Might Quantum Probability be Classically-Explainable Based on Motion Through the Planck Vacuum?

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This paper is a strictly *qualitative* attempt to lay a foundation for understanding on a classical, non-probabilistic, basis, the probabilities associated with the path movement of quantum particles.

To start, let's consider an analogy. The reader may be familiar with the "binary ball drop" which can be found in some science museums. A ball is dropped onto an array of fixed posts in the binary configuration shown in Figure 1 below, and after its journey, lands in a bin below. At each post, the ball must go either left or right, with what we idealize to be a 50%-50% probability at each post, as shown. If a large number of balls are dropped, then some will land in each bin, and the probability distribution will be the familiar distribution used, for example, to catalogue "heads" and "tails" from a large number of coin tosses. With five layers of posts as illustrated below, for $32 = 2^5$ ball drops, the most likely distribution of balls landing in each bin is the familiar binomial 1-5-10-10-5-1 distribution as illustrated.

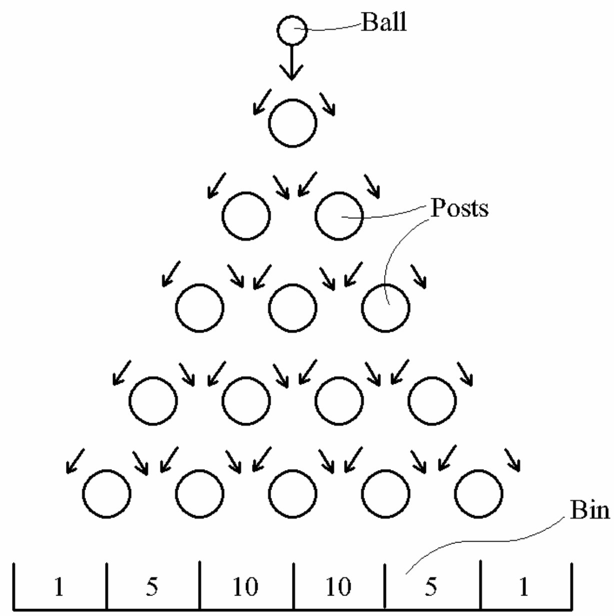

Figure 1: Binary Ball Drop

Now, while the landing of each ball is probabilistic, classical theory posits that if one were to know with absolute precision the exact trajectory, spin, temperature etc., of each ball as it is first dropped, and whether an extra piece of dust had landed on the posts, whether there was any wind current, etc., and perhaps dozens of other variables, one could in theory determine exactly where the ball would end up. Thus, a causal explanation is possible in theory, though of course, from a practical standpoint, enumerating all of these many variables is next to impossible, so the outcome for any given ball is fully probabilistic, and the best we can do is tell what the distribution looks like for a large number of balls.

Now, in the museum, one is able to "look" at the posts, so it is possible to arrive at a quite sensible explanation for why the balls distribute into the bins as they eventually do. But, suppose these posts were to be hidden from view in a "black box" and all that could be seen were the balls entering the black box and then emerging into the bins in some probability distribution. In this event, the observer might conclude that it was an inherent property of a ball to probabilistically end up in some bin according to a binary probability distribution, but one would have no good explanation of the mechanism. One might even develop a "path integral" formulation to try to understand how it is that any given ball goes from the place where it is dropped, to arrive in the particular bin in which it ends up. Of course, if one were trying to reverse-engineer what is inside the black box, one might use the observed "output" binomial probability distribution to infer the particular post configuration inside the black box, because such a configuration of posts would give a plausible explanation for the probability distribution of balls which comes out of the black box. In this analogy, the bins are the "output detector."

Now, let us consider the path of a coherent particle, say an electron or a photon, through the Planck vacuum as that vacuum was first formulated by Wheeler. An easy way to think about Planck length physics is to recall the factor GM^2 which sits atop Newton's law of gravitation, and to recognize that the Planck mass M_P is *defined* as a mass for which this interaction strength is given by $GM_P^{\;2} \equiv \hbar c$. This, of course, brings both Planck's and Newton's constants as well as the speed of light into play. From there, all else follows. The Planck mass is $M_P = \sqrt{\frac{\hbar c}{G}}$, the Planck energy is thus $E_P = M_P c^2 = \sqrt{\frac{\hbar c^5}{G}}$ =1.221 x 10^{19} GeV, and the Compton wavelength of a Planck mass M_P, known as the Planck length, is given by $r_P = \frac{\hbar}{cM_P} = \sqrt{\frac{G\hbar}{c^3}}$ = 1.616 x 10^{-35} meters. Thus, the Planck time is $t_P = \frac{r_P}{c} = \sqrt{\frac{\hbar G}{c^5}}$ = 5.39121x10^{-44} sec. All of the foregoing is well-known and established physics.

It is also helpful to consider that the gravitational potential V_P between two Planck masses separated by the Planck length is $V_P = -\frac{GM_P^{\;2}}{r_P} = -G\frac{\hbar c}{G}\sqrt{\frac{c^3}{\hbar G}} = -\sqrt{\frac{\hbar c^5}{G}} = -E_P$. *The negative sign for the potential is vital*; in this way, a swarm of Planck masses with energy E_P sitting apart from one another by r_P will be naturally interlaced with an countervailing swarm of Planck masses with gravitational potential energy given by $V_P = -E_P$. Over any scale of observation sufficiently larger than the Planck scale, these positive and negative energies cancel, and the result is a vacuum with (net) energy $E = 0$. This is what Wheeler first dubbed the "geometrodynamic vacuum." This too, is all well known.

Now, as shown in Figure 2 below, we draw an "idealized" vacuum where positive and negative energy Planck-scale fluctuations of $+m = M_P$ and $-m = -M_P$ are interlaced with one another to form a net vacuum over any larger scale of observation. We now take an single electron or photon of positive (+) energy and fire it from a "source," through the vacuum, toward a detector. Let us suppose that while traveling through the vacuum, the + mass/energy of the electron or photon (quantum particle) will be *attracted* to the + mass/energy of the +m Planck fluctuations and *repelled* by the –m Planck fluctuations. Thus, one may think of each –m fluctuation as analogous to the "posts" in figure 1 and each +m fluctuation as analogous to the "passages" between the posts through which the ball travels. Or, at the very least, foregoing "repulsion" between + and – masses, let us presume that certain paths will be easier to travel than others, and that the quantum particle will choose the geodesic path of least resistance (minimized action) through this "foamy" array of fluctuations.

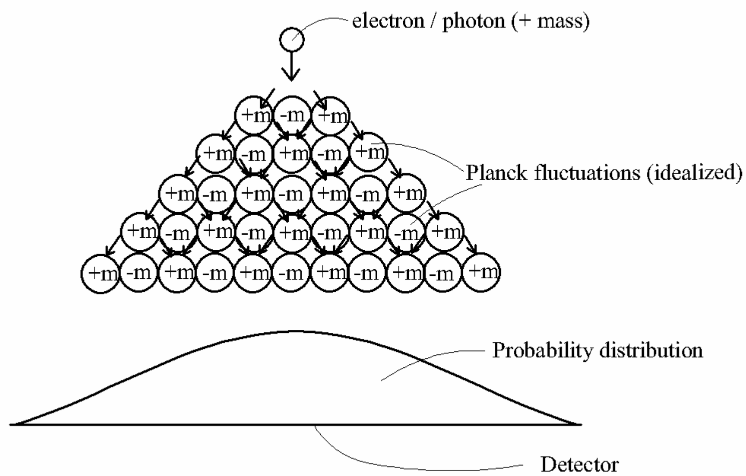

Figure 2: Quantum Particle Path Through Plank Vacuum

Now, to our daily observation, the Planck vacuum is indeed a "black box." When we shoot a quantum particle out from a source and then see where it lands on a detector, we do not and cannot see any of the collisions which this particle has with the Planck-scale fluctuations on its way through the black box vacuum toward a location on the detector. All we see is the "output" probability distribution. Because the probability distribution for a quantum particle to strike a detector is not a binomial, we know that the configuration of Planck fluctuations shown in Figure 2 is *not* the configuration of fluctuations needed to "reverse engineer" the observed probability distributions on the detector. But, the challenge is clear:

If one follows this sort of reasoning, then the probability distribution for an electron or photon or similar particle to strike a detector is the best evidence we have available to infer what the fluctuations in the Planck vacuum actually looks like. For example, one would be naive to suppose that each fluctuation is exactly equal in magnitude to the Planck mass, but would be better advised to consider some form of *distribution* of fluctuations about an expectation value given by the Planck mass. Perhaps the Planck blackbody spectrum is a good starting point for a "natural" energy distribution. Because the fluctuations come into and out of existence over a time frame of 10^{-44} seconds, this is certainly not the fixed, static array of the binary ball drop. But, in the most salient features, the analogy may hold very well.

In particular, one could take the view that it is possible, in theory, to know exactly where each electron will land on the detector, if one could know the precise pattern of fluctuations it encounters along the way and how it impinges on those fluctuations. Just like knowing the wind currents and the dust deposits in the binary ball drop. Each single particle will end up at a particular locale on the detector, and it will not be possible to know for sure where any given particle will end up (which bin it gets into), but *NOT because this is unknowable*. Rather, because the number of variables one needs to account for is beyond human capacity. But in the aggregate, one will still have quite a precise idea of how the quantum particles distribute onto the detector (into the bins).

Now, let's put this in some physical context. The above analogy is intended to apply to the *free propagation* of a quantum particle, and thus, to what is often approached in physics by way of the Feynman path integral. Even if it should become possible to "reverse engineer" the "black box" of the Planck vacuum from the probability distributions for free quantum particles to strike detectors, we still have not here explained how a "single" electron can pass through "two" (or more) slits and thus "interfere" with itself. That is the subject of a separate discussion. However, it is not clear that the probabilistic model has any more than the analogy here, to teach us about how a single electron can go through both slits and interfere with itself. Wave / particle duality, while also lack a clearer physics picture and is more in the nature of "hand-waving" over something we really don't understand, is what is used for that purpose.

I offer the foregoing as a starting point for discussion of the probabilistic aspects of quantum theory, intending to also discuss refraction and diffraction experiments, in the hopes of arriving at a better understanding of what is "really" going on at the smallest scales of natural phenomenon. I welcome discussion about the limitation of the analogies laid out above in the hope of collectively fleshing out a better picture of quantum reality.