Can a particle behave as a wave in self-reference frame ?

Authors: Qiankai Yao

Date: 2025-07-09T22:47:31+00:00

Abstract

As to matter wave, an interesting question is whether a particle can behave as a wave in the frame tied toitself. If the answer is negative, it is possible to establish a self-reference frame to cancel the particle'swaveform, and even develop a metric field equation to describe wave-particle duality as a geodesic effect.Meanwhile, it also shows that in addition to on-site verification, another efficacy of physicalmeasurement is to systematically reset the quantum geodesic curve of measured object. This retroactivereset not only prunes a randomly selectable history into a causal course with specific trend, but alsomakes the verified a historical inevitability dominated by geodesic geometry. The procedure adopted herewill provide a conceptually different explanation for irreversible quantum collapse and entanglement.

Full Text

Can a Particle Behave as a Wave in Its Self-Reference Frame?

Qiankai Yao
School of Physics, Henan University of Technology, Zhengzhou, China

Abstract. Regarding matter waves, a fundamental question is whether a particle can behave as a wave in a reference frame tied to itself. If the answer is negative, one could establish a self-reference frame to cancel the particle's waveform and even develop a metric field equation to describe wave-particle duality as a geodesic effect. Meanwhile, beyond on-site verification, another crucial efficacy of physical measurement is to systematically reset the quantum geodesic curve of the measured object. This retroactive reset not only prunes a randomly selectable history into a causal course with a specific trend but also makes the verified outcome a historical inevitability dominated by geodesic geometry. The approach adopted here provides a conceptually different explanation for irreversible quantum collapse and entanglement.

Keywords: Self-reference frame; Uncertainty principle; Complementarity principle; Quantum geometrization

1. Introduction

Based on the simple belief that "space is not a thing"—that the ever-changing relation of matter and energy is reflected by an ever-changing geometry—general relativity describes gravitation as a geometric effect that leads to the existing reality, but no other possibilities. A similar opinion was generalized as the radical statement from sum-over-histories that "reality is (just as classically) a single history" [13,14].

2. Basic Considerations

One of the distinctive features of the quantum world is the wave-particle duality exhibited by matter particles. In the Schrödinger picture, this duality is structurally integrated into a wave packet $\psi(x, t)$, whose diffusion field can be cast in a specific form. By contrast, the Heisenberg picture focuses more on depicting quantum motion as a random drift process governed by a classical-type equation where H is the Hamiltonian. The agreement between these two pictures requires that the quantum motion as a wave and as a particle are physically equivalent.

In statistics, random drift is typically modeled as a Wiener process [15], as if the target object is subjected to a "fictitious" random impulse without a clear source, called an inertial impulse—analogous to an inertial force $m\mathbf{a}$ being introduced in a frame accelerating with $-\mathbf{a}$. This analogy implies that although random drift weakens the descriptive efficacy of the point model [16], it reveals a more general symmetry: the physics recreated by all viewed aspects must be the same [17,18]. On these grounds, we prefer to view random drift as a non-inertial feature of the reference frame, and elucidating its physical consequence will be the starting point for moving toward quantum geometrization.

Subsequently, a self-reference problem arises: can a particle behave as a wave when referenced to itself? Or can one see oneself as a wave? A reliable answer should be "no" rather than "yes," because physical integrity determines that a self-referencing particle can only locate itself as an indivisible whole at the coordinate origin (defined by a delta function). Regarding this issue, an explanation is that the reference frame is not a degree of freedom in self-narrative [4,9]. According to Breuer [10], it is impossible for an observer to distinguish all present states of a reference system that includes himself/herself, irrespective of whether the system is classical or non-classical.

Although reference selectivity isn't practically considered a degree of freedom, each measurement (whenever and wherever performed) is always made under specific conditions. This implies that any viewed aspect has no absolute meaning; even the same target object may appear different under different reference standards [4,17], exhibiting complementary relativity. Similarly, the performances of a classical moving body in different frames are exclusive but maintain covariant unity, giving relativistic complementarity.

If that is so, it allows establishing a self-reference frame bound to the target particle, which can serve as a local inertial frame to cancel its diffusion field, just as an accelerating frame cancels gravity. For quantum geometrization, this canceling is so meaningful that it prompts us to reexamine Copenhagen's view [19,20] and restate its three essentials as follows:

Uncertainty principle (measurement is uncertain): No object is strictly measurable, nor is any reference frame perfect enough to be free of measurement defects. The equivalence of these two statements can be proved by showing that if either is false, so is the other, making it physically impossible to tell whether uncertainty comes from the measured object or the reference system.

Complementarity principle (transformation has complementary relativity): The dual aspects of each matter particle are exclusive at a specific moment but unified at a higher level [19]; that is, even if not all aspects can be viewed simultaneously, each viewed aspect must point to the same physics [18]. In other words, physics reflected by various aspects must be the same [17]. This actually tells us that physical laws are valid in all reference systems, including non-inertial drift frames, working as a broader covariance principle.

Probability interpretation (induction is based on statistics): The probability of finding a particle at a given position is spread out like a waveform, and the waveform controls the allocation of the particle to space in magnitude. So physically, a matter particle is neither a pure particle nor a pure wave, but geodesic geometry shapes it to resemble both.

3. Quantum Metric Field Equation

Once given geometric meaning, matter itself is no longer a passive participant moving in a prepared manifold but an active creator of curved space and a dual-task performer of wave and particle. To borrow Wheeler's statement for gravitation [22], "Matter as an energy source tells space how to curve, and space in turn tells matter how to move like both a wave and a particle."

Based on this borrowed statement, we rewrite the Klein-Gordon equation $i\partial_t\psi = \partial_x\psi$ for a charged particle q in an external field A_μ as

$$\mathcal{L} = \frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi - V(\phi)$$

By operator correspondence (proper time), it can be turned into an invariant interval $\tau = \int \sqrt{g_{\mu\nu}dx^\mu dx^\nu}$ where $\eta_{\mu\nu}$ is the Minkowski metric. This interval suggests treating matter waves as metric pilot waves.

In standard configuration, the non-vanishing components of the quantum affine connection are [21]

$$\Gamma^{\lambda}_{\mu\nu} = \frac{1}{2} g^{\lambda\sigma}(\partial_\mu g_{\nu\sigma} + \partial_\nu g_{\mu\sigma} - \partial_\sigma g_{\mu\nu})$$

The situation encourages us to infer that a non-drifting frame with diffusion field is equivalent to that without diffusion field but drifting with some velocity. In this regard, a referable precedent is the equivalence principle that a non-accelerating frame with gravity g is equivalent to that without gravity but accelerating with $-g$.

With the derivative relation of the metric, the Ricci tensor can be obtained by

$$R_{\mu\nu} = \partial_\lambda \Gamma^{\lambda}_{\mu\nu} - \partial_\nu \Gamma^{\lambda}_{\mu\lambda} + \Gamma^{\lambda}_{\lambda\sigma}\Gamma^{\sigma}_{\mu\nu} - \Gamma^{\lambda}_{\mu\sigma}\Gamma^{\sigma}_{\lambda\nu}$$

Referring to the geometrized scheme of relativity for gravitation, we characterize each quantum as a "diffuson" with intensity diffusivity tensor as the source of inducing the quantum metric field, that is

$$\Pi_{\mu\nu} \sim T_{\mu\nu}$$

where ρ and p are the diffusivity density and pressure, and u^μ the 4-velocity, corresponding to a conservation law $\nabla_\mu T^{\mu\nu} = 0$. Accordingly, the system Lagrangian can be written as

$$\mathcal{L} = \frac{1}{2\kappa}(\mathcal{R} - 2\Lambda)$$

where κ is an undetermined parameter. Hence, by the variation principle $\delta \int d^{4x}\sqrt{-g}\mathcal{L} = 0$, we get an equivalent of the diffusivity tensor

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \kappa T_{\mu\nu}$$

where the reduced energy density and stress read

$$\rho = \frac{mc^2}{\hbar^3}, \quad p = \frac{1}{3}\rho$$

representing a converted mass by Planck mass m_P. The result means that for a matter particle, there always comes with an effective energy source to curve its own motion space. That way, Eq.(4) can be equivalently rewritten as

$$\mathcal{R}_{\mu\nu} - \frac{1}{2}\mathcal{R}g_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu}$$

that, in addition to participating in gravitation, each mass also serves as a diffusion source, including a negative diffusion pressure of one-third intensity $p \sim -\frac{1}{3}\rho$, to induce its quantum metric field.

Now that quantum motion is a geometric behavior, like gravitation, it should represent a specific action, called self-repulsion. So, by applying Eq.(4) to a mass point m fixed at the origin with $r \to 0$, we derive a Schwarzschild-type solution

$$ds^2 = -\left(1 - \frac{2GM}{rc^2}\right)c^{2dt^2} + \left(1 - \frac{2GM}{rc^2}\right)^{-1} dr^2 + r^{2d}\Omega^2$$

For the hydrogen atomic system, Eq.(4) or (6) provides a radial ground-state solution

$$\psi_{nlm}(r,\theta,\phi) = R_{nl}(r)Y_{lm}(\theta,\phi)$$

where α is the fine-structure constant. In reality, owing to $2\alpha^{-1} \approx 137$, the ground-state energy tends to the Schrödinger result. The whole atom should reach a balance between Coulomb attraction and quantum repulsion (on charge e), that is

$$\frac{e^2}{4\pi\epsilon_0 r^2} = \frac{\hbar^2}{mr^3}$$

The balance requires $\sigma_c = \alpha\hbar$, with a central valid radius $r_c = a_0$. Now, if assuming that α increases with Coulomb attraction, the extra-nuclear electron cloud described by Eq.(7) would shrink until Landau-fall occurs at $\alpha = 1/2$. Hereby, it delimits the last defense line for the electron against central attraction, on which the repulsion effect has just reached its upper limit. For large mass, φ_{rep} tends to zero, and once in motion, it will take on a delayed form

$$\varphi_{rep}(t) = \varphi_{rep}(0)e^{-t/\tau}$$

Accordingly, the falling solution reads

$$r(t) = r_0 - \frac{1}{2}gt^2$$

The results show that the larger the mass (speed), the flatter the motion space, and the particles exhibit more classical behavior.

Following this is a falling current near the core region

$$\mathbf{J} = \rho \mathbf{v}$$

Meanwhile, to regain the original intention of variational analysis, it needs to calculate an energized field

$$\mathbf{E} = -\nabla \varphi - \frac{\partial \mathbf{A}}{\partial t}$$

where $\hat{r}$ is the radial unit vector. Thus it can be seen that whether Landau-fall can occur depends entirely on the competition between attraction and repulsion, that is, only when the former exceeds the latter in strength can the electron fall toward the center.

4. Quantum Geodesic Equation

Just like relativistic motion in an external field, when a charged mass follows a geodetic curve in self-curving space, it must also be subject to the same extremum condition for fixed-end path variation, namely

$$\delta \int_{\tau_1}^{\tau_2} d\tau = 0$$

Measurement is essentially a retroactive reset of the quantum motion history, just as a verified motion plays the role in classical physics.

So far, we have presented a dual picture of wave and particle chasing each other along a geodesic curve: as long as the wave is reachable, there may be an objective reality being recreated by the observables. In this picture, the wave is a metric pilot wave induced by the particle, and the particle is a materialized objective reality deconstructed from the wave. That way, although always realized as a whole entity in each measurement, any matter particle is still shaped into a dispersed wave by its geodesic geometry [14].

The coexistence of wave and particle trajectories in the geodesic equation not only reflects the established way in which one aspect enables the other but also indicates the logical status of physical verification: everything verified is a historical inevitability. This assertion contains two absolute meanings: 1) Any measurement must exert influence on the verified object and provoke a subsequent response. 2) Any unverified state can never serve as an objective reality to cause substantial physical consequences, embodying the empirical characteristics of the quantum world.

Particularly, as an extension of Newton's third law, if the first were false, it would be possible to perfectly infer an undisturbed state by unidirectional influence, violating the uncertainty principle. Once the second is broken, one may use an unverified quantum (as an original) to induce another (as a target) to exactly share its state, violating the no-cloning theorem [24].

With the derivative relation of the quantum metric, Eq.(8) can be separated into two parts

$$\mathcal{L}_{wave} = \mathcal{L}_{particle} + \mathcal{L}_{interaction}$$

Its universal validity requires both sides to be zero, yielding a wave-particle fusion form

$$\Psi = \psi_{wave} \otimes \psi_{particle}$$

In this way, wave-particle duality is integrated into a self-sustaining geometric structure. Due to being directed by quantum geodesic geometry, no particle can travel along a decisive path; only practical measurement convinces the observer that it is always able to timely write its verified first-hand data into geodesic instruction, so as to inevitably lead itself to the collapse target $\Psi_n(t)$. That way, the verified can always act as a de facto anchor point to anchor a geodesic smoothly connected to the "decisive starting point" $\Psi_n(0)$, thus making itself a geodesic-directed inevitability.

In principle, it is characterized as a fixed-end path variation of collapse

$$\delta S = 0 \quad \text{with} \quad \Psi(t=0) = \Psi_{initial}, \Psi(t=t_f) = \Psi_{final}$$

Obeying geodesic instruction, the collapse system must systematically reset its evolution history, namely

$$\Psi_{collapse} = \mathcal{T} \exp\left(-\frac{i}{\hbar}\int H dt\right)\Psi_{initial}$$

Along which, entanglers can naturally achieve geometric sharing of a specific state, shown in Fig.1. In that case, what it follows is no longer a world line smoothly connected to the unverified state before collapse, but an anchored one by the verified after collapse. This non-traceability of the primitive unverified state determines the irreversibility or time-reversal asymmetry of quantum collapse.

5. Quantum Collapse and Entanglement

In physics, quantum collapse is stated as that verifying an unknown state enables its wave function—initially in a superposition of several eigenstates (prepared at $t < 0$)—to suddenly reduce to a single eigenstate (at time $t = 0$) [21], namely

$$|\psi\rangle = \sum_n c_n |\phi_n\rangle \xrightarrow{\text{measurement}} |\phi_k\rangle$$

Different from the above mode, we here stress that regardless of the previous state, the collapse system is geodesic-path directed. The electron motion was faithfully generated as a lifetime historical archive. Thus embodies the basic spirit of physical cognition: existence is reasonable, and reasonableness must be subject to causality. Logically, looking back, behind every physical reality validated is a decisive (rather than optional) reset history, which could always move toward that physical reality.

Thereby, associating with Schrödinger's thought experiment, when the cat's life or death status is verified by an unboxing operation, one has to assume that it initially followed a continuous geodesic path to inevitably move toward that final fate. Since quantum collapse represents a structural switching (rather than a cliff-like fracture) of world line, we would rather refer to its occurrence as a historical reconstruction.

Based on the above analysis, we here review the double-slit experiment [25]: 1) How does an electron simultaneously pass through two slits? 2) Why can measurement destroy interference? 3) Does the delayed-choice experiment [26] mean that the present can affect the past?

Firstly, due to geometric self-determination in motion, each electron fired toward two slits always presets a double-branch geodesic curve for itself to follow, exhibiting as a coherent double wave. As long as this metric pilot wave is unobstructed, it has the opportunity to allocate the target electron in place according to the overall layout of geodesic geometry. Seemingly, an electron, as a physical entity recreated by the wave, passes through two slits simultaneously.

Secondly, once an electron is verified to pass through a specific slit, the reason must be due to the guidance of its reset geodesic path. This doesn't mean the present can affect the past but clarifies which path has actually been rooted in the original coupling mechanism. The physical measurement itself is nothing but a browsing of its regenerated historical archive. Thus, in this sense, there is no need for any "spooky action at a distance" to communicate at all.

In physics, entanglement refers to the phenomenon where coupled quanta remain synchronously correlated even after decoupling, such that any of them with random autonomy seems to instantaneously "know" what operation has been performed on the other. With this, some doubts arise, but from a geometric perspective, it appears natural. To illustrate, we rewrite the Klein-Gordon equation for a multi-body system with coordinates x_i:

$$\left(\sum_i \partial_\mu^i \partial_i^\mu + m^2 \right) \Psi = 0$$

Taking formula (3) as a precedent, the composite line element

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu$$

provides a multi-body metric field equation

$$G_{\mu\nu} = 8\pi T_{\mu\nu}$$

Then, the least action principle becomes

$$\delta \int d^{4x} \sqrt{-g} \mathcal{L}_{matter} = 0$$

For two entanglers with wave functions $|\psi_1\rangle$ and $|\psi_2\rangle$, it gives

$$|\Psi\rangle = \frac{1}{\sqrt{2}}(|\psi_1\rangle|\phi_1\rangle + |\psi_2\rangle|\phi_2\rangle)$$

When an eigenstate $|\psi_n\rangle$ is verified, there must be a variation to anchor its world line, namely

$$\text{collapse: } |\Psi\rangle \rightarrow |\psi_n\rangle|\phi_n\rangle$$

[Figure 1: see original paper] Quantum entanglement: (i) denotes the irreversible collapse of wave function; (ii) the structural reset of geodesic curve; (iii) coupling correlation; (iv) geodesic guidance; and (v) geometric sharing of entangled states.

The figure presents that quantum entanglement exists everywhere, and attributing it to the measured object or measurement system is physically equivalent.

6. Summary

Regarding reference physics, two basic understandings have been reached: 1) Random drift is a non-inertial feature of reference frame, revealing a more general symmetry that physics recreated by all viewed aspects must be the same [17]. 2) Physical laws are valid in all reference frames, including non-inertial drift ones, working as a broader covariance principle.

On these grounds, we have obtained the geometrized form of quantum motion equation and even interpreted wave-particle duality as a geodesic effect. Specifically, matter as an objective entity (matter attribute) induces space curving (spacetime attribute), and space in turn tells matter how to exhibit wave-particle duality (motion attribute), resulting in a self-sustaining structure of quantum motion. This structure not only embodies the geometric unification of matter, spacetime, and motion but also determines that the influence exerted by an observer as a measured subject (through tools or media) on the measured object must also have natural geometric characteristics. That way, if one wants to know what state a target object is in, one has to ascertain its self-curving geometry that has systematically removed all possible options incompatible with on-site verification. In the ascertained space manifold, collapse means a structural reset of geodesic curve, and entanglement a geometric sharing of verified state.

References

[1] A. Einstein et. al., *The principle of relativity* (Dover, New York, 1952).
[2] T. P. Cheng, *Relativity, gravitation and cosmology* (Oxford University Press, Oxford, 2005).
[3] P. S. Wesson, Phys. Lett. B 701, 379(2011).
[4] G. Flaminia, et. al., Nat. Commun. 10, 494(2019).
[5] W. Heisenberg, *Physics and Philosophy* (Harper & Row Publishers, New York 1958).
[6] J. A. Wheeler, et. al., Am. J. Phys. 52, 955 (1984).
[7] R. M. Angelo & A. D. Ribeiro, J. Phys. A 45, 465306(2012).
[8] B. N. Katz, et. al., Phys. Rev. A 92,042104(2015).
[9] D. M. Chiara, J. Philos. Logic 6, 331(1977).
[10] T. Breuer, Philos. Sci. 62, 197(1995).
[11] A. Peres, *Quantum theory: concepts and methods* (Kluwer Academic Publishers, 1995).
[12] B. G. Englert, et. al., Nature 375, 367(1995).
[13] S. Sinha & R. D. Sorkin, Found. Phys. Lett. 4, 303(1991).
[14] P. Krtous, Classical and Quantum Gravity 21, 1519(2004).
[15] L. A. Shepp, Annals of Mathematical Statistics 38, 1912(1967).
[16] J. E. G. Farina, Mathematical Gazette 74, 410 (1990).
[17] Y. Aharonov & T. Kaufherr, Phys. Rev. D 30, 368(1984).
[18] S. T. Pereira & R. M. Angelo, Phys. Rev. A 91.2, 022107(2015).
[19] H. Dipankar, Resonance 18, 905(2013).
[20] P. Janotta & H. Hinrichsen, Journal of Physics A: Mathematical and Theoretical 47, 323001(2014).
[21] J. V. Neumann, *Mathematical foundations of quantum mechanics* (Princeton University Press 1955).
[22] C. W. Misner, et. al., *Gravitation* (Freeman Press, San Francisco, 1973).
[23] J. D. Norton, Causation as Folk Science, Philosophers' Imprint. 3 (4), 1(2003).
[24] W. K. Wootters & W. H. Zurek, Nature 299, 802 (1982).
[25] P. Storey, et. al., Nature 367, 626(1994).
[26] A. Peruzzo, et al., Science 338, 634(2012).

Note: Figure translations are in progress. See original paper for figures.