A New Effect in Black Hole Physics

Amal Pushp*

Delhi Public School, Patna, India

Quantum fluctuations in the cosmic microwave background radiation reveal tiny fluctuations in the average temperature of the universe. This corresponds to differences in photon energies of Cmb in different regions of the universe. So initially, assuming two black holes with exactly same macroscopic properties, located in two different regions of the universe in accordance with Cmb anisotropy, i.e. one in a region with higher energy per photon and the other in a region with lower photon energy, it is found that this brings about inhomogeneity in the mass, temperature (event horizon) and entropy of the two black holes at the microscopic level. The final calculations show the deviation in properties of one black hole from the other on the microscopic scale. The arguments and calculations form the basis for a new effect in black hole physics.

Keywords: Black holes, Cosmic microwave background

I.INTRODUCTION

In this paper, calculations and arguments are reported which gives us a basis of a new effect in black hole physics. The paper contains various symbols describing the different properties at different stages of the black holes which are worth noting in order to avoid confusion in later calculations.

FOR BLACK HOLE 1:

$h\nu_1 N$ – Photon intensity (in terms of energy) near the black hole

m_1 – Initial mass of the black hole

m_2 – Mass of the black hole taking into account the absorption of Cmb

Δm – Mass change due to absorption of Cmb photons

t_1 – Initial temperature of event horizon

t_2 – Temperature of event horizon taking into account the absorption of Cmb

Δt – Temperature change due to Cmb absorption

s_1 – Initial entropy of the black hole

s_2 – Entropy of the black hole taking into account the absorption of Cmb

Δs –Entropy change due to Cmb absorption

FOR BLACK HOLE 2:

Similarly, $h\nu_2 N$, m'_1, m'_2, $\Delta m'$, t'_1, t'_2, $\Delta t'$, s'_1, s'_2 and $\Delta s'$ for this black hole.

SYMBOLS REPRESENTING THE FINAL EQUATIONS:

ΔM – Represents magnitude of difference in mass $(\Delta m - \Delta m')$ between the two black holes due to Cmb anisotropy.

ΔT – Represents magnitude of difference in temperature $(\Delta t' - \Delta t)$ between the two event horizons due to Cmb anisotropy.

ΔS – Represents magnitude of difference in entropy ($\Delta s' - \Delta s$) between the two black holes due to Cmb anisotropy**.**

The proposed theory in this note is based on some initial assumptions which must be considered at first before proceeding into further description and calculations.

- The black holes don't absorb radiation (or matter) other than Cmb.
- It is assumed that the two black holes taken into consideration are located in two different regions of space in accordance with Cmb anisotropy, such that $h\nu_1 N > h\nu_2 N$ (see, e.g. Refs. [1-3]).

  So even if the intensity of photons near the two black holes is same, the energies are different.

- Absorption of Cmb photons from regions other than near the black hole is ignored.

  One may find that the justification for the third assumption is the fact that the vastness of the universe and the finite speed of light would hardly allow the absorption of photons from regions other than the black hole's region in spacetime.

We consider the two black holes at their initial stage (at first the absorption of Cmb photons is ignored). So,

$$m_1 = m'_1 \tag{1}$$

$$t_1 = t'_1 \tag{2}$$

$$s_1 = s'_1 \tag{3}$$

Now we take into account the absorption of background radiation by the black holes from their respective regions. This means that the black holes are gaining energy 'E' from Cmb photons and from Einstein's principle, gaining energy is equivalent to gaining mass by an amount $\frac{E}{c^2}$, where c^2 makes the equivalence, between energy and mass, possible (See, e.g. Ref. [6]). Considering the above notion as a fact, we arrive at the result that Black Hole 1 would gain more mass from Cmb than Black Hole 2 due to the anisotropy ($h\nu_1 N > h\nu_2 N$). See, e.g. Refs. [4-5].It can be seen here clearly that mass $\propto h\nu N$.

$\therefore\ m_2 > m'_2\ and\ t_2 < t'_2$, as temperature varies inversely with mass in particular for a black hole, see, e.g. Ref. [7]. Also, $s_2 < s'_2$ as with a decrease in temperature the entropy would also decrease (strictly for the black hole systems).We would be considering independent cases for the two black holes first and then finally derive the difference in mass (ΔM),temperature (ΔT) and entropy (ΔS) between the two black holes due to Cmb fluctuations. For simplicity in our derivations we would be considering non-rotating (Schwarzschild) black holes which are a solution to the Einstein field equations and have the metric,

$$ds^2 = -\left(1 - \frac{2M}{r}\right) dt^2 + \left[\frac{1}{\left(1-\frac{2M}{r}\right)}\right] dr^2 + r^2 d\Omega^2 \tag{4}$$

And whose radius is expressed as,

$$r_s = \frac{2GM}{c^2} \tag{5}$$

II. CASE OF BLACK HOLE 1

For a non-rotating (Schwarzschild) black hole, we have,

$$T = \frac{\hbar c^3}{8\pi G M K_B} \tag{6}$$

The above expression represents the temperature of Hawking radiation, see, e.g. Refs. [7-9].

Eq. (6) can be written as,

$$M = \frac{\hbar c^3}{8\pi G T K_B} \tag{7}$$

Initially for the black hole,

$$m_1 = \frac{\hbar c^3}{8\pi G t_1 K_B} \tag{8}$$

Now, taking the point of view that Cmb radiation is being absorbed by the black hole, we can write,

$$m_2 = \frac{\hbar c^3}{8\pi G t_2 K_B} \tag{9}$$

Since $m_2 > m_1$, the change in mass,

$$\Delta m = m_2 - m_1 = \frac{\hbar c^3}{8\pi G t_2 K_B} - \frac{\hbar c^3}{8\pi G t_1 K_B} = \frac{\hbar c^3}{8\pi G K_B}\left(\frac{1}{t_2} - \frac{1}{t_1}\right) \tag{10}$$

Proceeding in this manner the change in temperature of its event horizon can be calculated.

We have,

$$t_1 = \frac{\hbar c^3}{8\pi G m_1 K_B} \tag{11}$$

And $t_2 = \frac{\hbar c^3}{8\pi G m_2 K_B}$ (12)

Since $t_1 > t_2$,

The change in temperature,

$$\Delta t = t_1 - t_2 = \frac{\hbar c^3}{8\pi G m_1 K_B} - \frac{\hbar c^3}{8\pi G m_2 K_B} = \frac{\hbar c^3}{8\pi G K_B}\left(\frac{1}{m_1} - \frac{1}{m_2}\right) \tag{13}$$

The entropy of a black hole is given by the Bekenstein-Hawking formula,

$$S_{BH} = \frac{c^3 A}{4\hbar G} \tag{14}$$

Initially for the black hole,

$$s_1 = \frac{c^3 A_1}{4\hbar G} \tag{15}$$

Now as a result of absorption of Cmb, we can write,

$$s_2 = \frac{c^3 A_2}{4\hbar G} \tag{16}$$

Since $s_1 > s_2$,

The change in entropy,

$$\Delta s = s_1 - s_2 = \frac{c^3 A_1}{4\hbar G} - \frac{c^3 A_2}{4\hbar G} = \frac{c^3}{4\hbar G}(A_1 - A_2) \tag{17}$$

III. CASE OF BLACK HOLE 2

Working out the calculations in similar manner as for the first black hole, we get,

Change in mass of the black hole,

$$\Delta m' = m'_2 - m'_1$$

$$= \frac{\hbar c^3}{8\pi G K_B}\left(\frac{1}{t'_2} - \frac{1}{t'_1}\right) \tag{18}$$

Change in temperature of its event horizon,

$$\Delta t' = t'_1 - t'_2$$

$$= \frac{\hbar c^3}{8\pi G K_B}\left(\frac{1}{m'_1} - \frac{1}{m'_2}\right) \quad (19)$$

And Change in entropy,

$$\Delta s' = s'_1 - s'_2 = \frac{c^3 A'_1}{4\hbar G} - \frac{c^3 A'_2}{4\hbar G} = \frac{c^3}{4\hbar G}(A'_1 - A'_2) \quad (20)$$

IV. FINAL CALCULATIONS

In this section, we derive the difference in mass, temperature and entropy (due to Cmb fluctuations), between the two black holes considered.

Since $\Delta m > \Delta m'$ $\quad (h\nu_1 N > h\nu_2 N)$

We get from eqs. (10) & (18),

$$\Delta M = \Delta m - \Delta m' = \frac{\hbar c^3}{8\pi G K_B}\left(\frac{1}{t_2} - \frac{1}{t_1}\right) - \frac{\hbar c^3}{8\pi G K_B}\left(\frac{1}{t'_2} - \frac{1}{t'_1}\right)$$

$$= \frac{\hbar c^3}{8\pi G K_B}\left[\left(\frac{1}{t_2} - \frac{1}{t_1}\right) - \left(\frac{1}{t'_2} - \frac{1}{t'_1}\right)\right]$$

$$= \frac{\hbar c^3}{8\pi G K_B}\left[\left(\frac{t_1 - t_2}{t_2 t_1}\right) - \left(\frac{t'_1 - t'_2}{t'_2 t'_1}\right)\right]$$

$$\therefore \Delta M = \Delta m - \Delta m' = \frac{\hbar c^3}{8\pi G K_B}\left[\left(\frac{t_1 - t_2}{t_2 t_1}\right) - \left(\frac{t'_1 - t'_2}{t'_2 t'_1}\right)\right] \quad (21)$$

And Since $\Delta t' > \Delta t$ $\quad (T \propto \frac{1}{M})$

We get from eqs. (19) & (13),

$$\Delta T = \Delta t' - \Delta t$$

$$= \frac{\hbar c^3}{8\pi G K_B}\left(\frac{1}{m'_1} - \frac{1}{m'_2}\right) - \frac{\hbar c^3}{8\pi G K_B}\left(\frac{1}{m_1} - \frac{1}{m_2}\right)$$

$$= \frac{\hbar c^3}{8\pi G K_B}\left[\left(\frac{1}{m'_1} - \frac{1}{m'_2}\right) - \left(\frac{1}{m_1} - \frac{1}{m_2}\right)\right]$$

$$= \frac{\hbar c^3}{8\pi G K_B}\left[\left(\frac{m'_2 - m'_1}{m'_1 m'_2}\right) - \left(\frac{m_2 - m_1}{m_1 m_2}\right)\right]$$

$$\therefore \Delta T = \Delta t' - \Delta t = \frac{\hbar c^3}{8\pi G K_B}\left[\left(\frac{m'_2 - m'_1}{m'_1 m'_2}\right) - \left(\frac{m_2 - m_1}{m_1 m_2}\right)\right] \quad (22)$$

Now $\Delta s' > \Delta s$ (since $\Delta t' > \Delta t$)

We get from eqs. (20) and (17),

$$\Delta S = \Delta s' - \Delta s = \frac{c^3}{4\hbar G}(A'_1 - A'_2) - \frac{c^3}{4\hbar G}(A_1 - A_2)$$

$$= \frac{c^3}{4\hbar G}[(A'_1 - A'_2) - (A_1 - A_2)]$$

$$= \frac{c^3}{4\hbar G}[(A'_1 - A_1) + (A_2 - A'_2)]$$

$$\therefore \Delta S = \Delta s' - \Delta s = \frac{c^3}{4\hbar G}[(A'_1 - A_1) + (A_2 - A'_2)] \quad (23)$$

Equations (21), (22) and (23) represent the predicted effect.

Dr. Hawking's discovery of the temperature dependent radiation emanating from black holes is significant only on the microscopic level. It can be seen here as well that the predicted phenomenon strictly falls in the microscopic domain even though black holes are large-scale cosmological objects. Microscopic effects arise in cosmology too and this prediction is one example of it alongside few more (like hawking radiation and unruh effect), see, e.g. Refs. [7, 10-15]. The two fundamental constants, $\hbar$ (represents quantum mechanics) and G (represents gravity) in the above equations tell us that the predicted astrophysical effect is an indication towards the quantum theory of gravity, which is yet to be achieved. Although it would be difficult for the astronomers to collect observational evidences and data related to the prediction, an important advantage however is the clarity in the prediction and its theoretical formulation which would be helpful in further insights into astrophysical phenomena. The predicted effect has an important consequence according to which, no two black holes, in different regions of spacetime, would have the same mass, temperature (event horizon) and entropy as viewed on the microscopic scale, provided that the inequality condition, $h\nu_1 N > h\nu_2 N$, is satisfied.

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*Corresponding author:

amalpjha2701@gmail.com