Indeterminism as a Consequence of Changing Quantities

Greg P. Proper, P.E.*
Professional Engineer (ret.)

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Quantum Theory is embodied by the Heisenberg Uncertainty Principle (HUP) which states that there is a natural limitation in the measurement of certain paired quantities. Perhaps the most direct explanation for this limitation is that uncertainty is caused by changes in the quantities themselves as the Universe evolves. This short paper references a solution to Einstein's field equations that forms the basis for a cosmology in which the base quantities of space, time and energy (mass) change monotonically in an opposing manner parameterized by the expansion (a).[1] Each instance of a would therefore be defined by its own unique inertial frame. The author postulates just such a possibility and then utilizes the HUP relationship to determine if an identifiable number appears mathematically. In this case a relatively straight forward calculation produces a number within a few percentage points of the empirically derived h.

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I. AN INDETERMINISTIC WORLD

Consider the perspectives of two different observers. One observer resides within the continually changing system while the other is external to it. From the perspective of the internal observer events unfold normally. However, from the perspective of the external observer the system and all objects within it undergo a monotonically increasing expansion a. Furthermore, commensurate with this expansion, time also increases with a. Space and time are thus both parameterized by the expansion a and can be defined by the comoving coordinates t_0 and R_0. Mass (energy) also scales but inversely as this world ages, so a unit mass can also be said to be comoving. The change that occurs with a in each of these base quantities is thus:

$$t = at_0 \rightarrow \Delta t = \Delta a t_0. \tag{1}$$

$$R = aR_0 \rightarrow \Delta R = \Delta a R_0. \tag{2}$$

$$m = \frac{1}{a}m_0 \rightarrow |\Delta m| = \frac{\Delta a}{a^2}m_0. \tag{3}$$

The radical notion here is that time will not pass unless a increases monotonically (whereas, normally t is considered the controlling independent variable in most physics equations).

An analogy to the equations of conformal-time cosmology can be utilized here. The system geometry can be described by the following (Euclidean) evolving metric:

$$\mathrm{d}s^2 = -a^2\mathrm{d}t^2 + a^2R_0^2(\mathrm{d}\chi^2 + \chi^2(\mathrm{d}\theta^2 + sin^2\theta\mathrm{d}\phi^2)). \tag{4}$$

* gproper@arvig.net

Evolving spacetime geometries such as (4) are comprised of a foliation of 3D spherical surfaces. The spatial portion of the geometry is comprised of three angular components and is thus circumferential while a is a radial scalar (*i.e.* $a \propto R$). A constant of proportionality will therefore be needed in order to account for the geometric differences between the radial scalar a and the vector portion of the metric (*i.e.* $\mathrm{d}\chi^2 + \chi^2(\mathrm{d}\theta^2 + sin^2\theta\mathrm{d}\phi^2)$). The spatial portion of (4) has magnitude:

$$||\mathrm{d}\mathbf{x}|| = a\left(R_0\sqrt{(\mathrm{d}\chi^2 + \chi^2(\mathrm{d}\theta^2 + sin^2\theta\mathrm{d}\phi^2))}\right),$$

and it changes with a as:

$$\Delta||\mathrm{d}\mathbf{x}|| = \Delta a\left(R_0\sqrt{(\mathrm{d}\chi^2 + \chi^2(\mathrm{d}\theta^2 + sin^2\theta\mathrm{d}\phi^2))}\right).$$

If we imagine the expansion affecting an infinitesimal cubit of space, then $\Delta||\mathrm{d}\mathbf{x}||$ can be generalized to a single component:

$$\Delta||\mathrm{d}\mathbf{x}|| = \Delta a(R_0\sqrt{3}\mathrm{d}\chi).$$

As stated previously, $R_0\sqrt{3}\mathrm{d}\chi$ is a circumferential distance while $a \propto R$ (*i.e.* 2). Since R_0 is already accounted for in (2), this means that any change in the magnitude of any generic $\mathbf{x}$ (*i.e.* $\Delta\mathbf{x}$) is related to any change in the radial scalar a (*i.e.* Δa) by $\sqrt{3}(2\pi)$. (1) further requires $a \propto t$. Therefore, the constant of proportionality between the scalar and vector components of the metric is also $\sqrt{3}(2\pi)$.

Next note that the quantity velocity $\mathbf{v}$ is invariant with respect to the expansion:

$$\mathbf{v} = \frac{\Delta\mathbf{x}}{\Delta t} = \frac{\Delta a R_0}{\Delta a t_0} = \left(\frac{R_0}{t_0}\right).$$

Substituting this relationship along with the change equations into the position-momentum ($\Delta\mathbf{p}\Delta\mathbf{x} \geq h$)

uncertainty relationship gives:

$$\mathbf{\Delta p \Delta x} \rightarrow |\Delta m| \left(\frac{\mathbf{\Delta x}}{\Delta t}\right) \mathbf{\Delta x} \propto \left[\frac{\Delta a}{a^2}(m_0)\left(\frac{R_0}{\mathrm{t}_0}\right)\Delta a(R_0)\right]. \tag{5}$$

(5) quantifies the absolute limit in accuracy that can be obtained when certain measurements are attempted.

After adding the constant of proportionality that equates the geometric difference between the vector $\mathbf{\Delta x}$ (which occurs twice on the left-hand side of (5)) to the radial scalar Δa (which is $\propto \Delta R$ and occurs twice on the right-hand side), (5) becomes:

$$\mathbf{\Delta p \Delta x} \geq (\sqrt{3}(2\pi))^2 \left(\frac{\Delta a}{a}\right)^2 \mathrm{m_0 R_0^2 / t_0}. \tag{6}$$

(1) further requires:

$$\frac{\Delta a}{a} = \frac{\Delta t}{t}.$$

Substituting the above relationship into (6) gives:

$$\mathbf{\Delta p \Delta x} \geq 12\pi^2 \left(\frac{\Delta t}{t}\right)^2 \mathrm{m_0 R_0^2 / t_0}. \tag{7}$$

The metric (4) is provided only to equate the relationship between temporal and spatial components and to develop the constant of proportionality. The t_0, R_0, and m_0 terms, although present in cosmology, have no basis here other than to act as dimensional place holders. Generic place holders for mass m_u, length l_u and time t_u can, therefore, be substituted.

Solving (7) using $t_0 = 4.3 \times 10^{17}$s (*i.e.* 13.7by) and $\Delta t = 1$s (the default unit used in empirical measurement) gives:

$$\mathbf{\Delta p \Delta x} \geq 6.4 \times 10^{-34} \mathrm{m_u l_u^2 / t_u}. \tag{7}$$

This compares quite favorably (within a few percentage points) to the accepted, experimentally-determined value of h (*i.e.* $6.6 \times 10^{-34} \mathrm{kg - m^2/s}$), although the result seems independent of the system of units used.

II. CONCLUSION

The multiverse allows possible universes with different physical constants and different fundamental physical laws. Even more fundamental then the laws and constants are the quantities by which the constants are characterized and which serve as input and output to the laws. There are four prime quantities by which all others are formed. These four are space, time (the speed of clocks), energy (mass) and charge. It is commonly assumed that these four must be invariant or such a universe described herein would be lifeless and unstable. Yet the quantum numbers which dictate the stability of atoms are all quantized based on the quantity angular momentum; and if the prime quantities of space, time, and mass would vary parametrically as in (1), (2), and (3) then the quantity angular momentum would remain invariant (*i.e.* the a's would cancel out). Similarly, the quantity velocity which figures prominently in conservation laws would also remain invariant. The appealing notion about such a universe is that it would absolutely have to be indeterministic as the passage of time is intrinsic to any measurement.

(7) is extremely close to the empirical h which would seem an unlikely coincidence for a number with an exponent of -34.

[1] Proper, Greg P. "A Solution to Einstein‘s Field Equations that Results in a Sign Change in the Analogous Friedmann Acceleration Equation" OSP Journal of Physics and Astronomy, JPA-4-151.