Does Heisenberg's Uncertainty Collapse at the Planck Scale? Heisenberg's Uncertainty Principle Becomes the Certainty Principle

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Abstract

In this paper we show that Heisenberg's uncertainty principle, combined with key principles from Max Planck and Einstein, indicates that uncertainty collapses at the Planck scale. In essence, the uncertainty principle becomes the certainty principle at the Planck scale. This can be used to find the rest-mass formula for elementary particles consistent with what is already known. If this interpretation is correct, it means that Einstein's intuition that"God Does Not Throw Dice with the Universe" could also be correct. We interpret this to mean that Einstein did not believe the world was ruled by strange uncertainty phenomena at the deeper level, and that level is the Planck scale where all uncertainty seems to collapse. The bad news is that this new-found certainty can only can last for one Planck second!

Key words: Heisenberg's uncertainty principle, Planck length, Planck momentum.

1 The Three Giants

In 1899, Max Planck introduced what he called natural units, namely the Planck length, the Planck mass, the Planck second, and the Planck energy [1, 2]. He derived these fundamental units from Newton's gravitational constant [3], the speed of light, and the Planck constant. In 1905, Albert Einstein introduced special relativity theory [4]. In 1927, Heisenberg introduced the Heisenberg uncertainty principle. The Heisenberg uncertainty principle is one of the cornerstones in quantum mechanics. The Planck constant is also a key here. However, the Planck length, the Planck mass, the Planck energy, and the Planck time has never been really understood or directly linked to a consistent quantum theory.

Albert Einstein is, of course, also one of the founders of quantum theory, in particular with his insight on the photoelectric effect. However, he was very skeptical on much of what followed in quantum physics, especially in relation to strange uncertainty phenomena. It was necessarily the case that he did not believe in such models, but he felt that the theories did not capture the full picture of reality. Einstein is famous for his statement, see [5]

> God Does Not Throw Dice with the Universe

From the derivations and logical reasoning that we work with here, it looks like Einstein was right on this point, even though many have maintained that he has been wrong on this point. We will use concepts from special relativity theory, Max Planck, and Heisenberg, and we find that the unification of these three Giants of Physics seems to lead to a breakdown of uncertainty at the Planck scale. Further, this can be used to derive well known formulas for the rest-mass of particles.

2 Does Uncertainty Collapse at the Planck Scale?

Heisenberg's uncertainty principle is given by

$$\Delta p \Delta x = \hbar \tag{1}$$

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The momentum at low velocities is given by $p \approx mv$ and the relativistic momentum is $p = \frac{mv}{\sqrt{1-\frac{v^2}{c^2}}}$. The Planck momentum, according to modern physics, is known to be

$$p_p = m_p c \tag{2}$$

It is very important to pay attention to the fact that there is no v in this formula. The velocity v can take a series of values below the speed of light, while the speed of light itself is constant and the same from any reference frame[1].

Lloyd Motz, while working at the Rutherford Laboratory in 1962, [6, 7, 8] suggested that there was probably a very fundamental particle with a mass equal to the Planck mass; today it is known as the Planck mass particle. We will claim that only the Planck mass particle can have a momentum off $p = mc$. No particle with rest-mass can move at the speed of light, as it would require an infinite amount of energy to reach this velocity. Thus, we will not claim that the Planck particle can move at the speed of light, rather, as we will see, the contrary. We claim the Planck mass particle is not exempt from the relativistic rules; it also must follow the relativistic momentum formula of Einstein, which gives

$$p_p = \frac{m_p c}{\sqrt{1-\frac{v^2}{c^2}}} = m_p c \tag{3}$$

However, this can only happen if $v = 0$. In a series of articles, Haug has shown that the Planck mass particle is unique in this respect: the Planck mass particle must be at absolutely rest, even as observed across any reference frame. Based on a long series of different arguments, Haug [9, 10, 11, 12, 13] has shown that the maximum velocity any particle with rest-mass can attain is

$$v_{max} = c\sqrt{1-\frac{l_p^2}{\bar{\lambda}^2}} \tag{4}$$

where $\bar{\lambda}$ is the reduced Compton wavelength of the particle and l_p is the Planck length. Only for the Planck mass particle does $\bar{\lambda} = l_p$, and only for the Planck mass particle do we have maximum velocity of zero. All other known particles have maximum velocities extremely close to that of the speed of light, but these far exceed what can be achieved at the Large Hadron Collider today, making empirical work difficult. This maximum velocity and view that the Planck mass particle must stand absolutely still mean that the Lorentz symmetry must be broken at the Planck scale, something that is predicted by several quantum gravity theories. All other particles can show a wide range of momentum, because they can have significant variations in their velocity and therefore, they also have uncertainty in their momentum.

As long as we assume that the Planck particle has a known momentum of $m_p c$, then we find that

$$\begin{aligned} \Delta p_p \Delta x &\leq \hbar \\ m_p c \Delta x &\leq \hbar \\ m_p c &\leq \frac{\hbar}{\Delta x} \\ m_p &\leq \frac{\hbar}{\Delta x}\frac{1}{c} \end{aligned} \tag{5}$$

We know that the mass of any elementary particle can be written in the form

$$m = \frac{\hbar}{\bar{\lambda}}\frac{1}{c} \tag{6}$$

and since the reduced Compton wavelength of the Planck mass particle is $\bar{\lambda} = l_p$ then we must have

$$m_p = \frac{\hbar}{l_p}\frac{1}{c} \tag{7}$$

Inputting formula 7 into formula 5 and solving with respect to Δx we get

$$\begin{aligned} \frac{\hbar}{l_p}\frac{1}{c} &\leq \frac{\hbar}{\Delta x}\frac{1}{c} \\ \Delta x &\leq l_p \end{aligned} \tag{8}$$

[1] As measured with Einstein Poincaré synchronized clocks.

However, many (physicists are of the opinion that the Planck length is the minimum distance we can measure, and this would probably mean that we cannot have an inequality in this special case, but only an equality. So, we think the correct interpretation is that

$$\Delta x = l_p \tag{9}$$

This means Δx not can go below l_p. The maximum momentum (the Planck momentum) is the only certain momentum, which gives a certain lower limit on the position uncertainty for a Planck particle equal to the Planck length. This means that at the Planck scale Heisenberg's uncertainty principle breaks down and becomes the certainty principle

$$\begin{aligned} \Delta p \Delta x \leq \hbar \\ m_p c l_p &= \hbar \end{aligned} \tag{10}$$

That is to say, at the Planck scale, we claim all uncertainty will likely disappear, but this world is certain only for one Planck second. The Planck momentum is linked to the speed of light and no mass can move at the speed of light. However, a Planck particle can and must dissolve into pure energy within one Planck second.

Another hint here is the Planck acceleration that is given by $a_p = \frac{c^2}{l_p} \approx 5.56092 \times 10^{51}\ m/s^2$. The Planck acceleration is assumed to be the maximum possible acceleration by some physicists, see [14, 15], for example. Even after one Planck second, the Planck acceleration will bring an object at rest up to the speed of light. No particle that also has mass after undergoing acceleration can therefore undergo Planck acceleration. The solution is simply that only the Planck mass particle can undergo (and is even is the cause of) Planck acceleration. It is an internal acceleration, which simply means the Planck mass particle dissolves back into energy after one Planck second.

Still, for all non-Planck particles we have

$$\begin{aligned} \Delta p \Delta x &= \hbar \\ \Delta \frac{mv}{\sqrt{1-\frac{v^2}{c^2}}} \Delta x &= \hbar \end{aligned} \tag{11}$$

If we now assume we know the rest-mass of the particle in question, an electron, for example, then the uncertainty in momentum must come from the uncertainty in the velocity. This means we have

$$\frac{m\Delta v}{\sqrt{1-\frac{(\Delta v)^2}{c^2}}} \leq \frac{\hbar}{\Delta x} \tag{12}$$

Now if we set Δx to what we know is the minimum possible uncertainty in it, namely the Planck length, and we know the rest-mass of the particle, then it is even more clear that what is causing the uncertainty in the momentum is the uncertainty in the velocity:

$$\begin{aligned} \frac{m\Delta v}{\sqrt{1-\frac{(\Delta v)^2}{c^2}}} l_p &\geq \hbar \\ \frac{\frac{\hbar}{\bar{\lambda}}\frac{1}{c}\Delta v}{\sqrt{1-\frac{v^2}{c^2}}} l_p &\geq \hbar \\ \frac{\frac{1}{c}\Delta v}{\sqrt{1-\frac{(\Delta v)^2}{c^2}}} &\geq \frac{\bar{\lambda}}{l_p} \\ \frac{\Delta v}{\sqrt{1-\frac{(\Delta v)^2}{c^2}}} &\geq \frac{\bar{\lambda}}{l_p} c \end{aligned} \tag{13}$$

Solved with respect to Δv this gives

$$\begin{aligned}
\frac{v^2}{1-\frac{(\Delta v)^2}{c^2}} &\geq \frac{\bar{\lambda}^2}{l_p^2}c^2 \\
(\Delta v)^2 &\leq \frac{\bar{\lambda}^2}{l_p^2}c^2\left(1-\frac{(\Delta v)^2}{c^2}\right) \\
(\Delta v)^2\left(1+\frac{\bar{\lambda}^2}{l_p^2}\right) &\leq \frac{\bar{\lambda}^2}{l_p^2}c^2 \\
(\Delta v)^2 &\leq \frac{\frac{\bar{\lambda}^2}{l_p^2}c^2}{\left(1+\frac{\bar{\lambda}^2}{l_p^2}\right)} \\
\Delta v &\leq \frac{c}{\sqrt{1+\frac{l_p^2}{\bar{\lambda}^2}}} \qquad (14)
\end{aligned}$$

This is basically the same derivation as given by Haug previously. What is new in this paper is that we are showing that the Heisenberg's uncertainty principle likely leads to a breakdown of uncertainty at the Planck scale.

3 Kinetic Energy Uncertainty in the Heisenberg Principle

Again, Heisenberg's uncertainty principle is given by

$$\Delta p \Delta x = \hbar \qquad (15)$$

To turn this into kinetic energy, we have to multiply by $\frac{c^2}{v}$ and subtract the rest- mass of the particle mc^2. This gives

$$\begin{aligned}
\frac{mv\frac{c^2}{v}}{\sqrt{1-\frac{v^2}{c^2}}}-mc^2 &\leq \frac{\hbar c^2}{v_{max}}-mc^2 \\
\frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}}-mc^2 &= \frac{\hbar c^2}{\Delta x \Delta v}-mc^2 \qquad (16)
\end{aligned}$$

However, we will assume the maximum velocity for any given particle is the only certain velocity, as it is given by the formula $v_{max} = c\sqrt{1-\frac{l_p^2}{\bar{\lambda}^2}}$. Further, at this certain velocity we will claim the position uncertainty is reduced to the Planck length, and we obtain

$$\begin{aligned}
\frac{mv\frac{c^2}{v}}{\sqrt{1-\frac{v^2}{c^2}}}-mc^2 &\leq \frac{\hbar c^2}{v_{max}}-mc^2 \\
\frac{mc^2}{\sqrt{1-\frac{(\Delta v)^2}{c^2}}}-mc^2 &\leq \frac{\hbar c^2}{l_p\sqrt{1-\frac{l_p^2}{\bar{\lambda}^2}}}-mc^2 \qquad (17)
\end{aligned}$$

Since $\bar{\lambda} >> l_p$ for any observed particle so far, we can approximate this very well as

$$\begin{aligned}
\frac{mc^2}{\sqrt{1-\frac{(\Delta v)^2}{c^2}}}-mc^2 &\lesssim \frac{\hbar c}{l_p\left(1-\frac{1}{2}\frac{l_p^2}{\bar{\lambda}^2}\right)}-mc^2 \\
\frac{mc^2}{\sqrt{1-\frac{(\Delta v)^2}{c^2}}}-mc^2 &\lesssim \frac{\hbar c}{l_p}-mc^2 \\
\frac{mc^2}{\sqrt{1-\frac{(\Delta v)^2}{c^2}}}-mc^2 &\lesssim \frac{\hbar c}{l_p}-\frac{\hbar}{\bar{\lambda}}\frac{1}{c}c^2 \\
\frac{mc^2}{\sqrt{1-\frac{(\Delta v)^2}{c^2}}}-mc^2 &\lesssim \hbar c\left(\frac{1}{l_p}-\frac{1}{\bar{\lambda}}\right) \qquad (18)
\end{aligned}$$

This is the same kinetic energy limit given by Haug in his previous work [16]. The approximation formula above does not hold for the Planck mass particle where we have

$$\begin{aligned}\frac{m_p c^2}{\sqrt{1-\frac{(\Delta 0)^2}{c^2}}} - m_p c^2 &= \frac{\hbar c^2}{l_p\sqrt{1-\frac{l_p^2}{l_p^2}}} - m_p c^2 \\ 0 &= 0\end{aligned} \tag{19}$$

That is to say, the Planck mass does not have normal kinetic energy; it is all rest-mass energy that will burst into pure energy within one Planck second.

4 Conclusion

In this paper, we have shown that Heisenberg's uncertainty principle likely collapses to a certainty principle at the Planck scale. This indicates that Einstein was right when he claimed "God Does Not Throw Dice." The Planck mass particle is unique and is the only particle that has a known momentum equal to $p = mc$. There is no room for uncertainty in the velocity of a Planck mass particle simply because it is at absolute rest, even as observed across different reference frames.

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