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Time in Physics

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Abstract: ***The understanding of time in physics has undergone profound changes from classical mechanics to relativity and quantum mechanics. In Newtonian mechanics, time is regarded as an absolute and uniform passage, independent of external phenomena, and is a fundamental parameter of the equations of motion. Relativity emphasises the relativity of time and its close connection with the motion of matter, proposes an operational definition of the simultaneity of distant events, and develops Minkowski's view of spacetime and Riemannian curved space-time. In quantum mechanics, time is often regarded as a parameter external to the microscopic system rather than an observable quantity. Although some scholars have attempted to introduce time operators, they have not yet gained widespread recognition. Overall, the understanding of time in physics continues to deepen with the development of theory. Still, the unity of classical and quantum mechanics in time remains an unsolved problem.***

Keywords: ***Relativity, Minkowski Spacetime, Quantum Mechanics, Time Operator***

I. INTRODUCTION

This article will start with the concept of time in Newtonian mechanics and gradually explore the relativity and dynamic characteristics of time in relativity and field theory. Finally, it will analyse the non-dynamic characteristics of time in quantum mechanics and its correlation with macroscopic time. Through this exploration, we aim to gain a deeper understanding of the evolution and development of time in physics, as well as the rich connotations and characteristics it exhibits under different theoretical frameworks.

II. TIME IN NEWTONIAN MECHANICS

The Greeks were the creators of the concept of measuring time. The Pythagorean school said that '*time is the celestial sphere*', Plato said that '*time is the movement of the celestial sphere*', Aristotle said that *'time is the number of movements'*, all linking time with the measurement of movement, especially the measurement of celestial sphere movement. The essence of the scientific revolution in the 16th and 17th centuries was the revival of the Greek classical scientific spirit, especially the revival of Pythagoreanism and Platonism. Therefore, there is no revolutionary change in the concept of time; modern science, born out of the scientific revolution, continues to utilise the idea of measuring time.

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The new contribution of modern science to the concept of measuring time is that it emphasizes the aspect of measuring time and fully mathematises it. Within the framework of Aristotelian physics and subsequent developments by Galileo and Newton, an absolute concept of simultaneity in time exists. As Copernicus noted, the sun is at the centre of the universe, and light illuminates the entire universe instantaneously, introducing the concept of action at a distance in astronomy.

Roger Penrose pointed out, ' *In the Aristotelian physics, —and, indeed, in later dynamical scheme(s) of Galileo and Newton—there is an absolute notion of temporal simultaneity'* [1], p384]. *'It is appropriate to consider spacetime as a simple product,* $A=E^1 \times E^3$*, which I call Aristotelian space time. This is simply the space of pairs (t, x), where t is an element of* E^1*, a time, and x is an* E^3*, a 'point of space*' [1], p385]. In 1638, Galileo introduced the idea that relatively uniform linear motion is indistinguishable, abolishing Aristotle's concept of absolute position. Galileo's spacetime is a fibre bundle composed of a base space E1 and fibres E3, so there is no point-by-point identity (no absolute space) between different E3 fibres. Each spacetime event is naturally assigned a time (absolute time) through canonical projection [1], p. 387]. $\hat{G}$ is an affine space whose affine structure is limited to a single E_3 fibre and is equivalent to the Euclidean affine structure of each E^3 [1], p388-389]. Galileo spacetime can also be viewed as a manifold with zero curvature and zero torsion connection.

The concept of time in modern physics was first clarified by Barrow, whose significance lies in his influence on Newton. In his collection of lectures on geometry, Barrow carefully summarised and generalized the views of modern natural philosophers on events, providing an entirely mathematical physical measure of time. He advocated that time and space exist independently of material motion or even the world.

'*Time does not necessarily mean real existence, but only the ability or possibility of existence to persist, just as space represents the measurement ability of its contents. You may ask why you do not use motion to explain time, whether time does not* necessarily *mean motion. My answer is that, regarding the absolute and intrinsic nature of time, time does not necessarily mean motion. The amount of time itself does not depend on the motion or stillness of things, because time passes at an equal rate regardless of whether things are in motion or at rest, whether we are sleeping or awake. If all stars remain stationary from the beginning, no part of time will be lost. As a quantity itself, it is an absolute quantity independent of all motion, although we cannot say what this pure quantity is unless we measure it'* [2], p135~136].

Barrow's view expressed the general psychology of people about time in the clock age: time is everywhere, always present, whether you are working, resting, sleeping, or awake. However, it is also elusive and abstract. As a mathematician, Barrow referred to this as absolute time, or mathematical time.

The ideological elements contained in Newton's absolute view of time were already fully prepared by Barrow, waiting for Newton to announce them officially. In his book '*Mathematical Principles of Natural Philosophy,*' Newton wrote that *'Absolute, true, and mathematical time of itself and by its nature flows uniformly on, without regard to anything external. It is also called duration.Relative, apparent, and common time is a sensible and external measure of duration (whether accurate or variable) using motion, and is commonly used in place of true time, such as an hour, day, month, or year.*' Unlike the absolute space view, the absolute time has never been experimentally proven, Newton designed the famous bucket experiment to prove the existence of absolute space, which is different from relative space. Even after the emergence of relativity, the general public's perception of time in our technological age remains rooted in absolute simultaneity and absolute time, which Newton believed to be completely self-evident.

Newton clarified that absolute time is only one factor inherent in the equation of motion, and it can only be measured through the equation of motion, which allows for the distinction between apparent and usual time. That is to say, the determination of apparent time assumes the existence of a real time. In other words, even if we disagree with Newton's absolute view of spacetime, we can see from Newton's statement that in classical mechanics, time as a dynamic variable is premised on being a non-dynamic parameter, and the latter is more fundamental.

In short, the concept of time in classical physics is to measure time, and it is a scaled time in an absolute coordinate system. The fundamental attitude of Newtonian mechanics towards time is to apply it as an essential parameter rather than interpreting it. In Newtonian mechanics, time is a predetermined and unchanging framework. In classical mechanics, there is no distinction between time as a dynamic variable and time as a non-dynamic parameter. An ideal clock can be envisioned, meaning that the reading of a perfect clock is consistent with the passage of absolute time. Therefore, Newton's concern that '*there may not be any motion that can accurately measure time*' does not exist in classical mechanics.

As a coordinate, time originally had a direction, but Newton's dynamics eliminated this factor. In Newton's second law, time appears in the form of a square, so directionality is erased by the square. Substituting $-t$ into the equation yields the same result as $+t$. This means that in Newton's physical world, the temporal directionality of bodily processes, whether they point to the past or the future, is indistinguishable in Newtonian mechanics.

III. TIME IN RELATIVITY AND FIELD THEORY

In a limited sense, relativity constitutes a revolution in classical physics. Still, the thoroughness of this revolution cannot be exaggerated, as Einstein said, '*It is only a modified theory of physics based on the principles of relativity.*' [3], p369] The so-called time in relativity is still measured time. Within this range, relativity considerably revised Newton's concept of time. Still, it did not raise any objections to the measurement of time itself, nor did it introduce new concepts of time outside of the measurement of time. On the contrary, it further emphasizes the nature of measuring time, pointing out that Newton's absolute time fundamentally does not meet the measurement requirements. Relativity time is the refinement of measuring time.

Time originally refers to counting periodic motion, inseparable from matter's motion. It is not easy to understand what time is without the motion of matter. Due to specific theological considerations, Newton introduced the concepts of absolute space and time, cutting off the natural connection between measuring time and material motion. The situation has been reversed: it is not the measurement of time that depends on the movement of matter to determine itself, but the movement of matter depends on absolute time to differentiate itself, and absolute time itself determines itself.

Newtonian mechanics posits the existence of a universal time that applies equally to all places and reference frames. Therefore, when two events co-occur, they carry absoluteness at the same or other locations. They are all simultaneous, whether viewed from the inertial frame relative to the event at rest or from the inertial frame relative to the event in motion. Classical mechanics advocates absolute simultaneity. The simultaneity of two events in the exact location can be easily confirmed. Still, the absolute simultaneity of events in different locations requires a signal that propagates at an infinite speed. Otherwise, observers in other places will conclude that the two events occurred in various orders.

However, signals propagating at infinite speeds cannot be found in the physical world. Relativity assumes that the speed of light is the maximum speed at which any signal can propagate. Therefore, Einstein chose optical signals as the signal defining simultaneity. The absence of instantaneous signals means that absolute simultaneity is impossible. Einstein provided an operational definition for the simultaneity of remote events. Let C be the midpoint of AB, and when two events occur, A and B emit an optical signal in each direction towards C. If both optical signals are received by point C simultaneously, then the two events occurring at A and B are considered simultaneous.

For different reference frames, the speed of the light source is different. Suppose the speed of light varies with the motion of the light source and satisfies the velocity superposition theorem. In that case, the speed of light cannot be equal in the AC and BC directions in different reference frames. Therefore, to ensure the definition of simultaneity in different reference frames, the speed of light should not vary with the motion of the light source, which is precisely implied by the Michelson-Morley experiment and is necessary for Maxwell's equations that comply with the principle of relativity. After defining the simultaneity of remote events, we can easily see the relativity of their simultaneity: two events that co-occur in one reference frame generally do not co-occur in the other reference frame. From here, various counterintuitive conclusions in relativity can be drawn: the length of moving objects decreases, the rhythm of moving clocks slows down, and so on. If EPR quantum correlations are understood by entanglement realism, the

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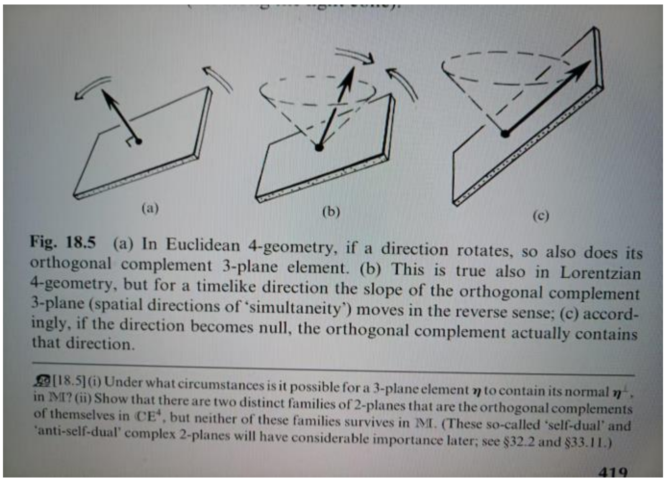
correlations between separated particles co-occur. However, in a particular reference frame, it seems that one measurement occurred first, affecting another measurement faster than the speed of light. In another frame of reference, the timing of the effects of superluminal light is reversed.

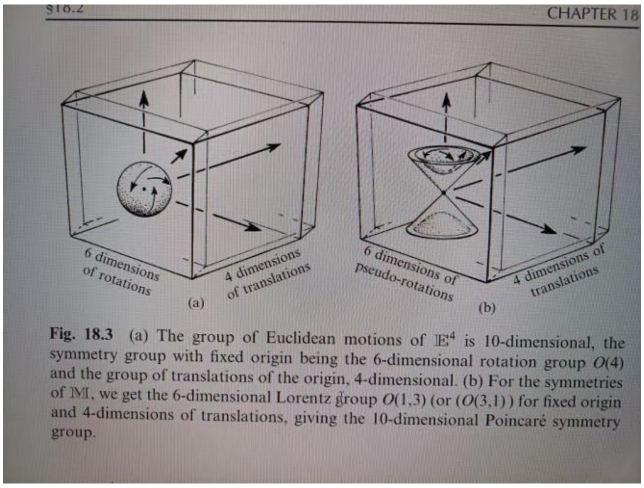
Einstein's act of restoring the essence of measuring time reconnected time, space, and the motion of matter. From the measurement perspective, time and space are no longer independent entities, but rather two aspects of an inseparable unity. Minkowski developed this idea by combining time and space into the concept of space-time. He pointed out, ' *Henceforth, space by itself and time by itself are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality*.' [4], p75~80] The world is no longer the evolution of material objects in three-dimensional space in one-dimensional time, as traditionally thought. On the contrary, the world itself is a four-dimensional space-time manifold, a whole universe, and the world we experience at every moment is only a specific section or slice in the four-dimensional continuum. The world is like a film, presenting its images to us one by one.

Minkowski's representation of spacetime can easily lead to a static understanding of space-time, as the British science fiction writer H.G. Wells said in his book *'The Time Machine'* through the protagonist: **'**There is no difference between Time and any of the three dimensions of Space except that our consciousness moves along it [5], p 132] Minkowski spacetime M is flat, with evenly distributed light cones. As a zero surface, light cones are even more fundamental than spacetime metrics, as they determine the causal structure of spacetime.



[Fig.1: Rotation in E4 [1], p419]]

In the early days of relativity, there was a trend to emphasise the similarity between M-geometry and the general 4-dimensional Euclidean geometry E4 by taking the time coordinate t as a pure imaginary number, t = iω. Stephen Hawking introduced the concept of virtual time, equivalent to spatial coordinates in quantum field theory in curved spacetime, to eliminate singularities in spacetime. This concept provides a clever physical explanation for the mathematical concept. Roger Penrose pointed out that the Euclidean motion group of E^4 is 10-dimensional: the fixed 6-dimensional rotational symmetry group O (4) of the origin, plus the 4-dimensional translational symmetry group of the origin. For the symmetry of M, we obtain a 6-dimensional Lorentz group O (1,3) (or O (3,1)) with a fixed origin and a 4-dimensional translational symmetry group, resulting in a 10-dimensional Poincaré group [1], p418].



[Fig.2: The Group of M [1], p416]]

A 3-dimensional sphere of E^4 is equivalent to a 3-dimensional hyperbolic surface in M. We can define a velocity space H+ in M, where the relativistic velocity superposition is comparable to the sum of hyperbolic lengths. The Minkowski spacetime M can be further extended to Einstein spacetime in general relativity, which has curvature but no torsion. In a vacuum, light always travels along geodesics, and celestial bodies move freely only under the action of gravity. Whether it is the separation or convergence of celestial bodies during the expansion or contraction of the universe, celestial bodies revolving around each other, except for their self-rotations, are described by geodesics.

Penrose pointed out that the celestial sphere S, as seen by observer O, is a 3D projection of the past light cone with O as its origin in M. Stars at different distances are located at various times in the past on the celestial sphere. The Riemann sphere possesses a conformal structure, although it lacks a specific metric; therefore, there is no concept of distance between adjacent points or the length of a curve. Still, there is an absolute concept of the angle between curves defined on the sphere. Any allowed (i.e. conformal) transformation from a Riemann sphere to itself must be conformal. Therefore, the shape of the (infinitely small) block must conform to this transformation, although its size may change. In addition, circles of any size on the sphere still transform into circles, precisely the structure of the celestial sphere S. Correspondingly, the circular pattern of a star perceived by one observer must also appear circular to another observer. [1], p429-430] John L. Synge made the following proof: Consider a geometric configuration consisting of a past light cone C of event O and a 3D (class-like) plane P passing through O, where Σ P is the cross-section of C and P. In a Minkowski reference frame, describe the spatial trajectories of C and ∑, respectively, and describe their temporal changes. Please explain why the observer at point O sees ∑ it as a circle, and explain in a reference frame-independent way that this geometric configuration characterises the radiation target that the observer sees as a circle. [1], p429-430]

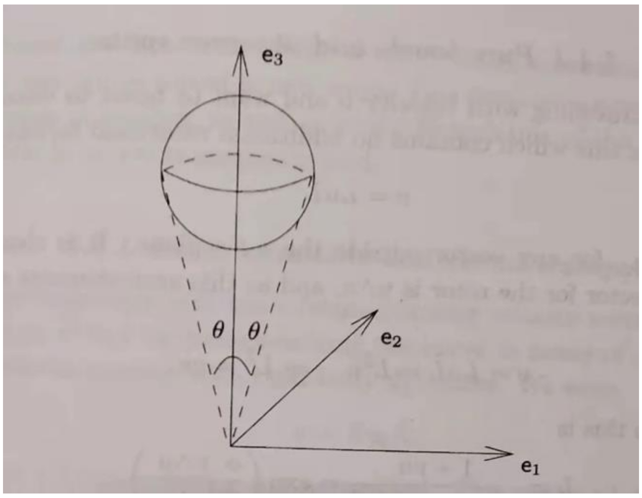
This means that a convenient label for celestial bodies in the sky is a complex number assigned to each (up to ∞) celestial body. After considering the energy and helicity of photons, Penrose also extended the spherical polar coordinates of complex parameters to the twistor theory that describes the spacetime structure of quantum mechanics.

Due to the lack of emphasis on the difference between measuring the shape of an object at the same time in relativity and seeing the visual image of an object at the same position, there is a profound misunderstanding misunderstanding in Gaimov's '*Adventures in the Physical World*' and Lorentz's statement that we can see or measure the contraction of high-speed moving objects: we can see that when a spherical planet moves at a speed v (close to the speed of light) relative to a fixed reference frame, the shape of the earth is described as compressed along the direction of motion by a factor $\gamma = \sqrt{1-v^2/c^2}$ In this reference frame. But Penrose pointed out that because the observer sees light from the back of the sphere travelling further than light from the front, the shape of the planet they see appears to be a sphere that has rotated at an angle. [1], p431]

[Fig.3: Gaimov's 'Adventures in the Physical World']

In the following figure, if one observer and the ball are both in a stationary reference frame, the edge of the observed ball is a circle defined by the following unit vector, where θ is a fixed value. The centre of the ball is on the 3-axis, which is a circle with an angle of 2θ open to the observer at the coordinate origin. If the velocity of another observer is along the 1-axis, the vector n is transformed into n'. Because the Lorentz transformation is conformal, for the second (moving) observer, the edge of the ball they see is open at the same angle to vector c. Hence, vector c passes through the centre of the ball, while the outer edge of the ball remains a circle.

In both special and general relativity, due to the limitation of the causal relationship between the speed of light and the cone of light, a rotating disk cannot extend infinitely, resulting in an edge rotation speed exceeding the speed of light. In the pre-relativistic worldview, where instantaneous actions at a distance are possible, the rotation of the celestial sphere, which Plato regarded as time itself, appears to be in a state where any two points on the celestial sphere are simultaneously at a particular moment. The entire celestial sphere appears on some simultaneous plane of the four-dimensional spacetime map. However, as Eddington pointed out, ignoring the vacuum situation where interstellar matter may alter the speed of light in space, all the stars we see are located on the past light cone in 4-dimensional spacetime. If we consider the interference of interstellar matter or other factors, the stars we see are located inside the past cone of light. In relativity, the celestial sphere is not a space separate from time itself, but a complex Riemann sphere that encodes the positions and historical moments of heavenly bodies.



[Fig.4: A Ball in High-Speed Motion]

On Einstein's path from special relativity to general relativity, he did not prioritise the development of special relativity in acceleration frames that did not consider gravitational effects, just as D'Alembert introduced the concept of inertial force in acceleration frames to promote Newton's laws of motion in inertial frames. Instead, under the guidance of equivalence principles, he treated universal gravity as a deformation of spacetime, similar to that caused by accelerated motion. Due to the non-uniform and isotropic distribution of gravity, the spacetime deformation of each point in the gravitational field caused their local inertial frames to deviate from geodesic lines, which required the introduction of curved spacetime to replace the inertia-gravity field. This inertia-gravity field not only encompasses the relativistic extension of Newton's gravity but also accounts for the relativistic effects of the inertial force accompanying accelerated motion, thereby integrating into the theory of relativity and gravity. A misconception based on Mach's principle is that treating the geocentric system with general relativity appears to be a reference frame centred on the Earth, with the equatorial plane being a rotating disk. But this understanding is incorrect. Firstly, Einstein pointed out that there are no longer rigid bodies in relativity. Naturally, no rigid rotational system can infinitely extend the Earth's equator towards the sky. Secondly, the linear velocity at the edge of the rotating disk is at the speed of light, which is an insurmountable limit. At the same time, the radius of the celestial sphere in the geocentric system seems to extend infinitely. Finally, as Eddington and Penrose pointed out out, whether in the stationary reference frame of the celestial sphere or the geocentric reference frame of the celestial sphere's rotation, the apparent motion of the celestial sphere is nothing more than the apparent rotation of the light cone around the time axis in the past, and the image of heavenly bodies at different times in the past will not cause Doppler frequency shift due to this apparent rotation. In relativity, we must abolish the instantaneous effect of action at a distance while preserving Copernicus' distinction between visual motion and absolute motion: the real rotational motion relative to the observer is accompanied by significant transverse Doppler and aberration effects, while the visual rotational motion caused by the observer's autorotation does not produce a Doppler shift or aberration effect at the center of autorotation.

In 1949, Gödel wrote an influential paper defending the static interpretation of spacetime. He believed that the relativity of simultaneity shattered the objectivity of temporal continuity, thus confirming the views of philosophers such as Parmenides and Kant, as well as modern idealists, who viewed change as a fantasy or a phenomenon arising from specific ways of perceiving it. As supplementary evidence against the objectivity of temporal continuity, he proposed mathematical possibilities for specific rotating universe models, in which '*it is possible to wander in any past, present, or future region and turn back, just as it is possible to wander in different parts of space in other worlds.*' Gödel estimated the speed and fuel required for such a fantasy journey. This spacecraft will be the implementation of Wells' time machine.

Although cautious, Einstein's comments on Gödel's article were sympathetic. Einstein indeed insisted on the view that '*we cannot send electrical signals to the past,*' but he modified his position in the following way: objectively speaking, it is impossible to send electrical signals to the past; But this is not necessarily true for microscopic phenomena, as they appear to be reversible. Not only that, Einstein also said that if we agree with Gödel's possibility of closed time-like lines on a large scale in the universe, then the succession relationship itself is relativised。 Because on a closed world line, saying that A comes before B instead of the opposite is a habit. In other words, Einstein considered the possibility in 1949 that irreversible time was confined to what Reichenbach referred to as the '*intermediate dimensional world*', and did not appear at the cosmological and microscopic scales. Of course, he also cautiously added, '*The cosmological solution to the gravitational equation (whose cosmological constant is not equal to zero) has already been obtained by Mr. Gödel. It is interesting to estimate whether these solutions will not be discarded based on physical reasons.*' Regardless of these reservations, Einstein came closer to a spatialised explanation in 1949 than in 1928 [6], p312~313].

Chapik from the United States pointed out that Gödel and others correctly noted that relativistic spacetime has a characteristic distinct from Newtonian spacetime, which is the relativity of simultaneity. However, contrary to their belief, the relativity of simultaneity does not imply that the passage of time and change have lost their objective status. If the passage of time or duration is entirely synonymous with the classical Newtonian event flow time, which is composed of moments in the entire universe, then Gödel's conclusion would be correct. This was unquestionably accepted throughout the classical era, in the same way that space is defined as Euclidean space. Gödel and modern Eleatic philosophers did not consider the possibility that Newtonian time may be only a special case of a broader concept of time. Negating Newtonian time does not lead to the disappearance of time and change.

In the universe of relativity, there are only two types of relationships: sequential causal relationships and simultaneous non-causal relationships. Because the universe comprises a dynamic network of irreversible causal lines, absolute irreversibility in relativity is extended to the entire universe. It is not the irreversibility of Newtonian time. According to Newton's view, the process of the world is composed of a series of irreversible moments across the globe, known as the moment everywhere profile, which is unacceptable in the relativistic universe. In relativity, the three-dimensional space is an arbitrary instantaneous cross-section in the four-dimensional process at any given moment. This artificial cross-section is replaced by the non-causal region of the four-dimensional process, which separates the posterior cone of the causal past from the anterior cone of the causal future. The distinction between the past and the present future is more effective than in classical physics. According to Chapik's viewpoint, the relativistic union of space and time is appropriately characterized as the dynamic transformation of space rather than the spatialisation of time [6], p. 324~325].

Whether time is a non-dynamic parameter or a dynamic variable in relativity is like the problem in classical mechanics. In relativity, there are still local ideal clocks but no global absolute clocks. In the Klein-Gordon theory of Hamiltonian systems and electromagnetic field theory, the time part of the field is shown as a parameter (Lagrange multiplier) rather than a dynamic variable.

IV. TIME IN QUANTUM MECHANICS

Prigogine believed natural laws express certainty from classical perspectives, including quantum mechanics and relativity. We can use certainty to predict the future or 'trace' the past, provided that appropriate initial conditions are given. Einstein believed that quantum mechanics cannot accurately predict the future or trace back to the past. Some scholars also believe that over time, the state information covered by the light cone in relativity constantly expands; unknown initial boundary conditions in the spacelike region are continuously transformed into observable initial boundary condition information in the lightlike and timelike regions. Therefore, it is impossible to deduce the future from the state information at a certain point in the past.

In the practical application of quantum mechanics that we have described, most scholars believe that the 'time' appearing in the equation is not an observable measure of quantum mechanics (otherwise it should be represented by a time operator), but rather a parameter external to the microscopic system, an external topologically ordered coordinate. This 'time' does not refer to anything inside the quantum system, but rather to the time measured by the macroscopic clock. Some scholars Additionally, it is argued that time can be regarded as an observable quantity in quantum systems; however, the reasons for this assertion are insufficient. Many problems discussed in quantum mechanics are essentially time-independent; these problems, such as the scattering of one system by another, are generally treated as static processes and are determined by the eigenvalue spectra of all physical operators. Furthermore, any prediction of time involved in quantum mechanics, when put into practice and verified in real time, is measured by laboratory clocks.

Suppose an operator T satisfies the commutative relationship [T, H] =ih/2 π with the Hamiltonian H, which can be introduced. In that case, the time-energy and position-momentum relationships can be logically placed in the same position. Relativity requires equal treatment of time, position coordinates, energy, and momentum components. Driven by this requirement, Schrödinger explored the possibility of a four-dimensional multiplication Hermitian operator in 1931, but he was unsuccessful.

After Prigogine's micro irreversible process was proposed, W. Schommers from Germany proposed a similar scheme for constructing time operators, treating time t as a statistical variable. This approach introduced concepts such as time operators and operators related to time coordinates, and utilised ecological paradigms to understand quantum evolution. These attempts may be inspiring, but there is still no strong experimental support, and the issue of how time at different levels can be unified on a single scale is also a significant problem. The most crucial difficulty in introducing 'internal time' and time operators is that their construction overly relies on the evolution mode of specific quantum ensembles, with too much individuality. Their connection to relativistic effects remains unclear, despite the determinacy of macroscopic time and the potential simultaneity conditions that may arise during the evolution of various quantum ensembles. These unsuccessful attempts have led people to question whether the formulation of time operators requires transformation through conceptual analysis.

Dutch philosopher of science Jan Hilgevoord pointed out that it is correct to believe that fundamental quantum mechanics is not relativistic; However, most scholars believe that three spatial coordinates are operators in quantum mechanics, which is incorrect. In the Hamiltonian description of classical or quantum mechanics, the position variable q is conjugate to the generalised momentum. When the object is considered a particle, we must distinguish the position variable q from the coordinate x. In quantum theory, the operator is the position variable q rather than the spatial coordinate x. The fundamental issue underlying the time problem in quantum mechanics is the confusion between q and x.

The behaviour of spatial translation (and rotation) at the position q of a point particle, along with the considerable similarity between the point coordinates x in three-dimensional space, blurs the significant conceptual differences between the two. The widespread application of the concept of a particle's position has dramatically increased this confusion. In many discussions of classical mechanics, the clear distinction between x and q has never been made.

In relativity, the coordinates x and t are transformed as components of a Lorentz four vector. This has led people to believe that the position q of a particle should also be a part of the four components, with a time coordinate t as the fourth component. However, q is a dynamic variable that belongs to a material system with universal space-time coordinates t. No one would consider adding t to the position variable of an arbitrary material system (such as a rigid body) to form a 4-dimensional vector. In this case, the similarity between point particles and spatial points misleads people. Attention should be paid to the system composed of several particles: in this case, people will have to combine all positional variables with the same time t; However, in reality, due to the different motion states of each particle, each particle has its unique time variable, and only these unique time variables are covariant with the position variable in relativity.

Therefore, the symmetry of a set of space-time may not necessarily imply the exact symmetry of every physical system in this spacetime. A point particle being at a point is just a situation. It is not simply a dynamic variable that can combine positional variables to form four vectors. The position of point particles is an essentially non-covariant concept. On the other hand, momentum and energy form a four-vector system in relativity.

Suppose people seek time operators in quantum mechanics. In that case, they should not quantize the universal time coordinate t, but consider the class like (literally) dynamic variables of special physical systems, such as clocks. Since clock variables are ordinary dynamic variables, quantization should not be a problem. However, this shakes the concept of time in quantum mechanics, just as the discreteness of the eigenvalues of system energy makes the idea of energy unreliable.

In Schrödinger's quantum mechanics, the parameter t is not observable. No operator corresponds to 'time t' in the Hilbert space of the state vector, so the effect of t is that of a non-dynamic variable. Someone may say, Doesn't a clock measure the result of the 'time t'? Answer: No. Because 'measuring with a clock' itself implies that a dynamic process is taking place, what is measured is the dynamic variable (such as the position of the clock pointer) rather than the non-dynamic time parameter t itself, as referred to here. Of course, conventional (non-gravitational) quantum mechanics has an entirely satisfactory explanation. This explanation aligns well with the experiment. However, it is worth noting that the concept of time plays a crucial role in this context. Measurement is conducted at a particular 'moment', and probability is the conditional probability for this measurement. The importance of time in quantum measurement is particularly reflected in the quantum Zeno effect and the anti-Zeno effect. The impact of discrete measurement and continuous measurement is very different. The measurement itself affects the evolution rate of the quantum system, and quantum time can 'stop' during constant measurement. Unlike the Zeno paradox in history, the Zeno paradox holds that we arrive after; the arrow does not move' when 'analyzing' it, which is a true paradox; The quantum Zeno effect is an inevitable consequence of quantum theory, which refers to the continuous measurement providing a Hamiltonian that maintains 'atomic decay, Continuous measurement is the interaction mechanism that maintains quantum time 'stopping'.

In 1989, R. Wald proposed the 'no ideal clock' theorem. This theorem states that in Schrödinger's quantum mechanics, an accurate clock that can 'move forward with time' must have a non-zero probability of 'moving backwards with time'. From this theorem, it can be concluded that attempting to replace the Schrödinger time parameter τ with the dynamic variable t can only provide a rough, approximate theoretical explanation. In other words, no real dynamic variable can fully reflect the 'Heraclitic properties' required by the time variable. Any real dynamic variable may have the same value at two different Schrödinger coordinate times.

In ordinary quantum mechanics, considering any system, its Hamiltonian H is limited only by the basis. We seek an observable quantity (i.e. operator) T that acts as a 'monotonic ideal clock' in the following sense. For some initial state selections, its observable value monotonically increases with the Schrödinger time t. Since T may have a continuous spectrum, let us elaborate on the minimum condition for such an operator T. We divide T into finite-sized non-overlapping intervals. We require T to have an infinite sequence $|T_0\rangle$, $|T_1\rangle$, $|T_2\rangle$... with the following properties: (1) Each $|T_n\rangle$ is an eigenvalue of an operator projected onto a spot interval centered on T_n, and $T_0<T_1<T_2<$; (2) For each n, there exists a non-zero probability that m>n and t>0, such that the amplitude from $|T_n\rangle$ to $|T_m\rangle$ will not disappear within time t (i.e. the 'clock' has a non-zero probability of heading towards the future); (3) For every m and all t>0, within time t, in the case of n<m, the amplitude from $|T_m\rangle$ to any $|T_n\rangle$ disappears (i.e. the 'clock' cannot go back in time). So, we have the following 'no ideal clock theorem'.

Theorem: If the basis constrains the Hamiltonian H, no operator T satisfies the above three properties.

Proof: Assuming n and m satisfy condition (2), consider a quantity $f(t) = \langle Tn \,|\, \exp(-iHt) \,|\, Tm \rangle$ ... (1)

Among them, t ∈ C, time has complex components in quantum theory. Since the base constrains H, f is monotonic and lies in a lower t-half plane. Therefore, f will not disappear in any open real t-interval unless it is at $t \le 0$ with an imaginary part. Since through property (3), for t>0, we have f (t)=0, which leads to the conclusion that for all real times t, f (t)=0. However, for all t>0, we have $\langle Tm \,|\, \exp(-iHt) \,|\, Tn \rangle = \langle Tn \,|\, \exp(+iHt) \,|\, Tm \rangle^* = f^*(-t) = 0$ ... (2)

This conflicts with property (2).

If another parameter τ is introduced, and τ is a monotonic function of t, τ=τ (t), and the set of all dynamic variables is represented by Z with a state vector of ψ (z), then the Schrödinger equation can be written as

$$i\hbar\, \partial\psi(\tau, z)/\, \partial\tau = N(\tau) H \psi(\tau;\, z) \quad \ldots \quad (3)$$

In the equation, N (τ) is any function of τ. If it is assumed that ψ is independent of τ (does not vary with τ), then as usual, for a fixed τ, the probability amplitude of the state when the dynamic variable is Z is given by ψ (τ; z), and the t-value obtained by the observer only represents the time sequence of the events he observes and has no other meaning. Only when a certain quantity in the dynamic variable z can be regarded as a 'good clock variable', does the value of this clock variable have temporal significance in dynamics.

The 'good clock variable' T can be defined as follows:

The dynamic variable T is a good clock variable in the interval I [a, b], when the state vector ϕ and Hamiltonian H of the system satisfy the following conditions:

(1) For all $\tau \in I$, T can be almost completely separated from other dynamic variables χ; In this sense, ϕ can take an approximate form

$$\phi(\tau; T, x) \cong \chi(\tau; T)\, \phi(\tau; x) \quad \ldots \quad (4)$$

And

$$H \cong (HT + Hx)\psi \quad \ldots \quad (5)$$

In the formula, HT is independent of x; H_x is unrelated to T.

(2) At every $\tau \in I$, where $\phi(\tau; T, x)$ has a peak $f(\tau)$ at T (where $f(\tau)$ is a monotonic function of τ), then $\phi(\tau; x)$ can be replaced by the 'equivalent wave function' ψ(T; x):

$$\psi(T;\, x) \equiv \phi(\tau(T);\, x) \quad \ldots \quad (6)$$

$$T = \int N(\tau)\, d\tau \quad \ldots \quad (7)$$

And ψ (T; x) satisfies the equation $-i\hbar\psi/\partial T + Hx\ \Omega \approx 0$ (8)

This indicates that the time parameter t as a dynamic variable in quantum mechanics is conditional [7], p2598~2609].

In 1926, Dirac pointed out that the principle of relativity requires that the time variable should be treated equally with other variables, and therefore it must be a q-number [8], p195]; '*This obvious relativistic invariance is achieved by introducing a single time for* each *particle.*'[9], p422]. In 1927, Dirac introduced three concepts of time in '*On Quantum Electrodynamics*': '*In addition to the common time T and the field time t, individual times* $t_s = t_1, t_2, t_n$ *are introduced for each particle.* '[9], p422] However, in the Schrödinger equation, there is only a common time T, and the probability amplitude is not a relativistic invariant.

Different particles have different time variables linked to the same time through quantum measurements. Like non-equilibrium molecular ensembles, molecular ensembles have different velocity distributions and tend towards thermal equilibrium states with the same velocity distribution through relaxation processes. The standard time T mentioned by Dirac refers to the Newton time measured by experimental instruments. It is a classical approximation time that occurs when the instrument scatters many particles, originally in different velocity distributions and with individual particle times (relativistic time). The relaxation process of high-energy particles is also the process by which relativistic effects fade into classical effects. The time of electromagnetic fields, like the individual time of particles, exhibits Lorentz covariance. In the Feynman diagram, Dirac's multi-level time is overly simplified, and the individual time of particles is projected onto the time coordinates of experimental instruments or classical electromagnetic fields through the statistical average of path integration, resulting in oscillatory movement of particles. Let us consider the motion of an electron. It is equivalent to two massless particles vibrating at the speed of light, shaking back and forth, and the forward left-handed zig motion immediately becomes the backwards right-handed zig motion, and vice versa.

Repeat this repeatedly, forming a finite distance. Although the overall average velocity of electrons is less than the speed of light, the instantaneous velocity of electrons we measure is less than that of light. In Penrose's view, the overall movement of electrons is represented by a matrix consisting of an infinite superposition of a finite number of zigzag particles. As a Feynman propagator, it is equivalent to the U-evolution of the wave function in the Schrödinger equation. The Feynman diagram represents various loop diagrams of particle interactions, comparable to the R evolution in ordinary quantum mechanics, providing multiple probabilities of the interaction process [1]. p630-631].

In the exploration of loop quantum gravity, Carlo Rovelli believed that we can arbitrarily agree on a periodic spatial motion as a clock, thereby obtaining a quantum gravity equation that seems to have no time axis, which means the disappearance of time: '*We have found that time has disappeared from the Wheeler DeWitt equation*', said Carlo Rovelli, '*It is a question that many theorists have been puzzled by. This may be the best way to think about quantum reality: to abandon the* concept *of time. That is to say, the basic description of the universe must not involve time* [10]. Lee Smolin believes we need a new quantum mechanics that treats any quantum system as part of the same universe, with self-consistent landscape transformations between them. We can select the absolute rest state and the optimal observer state of the universe, making the microwave background radiation appear uniform and isotropic. In the cosmological description of general relativity, we can choose the global optimal time, allowing time to be reborn. In Lee Smolin's view, the cosmological principle and microwave background radiation with equal temperature in all directions are the methods for selecting the best observer to define the global optimal time using the maximum range of thermal equilibrium states [11].

To understand Lee Smolin's viewpoint, we must consider the in-depth study of relativistic thermodynamics by Zhao Zheng, a Chinese student of Prigogine and an expert in relativity. In special relativity, clocks at different points in space that are stationary in the same inertial frame can always be calibrated using optical signals based on the uniformity and isotropy of the speed of light, thereby synchronising them and establishing a time plane for the entire space. However, achieving it may not be possible in various arbitrary coordinate systems of general relativity. Landau et al. proposed the condition of simultaneous transitivity, which means that a unified time plane can be established in spacetime when defining an enormous scope of simultaneity. Only when using a time axis orthogonal system can the coordinate clocks of each point in space be synchronised and a time plane established. This is equivalent to the wavefront of light emitted from a light source being spherical, although the speed of light can vary at different times. Zhao Zheng believes that in any reference frame of curved spacetime, the 'transitivity of clock speed synchronization' is equivalent to the 'transitivity of thermal equilibrium', comparable to the 0th law of thermodynamics. The necessary and sufficient condition for the zero law of thermodynamics to hold in Riemannian spacetime is that. $\frac{\partial}{\partial t}(\frac{g_{0i}}{g_{00}})=0$. Zhao Zheng speculates that space-time may exist where thermal equilibrium lacks transitivity [12], p339-353].

However, suppose we recognise that the U/R evolution distinction in quantum mechanics is only a distinction between the decoupling evolution of microscopic objects and instruments, and the orbital transition of instrument atoms triggered by the coupling of microscopic objects with the instruments. In that case, we will find that the linear superposition state of U evolution is just a description of various orbital transition combinations that microscopic objects may trigger in instrument atoms. In statistical mechanics, although the same temperature corresponds to the same molecular velocity distribution ensemble, the velocity of each molecule within the ensemble remains different. Similarly, a quantum superposition state is an ensemble representation of various possibilities that trigger atomic orbital transitions in an instrument. Once the orbital transition of an instrument atom occurs, the quantum superposition state will undergo irreversible evolution through decoherence, resonate with a specific orbital in the atom, and enter the eigenstate of the atom triggered by the orbital transition. The multi atoms' structure of the instrument is equivalent to quantum measurement with a pair of compound eyes imaging process like that of insects: the multiple images in the compound eye appear to be in a quantum state like linear superposition, and once an insect captures an object, the superposition state of the object in the compound eye collapses into a single object that the insect perceives through touch. There is no mysterious quantum multi-worlds division or the superposition of multiple mental states in the mind here, but rather a hierarchical jump between temperature description and molecular velocity distribution description, like the thermodynamic ensemble, which does not correspond one-to-one. Suppose we do not understand that quantum measurement involves repeated jumps in the description of quantum ensembles at different levels, as well as a single-level understanding. In that case, we will encounter the false problem of decoupling the U-process from the instrument (closed, linear, reversible description), being unable to understand the R-process associated with the instrument (open, nonlinear, irreversible description), and the illusion that the quantum world is in an unrestricted measurement split.

V. CONCLUSION

From the above aspects, we can conclude that time as a parameter or dynamic variable does not affect the form of the system's motion law in the Lagrangian system of classical mechanics. Still, in the Hamiltonian system, time is more like a non-dynamic variable. In quantum mechanics, time as a dynamic variable must satisfy certain conditions. These results indicate that the issue of time is not well unified in classical mechanics and quantum mechanics. Due to Einstein's failure to prioritise the development of an acceleration theory that considers gravitational effects, the relativistic effects involving the physical mechanisms of object acceleration and rotational motion require further investigation.

DECLARATION STATEMENT

I must verify the accuracy of the following information as the article's author.

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