

Probability Gap and Conservation of Quantum Gravity Probabilities: From Individual Probabilities to Aggregate Event Counts

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Abstract

Both Albert Einstein and Louis de Broglie were dissatisfied with the type of quantum probabilities found in standard quantum mechanics. We have recently introduced a new formulation of quantum mechanics in which the quantum gravity probabilities are more closely aligned with what de Broglie was seeking and hoping for. We show that if energy is conserved, then the corresponding total aggregate collision-event count is also conserved. Furthermore, we suggest that there must exist a probability gap above zero, that is, a lowest non-zero individual probability. Individual quantum gravity probabilities are therefore not continuous from zero to one, but instead exhibit a finite probability gap. Quantities larger than one are not single probabilities; they are aggregate collision-event counts obtained by summing many bounded individual probabilities.

Keywords

Quantum Gravity Probabilities, Aggregate Event Counts, Probability Gap, Conservation Laws, Quantum Gravity

1. Quantum Probabilities

Quantum probabilities entered physics with the development of quantum mechanics. In particular, the Born [1] rule has received much attention. It states that the probability density of finding a particle at a given point, when measured, is proportional to the square of the magnitude of the particle's wave function at that point.

It is well known that neither Einstein nor Louis de Broglie was fully satisfied with the somewhat "exotic" probabilities introduced in quantum mechanics. This

does not mean that they were against probabilistic theories per se. For example, Louis de Broglie in 1967 made this point quite clearly:

“We have to come back to a theory that will be way less profoundly probabilistic. It will introduce probabilities, a bit like it used to be the case for the kinetic theory of gases if you want, but not to an extent that forces us to believe that there is no causality.” —Louis de Broglie, 1967.

Louis de Broglie, in the same interview, stated that Einstein had similar views. To this day, quantum probabilities continue to be discussed and, in several interesting ways, further clarified or extended; see, for example, [2]-[8].

In this paper, we investigate how a new type of quantum-gravity probability appears to fulfill de Broglie’s vision. Quantum-gravity probabilities allow us to describe matter, energy, time, space, and even gravity using standard frequency probabilities. Quantum-gravity probabilities are not a supplement to quantum mechanics; rather, they replace quantum mechanics and unify gravity with the other parts of physics. In our view, this is rather revolutionary, as it makes physics simple and intuitive.

2. The New Quantum Gravity Probabilities

We [9] [10] have recently introduced a new quantum gravity theory that can be unified with a modified and strongly simplified quantum mechanics model. In this paper, we present the model’s core postulates and define “*quantum gravity probability*,” “*collision state*,” “*aggregate event count*,” and “*Planck-time observational window*.” In this new model, rest mass is given as collision time:

$$\bar{m} = \frac{l_p}{c} \frac{l_p}{\lambda} = t_p \frac{l_p}{\lambda} \quad (1)$$

and energy is given as the collision length

$$\bar{E} = l_p \frac{l_p}{\lambda} \quad (2)$$

where $l_p = \sqrt{\frac{G\hbar}{c^3}}$ is the Planck [11] [12] length and $t_p = \sqrt{\frac{G\hbar}{c^5}}$ is the Planck time. Interestingly, the Planck units can also be found totally independent of any knowledge of G , see [13]-[15]. In the simplest visualization of this model, two indivisible particles move back and forth, each across the reduced Compton wavelength of the particle, in order to collide with each other. This collision has a duration equal to the Planck time. Thus, at the Compton periodicity there is a collision, and this collision has a duration of the Planck time. If the particle is observed during a Planck-time observational window, then $\frac{l_p}{\lambda}$ is the probability of observing the particle in an internal collision state, and t_p is the duration of the collision between two indivisible particles. To obtain the standard kilogram mass, we simply multiply this by $\frac{\hbar}{l_p^2}$, which gives

$$m = \frac{\hbar}{c} \frac{1}{\bar{\lambda}} \quad (3)$$

However, the kilogram definition itself contains no information about the duration of these collisions, nor does it contain information about the probability of being in such a state. The formula just given can be obtained simply by solving the reduced Compton [16] wavelength formula, $\bar{\lambda} = \frac{\hbar}{mc}$, with respect to m .

We claim that the standard kilogram mass and the joule energy do not contain the important quantum aspects of the real mass and energy needed to make gravity predictions. However, in standard physics one indirectly transforms the kilogram mass or the joule energy to collision time and collision length when working in gravity by using the gravity constant that was actually introduced first in 1873 by Cornu and Baille [17] as well as the Einstein gravitational constant. The Einstein gravitational constant is given as $\frac{8\pi G}{c^4}$. The 8π comes from the surface area of a sphere in 3D space via Gauss's law for gravity. The other part, $\frac{G}{c^4} = \frac{l_p^2}{\hbar c}$, when it multiplies kilogram mass or joule energy, converts these conventional units into the collision-time and collision-length quantities used in the present framework:

$$\frac{G}{c^4} E = \frac{G}{c^4} \hbar \frac{c}{\bar{\lambda}} = \frac{l_p^2}{\hbar c} \hbar \frac{c}{\bar{\lambda}} = l_p \frac{l_p}{\bar{\lambda}} = \bar{E} \quad (4)$$

Returning to the quantum probability given above, the shortest possible reduced Compton wavelength for a particle is the Planck length; this corresponds to the Planck-mass particle. The probability for the Planck-mass particle to be in a collision state, if it is observed within the Planck-time observational window, is then

$$P = \frac{l_p}{\bar{\lambda}} = \frac{l_p}{l_p} = 1 \quad (5)$$

This is the case for the Planck-mass particle; it is the only particle with probability one. One simply cannot observe a Planck-mass particle within a Planck-time window without the Planck-mass particle being in a collision state. If it is not in a collision state, it is not a Planck-mass particle. If the mass is moving, relativistic effects must be taken into account, and the mass is then given as the relativistic mass:

$$m_r = \frac{l_p}{c} \frac{l_p}{\bar{\lambda}} \gamma = t_p \frac{l_p}{\bar{\lambda} \sqrt{1 - \frac{v^2}{c^2}}} \quad (6)$$

The t_p term is again the duration of the collisions between two indivisible particles when they collide inside the particle in question. The last part of the equation represents a quantum probability for the particle to be in a collision state when it is observed within the Planck-time window. That is, this probability is

given by

$$P = \frac{l_p}{\bar{\lambda} \sqrt{1 - \frac{v^2}{c^2}}} \quad (7)$$

If v is very close to c , then this probability could exceed unity, which would be unacceptable for an individual probability. However, for an elementary particle the velocity limit is not simply $v < c$, but rather

$$v \leq c \sqrt{1 - \frac{l_p^2}{\bar{\lambda}^2}} \quad (8)$$

This new maximum velocity is described in much more detail in [9] [18] and was first presented in a more general form at the Royal Institution¹ in 2015. If one inserts this maximum velocity into the quantum probability formula, one gets

$$P = \frac{l_p}{\bar{\lambda} \sqrt{1 - \frac{\left(c \sqrt{1 - \frac{l_p^2}{\bar{\lambda}^2}} \right)^2}{c^2}}} = 1 \quad (9)$$

This means this type of quantum probability for an individual elementary particle can never be higher than one. Interestingly, the maximum velocity for the Planck-mass particle is always:

$$v_{\max} \leq c \sqrt{1 - \frac{l_p^2}{l_p^2}} = 0 \quad (10)$$

That is, the Planck-mass particle is always at rest. At first, this may sound inconsistent, because it might seem to break the relativity principle. However, when one understands that the Planck-mass particle has a radius equal to the Planck length and exists only for the Planck time, the situation becomes clear. The Planck-mass particle can therefore only be observed from itself, meaning it can only be observed in its own rest frame; see [19]. The Planck-mass particle dissolves after a Planck time and must therefore be observed from itself, as nothing can travel farther than the Planck length within the Planck time. Furthermore, the smallest probability for observing a collision event when observing an elementary particle inside a Planck-time observational window is:

$$P = \frac{l_p}{\bar{\lambda}} \quad (11)$$

This is the rest-mass quantum probability. If the same particle is moving relative to the observer, then the quantum gravity probability increases, but its maximum value is one.

Furthermore, energy in our model is given as collision length. Rest-mass energy is given by

¹Presentation by Espen Gaarder Haug, at the 14-10 Club at the Royal Institution, London, October 15, 2015.

$$\bar{E} = l_p \frac{l_p}{\bar{\lambda}} \quad (12)$$

and relativistic energy is given as

$$\bar{E} = l_p \frac{l_p}{\bar{\lambda}} \gamma = l_p \frac{l_p}{\bar{\lambda} \sqrt{1 - \frac{v^2}{c^2}}} \quad (13)$$

To obtain the energy in joules, one needs to multiply this by $\frac{\hbar c}{l_p^2}$. Thus, l_p is the collision length, and $\frac{l_p}{\bar{\lambda} \sqrt{1 - \frac{v^2}{c^2}}}$ is the probability for the photon to be in a collision state. Note that part of the Einstein [20] constant in general relativity is given by $\frac{G}{c^4} = \frac{l_p^2}{\hbar c}$, so part of the Einstein constant simply serves to convert joule energy into collision-length energy, since only this incorporates gravity into the energy or energy equivalent of the mass.

The de Broglie [21] [22] wavelength $\lambda_b = \frac{h}{mv\gamma}$ is normally considered to be the matter wavelength. However, as discussed in several of our earlier papers, we have argued that the Compton wavelength is the real matter wavelength and that the de Broglie wavelength is a mathematical derivative of the Compton wavelength. The Compton wavelength is valid for $0 \leq v < c$, while the de Broglie wavelength is not mathematically valid for $v = 0$; see Haug [23] for a detailed discussion.

3. The Probability Gap

We have seen in the section above that no such quantum gravity probability can exceed one for elementary particles. Interestingly, our theory also leads to a probability gap. A probability gap is the smallest possible probability that can be observed above zero. The smallest probability above zero for an elementary particle to be in a collision state is simply $P = \frac{l_p}{\bar{\lambda}}$, where again $\bar{\lambda}$ is the reduced Compton wavelength of the particle of interest. This is the rest-mass probability for that particle to be in a collision state within a random Planck-time observational window.

The smallest probability in the Hubble [24] and Lemaître before [25] sphere is given by $P_H = \frac{l_p}{2\pi R_H} \approx 1.86 \times 10^{-62}$. We conjecture that this is the ultimate probability gap: no probability above zero can be smaller than this. This corresponds to a situation in which one starts with a mass consisting of two photons colliding; this system represents the observer. The system then splits into two photons that travel along the Hubble surface until they reunite and collide again. If we were to observe these two photons at a random Planck-time interval, this

would be the probability of observing them in a collision state.

One could discuss whether the relevant scale should be the diameter, how the circumference of the universe expands with time, and how the standard cosmological model does not assume the Hubble radius to be the outer limit of the universe due to accelerated expansion. However, this reflects our viewpoint within black-hole cosmology, where we assume that the observable universe resides inside a Hubble-sphere extremal black hole.

We conjecture that individual, non-aggregated quantum gravity probabilities must be quantized in the form:

$$P = \frac{1}{n} \quad (14)$$

where n is an integer. This means we can have probability $P = \frac{1}{1} = 1$, which is the quantum gravity probability for observing a Planck-mass particle in a collision state, since the Planck-mass particle is the collision of two indivisible particles. The next quantum gravity probability will be $P = \frac{1}{2}$, which corresponds to a half Planck-mass particle, so there is no probability between 1 and one-half. The next probability is $P = \frac{1}{3}$, which corresponds to a particle with a mass of one-third of the Planck mass. The lowest possible probability is $\frac{1}{n_u}$, where n_u is the number of Planck lengths across the Hubble radius of the universe, so $n_u = \frac{R_H}{l_p}$ and R_H is such that this is an exact integer.

The individual, non-aggregated quantum gravity probabilities in the natural unit system must take the form $P = \frac{l_p}{\lambda} = \frac{1}{n}$ where $l_p = 1$ and n is an integer. The reason n is an integer is a conjecture, but not without motivation. We can only observe Planck-time windows, nothing shorter because a collision between two indivisible particles lasts the Planck time. Our even most precise hypothetical clock is therefore a Planck-time clock. If one collision can happen inside a 100-Planck-time observational window, then the probability for this event to happen in a Planck-time window is $P = \frac{1}{100}$. Elementary particles have a Planck event every Compton time. This means the reduced Compton wavelength divided by the Planck length likely must be an integer. However, even the electron reduced Compton wavelength is enormous compared to the Planck length.

4. Aggregate Collision-Event Counts

The shortest possible reduced Compton wavelength for an elementary particle is the Planck length, which belongs to the Planck-mass particle. In the present theory, the Planck-mass particle is the elementary collision event from which other elementary particles are constituted. This Planck-mass event can be described as

a photon-photon collision lasting one Planck time.

Masses larger than the Planck mass have reduced Compton wavelengths shorter than the Planck length if one applies the ordinary Compton formula directly. In the present framework, this should not be interpreted as a physical wavelength shorter than the Planck length. Rather, it is an aggregate representation of the reduced Compton wavelengths of the elementary constituents of the composite mass. We therefore have (see [26])

$$m = m_1 + m_2 + m_3 + \cdots + m_n + \frac{E_1}{c^2} + \frac{E_2}{c^2} + \frac{E_3}{c^2} \cdots + \frac{E_N}{c^2}, \quad (15)$$

where m is a composite mass and m_i are the masses of the elementary particles making up the composite mass. This implies

$$\frac{\hbar}{\bar{\lambda}} \frac{1}{c} = \frac{\hbar}{\lambda_1} \frac{1}{c} + \frac{\hbar}{\lambda_2} \frac{1}{c} + \frac{\hbar}{\lambda_3} \frac{1}{c} + \cdots + \frac{\hbar}{\lambda_n} \frac{1}{c},$$

$$\bar{\lambda} = \frac{1}{\frac{1}{\lambda_1} + \frac{1}{\lambda_2} + \frac{1}{\lambda_3} + \cdots + \frac{1}{\lambda_n}}. \quad (16)$$

It is important to distinguish the interpretation of the same symbol P in the individual and aggregate cases. For an elementary particle, P denotes an individual quantum gravity probability: the probability that the particle is in an internal collision state during a Planck-time observational window. In this case it is always bounded by

$$0 \leq P \leq 1. \quad (17)$$

Thus, no single elementary collision-state probability exceeds unity.

When the same symbol P is used for a composite system, a macroscopic mass, or the universe as a whole, it denotes the sum of many individual bounded collision-state probabilities. If this sum satisfies $P > 1$, it should not be read as a single probability in the Kolmogorov sense, but as an *aggregate collision-event count*, or simply an *aggregate event count*. There is no contradiction in such a sum exceeding unity. For example, in ordinary probability theory, the expected number of successes in N trials is $\sum_i p_i$, which can be larger than one even though each individual probability satisfies $0 \leq p_i \leq 1$.

In the present framework, $P > 1$ gives the expected number of Planck-scale collision events in a specified Planck-time observational window. Thus, $P = 4.5$ should be read as an aggregate event count: four Planck-scale collision events are certain in the specified observational window, with an additional probability of 0.5 for one more event. Likewise, the universal quantity discussed below denotes the aggregate expected number of Planck-mass collision events per Planck-time observational window, not a single probability larger than one. In short, throughout the paper the notation is kept as P : when $0 \leq P \leq 1$, P is an individual quantum gravity probability; when $P > 1$, P is an aggregate event count.

5. Conservation of Aggregate Event Counts

In the present theory, as in standard theory, mass-energy is conserved. Since the individual quantum gravity probability is tied to the Compton-Planck structure of mass-energy, conservation of mass-energy implies conservation of the total aggregate event count. More precisely, the total aggregate event count is equal to the Planck length divided by the reduced Compton wavelength associated with the total mass equivalent under consideration. For the observable universe, we claim that this mass is either the critical Friedmann mass or, more likely, exactly twice that value, based on the extremal solutions to Einstein's field equations; see Haug [27]. Thus, we write

$$P_{\Sigma} = \frac{l_p}{\lambda_u} = \frac{l_p}{\frac{\hbar}{M_u c}} = \frac{l_p c^4}{\hbar G H_0} \approx 8.54 \times 10^{60}, \quad (18)$$

where $P_{\Sigma} > 1$ and therefore denotes an aggregate event count, not a single probability.

This dimensionless number tells us that there are approximately 8.54×10^{60} Planck-mass collision events, each lasting one Planck time, in any given Planck-time observational window within the entire observable universe. This is the number of collision states per Planck time in the universe and can be interpreted as a quantum gravity computer; see [28].

The conservation of the aggregate event count is likely both local and global. This is another way of expressing conservation of mass-energy in the present framework: mass can be converted into energy, and energy can be converted into mass, while the corresponding total aggregate collision-event count is conserved.

6. Quantum Gravity Probabilities and Aggregate Event Counts in Natural Units

If we measure all quantities in numbers of Planck units, then $G = \hbar = c = 1$ and $l_p = \sqrt{\frac{G\hbar}{c^3}} = 1$. An individual quantum gravity probability is then given by:

$$P = \frac{l_p}{\lambda} = \frac{1}{\lambda} \quad (19)$$

where the reduced Compton wavelength is now measured in numbers of Planck units. The following table shows a series of gravitational predictions from Newtonian gravity [29] and Einstein's gravitational theory [20] in their normal notation, and from a deeper perspective in natural units. In natural units, these gravitational quantities are related to P , where P is an individual quantum gravity probability when $0 \leq P \leq 1$ and an aggregate event count when $P > 1$, together with variables such as the center-to-center distance between the gravitational objects.

The Schwarzschild [30] [31] solution can then simply be expressed as:

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

$$ds^2 = -\left(1 - \frac{P}{r}\right) c^2 dt^2 + \left(1 - \frac{P}{r}\right)^{-1} dr^2 + r^2 d\Omega^2 \quad (20)$$

That is, the Schwarzschild time and line elements are essentially expressed through one minus P divided by the center-to-center distance between the relevant gravitational objects; for a macroscopic source mass this P is an aggregate event count (**Table 1**).

Table 1. The table shows that all observable gravitational phenomena predicted by Newtonian gravity and general relativity can be understood at a deeper level. In the natural unit system, they are simply related to P for the relevant gravitational mass and to variables such as the center-to-center distance between the mass and the affected object (r). For macroscopic masses, $P > 1$ and is interpreted as an aggregate event count.

Property	SI units	Natural units
Key insight:		
Quantum gravity probability (quantity)	$P = \frac{l_p}{\lambda_M}$	$P = \frac{1}{\bar{\lambda}_M}$
Mass	$M = \frac{\hbar}{\lambda_M} \frac{1}{c} \text{ (kg)}$	$M = \frac{1}{\bar{\lambda}_M} = P$
Gravitational parameter	$GM = c^2 l_p \frac{l_p}{\lambda_M}$	$GM = \frac{1}{\bar{\lambda}_M} = P$
Newton dark star radius	$r_N = \frac{2GM}{c^2} = 2l_p \frac{l_p}{\lambda_M}$	$r_N = 2 \frac{1}{\bar{\lambda}_M} = 2P$
Gravity acceleration	$g = \frac{GM}{r^2} = l_p \frac{c^2}{r^2} \frac{l_p}{\lambda_M}$	$g = \frac{1}{\bar{\lambda}_M} \frac{1}{r^2} = \frac{P}{r^2}$
Orbital velocity	$v_o = \sqrt{\frac{GM}{r}} = c \sqrt{\frac{l_p}{r} \frac{l_p}{\lambda_M}}$	$v_o = \sqrt{\frac{1}{\bar{\lambda}} \frac{1}{r}} = \sqrt{\frac{P}{r}}$
Orbital time	$t = \frac{2\pi r}{\sqrt{\frac{GM}{r}}} = \frac{2\pi r}{c \sqrt{\frac{l_p}{r} \frac{l_p}{\lambda_M}}}$	$t = \frac{2\pi r}{c \sqrt{\frac{1}{r} \frac{1}{\bar{\lambda}_M}}} = \frac{2\pi r}{c \sqrt{\frac{P}{r}}}$
Orbital distance	$D = \frac{t}{\sqrt{\frac{GM}{r}}} = \frac{t}{c \sqrt{\frac{l_p}{r} \frac{l_p}{\lambda_M}}}$	$D = \frac{t}{\sqrt{\frac{1}{\bar{\lambda}_M} \frac{1}{r}}} = \frac{t}{\sqrt{\frac{P}{r}}}$
Periodicity pendulum (clock)	$t = 2\pi \sqrt{\frac{L}{g}} = 2\pi r \sqrt{\frac{L}{GM}} = \frac{2\pi r}{c} \sqrt{\frac{L}{l_p \frac{l_p}{\lambda_M}}}$	$t = 2\pi r \sqrt{\frac{L}{\frac{1}{\bar{\lambda}_M}}} = 2\pi r \sqrt{\frac{L}{P}}$
Frequency Newton spring	$f = \frac{1}{2\pi} \sqrt{\frac{k}{m}} = \frac{1}{2\pi r} \sqrt{\frac{GM}{x}} = \frac{c}{2\pi r} \sqrt{\frac{l_p}{x} \frac{1}{\lambda_M}}$	$f = \frac{1}{2\pi r} \sqrt{\frac{1}{x} \frac{1}{\bar{\lambda}_M}} = \frac{1}{2\pi r} \sqrt{\frac{P}{x}}$
Velocity ball Newton cradle ^a	$v_{out} \approx \sqrt{2 \frac{GM}{r^2} H} = \frac{c}{r} \sqrt{2H l_p \frac{1}{\lambda_M}}$	$v_{out} \approx \frac{1}{r} \sqrt{2H \frac{1}{\bar{\lambda}_M}} = \frac{1}{r} \sqrt{2HP}$
Deflection	$\delta = \frac{2GM}{c^2 r} = \frac{2l_p}{r} \frac{l_p}{\lambda_M}$	$\delta = \frac{2}{r} \frac{1}{\bar{\lambda}_M} = \frac{2P}{r}$
Advance of perihelion	$\sigma = \frac{6\pi GM}{a(1-e^2)c^2} = l_p \frac{6\pi}{a(1-e^2)} \frac{l_p}{\lambda_M}$	$\sigma = \frac{6\pi}{a(1-e^2)} \frac{1}{\bar{\lambda}_M} = \frac{6\pi}{a(1-e^2)} P$

Continued

Gravitational redshift	$z = \frac{\sqrt{1 - \frac{2GM}{r_1 c^2}}}{\sqrt{1 - \frac{2GM}{r_2 c^2}}} - 1 = \frac{\sqrt{1 - \frac{2l_p}{r_1 \lambda_M}}}{\sqrt{1 - \frac{2l_p}{r_2 \lambda_M}}} - 1$	$z = \frac{\sqrt{1 - \frac{2}{r_1 \lambda_M}}}{\sqrt{1 - \frac{2}{r_2 \lambda_M}}} - 1 = \frac{\sqrt{1 - \frac{2}{r_1 P}}}{\sqrt{1 - \frac{2}{r_2 P}}} - 1$
Time dilation	$t_r = t_f \sqrt{1 - \frac{2GM}{r c^2}} = T_f \sqrt{1 - \frac{2l_p}{r \lambda_M}}$	$t_r = t_f \sqrt{1 - \frac{2}{r \lambda_M}} = t_f \sqrt{1 - \frac{2}{r P}}$
Deflection GR Einstein	$\delta = \frac{4GM}{c^2 R} = 4 \frac{l_p}{r \lambda_M}$	$\delta = 4 \frac{1}{r \lambda_M} = 4 \frac{P}{r}$
Microlensing	$\theta_E = \sqrt{\frac{4GM}{c^2} \frac{d_s - d_L}{d_s d_L}} = 2 \sqrt{l_p \frac{d_s - d_L}{\lambda_M d_s d_L}}$	$\theta_E = 2 \sqrt{\frac{1}{\lambda_M} \frac{d_s - d_L}{d_s d_L}} = 2 \sqrt{P \frac{d_s - d_L}{d_s d_L}}$

^aWhere H is the height of the ball drop.

7. Short Comparison with Standard Quantum Probabilities

The new quantum gravity probabilities proposed here have a probability gap and are always positive. Individual quantum gravity probabilities are bounded between zero and one, while aggregate event counts may exceed one because they are sums of many individual probabilities. In standard quantum mechanics, probabilities are also positive and conserved through unitary evolution, but they are not normally expected to have a finite probability gap. The following table summarizes the main comparison (**Table 2**).

Table 2. Comparison of standard quantum probabilities with the proposed quantum gravity probabilities from collision space-time theory.

	Standard quantum probabilities	New quantum gravity probabilities
Probability gap	Not expected	Yes
Conservation of probabilities	Yes	Yes
Probabilities always positive	Yes	Yes
	except for Wigner functions, which are quasi-probabilities	
Individual probabilities bounded by 1	Yes	Yes
Aggregate quantities above 1	Expected values or counts	Aggregate event counts
Directly incorporated in gravity	No, not in standard quantum mechanics	Yes, in the proposed framework

8. Relation to the Born Rule and Standard Probability Conservation

The quantum gravity probabilities introduced in this paper are intended as a replacement for the usual probability interpretation of quantum mechanics, not merely as an additional probability concept appended to it. In standard quantum

mechanics, the Born rule assigns measurement probabilities from the squared modulus of the wave function, $|\psi|^2$, and probability conservation is normally expressed through the normalization of the wave function under unitary time evolution. In the present framework, probability is instead tied directly to the Planck-scale collision structure of matter and energy. The basic individual probability is the probability that a particle is in an internal collision state during a Planck-time observational window, given by quantities such as $P = l_p / \bar{\lambda}$ for a particle at rest, with the relativistic extension given above. Thus, probability is no longer taken to be a primitive rule attached to the wave function, but is derived from the Compton-Planck structure of the particle itself.

From this perspective, the Born rule should be viewed as an effective statistical rule that applies within the standard quantum-mechanical description, while the quantum gravity probabilities proposed here are claimed to provide the deeper underlying probability structure. The conservation law in this model is also different in origin from standard quantum-mechanical normalization. Rather than following from the unitary evolution of a wave function, conservation of the total aggregate event count follows from conservation of mass-energy: if total energy is conserved, then the corresponding total aggregate collision-event count is conserved as well. In this sense, the proposed framework is a replacement and deeper reformulation of quantum probability, with the Born rule interpreted as an emergent or effective description rather than as the fundamental probability principle.

9. Conclusion

We have demonstrated how large parts of modern physics can be modeled in terms of individual quantum gravity probabilities and aggregate collision-event counts. Individual probabilities have a probability gap, that is, a minimum probability above zero, and they are bounded between zero and one. Aggregate event counts may exceed one because they are sums of individual bounded probabilities, and the total aggregate event count is conserved when mass-energy is conserved. These new quantum gravity probabilities are closer to what, for example, de Broglie suggested could exist for a more fundamental theory than the probabilities used in standard quantum mechanics.

Ethics Approval

Not applicable. The paper is purely mathematical and the research has been conducted under high ethical standards.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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