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A Dynamical Origin of Wave-Particle Duality from Stochastic Mass-Energy Interconversion

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Abstract

Wave-particle duality remains one of the most conceptually unresolved features of quantum mechanics. Although the quantum formalism predicts interference and localization phenomena with great precision, it provides no physical account of how a single quantum object exhibits both behaviors. In this work, a dynamical mechanism for wave-particle duality is proposed based on spontaneous stochastic mass-energy interconversion at subatomic scales. By allowing inertial mass to fluctuate in accordance with Einstein's mass-energy equivalence, a modified Schrödinger dynamics is obtained in which stochastic variations in kinetic energy generate path-dependent phase accumulation. Applied to the double-slit experiment, the framework shows that quantum interference arises from coherent kinetic-phase dynamics, while particle-like localization emerges naturally at detection without invoking observer-dependent collapse. The formalism yields closed-form expressions for interference visibility, predicts a characteristic dependence of coherence loss on particle mass, momentum, and flight time, and admits a transparent path-integral interpretation. Crucially, the theory is explicitly falsifiable: existing neutron and atom interferometry experiments already place stringent upper bounds on the strength of mass-energy fluctuations, and next-generation interferometers can directly test the predicted scaling. The results provide a physically grounded account of wave-particle duality that preserves the standard quantum formalism while making clear, experimentally testable predictions.

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1. Introduction

Wave-particle duality lies at the historical and conceptual foundation of quantum mechanics. From the earliest studies of light and matter, experiments have repeatedly shown that entities traditionally regarded as particles can exhibit interference and diffraction, while entities regarded as waves can produce localized, particle-like detection events. The double-slit experiment, first performed with light and later extended to electrons, neutrons, atoms, and even large molecules, remains the clearest illustration of this dual behavior. When particles traverse the apparatus one at a time, an interference pattern nevertheless emerges over many detection events, even though each individual detection is localized.

Quantum mechanics successfully predicts these outcomes through the evolution of the wavefunction and the Born rule. However, the theory does not explain *how* a single particle propagates as a delocalized wave yet produces a localized detection. Interpretations invoking complementarity, wavefunction collapse, or epistemic descriptions of quantum states treat wave-particle duality as a fundamental or observer-dependent feature rather than as the result of an underlying physical mechanism. As a result, the duality itself remains conceptually opaque.

At the same time, quantum field theory reveals that vacuum and matter are intrinsically dynamic. Vacuum fluctuations, transient particle creation, and energy exchange occur even in the absence of real particles. These phenomena suggest that quantities treated as fixed parameters in

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nonrelativistic quantum mechanics may fluctuate at microscopic scales. Among these quantities is inertial mass, which relativity identifies as a form of energy through Einstein's mass-energy equivalence. While mass is normally taken to be fixed in quantum mechanics, no fundamental principle forbids small, rapid fluctuations provided conservation laws hold in expectation.

Recent work has proposed that intrinsic quantum uncertainty may originate from spontaneous stochastic mass-energy interconversion at subatomic scales rather than from irreducible indeterminism alone [1]. In this scenario, inertial mass fluctuates due to underlying vacuum dynamics, introducing stochasticity directly into the kinetic phase of a quantum system. Importantly, this framework does not modify the axioms of quantum mechanics, but supplements the standard formalism with a physically motivated source of phase dynamics.

The findings reported in *Observation of quantum effects on radiation reaction in strong fields* provide substantive experimental support for a theory of stochastic mass-energy interconversion by showing that, in the strong-field quantum regime, the transfer of energy from relativistic electrons to emitted radiation is not adequately described as a smooth, continuous process, but instead is governed by discrete quantum events. The article demonstrates a high-significance (>5σ) observation of radiation reaction and presents strong evidence that quantum radiation-reaction models outperform the classical description, primarily because the quantum models more accurately reproduce the observed electron energy losses and photon spectra. Of particular relevance to a stochastic interconversion framework, the paper states that photon emission in this regime "becomes stochastic," with single emissions capable of removing significant fractions of an electron's energy, and further shows that the quantum-stochastic model predicts spectral broadening arising from probabilistic emission. Experimentally, the measured post-collision spectra exhibit lower electron energies, broader distributions, and a strong correlation between greater photon yield and greater electron energy loss, all of which are consistent with quantized, probabilistic matter-to-radiation energy transfer. Although the study does not establish a universal theory of stochastic mass-energy interconversion in all physical contexts, it does furnish compelling evidence that under extreme electromagnetic conditions, energy conversion between matter and radiation proceeds through inherently probabilistic quantum processes rather than purely deterministic classical dynamics [2].

The present work applies this framework to wave-particle duality. By analyzing the canonical double-slit experiment, it is shown that quantum interference arises from coherent, path-dependent accumulation of kinetic phase driven by mass-energy fluctuations, while particle-like localization emerges naturally at detection through dynamical decoherence. The result is a concrete, testable account of wave-particle duality consistent with standard quantum mechanics.

2. Stochastic Mass-Energy Dynamics

2.1. Fluctuating Mass Hypothesis

The inertial mass of a particle is postulated to fluctuate in time according to

$$m(t) = m_0 + \delta m(t), \tag{1}$$

where m_0 is the mean rest mass and $\delta m(t)$ is a stationary stochastic process satisfying

$$\langle \delta m(t) \rangle = 0, \tag{2}$$

$$\langle \delta m(t)\, \delta m(t') \rangle = \sigma_m^2\, \delta(t - t'). \tag{3}$$

These fluctuations correspond to spontaneous mass-energy interconversion,

$$\delta E(t) = c^2\, \delta m(t), \tag{4}$$

and conserve energy in expectation.

doi:10.20944/preprints202601.1796.v3

2.2. Modified Schrödinger Equation

The time-dependent Hamiltonian is

$$H(t) = \frac{p^2}{2m(t)} + V(\mathbf{x}), \tag{5}$$

which, expanded to first order in $\delta m(t)$, becomes

$$H(t) \approx \frac{p^2}{2m_0} - \frac{p^2}{2m_0^2}\,\delta m(t) + V(\mathbf{x}). \tag{6}$$

The Schrödinger equation then reads

$$i\hbar\frac{\partial\psi}{\partial t} = \left[\frac{p^2}{2m_0} + V(\mathbf{x})\right]\psi - \frac{p^2}{2m_0^2}\,\delta m(t)\,\psi. \tag{7}$$

The stochastic term introduces a kinetic-phase contribution

$$\delta\phi(t) = -\frac{1}{\hbar}\int \frac{p^2}{2m_0^2}\,\delta m(t)\,dt. \tag{8}$$

3. Double-Slit Interference

3.1. Two-path state

After the slits, the wavefunction is a coherent superposition,

$$\psi(\mathbf{x},t) = \psi_1(\mathbf{x},t) + \psi_2(\mathbf{x},t), \tag{9}$$

with detected intensity

$$I(\mathbf{x}) = |\psi_1|^2 + |\psi_2|^2 + 2\,\mathrm{Re}\{\psi_1^*\psi_2\}. \tag{10}$$

3.2. Stochastic phase accumulation

Along each path i, the accumulated phase is

$$\phi_i = \frac{1}{\hbar}\int_0^T \frac{p_i^2}{2m(t)}\,dt, \tag{11}$$

which separates into mean and stochastic parts,

$$\phi_i = \phi_i^{(0)} + \delta\phi_i. \tag{12}$$

The relative phase governing interference is

$$\Delta\phi = \phi_1 - \phi_2. \tag{13}$$

4. Fringe Visibility and Decoherence

Define the coherence functional

 doi:10.20944/preprints202601.1796.v3

$$\Gamma(T) = \langle e^{i\Delta\phi} \rangle. \tag{14}$$

The ensemble-averaged intensity is

$$\langle I \rangle = |\psi_1|^2 + |\psi_2|^2 + 2\,\mathrm{Re}\{\Gamma(T)\psi_1^*\psi_2\}. \tag{15}$$

For Gaussian mass fluctuations,

$$\Gamma(T) = \exp\left[-\frac{p^2}{2m_0^2}\sigma_m^2 T\right]. \tag{16}$$

5. Path-Integral Formulation

The action along a path is

$$S = \int_0^T \left[\frac{1}{2}m(t)\dot{x}^2 - V(x)\right] dt, \tag{17}$$

with stochastic contribution

$$\delta S = \int_0^T \frac{1}{2}\dot{x}^2\,\delta m(t)\,dt. \tag{18}$$

The interference cross term becomes

$$\left\langle e^{\frac{i}{\hbar}(S_1 - S_2)} \right\rangle = \exp\left[-\frac{\langle(\delta S_1 - \delta S_2)^2\rangle}{2\hbar^2}\right]. \tag{19}$$

6. Which-Path Detection and Decoherence

Which-path measurements couple to kinetic energy and therefore to the stochastic phase, dynamically driving

$$\Gamma(T) \to 0 \quad \text{as} \quad \sigma_m^2 T \to \infty. \tag{20}$$

No observer-dependent collapse is required.

7. Comparison with Standard Interpretations

Interpretationally, the present proposal is closest to approaches that seek to explain the measurement transition without taking wave-particle duality itself as a primitive postulate. In Bohr's complementarity framework, the wave and particle aspects are not simultaneous properties of a microscopic object but mutually exclusive descriptions tied to experimental arrangement [17]. That move was historically decisive, but it is intentionally operational rather than dynamical: complementarity tells us why both descriptive languages are needed, yet it does not identify a microscopic process that generates interference in one context and localization in another. The stochastic mass-energy picture developed here aims to supply exactly that missing dynamical layer. It leaves the empirical content of complementarity intact while proposing that the phase structure ordinarily encoded abstractly in the wavefunction is physically sustained by fluctuating kinetic energy.

Relative-state or many-worlds approaches eliminate collapse by insisting on universal unitary evolution [18]. On that reading, interference persists because amplitudes in different branches remain coherent until environmental entanglement makes them effectively autonomous. Bohmian

 doi:10.20944/preprints202601.1796.v3

mechanics resolves the same problem differently, by assigning particles definite trajectories guided by a real pilot wave [19]. Both programs give wave-particle duality a more explicit ontology than textbook Copenhagen, but they do so by enlarging the ontology of the theory—either to branching worlds or to a dual structure of particle plus guiding field. The present model takes a narrower route. It remains single-world and does not add hidden trajectories or branching sectors; instead, it attributes the crucial phase dynamics to stochastic mass-energy exchange acting within otherwise standard quantum evolution.

Statistical and epistemic interpretations push in the opposite direction by refusing to read the quantum state as a literal physical wave. In Ballentine's statistical interpretation, the wavefunction characterizes ensembles rather than individual systems [20]. More recent psi-epistemic analyses and QBist formulations likewise treat the quantum state primarily as information, knowledge, or rational expectation rather than as a directly physical field [21,22]. These views are powerful in clarifying what quantum states mean, but precisely because they are interpretationally deflationary they do not by themselves provide a microscopic account of how interference visibility is generated or lost in a concrete apparatus. By contrast, the present framework is explicitly mechanism-seeking: the coherence functional Γ is not merely a bookkeeping device for an observer's uncertainty, but a calculable measure of how stochastic kinetic phase remains correlated across paths.

Decoherence-based accounts come closer in spirit to the present work, because they explain the disappearance of interference through physical entanglement with uncontrolled degrees of freedom rather than through a special observer-triggered collapse. Zurek's formulation of decoherence and einselection, together with the broader decoherence literature already cited in Ref. [9], shows how environmental monitoring selects preferred states and suppresses off-diagonal coherence [9,23]. Objective-collapse models such as that of Ghirardi, Rimini, and Weber go further by modifying the dynamics so that macroscopic superpositions become unstable in principle [24]. The stochastic mass-energy model proposed here differs from both lines of thought. It does not replace Schrödinger evolution with a new collapse law, yet it also does not leave decoherence entirely external to the system-environment boundary. Instead, it suggests that part of the phase randomization relevant to localization may be intrinsic, rooted in subatomic mass-energy fluctuations that can be bounded by interferometry.

Seen in this context, the distinctive claim of the present theory is not that it abolishes the interpretational debates, but that it changes where those debates are anchored. Wave-particle duality need not be accepted as a brute fact, nor explained by multiplying worlds, hidden trajectories, or purely epistemic state assignments. It can be treated as an emergent consequence of stochastic phase formation in a single-world quantum dynamics. That is a stronger claim than a reinterpretation of the textbook formalism and a weaker claim than a wholesale replacement of it, which is why the proposal stands or falls on the quantitative visibility bounds derived in Sec. 8 rather than on interpretational preference alone.

8. Experimental Outlook

From a measured visibility $V(T)$, the fluctuation strength is bounded by

$$\sigma_m^2 \leq \frac{2m_0^2}{p^2 T} \ln\left(\frac{1}{V}\right). \tag{21}$$

Neutron interferometry experiments constrain

$$\sigma_m/m \lesssim 10^{-15}, \tag{22}$$

while atom and molecular interferometers can improve these bounds by several orders of magnitude. The predicted scaling differs from environmental decoherence, enabling clean experimental discrimination.

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9. Discussion

This concept reframes wave-particle duality as an emergent dynamical phenomenon rather than a primitive axiom of quantum theory. Allowing inertial mass to fluctuate stochastically in accordance with mass-energy equivalence provides a concrete physical mechanism for the coexistence of delocalized propagation and localized detection.

A central conceptual shift is the relocation of quantum "waviness" from the abstract wavefunction to the kinetic phase accumulated through mass-energy fluctuations. Whereas conventional quantum mechanics attributes interference to superposition without an underlying physical carrier, the present framework traces interference to coherent phase accumulation along spacetime paths driven by correlated variations in kinetic energy.

The model accounts for the dependence of interference visibility on mass, velocity, and flight time, explains the dynamical suppression of interference under which-path detection, and aligns with decoherence theory while supplying a microscopic origin for decoherence rates. The formal structure of quantum mechanics remains unchanged; only the physical interpretation of phase is extended.

Connections to quantum field theory are immediate, as vacuum fluctuations and virtual particle processes already involve transient mass-energy exchanges. The present work suggests that such processes may underpin nonrelativistic quantum phenomena and may provide a bridge toward semiclassical gravity.

The theory is falsifiable. Existing neutron and atom interferometry already impose stringent bounds, and next-generation experiments may decisively test the model.

Placed alongside complementarity [17], many-worlds [18], Bohmian mechanics [19], statistical and psi-epistemic approaches [20–22], decoherence [9,23], and objective-collapse models [24], the present proposal is best understood as a dynamical-completion hypothesis: it preserves the formal apparatus of ordinary quantum mechanics while attempting to supply a physical origin for the phase correlations whose loss produces the appearance of collapse.

The present framework suggests that wave-particle duality need not be treated as a primitive statement about the ontology of the wavefunction. Instead, the wave-like aspect of quantum propagation can be understood as the accumulation of kinetic phase along spacetime paths when inertial mass is allowed to fluctuate stochastically about its mean value in a manner consistent with mass-energy equivalence [1,5,10]. In this reading, the wavefunction remains the correct calculational object, but its observable phase structure is tied to an objective dynamical process: transient mass-energy exchange. This shifts the interpretive burden from abstract superposition alone to a concrete source of phase noise and phase correlation. If the same stochastic process also underlies the energy variance discussed in Ref. [1], then wave-particle duality and uncertainty become related consequences of a single submicroscopic mechanism rather than separate axioms.

A notable consequence is that interference depends not only on geometric path difference but also on the statistical structure of the mass fluctuations sampled along each path. The persistence of fringes therefore requires that the stochastic phase increments remain sufficiently correlated across the two arms of the interferometer. For nearby paths, it is natural within the model to attribute this correlation to a common vacuum environment or common underlying field, so that stochastic phase differences do not average immediately to zero. In that limit the conventional interference term is recovered, multiplied by a damping factor encoded in the coherence functional Γ. The theory thus retains the standard interference pattern as a limiting case while also providing a mechanism for reduced visibility when the fluctuations decorrelate. This extends the path-integral viewpoint of Feynman and Hibbs by attaching physical significance to the phase-bearing action itself rather than leaving it as a purely formal amplitude weight [5].

This dynamical picture also sharpens the meaning of localization at detection. In the standard formalism, a detector registers a localized event even when the pre-detection state is spatially delocalized. Here, localization is interpreted as the point at which the fluctuating kinetic phase ceases to remain coherently shared across alternatives and becomes conditioned by the detector interaction. Which-path detection then destroys interference because it fixes or randomizes the relevant phase

 doi:10.20944/preprints202601.1796.v3

relation, driving $\Gamma \to 0$ without the need to posit a special observer-dependent collapse rule [9]. In that sense the present model is not a rejection of decoherence theory but a candidate microscopic completion of one aspect of it: it proposes a specific physical origin for part of the phase randomization that decoherence phenomenology normally parameterizes more generally.

The model furthermore invites a re-examination of the quantum-classical boundary. Because the visibility factor derived in Eq. (16) scales with momentum, flight time, and fluctuation strength, increasingly massive or energetic systems should become progressively more vulnerable to phase washout if the stochastic coupling is real. The expansion material frames this as intrinsic decoherence: a loss of coherence that would persist even after conventional environmental channels are strongly suppressed. That conjecture is stronger than standard environmental decoherence and is therefore experimentally valuable, because it yields a clean falsifiability criterion. If future interferometers continue to preserve visibility at masses and velocities where the present stochastic model predicts suppression, then the allowed fluctuation strength σ_m must be pushed downward or the hypothesis rejected. If, however, an unexplained rolloff in visibility survives vacuum, thermal, and vibrational controls, the result would point to a genuinely internal contribution to decoherence [6,9,11].

This is precisely why heavy-particle interferometry is such an important proving ground. Matter-wave experiments have already demonstrated coherent interference for molecules with masses beyond 25 kDa, showing that quantum superposition survives far into the mesoscopic regime [8,12]. These results do not confirm the present theory, but they significantly narrow the available parameter space and establish a concrete benchmark for any proposed intrinsic decoherence mechanism. In the same spirit, proposed nanoparticle and nanocrystal superposition experiments are especially relevant because they target objects large enough to magnify hypothetical non-environmental decoherence channels while still allowing careful control of external noise [13,14]. Within the present framework, such platforms could test whether coherence loss follows purely environmental scaling or whether an additional mass- or kinetic-energy-dependent contribution emerges.

The expansion material also identifies a particularly sharp discriminant: a velocity-visibility anomaly. In conventional interferometric reasoning, increasing beam velocity can improve coherence by shortening the transit time during which external perturbations act. In the present stochastic-mass framework, however, the same increase in momentum enhances the kinetic-phase sensitivity to $\delta m(t)$, so that beyond some regime visibility could decrease rather than improve. A controlled scan of fringe visibility versus velocity in atom interferometers would therefore be highly informative. Because three-grating atom interferometers already allow precise control of velocity selection and long-baseline phase measurement [8], this prediction can be cast as a direct null test. Just as importantly, the detector-resolution argument developed in the expansion shows that, for laser-grating interferometers, the observable fringe period is set primarily by the grating geometry rather than by the de Broglie wavelength itself. A visibility loss at high velocity would therefore not automatically reduce to a trivial failure to resolve progressively finer matter-wave structure. That makes the proposed velocity test conceptually cleaner than it first appears.

A broader implication concerns the relation between this nonrelativistic model and adjacent areas of physics. The hypothesis draws motivation from the fact that quantum field theory already accommodates vacuum fluctuations and transient energy exchange, while general relativity assigns dynamical significance to mass-energy as the source of spacetime curvature [10]. The present work does not derive gravity from the stochastic mass term, nor does it establish that interferometric phase noise should appear directly in gravitational-wave observatories. Still, the suggestion that subatomic mass-energy fluctuations might leave signatures across both quantum-coherence experiments and precision gravitational sensing is an intriguing research direction rather than a demonstrated consequence. Existing stochastic-background searches by LIGO/Virgo and the design goals of LISA show that instrumentation now exists, or is being developed, that can constrain extremely weak broadband signals [15,16]. Any attempt to connect those searches to the present model would require a far more explicit mapping between σ_m and an observable strain spectrum than is provided here, but the idea is sufficiently concrete to motivate future work.

Finally, the value of the proposal lies in its falsifiability. The formalism preserves ordinary quantum mechanics when σ_m → 0, so it is not insulated from experimental failure. Neutron, electron, atom, and molecule interferometry already bound the admissible fluctuation strength [6–8,12], and next-generation mesoscopic interferometers will tighten those bounds further [11–14]. The most productive way to read the present theory, then, is as a dynamical hypothesis about the physical origin of quantum phase, one that yields quantitative consequences for visibility, mass scaling, momentum scaling, and detection. Whether those consequences ultimately survive experiment remains open. What the framework contributes, however, is a program in which wave-particle duality is no longer merely named, but linked to parameters that can in principle be measured, constrained, or ruled out.

10. Conclusion

Wave-particle duality can be understood as a consequence of spontaneous stochastic mass-energy interconversion. Interference emerges from coherent kinetic-phase dynamics, while particle-like localization arises naturally at detection. The framework removes the need for observer-dependent collapse, preserves standard quantum mechanics, and makes explicit, falsifiable predictions. Whether confirmed or constrained, the model sharpens our understanding of quantum behavior and the physical meaning of phase.

Declarations

During the preparation of this work, the author used ChatGPT-5.2 for structural assistance and equation formatting. All content was reviewed and edited by the author, who takes full responsibility for the manuscript.

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References

1. [1] R. E. Willis, Spontaneous stochastic mass–energy interconversion: Implications for the Heisenberg Uncertainty Principle and a Theory of Everything, Appl. Phys. Res. 17, 105 (2025), doi:10.5539/apr.v17n1p105.
2. [2] Los, E.E., Gerstmayr, E., Arran, C. *et al.* Observation of quantum effects on radiation reaction in strong fields. *Nat Commun* **17**, 1157 (2026). https://doi.org/10.1038/s41467-025-67918-8
3. [3] T. Young, The Bakerian Lecture: Experiments and calculations relative to physical optics, Philos. Trans. R. Soc. Lond. 94, 1 (1804).
4. [4] C. Davisson and L. Germer, Diffraction of electrons by a crystal of nickel, Phys. Rev. 30, 705 (1927), doi:10.1103/PhysRev.30.705.
5. [5] R. P. Feynman and A. R. Hibbs, Quantum mechanics and path integrals, McGraw–Hill, New York (1965).
6. [6] H. Rauch and S. A. Werner, Neutron interferometry: Lessons in experimental quantum mechanics, Oxford University Press, Oxford (2000).
7. [7] A. Tonomura, J. Endo, T. Matsuda, T. Kawasaki, and H. Ezawa, Demonstration of single-electron buildup of an interference pattern, Am. J. Phys. 57, 117 (1989), doi:10.1119/1.16104.
8. [8] A. D. Cronin, J. Schmiedmayer, and D. E. Pritchard, Optics and interferometry with atoms and molecules, Rev. Mod. Phys. 81, 1051 (2009), doi:10.1103/RevModPhys.81.1051.
9. [9] E. Joos, H. D. Zeh, C. Kiefer, D. J. W. Giulini, J. Kupsch, and I.-O. Stamatescu, Decoherence and the appearance of a classical world in quantum theory, Springer, Berlin (2003).
10. [10] A. Einstein, Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?, Ann. Phys. 17, 132 (1905), doi:10.1002/andp.19053231314.

11. [11] M. Arndt and K. Hornberger, Testing the limits of quantum mechanical superpositions, Nat. Phys. 10, 271–277 (2014), doi:10.1038/NPHYS2863.
12. [12] Y. Y. Fein, P. Geyer, P. Zwick, F. Kiałka, S. Pedalino, M. Mayor, S. Gerlich, and M. Arndt, Quantum superposition of molecules beyond 25 kDa, Nat. Phys. 15, 1242–1245 (2019), doi:10.1038/s41567-019-0663-9.
13. [13] O. Romero-Isart, Quantum superposition of massive objects and collapse models, Phys. Rev. A 84, 052121 (2011), doi:10.1103/PhysRevA.84.052121.
14. [14] G. Gasbarri, A. Belenchia, M. Carlesso, S. Donadi, A. Bassi, R. Kaltenbaek, M. Paternostro, and H. Ulbricht, Testing the foundation of quantum physics in space via interferometric and non-interferometric experiments with mesoscopic nanoparticles, Commun. Phys. 4, 155 (2021), doi:10.1038/s42005-021-00656-7.
15. [15] B. P. Abbott et al. (LIGO Scientific Collaboration and Virgo Collaboration), Search for the isotropic stochastic background using data from Advanced LIGO's second observing run, Phys. Rev. D 100, 061101(R) (2019), doi:10.1103/PhysRevD.100.061101.
16. [16] P. Amaro-Seoane et al., Laser Interferometer Space Antenna, arXiv:1702.00786 [astro-ph.IM] (2017).
17. [17] N. Bohr, The quantum postulate and the recent development of atomic theory, Nature 121, 580 (1928), doi:10.1038/121580a0.
18. [18] H. Everett, "Relative state" formulation of quantum mechanics, Rev. Mod. Phys. 29, 454 (1957), doi:10.1103/RevModPhys.29.454.
19. [19] D. Bohm, A suggested interpretation of the quantum theory in terms of "hidden" variables. I, Phys. Rev. 85, 166 (1952), doi:10.1103/PhysRev.85.166.
20. [20] L. E. Ballentine, The statistical interpretation of quantum mechanics, Rev. Mod. Phys. 42, 358 (1970), doi:10.1103/RevModPhys.42.358.
21. [21] N. Harrigan and R. W. Spekkens, Einstein, incompleteness, and the epistemic view of quantum states, Found. Phys. 40, 125 (2010), doi:10.1007/s10701-009-9347-0.
22. [22] C. A. Fuchs and R. Schack, Quantum-Bayesian coherence, Rev. Mod. Phys. 85, 1693 (2013), doi:10.1103/RevModPhys.85.1693.
23. [23] W. H. Zurek, Decoherence, einselection, and the quantum origins of the classical, Rev. Mod. Phys. 75, 715 (2003), doi:10.1103/RevModPhys.75.715.
24. [24] G. C. Ghirardi, A. Rimini, and T. Weber, Unified dynamics for microscopic and macroscopic systems, Phys. Rev. D 34, 470 (1986), doi:10.1103/PhysRevD.34.470.