Int J Theor Phys (2009) 48: 3421–3425
DOI 10.1007/s10773-009-0148-1

Planck Oscillators and Gravitation

B.G. Sidharth · B.M. Birla

Received: 11 July 2009 / Accepted: 7 September 2009 / Published online: 22 September 2009

Abstract We consider a model for an underpinning of the universe: there are oscillators at the Planck scale in the background dark energy. Starting from a coherent array of such oscillators it is possible to get a description from elementary particles to Black Holes including the usual Hawking-Beckenstein theory. There is also a characterization of Gravitation in the above model which points to a unified description with electromagnetism.

Keywords Planck · Gravitation · Oscillators

1 Introduction

We would first like to briefly touch upon the Planck oscillator model which, over the years, successfully describes phenomena from an elementary particle to the universe itself.

Max Planck, more than a century ago introduced a combination of the well known fundamental constants, $\hbar, G, c$ that gave a length, mass and time scale viz.,

$$
\begin{aligned}
l &= \sqrt{\frac{\hbar G}{c^3}} \sim 10^{-33}\ \text{cm} \\
m &= \sqrt{\frac{\hbar c}{G}} \sim 10^{-5}\ \text{gm} \\
t &= \sqrt{\frac{\hbar G}{c^5}} \sim 10^{-42}\ \text{sec}
\end{aligned} \tag{1}
$$

B.G. Sidharth
International Institute for Applicable Mathematics & Information Sciences, Hyderabad, India

B.G. Sidharth
Udine, Italy

B.M. Birla (✉)
Science Centre, Hyderabad 500 063, Adarsh Nagar, India
e-mail: hyd1_birlasc@sancharnet.in

We can easily verify that l plays the role of the Compton length and the Schwarzchild radius of a black hole of the mass m [1]

$$l = \frac{\hbar}{2mc}, \qquad l = \frac{2Gm}{c^2} \tag{2}$$

Today in various Quantum gravity approaches the Planck length l is considered to be the fundamental minimum length, and so also the time interval t. Spacetime intervals smaller than given in (1) and (2) are meaningless both classically and Quantum mechanically. Classically because we cannot penetrate the Schwarzchild radius, and Quantum mechanically because we encounter unphysical phenomena inside a typical Compton scale. All this has been discussed in greater detail by the author and others (cf. ref. [2] and several references therein). In any case, it is worth pointing out that Quantum mechanically it is meaningless to speak about spacetime points, as these would imply infinite momenta and energy. This is at the root of the infinities and divergences that we encounter, both in the classical theory of the electron as also in Quantum mechanics and Quantum Field Theory. In Quantum Field Theory we have to take recourse to the mathematical device of Renormalization to overcome this difficulty.

At another level, it may be mentioned that the author's 1997 model invoked a background dark energy and fluctuations therein to deduce a model of the universe that was accelerating with a small cosmological constant, together with several other relations completely consistent with Astrophysics and Cosmology (cf. ref. [3] and several references therein). At that time it may be recalled, the accepted standard big bang model told us that the universe was dominated by dark matter and was consequently decelerating and would eventually come to a halt. However the observations of distant supernovae by Perlmutter and others confirmed in 1998 the dark energy driven accelerating universe of the author. All this is well known.

2 The Planck Oscillator Model

It is against this backdrop that the author had put forward his model of Planck oscillators in the dark energy driven Quantum vacuum, several years ago (cf. ref. [4] and several references therein, [5]). To elaborate let us consider an array of N particles, spaced a distance Δx apart, which behave like oscillators that are connected by springs. As is known we then have [4, 6–8] (cf. in particular ref. [8])

$$\begin{aligned} r &= \sqrt{N \Delta x^2} \\ ka^2 &\equiv k\Delta x^2 = \frac{1}{2} k_B T \end{aligned} \tag{3}$$

where k_B is the Boltzmann constant, T the temperature, r the total extension and k is the spring constant given by

$$\omega_0^2 = \frac{k}{m} \tag{4}$$

$$\omega = \left(\frac{k}{m} a^2\right)^{\frac{1}{2}} \frac{1}{2} = \omega_0 \frac{a}{r} \tag{5}$$

It must be pointed out that (3) to (5) are general and a part of the well known theory referred to in [6–8]. In particular there is no restriction on the temperature T. m and ω are the mass of the particle and frequency of oscillation. In (4) ω_0 is the frequency of the individual oscillator, while in (5) ω is the frequency of the array of N oscillators, N given in (3).

We now take the mass of the particles to be the Planck mass and set $\Delta x \equiv a = l$, the Planck length as the mass and length are free parameters. We also use the well known Einstein-de Broglie relations that give quite generally the frequency in terms of energy and mass.

$$E = \hbar\omega = mc^2 \tag{6}$$

It may be immediately observed that if we use (4) and (3) we can deduce that

$$k_B T \sim mc^2$$

Independently of the above steps this agrees with the Beckenstein temperature of a Black Hole of Planck mass in the usual theory. Indeed, Rosen [9] had shown that a Planck mass particle at the Planck scale can be considered to be a Universe in itself with a Schwarzchild radius equaling the Planck length.

Thus we have shown from the above theory of oscillators that an oscillator with the Planck mass and with a spatial extent at the Planck scale has the same temperature as the Beckenstein temperature of a Schwarzchild Black Hole of mass given by the Planck mass. We may reiterate that while (3) to (5) are valid generally, in the special case where the mass is taken to be the Planck mass and the distance a is taken to be the Planck length, we get a complete identification with the corresponding Schwarzchild Black Hole and the Beckenstein temperature. The above results can be obtained by a different route as described in [10].

It has also been shown that, given the well known effect that the universe consists of $N \sim 10^{80}$ elementary particles like the pion, it is possible to deduce that a typical elementary particle consists of $n \sim 10^{40}$ Planck oscillators. These form a coherent array described by (3) to (6) above as can be easily verified (cf. refs. [3–6]): Briefly, to recapitulate the known theory, using $N = n \sim 10^{40}$ in (3) we get

$$r = \sqrt{n}l \equiv L \sim 10^{-13} \text{ cm}$$

r now being a typical elementary particle, Compton length L. Similarly, we can get from (5), M being the mass of an elementary particle,

$$M = \frac{m}{\sqrt{n}} \sim 10^{-25} \text{ gm}$$

It must be mentioned that in this theory, furthermore, $n \sim \sqrt{N}$, where $N \sim 10^{80}$ is the number of elementary particles in the universe (cf. ref. [10]).

It has also been shown that in the above approach there is a pleasing correspondence with the usual Hawking-Beckenstein theory of Black Hole Thermodynamics [11].

3 Gravitation

We can push the above consideration further. So far we have considered only a coherent array. This is necessary for meaningful physics and leads to the elementary particle masses and their other parameters as seen above. Cercignani [12] had used Quantum oscillations, though just before the dark energy era—these were the usual Zero Point oscillations, which had also been invoked by the author in his model. Invoking gravitation, what he proved was, in his own words, "Because of the equivalence of mass and energy, we can estimate that this (i.e. chaotic oscillations) will occur when the former will be of the order of $G[(\hbar\omega)c^{-2}]^2[\omega^{-1}c]^{-1} = G\hbar^2\omega^3c^{-5}$, where G is the constant of gravitational attraction and we have used as distance the wavelength. This must be less than the typical electromagnetic energy $\hbar\omega$. Hence ω must be less than $(G\hbar)^{-1/2}c^{5/2}$, which gives a gravitational cut off for the frequency in the zero-point energy."

In other words he deduced that there has to be a maximum frequency of oscillators given by

$$G\hbar\omega_{\max}^2 = c^5 \tag{7}$$

for the very existence of coherent oscillations (and so a coherent universe). We would like to point out that if we use (6) encountered above in (7) we get the well known relation

$$Gm_P^2 \approx \hbar c \tag{8}$$

which shows that at the Planck scale the gravitational and electromagnetic strengths are of the same order. This is not surprising because it was the very basis of Cercignani's derivation—if indeed the gravitational energy is greater than that given in (8), that is greater than the electromagnetic energy, then the Zero Point oscillators, which we have called the Planck oscillators would become chaotic and incoherent—there would be no physics.

Let us now speak in terms of the background dark energy. We also use the fact that there is a fundamental minimum spacetime interval, namely at the Planck scale. Then we can argue that (8) is the necessary and sufficient condition for coherent Planck oscillators to exist, in order that there be elementary particles which as noted above has been shown to be the number of $n \sim 10^{40}$ coherent Planck oscillators, and the rest of the requirements for the meaningful physical universe. In other words gravitational energy represented by the gravitation constant G given in (8) is a measure of the energy from the background dark energy that allows a physically meaningful universe—in this sense it is not a separate fundamental interaction.

It is interesting that (8) also arises in Sakharov's treatment of gravitation where it is a residual type of an energy [2, 13].

To proceed if we use the expression for the elementary particle mass M seen above in terms of the Planck mass in (8), we can easily deduce

$$GM^2 \approx \frac{e^2}{n} = \frac{e^2}{\sqrt{N}} \tag{9}$$

where now $N \sim 10^{80}$, the number of particles in the universe.

Equation (9) has been known for a long time as an empirical accident, without any fundamental explanation. Here we have deduced it on the basis of the Planck oscillator model. Equation (9) too brings out the relation between gravitation and the background Zero Point Field or Quantum vacuum or dark energy. It shows that the gravitational energy has the same origin as the electromagnetic energy but is in a sense a smeared out effect over the N particles of the universe. In the context of the above considerations that (9) is deduced and not empirical as in the past, we can now claim that (9) gives the desired unified description of electromagnetism and gravitation.

4 Remarks

Another way of looking at the above distributional nature of Gravitation is by considering the whole gravitational energy of an elementary particle (like the pion) of mass M, with respect to all other N elementary particles in the universe. This is

$$E = \frac{GNM^2}{R} \tag{10}$$

where R is the extent of the universe. It has been shown elsewhere (this also follows from (3) with $\Delta x =$ Compton wavelength L of the mass) by different routes [10, 14] that

$$R = \sqrt{N} L \tag{11}$$

Actually this is the well known Weyl-Eddington formula, also known empirically for nearly a century. Here we stress the fact that (11) is not empirical, but rather follows from the theory. Using (11) in (10) and equating it to the electromagnetic energy of a single particle (with charge) viz., e^2/L, we get

$$GM^2 = e^2/\sqrt{N},$$

which is (9). Here the gravitational energy of the particle, unlike its electromagnetic energy comes from its "interaction" with all other particles in the universe.

5 Conclusion

It is possible to consider the universe to have an underpinning of oscillators in the background dark energy. This leads to a meaningful description of the universe of elementary particles and also of black hole thermodynamics. Finally it provides a description of gravitation, not as a separate fundamental interaction, but rather as the energy of the background dark energy that is a result of the fact that there is a minimum fundamental spacetime interval in the universe.

References

1. Kiefer, C.: Quantum Gravity. Clarendon, Oxford (2004)
2. Sidharth, B.G.: Thermodynamic Universe. World Scientific, Singapore (2008)
3. Sidharth, B.G.: Chaotic Universe: From the Planck to the Hubble Scale. Nova Science, New York (2001)
4. Sidharth, B.G.: The Universe of Fluctuations. Springer, Netherlands (2005)
5. Sidharth, B.G.: Found. Phys. Lett. **17**(5), 503–506 (2004)
6. Sidharth, B.G.: Found. Phys. Lett. **15**(6), 577–583 (2002)
7. Goodstein, D.L.: States of Matter. Dover, New York (1975), pp. 462ff
8. Jack Ng, Y., Van Dam, H.: Mod. Phys. Lett. A **9**(4), 335–340 (1994)
9. Rosen, N.: Int. J. Theor. Phys. **32**(8), 1435–1440 (1993)
10. Sidharth, B.G.: Int. J. Mod. Phys. A **21**(31), 6315 (2006)
11. Sidharth, B.G.: Int. J. Theor. Phys. **48**(8), 2427–2431 (2009)
12. Cercignani, C.: Found. Phys. Lett. **11**(2), 189–199 (1998)
13. Sakharov, A.D.: Sov. Phys. Doklady **12**(11), 1040–1041 (1968)
14. Sidharth, B.G.: Int. J. Mod. Phys. A **13**(15), 2599 (1998)