Quantization of the Universe as a Black Hole

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ABSTRACT

It has been shown that black holes can be quantized by using Bohr's idea of quantizing the motion of an electron inside the atom. We apply these ideas to the universe as a whole. This approach reinforces the suggestion that it may be a way to unify gravity with quantum theory.

Subject headings: Cosmology; gravity; black hole; quantization.

1. Introduction

He and Ma (2011) have shown that it is possible to consider black holes as quantized objects. Our approach here is to apply this idea to the universe. This is in line with the previous work that considers the universe to be a black hole (Alfonso-Faus 2010). We find here the equivalent quantum number for the universe and present the bit as the quantum of the gravitational potential, as already noted in Alfonso-Faus (2011)a. This number is close to 10^{122}. We note that this big number is close to, if not the same, the worrying discrepancy that one has between the cosmological constant value, from cosmological observations, and the value obtained from the standard theory of particles (Alfonso-Faus 2009). A likely explanation for this discrepancy has also been advanced by Santos (2010a, 2010b and 2011). This strongly suggests that our universe can be considered to be an excited state of Planck's quantum black hole. Again, this is reinforced by the fact that the natural units, Planck's units, when multiplied by the big number 10^{61}, give the well known physical properties of the universe, mass, length and time. Also the entropy of the universe, as a black hole, is linked to this quantum number being of the order of the square of it, nearly the same as the estimation made by Eagan and Lineweaver (2010). Finally we refer to the consideration made by Lloyd (2002) in the sense of the universe as being similar to a quantum computer, where the big number 10^{120} plays the role of the maximum number of elementary operations made by the universe on 10^{90} bits (LLoyd 2002). Our estimate has gone further, the number of bits is found to be 10^{122} (Alfonso-Faus 2011b).

2. Quantization of the Universe as a Black Hole

We reinforce the statement of He and Ma (2011): *We anticipate that these ideas will lead to new understanding and perspective on gravity.*

The Schwarzschild radius $R = 2GM/c^2$ of a black hole may be combined with the Compton wavelength $\bar{\lambda} = \hbar/Mc$ to give (He & Ma 2011):

$$R\bar{\lambda} = 2(l_p)^2 \tag{1}$$

where l_p is the Planck's length $l_p = (Gh/c^3)^{1/2}$, G the gravitational constant, $\hbar$ the Planck's constant and c the speed of light. Relation (1) states that the geometric mean between R and $\bar{\lambda}$ is of the order of Planck's length. For a black hole, mass and length are proportional. Since the Planck's units correspond to a quantum black hole; the generalization of the relation (1) gives as a result that all properties of a black hole, length R, mass M and characteristic time R/c, are related in this way. It means that any black hole (R, M) has a *conjugate* black hole given by the relation (1), with properties of mass m and Schwarzschild radius $\bar{\lambda}$ such that (1) is satisfied.

We have presented, and analyzed elsewhere (Alfonso-Faus 2010), the universe as a black hole. There have also been arguments in favor of considering the universe, as a whole, to be a quantum object (González-Díaz 2011). The combination of these two ideas gives us a result that is related to expression (1): The universe behaves as a quantum black hole (Alfonso-Faus 2010). All that is needed is to generalize Planck's constant. Applying (1) to the universe, with $R \approx 10^{28} cm$, mass $M \approx 10^{56} g$ and characteristic time $t_0 \approx 4.3 \times 10^{17} s$, we get the conjugate black hole:

$$\begin{aligned} r &\approx \frac{2(l_p)^2}{R} \approx 5.2\ 10^{-94} cm \\ m &\approx \frac{2(m_p)^2}{M} \approx 10^{-65} g \\ \tau &\approx \frac{2(t_p)^2}{t_0} \approx 1.35\ 10^{-104} s \end{aligned} \tag{2}$$

where $m_p = (\hbar c/G)^{1/2}$ is Planck's mass and $t_p = (G\hbar/c^5)^{1/2}$ is Planck's time.

The mass $m \approx 10^{-65} g$ of the conjugate black hole of the universe has been identified with the quantum of the gravitational potential field (Alfonso-Faus 2011a) and the bit (Alfonso-Faus 2011b). This is in line with the suggestion that this is a possible way to unify gravity with quantum theory. Besides, the information-entropy relation, based on the bit, the Padmanabhan (2010a, 2010b and references therein) proposal that gravity has an entropic or thermodynamic origin, and the Verlinde interpretation of gravity as an emerging entropic force (Verlinde 2011), gives us a hope in this direction.

The physical properties of the bit in (2) clearly imply a number of bits for the universe of $M/m \approx 10^{122}$. On the other hand the Hawking entropy for a black hole (Hawking 1975), (the Bekenstein limit, see Bekenstein 1972) is for the universe:

$$S = \frac{4\pi k}{\hbar c}\, GM^2 = \pi k \left(\frac{R}{l_p}\right)^2 \approx k 10^{122} \tag{3}$$

Here we see that the entropy of the bit is just k, the Boltzmann's constant, and the information of the universe, as a black hole, is $\approx 10^{122}$ bits, its quantum number. All these results are in line with the results in He & Ma (2011) that we have applied here to the universe. In particular the energy difference between two nearby states for the universe is

$$\Delta E \approx \frac{m_p c^2}{2\ 10^{61}} \approx 10^{-65} \text{ grams} \times c^2 \tag{4}$$

which is the energy of one bit, the quantum black hole in (2). This means that each jump in the excitation of the universe implies precisely this energy. The excitation of the universe is given by the increase in its number of bits, one by one.

3. Conclusions

Our approach shows that the expansion of the universe implies the increase of entropy, and consequently the increase in its information content given by its quantum number. This increase can be explained as a process of sequential growing: this gives the chain of elements formed by a causal set of the initial black holes (Gudder 2011) . This picture reinforces the idea of the universe as being a quantum computer, advanced by Lloyd (2002).

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