A note on the paper, ”The Universe of Fluctuations”

B.G. Sidharth
Centre for Applicable Mathematics & Computer Sciences
B.M. Birla Science Centre, Adarsh Nagar, Hyderabad - 500 063 (India)

Abstract

We examine how the consequences which follow from a recent model, both in cosmology and at the elementary particle level have since been observationally and experimentally confirmed. Some of the considerations of the model are also justified from alternative viewpoints. It is also shown how the standard Big Bang and quark models can be recovered from the above theory.

1 Introduction

In the above paper hereinafter referred to as [1] (cf. also references [2, 3]), it was pointed out that Fermions could be treated as Kerr-Newman type Black Holes, but with an important Quantum Mechanical proviso: One has to take into consideration the fact that arbitrarily small space time intervals are purely classical concepts, or as pointed out in [4], classical approximations. Strictly speaking there is a space-time quantization as pointed out in [4]. That is, there are minimum space time intervals, viz., the Compton wavelength and time, reminiscent of the earlier concept of the chronon [5, 6]. (Moreover, as pointed out in [6], this may well be more fundamental than energy quanta which latter can be shown to follow from the former.)

0 Email:birlasc@hd1.vsnl.net.in
In this light, the naked singularity which arises in the description of elementary particles as Kerr-Newman Blak Holes disappears and as shown in [1, 2, 3] one gets a rationale for the electron’s anomalous gyro magnetic ratio \( g = 2 \), the neutrino’s handedness and several other otherwise adhoc features including a possible scheme for the unification of electromagnetism and gravitation.

In particular as was seen in [1] one could get a cosmological scheme from the above which deduces from theory the values of cosmological quantities like the age, radius and mass of the universe, the Hubble Constant the cosmological constant and so on, as also the well known inexplicable Dirac Large Number coincidences, but also the equally mysterious Weinberg relation between the pion mass and Hubble constant (cf. also [4]), given \( N \), the number of baryons as the only large scale parameter, retaining the well known microphysical constants [9]. The model also predicts an ever expanding, accelerating universe.

In this note we on the one hand draw attention to some of these and other consequences of the above model and point out that these have since been confirmed by observation and experiment. On the other hand, we will show how standard theory— the Big Bang model and the quark model— can be recovered from the new approach. In the process, we also get a rationale for quantum non-locality, which no longer shows up as being spooky.

## 2 Fluctualional Cosmology

We briefly recapitulate the main results of the cosmological model described in reference [1, 8]. The main concepts are:

From a background Zero Point Field, particles, typically pions, are fluctuationally created within space time intervals \((l, \tau)\), the Compton wavelength and Compton time of the particle. Further given \( N \) particles (typically pions) in the universe at any epoch, \( \sqrt{N} \) particles are fluctuationally created. From here it was shown that the mass and the radius of the universe would follow via the equations

\[
M = Nm,
\]

where \( m \) is the pion mass, and

\[
R = \frac{GM}{c^2}
\]

2
where $M$ and $R$ are the mass and radius of the universe and $N$, the sole cosmological or large scale parameter is the number of particles $\sim 10^{80}$ in the universe.

Next using the fact that

$$\frac{dN}{dt} = \sqrt{N} \frac{\tau}{\hbar} = \frac{mc^2}{\hbar} \sqrt{N}$$

we deduce on integration from $t = 0, N = 0$ to the present epoch, that,

$$\sqrt{N} = \frac{2mc^2}{\hbar} T$$

where $T$ is the age of the universe and from the above $\approx 10^{17} \text{secs.}$, which is correct.

From the above it was shown in [1] that the Hubble Constant is given by

$$H = \frac{Gm^3c}{\hbar^2}$$

which is correct, or equivalently

$$m = (\frac{\hbar^2H}{Gc})^{1/3} \quad (2)$$

This has been considered to be a mysterious relation, as pointed out [10], an inexplicable coincidence linking a typical elementary particle mass to cosmological parameters. However in our model it follows as a natural consequence to the theory.

Moreover it was also shown that we get the cosmological constant also consistently as

$$\Lambda \sim H^2$$

According to this model the universe would accelerate and continue to expand for ever with ever decreasing density. It is remarkable that these conclusions have very recently been confirmed by several independent teams of observers [11, 12, 13].

All this apart, in the above model the supposedly mysterious large number coincidences which lead to Dirac’s large number hypothesis are actually consequences of the theory (cf.ref.[8] also).
To get further insight, we observe that, as noted in the introduction, the concept of space time points is but a classical approximation which has been critically examined (cf. for example reference[14]). We argued in [1] that as with the earlier concept of a minimum time unit, the chronon, the Compton time is physically the meaningful concept, as also the minimum length unit viz., the Compton wavelength.

It was suggested that an elementary particle was clearly a fudge, a Kerr-Newman type Black Hole within the above Compton wavelength, within which we encounter as is well known Zitterbewegung and superluminal non-local effects. It was pointed out that the fact that a Dirac particle has luminal velocity, if treated as a point is symptomatic of the fact that these Fermions are manifestations of the background Zero Point Field trapped within the Compton wavelength. Equivalently, it was argued that one could think of the universe as containing $N$ such luminal instantaneous particles or Ganeshas which would then have a statistical uncertainty in position of $\frac{V}{N}$, $V$ being the total volume of the universe. Whence it was shown that the typical volume of uncertainty

$$\frac{V}{N} \sim \lambda_{\text{thermal}}^3 \approx \left( \frac{\hbar}{\sqrt{m^2 c^2}} \right)^3 = \left( \frac{\hbar}{m c} \right)^3,$$

in this case, owing to the luminal (r.m.s) velocity.

Indeed, another way of looking at this is, as is known[15], for an assembly of $N$ particles in a volume of radius $R$, a typical uncertainty length $l$ is given by

$$l \approx \frac{R}{\sqrt{N}}, \quad (3)$$

which is indeed true for the pion Compton wavelength. Alternatively, the above relation can be deduced by using the fact that when the number of fluctuations in the number of particles is $\sqrt{N}$, the excess electrostatic potential energy of the electrons, for example is given by $\frac{e^2 \sqrt{N}}{R}$ which is balanced by the electron energy $m_e c^2$ (cf.[1] for details).

It was pointed out that this was a holistic picture: The Quantum Mechanical uncertainty and therefore the minimum space time intervals are a result of the universe as a whole.

It is possible to come to this conclusion by yet another route. As is known[16], the fluctuation in the mass of a typical elementary particle like the pion, due
to the fluctuation of the particle number $\sim \sqrt{N}$ is given by
\begin{equation}
\frac{G\sqrt{N}m^2}{c^2R}
\end{equation}
whence we get
\begin{equation}
(\Delta mc^2)T = \frac{G\sqrt{N}m^2}{R}T = \frac{G\sqrt{N}m^2}{c}
\end{equation}
One can now easily verify that,
\begin{equation}
\hbar \approx \frac{G\sqrt{N}m^2}{c},
\end{equation}
so that (4) gives us the well known Quantum Mechanical equation
\begin{equation}
\Delta E \Delta t \approx \hbar.
\end{equation}
Equation (5) gives us the Quantum Mechanical Planck constant $\hbar$ in terms of classical quantities, more accurately, in terms of the classical fluctuation in particle number $\sqrt{N}$. Further (5), as can be verified is equivalently, the well known electromagnetism/gravitational interaction ratio
\begin{equation}
e^2/Gm^2 \sim 10^{-40}
\end{equation}
on using the relation $c\hbar = 137e^2$ which again is nothing but the equation (3). In other words the Heisenberg uncertainty relation for energy and time period follows from the fluctuation in particle number. Similarly the corresponding Heisenberg relation for momentum and distance can also be shown to hold.
In this light of what has been called the micro-macro nexus in \cite{1} the mysterious Weinberg relation (2) is perfectly meaningful. Similarly also the curious fact that, as pointed out in \cite{17} the radiation time for a pion equals the age of the universe. Infact it can be seen why the large number coincidences including (5), are no coincidences at all: All these express the fact that the small is tied up with the large by the mechanism discussed above.
It has also been argued by the author (cf.ref.\cite{7}) that in this light the supposedly spooky quantum non-locality, or the breakdown of local realism is physically meaningful. The point is, and we emphasize this, the space time measurements we make with the minimum uncertainty intervals, are the
physically meaningful measurements, and these are holistic: Local realism is a purely classical concept and as such is approximate. Indeed if in (3) \( N \to \infty \), then \( l \to 0 \) and we have the classical space-time points.

Once it is recognized that our classical concept of space time is an approximation with the minimum space time interval \( \to 0 \), it is easy to reconcile our theory with a big bang scenario. Infact in equation (1), if \( \tau \to 0 \) we get a singular creation– all particles being created momentarily as \( \frac{dN}{dt} \to \infty \).

To examine this situation in greater detail we observe that, as noted by several authors [18, 19], the minimum space time intervals are at the Planck scale. Indeed, at the Planck scale Quantum Mechanics and classical General Relativity meet [20]. An easy way in which this can be seen is by considering a Planck mass \( m_P \sim 10^{-5} \text{gms} \) for which we have

\[
\frac{Gm_P}{c^2} = \hbar/m_Pc
\]

The left side of (7) represents the classical Schwarzchild Black Hole radius while the right side is the Quantum Mechanical Compton wavelength (of course, these particles are too massive to be termed really elementary, and moreover they are too short lived with life times \( \sim 10^{-42} \text{secs} \), that is the Planck time).

Another way of looking at (7) is that at the Planck scale, it can also be written as

\[
\frac{Gm_P^2}{c^2} \approx 1,
\]

This shows that the entire energy is gravitational as compared to the usual equation (3).

We now use the fact that our minimum space time intervals are \((l_P, \tau_P)\), the Planck scale, instead of \((l, \tau)\) of the pion, as above (cf.also Section 4).

With this new limit, it can be easily verified that the total mass in the volume \( \sim l^3 \) is given by

\[
\rho_P \times l^3 = M
\]

where \( \rho_P \) is the Planck density and \( M \) as before is the mass of the universe. Moreover the number of Planck masses in the above volume \( \sim l^3 \) can easily be seen to be \( N' \sim 10^{60} \). However, it must be remembered that in the physical time period \( \tau \), there are \( 10^{20} \) (that is \( \frac{\tau}{\tau_P} \)) Planck life times. In other words the number of Planck particles in the physical interval \((l, \tau)\) is \( N \sim 10^{80} \), the
total particle number. That is from the typical physical interval \((l, \tau)\) we recover the entire mass and also the entire number of particles in the universe, as in the Big Bang theory. This also provides the explanation for the above puzzling relations like (8).

That is the Big Bang theory is a characterization of the new model in the classical limit at Planck scales.

### 3 The Quark Model

In reference[4], our starting point for the description of an elementary particle in classical terms was from the linearized theory of General Relativity viz., (cf. ref.[4]),

\[
g_{\mu \nu} = \eta_{\mu \nu} + h_{\mu \nu}, h_{\mu \nu} = \int \frac{4T_{\mu \nu}(t - |\vec{x} - \vec{x}'|, \vec{x}')}{|\vec{x} - \vec{x}'|} d^3x' \tag{9}
\]

with the usual notation.

As pointed out in references[1, 2, 3], starting from (9) and treating the Compton wavelength as the boundary we can recover the spin half, the gravitational potential and the electrostatic potential, as also the relation (6). Specifically the electrostatic potential is given by

\[
e'e' = A_0 \approx \frac{2\hbar G}{r} \int \eta^{\mu \nu} \frac{d}{d\tau} T_{\mu \nu} d^3x' \tag{10}
\]

where \(e'\) is the test charge.

In all these cases we consider, distances large compared to the Compton wavelength. But, as was shown (cf.ref.[3]), for distances comparable to the Compton wavelength \((9)\) leads to a QCD type potential viz.,

\[
4 \int \frac{T_{\mu \nu}(t, \vec{x})}{|\vec{x} - \vec{x}'|} d^3x' + \text{(terms independent of \(\vec{x}\))},
\]

\[
+ 2 \int \frac{d^2}{dt^2} T_{\mu \nu}(t, \vec{x}) \cdot |\vec{x} - \vec{x}'| d^3x' + 0(|\vec{x} - \vec{x}'|^2) \propto -\frac{\alpha}{r} + \beta r \tag{11}
\]

This is suggestive of the fact that the Quark model also would follow from the above considerations. We will show that this is indeed the case. First we
will see how the puzzling 1/3 and 2/3 charges of the quarks emerge. Our starting point is the expression for the electrostatic potential (10). We first note that the electron’s spin half which is correctly described in the above model of the Kerr-Newman Black Hole, outside the Compton wavelength automatically implies three spatial dimensions [21, 22]. This is no longer true as we approach the Compton wavelength in which case we deal with low space dimensionality [23]. This indeed has been already observed in experiments with nanotubes [24, 25]. In other words for the Kerr-Newman Fermions spatially confined to distances of the order of their Compton wavelength or less, we actually have to consider two and one spatial dimensionality.

Using now the well known fact [26] that each of the $T_{ij}$ in (10) or (11), is given by $\frac{1}{3}\epsilon$, $\epsilon$ being the energy density, it follows from (10) that the particle would have the charge $\frac{2}{3}e$ or $\frac{1}{3}e$, as in the case of quarks. Moreover, as noted earlier (cf. ref. [3] also), because we are at the Compton wavelength scale, we encounter predominantly the ”negative energy” components $\chi$ of the Dirac four spinor $\left( \begin{array}{c} \chi \\ \psi \end{array} \right)$ with opposite parity. So, as with neutrinos (discussed in ref. [3]), this would mean that the quarks would display helicity, which indeed is true: As is well known, in the $V - A$ theory, the neutrinos and relativistic quarks are lefthanded while the corresponding anti-particles are right handed (brought out by the small Cabibo angle) [27]. All this also automatically implies that these fractionally charged particles cannot be observed individually because they are by their very nature spatially confined. This is also expressed by the confining part of the QCD potential (11). We come to this aspect now.

Let us consider the QCD type potential (11). To facilitate comparison with the standard literature [28], we multiply the left hand expression by $\frac{1}{m}$ (owing to the usual factor $\hbar^2$) and also go over to natural units $c = \hbar = 1$ momentarily. The potential then becomes,

$$\frac{4}{m} \int \frac{T_{\mu\nu}}{r} d^3x + 2m \int T_{\mu\nu} d^3x \equiv -\frac{\alpha}{r} + \beta r$$

(12)

Owing to the well known relation (cf. ref. [4])

$$Gm = \int T^{00} d^3x$$
\( \propto O(1) \) and \( \beta \sim O(m^2) \), where \( m \) is the mass of the quark. This is indeed the case for the QCD potential (cf. ref. [28]). Interestingly, as a check, one can verify that, as the Compton wavelength distance \( r \sim \frac{1}{m} \) (in natural units), the energy given by (12) \( \sim O(m) \), as it should be. Thus both the fractional quark charges (and handedness) and their masses are seen to arise from this formulation.

To proceed further we consider (10) (still remaining in natural units):

\[
\frac{e^2}{r} = 2Gm_e \int \frac{T_{\mu \nu}}{r} \eta^{\mu \nu} d^3 x \tag{13}
\]

where at scales greater than the electron Compton wavelength, \( m_e \) is the electron mass. At the scale of quarks we have the fractional charge and \( e^2 \) goes over to \( \frac{e^2}{10} \approx \frac{1}{1370} \sim 10^{-3} \).

So we get from (13),

\[
\frac{10^{-3}}{r} = 2Gm_e \int \eta^{\mu \nu} \frac{T_{\mu \nu}}{r} d^3 x
\]

or,

\[
\propto \frac{1}{r} \approx 2G \cdot 10^3 m_e \int \eta^{\mu \nu} \frac{T_{\mu \nu}}{r} d^3 x
\]

Comparison with the QCD potential (12) shows that the now fractionally charged Kerr-Newman fermion, viz the quark has a mass \( \sim 10^3 m_e \), which is correct.

If the scale is such that we do not go into fractional charges, we get from (13), instead, the mass of the intermediary particle as \( 274m_e \), which is the pion mass.

All this is of course completely consistent with the physics of strong interactions.

4 Discussion

We have seen above that the Compton wavelength and time on the one hand and the pion on the other have played a crucial role, and we have argued that this is not accidental.

Indeed, it can be shown that the Compton wavelength and time are the critical scales at which particle creation takes place, and moreover our earlier
conclusion that at about the Planck mass, the number of particles $\sim 10^{80}$ (the number of elementary particles) can also be deduced from considerations of $GUT$\cite{29}. All this throws further light on (8) and the subsequent considerations.

As for the role of the pion as a typical elementary particle, this has been recognized because of its role in strong interactions. Interestingly, very much in the spirit of the above considerations of particle creation from a background ZPF, the critical mass at which a background photon vapour condenses into particles is of the order of the pion mass itself\cite{30}.

Finally it may be remarked that our conclusion in Section 3 that at the Compton wavelength scale, and therefore, as argued, in our model, in two and one dimensions, handedness shows up, can be easily verified from the relativistically covariant equations in these dimensions\cite{31}.

References

[1] Sidharth, B.G., ”Universe of Fluctuations”, Int.J. of Mod.Phys.A 13(15), 1998.

[2] Sidharth, B.G., Gravitation and Cosmology, 4 (2) (14), 1998.

[3] Sidharth, B.G., ”Quantum Mechanical Black Holes: Towards a Unification of Quantum Mechanics and General Relativity”, IJPAP, 35, 1997.

[4] Misner, C.W., Thorne, K.S., and Wheeler, J.A., Gravitation, Freeman, San Francisco, 1973.

[5] Caldirola, P., ”Relativity, Quanta and Cosmology”, Johnson Reprint Corp., New York, 1979.

[6] Finkelstein, D., Saller, H., and Tang, Z., ”Gravity Particles and Space Time”, Eds. Pronin, P., Sardanashvily, G., World Scientific, Singapore, 1996.

[7] Sidharth, B.G., ”A New Approach to Locality and Causality”, Vigier Symposium, Canada, 1997. (Also xxx.lanl.gov, quant-ph 9805008).

[8] Sidharth, B.G., Int.J.Th.Phys. 37(4),1998.
[9] Melnikov, V.N., International Journal of Theoretical Physics, 33 (7) 1994.

[10] Weinberg, S., ”Gravitation and Cosmology”, Wiley, New York, 1972.

[11] Perlmutter, S., et.al. Nature391 (6662), 1998.

[12] Branch, D., Nature391 (6662), 1998.

[13] Report in Science, February 27, 1998.

[14] Sonego, S., Phys Letts A 208, 1995.

[15] Smolin, L., in ”Quantum Concepts in space and time”, Eds., Penrose, R., and Isham, C.J., Clarendon Press, Oxford, 1986.

[16] Hayakawa, S., Suppl of PTP Commemorative Issue, 1965.

[17] Sivaram, C., Am.J.Phys., 51 (3), 1983.

[18] Padmanabhan, T., Classical and Quantum Gravity, 4L, 107, 1987.

[19] Winterberg, F., Intl.J.Th.Phys., 33(6), 1994.

[20] Sivaram, C., and Sinha, K.P., Lett. Nuovo. Cim. 10 (6) 1974.

[21] Wheeler, J.A., ”Superspace and the Nature of Quantum Geometrodynamics”, Battelles Rencontres, Lectures, Eds., De Witt, B.S., and Wheeler, J.A., Benjamin, New York, 1968.

[22] Penrose, R., ”Angular Momentum: An approach to combinational space-time” in, ”Quantum Theory and Beyond”, Ed., Bastin, T., Cambridge University press, Cambridge, 1971.

[23] Sidharth, B.G.,”Quantum Mechanical Black Holes: An Alternative Perspective”, in ”Frontiers of Quantum Physics”, Eds., Lim, S.C., et al, Springer- Verlag, 1998.

[24] Odom Teri Wang, Huang Jin-Lin, Philip Kim and Charles M. Lieber, Nature391,1998.
[25] Delaney, P., Choi, H.J., Ihm, J., Louie, S.G. and Cohen, M.L., Nature391, 1998.

[26] Narlikar, J.V., "Introduction to Cosmology", Foundation Books, New Delhi, 1993.

[27] Griffiths, D., "Introduction to Elementary Particles", Wiley, New York, 1987.

[28] Lee, T.D., "Particle Physics and Introduction to Field Theory", Harwood Academic Publishers, New York, 1981.

[29] Grib, A.A., Gravitation and Cosmology, Vol 2, No. 3 (7), 1997.

[30] Castell, L., in "Quantum Theory and Gravitation", Ed., Marlow, A.R., Academic Press, New York, 1980.

[31] Zee, A., "Unity of Forces in the Universe", Vol.II, World Scientific, Singapore, 1982, and several papers reproduced and cited therein.