Article

On the Temperature of Black Hole

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Abstract

During the collapse of a massive star, at the moment of formation of black holes, a large quantity of heat is generated and thereby its internal temperature increases. At increasing mass density and increasing internal temperature, nuclear interactions like fusion of quarks, will take place and generate more heat causing the black hole internal temperature to increase further. At one particular temperature, its thermal energy density approaches its mass-energy density and thus the black hole starts maintaining its structural stability against further collapse. With this new concept, the famous Hawking's black hole temperature formula can be obtained directly wherein 'mass of black hole' is being replaced by the geometric mean of 'Black hole mass and the Planck mass'. Thus it can be suggested that, black holes are hot but not cold.

Key Words: Black Hole, formation, temperature, massive star, hot, cold.

1. Introduction

Black holes have progressed from a curiosity of mathematical physics to a tool for building or studying models in other branches of physics. Examples range from feedback mechanisms that may control the formation and evolution of galaxies [1] and the formation of the whole universe [2,3,4]. However, black holes remain fascinating objects in their own right and may yet reveal deep clues to further revolutions in fundamental physics. Very recently S.W. Hawking modified his Black hole theory [5] with "Apparent horizons". This brought a serious confusion among the black hole physicists and whole science community. In his words: "There is no escape from a black hole in classical theory. Quantum theory, however, enables energy and information to escape from a black hole". He admits that, a full explanation of the process would require a theory that successfully merges gravity with the other fundamental forces of nature. But that is a goal that has eluded physicists for nearly a century. However 'the correct treatment'- 'remains a mystery'. Abhas Mitra [6] showed that true black holes can never form. In his opinion the so-called black holes observed by astronomers are actually radiation pressure supported Eternally Collapsing Objects (ECOs). These balls of fire are so hot that even neutrons and protons melt there and their outward radiation pressure balances the inward pull of gravity to arrest a catastrophic collapse before any Black Hole or 'singularity' would actually form.

The two fundamental questions to be answered are: 1) Are black holes really black? and 2)Are black holes really cool? Note that, after 40 years of a great effort, in a quantum mechanical

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approach and by considering black hole 'event horizons' as "apparent", S.W. Hawking suggests that black holes are not perfectly black! In this paper the authors made an attempt to understand the reality of the existence of 'cold black holes'. Thinking that massive stars that collapse may generate heat, the authors proposed the existence of stable and hot black holes. The basic concept of this article is published in the 59th Indian DAE Symposium proceedings [7] as a two page contribution. If it is proved to be realistic, existence of 'cold black holes' can be relinquished. If so, basics of black hole physics must be reviewed and revised at fundamental level.

2. Apparent horizons and natural escaping of photon

According to S.W. Hawking, black hole event horizons are 'Apparent' and "energy and information" can escape from the black hole. This concept can be understood in the following way. Being a quantum mechanical object, even though surface gravity is high, photon will escape from the massive black hole'sevent horizon. Clearly speaking during its escape from the massive black hole'sevent horizon, photon may lose energy due to massive black hole's surface gravity and show gravitational redshift but it will not lose its speed. Thus with increasing redshift photon will continue its journey until its energy becomes zero and redshift reaches infinity. For a photon moving towards the massive black hole's horizon, its speed remaining constant it experiences gravitational blue shift and again speed remaining constant it leaves the massive black hole's horizon by losing its acquired (blue shift) energy by gravitational redshift. Compared to the photon that originates from the black hole, photon that enters and leaves the black hole will make a long journey. In this view, with respect to photons, 'event horizons' can be considered as 'Apparent horizons' or 'Quantum horizons'.

3. Critical review on the gravitational collapse

The primary mechanism for black hole formation is expected to be the gravitational collapse of massive stars. Gravitational collapse occurs when any star's internal pressure is insufficient to resist its own gravity. For stars this usually occurs either because it has too little "fuel" left to maintain its temperature through stellar nucleosynthesis and its temperature is no longer high enough to prevent it from collapsing under its own weight. The collapse may be stopped by the degeneracy pressure of the star's constituents, condensing the matter in an exotic denser state. The result is one of the various types of compact star. The type of compact star formed depends on the mass of the remnant.

In this context, the authors stress the fact that during the gravitational collapse, matter content of the massive star experiences heavy compression and there by a large quantity of heat will be generated. Thus temperature of the collapsing star again increases. As long as the compression proceeds, temperature increases. At one critical point, thermal energy density of the collapsing star reaches its mass density and results in the formation of a stable and hot black hole and there will be no further collapse. With this simple concept, the famous Hawking's black hole temperature formula can be obtained directly wherein the two important changes are: 1) Mass of black hole is being replaced by the geometric mean of Black hole mass and the Planck mass. 2) Coefficient $(1/8\pi)$ is being replaced by $\left(45/32\pi^3\right)^{\frac{1}{4}} \cong 0.4615$.

4. Quantum mechanical stable black holes

Based on the above concept and with reference to the nucleon and electron rest masses, two types of stable black holes can be predicted in the following way.

A) With reference to the Compton wave length of nucleon, there may exist a massive black hole with mass density in the following way.

$$\left[M_B\left(\frac{4\pi}{3}R_B^3\right)^{-1}\right] \cong m_n\left(\frac{4\pi}{3}\left(\frac{\hbar}{m_n c}\right)^3\right)^{-1} \tag{1}$$

Here, (M_B, R_B) represent the mass and radius of a black hole respectively and m_n is the mass of nucleon. On simplification,

$$M_B \cong \sqrt{\frac{\hbar^3 c^3}{8G^3 m_n^4}} \cong \frac{M_P^3}{\sqrt{8}m_n^2} \cong 1.3\times 10^{30}\ \text{kg.} \tag{2}$$

where $M_P \cong \sqrt{\frac{\hbar c}{G}}$ is the Planck mass. This obtained black hole mass is 2.2154 times less than the Chandrasekhar mass limit [8].

B) With reference to the Compton wave length of electron, there may exist a massive black hole with mass density in the following way.

$$\left[M_B\left(\frac{4\pi}{3}R_B^3\right)^{-1}\right] \cong m_e\left(\frac{4\pi}{3}\left(\frac{\hbar}{m_e c}\right)^3\right)^{-1} \tag{3}$$

Here m_e is the mass of electron. On simplification,

$$M_B \cong \sqrt{\frac{\hbar^3 c^3}{8G^3 m_e^4}} \cong \frac{M_P^3}{\sqrt{8}m_e^2} \cong 4.38\times 10^{36}\ \text{kg} \tag{4}$$

This can be compared with the Milkyway central black hole of mass 4.3 million solar masses.

5. Thermal energy density of black holes

According to Abhas Mitra - the so called black holes observed by astronomers are actually radiation pressure supported Eternally Collapsing Objects (ECOs). These balls of fire are so hot that even neutrons and protons melt there and their outward radiation pressure balances the inward pull of gravity to arrest a catastrophic collapse before any Black Hole or 'singularity' would actually form. Following the notion of hot ECOs and black hole's 'virtual' event horizons, to stop further collapse, for any black hole to maintain its black hole radius or its structure, its thermal energy density must be equal to its mass-energy density. Clearly speaking,

$$aT_B^4 \cong \left[M_B c^2 \left(\frac{4\pi}{3} R_B^3 \right)^{-1} \right] \tag{5}$$

With reference to the compound radiation energy density constant, $a \cong \frac{\pi^2}{15}\frac{k_B^4}{\hbar^3 c^3}$ and the Planck mass, $M_P \cong \sqrt{\frac{\hbar c}{G}}$ - above relation can be simplified into the following form.

$$T_B \cong \left(\frac{45}{32\pi^3} \right)^{\frac{1}{4}} \frac{\hbar c^3}{Gk_B\sqrt{M_B M_P}} \cong 0.4615 \cdot \frac{\hbar c^3}{Gk_B\sqrt{M_B M_P}} \tag{6}$$

This is similar to the Hawking's black hole temperature formula [9]. According Hawking, temperature of a black hole is given by the following famous relation.

$$T_B = \frac{\hbar c^3}{8\pi k_B G M_B} \tag{7}$$

Here, (M_B, T_B) represent the mass and temperature of the black hole respectively. Note that, so far Hawking's proposal is not verified and not confirmed by any of the advanced astrophysical observations or Large Hadron Collider experiments [10,11]. It is being believed only on the advanced quantum mechanical theoretical and mathematical formulations and modesty.

Similar to the Hawking's black hole temperature formula, above relation (6) can be re-expressed as follows.

$$T_B = 0.4615\sqrt{\frac{M_B}{M_P}} \cdot \left(\frac{\hbar c^3}{k_B G M_B} \right) \tag{8}$$

Now the concepts A and B of section (3) can be expressed in the following way.

A) With reference to the Compton wave length of nucleon, there may exist a hot and stable massive black hole with thermal energy density in the following way.

$$aT_B^4 \cong M_B c^2 \left(\frac{4\pi}{3} R_B^3 \right)^{-1} \cong m_n c^2 \left(\frac{4\pi}{3} \left(\frac{\hbar}{m_n c} \right)^3 \right)^{-1} \tag{9}$$

where T_B represents temperature required to maintain the black hole's further collapse.

$$T_B \cong \left[\frac{m_n c^2}{a}\left(\frac{4\pi}{3}\left(\frac{\hbar}{m_n c}\right)^3\right)^{-1}\right]^{\frac{1}{4}} \cong 8.46\times10^{12}\ \text{K} \tag{10}$$

B) With reference to the Compton wave length of electron, there may exist a hot and stable massive black hole with thermal energy density in the following way.

$$aT_B^4 \cong M_B c^2\left(\frac{4\pi}{3}R_B^3\right)^{-1} \cong m_e c^2\left(\frac{4\pi}{3}\left(\frac{\hbar}{m_e c}\right)^3\right)^{-1} \tag{11}$$

To have stability against the gravitational collapse, black hole of mass $4.38\times10^{36}\ \text{kg}$ requires a temperature,

$$T_B \cong \left[\frac{m_e c^2}{a}\left(\frac{4\pi}{3}\left(\frac{\hbar}{m_e c}\right)^3\right)^{-1}\right]^{\frac{1}{4}} \cong 4.6\times10^{9}\ \text{K} \tag{12}$$

6. The classical limits of force and power

Without considering the current notion of black hole physics, Schwarzschild radius of a black hole can be estimated with the characteristic limiting force of magnitude $\left(c^4/G\right)$. The outstanding problem in particle physics today is the inclusion of gravity in a single, unified quantum theory of all the fundamental interactions. Particle physicists have long suggested that the four observed fundamental forces of nature (the gravitational, electromagnetic, weak nuclear and strong nuclear forces) are separate, low energy manifestations of what was once a single force at times close to the Big Bang. It is postulated that as the universe expanded and cooled, this single force gradually broke down into the four separate interactions as observed today. However, unification theories that seek to unify the force of gravity with all the other forces (Theories of Everything) remain elusive, as the gravitational interaction lacks a quantum formulation.To unify cosmology, quantum mechanics and the four observed fundamental cosmological interactions – certainly a 'unified force' is required. In this connection $\left(c^4/G\right)$ can be considered as the classical force limit. Similarly $\left(c^5/G\right)$ can be considered as the classical power limit. If it is true that c and G are fundamental physical constants in physics, then $\left(c^4/G\right)$ and $\left(c^5/G\right)$ can also be considered as fundamental compound physical constants. These classical limits are more powerful than the Uncertainty limit. Note that by considering the classical force limit $\left(c^4/G\right)$, the famous Planck mass can be obtained.

6.1. Simple applications of $\left(c^4/G\right)$

a) Magnitude of force of attraction or repulsion between any two charged particles never exceeds $\left(c^4/G\right)$.

b) Magnitude of gravitational force of attraction between any two massive bodies never exceeds $\left(c^4/G\right)$.
c) Magnitude of mechanical force on a revolving/rotating body never exceeds $\left(c^4/G\right)$.
d) Magnitude of electromagnetic force on a revolving body never exceeds $\left(c^4/G\right)$.

6.2. Simple applications of $\left(c^5/G\right)$

a) Mechanical power never exceeds $\left(c^5/G\right)$
b) Electromagnetic power never exceeds $\left(c^5/G\right)$
c) Thermal radiation power never exceeds $\left(c^5/G\right)$
d) Gravitational radiation power never exceeds $\left(c^5/G\right)$

6.3 To derive the Planck mass

So far no theoretical model proposed a derivation for the Planck mass. To derive the Planck mass the following two conditions can be given a chance.

Assuming that gravitational force of attraction between two Planck particles of mass (M_P) separated by a minimum distance (r_{min}) be,

$$\left[\frac{GM_P M_P}{r_{\min}^2}\right] \equiv \left(\frac{c^4}{G}\right) \tag{13}$$

With reference to wave mechanics, let

$$2\pi . r_{\min} \cong \lambda_P = \left[\frac{h}{c.M_P}\right] \tag{14}$$

Here, λ_P represents the wavelength associated with the Planck mass. With these two assumed conditions Planck mass can be obtained as follows.

$$M_P = \sqrt{\frac{hc}{2\pi G}} \cong \sqrt{\frac{\hbar c}{G}} \tag{15}$$

7. Understanding the Schwarzschild radius of a black hole

The four basic physical properties of a rotating black hole are its mass, size, angular velocity and temperature. Without going deep into the mathematics of black hole physics, in this section, an attempt is made to understand the Schwarzschild radius of a black hole.

In all directions if a force of magnitude (c^4/G) acts on the mass-energy content of the assumed celestial body it approaches a minimum radius of (GM/c^2) in the following way. Origin of the force (c^4/G) may be due to self-weight or internal attraction or external compression.

$$R_{\min} \cong \frac{Mc^2}{\left(c^4/G\right)} \cong \frac{GM}{c^2} \tag{16}$$

If no force (of zero magnitude) acts on the mass content M of the assumed massive body, its radius becomes infinity. With reference to the average magnitude of $\left(0, \frac{c^4}{G}\right) \cong \frac{c^4}{2G}$, the presently believed Schwarzschild radius can be obtained as

$$\left(R\right)_{ave} \cong \frac{Mc^2}{\left(c^4/2G\right)} \cong \frac{2GM}{c^2} \tag{17}$$

This proposal is very simple and seems to be a unified form of Special theory of relativity and General theory of relativity.

8. Conclusion

With reference to Hawking's view and Abhas Mitra's view, in a unified picture it can be suggested that, when acollapsing star's mass density approaches the nuclear mass density, internal temperature increases which in turn generates more heat resulting in a high temperature stable massive black holes with mass close to 10^{30} kg. It can be also be stressed, suggested and confirmed that black holes are hot like ordinary stars[12] and emits radiation in all directions through their apparent horizons. Now it seems essential to review and revise the basics laws of black hole physics.

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