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Article

Basic Principles of Physics and Their Applications, and Logical Structure of Quantum Mechanics

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Abstract: For the basic principles of physics, we sum up: 1. Symmetry principle and its violation. 2. Various conservation principles and the generalized conservation principle. 3. Limit value principle and the variational principle, which is quantitative methods and the concrete processes on move or change of these conservation quantities. 4. Statistical principle, which combining symmetry violation obtains entropy. 5. Relativity principle. 6. Correspondence principle, uncertainty principle and approximate principle. We discuss simultaneously their applications. For all principles we try to sum up a table. Based on the analysis of the logical structure of quantum mechanics, we proposed that the duality is the only basic principle of quantum mechanics. Statistics is the corresponding mathematical character. The other principles are all physical or mathematical results derived from this. From this we describe a figure of the structure system of quantum mechanics. Gravitational waves are tests of general relativity, and proved they are nonlinear waves. GW 170817 proved that both velocities of gravitational wave and electromagnetic wave are different. We calculate gravitational redshift and the deflection of light for BNS, delay time is 0.1792s.

Keywords: basic principle, symmetry, conservation, statistics, relativity, quantum mechanics, limiting value, variation, logical structure, gravitational wave.

1. Introduction

Einstein and Infeld described the evolution of physics, and pointed out that in whole scientific history someone try come down to several simple basic principles for complex natural phenomena [1]. So far the two greatest recognized scientific theories are relativity and quantum theory since 20 century. The basic principles of special and general relativity are very clear and simple. But, the principles of quantum mechanics are more complex [2-5].

Generally, Houston discussed the principles of mathematical physics [6], which includes Newton's three laws, the conservation laws of mechanics, principles of superposition and decomposition, Hamilton's principle and Lagrange's equation and Hamilton's canonical equations, the laws of thermodynamics, statistical mechanics, Maxwell's equations and relativity. They are namely whole physics except quantum theory. We summed up the basic principles of physics from quantum mechanics and relativity [7] and from the analytical mechanics and the classic physics [8]. Particularly, Chaikin, et al., researched the principles of condensed matter physics [9].

2. Symmetrical Principle as the Highest Principle

The symmetrical principle is a universal principle. Heisenberg pointed out that symmetry constructs often the main character of a theory [10]. Feynman discussed symmetry in physical laws [11]. Roman said that all basic laws of nature possess some symmetries [12]. Zichichi edited *Symmetries in Elementary Particle Physics*, which includes 15 articles written by Feynman, Kabir, Berman, Zweig, Gatto, et al [13]. Gibson and Pollard researched symmetry principles in particle physics [14]. Marsden and Ratiu studied mechanics and symmetry [15].

Symmetry is related with certain invariance principle, whose mathematical method is group theory. General symmetrical principle may include the relativity principle (in which various frames of reference are symmetry), the equivalence principle (various equivalence quantities are symmetry), and both correspond to the permutation group. Moreover, the symmetrical principle includes Newton’s third law (acting force and anti-acting force are symmetry), the periodic table of chemical elements, and various equilibriums, equalities, identities, commutations and unifications, etc.

Schrödinger equation of quantum mechanics is based on the microscopic wave-particle duality, and develops similarity between geometrical optics and classical mechanics, then obtains result by energy E and momentum p replaced into the general wave equation. Contrarily, based on the universal wave-particle duality, along an opposite direction of the developed quantum mechanics, we applied a method where the wave quantities frequency v and wave length λ are replaced on various mechanical equations, and obtained some new results. It is called the mechanical wave theory. From this we derived new operators, and some nonlinear equations and their solutions, which may be probably applied to quantum theory [16,17].

Development of duality is general symmetry. In particle physics main symmetries and their violations are four types [18]: (1). The permutation symmetry: Bose-Einstein and Fermi-Dirac statistics; (2). Continuous space-time symmetry, for example, uniformity of space-time, isotropy of space and so on; (3). Discrete symmetry， space-time reversal, and P (parity), C (charge conjugation), T (time reversal) symmetries in particle physics, etc; (4). Unitarity symmetry, which includes symmetry with conservation of charge, baryon number, lepton number, and symmetry of isospin I, etc.

Symmetry may be symmetry of direction in space-time, symmetry of physical quantity, symmetry of mathematical form in equation, etc., symmetry of property, symmetry of frame of reference and so on. Symmetry has five forms: complete symmetry (equality), mirror symmetry (reversing symmetry), D symmetry (de-symmetry, similarity), anti-symmetry and asymmetry. Symmetry in time brings cadence and periodicity. In fractals there is self-similarity. The renormalization group is the scaling invariable, and is independent of energy. In a word, symmetry runs through whole nature, in despite of their states and forms. Therefore, the symmetrical principle is the highest principle, and is called principle in principles.

In special relativity we researched the two symmetrical structures of the timelike and the spacelike intervals, both are topologically separated. From this and based on the basic principles of the special relativity, we may derive simultaneously the Lorentz transformation (LT) with subluminal v<c and the general Lorentz transformation (GLT) with superluminal $\bar{v}$>c. In deriving LT, an additional independent hypothesis has been used, thus the values of velocity are restricted absolutely, and the spacelike interval is excluded. LT and GLT are connected by the de Broglie relation $v\bar{v}=c^2$. Further, we think that LT is unsuitable for photon and neutrino, the photon transformation (PT) is unified for space $x'=r+ct$ and time $t'=t+(r/c)$. It may reasonably overcome some existing difficulties, and cannot restrict that the rest mass of photon and neutrino must be zero. LT, GLT and PT together form a complete structure of the Lorentz group [19-21].

General relativity has the equivalence principle, which shows symmetry between gravitational field and non-inertial system. Further, we proposed the extended general relativity [22].

We proposed that the Titius-Bode law may be represented to a new form $r_n=an^2$. From this it can be developed to a similar theory with the Bohr atom model, and we obtained the quantum constants $H=(aGM_O)^{1/2}$ of the solar system. Such we described quantitatively the symmetry relation between the Solar system and atom model, in which many quantities of the solar system can be quantized. Then the astronomical quantum theory and corresponding Schrödinger equation are derived, and the distance rule is a statistical result of planet evolution [23,24]. Further, we proposed the extensive quantum theory, which has similar formulations but different quantum numbers h→H(h_i), and they are symmetry each other [25-27], and show the cosmic-microscopic fractal [28]. We discussed the symmetry of space-time and both as four vector, and the diversity of space-time and symmetrical breaking [29]. In a word, various extended theories [19-28] all possess symmetry and invariance.

In classical physics there are some similar formula: kinetic energy $T = \frac{1}{2}mv^2$, kinetic energy for rotation $T = \frac{1}{2}I\omega^2$, elastic potential energy $V = \frac{1}{2}kx^2$, energy density of electric field $W = \frac{1}{2}\varepsilon E^2$, energy density of magnetic field $W = \frac{1}{2}\mu H^2$, energy of capacitor $W = \frac{1}{2c}Q^2$, total energy of resonator $V = \frac{1}{2}kA^2$, dissipation function $F = \frac{1}{2}c\dot{x}^2$ and so on, their basic forms are analogous each other. This is a formal symmetry. From kinetic energy derives momentum $P = \frac{dT}{dv} = \mathrm{mv}$, further may derive various similar extensive momentum, for instance, one of rotation $M = I\omega$, elastic force $F = kx$, electric displacement vector $D = \varepsilon E$, magnetic induction $B = \mu H$, etc. This shows also symmetry.

In quantum mechanics, as identical particle bosons have symmetry, while fermions have anti-symmetry [5], both are represented, respectively, by commutation and anti-commutation relations. In collision theory and Feynman diagrams there are various symmetries. Veneziano model proposed in 1968 [30] epitomized some erenow quantum theories, which may derive duality, a resonance of s-channel corresponds to infinity Regge trajectories of t-channel; contrarily, a Regge trajectory of t-channel corresponds to infinity resonances of s-channel. In the bootstrap model developed by Chew, et al., various elementary particles are complete equality, and they are symmetry, and are composed each other and have not low level structures. Bootstrap and quark possess also duality.

The U(1) symmetry may obtain the conservation of charge and quantum electrodynamics (QED), etc. Symmetry is developed to SU(2), etc., which may obtain Yang-Mills field. Its general form is Utiyama field and other non-Abel gauge theory. Generally, there has formally a similarity between field theory and statistical mechanics [31,32], which is also a symmetry.

Applications of symmetrical principle may often derive some new results. For example, Maxwell's displacement current, de Broglie's matter wave, Dirac predicted antiparticle and monopole, etc. Weisskopf discussed that symmetry played role in nuclei, atom and complex structures [33]. Ginocchio studied the relativistic symmetry in nuclei [34]. Zhilinski discussed the symmetry, invariance and topology in molecular model [35].

Based on the supersymmetry between fermions and bosons, the string model is developed to the well-known superstring theory. We researched some new representations of the supersymmetric transformations and the supermultiplets. Based on these representations, Graded Lie Algebras and various formulations (equations, commutation relations, propagators, Jacobi identities, etc.) of bosons and fermions may be unified. On the one hand, the mathematical characteristic of particles is proposed: bosons correspond to real number, and fermions correspond to imaginary number, respectively. Such fermions of even (or odd) number form bosons (or fermions), which is just consistent with a relation between imaginary and real number. The imaginary number is only included in the equations, forms, and matrixes of fermions. It is connected with relativity. On the other hand, the unified forms of supersymmetry are also connected with the statistics unifying Bose-Einstein and Fermi-Dirac statistics, and with the possible violation of Pauli exclusion principle; and a unified partition function is obtained [36,37]. A developed direction of particle physics and modern science is possibly the higher dimensional complex space. Cariglia, et al., studied classification of supersymmetric spacetimes in eleven dimensions [38].

Symmetry is very beautiful, but nature often violates spontaneously symmetry. All validity of symmetry principle depends on theoretical hypothesis of unobservable quantity. But, once an unobservable quantity is in fact observable one, it will produce violation of symmetry [18]. Furthermore, any symmetry all corresponds to degeneracy at some aspects, under a certain condition this symmetry is violated probably. This explains also relative and approximation of laws. The second law of thermodynamics and various irreversible processes all reflect symmetrical violation at time reversal. Parity is usually conservation, but it is violation in weak interactions. From this T.D. Lee and C.N. Yang initiate new era searched violation of symmetry. Further, physicists found PC and T are not also conservation under some conditions. But, so far PCT is still invariant and symmetry. Chiral symmetry may derive conserved vector current (CVC) and conserved axial vector current (CAC), and chiral symmetry violation derives partially conserved axial vector current (PCAC). Generally, particle physics introduces symmetry violation spontaneous Higgs mechanism.

Because particles possess the SU(3) symmetry, from this Gell-Mann predicted Ω^-, and obtains quark model. While broken symmetry SU(3) derives GMO mass formula [14]. Its further violation may obtain more accurate mass formula [19,39]. According to the symmetry of s-c quarks in the same generation for heavy flavor hadrons octet and decuplet classified by SU(3) which made of u,d and c quarks, we derived the similar mass formulas only S→C:

$$M = M_0 + AC + B[I(I+1) - C^2/4]. \qquad (1)$$

And

$$M = M_0 + AC + B[I(I+1) - C^2/2]. \qquad (2)$$

Using the two formulas we predicted $m(\Xi_{cc}) = 3715$ or 3673MeV [40,39]. In 10 July 2017 LHC announced to observe the new doubly charmed baryon $\Xi_{cc}^{++} = ucc$, whose mass is 3621.40±0.72(stat.)±0.27(syst.)MeV, and decay mode is $\Xi_{cc}^{++} \to \Lambda_c^+ K^- \pi^+ \pi^+$ [41]. New experimental data agree more on Eq.(2), whose error only is 1.4%. Moreover, there should have $\Xi_{cc}^{+} = dcc$, both form

I=1/2 doublet with near mass and decay mode $\Xi_{cc}^{+} \to \Lambda_{c}^{+} K^{-} \pi^{+} \pi^{0}$. Further, we predicted m(Ω_{cc}^{+})=3950.8 or 3908.2MeV [40,39], and which is more possibly 3908.2MeV by LHC experiments.

At present the standard model of particle physics has the best complete symmetry, in which quarks and leptons are symmetry in each generation, and three generations are also symmetry:

$$\begin{pmatrix} u \\ d \end{pmatrix} \sim \begin{pmatrix} \nu_e \\ e^{+} \end{pmatrix}; \begin{pmatrix} c \\ s \end{pmatrix} \sim \begin{pmatrix} \nu_\mu \\ \mu^{+} \end{pmatrix}; \begin{pmatrix} t \\ b \end{pmatrix} \sim \begin{pmatrix} \nu_\tau \\ \tau^{+} \end{pmatrix}. \quad (3)$$

But, the standard model implies also some contradictions on symmetries. The three generations of quark-lepton deviate from the SU(3) symmetry, and should form six symmetrical SU(2) groups. According to the complete symmetry, on the analogy of an isospin doublet u-d (I=1/2), we obtain various symmetrical isospin doublets: c-s, t-b, and three generations of lepton:

$$(\nu_e - e, \nu_\mu - \mu, \nu_\tau - \tau). \quad (4)$$

But it is different that s and c quarks are two isospin singles (I=0) [42]. Moreover, according to the symmetry of leptons, three neutrinos may not oscillate, and should be decay $\nu_\tau \to \nu_\mu \to \nu_e$.

From symmetry and its violation may research various unified theories of interactions in particle physics. Weinberg and Salam proposed electroweak unified SU(2)$\otimes$U(1) theory. Bars, et al., proposed first unified gauge theories of strong, weak, and electromagnetic interactions [43,44]. Pati and Salam researched unified lepton-hadron symmetry with group SU(2')$\otimes$U(1)$\otimes$SU(3'') and a gauge theory of the basic interactions [45]. Georgi and Glashow proposed grand unified theory (GUT) with SU(5) symmetry for all elementary-particle forces [46]. Barr and Raby discussed minimal SO(10) unification in supersymmetry [47]. Kakushadze and Tye studied classification of three-family grand unification with SO(10), E(6), SU(5) and SU(6) models in string theory [48]. Das and Jain searched dynamical gauge symmetry breaking in an SU(3)$\otimes$U(1) extension of the standard model [49]. Triantaphyllou, et al., researched strongly interacting fermions from a higher (4-12) dimensional unified gauge theory [50]. We proposed the simplest unified gauge group GL(6,C) of four-interactions [19,51], and researched a possible form of Lagrangian in this scheme, and obtained some relations among these results and other unified theories, and the equations of different interactions [51].

In neurobiology two wings of Lorenz model in chaos are symmetry (Fig.1), which may describe two hemispheres of brain and human thinking [52]. It shows that life lies in cooperation in chaos.

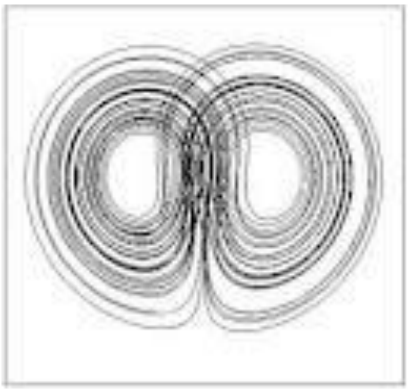

Fig. 1. X-Z view of Lorenz model

Based on the extensive quantum theory of biology and NeuroQuantology, the Schrödinger equation with the linear potential may become the Bessel equation. Its solutions are Bessel functions, and may form the double helical structure of DNA in three dimensional spaces [53], in which A-T and G-C, and double helixes are symmetry (Fig. 2).

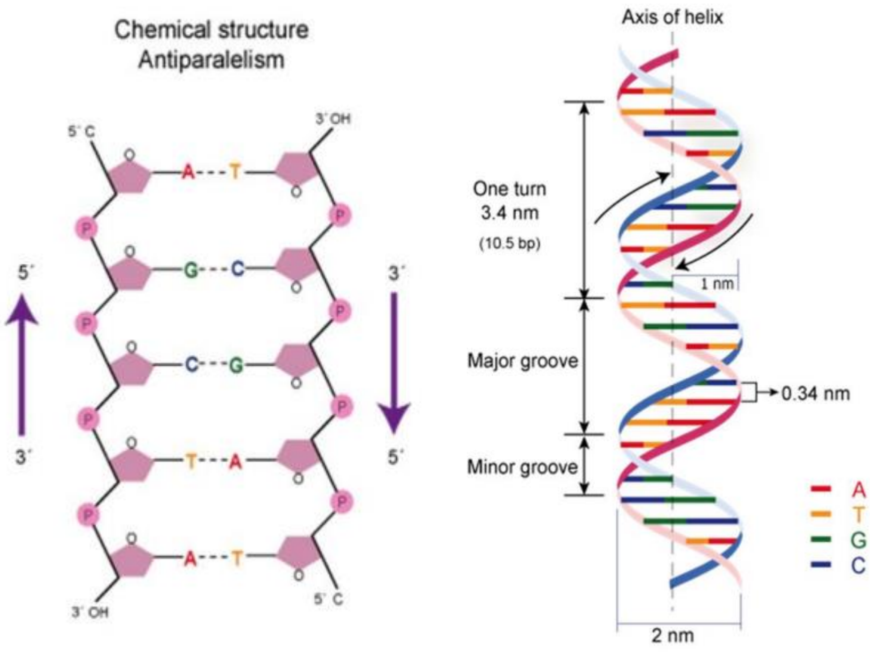

Fig.2. The double helical structure of DNA

Generally, Platonic solids and Chinese Tai-Ji Figure and Five-Elements all possess complete symmetry. Tai-Ji Figure as Bohr's family badge represents the complementary principle. Yin-Yang symmetric group and the rotational group of five elements are the mathematical base of Traditional Chinese Medicine [54]. Further, we proposed the promotion-restraint sustainable developed pattern on the Five-Elements [55], whose is also symmetry (Fig.3):

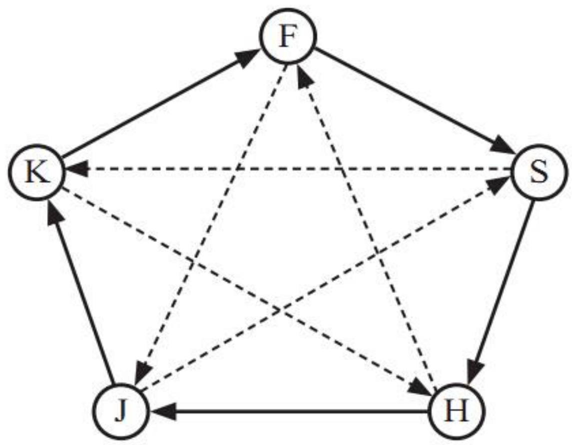

Fig. 3. Promotion-Restraint Developed Pattern on the Five-Elements

Here the five elements may be social (S) progress (democracy, justice, stabilization), economical development (F), science-technology (K), education-civilization (J) and environment-resource (H). The solid lines represent promotion relations, and the dotted lines represent restraint relations. Both relations are all internal interactions in a system. In graph theory the promotion and restraint relations are just a graph isomorphic to its complement [56].

We discussed the Dirac's negative energy state (i.e., Dirac Sea), which should be necessarily developed to the negative matter [57-62]. The negative matter possesses some new characteristics, which are mainly the gravitation each other, but the repulsion with all positive matter [59]. This is the simplest candidate of dark matter, and a huge repulsive force between the positive matter and negative matter shows dark energy, and creates inflation cosmos. Such it can explain some characteristics of the dark matter and dark energy, and we proposed some testable ways [57-62].

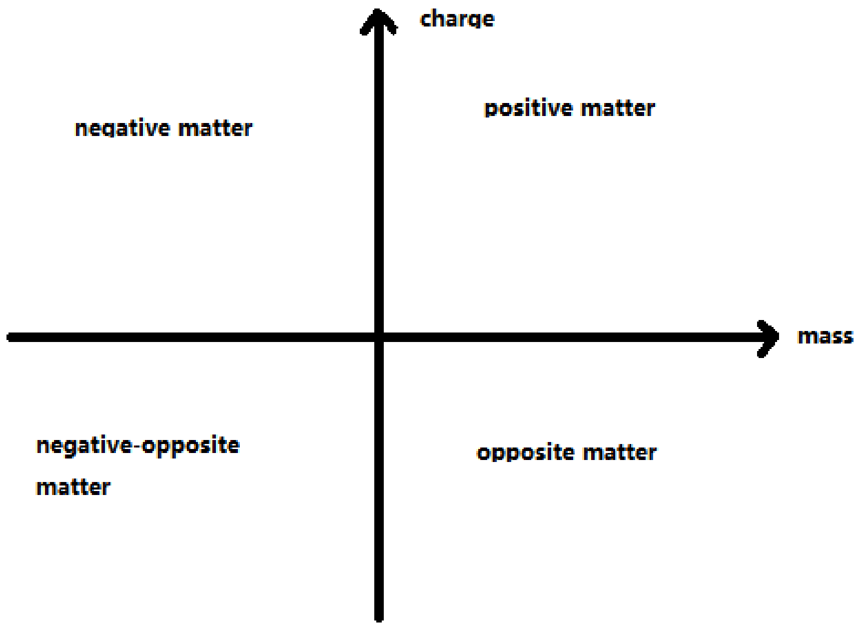

Fig. 4. The new most perfect symmetrical world

Dirac pointed out: The physical laws are symmetrical between the positive and negative charge [2]. Further, the physical laws should be also symmetrical between the positive and negative matters. It forms just the most perfect symmetrical world that four matters on positive, opposite, and negative, negative-opposite particles exist together [63]. If the negative matter is verified, a new and complete world will be exhibited (Fig. 4).

From relativity and quantum theory to particle physics, modern physics shows that the symmetrical principle and violation of symmetry under certain condition is the highest basic principle in Universe.

3. Conservation Principle and Generalized Conservation Principle

The developed history of science testifies already that the conservation of energy law is one of foremost principles. A.N. Whitehead pointed out, essence of any things all possess two principles: change and conservation. Classical mechanics is the conservation of mechanical energy, whose development is the first law of thermodynamics:

$$\Delta U = \Delta Q + \Delta W , \qquad (5)$$

and various energy conservation laws.

The continuous equation reflected invariable matter is:

$$\frac{\partial \rho_M}{\partial t} + \nabla(\rho_M \vec{v}) = \frac{\partial}{\partial x_\mu}(\rho_M v_\mu) = 0 . \qquad (6)$$

Generally, there are various conservations of momentum, angular momentum, mass, electric charge q, baryon number B, lepton number l and so on. Further, we proposed the generalized conservation principle. In any natural processes there is certain total quantity, which is always invariant. It includes usually various conservation principles on different movement quantities Q and the equal-proportional matter quantities M [7,8]. But, the definite of mass for interacting energy is hard except as the mass of total system. General movement quantities include energy, momentum, angular momentum, various forces and potentials, frequency in wave, etc.

General form of the generalized conservation law may be equation:

$$\frac{dG}{dq} = \frac{\partial G}{\partial q} + [G,W] = 0 . \qquad (7)$$

It represents the quantity G is conservation for generalized coordinate q. These generalized conservation laws may be represented by four dimensional divergence forms:

$$\frac{\partial S_i}{\partial x_i} = 0. \qquad (8)$$

In analytical mechanics d'Alembert principle is:

$$-m_i a_i + F_i + R_i = 0. \quad (9)$$

Here $-m_i a_i$ is inertial force, R_i is confined counterforce. This is a disposed way of kinetics by statics. It may consider a generalized conservation law, and is represented by conservation form: $d(Q-A)=0$, in which $-A$ is generalized movement quantity. Or it is represented by the transformation $dQ=dA=Fdq$, which is also the extensive virtual work principle $\delta W = \sum_i F_i \delta r_i = 0$. In a word, virtual transformed quantity of any generalized movement quantity Q all is zero, i.e.

$$\delta E = \sum_i Q_i \delta q_i = 0. \quad (10)$$

D'Alembert-Lagrange equation is extended to:

$$\delta(E-A) = \sum_i (Q_i - N_i)\delta q_i = 0. \quad (11)$$

This is the universal equation in physics.

At certain extent, any equality all represents conservation of certain quantity. This mathematical form is $dA = \Lambda dX$, here Λ is generalized force and dX is a generalized displacement, which includes time t. For instance, dQ=dA, in which dQ is change of certain movement quantity Q, and dA is equivalence of corresponding outside action. Assume that $Q' = -A$, so $d(Q+Q')=0$ represents the generalized conservation law. Sum of movement quantity and transformation quantity is conservation. Other includes dE=dQ, dP=Fdt and dG=Mdt, etc.

Any constant all explains certain moving or substantial conservation, and fixed composed rules. Any equivalence represents a quantitative relation of their transformations. For example, Avogadro's number shows fixed molecule number per mol substance; Planck constant shows that energy of various quantum ground states is invariant. At certain aspect, normalization is also conservation, and it is namely the probability conservation in quantum mechanics.

A certain extent, the most general matter quantities may reduce to basic charges with four interactions: mass, electric charge, hadron charge, and weak interaction charge with all particles except photon. The conservation laws of B, *l* and q construct stability of world. Kirchhoff first law in electromagnetism points out, algebraic sum of all currents at nodes is zero. In Feynman diagram, algebraic sum of baryon number B and lepton number *l* at each intersection point is zero. Both show that corresponding quantities are all conservation.

We proposed the extensive energy E conservation laws in social science, which may include all of population, natural resources, fund, land, time, etc., are fixed. Earth is only one. In an isolated system dE/dt=0 [64].

Moreover, total movement quantities Q and their change dQ are often proportional and indistinguishable coexistence with matter quantities M and their change dM. For example, force *F=ma*, momentum P=mv, kinetic energy $T = mv^2/2$, *E=hv*; and Lorentz motion equation, Maxwell equations of electromagnetic field, Einstein equations of gravitational field, etc. In particular, the well-known relation $E = mc^2$ points out mass and energy are conservation at the same time, but both are not translation each other. $E = mc^2$ determines relation of energy and mass, for example, mass of photon is $m = h\nu/c^2$. Therefore, movement quantity conservation laws and matter quantity conservation laws are usually unified, both are equivalent. They may be unified by Q=CM, in which C is constant, and Q and M are all conservation. The equivalent principle *a=H* and *a=(e/m)H* are all relations between movement quantity *a* (acceleration) and matter quantity H (field strength). This is also symmetry between movement quantity and matter quantity.

Movement quantity increases or decreases, and corresponding matter quantity also increases or decreases, and vice versa. Some constants indicate the corresponding relations between movement quantity and matter quantity. The certain movement quantity Q is represented by certain matter quantity M. Both are unified, and it is just monism. Because conservations of both aspects possess universality, and non-conservation system is only one without consider some forms of movement quantity or matter quantity. The classical form of conservation law may be:

$$\frac{\partial T_{ik}}{\partial x_i} = 0, \qquad (12)$$

in which T_{ik} is energy-momentum tensor.

They may include jump of particles and displacement rule, annihilation and creation of various equal negative and opposite matter, and chemical reactions, etc. The conservation of generalized movement quantity is a universal rule, but main quantities are different for different aspects and levels, for example, kinetic energy and potential energy (mechanical energy), force in mechanics; pressure in hydrodynamics; energy in thermodynamics; voltage in electrics; it is $H\psi$ in quantum mechanics. This explains diversity of moving form, and complexity of world. The energy conservation law shows unification of different physical processes.

Feynman discussed symmetry and conservation laws [11]. Both general relations are Noether's theorem: if a system under a certain transformation group is invariance:

$$x_\mu \to x'_\mu, \psi_\alpha(x) \to \psi'_\alpha(x'), \qquad (13)$$

the symmetry will produce necessarily a certain conservative quantity. For the continuous symmetric groups, any system, which may be represented by Lagrangian *L*, corresponds to the conservation law of differential form:

$$\partial_\mu f_\mu = \partial_\mu[(L\delta_{\mu\nu} - \frac{\partial L}{\partial\partial_\mu\psi_\alpha}\partial_\nu\psi_\alpha)\delta x_\nu + \frac{\partial L}{\partial\partial_\mu\psi_\alpha}\delta\psi_\alpha] = 0. \qquad (14)$$

Or a conserved energy-momentum tensor exists for any displacement [12]:

$$\partial_{\mu} T_{\mu\nu} = \partial_{\mu}[(-g_{\mu\nu} L) + \sum_{r} \frac{\partial L}{\partial(\partial\varphi_r / \partial x_{\mu})} \frac{\partial\varphi_r}{\partial x^{\nu}}] = 0 . \qquad (15)$$

A well-known example is that uniform space-time corresponds to conservation of momentum-energy. Charge, etc., conservation correspond to symmetry of particles conjugation, parity conservation corresponds to symmetry of space inversion. A conserved quantity is related with an invariant of symmetry group. Further, we searched generalized Noether's theorem and evolutional world [65,66]. Moreover, Hurth and Skenderis researched quantum Noether's method [67].

In a word, the conservation laws of various movement and matter quantities are the basic principle in nature. Dirac insisted that important things in Universe represent invariants in transformations, or generally, some approximate invariants [2]. Whole physical developments validate that matters and their movements are always conservation, and which is an unshakeable universal law.

4. Other Principles

4.1. Limit Value and Variational Principle

The conservation principle possesses different concrete forms for various regions, but it is universal. For different regions it adds other laws, for example, adds entropy increase law for thermodynamics, and adds various least action principles for mechanics, electromagnetic theory, quantum mechanics, etc. The quantitative rules and methods and the concrete processes on move or change of these conservation quantities are the limiting value principle, which tend to those states with shortest time, lowest energy and least action, etc. Its mathematical method is the variational principle. Marsden, et al., study the variational principle from symmetry in mechanics [15]. It includes the principle of Fermat least time in optics, general principle of least action [11], geodesics, quantum ground states, virtual displacement, Hamilton's principle, even may include the generalized inertial principle, which is extension of Galileo-Newton inertia. It exists only in inertial movement, and may be applied from one freedom to multi-freedom system and in geared robotic mechanisms [68].

We proposed that the generalized inertial principle may represent an appetence on utmost decrease change and keep actuality for object and its movement. It includes inertial law and friction, liquid surface tension, elasticity and plasticity, Lenz law and tends to equilibrium, spontaneity of particles at ground state, etc. Its philosophical basis should be related with Occam razor.

Eringen published *Basic Principles of Continuum Physics*, which discussed the variational principle [69]. Kristály, et al., studied the variational principles in mathematics, physics, geometry, economics, and qualitative analysis of nonlinear differential equations, etc [70].

The variational principle shows that various real movement quantities are some limit values under certain conditions, and any fact physical phenomena all tend to ground state, equilibrium, probability increase. This may be Gauss' principle of least constraint, Hertz's principle of least curvature, the shortest path principle and geodesic equation, least action principle or limit value principle, etc. It includes freely falling body, free molecular flow and diffusion, heat exchange, self-excitation emission, etc. For the least action principle, great scientists Fermat, Leibniz, Euler, Lagrange, Gauss, Hamilton, Maxwell, Helmholtz, Hertz, et al., made outstanding contributions. Poincare said, the least action principle and energy conservation principle as universal principles have very high value.

Hamilton principle point out, fact movements obey the variational principles:

$$\delta S = \delta\int (Q+A)dq = \delta\int L(q^i, \dot{q}^i, t)dt = 0. \quad (16)$$

They play a fundamental role throughout mechanics, both in particle mechanics and field theory [15]. This is the highest principle in all physics, i.e., the action S with limit value. In the usual way it is equivalent to the Euler-Lagrange equations:

$$\frac{d}{dt}\frac{\partial L}{\partial \dot{q}^i} - \frac{\partial L}{\partial q^i} = 0. \quad (17)$$

The least action principle may derive equation of light ray, Newton second law, Lagrange equations in conservative and non-conservative systems, hydrodynamics, basic equations and laws in thermodynamics, electromagnetic theory, relativity mechanics and quantum mechanics, etc., from formula $S = \int L dt$. Its method is to find corresponding concrete forms of Lagrangian density in various different theories. It is connected with symmetry and conservation law, and may describe phenomena in any field and systems with any freedom.

Based on the complete similarity between Fermat principle $\delta\int n(x,y,z)ds = 0$ in optics and Maupertuis principle $\delta\int mv(x,y,z)dl = 0$ of particle, de Broglie derived quantitatively duality unified wave and particle. Then Feynman started from the least action principle in quantum mechanics obtained the path integral method in quantum mechanics. Planck concluded that Hamilton principle may unify various parts of physics to a whole, the least action principle is a universal for all reversible process.

Moreover, the least action principle is extended and developed to various aspects. Paul Samuelson, Nobel Economics Prize gainer in 1970, researched the maximum principle in analytical economics.

Of course, the limit problem probably exists in non-solution or inexistence in mathematics and physics. This is degeneration of limit rule. In statistical theory the exception case for minimal probability may exist.

4.2. Statistical Principle

The statistical rule in physics includes molecular motion, thermodynamics, quantum theory, and radioactive decay, etc. Feynman discussed the principles of statistical mechanics [11]. Tsallis entropy and new statistics describe generally much phenomena in nature. Statistics is necessarily a result of a great deal chance, but it is not always right. Statistics admits exception, so it possesses approximation.

In *Natural Philosophy of Cause and Chance* M. Bohn proposed the principle of proximity and the principle of precedence for cause [71]. Bohn pointed out, any scientific theory has only the probability meaning [71], which is namely chance principle, i.e., statistics principle. In quantum mechanics there is the statistical interpretation. Heisenberg considered that statistical essence of microscopic physical laws cannot be avoided [10]. In particle physics there are many statistical models [72,73,19], for example, Fermi statistics model, Landau hydrodynamics model, Hagedorn statistical thermodynamical model, the fireball and multi-fireball model, the multiperipheral model, the FF quark cascade model, statistical phase-space model, diffractive fragmentation model, some multi-particle production models and so on. Further, we proposed new symmetry-statistics duality [19,17].

Thermodynamics is based on statistics, and includes entropy, in which there is principle of maximal entropy. Usual entropy increases always in isolated system, and defines an arrow of time [74]. Prigogine proposed the theory of dissipative structure, which recovers partly symmetry of entropy for open system. We researched possible entropy decrease in isolated system when various internal complex interactions exist [75-84]. Further, we proposed a universal formula for any isolated system [76]:

$$dS = dS^a + dS^i. \tag{18}$$

It is symmetry with a well-known formula:

$$dS = d_i S + d_e S, \tag{19}$$

in the theory of dissipative structure. From this we derived a complete symmetrical structure on change of entropy:

$$Entropy \to \begin{cases} increase. \\ decrease \to \begin{cases} \mathrm{dS} = \mathrm{d_i} S + \mathrm{d_e} S. \\ dS = dS^a + dS^i. \end{cases} \end{cases} \tag{20}$$

Here entropy decrease may be the dissipative structure for an open system, or be the internal interactions for an isolated system [84]. In combinatorial mathematics, Ramsey's theorem states that one will find monochromatic cliques in any edge labelling of a sufficiently large complete graph [85]. T.S. Motzkin pointed out that Remsey theorem proved that complete confusion and disorder are impossible [86]. It is a mathematical negation for maximum entropy and heat death of Universe. In 1959 Paul Erdos and A. Renyi researched stochastic graph, and found that under the most stochastic state the order structure will be spontaneously produced. Further, S. Kauffman proposed the theory of life origin on spontaneously catalyzed network. If black hole corresponds to entropy increase, so the Hawking's evaporation of black hole and the white hole should be symmetrical entropy decrease [82].

In modern physics chaos further points clearly out coexistence of determination and probability. From statistics, quantum mechanics and modern physics we may know that statistics principle is also a basic principle in nature.

4.3. Relativity Principle

Special relativity is very beautiful theory, whose basic principles are the special relativity principle and the constancy principle of the velocity of light. Special relativity principle points out all physical rules are the same for various inertial systems, and general relativity principle is extended to general frames of reference on any motion. Its mathematical form is covariance of equations, etc. Heisenberg pointed out that the relativity principle forms a very universal natural rule [10].

Based on the special relativity principle, an invariant speed c_h is necessarily obtained. Therefore, the exact basic principles of the special relativity should be redefined as: I. The special relativity principle, which is symmetry for any inertial system, and derives necessarily an invariant speed c_h. II. Suppose that the invariant speed c_h in the theory is the speed of light in the vacuum *c*. If the second principle does not hold, for example, the superluminal exist, the theory will be still the extensive special relativity, in which the formulations are the same, only c is replaced by the invariant speed $c \rightarrow c_h$ [19,21]. These speeds are symmetry, while the constancy principle of the velocity of light in the vacuum is violation of symmetry. If the invariant speed c_h are various invariant velocities, the diversity of space-time will correspond to many worlds. Moreover, we proved that local Lorentz transformations for different systems cannot derive varying speed of light [21].

We introduced a principle of equivalence for the electromagnetic field: A non-inertial system with acceleration is equivalent to a certain electromagnetic field, in which the ratio of charge to mass is the same [22]. From this principle an electromagnetic general relativity can be derived, whose formulations are completely analogous to Einstein's general relativity. In the electromagnetic case, the field is regarded as a type of curved space-time for charged bodies, where space-time is separated into many layers, whose curvatures are different for different ratios of charge to mass. In a general case, electrodynamics can be obtained from this theory. Such the gravitational and electromagnetic fields are symmetry and unified. Its high-order approximation will deviate from the present electromagnetic theory, and we discussed the four possible tests for this theory and some notable problems [22]. We proposed the most universal principle of extended equivalence, in which various fields and non-inertial system are equivalence and symmetry. The two types of system are relative. The fields and forces exist for the inertial systems; but the fields and forces do not exist for the non-inertial systems, they show the inertia forces. Both are undistinguishable. This is the most universal extended general relativity. Further, all of forces and fields are equivalent to each other through the same non-inertial systems, and are unified to a non-inertial system and Riemannian geometry of curved space-time. This idea is more universal than the concrete forces and fields; all become various deviations of pure geometry from the Euclidean geometry. This is the unification from various different forces and fields to the same non-inertial system. Such different fields, forces, and interactions may actually be various geometries of different space-time [22].

In 2004 Nobel Physics Prize gainer F. Wilczek pointed out that once applied representation of gauge field, general relativity and electromagnetic field are similar, and possess curved tracks. And so are also other basic interactions [87].

4.4. Correspondence Principle, Uncertainty and Approximate Principle

It is known that relativity and quantum mechanics obey the correspondence principle. It is a fundamental method of scientific development, which is a continuous process with inheritance and different stages.

Quantum mechanics derives the uncertainty principle. From this and its development we discussed the uncertain physics, and general uncertain sciences [88]. While fluctuation and statistics, and chaos in nonlinear theory all show uncertainty. Further, the uncertainty principle may be extended to approximate principle, which may be origin of experiments, be based on models, which are usually approximate simplified models. Actual any physical and scientific laws are based on the experiments and measure, which have always some errors, and cannot be absolute exact.

Although idea experiments may be exact, but, fact experiments and many sciences of incapable experiments (astronomy, earthquake, history, etc.) are uncertain and approximate. Further, any physical laws and sciences all possess approximate, because they all must exist under some conditions, and be certain idea approximation. All sciences are relative, and applied ranges of any ideas all possess locality. Any idea states all are these simplified approximate descriptions under some conditions, for example, reversible, uniformity, continuousness, etc. Furthermore, future is always incapable complete certain, and cannot be exact predictions. Dirac pointed out that probably all natural rules are only approximate. The maximal base of uncertainty and approximate principle is complexity of world. Their logical and essential base should be related with Godel's incompleteness theorem.

In a word, basic principles of physics are: 1. Symmetry principle and its violation. 2. Various conservation principles and the generalized conservation principle. 3. Limit value principle and the variational principle, which is quantitative methods and the concrete processes on move or change of these conservation quantities. 4. Statistical principle, which combining symmetry violation obtains entropy. 5. Relativity principle. 6. Correspondence principle, uncertainty principle and approximate principle. For this we try to sum up a following table:

1.**symmetry principle** → 5.relativity principle as special example.
↓ ↘ 6.correspondence principle which is special symmetry.
2.**conservation principles** → 3.variational principle as quantitative methods.

4.**statistical principle** as a mathematical method.

5. Basic Principle and Logical Structure of Quantum Mechanics

Based on the analysis of the logical structure of quantum mechanics, we proposed that the wave-particle duality is the only basic principle of quantum mechanics. Statistics is the corresponding mathematical character [19]. The other principles [2-6] are all physical or mathematical results derived from this. Duality unifies Planck formula E=hv and de Broglie formula $p = h/\lambda$ to $p_i = hk_i$. Based on the duality and symmetry between geometrical optics and Hamilton mechanics, Schrödinger equation, Klein-Gordon equation and Dirac equations are derived. At the same time a represent of plane wave $A = A_0 \exp(ik_i x_i)$ extends to the wave function of free particle $\psi = A\exp(ip_i x_i / h)$. Its differential derives namely operator represent of physical quantity:

$$p_i = -ih\frac{\partial}{\partial x_i}. \quad (21)$$

The uncertainty principle has universal meaning for various waves, which explains only limit and approximation of microscopic measure and theory. From operator represent and the uncertainty principle may derive the conjugate quantities and commutation relations.

Wave property as probability wave may be exhibited only for much particle events, which obeys identical principle. From this obtains Bose-Einstein statistics and Fermi-Dirac statistics, one of whose result is Pauli exclusion principle. Such quantum mechanics is statistical. Mathematical basis of quantum statistics obtains necessarily the definition of average value, and eigen equations, which combing operator represent may derive:

$$p_i\psi = -ih\frac{\partial}{\partial x_i}\psi. \quad (22)$$

and various equations of quantum mechanics. Since physical quantities are observable, they must be real numbers, Hermitian operators, and eigen-functions are orthogonality, normalization, completeness and closed. Particle number conservation can become statistical probability is independent of time, which obtains that the wave equations are finite, continuity and single value. Complementary principle as an extensive duality is namely a symmetrical principle. The superposition principle is mathematical property of quantum mechanics. We describe these conclusions as following figure 5:

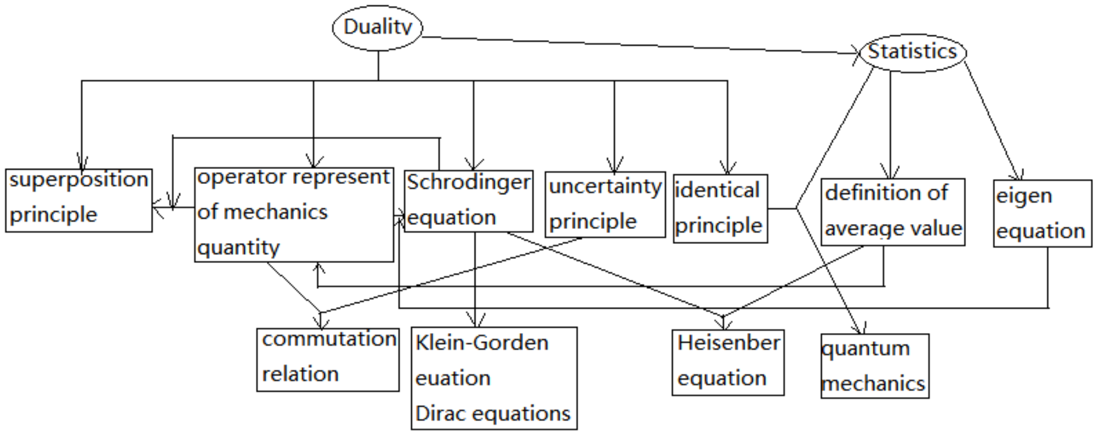

Fig. 5. Structure system of quantum mechanics

Although it may be general superposition principle described by Dirac [2], but the present applied superposition principle is linear form $\psi=\sum_n c_n\psi_n$. It should be developed to the general nonlinear form. We proposed a possible nonlinear approach of quantum mechanics. Its mathematical base is the nonlinear operators:

$$p_\mu=-i\eta(F\frac{\partial}{\partial x_\mu}+i\Gamma_\mu), \qquad (23)$$

so Klein-Gordon equation and Dirac equations are respectively:

$$(F^2\square+\Gamma_\mu^2-m^2)\varphi=-J, \qquad (24)$$

and $$\gamma_\mu(F\partial_\mu+i\Gamma_\mu)\psi+\mu\psi=j. \qquad (25)$$

The quantum commutation and anticommutation belong to F and Γ_μ. This theory may include the renormalization, which is the correction of Feynman rules of curved closed loops. We think the interaction equations must be nonlinear. Many theories, models and phenomena are all nonlinear, for instance, soliton, nonabelian gauge field, and the bag model, superstring, etc. Moreover, the nonlinear effects exist possibly for various interactions, for single particle, for high energy, and for small space-time, etc. The relations among nonlinear theory and electroweak unified theory, and QCD, and CP nonconservation, etc., are expounded. Some known and possible tests are discussed [19,89,90].

Quantum field theory is only that the duality is extended to field. It is quantization of field (i.e., second quantization), one of whose mains is becomes to the particle number representation, in which particle number is variable. In quantum mechanics the space-time representation and the symmetrical energy-momentum representation, and particle number representation in quantum field theory together reflect the affinity between movement quantity and matter quantity.

Further, we researched the microscopic relativity and the macroscopic and extensive quantum theory as a possible way unified relativity and quantum theory, and investigated some possible methods, which modify and develop relativity and quantum theory [91].

6. Gravitional Waves Proves Some Tests of General Relativity

Recently, gravitational wave forms a focus of scientific development. First, LIGO and Virgo observed gravitational waves from a binary black hole (BBH) merger [92,93]. From this Rainer Weiss, Barry C. Barish and Kip S. Thorne wined the 2017 Nobel Prize in Physics. We forecasted that further investigations may discover difference between gravitational wave and electromagnetic wave [94]. In 2017 LIGO and Virgo observed gravitational waves from a binary neutron star (BNS) inspiral. In GW170817, about 100 seconds before the neutron stars merged they were separated by about 400 kilometers, but completed about 12 orbits every second [95].

The gravitational wave based on the nonlinear equations of general relativity for the strong gravitational field should be nonlinear wave, and possesses some different characteristics with the electromagnetic wave. The nonlinearity of the gravitational wave originates from a nonlinear essence of the gravitational field, and some solutions of the equations are discussed quantitatively [96]. New observed gravitational waves are tests of general relativity, and proved they are nonlinear waves. Because binary black hole merger [92,93] and binary neutron star merger [95] must be nonlinear mechanics, so gravitational waves with large energy must be pulse waves (solitons), for example, GW150914, 151216 BBH and GW170817, 170825 BNS, etc., are all separated.

Moreover, detectors observed association with the γ-ray burst (GRB) 1.7s after GW170817 [95]. This is very small value, but, it proved clearly both velocities of gravitational wave and electromagnetic wave are different [96], and is inevitable result of general relativity.

Generally assume that velocity of gravitational wave is also the speed of light. We proposed that the two velocities should be different, i.e., the velocity of the gravitational wave will deviate from the velocity of light, at least since light deflects while the gravitational wave propagates along a straight line in a strong gravitational field, like an electromagnetic wave in an electromagnetic field [96].

It is well-known in general relativity that gravitational redshift for light and electromagnetic wave is:

$$Z = \Delta v / v = GM / c^2 R. \quad (26)$$

The angle of deflection for light is

$$\alpha = 4GM / c^2 R. \quad (27)$$

Gravitational waves and electromagnetic waves are all in curved space-time, but, gravitational waves are not influenced by gravitational redshift and the deflection of light.

First, we consider the gravitational redshift of electromagnetic wave, so difference of both velocities of gravitational wave and electromagnetic wave should be:

$$\Delta V = c_g - c_{em} = c(GM / c^2 R)\,. \quad (28)$$

For gravitational waves from a binary neutron star inspiral, its value is:

$$\Delta V = \frac{6.67\times10^{-8} cm^3 g^{-1} s^{-2} \times 2.26\times 2\times10^{33} g}{3\times10^{10} cms^{-1} \times 4\times10^{7} cm} = 2.51\times10^{8} cms^{-1}. \quad (29)$$

Here mass of neutron star M=2.26 M_O for before merged, and merged region of binary neutron stars (BNS) is about 400 kilometers. It is 0.84% of speed of light.

Difference of time is only determined by gravitational redshift, so

$$\Delta t = R / \Delta V = cR^2 / GM\ , \quad (30)$$

its value is:

$$\Delta t = \frac{3\times10^{10} cms^{-1} (4\times10^{7} cm)^2}{6.67\times10^{-8} cm^3 g^{-1} s^{-2} \times 2.26\times 2\times10^{33} g} = 0.1592 s\,. \quad (31)$$

We take mass of neutron star M=2.74 M_O (for after merged), results (29) and (31) are similar.

Next, we consider the angle of deflection of light in the gravitational field, so gravitational wave and electromagnetic wave have different paths, their difference are:

$$\Delta r = r_{em} - r_g = \frac{R}{\sin\alpha} - \frac{R}{tg\alpha} = \frac{R}{\sin\alpha}(1-\cos\alpha) = R\alpha / 2 = 2GM / c^2. \quad (32)$$

Time of gravitational wave through this path is:

$$t_g = \frac{r_g}{c} = \frac{R}{c(tg\alpha)} \approx cR^2 / 2GM = 0.02 s\,. \quad (33)$$

Time of electromagnetic wave through this path by Eq.(29) is:

$$t_{em} = \frac{r_{em}}{c'} = \frac{R}{0.9916 c(\sin\alpha)} \approx cR^2 / 4GM = 0.04 s\,. \quad (34)$$

Such difference of time is $\Delta t' = 0.02 s$ since the deflection of light.

We calculate to obtain total delay time is 0.1792s for BNS by gravitational redshift and the deflection of light. It is about 1/10 of observed delay time 1.7s. The gravitational wave and electromagnetic wave pass through the luminosity distance about 40 megaparsecs (about 130 million lightyears) and many gravitational redshifts and deflections, it is possible that both difference increases 10 times.

In a word, gravitational waves test not only general relativity, and proved they are nonlinear waves. Further, GW 170817 proved that both velocities of gravitational wave and electromagnetic wave are different. Generally, the velocities of gravitational and electromagnetic waves are different for bimetric or vector-tensor or stratified theories, they are the same in general relativity or scalar-tensor theories [97]. Gravitation is tensor field, and electromagnetic field is vector field. We researched the electromagnetic general relativity [22], which is tensor field. So gravitational waves may test vector-tensor theory and tensor-tensor theory. 2018 is also 100 anniversary of the gravitational wave predicted by Einstein.

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