On the origin and detection of the osmotic momentum in quantum mechanics

Knud Haugaard Sørensen*

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Abstract

This paper explores the concept of osmotic momentum within quantum mechanics, offering a novel theoretical framework that integrates stochastic mechanics with generalized electrodynamics. By revisiting Edward Nelson's interpretation of the Schrödinger equation, we propose that osmotic momentum arises from interactions with gauge waves—an extension to classical field components. Additionally, we outline a method for experimental detection of these waves using a "quantum lens," a device designed to convert gauge waves into detectable photons. This work bridges gaps between quantum mechanics, gravity, and dark energy, suggesting that gauge waves could unify these phenomena under a common theoretical framework. Experimental validation of this model could redefine our understanding of quantum and relativistic systems.

1 Introduction

The development of quantum mechanics marks one of the most transformative revolutions in scientific history. At the dawn of the 20th century, classical physics, built on the principles of Newtonian mechanics, dominated our understanding of the natural world. However, as scientists began probing the atomic and subatomic realms, they encountered phenomena that defied classical explanations. Observations of black-body radiation, the photoelectric effect, and atomic spectra revealed mysterious behaviors that needed a paradigm shift.

*khs@physicist.net

This paradigm shift began with pioneers like Max Planck, who in 1900 introduced the idea of quantized energy levels [1], suggesting that energy could only be absorbed or emitted in discrete packets, or "quanta". This radical notion paved the way for Albert Einstein, who extended the idea in 1905 to explain the photoelectric effect [2], laying the groundwork for the wave-particle duality of light.

Building on these revolutionary ideas, Niels Bohr in 1913 provided a quantum model of the atom [4, 5, 6] that explained the Rydberg formula for the spectral lines observed in hydrogen. His model proposed that electrons orbit the nucleus in quantized states and emit or absorb light only when transitioning between these levels. This explanation not only validated the Rydberg formula, but also marked the first quantum theory of atomic structure, solidifying quantum mechanics as a framework for understanding the atomic world.

In the 1920s, quantum mechanics blossomed further through the contributions of Werner Heisenberg [7], Erwin Schrödinger [8] and Niels Bohr. Schrödinger's wave function formalism and Heisenberg's uncertainty principle redefined our conception of reality, introducing a framework where particles existed in a superposition of states until observed.

When Erwin Schrödinger published his famous equation [8] in 1926 he left an important question unanswered, how to interpret the wave function. This has led to the development of various interpretations, each attempting to clarify the nature of quantum reality.

Among these, the Copenhagen interpretation, pioneered by Niels Bohr and Werner Heisenberg [9, 10], remains one of the most widely taught. It suggests that quantum systems exist in a superposition of states, described by a wave function until measured. Upon observation, the wave function "collapses" to a single outcome. However, this idea of collapse raised questions about the role of the observer and the nature of reality, sparking debate and skepticism among physicists.

An alternative to this probabilistic view is the interpretation of many worlds, formulated by Hugh Everett [11, 12]. This theory proposes that all possible outcomes of a quantum event actually occur, each in its own branching universe. According to many-worlds, the wave function never collapses; instead, every observation splits the universe into a multitude of parallel realities, where each possible outcome of every quantum event is realized.

In contrast to these views, De Broglie-Bohm theory (or Bohmian mechanics) offers a deterministic explanation. Proposed by Louis de Broglie and later expanded by David Bohm [13, 14], this interpretation suggests that particles have defined positions at all times, guided by a 'pilot wave'. Here, quantum mechanics behaves more like a hidden variable theory, where unseen forces guide particles along specific trajectories, preserving causality and determinism within the quantum framework.

Further expanding these ideas, Edward Nelson's stochastic mechanics [15] proposes a picture of quantum dynamics based on randomness. Nelson argued that quantum behavior could be explained as the result of underlying stochastic (random) processes, where particles undergo Brownian-like motion due to fluctuating hidden variables. In this interpretation, randomness is not a fundamental feature of nature, but arises from interactions with an unseen environment.

In 1926, Erwin Madelung [16] introduced a novel hydrodynamical interpretation of quantum mechanics, reformulating the Schrödinger equation to resemble the equations of fluid dynamics. This approach allows quantum particles to be viewed as fluid-like entities that flow according to a quantum potential. Madelung's interpretation captures the probabilistic distribution of quantum particles as a kind of fluid density, with dynamics governed by an additional quantum force derived from the curvature of the wave function. By transforming the complex Schrödinger equation into a system of real, coupled equations, Madelung provided a compelling analog for quantum behavior, suggesting that particles move within an underlying fluid governed by both classical forces and an enigmatic quantum force. Although it does not alter the predictions of quantum mechanics, Madelung's hydrodynamical model offers an intuitive perspective that bridges classical fluid mechanics with quantum theory, influencing later studies in quantum fluid dynamics and interpretations like the de Broglie-Bohm pilot-wave theory.

And in 1999, Alexander Gresten [17] showed that if you write the equation for a massless spin 1 particle and set $\vec{\psi} = \vec{E} - i\vec{B}$, then solutions will also be solutions to Maxwell equations. In a follow-up comment, Valeri V. Dvoeglazov [18] points out that solutions to the generalized Maxwell equations also solve the massless spin 1 equation. This gives an interesting suggestion on how to interpret $\vec{\psi}$, at least for photons.

More recently, fluid dynamics experiments have offered an unexpected and tangible model for studying quantum-like behavior. One striking example is the silicon droplet experiment pioneered by Yves Couder and Emmanuel Fort [19, 20, 21]. In these experiments, droplets of silicon oil, called 'bouncers', are made to vibrate on the surface of a vibrating oil bath, where they interact with the waves they generate. This setup mimics some quantum phenomena, such as wave-particle duality, interference patterns, and quantized orbits, providing a physical analogy that captures the dynamic nature of quantum systems. The silicon droplet experiment, though classical, reveals the interplay between a particle and a guiding wave field, bearing a strong resemblance to Bohm's pilot wave model and inspiring new ways of thinking about quantum dynamics.

Finally, gauge theory has become essential to modern quantum physics [22, 23, 24, 25, 26, 27, 28, 29], used to describe interactions between particles through fields. At its core, gauge theory examines symmetries in physical systems, focusing on how these symmetries can produce forces and interactions. Central to gauge theory is the idea that certain parameters, known as gauge functions, represent non-physical and redundant degrees of freedom — values that can change without affecting the observable quantities of the system. To account for these redundancies, gauge theory seeks to formulate a Lagrangian, which remains invariant under gauge transformations.

The quest to understand quantum mechanics has thus spawned a variety of interpretations and experimental analogs, each attempting to address questions about the nature of reality, causality, and measurement. As these perspectives continue to evolve, so too does our toolkit for exploring quantum phenomena. From abstract wave functions to oil droplets dancing on a vibrating surface, physicists are developing increasingly innovative methods to investigate the strange dynamics that underpin the quantum world.

Another pillar we will build on is generalized electrodynamic, which history starts with Ampère's force law, formulated by André-Marie Ampère in the 1820s [31]. The law describes the force between two current-carrying conductors. Ampère discovered that parallel currents attract, while antiparallel currents repel, a fundamental principle for understanding electromagnetic forces. However, in addition to the transverse force, Ampère's work hinted at a longitudinal force component—a lesser-known aspect suggesting that conductors carrying current in the same direction could experience a repulsing force along the line connecting them. Although Ampère initially observed it, the longitudinal force was largely overshadowed by the development of James Clerk Maxwell's field-based electromagnetic theory, which focuses on the transverse forces associated with changing magnetic and electric fields, which is sufficient to describe normal electric circuits. In the 20th century, however, some researchers reproduced Ampère's and similar experiments [32, 33, 34, 35, 36] and explored extensions to classical electrodynamics [37, 38, 39, 40, 41, 42, 43, 44] that could account for longitudinal forces directly between current elements. This work contributed to generalized electrodynamics, a framework that goes beyond Maxwell's equations to include additional field components that may explain certain quantum phenomena. Generalized electrodynamics remains a niche but intriguing area of research, linking historical insights from Ampère's early observations to modern theoretical physics. While as a niche research area, the vocabulary lacks standardization, and authors often use different words for the same concepts.

Finally, Milo Wolff's Wave Structure of the Electron [45] proposes a unique perspective on the nature of subatomic particles, suggesting that particles like electrons are not point-like entities but rather spherical standing waves. According to Wolff, an electron consists of a continuous inward and outward wave interference pattern, which he argued could account for properties such as charge and mass without needing point particles. The inward wave converges toward a central point, while the outward wave radiates from it, creating a self-sustaining wave structure that gives the electron its observed stability and characteristics. A missing insight in the article was that Wolff never specified what was waving. While we lean on Milo's model, other particle models have also been suggested [46, 47, 48, 49]

2 The osmotic momentum of quantum mechanics

In 1966 Edward Nelson published an article where he derived Schrödinger's equation [15].

Edward considered a system where the particle is also influenced by Brownian motion. The particle then have 2 contributions to its momentum, the first one $\vec{p}$ is from the potential V and the second part $\vec{o}$ is from the Brownian environment and is named the osmotic momentum.

$$\begin{aligned} \psi &= e^{R+iS} \\ \vec{p} &= \hbar\vec{\nabla}S \\ \vec{o} &= \hbar\vec{\nabla}R \end{aligned} \tag{1}$$

Notice the way the wave-function is split is a little different from David Bohm's more well known approach. [14] By using a stochastic description with $R = \frac{1}{2}\ln(\rho)$, Edward was able to drive the Schrödinger equation. To show the relation between the momenta and the Schrödinger equation, we will just expand the latter. Starting from:

$$i\hbar\frac{\partial\psi}{\partial t} = V\psi - \frac{\hbar^2}{2m}\vec{\nabla}^2\psi \tag{2}$$

Substituting $\psi = e^{R+iS}$ and differentiating.

$$\hbar e^{R+iS}(i\frac{\partial R}{\partial t} - \frac{\partial S}{\partial t}) = Ve^{R+iS}$$
$$- \frac{\hbar^2}{2m}e^{R+iS}((\vec{\nabla}R)^2 - (\vec{\nabla}S)^2 + 2i(\vec{\nabla}R)\cdot(\vec{\nabla}S) + \vec{\nabla}^2R + i\vec{\nabla}^2S) \quad (3)$$

Removing the common $\psi = e^{R+iS}$ factor and taking the gradient on both sides.

$$\hbar(i\frac{\partial\vec{\nabla}R}{\partial t} - \frac{\partial\vec{\nabla}S}{\partial t}) = \vec{\nabla}V$$
$$-\frac{\hbar^2}{2m}(2(\vec{\nabla}R\cdot\vec{\nabla})\vec{\nabla}R - 2(\vec{\nabla}S\cdot\vec{\nabla})\vec{\nabla}S + 2i\vec{\nabla}((\vec{\nabla}R)\cdot(\vec{\nabla}S)) + \vec{\nabla}^2\vec{\nabla}R + i\vec{\nabla}^2\vec{\nabla}S) \quad (4)$$

Substituting with $\vec{p} = \hbar\vec{\nabla}S$ and $\vec{o} = \hbar\vec{\nabla}R$ and splitting the real and imaginary part gets us:

$$\begin{aligned}\frac{\partial\vec{p}}{\partial t} &= \frac{1}{m}((\vec{o}\cdot\vec{\nabla})\vec{o} - (\vec{p}\cdot\vec{\nabla})\vec{p} + \frac{\hbar}{2}\vec{\nabla}^2\vec{o}) - \vec{\nabla}V \\ \frac{\partial\vec{o}}{\partial t} &= -\frac{1}{m}(\vec{\nabla}(\vec{o}\cdot\vec{p}) + \frac{\hbar}{2}\vec{\nabla}^2\vec{p})\end{aligned} \quad (5)$$

These are two couple equations equivalent to Edward's equations, except velocities were used in he's article. Compared with the Copenhagen interpretation, you could say that Edward Nelsons interpretation still agree that $\psi\psi^*$ is a probability distribution, but the latter tells us that it comes from a stochastic description of the Brownian interaction.

The following figure illustrates the osmotic momentum for the ground-state of a particle in at 2D harmonic potential[50].

$$\chi_{00} = \sqrt{\frac{2m\omega}{h}}e^{-\frac{m\omega}{2\hbar}(x^2+y^2)} \rightarrow \vec{o}_{00} = \frac{\hbar}{2}\vec{\nabla}\ln(\chi_{00}\chi^*_{00}) = -m\omega\begin{pmatrix}x\\y\end{pmatrix} \quad (6)$$

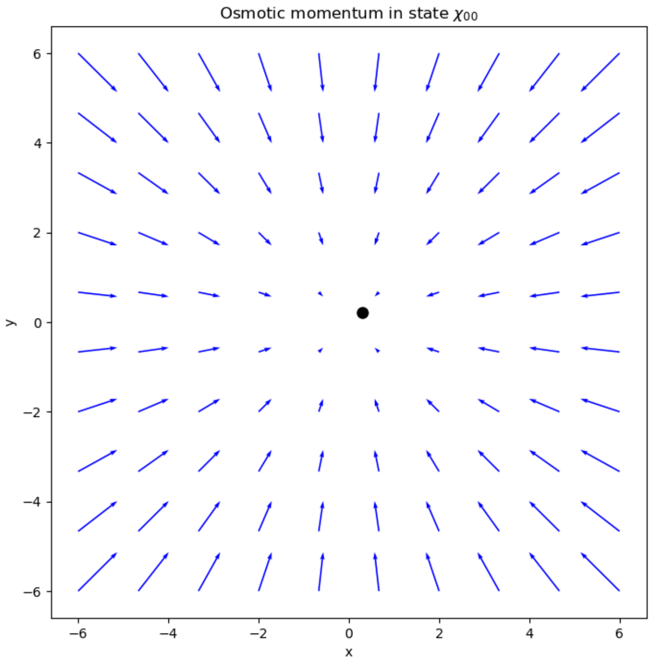

Figure 1: Osmotic momentum for a particle in a 2D harmonic potential.

Another thing that Edward's paper touches briefly upon is that the Schrödinger equation is expressing an average energy equation. A viewpoint that is examined more deeply in [51] and also expanded to the Dirac equation.

While the Schrödinger equation normally is written as in (2), it is actually used for calculations like:

$$\langle\psi|i\hbar\frac{\partial}{\partial t} + \frac{\hbar^2}{2m}\vec{\nabla}^2 - V|\psi\rangle = 0 \tag{7}$$

Where $\langle| \; |\rangle$ is Dirac's well-known bra-ket notation that notes an integration over space and time, resulting in an average value given ψ is normalized.

This tells us that it express energy conservation on average. Indicating that energy must flow in and out of a quantum system in a balance way. Such that the energy flowing in is equal to the energy flowing out over time.

While Edward Nelson article don't give an explanation for the origin of the Brownian interaction, we will see that a possible answer can be obtained from generalized electrodynamics.

3 Generalized electrodynamics

To write down generalized electrodynamics, we start with the electric charge and current density $\rho(t,\vec{r})$, $\vec{\jmath}(t,\vec{r})$ in Gauss units, and leave out material parameters to keep it simpler. The electric potential and vector potential can then be defined as

$$\begin{aligned} \phi(t,\vec{r}) &= \int_V \frac{\rho(t-|\vec{r}_s-\vec{r}|/c,\vec{r}_s)}{|\vec{r}_s-\vec{r}|} d\vec{r}_s \\ \vec{A}(t,\vec{r}) &= \frac{1}{c}\int_V \frac{\vec{\jmath}(t-|\vec{r}_s-\vec{r}|/c,\vec{r}_s)}{|\vec{r}_s-\vec{r}|} d\vec{r}_s \end{aligned} \tag{8}$$

Then the electric and magnetic fields can be expresses like this:

$$\begin{aligned} \vec{E} &= -\vec{\nabla}\phi - \frac{1}{c}\frac{\partial \vec{A}}{\partial t} \\ \vec{B} &= \vec{\nabla}\times\vec{A} \end{aligned} \tag{9}$$

By writing up the wave equation for the potential.

$$\frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} - \vec{\nabla}^2\phi = \frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} - \vec{\nabla}^2\phi$$

One can derive the field equations by substituting the right-hand side (rhs) and differentiate under the integration on the left-hand side (lhs).

$$\begin{aligned} \text{(rhs)} \qquad \frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} - \vec{\nabla}^2\phi &= \frac{1}{c^2}\frac{\partial^2\phi}{\partial t^2} - \vec{\nabla}\cdot\left(-\vec{E} - \frac{1}{c}\frac{\partial \vec{A}}{\partial t}\right) \\ &= \vec{\nabla}\cdot\vec{E} + \frac{1}{c}\frac{\partial}{\partial t}\left(\frac{1}{c}\frac{\partial\phi}{\partial t} + \vec{\nabla}\cdot\vec{A}\right) \end{aligned} \tag{10}$$

Integration is done by first simplifying with $\vec{D} = \vec{r}_s - \vec{r}$, $D = |\vec{D}|$ and $\tau = t - D/c$, following [52]

$$
\begin{aligned}
\text{(lhs)} \quad \frac{1}{c^2}\frac{\partial^2 \phi}{\partial t^2} - \vec{\nabla}^2\phi &= \int_V (\frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \vec{\nabla}^2)\frac{\rho(\tau, \vec{r}_s)}{D} d\vec{r}_s \\
&= \int_V \frac{1}{c^2}\frac{\partial \rho(\tau, \vec{r}_s)}{\partial \tau^2}\frac{1}{D} \\
&\quad - (\frac{1}{D}\vec{\nabla}^2\rho(\tau, \vec{r}_s) + 2\vec{\nabla}\rho(\tau, \vec{r}_s)\cdot\vec{\nabla}(\frac{1}{D}) + \rho(\tau, \vec{r}_s)\vec{\nabla}^2(\frac{1}{D}))d\vec{r}_s \\
&= \int_V \frac{1}{c^2}\frac{\partial \rho(\tau, \vec{r}_s)}{\partial \tau^2}\frac{1}{D} - (\frac{1}{D}(\frac{1}{c^2}\frac{\partial \rho(\tau, \vec{r}_s)}{\partial \tau^2} - \frac{2}{cD}\frac{\partial \rho(\tau, \vec{r}_s)}{\partial \tau}) \\
&\quad + \frac{2}{cD^2}\frac{\partial \rho(\tau, \vec{r}_s)}{\partial \tau} - 4\pi\rho(\tau, \vec{r}_s)\delta(\vec{D}))d\vec{r}_s \\
&= 4\pi \int_V \rho(\tau, \vec{r}_s)\delta(\vec{D})d\vec{r}_s \\
&= 4\pi\rho(t, \vec{r})
\end{aligned}
$$

When the two sides is put together, we get:

$$\vec{\nabla}\cdot\vec{E} + \frac{1}{c}\frac{\partial}{\partial t}\left(\frac{1}{c}\frac{\partial \phi}{\partial t} + \vec{\nabla}\cdot\vec{A}\right) = 4\pi\rho(t, \vec{r}) \tag{11}$$

By using similar approach on $\vec{A}$ [44] we get:

$$\vec{\nabla}\times\vec{B} - \frac{1}{c}\frac{\partial \vec{E}}{\partial t} - \vec{\nabla}\left(\frac{1}{c}\frac{\partial \phi}{\partial t} + \vec{\nabla}\cdot\vec{A}\right) = \frac{4\pi}{c}\vec{\jmath}(t, \vec{r}) \tag{12}$$

Now, notice that we have the terms $\frac{1}{c}\frac{\partial \phi}{\partial t} + \vec{\nabla}\cdot\vec{A}$ in both equations, normally a gauge condition is applied to these terms like the Lorenz gauge $\frac{1}{c}\frac{\partial \phi}{\partial t} + \vec{\nabla}\cdot\vec{A} = 0$ but in generalized electromagnetism we define an extra field component.

$$E_t = \frac{1}{c}\frac{\partial \phi}{\partial t} + \vec{\nabla}\cdot\vec{A} \tag{13}$$

In this paper, I will call it the time component of the electric field and use the symbol E_t which fits with the other components of the electric field vector E_x, E_y, E_z.

There are two good reasons why these components might have been left out of classical electrodynamics. The first is that early electrodynamics were developed to understand electric circuits. When you integrate this component over a closed circuit the positive and negative contributions cancel out and one gets zero. Hence, the theory for a closed electronic circuit works fine without this component. The second reason is that the units for the components are power per charge, so it seems to describe energy flowing in and out of the circuit, an apparent violation of the energy conservation law. Still, we will see later (25) that this isn't the case.

Using this symbol in these two equations and div and curl on the field definitions, we can now write the 4 generalized field equations as:

$$\begin{aligned}\vec{\nabla}\cdot\vec{E}+\frac{1}{c}\frac{\partial E_t}{\partial t}&=4\pi\rho\\ \vec{\nabla}\times\vec{B}-\frac{1}{c}\frac{\partial\vec{E}}{\partial t}-\vec{\nabla}E_t&=\frac{4\pi}{c}\vec{\jmath}\\ \vec{\nabla}\cdot B&=0\\ \vec{\nabla}\times E+\frac{1}{c}\frac{\partial\vec{B}}{\partial t}&=0\end{aligned}\tag{14}$$

4 On the wave nature of particles

If we write up the charge continuity expression and substitute in the field equations, we get a wave expression in E_t:

$$\begin{aligned}&\frac{\partial\rho}{\partial t}+\vec{\nabla}\cdot\vec{\jmath}\\ &=\frac{1}{4\pi}\frac{\partial}{\partial t}\left(\vec{\nabla}\cdot\vec{E}+\frac{1}{c}\frac{\partial E_t}{\partial t}\right)+\frac{c}{4\pi}\vec{\nabla}\cdot\left(\vec{\nabla}\times\vec{B}-\frac{1}{c}\frac{\partial\vec{E}}{\partial t}-\vec{\nabla}E_t\right)\\ &=\frac{c}{4\pi}\left(\frac{1}{c^2}\frac{\partial^2 E_t}{\partial t^2}-\vec{\nabla}^2E_t\right)\end{aligned}\tag{15}$$

If we have charge continuity:

$$\frac{\partial\rho}{\partial t}+\vec{\nabla}\cdot\vec{\jmath}=0\tag{16}$$

Then we also get a wave equation for standing wave in E_t:

$$0=\frac{c}{4\pi}\left(\frac{1}{c^2}\frac{\partial^2 E_t}{\partial t^2}-\vec{\nabla}^2E_t\right)\tag{17}$$

Let us use that, as a hint, to model electrically charged particles as spherical standing waves in E_t. The spherical wave equation in 3D is well known [53, 54], in spherical coordinates (r,θ,ϕ) the solution can be written as a linear combination of terms on the form:

$$R(r)\Theta(\theta)\Phi(\phi)T(t) \tag{18}$$

When only looking for real solutions.

We have T(t) on the form $A_T\cos(kct)+B_T\sin(kct)$ where $k, A_T, B_T \in \mathbb{R}$ are constants.

$\Phi(\phi)$ have the form $A_\Phi\cos(m\phi)+B_\Phi\sin(m\phi)$ here $A_\Phi, B_\Phi \in \mathbb{R}$ and $m \in \mathbb{Z}$.

$\Theta(\theta)$ is associated Legendre polynomials in $\cos(\theta)$: $\Theta(\theta) = P_l^m(\cos(\theta))$

Here l is in $\mathbb{N}$ and the polynomial is non-zero when $-l \leqq m \leqq l$.

The polynomials can be found by:

$$P_l^m(x) = \frac{(1-x^2)^{m/2}}{2^l l!}\left(\frac{\partial}{\partial x}\right)^{m+l}\left(x^2-1\right)^l \tag{19}$$

At last $R(r)$ are a spherical Bessel functions $j_l(kr)$, they have the form:

$$j_l(x) = (-1)^l x^l \left(\frac{\partial}{x\partial x}\right)^l \frac{\sin(x)}{x} \tag{20}$$

Writing up one of the simplest non-zero solution, when $l, m = 0$, $A_\phi, A_T = 1$ and $B_\Phi, B_T = 0$ we have:

$$E_t(t,r,\theta,\phi) = j_0(kr)P_0^0(cos(\theta))\cos(kct) = \frac{\sin(kr)}{kr}\cos(kct) \tag{21}$$

5 The origin of the osmotic momentum

In electromagnetism, it is well known that one can add a gauge function $S(t,\vec{r})$ to the potential without it having any influence on the fields. In a simple system without charge ρ and current $\vec{\jmath}$ densities, we can write:

$$\begin{aligned} \phi &= -\frac{1}{c}\frac{\partial S}{\partial t} \\ \vec{A} &= \vec{\nabla} S \end{aligned} \tag{22}$$

Inserted into the field expressions (9), all terms cancel out:

$$\begin{aligned} \vec{E} = -\vec{\nabla}\phi - \frac{1}{c}\frac{\partial\vec{A}}{\partial t} = \vec{\nabla}\frac{1}{c}\frac{\partial S}{\partial t} - \frac{1}{c}\frac{\partial\vec{\nabla}S}{\partial t} = 0 \\ \vec{B} = \vec{\nabla}\times\vec{A} = \vec{\nabla}\times\vec{\nabla}S = 0 \end{aligned} \tag{23}$$

But they don't cancel out in the electric time component:

$$E_t = \frac{1}{c}\frac{\partial\phi}{\partial t} + \vec{\nabla}\cdot\vec{A} = -\frac{1}{c^2}\frac{\partial^2 S}{\partial t^2} + \vec{\nabla}^2 S \tag{24}$$

The resulting wave equation:

$$E_t = -\frac{1}{c^2}\frac{\partial^2 S}{\partial t^2} + \vec{\nabla}^2 S \tag{25}$$

Describing how the gauge waves interact with the electric time component.

It solves the problem with energy conservation of E_t, as energy is just converted to and from the gauge waves radiation field.

If we take the simplest particle-wave from (21) and integrate it over space to get the average value:

$$\begin{aligned} \overline{E}_t(t) &= \iiint E_t(t, r, \theta, \phi) dr d\theta d\phi \\ &= 4\pi \int_0^\infty \frac{\sin(kr)}{kr} dr \cos(kct) = \frac{2\pi^2}{k}\cos(kct) \end{aligned} \tag{26}$$

As the expression cycles between negative and positive with time, so will the flow of energy move in and out from the particle-wave to the gauge wave radiation field, and it is easy to see that if we integrate time out $\int dt$ we get zero just like in (7).

This explains why the Schrödinger and Dirac equations are average energy equations [15, 51]. The particle's energy will change rapidly on a short timescale, but it will remain unchanged on average.

Establishing gauge waves as the source for Edwards osmotic momentum and Brownian interaction.

Next, we will study how the gauge waves can be detected.

6 Detecting Gauge-waves

Gauge waves can be detected through their interaction with gradients in the time component of the electric field (E_t).

From the generalized field equations, (14) we can derive the wave equations in the fields.

$$\begin{aligned} \frac{1}{c^2}\frac{\partial^2 \vec{E}}{\partial t^2} - \vec{\nabla}\vec{\nabla}\cdot\vec{E} + \vec{\nabla}\times\vec{\nabla}\times\vec{E} &= 4\pi\left(-\vec{\nabla}\rho - \frac{1}{c^2}\frac{\partial \vec{\jmath}}{\partial t}\right) \\ \frac{1}{c^2}\frac{\partial^2 \vec{B}}{\partial t^2} + \vec{\nabla}\times\vec{\nabla}\times\vec{B} &= \frac{4\pi}{c}\vec{\nabla}\times\vec{\jmath} \end{aligned} \tag{27}$$

For regions without sources ($\rho = 0, \vec{\jmath} = 0$) the wave equations can be rewritten using the field equation(14):

$$\begin{aligned} \frac{1}{c^2}\frac{\partial^2\vec{E}}{\partial t^2} + \vec{\nabla}\times\vec{\nabla}\times\vec{E} = -\frac{1}{c}\frac{\partial\vec{\nabla}E_t}{\partial t} \\ \frac{1}{c^2}\frac{\partial^2\vec{B}}{\partial t^2} + \frac{1}{c}\frac{\partial\vec{\nabla}\times\vec{E}}{\partial t} = 0 \end{aligned} \tag{28}$$

These equations describe a transverse electromagnetic (EM) wave equation with an additional source term related to $\vec{\nabla}E_t$.

When a gauge wave encounters this gradient, its interaction generates a photon that can be captured by a camera or optical detector. This process provides an indirect yet observable method for confirming the presence of gauge waves.

Detecting gauge waves would provide experimental confirmation of their existence, offering a vital link between theory and observation while advancing our understanding of fundamental quantum phenomena.

7 Constructing a quantum lens

To detect gauge waves experimentally, we propose the development of a device[1] called the "quantum lens" [55], which converts gauge wave interactions into detectable photons. This detection relies on the interaction between gauge waves and a carefully engineered gradient in the time component of the electric field, E_t. When a gauge wave interacts with this gradient, it induces changes that can generate photons. These photons can then be captured using a standard optical or electromagnetic detection system.

The creation of the required E_t gradient involves a magnetic vortex. Based on the second generalized electrodynamics equation (14) with $\vec{j}$ removed:

$$\vec{\nabla}\times\vec{B} - \frac{1}{c}\frac{\partial\vec{E}}{\partial t} - \vec{\nabla}E_t = 0, \tag{29}$$

a magnetic vortex ($\vec{\nabla}\times\vec{B}$) can be induced by introducing an electric field pulse $\frac{1}{c}\frac{\partial\vec{E}}{\partial t}$ between two strong magnets aligned in opposing directions. After the pulse, this configuration ensures that the contribution from $\frac{1}{c}\frac{\partial\vec{E}}{\partial t}$ is minimized, isolating the gradient in E_t as the dominant factor for generating photons.

[1] Patent pending.

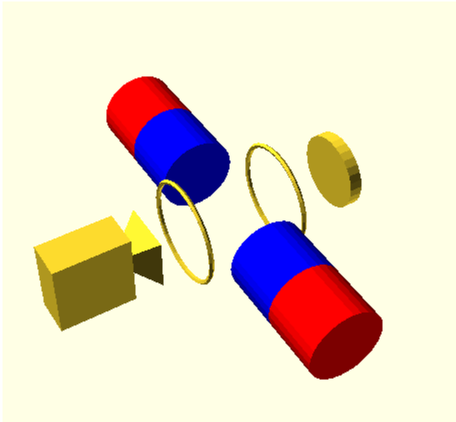

Figure 2: Quantum lens sketch

The experimental setup, shown in Figure 2, consists of several key components:

- **Two powerful magnets**, aligned in opposite directions, to create the necessary magnetic field configuration.
- **Two conducting rings**, designed to establish an electric field between them.
- **A sample holder**, where materials or systems under study can be placed.
- **A detection camera**, capable of capturing photons generated by the gauge wave interactions.

The entire apparatus would be placed within a cryostat and cooled to deci-kelvin temperatures. This low-temperature environment reduces noise and thermal fluctuations, thereby increasing the sensitivity of the detection system. Additionally, cooling might slow down the gauge wave interaction processes, improving measurement precision.

This quantum lens design offers a practical path toward detecting gauge waves and validating their existence. Successful detection would provide empirical support for the theoretical framework presented in this work, and open new avenues for exploring gauge wave interactions.

8 Gauge-waves, Gravity and Dark energy

The interplay between gauge waves and particle waves offers new insights into the fundamental forces shaping our universe. One intriguing possibility is that gauge waves might be responsible for gravity. This could arise through a screening effect, where particle waves partially shield each other from the radiation pressure of gauge waves. Such a mechanism would create a gradient in radiation pressure, giving rise to the gravitational force. Mathematically, this concept can be expressed as [56]:

$$\vec{g} \propto -\vec{\nabla} E_t = \vec{\nabla}(\frac{1}{c^2}\frac{\partial^2 S}{\partial t^2} - \vec{\nabla}^2 S) \tag{30}$$

Furthermore, gauge waves may also contribute to the phenomenon of dark energy [57]. Their inclusion in the stress-energy tensor of general relativity [58] would result in an additional energy density, producing a repulsive force. This effect could account for the observed acceleration of the universe's expansion, suggesting that gauge waves play a dual role: mediating attractive gravitational forces and repulsive dark energy effects.

These ideas imply that both gravity and dark energy, often treated as distinct phenomena, may stem from a unified mechanism rooted in gauge wave interactions. This unification would bridge quantum mechanics and general relativity, suggesting that both theories are approximations of a deeper gauge wave framework.

While this proposal is still in its early stages, it highlights the potential of gauge wave theory to address longstanding questions in fundamental physics. Future theoretical work and experimental validation, particularly through the detection of gauge waves, will be crucial in assessing these hypotheses. If verified, this framework could transform our understanding of the forces governing the universe.

9 Discussion

By relating Edward Nelson's stochastic mechanics with generalized electrodynamics, this work introduces a deterministic framework that offers an alternative to probabilistic quantum interpretations. Notably, this approach aligns with the concept of unhidden variables, as it posits observable, testable field interactions as the underlying drivers of quantum phenomena.

The parallels with Albert Einstein's work on Brownian motion [59, 60] are particularly striking. Just as Einstein demonstrated that the erratic motion of pollen particles in water could be explained by interactions with unseen atomic forces, this study suggests that quantum systems are influenced by analogous gauge wave interactions at a much smaller scale. This similarity underscores the continuity of scientific inquiry in uncovering hidden layers of physical reality through testable models.

If gauge waves can be detected experimentally, as proposed through the quantum lens design, this would mark a paradigm shift in quantum theory. Unlike hidden variable theories that rely on abstract, unobservable mechanisms, the unhidden variable framework advanced here provides a tangible basis for experimental validation. By converting gauge waves into photons, the quantum lens could open the door to directly observing these previously elusive phenomena, challenging traditional interpretations like the Copenhagen model and providing empirical support for deterministic quantum mechanics.

The implications extend beyond quantum mechanics. The hypothesis that gauge waves contribute to gravity and dark energy suggests a potential unification of quantum and relativistic physics. The notion that gauge waves mediate radiation pressure gradients offers an innovative mechanism for gravitational attraction and the repulsive effects attributed to dark energy. Such a unification could bridge two foundational yet historically incompatible theories of modern physics.

However, this work is not without challenges. Experimentally, the detection of gauge waves requires precision instruments, such as deci-kelvin cryostats and superconducting magnet setups, to minimize noise and ensure sensitivity. Theoretically, questions remain about how gauge waves interact with quantum entanglement, how they influence particles of varying spins, and their role in quantum non-locality.

10 Conclusion

This study presents a theoretical framework for understanding osmotic momentum in quantum mechanics, attributing its origin to interactions with gauge waves. By modeling these interactions and proposing their detection through a "quantum lens", we have outlined a path toward experimental validation of this concept. This approach aligns with broader efforts to bridge quantum mechanics and general relativity, suggesting that gauge waves could underlie phenomena such as gravity and dark energy.

The proposed quantum lens offers an innovative method for uncovering hidden variables, transitioning this theory from speculative to observable science. If successful, it would mark a significant step in reconciling quantum theory and relativistic models, while opening new avenues for research in particle dynamics, field interactions, and cosmology. Future work should focus on refining the experimental design, exploring implications for quantum entanglement, and extending this model to account for particles of varying spins. Collaboration with experts in cryogenics and superconducting systems will be pivotal to realizing this next phase.

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