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Thermodynamics of LHC-black Holes: A Review

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Abstract: In this study, we review the effect of gravitational corrections to the Bekenstein-Hawking entropy. In this approach, the black hole lifetime can be obtained.

Key words: LHC-black holes, quantum gravitation, Bekenstein-Hawking entropy

INTRODUCTION

Theoretical study of the black hole production, in high-energy collisions, goes back to the study of Penrose (1974) the mechanism of black hole production by LHC introduced by Giddings and Thomas (2002) and Dimopoulos and Landsberg (2001). Production of black holes by particle accelerators is an even more exciting possibility, when it comes to producing high-energies, no device out does accelerators such as LHC and Tevatron. These machines accelerate subatomic particles to velocities exceedingly close to the speed of light. These particles then have enormous kinetic energies. At the LHC, a proton will reach energy of roughly TeV (Giddings and Thomas, 2002; Dimopoulos and Landsberg, 2001; Anchordoqui *et al*., 2003). According to Einstein special relativity this energies are equivalent to a mass of 10^{-23} k.g. when two particles collide at close range, their energy in concentrated into a tiny region of space. Black hole factories are microscopic, comparison in size to elementary particles, they could evaporate shortly after they formed, because the emission carries off energy, the mass of black hole tend to decrease. Therefore a black hole factory is highly unstable. The evaporation of these holes would leave very distinctive imprints on the detectors. Typical collisions produce moderate numbers of high-energy particles, but decaying black hole is different. According to Hawking (1975), the black hole radiates a large number of particles and the prospect of producing black holes on Earth may strike. How do we know that would safely decay, as hawking predicted, instead of continuing to grow, eventually consuming the entire planet? Recently we have calculated the hawking radiation of the black hole at a higher dimensional space-time (Dehghani and Farmany, 2009a, b; Farmany *et al*., 2008). Here, we review the new approaches to calculating the black hole entropy and we suggest a new method for calculation of the lifetime of the LHC-black hole.

Let, we begin with a black hole that live on d-dimensional space time. A d-dimensional (Schwarzschild) black hole as LHC-black hole is defined by:

$$ds^2 = (1-\theta_{d-2})c^2dt^2 - (1-\theta_{d-2})^{-1}dr^2 + r^2 d\Omega_{d-2} \quad (1)$$

Where:

$$\theta_{d-2} = \frac{16\pi G_d M}{(d-2)\Omega_{d-2}c^2 r^{d-3}}$$

and G_d is the d-dimensional Newton constant. Consider a black hole factory as a d-dimensional cube of size equal to twice its radius (Schwarzschild radius) r_s the uncertainty in the position of a hawking particle, during the emission, is:

$$\Delta x \approx 2r_s = 2\lambda_d (\frac{G_d M}{c^2})^{1/d-3} \quad (2)$$

Where:

$$\lambda_d = (\frac{16\pi}{(d-2)\Omega_{d-2}})^{1/d-3}.$$

Using the usual uncertainty principle the uncertainty in the energy of hawking particle is:

$$\Delta E \approx c\Delta p \approx \frac{\hbar c}{2\lambda_d}(\frac{\hbar m}{cM_p})^{-\frac{1}{d-3}} \quad (3)$$

Where:

$$m = \frac{M}{M_p}$$

is the mass in the Planck unit, M_p is the d-dimensional Planck mass. ΔE is identified with the temperature of black

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hole radiation. Setting the black hole radiation mass m to d-3/4π it is easy to obtain the temperature of the black hole in d-dimensional space-time:

$$T = \frac{(d-3)}{4\pi\lambda_d} M_p c^2 m^{-1/d-3} \tag{4}$$

The evaporation of black hole would leave very distinctive imprints on the detectors and temperature of such black hole could be calculated. To study the quantum gravity effects in the hawking temperature, one can take into account the generalized uncertainty principle. Generalized uncertainty principle have been the subject of much interesting works over the years and a lot of papers have been appeared in which that the usual uncertainty is modified at the framework of microphysics as (Farmany *et al*., 2007; Farmany, 2010):

$$\Delta x \geq \frac{\hbar}{\Delta p} + l_{pl}^2 \frac{\Delta p}{\hbar} \tag{5}$$

where, l_{pl} is the Planck length. The term:

$$l_p^2 \frac{\Delta p}{\hbar}$$

in Eq. 5 show the gravitational effects to usual uncertainty principle. In the canonical quantum gravity the area of black hole factory is quantized as $A = n\alpha\hbar(\text{with}\, G = c = 1)$. For this reason we must obtain the lower bound on the black hole factory radius. Consider a quantum black hole factory, an attempt to measure the radius of the black hole, more precisely that is, to make R small-thus resulting in an increase of Δp, but according to Eq. 5 for detection of small distances by going to very high momenta, the behavior of Heisenberg microscope changes and a lower bound on the (Schwarzschild) radius r_s could be obtained. Setting r_s as Δx_i and inverting Eq. 5 we obtain:

$$\frac{r_s}{l_p^2}\left[1 - \sqrt{1 - \frac{l_p^2}{r_s^2}}\right] \leq \frac{\Delta p}{\hbar} \leq \frac{r_s}{l_p^2}\left[1 + \sqrt{1 - \frac{l_p^2}{r_s}}\right] \tag{6}$$

Comparing Eq. 2, 4 with 6 we obtains the Hawking radiation of black hole factory:

$$T' = \frac{(d-3)}{4\pi} \lambda_d m^{1/(d-3)} \left[1 - \sqrt{1 - \frac{1}{\lambda_d^2 m^{2/d-3}}}\right] M_p c^2 \tag{7}$$

Comparing Eq. 4 with Eq. 7 we find that the temperature of hawking radiation of black hole factory is hotter than the hawking calculations:

$$T' - T = \frac{(d-3)}{4\pi} \lambda_d M_{pl} c^2 m^{1/(d-3)} \left[1 - \frac{1}{\lambda_d^2 m^{2/d-3}} - \sqrt{1 - \frac{1}{\lambda_d^2 m^{2/d-3}}}\right] \tag{8}$$

Equation 8 shows that hawking temperature of LHC-black hole is hotter than the hawking temperature.

Let, we focus on the lifetime of the LHC-black hole. The black hole radiation losses the mass of black hole as:

$$\frac{dm}{dt} = -\frac{f(m)}{m^2} \tag{9}$$

The LHC-black hole will evaporates to receives the Planck mass. In this step, the LHC-black hole changes to a Higgs particle that have a Planck mass, so the lifetime of the black hole is:

$$\tau = \frac{4.8*10^4 t_p}{16g}\left[\frac{8}{3}m^3 + \ldots\right] \tag{10}$$

where, g is the number of particles that are emitted by LHC-black hole $3<g<100$.

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