Planck Particles and Quantum Gravity

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The alleged existence of so-called Planck particles is examined. The various methods for deriving the properties of these "particles" are examined and it is shown that their existence as genuine physical particles is based on a number of conceptual flaws which serve to render the concept invalid.

1 Introduction

The idea of the so-called Planck particle seems to have been around for quite some time now but has appeared in a number of totally different contexts. It seems to have been used initially as a means of making equations and expressions dimensionless by making use of suitable combinations of the universal constants c, the speed of light, G, Newton's universal constant of gravitation, and finally Planck's constant. As far as the third and final constant is concerned, it has appeared variously as the original h and in the reduced form $\hbar$. The combinations considered were those which ended up with the dimensions of mass or length or time and so, the idea of a "Planck particle" emerged.

Hence, initially the notion seems to have occurred via expressions deduced from dimensional considerations; no mention of an actual "particle" would have been included at this point presumably. Later, however, other arguments were introduced which lead to the same expressions. These included examining the equivalence of the Compton wavelength and Schwarzschild radius of a particle or drawing on results from Special Relativity and Quantum Mechanics. Finally, because the expressions incorporate the Planck constant, which is normally associated with quantum phenomena, and both the speed of light and the universal constant of gravitation, which are often associated with relativistic and gravitational phenomena, these "particles" seem to have been elevated to a position of importance and even physical reality which is difficult to justify.

Here the various methods of determining the expressions for the various physical quantities, such as mass and length, of these so-called Planck "particles" will be examined, before some conclusions about the actual "particles" themselves — including their physical existence — will be discussed.

2 The "Planck" quantities

(a) Dimensional analysis

Using the fundamental ideas of dimensional analysis allows the derivation of the Planck mass, Planck length, and all the other Planck quantities to be accomplished very easily. Taking c, G and h as the three basic quantities, the expression for the Planck mass is found easily by putting

$$\left(LT^{-1}\right)^{\alpha}\left(ML^{2}T^{-1}\right)^{\beta}\left(M^{-1}L^{3}T^{-2}\right)^{\gamma}=M\,,$$

where $\left(LT^{-1}\right)$, $\left(ML^{2}T^{-1}\right)$, $\left(M^{-1}L^{3}T^{-2}\right)$ are the dimensions of c, G and h respectively. Equating coefficients immediately gives

$$\text{Planck mass}\equiv\sqrt{\frac{ch}{G}}\,.$$

Similar manipulations give

$$\text{Planck length}\equiv\sqrt{\frac{hG}{c^{3}}}\quad\text{and}\quad\text{Planck time}\equiv\sqrt{\frac{hG}{c^{5}}}\,.$$

It is easy to see how expressions such as these could prove useful in making equations dimensionless and so more suitable for numerical work. However, the derivation of these expressions is seen to have been accomplished by a purely mathematical exercise; absolutely no physical argument has been involved!

(b) Compton wavelength and Schwarzschild radius

Another derivation involves the consideration of a body whose Compton wavelength equals its Schwarzschild or gravitational radius [1]. Immediately, this equivalence leads to

$$\frac{h}{mc}=\frac{2Gm}{c^{2}}\,,$$

from which it follows that

$$m=\sqrt{\frac{hc}{2G}}\,.$$

Corresponding expressions for the Planck length and Planck time follow easily and it is seen that the ratio of Planck mass to Planck length equals $c^2/2G$, which would make such a body, if it truly existed, a Michell-Laplace dark body or a Schwarzschild black hole.

However, the expressions derived by this route are seen to involve an extra figure two. This apparent little problem is overcome by using $\hbar$ instead of h in the dimensional analysis approach and by putting the Compton wavelength equal to π multiplied by the Schwarzschild or gravitational radius in the approach. Since the equivalence is purely arbitrary, introducing an extra arbitrary factor of π is not really a problem.

(c) The quantum/relativity approach

This approach makes use of the Heisenberg uncertainty principle [2]. The starting point is provided by the introduction of a Planck time, t_p, for which quantum fluctuations are felt to exist on the scale of the Planck length which is defined to be equal to $\ell_p = ct_p$. If a Planck density is denoted by ρ_p, a Planck mass may then be $m_p \cong \rho_p \ell_p^3$. Then, using Heisenberg's uncertainty principle in the form

$$\Delta E\,\Delta t \cong m_p c^2 t_p \cong \rho_p \left(ct_p\right)^3 c^2 t_p \cong \frac{c^5 t_p^4}{G t_p^2} \cong \hbar\,,$$

leads to

$$t_p \cong \sqrt{\frac{\hbar G}{c^5}} \cong 5.4{\times}10^{-44}\ \text{sec}\,.$$

Here the reduced Planck constant, $\hbar$, has been used as is more usual. The expressions for both the Planck mass and Planck length follow easily and their numerical values are

$$m_p \cong 2.2{\times}10^{-8}\ \text{kg} \quad \text{and} \quad \ell_p \cong 1.6{\times}10^{-35}\ \text{m}$$

respectively, where the value of the reduced Planck constant has been used.

These are the three basic properties associated with these so-called Planck "particles". It is quite common to note also that the corresponding Planck energy and Planck temperature are then given by

$$E_p = m_p c^2 \cong \sqrt{\frac{\hbar c^5}{G}} \cong 1.2{\times}10^{19}\ \text{GeV}$$

and

$$T_p = \frac{E_p}{k} \cong \sqrt{\frac{\hbar c^5}{G k^2}} \cong 1.4{\times}10^{32}\ \text{K}\,.$$

3 Planck particles as black holes

The arbitrary equality of the Compton wavelength to the alleged "Schwarzschild radius" has resulted in the claim that the so-called Planck particles are black holes. This conclusion is inadmissible for a number of reasons.

The expression

$$R = \frac{2Gm}{c^2}, \tag{1}$$

describes the Michell-Laplace dark body, a theoretical astronomical object having an escape velocity equal to that of light. This expression can be generalised to

$$R \leqslant \frac{2Gm}{c^2}, \tag{2}$$

to include escape velocities greater than that of light.

The radius R described by (1) and (2) is Euclidean, and therefore measurable in principle. The Compton wavelength is also measurable in principle because it too is Euclidean. However, (1) is routinely claimed to be the "Schwarzschild radius", the radius of the event horizon of the alleged black hole. (1) is also claimed to show that the escape velocity associated with a black hole is the velocity of light. Actually this is false. An alleged black hole has no escape velocity since it is claimed also that neither material object nor light may leave the event horizon. On the other hand, an escape velocity does not mean that a material object having an initial velocity less than the escape velocity cannot leave the surface of a gravitating body. A material object possessing an initial velocity less than the escape velocity may leave the surface of the host object, travel radially outward to a finite distance where it comes to rest momentarily before falling radially backwards to the host. If the escape velocity is the velocity of light, then light itself may leave the surface and travel radially outward to infinity and, therefore, escape. Hence, equation (1) does not specify an escape velocity for the alleged black hole. In truth, black holes have no escape velocity associated with them [3, 4].

Furthermore, in the case of the Michell-Laplace dark body, equation (1) specifies a Euclidean radius, whereas, in the case of the alleged black hole, the Schwarzschild radius is non-Euclidean. Moreover, in principle, R is a measurable length in the Euclidean space of Newton's theory, but in General Relativity R is not measurable in principle. Hence equating the Euclidean Compton wavelength to R given by (1) is conceptually flawed. In addition, in Einstein's gravitational field there are two radii — the proper radius and the radius of curvature. These are the same only in the infinitely far field where space-time is asymptotically Minkowski, (that is, pseudo-Euclidean) where the radii coalesce to become identical because, in Euclidean space, the radius of curvature and the proper radius are identical. Therefore, when the Compton wavelength is equated to (1) in the context of the black hole, which non-Euclidean Einstein radius does R specify?

It has been shown [5, 6] that when (1) is interpreted in terms of Einstein's gravitational field, the Schwarzschild radius R is actually the invariant radius of curvature of the fictitious point-mass, which corresponds to an associated invariant proper radius of zero. In ignorance of the fact that Einstein's gravitational field yields two different radii, physicists erroneously interpret R in equation (1) as a proper radius in Einstein's gravitational field and, therefore, allow it to go to zero, which is false! In their conception of R as a proper radius they also treat R as a measurable quantity in Einstein's gravitational field, as it is in Euclidean space, which is also false!

Hence, even if the equality of the Compton wavelength to the gravitational radius of curvature of a point-mass could be admitted, the alleged Planck particles would necessarily be point-masses, which are not only fictitious but also contradict the very meaning of the Compton wavelength and, indeed, the foundations of Quantum Mechanics. However, there can be no meaning to the equality of a measurable Euclidean length to an immeasurable non-Euclidean length to begin with. Not only that, there can be no meaning to the equality of a Euclidean length which is both the proper radius and the radius of curvature in Euclidean space and a non-Euclidean radius of curvature, which is not the same as the corresponding non-Euclidean proper radius. Consequently, claims that Planck particles are black holes are false, even if black holes actually exist. It might well be noted at this juncture that General Relativity, contrary to widespread claims, doesn't even predict the existence of black holes [5, 6].

Planck particles are presumed to be able to interact with one another. However, the black hole is allegedly derived from a solution to Einstein's gravitational field for a "point-mass". Therefore, the black hole is the result of a solution involving a *single* gravitating body interacting with a "test particle". It is *not* the result of a solution involving the gravitational coupling of two comparable masses. Since there are no known solutions to Einstein's field equations for multi-body configurations and since it is not even known if Einstein's field equations admit multi-body configurations [3], all conceptions of black hole interactions are meaningless. Consequently, Schwarzschild radius Planck particle interactions are also meaningless.

The claim that Planck particles were prolific during the early Universe but are now extremely rare is also erroneous. This follows since it has been proved that cosmological solutions to Einstein's field equations for isotropic type 1 Einstein spaces, from which the expanding Universe and the Big Bang have allegedly been derived, do not even exist.[7].

4 Comments and conclusions

Above, three ways of deducing expressions for the so-called Planck quantities have been outlined. In many ways, the first method indicates a good idea of the physical standing for the so-called Planck "particles". This first method is purely a mathematical manipulation of three man-made constants. At the end of the day, all numbers originate in a man-made model and so these three numbers, although assigned a seemingly exalted status as universal constants, are still members of that group of man-made objects. As mentioned already, the first method contains no physics and makes absolutely no pretensions to contain any. The second and third derivations, on the other hand, do seem to contain some physics as a basis for what follows. However, closer examination casts real doubt on this initial feeling. What physical basis is there in asserting the equivalence of the Compton wavelength and the Schwarzschild or gravitational radius of a particle? If one believes modern ideas, this merely asserts that the said particle is a "Schwarzschild black hole", and does so from the outset. The second of these two is simply a mathematical manipulation of symbols using Heisenberg's uncertainty principle as a starting point. The manipulations, as such, are reasonable enough, but is it valid to then make physical assertions about "particles" whose very existence depends only on these mathematical manipulations?

The alleged link between Quantum mechanics and General Relativity via the interpretation of the Compton wavelength as a Schwarzschild radius is clearly seen to be false. All that remains is an interpretation of Planck particles via equation (1) as it relates to the Michell-Laplace dark body radius. In this case, one may say only that the escape velocity associated with a Planck particle is the velocity of light in the flat three-dimensional Euclidean space of Newton. Of course, the Planck particles are thereby robbed of their more mysterious relativistic qualities and their primordial profusion. Black hole creation in the collision of a high energy photon with a particle and concomitant digestion of the photon is fallacious. Likewise there is no possibility of micro black holes being formed by fermion collision in particle accelerators.

There can be little doubt that Planck "particles" originated purely out of mathematical manipulations and there seems no reason to suppose that they exist or ever have existed as genuine physical particles. It is for that reason that it is worrying to see these objects being assigned an actual physical role in models of the early universe. Most books on this subject seem to regard Planck "particles" as genuine particles — mini black holes — which existed in large numbers during the very early stages of the formation of the universe but are now thought to be extremely rare, if not actually extinct. The grounds for this belief seem very shaky and it is claimed, for example, that the decay of a single Planck "particle" could lead to the production of $5{\times}10^{18}$ baryons [1]. It is also claimed that theory as presently available doesn't allow examination back beyond a time of approximately 10^{-43} seconds, the Planck "time" because, beyond that time, a theory of quantum gravity would be necessary. Hence, this time is effectively regarded as an actual barrier between the quantum and non-quantum world. Why? The relevance of this question lies in the fact that it is a purely arbitrary figure. The fact that it and the other Planck quantities depend on the reduced Planck constant, which is regarded as being a quantity associated with quantum mechanics, and the speed of light and the universal constant of gravitation, which are associated with relativistic and gravitational phenomena, is something which comes out of human choice not something which occurs naturally. It is interesting that quantities which have the dimensions of mass, length and time may be constructed from these three constants which appear so frequently in so many areas of theoretical science but that is all it is — interesting! It is not, at least as far as current scientific knowledge is concerned, any more significant than that. Playing around with numbers and combinations of numbers can be very fascinating but, if attempts are made to assign physical reality to the outcomes of such mathematical diversions, scientific chaos could, and probably will, ensue!

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