper. The wave-particle properties in the structure of photon plays a roll together in the process of emission, absorption and interference. Such structure makes the photon to act as both a wave and a particle at the same time, not "exhibit different characters for different phenomenon". It makes the dispute in the double slit experiment unnecessary. ± Charged elementary particles produced from a photon in the pair production will be proved in the paper it is

**Corresponding author: E-mail: chensennian@gmail.com;*

split equally point to point from the photon. So the particles possess double helix structure of mass density and charge $-e$ (or $+e$). The helically distributed charge $-e$ (or $+e$) carries a circular polarized external **E**-field to move with the same velocity V (a wave really). $\in, p$ Of the charged elementary particle and ν, λ of this E-wave will be proved to satisfy the de Broglie Relation here. It naturally leads to the differential equation of motion of such particles mathematically as same as the Schrodinger equation. Such differential equation of motion for the non-relativistic particles will be proved it is for the circular polarized structure and wave. Difference between helical $-e$ (or $+e$) and helical $\pm e$ makes the $\pm$ charged elementary particles and photon distinguishable or undistinguishable by the magnetic **B** effect and to obey different statistics, F-D statistics or B-E statistics; and obey the Pauli Exclusion Principle or not. Since the spin direction of the photon and $\pm$ charged elementary particles are decided by the direction of helical structure, anyone of these particles can only possess a definite direction of spin, so the entanglement is like a pair of gloves disregard of how far the distance between them. Because a particle cannot locate at two positions or possess two different magnitudes of energy at the same time, (otherwise, the particle will split or move with different speed simultaneously), the particle itself can take only one basis state (e.g. at a point in the interference pattern or in an eigen state of the atom or molecule) any time. Therefore, the idea like wave function collapse, electron cloud and both alive and dead Schrodinger cat are no longer necessary. At last, it is a proof that there is a particular relativistic property of the $\pm$ charged elementary particles in the equal energy process. It will affect the physical and chemical process in the atom and molecule.

Keywords: Double helical wave-particle structure; boundary membrane; $\in$-(energy) packet; ψ-(em) wave; intrinsic spin; intrinsic self-rotation; $\vec{\Phi}$-inertia vector; Φ-wave.

1. INTRODUCTION

Photon and $\pm$ charged elementary particles have many commonalities like constant spin, duality, $\in = h\nu$ and $p = h/\lambda$, etc.[1,2] Is there any mechanism to make these commonalities? Is it owing to having similar structures? A useful clue for our purpose is that the classical EM theory predicts that helical distribution of vector **E, H** plus speed c make the circular polarized light's angular momentum. [3,4] As for the photon, it possesses speed c and spin $\hbar$, weather photon spin and other basic properties are also owing to the similar **E, H** structure plus c ?

Our first object of study is an ordinary symmetrical EM-wave beam. We do not presuppose it having any relation with the photon and quantization. What we do is trying to find out the properties of the wave beam. Based on the experimental evidences, well known physical laws, theories and theoretical reasoning, we will prove that the EM beam is circular polarized; it is composed of an $\in$ - (energy) packet and a conical ψ - (EM) wave. $\in$ - Packet is a small and thin slice of circular polarized **E, H** field with energy $h\nu$ wrapped by a cylindrical side membrane. There is a pair of charges $\pm q$ distributed helically along the side membrane. Quantization of charge requires $\pm q = \pm e$, (or $\pm ne$), so the $\in$-packet is quantized. The $\in$-packet will be proved having many basic properties they are almost as same as the photon's like $\in = h\nu$, spin=constant $\hbar$, etc; the $\in$-packet floats on the front of the conical ψ-wave and moves together. $\in$-Packet and ψ-wave play a role together and simultaneously in the process of emission, absorption and interference; they exhibit wave property and particle property at the same time.

Next, we will prove the $\pm$ charged elementary particles produced from a photon in the pair production are split equally point to point from the photon, so, each particle produced has a helical structure and intrinsic spin $+\frac{\hbar}{2}$ or $-\frac{\hbar}{2}$. $\in, p$ Of the particle and ν, λ of the circular polarized **E** field carried by the helical distributed moving $-e$ or $+e$ will be proved to satisfy the de Broglie relations. Then differential equations of motion of such particles with both intrinsic spin and helical structure have the same mathematical form as the Schrodinger equation.

We will use the word "intrinsic" in the paper to modify the spin of the elementary particles under the meaning that the magnitude of spin is unchangeable under any condition as long as it is the particle itself.

2. THE SYMMETRICAL EM BEAM IS CIRCULAR POLARIZED AND HAS A SIDE MEMBRANE

The field intensity of a vibrating electric dipole at point O is. [5]

$$E(\rho,\vartheta,\nu,t)=\sqrt{\frac{\mu_0}{\varepsilon_0}}H=\frac{\pi \mathrm{M}_0\nu^2}{c^2\varepsilon_0\rho}\sin\vartheta\cos\omega(t-\frac{\rho}{c}) \qquad (1)$$

It gives $E=H=0$ when $\vartheta=0$. For any symmetrical EM beam from point O, **s**ymmetry demands its wave surfaces circular, the beam conical and $d\vartheta$ small enough. The beam will have $E=H=0$ at the tangent points if its lateral boundary is tangent to the line of $\vartheta=0$. Owing to the symmetry, all these symmetrical beams from point O must have $E=H=0$ on their whole lateral boundaries. Further more speaking, any other symmetrical beam from O must have the same property if its boundary is tangent to the former and so on. Then, the first important property of the symmetrical EM beams from point O is that its lateral boundary always satisfies $E=H=0$.

Let x,y be the rectangular coordinates on the wave surfaces, $z=\rho$ be the radius vector of the beam from point O and R be the radius of wave surface. Then the wave function of a symmetrical EM wave beam from point O is

$$E(r,z,\nu,t)=E_0(r,z)\cos 2\pi(\frac{t}{T}-\frac{z}{\lambda})$$

$$(E_0=A(\frac{r}{R})\frac{\nu^2}{z}\succ 0\ ,\ r=\sqrt{x^2+y^2}\prec R\ ,\ 0\prec\nu\prec\infty) \qquad (2)$$

We do not presuppose this wave beam has any relation with the photon and quantization.

For brevity, let us call the geometrical plane that is perpendicular to the EM beam the "observation plane (O-plane)". Of course, if the beam is conical, the "O-plane" implies the concentric spherical surfaces.

Eq. (2) will excite a standing wave on the O-plane at point z. Let $t=t'-\frac{z}{c}$, the standing wave function is

$$E(r,z,\nu,t)=A(\frac{r}{R})\frac{\nu^2}{z}\cos 2\pi\frac{t}{T} \quad (0\prec r\prec R\prec\infty)$$

$$A(\frac{r}{R})_{r=R}=0 \qquad (3)$$

The amplitude is always even and equal to zero at the side boundary $r=\pm R$. Its Fourier series is

$$A(\frac{r}{R})=\sum_{j=1}^{\infty}b_{2j-1}\cos 2\pi(2j-1)\frac{r}{4R}\overset{let}{=}\sum_{j=1}^{\infty}b_{2j-1}\cos 2\pi(2j-1)\frac{r}{\Lambda}$$

$$(\Lambda=4R\ ,|r|\le R) \qquad (4)$$

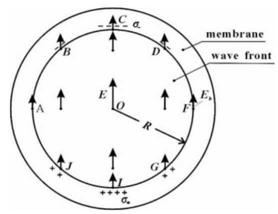

Fig. 1. Axial symmetry of $\vec{E}(E_x,E_y)$ on the $\in$-packet and circular polarized light cross sections. It forms double helix EH distribution along z. ($\vec{H}$ not drawn here)

Substitute Eq. (4) into (3), we have

$$E=\frac{\nu^2}{2z}\sum_{\kappa=2j-1,\,j=1}^{j\to\infty}[b_\kappa\cos 2\pi(\frac{r}{\Lambda_\kappa}-\frac{t}{T})+b_\kappa\cos(\frac{r}{\Lambda_\kappa}+\frac{t}{T})]$$

$$\overset{let}{=}E_+(r-\nabla t)+E_-(r+\nabla t)$$

$$(\Lambda_\kappa=\Lambda_{2j-1}=\frac{\Lambda}{2j-1},\ \Lambda=4R,\ \nabla=\frac{\Lambda}{T},\ |r|\le R) \qquad (5)$$

Here functions $E_+(r-\nabla t)$ and $E_-(r+\nabla t)$ are two compound traveling waves along opposite radial directions on the O-planes. It leads to the following three results: (A), (B) and (C):

(A) Symmetry requires all b_{2j-1} and eq. (4), (5) unrelated to the r direction. Since the radiation of vibrating $\vec{E}$ is anisotropic, [5] it will make the coefficients b_{2j-1} different in the different r-directions. So the EM-wave beam must be circular polarized (important property **II**). It makes the time average of any coefficient and $A(\frac{r}{R})$ to be rotational symmetry on the O-planes

The wave function of the right circular polarized conical EM- wave beam can be written as

$$E(r,z,\nu,t)=E_0(r,z)e^{2\pi i(\frac{z}{\lambda}-\nu t)}$$

$$(r\prec R\ ,\ E_0(r,z)=A(\frac{r}{R})\frac{\nu^2}{z}\succ 0\ ,\ \nu\lambda=c)$$

$$E(R,z,\nu,t)=0 \qquad (r=R) \qquad (6)$$

(B) Since the compound traveling waves $E_+(r-\nabla t)$ and $E_-(r-\nabla t)$ are tangent to the O-plane and all radial, so the energy flows that pass through any cross section in a same sector are equal. That is

$$S_+(r_i,z,t)r_i\delta\theta\delta z = S_+(r_\kappa,z,t)r_\kappa\delta\theta\delta z \quad (-R \prec r_i \prec r_\kappa \prec R) \tag{7}$$

Poynting Vectors tangent to the O-plane is $S_- = S_+ = \sqrt{\frac{\varepsilon_0}{\mu_0}}E_+^2 = \sqrt{\frac{\varepsilon_0}{\mu_0}}\frac{A^2(\frac{r}{R})}{z^2}\nu^4\sin^2\theta \succ 0$ .Let $r_i = r$, $r_\kappa \to R$ in eq. (7) and let $\lim_{r\to R} A(\frac{r}{R}) = +const. \overset{let}{=} A_R$ be the limit at the side boundary; the important property **III** is

$$A(\frac{r}{R}) = A_R\sqrt{\frac{R}{r}} \qquad (\ 0 \prec r \prec R\ ,\ A_R = \lim_{r\to R} A(\frac{r}{R})\ )$$

$$A(\frac{r}{R})_{r=R} = 0 \tag{8}$$

(C) for any θ , the limits of the Poynting Vectors $\lim_{r\to\pm R} E_\pm(\frac{r}{R}) = A_R\frac{\nu^2}{z}\sin\theta$ at two boundaries are equal and not zero in general. On the other hand, since all $\left|\cos 2\pi(2j-1)(\pm\frac{r}{4R})\right|_{r=\pm R} = 0 \quad (j=1,2,...)$, so eq. (5) gives

$$\left|E_+(r-\nabla t)+E_-(r+\nabla t)\right|_{r=\pm R} \equiv 0 \tag{9}$$

The compound traveling wave $E_+(r-\nabla t)$ and $E_-(r-\nabla t)$ tangent to the O-plane will reflect at the side boundary with 180^0 phase loss and becomes $E_-(r-\nabla t)$ and $E_+(r-\nabla t)$. It means that the train's whole side boundary surface is a surface of perfect reflection for the compound traveling wave $E_+(r-\nabla t)$ and $E_-(r-\nabla t)$. As well known, the reflection of EM wave can not happen between the vacuum or field itself; Reflection can only happen at the interface between two different media [4,5] For this circumstance, the only possibility is there must be a mass less media differed from vacuum, named membrane always around the side boundary to make the perfect reflection and keeps all EM beam's energy inside the boundary surface, not to diverge (important property **IV**).

We may be very shocked by the "EM-beam wrapped by a side membrane" It seems to be unbelievable. But in fact, when we used to say "photon is an energy packet", we really need an understood that the energy must be in a very small "carrier" or "box" differed from vacuum, otherwise nothing can prevent any kind of energy to diverge.

The existence of the side membrane leads to the following four results (C_1), (C_2), (C_3) and (C_4):

3. DOUBLE HELIX DISTRIBUTION OF $\pm$ CHARGES e AND STRESSES IN THE SIDE MEMBRANE. THE SYMMETRICAL EM BEAM IS CERTAINLY QUANTIZED

(C_1) The EM momentum rate of change perpendicular to the arc ds on the boundary is $\frac{2S(R,z,\theta)}{c}ds$. It will make a pair of circular tension $T(R,z,\theta)$ at two ends of the arc ds . According to the mechanical equilibrium condition, we have $2T\,d\varphi = 2T\frac{ds}{2R} = \frac{2S}{c}ds$. Where $d\varphi$ is the angle between the tangent and T . R Is the curvilinear radius of the wave surface. So

$$T(R,z,\theta) = \frac{2R}{c}S(R,z,\theta) = \frac{2R}{cz^2}\sqrt{\frac{\varepsilon_0}{\mu_0}}A_R^2\nu^4\sin^2\theta \tag{10}$$

The tension $T(R,z,\theta)$ on the boundary cross sections distributes double helically along z-axis. Maximum stress $\Sigma_{\max}$ happens at the points A and F ($\theta = \pm 90^0$) of all the wave surfaces.

$$\Sigma_A = \Sigma_F = \Sigma_{\max} \propto \frac{R}{z^2}A_R^2\nu^4 \tag{11}$$

Maximum $\Sigma_{\max}$ at the points A and F forms double helix along z-axis (important property **V**).

(C_2) Surface charge density σ_θ on the inner side of the membrane is $\sigma_\theta = D_n = \varepsilon_0 E_n$. Since $E_n = \frac{A_R}{z}\nu^2\cos\theta$, Fig. 1, so for the upper helical half the absolute value of σ_θ is

$$\sigma_\theta = \left|\varepsilon_0\frac{A_R}{z}\nu^2\cos\theta\right| \qquad (\ 0 \le \theta \prec \pi\ ) \tag{12}$$

The points of the same σ_θ (+ and -) on the inner side of the membrane form equal σ_θ-double helix along z-axis. The charges also distribute helically like the distribution of Σ and $\Sigma_{\max}$ (important property **VI**).

Total negative charge in the upper helical half of the membrane is

$$q = \int_{z}^{z+\delta} dz \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \sigma_\theta R\, d\theta = 2\varepsilon_0 \Phi A_R \nu^2 \delta \qquad (\Phi = \frac{R}{z}) \qquad (13)$$

The lower half has the same amount of $+q$. Where δ is the length of the charged side membrane.

According to the quantization principle of charge, the train with $q = \pm e$ is the lowest energy train that can exist isolated in reality. The others are $\pm ke\ (k = 2,3,...)$. Let us name the one ($q = \pm e$) as elementary train, if it possesses $\pm$ charge e, lowest energy $\in$ and shortest length δ (important property **VII**).

4. ELEMENTARY TRAIN IS COMPOSED OF AN $\in$ -(ENERGY) PACKET AND A CONICAL ψ -(EM) WAVE

(C_3) The wave surfaces will become bigger and bigger when the conical train moves forward. Maximum radius $R_{\max}$ must exist, otherwise the train will be broken at last and no finite energy ($\succ \varepsilon \succ 0$) can go far. It contradicts the observation facts.

When the EM train just emitted from a point source, its energy distributes all over the conical train. After the radius grows up to the $R_{\max}$, all or at least absolute majority energy will be restricted in a cylindrical side membrane of radius $R_{\max}$. We name it as $\in$-(energy) packet. The rest of it is a closely connected conical wave, named ψ - (EM) wave. The elementary train is composed of an $\in$-(energy) packet and a conical ψ -(EM) wave. They satisfy the same circular polarized wave function, eq. (6). They move synchronically with the same phase in free space until meeting an obstacle (important property **VIII**).

$\in$ -packet is a circular polarized **E,H** field wrapped by a cylindrical side membrane with helical distributed $\pm e$. Mechanical equilibrium among the helical distributed $\pm e$ and the stresses Σ_θ in the cylindrical membrane and the circular polarized EM field inside construct a very steady structure to keep its integrity, shape and size. The membrane is also an EM shield to prevent the external EM influences during the propagation.

We will prove that the $\in$-packet and ψ -wave structure makes the elementary train(s) to act as both a wave and a particle all the time, not “exhibit different characters for different phenomenon [3,6].

5. DERIVATION AND PROOF OF THE $\in$- PACKET’S OTHER BASIC PROPERTIES

(C_4) Since the EM-beam is very narrow, we can let $d\sigma_r = 2\pi z^2 \sin\varphi\, d\varphi \approx 2\pi r\, dr$ be the area of the ring on the wave surface. According to the Maxwell theory, average energy $\in$ of the conical $\in$-packet is

$$\in = \frac{1}{2}\int_{z-\delta}^{z} dz \int_0^R \varepsilon_0 \frac{A^2(\frac{r}{R})}{z^2} \nu^4 2\pi r\, dr \qquad (z \prec z_0 - L) \qquad (14)$$

Here we suppose the energy of the membrane can be neglected in comparison. L Is the length of the elementary train or ψ - wave, L is to be decided; δ is the length of the $\in$ -packet and membrane (we do not know if it is equal to L or not here); z_0 is the distance between the point source O and the end of the elementary train when its energy packet just becomes totally cylindrical. Eq. (14) and (8) give us

$$\in = \frac{1}{2}\int_{z-\delta}^{z} dz \int_0^{\Phi} 2\pi\varepsilon_0 A_R^2 \Phi\, \nu^4 d\varphi = \pi\varepsilon_0 A_R^2 \Phi^2 \nu^4 \delta$$

$$(\Phi = \frac{R}{z} = \frac{R_{\max}}{z_0}) \qquad (15)$$

After the $\in$ -packet becomes cylindrical, its amplitude is $A_R \sqrt{\frac{R_{\max}}{r}} \nu^2$. So for $z \succ z_0$, $\in$ -packet energy is

$$\in = \frac{1}{2}\int_{z_0}^{z_0+\delta} dz \int_0^{R_{\max}} 2\pi\varepsilon_0 A_R^2 R_{\max} \nu^4 dr = \pi\varepsilon_0 A_R^2 R_{\max}^2 \nu^4 \delta \qquad (16)$$

According to the conservation law of energy, Eq. (15) and (16) must equal, it leads to $z_0 = 1m$ for any ν. Any elementary trains of different frequencies spend the same time t_0 to become cylindrical:

$$t_0 = \frac{z_0}{c} = \frac{1}{c}\sec \qquad (z_0 = 1m) \qquad (17)$$

It is the important property **IX**. Eliminate δ from Eq. (13), (16) and let $q = e$, we have

$$\in = h\nu \qquad (18)$$

$$h = \frac{\sqrt{3}}{4} ceA_R \qquad (19)$$

h Is a constant independent of frequency ν. The energy that the $\in$-packet carries is proportional to the frequency ν (important property **X**) [7,8].

Quantization of EM energy is a consequent inference of the Maxwell EM theory itself as Einstein expected when he was alive. In fact, in 1905, Einstein first proposed that energy quantization was a property of EM radiation itself. The pivotal question was then: how to unify Maxwell's wave theory of light with experimentally observed particle nature? The answer to this question occupied the rest of Einstein's life, [9;10] although it was solved by the quantization way: quantum electrodynamics and its successor [7,11]. It is a pity that these theories paid little attention to the photon structure and the mechanism of spin. The work of this paper shows that the direction Einstein insisted is very instructive.

According to the special relativity $\in = mc^2$, the definition of inertia moment and eq. (16), the $\in$-packet's moment of inertia about z-axis on the O-plane is

$$I = \frac{\delta}{2}\int_0^{R_{\max}} r^2 \frac{\varepsilon_0}{c^2} A_R^2 R_{\max} \nu^4 2\pi dr \overset{(16)}{=} \frac{\in R_{\max}^2}{3c^2} \qquad (20)$$

During a beam of circular polarized light is incident on an absorbing surface, classical EM theory predicts that the surface must experience a torque. The calculation gives the torque T per unit area as [4], p219 of [3]

$$\mathrm{T} = \frac{\mathrm{I}}{2\pi\nu} \qquad (21)$$

Irradiance I of the beam is the power per unit area that the unit surface absorbs every second.
Since EM energy is quantized as proved in (C), let N be the number of $\in$-packets that hit the unit surface every second. So, N is the number of $\in$-packets in the cube $1(m^2)\times c(m)$ of the train that hits the unit surface with c in a second. Total spin and total energy of the $\in$-packets that the unit surface absorbs in a second is $\mathrm{T} = N\Sigma$ and $\mathrm{I} = N\in$ respectively. Where Σ and $\in$ are the $\in$-packet's spin and energy. So

$$\Sigma = \frac{\in}{2\pi\nu} \qquad (22)$$

According to the definition of particle's angular momentum $\Sigma = 2\pi\nu I$ and eq. (20), (22), we have

$$R_{\max} = \frac{\sqrt{3}c}{2\pi\nu} \qquad (23)$$

For visible light, if we take $\lambda = 6\times10^{-7}m$, then $R_{\max}$ is $1.7\times10^{-7}m$. The area $\pi R_{\max}^2 \approx 10^{-12}m^2$ of the $\in$-packet's cross section is really very small. It is a measure of the $\in$-packet's area of collision.

On the other hand, Eq. (18) and (22) give us the spin of the $\in$-packet with right helical structure:

$$\Sigma = \frac{h}{2\pi} \overset{let}{=} \hbar \qquad (24)$$

$\hbar$ Is a constant disregard of frequency ν. It is the translation motion of the helical structure of **E, H** plus intrinsic speed c make the $\in$-packet's constant spin $\hbar$ and $\in = h\nu$ (Speed condition is understood, because the condition $\nu\lambda = c$ in the eq. (6) must be satisfied)

If the elementary train is left circular polarized, its spin $-\hbar$ is in the opposite direction of helix on the O-planes independent of its travel direction +z or -z. $\in$-Packet's spin, right or left is decided by the direction of its **E,H** helical structure, not other factors. **$\in$-Packet can take only one fixed spin $\hbar$ or $-\hbar$** (important property **XI**).

On the other hand, since $z_0 = 1m$ and $\Phi = \frac{R_{\max}}{z_0} = R_{\max}$; let $q = e$, then Eq. (13) and (19) give:

$$\delta = \frac{\pi e^2}{4\varepsilon_0 h\nu} \qquad (25)$$

If we take h as Plank constant, then

$$\frac{\delta}{R_{\max}} = \frac{\sqrt{3}\pi^2 e^2}{6c\varepsilon_0 h} \approx 0.04 \qquad (26)$$

The $\in$-packet is a small and thin slice of circular polarized **E-H** field floating on the front of the ψ-wave.

Since the $\in$-packet possesses energy $\in = h\nu$, definite shape and volume, it is really a particle. So we can use Einstein relativistic formula $\in^2 = p^2c^2 + m_0^2c^4$ to it and let $m_0 = 0$, it gives

$$p = \frac{h}{\lambda} \qquad (\vec{p} = h\vec{\kappa}\,,\ \kappa = \frac{1}{\lambda}) \tag{27}$$

$\in$ -Packet possesses a momentum $p = h/\lambda$ (important property XIII).

$\in$-Packet as a mass less particle of speed c, it of course can play the role of force carrier for EM force.

Owing to the helical distributed $\pm e$ and extremely small size, the external electric and magnetic fields of the $\in$-packet's $\pm e$ will offset each other respectively, so the $\in$ - packet is "charge free" and "magnetic free". The $\in$ - packets with different spin directions are no way to distinguish. They are rigorously identical. This must be the reason why the $\in$-packets obey B-E statistics (important property **XIV**). [12], p212 in [7].

The classical formula of total power P emitted by a vibrating electric dipole $\mathrm{M} = \mathrm{M}_0 \cos 2\pi\nu t$ is

$$\mathrm{P} = \frac{16\pi^3 \mathrm{M}_0^2 \nu^4}{3\varepsilon_0 c^3} \overset{(19)}{=} \left(\frac{64\sqrt{3}\,\pi^3 \mathrm{M}_0^2}{9\varepsilon_0 c^4 e A_R}\nu^3\right) h\nu \overset{let}{=} N h\nu \tag{28}$$

Here N is the number of the elementary trains radiated every second. The source radiates $N \propto \nu^3$ $\in$ -packets every second and every $\in$-packet has energy $\in = h\nu$, so its radiative power is $\mathrm{P} \propto \nu^4$. The classical difficulty in the explanation of $\in = h\nu$ and $\mathrm{P} \propto \nu^4$ for the photon is no longer existed.

Eq. (16) gives us

$$\frac{\in}{\delta} = \pi\varepsilon_0 \nu^4 A_R^2 R_{\max}^2 = \varsigma(\nu) \tag{29}$$

For definite ν , $\in/\delta$ is constant. It means if a ν -train possesses higher energy $n\in = nh\nu$, it must have a longer membrane length $n\delta$ of the $\in$ - packets series (property XV).

Elementary train(s) and photon(s) possess almost all the same basic properties. It seems we can say such elementary EM-train is really a photon and vice versa. At least they are equivalent.

According to the important property **XI**, for the entanglement of two photons, it must be like a pair of gloves.

6. EXPERIMENTAL EVIDENCE FOR THE EXISTENCE OF ψ -WAVE. $\in$ -PACKET AND ψ -WAVE PLAY A ROLE TOGETHER AND SIMULTANEOUSLY IN THE PROCESS OF EMISSION AND ABSORPTION

For the Einstein spontaneous emission decrease of atom population in energy level 2 is

$$dN_2 = -AN_2 dt \tag{30}$$

A Represents transition probability per second. Then we have $N_2 = N_{20} e^{-At}$ and the radiative lifetime $\tau_{spon} = \frac{1}{N_{20}} \int_0^{N_{20}} t\, dN_2 = \frac{1}{A}$. In the viewpoint of that photon is an elementary train; to radiate a train needs a lasted time τ_0 . Quantization of charge makes any spontaneous elementary train of the same ν having the same τ_0 and the same train length $L = c\tau_0$. We suppose we can take $\tau_0 \approx \tau_{spon} = \frac{1}{A}$.

The elementary train radiated from level 2 is $E = E_0 e^{-2\pi i(\nu t - \frac{z}{\lambda})}$ ($E_0^2 = h\nu$, $0 \le t \le \tau_0$). But for the natural spectral line there is a frequency width $\Delta\nu$. It is owing to the finite length $L = c\tau_0$ of the train. Fourier analysis gives $\tau_{spon}\Delta\nu \ge 1$, so we have $\Delta\nu \approx \frac{1}{\tau_{spon}} \approx \frac{1}{\tau_0} \approx A$. Like A , $\Delta\nu$ is also a measure of the time τ_0.

Usually radiative lifetime is of order $10^{-8} \to 10^{-9}\,\mathrm{sec}$. So (a) the elementary train length $L = c\tau_0$ is about 0.1 $\leftrightarrow$ 1 meter ($\succ\succ \delta$); and (b) since the visible light ν is $(8 \to 4) \times 10^{14}\, 1/\mathrm{sec}$. so $\frac{\Delta\nu}{\nu} \approx 10^{-7} \to 10^{-6}$.

The width $\Delta\nu$ of natural spectral line means the electron radiates a continuous spectrum between $\nu - \frac{1}{2}\Delta\nu$ and $\nu + \frac{1}{2}\Delta\nu$. If we divide $\Delta\nu = (2n+1)\delta\nu$ into $2n+1\ (\succ\succ 1)$ parts of $\delta\nu$, the spectrum can be interpreted as that the electron radiates $2n+1$ spectral lines of energy $\delta\in_\kappa = \frac{h}{2n+1}(\nu_\kappa + \kappa\delta\nu)$, $(\nu_\kappa = \nu,\ \kappa = 0, \ldots \pm n)$ simultaneously. The total energy radiated is

$$\in=\frac{h}{2n+1}\sum_{\kappa=0}^{\pm n}(\nu_{\kappa}+\kappa\,\delta\nu)=h\nu\pm\frac{h}{2n+1}\sum_{\kappa=1}^{n}\kappa\,\delta\nu=$$

$$=h\nu\pm\frac{n(n+1)}{2(2n+1)}h\,\delta\nu\cong h(\nu\pm\frac{n}{4}\delta\nu)\cong h(\nu\pm\frac{\Delta\nu}{8})\cong h\nu \qquad (31)$$

It implies the continuous spectrum is equivalent to three EM train: $E=E_0 e^{-2\pi i(\nu t-\frac{z}{\lambda})}$, $\Delta E_{+}=\Delta E_0 e^{-2\pi i(\nu t+\frac{\Delta\nu}{8}t-\frac{z}{\lambda})}$ and $\Delta E_{-}=\Delta E_0 e^{-2\pi i(\nu t-\frac{\Delta\nu}{8}t-\frac{z}{\lambda})}$. They possess energy $(E_0)^2=h\nu$ and $(\Delta E_9)^2\cong\frac{h\Delta\nu}{8}$ respectively. Since $e^{2\pi i\frac{\Delta\nu}{8}t}+e^{-2\pi i\frac{\Delta\nu}{8}t}=2\cos(\frac{\pi\Delta\nu}{4}t)$, so we have

$$\Delta E=\Delta E_0 e^{-2\pi i(\nu t+\frac{\Delta\nu}{8}t-\frac{z}{\lambda})}+\Delta E_0 e^{-2\pi i(\nu t-\frac{\Delta\nu}{8}t-\frac{z}{\lambda})}$$

$$=2\Delta E_0\cos(\frac{\pi t}{4}\Delta\nu)\;e^{-2\pi i(\nu t-\frac{z}{\lambda})} \qquad (32)$$

The time t to radiate a spontaneous photon train from level 2 is τ_0, since $\tau_0\,\Delta\nu\ge 1$ and $\cos\pi/4=\sqrt{2}/2$ so

$$\Delta E\cong\sqrt{2}\;\Delta E_0 e^{-2\pi i(\frac{t}{T}-\frac{z}{\lambda})} \qquad (33)$$

Because a spontaneous photon is composed of an $\in$-packet and a ψ-wave, and $h\nu$ is solved by the Schrodinger equation, it must be carried by the $\in$-packet, so ΔE, eq. (33) must be the wave function of the ψ-wave. ψ-Wave possesses a real energy $(\sqrt{2}\Delta E_0)^2\cong\frac{h\,\Delta\nu}{4}$. It is decided by the existence of $\Delta\nu$; On the contrary, it is the finite length $L=c\tau_{spon}=c\tau_0$ of the elementary wave train to make the width $\Delta\nu$. So the line width $\Delta\nu$ and the existence of ψ-wave are interdependent. Existence of $\Delta\nu$ is really an important experimental evidence for the existence of the ψ-wave. It is also an experimental evidence for the photon's $\in$-packet and ψ-wave structure. Eq. (32) can be rewritten into a more accurate form:

$$\in=\frac{h}{2n+1}\sum_{\kappa=0}^{\pm n}(\nu_{\kappa}+\kappa\,\delta\nu)=h\nu\pm\frac{h}{2n+1}\sum_{\kappa=1}^{n}\kappa\,\delta\nu=$$

$$=h\nu\pm\frac{n(n+1)}{2(2n+1)}h\,\delta\nu\cong h(\nu\pm\frac{n}{4}\delta\nu)\cong h(\nu\pm\frac{\Delta\nu}{8})=h\nu+\frac{h\Delta\nu}{4} \qquad (34)$$

Since the photons from the universe all possess the $\Delta\nu$, so $\frac{h\Delta\nu}{4}$ is a loss-free energy for the ψ-wave to interfere and propagate; therefore the factor $\frac{1}{z}$ in the amplitude of ψ-wave, eq.(6) will never be zero, It implies we will have $\frac{1}{z}\to\frac{1}{z_{00}}$. The ψ-Wave will also become cylindrical at last

On the other hand, after the electron in ground state absorbs a $h\nu$-photon, it has the ability to jump up and make the spectral line width $\Delta\nu$ in the level 2. It means the electron in level 1 also possessing the energy of ψ-wave. It must be absorbed before jump. So both $\in$-packet and ψ-wave are emitted together and absorbed together in the atom and molecular.

7. $\in$-PACKET AND ψ-WAVE PLAY A ROLE TOGETHER IN THE DOUBLE SLIT EXPERIMENTS

For the single slit Fraunhofer diffraction, the irradiance distribution in the focal plain is $I_1=I_0(\sin\beta/\beta)^2$. p116 in [3] Since the space behind the slit is uniform, the $\in$-packet as a particle has straight trajectory here. For simplify, let us restrict our discussion in the small β region, so we can ignore the influence of diffraction. Then, above formula also represents the angular distribution of the number of $\in$-packet(s) behind the slit Δx it passes. This symmetrical deflection is owing to the symmetrical momentum $\pm\Delta p_x$ of the Heisenberg uncertainty principle at Δx [13,14].

For the double slit experiment, $\in$-packet as a particle, it can not split into two parts to pass two slits. Only the $\in$-packet with its ψ-wave and the ψ-wave from another slit can form the interference pattern in the focal plain. The irradiance distribution function of double-slit is $I_2=I_0(\frac{\sin\beta}{\beta})^2\cos^2\gamma$. P121 in [3] Here the factor $(\sin\beta/\beta)^2$ constitutes the envelop of the interference fringes given by the term $\cos^2\gamma$. If $\cos^2\gamma=1$ it means if no second ψ-wave (and its $\in$-packet) arrives at the focal plain or without the second slit, then $I_2=I_1$, two irradiance distribution functions become the same. So the envelop really represents the angular distribution of the $\in$-packet(s) behind the first slit Δx it passes, if we ignore the $\in$-packet(s) from the second slit. It also represents the number distribution of the $\in$-packet(s) from the first slit that arrives at the focal plane. It is the phase difference γ between the $\in$-packets and the ψ-wave from another slit at the focal point decided the relative degree of brightness of the fringes: brightest if $\cos^2\gamma=1$; darkest if $\cos^2\gamma=0$; the other is median bright. So the brightness of the fringe is not totally decided by the number of $\in$-packets (photons) that arrived at the point; it is also and even mainly decided by the phase difference between the $\in$-packets and the coherent ψ-wave from another slit at the point they meet. This phase difference restricts the ability or activity of the photon(s) (The probability of photon(s) to interact with matter).

So if we ignore the $\in$-packet(s) from the second slit, a half of the envelop $\frac{I_0}{2}(\frac{\sin\beta}{\beta})^2$ really represents the angular distribution of the $\in$-packet(s) behind the first slit Δx it passes. It also represents the number distribution of the $\in$-packet(s) from the first slit that arrives at the focal plain. It is the phase difference γ between the $\in$-packets and the ψ-wave from another slit at the focal point decided the relative degree of brightness of the fringes: brightest if $\cos^2\gamma=1$; darkest if $\cos^2\gamma=0$; the other is median bright. So the brightness of the fringe is not totally decided by the number of $\in$-packets (photons) that arrived at the point; it is also and even mainly decided by the phase difference between the $\in$-packets and the coherent ψ-wave from another slit at the point they meet. This phase difference restricts the ability or activity of the photon(s) (The probability of photon(s) to interact with matter).

We wonder if we can use this interesting property in the experiences and applications.

Since $\in$- packet and ψ-wave satisfy the same wave function eq. (6) (only difference is in the amplitude $E_0(r,z)=A(\frac{r}{R})\frac{v^2}{z}$ that contains different factor $\frac{1}{z_0}$ or $\frac{1}{z_{00}}$). Their partial derivatives are

$$\frac{h^2}{4\pi^2}\frac{\partial^2 E(x,y,z,t)}{c^2\partial t^2}=-\frac{(h\nu)^2}{c^2}E_0(x,y,z)e^{-2\pi i(\nu t-\frac{z}{\lambda})}$$
$$(\in \overset{(18)}{=} h\nu) \qquad (35)$$

$$\frac{h^2}{8m\pi^2}\frac{\partial^2 E(x,y,z,t)}{\partial z^2}=-\frac{1}{2m}(\frac{h}{\lambda})^2E_0(x,y,z)e^{-2\pi i(\nu t-\frac{z}{\lambda})}$$
$$(p \overset{(27)}{=} \frac{h}{\lambda}) \qquad (36)$$

For the relativistic particles, we find the solution of $\in, p$ from the eq. (35), (36) and substitute into $\in^2-p^2c^2=m_0^2c^4$, it leads to the Klein-Gordon equation

$$\frac{\partial^2 E}{c^2\partial t^2}=\frac{\partial^2 E}{\partial z^2}-\frac{m_0^2c^2}{\hbar^2}E \qquad (E=E(x,y,z,t)) \qquad (37)$$

Let $m_0=0$, the Klein-Gordon equation here becomes the Schrodinger equation for the photon:

$$\frac{\partial^2 E}{c^2\partial t^2}=\frac{\partial^2 E}{\partial z^2} \qquad (E=E(x,y,z,t)) \qquad (38)$$

Therefore, Maxwell wave equation is really the Schrodinger equation for the photon. ψ-Wave can be interpreted as the probability wave for the $\in$- packet(s) (photon).

8. EXISTENCE OF LONGER TRAIN IN EINSTEIN STIMULATED EMISSION [3]

For stimulated emission, the number of downward transitions from energy level 2 to level 1 in dt is

$$dN_2=-Bu_\nu N_2dt\,. \qquad (39)$$

There is no reason to prevent us to introduce the idea of average stimulated radiative lifetime:

$$\bar{\tau}_{stim}=\frac{1}{N_{20}}\int_0^{N_{20}}t\,dN_2=\frac{1}{Bu_\nu} \qquad (40)$$

Average EM train length for the stimulated emission is $\bar{L}_{stim}=c\bar{\tau}_{stim}=\frac{c}{Bu_\nu}$.

Since photon's $\in$-packet and ψ- wave are all circular polarized **E, H** field of speed c and satisfy the same wave function; their possible differences are just the magnitude of amplitude A_R and the length δ or L, so, similar to the eq. (15) the energy of the ψ - wave is $\in=\pi\varepsilon_0A_R^2\Phi^2\nu^4L$. Then similar relation $\in/L=\varsigma(\nu)$ like eq. (29) still holds. For definite ν, $\in/L$ is constant. Plus eq. (40) and $\tau_{spon}=\frac{1}{A}$, it gives us $\frac{\bar{\in}_{stim}}{\in_{spon}}=\frac{\bar{L}_{stim}}{L_{spon}}=\frac{\bar{\tau}_{stim}}{\tau_{spon}}=\frac{A}{Bu_\nu}$. Since $\in_{spon}=h\nu$, we have the average energy of the stimulated trains:

$\bar{\epsilon}_{stim} = \frac{A}{Bu_\nu} h\nu$. For natural light source and visible ray $\frac{A}{Bu_\nu} = (e^{\frac{h\nu}{\kappa t}} - 1) \succ\succ 1$, so we have

$$\bar{\epsilon}_{stim} = \kappa h\nu \qquad (k = \frac{A}{Bu_\nu} \succ\succ 1). \tag{41}$$

Average energy $kh\nu \succ\succ h\nu$ implies that the stimulated atoms may emit the trains of energy: $h\nu$ … $kh\nu$ … $n(\succ k)h\nu$. Stimulated atom spends more time to radiate a longer train with bigger energy.

Where do these extra energies storage in the atoms before emission? Fourier analysis gives us $\tau_{spon} \Delta\nu_{spon} \geq 1$ and $\bar{\tau}_{stim} \Delta_{stim} \geq 1$. Since $\tau_{spon} = \frac{1}{A}$, $\bar{\tau}_{stim} = \frac{1}{Bu_\nu}$ and eq. (40), the width of energy level 2 for the spontaneous emission $\Delta \epsilon_{spon}$ and stimulated emission $\Delta \epsilon_{stim}$ are

$$\Delta \epsilon_{spon} = h\Delta\nu_{spon} \geq hA \text{ .} \tag{42}$$

$$\Delta \epsilon_{stim} = h\Delta\nu_{stim} \geq hBu_\nu \tag{43}$$

Because $\frac{A}{Bu_\nu} \succ\succ 1$, so $\Delta \epsilon_{stim} \prec\prec \Delta \epsilon_{spon}$. It means that the energy is stored by the compression of the width of atom's energy level. Narrower width stores more energy, it spends more time to radiate a longer train with bigger energy just like a "spring" being compressed.

Eq. (39), (40) are also available for the level 1 by replaced subscript 2 to 1. Level 1 and 2 have the same average stimulated radiative lifetime. It infers that the electron at level 1 can accept a train of $h\nu$ or $2h\nu$ or…, and its ψ -wave directly (then even can accumulate them or vice versa) from the radiation field to compress energy level 1 and then jump to level 2 with energy $nh\nu$ $(n = 2,3,...)$ and corresponding ψ -wave. This result further approves above assertion that the ϵ -packet and the ψ -wave play a role together in the processes of emission and absorption.

It infers that the EM field in thermal equilibrium is composed of steady distributed $2\pi n\nu$ $(n = 1,2,3,...)$ standing ψ -waves (Fourier modes) and $nh\nu$ $(n = 1,2,3,...)$ energy packets (the state of n photons). [7] This result indicates the correctness and facticity of the Max Plank postulate. It led to the Plank's law in 1900 and opened the quantum epoch [11].

Laser and maser seems to be really the EM-trains with energy $nh\nu$ $(n \succ\succ 1)$. Its coherent length is nL .

Since an electron can only possess one of the spin $\pm\frac{\hbar}{2}$, so the electron at ground state in the atom can only absorbs a photon with opposite sign of spin $\mp\hbar$, then jumps to level 2 and becomes an electron with spin $\mp\frac{\hbar}{2}$. If this electron continues to absorb a photon $h\nu$ to compress energy level 2 and recover to its original spin $\pm\frac{\hbar}{2}$, the total spins of the two absorbed photons must be zero. Then we can easily arrive at a conclusion that the spin of the long stimulated photons train emitted with energy $nh\nu$ is $+\hbar$ or $-\hbar$ or zero. On the contrary, if the laser is composed of identical photons of same phase, its spin will be $+n\hbar$ or $-n\hbar$. This difference of assertions can be checked in the experiments we suppose.

9. PAIR PRODUCTION OF $\pm$ CHARGED ELEMENTARY PARTICLES FROM A PHOTON

For the pair production,[15,16] if a photon's energy is $\epsilon \succ 2mc^2$ and have assaulted by a heavy nucleus, strong compression will make the field intensity **E** and energy density $E^2\ (\propto A_R^2)$ in the ϵ -packet greatly increased. Plus symmetry it will cause the ϵ -packet to split along the double helix of maximum stress $\Sigma_{\max} \infty A_R^2$, eq. (11) into two equal parts with different sign of charge $+e$ and $-e$ (charges $\pm e$ are split from the photon, not produced from the vacuum. They ($\pm e$) must exist in the photons since the very beginning of the big bang. So $\pm$ charged elementary particles produced are certainly symmetrical and possess intrinsic spin $\hbar/2$ but different sign of charges. Since energy density E^2 at every point of the ϵ -packet bisects and transfers into two mass density $\sigma = \frac{1}{2}E^2$, vector $\vec{E}$ at every point must also bisect and transfer into two certain vectors $\vec{A}$ ($\vec{E} = 2\vec{A}$) in the $\pm$ charged elementary particles. For latter convenience, let $\sigma = \frac{1}{2}E^2 = 2A^2 \overset{let}{=} \Phi^2$, we have $\vec{\Phi} = \frac{\sqrt{2}}{2}\vec{E}$ and call $\vec{\Phi}$ as inertia vector. It implies that the vector (Φ_x,Φ_y) is still a plane vector tangent to the cross sections of the positive and negative charged particles. They ($\sigma(x.y)$ and (Φ_x,Φ_y)) distribute helically along z-axis like E^2 and field vector (E_x,E_y) in the $\in$ -packet and circular polarized light.

Besides, Just after the photon split, owing to the repulsion between the same sign of charge, the continuously distributed half-circular charged element $-dq$ (and $+dq$) will split into two $-2\times\frac{dq}{2}$ (and $+2\times\frac{dq}{2}$) and locate at two ends of the membrane diameter on every cross section. The semi-circular charge $-e$ (like electron) and $+e$ (like positron) has now become the charged double helices along the side membrane. Translation of $+e$ and $-e$ helices will produce different z-direction of magnetic **B** on the O-planes, It will cause the unformed $\pm$ charged particles move along opposite z-direction to depart and become the formed $\pm$ charged particles at last.

Charges $2\times\frac{dq}{2}$ at two ends of the diameter may change the distribution of the magnitude and direction of the inertia vector (Φ_x,Φ_y) (and mass density $\sigma(x.y)$) on the cross sections of the particle, but will keep x- axial and y-axial symmetry of the (Φ_x,Φ_y) and $\sigma(x.y)$ on the cross sections and double helix structure along z-axis.

Now let us consider the equation of motion of an ordinary particle it possesses right helical structure of inertia vector (Φ_x,Φ_y) (and mass density) and moves with velocity V along z-axis. Let λ_V be the pitch of the particle's equal inertia vector (Φ_x,Φ_y) (and equal mass density) helix. Then $T_V=\frac{\lambda_V}{V}$ is the time for the particle to move a pitch λ_V . It is also the time period for the mass elements and vector (Φ_x,Φ_y) from the same equal density helix to rotate a circle on the O-planes. Let $\Phi_0(x^2,y^2)$ be the axial symmetry inertia vector on the initial plane $(z=0)$ at $t=0$. Then

$$\Phi_x(x,y;z,t)=\Phi_0(x^2,y^2)\cos 2\pi(\frac{z}{\lambda_V}-\frac{t}{T_V}+\alpha)$$

$$\Phi_y(x,y;z,t)=\Phi_0(x^2,y^2)\sin 2\pi(\frac{z}{\lambda_V}-\frac{t}{T_V}+\alpha)$$

$$(\ \alpha=\alpha(x,y)\ ,\ T_V=\frac{\lambda_V}{V}\ ) \qquad (44)$$

is the function that represent double helix space distribution of the particle's inertia vector (Φ_x,Φ_y) and mass element $dm=\Phi^2dxdy$ at time t and its motion along z-axis with velocity V . It is such particle's equation of motion.

Observers will find very much circular loci on any O-plane. Every one of them is made by the successive mass element of the same helix. Translation motion makes the mass elements and inertia vector (Φ_x,Φ_y) from the same helix rotated on the O-planes similar to the situation of **E, H** and E^2 in the circularly polarized light and the $\in$ -packet. Angular frequency $\nu_V=\frac{1}{T_V}=\frac{V}{\lambda_V}$ and angular momentum $2\pi\nu_V I=2\pi\frac{V}{\lambda_V}I \quad (0\le V\prec c)$ increase as V increases if we suppose that λ_V does not vary or varies slower than the increase of V (It will be approved later. ref. eq. (49)). Maximum angular frequency and maximum angular momentum happen simultaneously at the limit of $V\to c$.

If a particle with intrinsic spin, such as $\hbar/2$ possesses right helical structure at the same time, the spin must be the maximum spin between $0\le V\prec c$. Otherwise it will increase as V increase. It contradicts the constancy of the intrinsic spin $\hbar/2$. Since maximum spin and maximum angular frequency happen at the same limit $V\to c$, so for the particle that possesses both intrinsic spin and right helical structure of inertia vector and mass density, the coefficient before t in Eq. (44) must be $\nu=\frac{1}{T}=\frac{c}{\lambda}$. It always rotates at maximum angular frequency ν on the O-planes despite the V large or small. Such particle's equation of motion is

$$\Phi_x(x,y;z,t)=\Phi_0(x^2,y^2)\cos 2\pi(\frac{z}{\lambda_V}-\nu t+\alpha)$$

$$\Phi_y(x,y;z,t)=\Phi_0(x^2,y^2)\sin 2\pi(\frac{z}{\lambda_V}-\nu t+\alpha)$$

$$(\ \alpha=\alpha(x,y)\ ,\ \nu=\frac{1}{T}=\frac{c}{\lambda}\ ) \qquad (45)$$

It can be rewritten in complex form as

$$\Phi(x,y,z,t)=\Phi_x+i\Phi_y=\Phi_0(x^2,y^2)e^{-2\pi i(\nu t-\frac{z}{\lambda_V}-\alpha)}$$

$$(\ \alpha=\alpha(x,y)\ ,\ \nu=\frac{1}{T}=\frac{c}{\lambda}\ ) \qquad (46)$$

A problem is what mechanism can make the angular frequency ν_V become ν so as always keeps its intrinsic (maximum) spin? In fact, for the particle of $V \prec c$, its frequency $\nu_V = \frac{1}{T_V} \prec \nu = \frac{1}{T}$ is not enough to produce the intrinsic spin. Conservation law of angular momentum requires there must be an additional self rotation frequency ν_{self} of the particle to meet this demand. It is [16]

$$[\frac{z}{\lambda_V} - (\nu_{self} + \nu_V)t] \overset{must}{=} (\frac{z}{\lambda_V} - \nu t) \qquad (\nu_{self} = \nu - \nu_V) \qquad (47)$$

Intrinsic spin and conservation law of angular momentum demands the existence of ν_{self} in the particles of $V \prec c$. So ν_{self} is also intrinsic for such particles. Intrinsic spin $\hbar/2$ and intrinsic ν_{self} of the $\pm$ charged elementary particles with $V \prec c$ are interdependent. Translation motion of helical structure plus intrinsic self-rotation ν_{self} defined in eq. (47) makes particle spin $\hbar/2$. It is the existence of ν_{self} that makes the particle to look like always having speed c to form the maximum frequency ν no matter the V large or small. Self rotation frequency ν_{self} varies with V : $\nu_{self} \to 0$ if $V \to c$; $\nu_{self} \to \nu$ if $V \to 0$.

10. $\pm$ CHARGED ELEMENTARY PARTICLE'S λ_V, ν AND p, $\in$ SATISFIES THE DE BROGLIE RELATION

(A) Infinite mass density does not exist in reality; $\pm$ charged elementary particles certainly have size no matter how small they are. The energy of a particle is $\in_V = \sqrt{p^2c^2 + m_0^2c^4}$ (we neglect the negative energy here, it leads to antiparticles as Dirac first showed) [11],[7] Eq. (45) and (46) show that $\pm$ charged elementary particles always possesses maximum angular velocity $\omega = 2\pi\nu$ and maximum rotational energy $\in_r$ no matter how large or how small the V is. So $\in_r$ equals to the particle's total energy $\in_{V=0}$ when $V = 0$. $\in_r = \in_{V=0} = m_0c^2$. Therefore, the rest energy m_0c^2 of elementary particle is its maximum self rotational energy, the energy closely connected to its intrinsic spin. Rest mass m_0 of the $\pm$ elementary particles is a measure of its maximum self angular frequency ν_{self}.

(B) A photon splitting equally into $\pm$ charged elementary particles must experience two stages: unformed mass less $\pm$ particle at light speed c and then materializes to the particle of lower speed V. Let $\in_{photon}$, p_{photon} be the photon's energy and momentum; $\in$, p and $\in_V$, p_V be the unformed and formed particle's energy and momentum respectively. Since $\in_{photon} = h\nu_{photon}$ and the unformed $\pm$ particle just split from the $\in$ -packet has both speed c and helical structure similar to the $\in$ -packet, so conservation law of energy gives us

$$\in = \frac{h\nu_{photon}}{2} \overset{let}{=} h\nu \qquad (48)$$

Then, we have $\lambda (= \frac{c}{\nu} = \frac{2c}{\nu_{photon}}) = 2\lambda_{photon}$. This elongation of pitch must be owing to the repulsion of the same sign of particle charges. Here $\nu = \frac{\nu_{photon}}{2}$ is the number of rings of the equal mass density helix every c meter in the unformed $\pm$ charged elementary particle. Speed c makes the unformed particle's mass element dm rotated ν cycles per second on the O-plane. So ν is just the same frequency in the eq.(45), (46).

When the unformed $\pm$ particle materialized into $\pm$ particle and its speed decreases to V , conservation of particle's energy $\in_V = h\nu = mc^2$ and the definition of particle momentum in the special relativity give us

$$p_V = mV = \frac{h\nu}{c^2}V = \frac{h}{\lambda}\frac{V}{c} \overset{let}{=} \frac{h}{\lambda_V^*} \qquad (\lambda_V^* = \frac{c}{V}\lambda = \frac{h}{p_V}) \qquad (49)$$

Here we let $\lambda_V^* = \frac{c}{V}\lambda$ is owing to the consideration of the dimension relation between the quantities. Since $\lambda_V^* \to \lambda$, if $V \to c$ and λ is the wave length (pitch) of the unformed $\pm$ particle at speed c , so λ_V^* must be the wave length (pitch) of the $\pm$ particle at speed V. This is just the λ_V in the eq. (45) and (46). So for the $\pm$ charged elementary particles, their equation of motion can be finally written as

$$\Phi(x,y,z,t) = \Phi_x + i\Phi_y = \Phi_0(x^2,y^2)e^{-2\pi i(\nu t - \frac{z}{\lambda_V} - \alpha)}$$
$$(\lambda_V = \frac{h}{p_V} = \frac{h}{mV}, \nu = \frac{\in}{h}) \qquad (50)$$

We have proved here that owing to the intrinsic spin and double helix structure of the vector

(Φ_x, Φ_y) (and mass density), p, $\in$ of the charged elementary particle and λ_V, ν in the wave function of the vector (Φ_x, Φ_y), eq. (50) satisfy the de Broglie relation $\lambda_V = \frac{h}{p_V} = \frac{h}{mV}$ and $\nu = \frac{\in}{h} = \frac{mc^2}{h}$ [17].

11. DIFFERENTIAL EQUATION OF MOTION FOR THE PARTICLES WITH HELICAL STRUCTURE AND SPIN

A question arises: when photon's $\in$-packet splits and transfers to $\pm$ charged elementary particles, what will happen to the ψ-wave? This wave has energy $\frac{h\Delta\nu}{4}$ and closely connected with the $\in$-packet. Logically speaking, this wave energy is impossible to disappear without sake. So the ψ-wave must also split and transfer to certain wave, named Φ-wave accompany with the $\pm$ charged elementary particles produced, In fact, such a Φ-wave is really the circular polarized external **E** field closely connected to the helical $+e$ or $-e$ in the charged elementary particle. Therefore, they ($\pm$ charged particle and its Φ-wave) must translate with the same velocity V and rotate with the same self frequency ν_{self}. In short, they are closely connected and move synchronically with the same phase.

Therefore the particle's inertia vector (Φ_x, Φ_y) and its Φ-wave have the same ν and λ_V. The wave functions of the Φ-wave and the vector (Φ_x, Φ_y) are similar. The only difference is their amplitude $\Phi_0(x^2, y^2)$ and having a factor $\frac{1}{z}$ or not. The conical Φ-wave function is

$$\Phi(x,y,z,t) = \Phi_{0'}(x^2,y^2)\frac{1}{z}e^{-2\pi i(\nu t - \frac{z}{\lambda_V} - \alpha)}$$

$$(\alpha = \alpha(x,y),\ \lambda_V = \frac{h}{p_V},\ \nu = \frac{\in}{h}) \qquad (51)$$

Here $\Phi_{0'}(x^2, y^2)$ is the amplitude of the Φ-wave on the initial plane $(z = z_0)$ at $t = 0$.

On the other hand, although charged elementary particle itself has wave function, eq. (50), it is difficult to explain double slits experiment alone. Because (i) the particle is too small to cover two slits; and (ii) as a particle, it can not split into two parts to pass two slits at the same time. Existence of the interference pattern means it is the charged elementary particle (with its Φ-wave) and the Φ-wave from another slit to form the interference pattern and decide the probability behavior of the particle behind the slits similar to the situation of the photon(s). The interference pattern exhibits all possible position (x, y, z) and its probability that the particle(s) can take one of them at a time. So Φ-wave is just the de Broglie wave, eq. (51). De Broglie wave is the circular polarized external E field carried by the double helix distributed $+e$ (or $-e$) in the moving charged particle.

Since electron can go far; so Φ-wave must also become cylindrical since certain finite distance z_{00}.

Like the photon is composted of $\in$-packet and ψ-wave, $\pm$ charged elementary particle is also composed of the particle itself and a closely connected de Broglie Φ-wave. They satisfy similar wave function eq. (50) and (51) respectively.

The modulus of de Broglie Φ-wave, eq. (51), is

$$\Phi^*(x,y,z,t)\Phi(x,y,z,t) = |\Phi(x,y,z,t)|^2 = \frac{1}{z^2}\Phi_{0'}^2(x^2,y^2)$$

$$(r \le R) \qquad (52)$$

It represents the number distribution of the charged elementary particles in the space-time. Eq.(52) is the probability distribution function or the probability density of the particle(s) [18].

As to the modulus from eq. (50):

$$\Phi^*(x,y,z,t)\Phi(x,y,z,t) \overset{(50)}{=} \Phi_0^2(x^2,y^2) = \sigma(x^2,y^2)$$

$$(r \le R) \qquad (53)$$

Originally, it interprets the distribution function of the particle mass density in the space-time. Because only when the volume $\Delta x, \Delta y, \Delta z$ we take are smaller than the volume of the particle, we can talk about the distribution of its mass $\sigma\,\Delta x, \Delta y, \Delta z$. But in reality, $\Delta x, \Delta y, \Delta z$ is far greater than the volume of elementary particles, so the mass distribution of the particles in the volume $\Delta x, \Delta y, \Delta z$ during Δt is always proportional to the number (or times) of the particles that locate inside the volume in Δt. So the interpretations of eq. (52) and (53) are all similar to the quantum mechanics interpretation.

Take derivatives from eq. (50) or (51). Because $\frac{\partial}{\partial z}\Phi_0(x^2,y^2)\frac{1}{z}$ is $\prec\prec \nu$ and $\prec\prec 1/\lambda$. This term is far smaller than other terms of the partial derivatives. It can be neglected. So the derivatives of the function of $\pm$ particle and its Φ-wave are the same as follow: [19]

$$\frac{ih}{2\pi}\frac{\partial\Phi(x,y,z,t)}{\partial t}=h\nu\Phi_0 e^{-2\pi i(\nu t-\frac{z}{\lambda_V})} \tag{54}$$

$$\frac{h^2}{4\pi^2}\frac{\partial^2\Phi(x,y,z,t)}{c^2\partial t^2}=-\frac{(h\nu)^2}{c^2}\Phi_0 e^{-2\pi i(\nu t-\frac{z}{\lambda_V})} \tag{55}$$

$$\frac{ih}{2\pi}\frac{\partial\Phi(x,y,z,t)}{\partial z}=-\frac{h}{\lambda_V}\Phi_0 e^{-2\pi i(\nu t-\frac{z}{\lambda_V})} \tag{56}$$

$$\frac{h^2}{8m\pi^2}\frac{\partial^2\Phi(x,y,z,t)}{\partial z^2}=-\frac{1}{2m}(\frac{h}{\lambda_V})^2\Phi_0 e^{-2\pi i(\nu t-\frac{z}{\lambda_V})}$$

$$(\lambda_V=\frac{h}{mV}=\frac{h}{p},\ \nu=\frac{mc^2}{h}=\frac{\in}{h},) \tag{57}$$

(A) For the non-relativistic particle, energy is relative. The constant m_0c^2 can be neglected in the energy expression $\in = m_0c^2+\in_k=\frac{p^2}{2m}$. Since $\in = h\nu$ and $p=\frac{h}{\lambda_V}$, eq. (54), (57) give us the differential equation of motion for the non-relativistic $\pm$ charged elementary particle:

$$i\hbar\frac{\partial\Phi(x,y,z,t)}{\partial t}=-\frac{\hbar^2}{2m}\frac{\partial^2\Phi(x,y,z,t)}{\partial z^2} \tag{58}$$

It has the same mathematical form as the usual Schrodinger equation [19]. De Broglie Φ-wave as a circular polarized wave and the particle as a moving circular polarized structure all satisfy this equation.

If the particle is left helical, eq. (50) and (51) have to be changed to the following:

$$\vec{\Phi}(x,y,z,t)=\Phi_x+i\Phi_y=\Phi_0(x^2,y^2)e^{2\pi i(\nu t-\frac{z}{\lambda_V}-\alpha)}$$

$$\vec{\Phi}(x,y,z,t)=\Phi_x+i\Phi_y=\Phi_{0'}(x^2,y^2)\frac{1}{z}e^{2\pi i(\nu t-\frac{z}{\lambda_V}-\alpha)}$$

$$(\lambda_V=\frac{h}{p_V},\ \nu=\frac{c}{\lambda}=\frac{\in}{h}) \tag{59}$$

They satisfy the partial differential equation mathematically like the positive sign Schrodinger equation:

$$i\hbar\frac{\partial\Phi(x,y,z,t)}{\partial t}=\frac{\hbar^2}{2m}\frac{\partial^2\Phi(x,y,z,t)}{\partial z^2} \tag{60}$$

Two charged elementary particles with different direction of helical e and inertia vector $(\Phi_x\Phi_y)$ have different sign of spin and satisfy different sign of Schrodinger type equations, Eq. (58) and (60) respectively, although their modulus, the distribution of particle(s)' probability density on any longitudinal plane (included coordinates plane) are the same. Two non-relativistic charged elementary particles with different sign of spin (for example, two electrons) do not satisfy the same sign Schrodinger equation either eq. (59) or eq. (60).

Besides, direct verification shows that any component of the eq. (50) or (51), like $\Phi=\Phi_0(x,y,z)\cos 2\pi(\nu t-\frac{z}{\lambda}-\alpha)$ or $\Phi=\Phi_0(x,y,z)\sin 2\pi(\nu t-\frac{z}{\lambda}-\alpha)$, or any linear combination of them does not satisfy eq. (58) or (60), Because these are plane wave, not circular polarized. Schrodinger equation is for the circular polarized wave.

12. DISCUSSION

(a) For the superposition principle, if the state of a particle (or a system) at each spatial position and time t is described in terms of a wave function as all of us used to do, the superposition principle is the idea that the particle or the system is in all possible states at the same time, until it is measured. After measurement it then fall to one of the basis states that form the superposition.

But for the case as we proved in this paper, $\pm$ charged elementary particle is composed of the particle itself and a closely connected de Broglie Φ-wave, the interpretation is different. The particle itself can take any basis state (e.g. at a point in the interference pattern or in an eigen state of the atom or molecule), at time t, but cannot take two or more basis states simultaneously. Because a particle cannot have two position or two energy at the same time, otherwise, the particle will split or move with different speed simultaneously.

Superposition principle for the particle itself and the Schrodinger equation here is just to bring in the general solution and integral constants. Depend on the given conditions, like the boundary condition, initial condition, normalizing condition, … the state of the particle can be decided definitely. As for the Φ -wave, it exhibits all the possible states and their probability that the particle can take one and only one of them at the moment t . So, for the wave-particle structure, both alive and dead Schrodinger cat does not exist.

For the double helix wave-particle structure of $\pm$ charged elementary particle, the idea of electron cloud is no longer existed and the idea of electron orbit corresponding to a set of definite quantum numbers is available.

(b) Theoretically speaking, a photon may produce a pair of quarks of helical structure if the photon has big enough energy and the charges in the $\in$-packets are $\pm\frac{e}{3}$ and $\pm\frac{2}{3}e$.

For the composite particle, such as all baryons and many atoms and nuclei, they are linearly composted of quarks, anti quarks and $\pm$ charged elementary particles. Because algebraic sum of spin requires the density helices of component particles coaxial, so these composite particles must also possess helical structure of mass and inertia vector (Φ_x,Φ_y) . Since they possess both helical structure and intrinsic spin, all the above and the following results must be also available to these particles.

We have proved here that intrinsic spin and helical structure of inertia vector are the sufficient condition for the fermions to possess circular polarized wave function, eq.(50)(51) and satisfy de Broglie relation and the differential equation of motion mathematically the same as the Schrodinger equation.

(c) Differed from the photon, all $\pm$ quarks, $\pm$ charged leptons, $\pm$ baryons and many atoms and nuclei fall into two categories. They carry the same sign of charge $-e$ or $+e$ but different directions of helical structure of charge, inertia vector (Φ_x,Φ_y) and mass. They will produce different directions of magnetic **B** on the O-planes during the same direction of translational motion. Two categories of these particles are distinguishable by their **B** directions. This is why such particles they differed from the photons that satisfy B-E statistics, these particles satisfy F-D statistics [7,12].

(d) If two electrons of different categories reside in the same orbital inside the atom or molecule, owing to the repulsion of opposite directions of **B**, the repulsive forces will adjust two electrons to be stable equilibrium; if these two electrons are of the same category, attractions of different magnitudes from two sides of the electron will make their equilibrium unstable and break the equilibrium. So, if two electrons are in stable equilibrium at a quantum state, they must be of different categories. Their helical structure of charge $-e$ must be of opposite directions. In other words, two or more electrons of the same category can not form the stable equilibrium in a quantum state. Similar reasons are also available to the fermions. This is very likely the reason for the Pauli Exclusion Principle.

(B) For relativistic particles, eq. (55),(57) give us the Klein-Gordon equation: [20,21]

$$\frac{\partial^2\Phi}{c^2\partial t^2}=\frac{\partial^2\Phi}{\partial z^2}-\frac{m_0^2c^2}{\hbar^2}\Phi \tag{61}$$

Let $m_0\to 0$, it becomes the "Schrodinger equation" for the photon(s), eq. (38). It has the same mathematical form as the Maxwell wave equation. Both $\in$-packet (photon) and its ψ -wave (= Φ -wave here) satisfy this "Schrodinger equation". ψ -wave is really the probability wave for the photon(s).

13. AN INTERESTING RELATIVISTIC PROPERTY OF THE $\pm$ CHARGED ELEMENTARY PARTICLES IN THE EQUAL ENERGY PROCESS

For the classical particles, rest mass m_0 in the formulas $\in=\frac{m_0c^2}{\sqrt{1-\beta^2}}$, $p=\frac{m_0V}{\sqrt{1-\beta^2}}$ and $\in=\sqrt{p^2c^2+m_0^2c^4}$ is constant irrelevant to the velocity V. But for the $\pm$ charged elementary particles and baryons, or in general, for the systems they possess both helical structure of inertia vector (mass density) and intrinsic spin simultaneously, the situation is different. Because the translational motion of helical structure of the inertia vector (mass density) will make $dm_j\,(j=1,2,...)$ from any equal density helix rotates on the O-planes. The angular frequency of dm_j being made by translational motion is $\nu_V=\frac{1}{T_V}=\frac{V}{\lambda_V}\overset{(49)}{=}\frac{V^2}{c\lambda}$. It gives

$$\beta^2 = \frac{\lambda}{c}\nu_V = \frac{\nu_V}{\nu} \quad (62)$$

$$1-\beta^2 = 1-\frac{\nu_V}{\nu} \overset{(47)}{=} \frac{\nu_{self}}{\nu} \quad (63)$$

Increasing of V will increase ν_V and $\frac{V^2}{1-\beta^2}$, but will decrease ν_{self}. On the other hand, we have

$$\in = \sqrt{\frac{m_0^2V^2}{1-\beta^2}c^2 + m_0^2c^4} = \sqrt{m_0^2(\frac{V^2c^2}{1-\beta^2}+c^4)} = \frac{m_0c^2}{\sqrt{1-\beta^2}} \overset{let}{=} M_0c^2 \quad (64)$$

In general, increasing of V will make energy $\in$ increased if m_0 are constant. But for the equal energy process, energy $\in$ and then M_0 of the $\pm$ elementary particles are constant and m_0 is variable. Let $V=0$, then $m_0 = M_0$, M_0 not m_0 is really the rest mass of the $\pm$ elementary particles in the equal energy process. In this process m_0 varies with V, why? Because $m_0 = M_0\sqrt{1-\beta^2} \overset{(63)}{=} M_0\sqrt{\frac{\nu_{self}}{\nu}}$ is a measure of particle's self rotation frequency it varies with V. Since $\in = \sqrt{p^2c^2+m_0^2c^4}$, for the equal energy process, m_0 Increases when V and p decreases and vice versa. Decrease of pc makes the increase of m_0 just like a new Δm_0 pouring into m_0. Δm_0 is transformed from Δpc. So for the particles (even system) with both helical structure and intrinsic spin, equal energy process is really a transformation process between the quantities pc and m_0. m_0 dependent on V is under this sense. So for the equal energy process of $\pm$ elementary particles (and the system mentioned above), in order to avoid confusion we had better to use m_V, p_V in the formulas: $\in = \sqrt{p_V^2c^2+m_V^2c^4}$, $p_V = \frac{m_VV}{\sqrt{1-\beta^2}} = M_0V$ and $\in = \frac{m_Vc^2}{\sqrt{1-\beta^2}}$. Then

$$m_V = M_0\sqrt{1-\beta^2} \overset{(62)}{=} \sqrt{\frac{M_0h}{c^2}\nu_{self}} \quad (65)$$

Here we use the de Broglie relation $\in = h\nu = M_0c^2$. m_V Is a measure of particle's self rotation frequency ν_{self} at velocity V. Maximum self-frequency ν_{self} happens at $V=0$ and $m_V = M_0$. Since $\beta^2 = \frac{\nu_V}{\nu}$, so

$$p_V = \frac{m_VV}{\sqrt{1-\beta^2}} \overset{(65)}{=} M_0V \overset{(61)}{=} \sqrt{M_0h\nu_V} \quad (66)$$

p_V is a measure of ν_V, the angular frequency made by the translation of helical structure of (Φ_x, Φ_y).

For the stationary state in the atoms or molecules, electron energy is constant, so its mass varies with V as $m_V = M_0\sqrt{1-\beta^2} \le M_0$. Then the reduced mass of the nucleus and electron is $\mu = \frac{m_VM_{nucleus}}{m_V+M_{nucleus}}$. It will make a perturbation by a small amount to its energy $E_n = -\frac{\mu e^4}{8\varepsilon_0^2n^2h^2}$ (For simplicity, here we take hydrogen $Z=1$ and Bohr orbits as example). It will shift the magnitude of E_n of any energy levels and makes a difference in energy between any two energy levels of the atom and molecular. It implies that the $m_V = M_0\sqrt{1-\beta^2}$ may influence the physical and chemical processes in the atom and molecule. For example, it may have an influence to the Lamb shift; for the stationary state, mass m_V of the moving electron in hydrogen varies periodically except circular motion. The periodic change of m_V will make its trajectory in the hydrogen to be no longer elliptical but still periodic (or very near periodic).

Besides, mass less $\pm$ elementary particles they just split from a photon in the pair production can materialize to the $\pm$ elementary particles with mass during its speed decrease to V. A question is that under certain condition, if the speed also decreases to $V \prec c$, can the photon itself materialize to a particle with mass? If it can and if it is also an equal energy process, then the particle's mass at speed V seems to be $m_V = \frac{h\nu}{c^2}\sqrt{1-\beta^2}$; for the laser, it seems to be $m_V = \frac{nh\nu}{c^2}\sqrt{1-\beta^2}$.

14. CONCLUSION

The purpose to find out the possible structures of photon and $\pm$ charged elementary particles and to prove that they have similar mechanism to make their commonalities has been achieved. The task, to derive and prove that the differential equations of motion of the particles with both double helix structures and intrinsic spin are mathematically as same as the Schrodinger equation has also completed.

Photon and $\pm$ charged elementary particle possess similar double helix wave-particle structure. They act as both a wave and a particle all the time, not “exhibit different characters for different phenomenon”.

They play a role together and simultaneously in the processes of emission, absorption and interference. For such double helix wave-particle structure, the idea like wave function collapse and electron cloud etc. are no longer necessary; the idea of the definite trajectory of electron in the atom and molecular is available; both alive and dead Schrodinger cat does not exist. The cat can take only one state, alive or dead at every moment despite of being observed or not.

But there is an important difference between the two kinds of structure: double helix distribution of $\pm e$ in the photon and $-e$ (or $+e$) in the charged elementary particle. The EM field produced from $\pm e$ will be offset each other. It makes the photons to be undistinguishable and obey B-E statistics;

As to the $\pm$ charged elementary particles, they fall into two categories. They carry the same sign of charge $-e$ (or $+e$) but different directions of helical structure of e and mass. They will produce different directions of magnetic **B** on the O-planes during the same direction of translational motion. Two categories of these particles are distinguishable by their **B** effect. It makes these particles to satisfy F-D statistics and obey the Pauli Exclusion Principle.

We have also proved in this paper that the Schrodinger equation is really the differential equation of motion for the particles they possess both intrinsic spin and double helix structure of inertia vector $\vec{\Phi}$ and mass (or **E, H** and energy density). It is the wave equation for the circular polarized wave, not for the plane wave. Non-relativistic charged elementary particles with different directions of spin satisfy different sign $\pm$ of Schrodinger equations. The elementary particles with different $\pm$ sign of spin do not satisfy the same sign Schrodinger equation.

For the entanglement, since each particle can take only one fixed direction of spin $+$ or $-$, the entanglement is like a pair of gloves no matter how far the distant from each other.

For the equal energy process of a charged elementary particle, we have proved that the mass m_V of the particle varies with speed V as $m_V = M_0\sqrt{1-\beta^2}$. For the stationary state in the atoms or molecules, it will affect the reduced mass of the nucleus and electron and affect their physical and chemical processes.

Double helix wave-particle structure of the $\pm$ charged elementary particles seems can be a reference or a proposal to the question that Prof. Steven Weinberg’ talked about the quantum mechanic at the fourth Patrusky Lecture at Science Writers 2016. [21].

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