CMBR AND BLACK HOLE’S EVAPORATION

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The black hole’s evaporation possibility is considered taking into account the CMBR existence as an external environment. It is found the upper limit of the black hole that is able to evaporate.

In 1975 S. Hawking published his famous paper [1] where he predicted a proper thermal black hole’s (BH) radiation. It has the “absolutely black body” spectrum (Fig.1) and an effective temperature $T_H \sim 1/m$, where m is the BH mass.

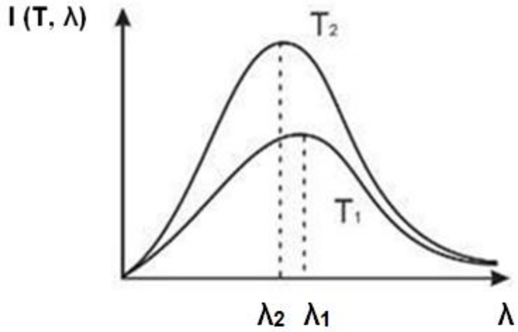

Figure 1. The thermal radiation intensity I (T, λ) vs temperature T and wave length λ. While a temperature increases ($T_2>T_1$), the maximal spectral length decreases inversely proportionally ($\lambda_2 < \lambda_1$).

Since a gravitational radius r of a non-rotational neutral BH is proportional to its mass we can state that $T_H \sim 1/r$. One usually deduces from this that an “isolated” BH will evaporate, its mass and radius will decrease, its temperature will increase with acceleration, so finally it will explode[1].

Meanwhile, we cannot consider such a process without taking into account the BH’s real environment. Particularly, one has to account some counteraction to its evaporation due to cosmic microwave background radiation (CMBR) that BH absorbs. Generally, a role of a matter can be more than this one of CMBR, but here we will consider the last only.

As we know, the Universe is fulfilled by CMBR whose spectrum is the thermal one too (Fig. 1) and corresponds to $T_{CMBR} \sim 3$ K (more precisely: 2.725 K, spectral maximum at λ=1.9 mm, frequency is 160.4 GHz). This is confirmed with the great accuracy by the FIRAS instrument of the COBE mission (NASA).

CMBR is irreversibly absorbed by BH and clearly counteracts to its Hawking’s radiation. Of course, the CMBR will dominate in the case when the BH horizon’s temperature $T_H < T_{CMBR}$. Since for a BH having the mass of Earth (6×10^{24} kg) the Hawking’s temperature is[2] $T_H \approx 0.02$ K and $r \approx 10$ mm we can find that for BH having $T_H \approx 3$ K its gravitational radius has to be less than 1.5 m ≈ 0.01 m × (3/0.02).

So, in the present cosmic epoch *a BH having the radius less than 1.5 m and the mass less 150 mass of Earth can only evaporate*. It is important that the temperature 3 K corresponds to the thermal radiation spectral wavelength maximum $\lambda_{3K} \approx 2$ mm that is much less than 1500 mm;

[1] Note, in 2014 in [2] some calculations were presented that showed that the star stops collapsing at a finite radius larger than its horizon, turns around and its core explodes, so such a BH cannot now exist at all.

[2] Author thanks Yu.A. Lebedev for revealing of an unfortunate mistake in the previous version of the paper.

because of that, a similar waves can be quite emitted by a body of such a size[3]. The same relationship (1: 750) between them is true at any time of the Universe history (Fig. 2) since the epoch of last scattering ($z \approx 1000$), because BH's maximal radius[4] r and maximal spectral wavelength λ of thermal radiation[5] are inversely proportional to temperature T_H. This situation has be the same in the future when the CMBR's temperature will further decrease.

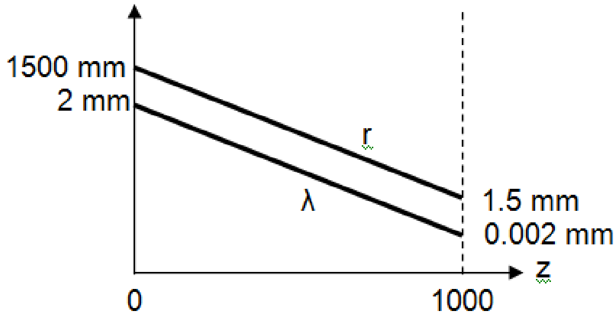

Figure 2. The maximal admissible gravitational radius r of an evaporated BH and maximal spectral wave length λ of its thermal radiation vs redshift z. A logarithmic scale is used for vertical axe. The redshift value z=0 corresponds to the present CMBR's temperature (~3 K), the redshift value z≈1000 corresponds to the last scattering epoch (~3000 K) when the universe size was 1000 times less.

References

[1] S. W. Hawking. "Particle Creation by Black Holes".Commun. math. Phys. 43, 199—220 (1975)
[2] Laura Mersini-Houghton and Harald P. Pfeiffer. Back-reaction of the Hawking radiation ux on a gravitationally collapsing star II: Fireworks instead of _rewalls. ArXiv:1409.1837v1 [hep-th] 5 Sep 2014
[3] Jacob D. Bekenstein. "Black holes and information theory". ArXiv:quant-ph/0311049v1 9 Nov 2003

[3] J. Bekenstein wrote analogously in [3]: "… a black hole's mass cannot be below a Planck mass ($2 \times 10{-}5$ g) because if it where, the hole would then be smaller than its own Compton length".
[4] Accordingly to the modern opinion the CMBR's temperature is inversely proportional to the Universe size.
[5] As the Wien displacement law states.