Hawking radiation cannot exist if quantum vacuum fluctuations are gravitational dipoles

Dragan Slavkov Hajdukovic, Institute of Physics, Astrophysics and Cosmology
Cetinje, Montenegro
dragan.hajdukovic@physac.me

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Abstract

It was recently suggested that what we call dark matter and dark energy, can be explained as the local and global effects of the gravitational polarization of the quantum vacuum by the immersed Standard Model matter. This result appears as the consequence of the working hypothesis that *by their nature quantum vacuum fluctuations are virtual gravitational dipoles.* Here, as a consequence of the same hypothesis we point out that instead of the non-existent thermal Hawking radiation there is a much stronger and potentially detectable, non-thermal radiation which is caused by the conversion of virtual particle-antiparticle pairs into real ones; this conversion happens deep inside the horizon of a black hole. Contrary to Hawking radiation which leads to the black hole information paradox, *there is no information loss paradox* within the framework of the quantum vacuum "enriched" with virtual gravitational dipoles.

Let us start with one of the most beautiful and the most famous relations of theoretical physics:

$$k_B T_H = \frac{\hbar c^3}{8\pi G M} \tag{1}$$

The physical meaning of the above relation [1] is that a Schwarzschild black hole of mass M radiates as a black body of temperature T_H; $\hbar, c, G$ and k_B are respectively the reduced Planck constant, the speed of light, the Gravitational constant and the Boltzmann constant.

The Hawking temperature is an extremely low temperature. If we limit ourselves to astronomical black holes which have masses in the range from a few solar masses to ten billion solar masses, the corresponding Hawking temperature varies from $10^{-8}K$ to $10^{-18}K$. The hottest black holes have a temperature 100 million times smaller than the tiny temperature of the cosmic microwave background. Even if the Hawking radiation exists, there is no way that we can detect such a miniscule radiation by observing the astronomical black holes.

It is amusing that such a tiny effect, if it exists, can cause one of the major problems in theoretical physics: the information loss paradox [2]. If the Hawking radiation does not exist, the information loss paradox does not exist as a well.

While it is always neglected, as a phenomenon depending on the existence of the quantum vacuum, Hawking radiation is *model-dependent*; it depends on the used model of the gravitational properties of the quantum vacuum. Hawking calculations correspond to the case when quantum vacuum fluctuations strictly behave as a positive gravitational charge; hence, Hawking calculations are invalid if, for instance, quantum vacuum fluctuations are virtual gravitational dipoles.

It was recently suggested [3, 4, 5, 6] that what we call dark matter and dark energy can be explained as the local and global effects of the gravitational polarization of the quantum vacuum by the immersed Standard Model matter. This result appears as the consequence of the working hypothesis, *that by their nature quantum vacuum fluctuations are virtual gravitational dipoles*; in particular this hypothesis is true if particles and antiparticles have the gravitational charge of the opposite sign, what is on the way to be tested by three competing experiments at CERN (ALPHA, AEGIS and GBAR). Here, as a consequence of the same hypothesis we suggest that instead of the non-existent thermal Hawking radiation there is a much stronger and potentially detectable, non-thermal radiation which is caused by the conversion of virtual particle-antiparticle pairs into real ones; this conversion happens deep inside the horizon by the virtue of extremely strong gravitational field (the particle-antiparticle creation rate increases with the strength of the field). Contrary to Hawking radiation which leads to the black hole information paradox, there is no information loss paradox within the framework of the quantum vacuum "enriched" with virtual gravitational dipoles.

Before any mathematical considerations let us note an obvious fact, if particles and antiparticles have the gravitational charge of the opposite sign *a black hole is also a white hole.* A black hole made from matter is a black hole for matter but *a white hole for antimatter*, while a black hole made from antimatter is a black hole for antimatter but white whole for matter. It would be better to call these objects *black-white holes* instead of black holes. And, this is compatible with General Relativity; to see it let us consider the simplest case of a Schwarzschild black hole made from matter. While it is often neglected, from a mathematical point of view there are two solutions: the positive mass Schwarzschild solution

$$ds^2 = c^2\left(1 - \frac{2GM}{c^2 r}\right)dt^2 - \left(1 - \frac{2GM}{c^2 r}\right)^{-1} dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi) \tag{2}$$

considered as the physical space-time metric; and the negative mass Schwarzschild solution

$$ds^2 = c^2\left(1 + \frac{2GM}{c^2 r}\right)dt^2 - \left(1 + \frac{2GM}{c^2 r}\right)^{-1} dr^2 - r^2(d\theta^2 + sin^2\theta d\varphi) \tag{3}$$

considered as a non-physical solution. It serves as the simplest example of a naked singularity [7] and a repulsive space-time allowed by mathematical structure of general relativity but rejected as non-physical (but, imagine Dirac neglecting his negative energy solution and missing the prediction of antimatter). However, in the framework of the gravitational repulsion between matter and antimatter, both solutions may be given a physical meaning: the metric (2) is the metric "seen" by a test particle, while the metric (3) is the metric "seen" by a test antiparticle. The major difference is that there is a horizon in the case of metric (2), while there is no horizon in the case of metric (3). In simple words, a black hole made from matter acts as a black hole with respect to matter and as a white hole with respect to antimatter.

Deep inside its matter horizon, antimatter particles can be created in two different ways. First, a black hole can absorb material from its neighborhood. It is obvious that, as the result of the collisions of the infalling material (analogous to collisions in our accelerators), different kinds of antiparticles can be created *inside the horizon* and (assuming the gravitational repulsion between matter and antimatter) long-living antiparticles would be violently ejected outside the horizon; hence black holes contribute to the high energy component of antimatter in cosmic rays. Of course, the ejection rate should be greater if the quantity of the infalling material is greater; a black-white hole behaves as an *irregular source* of antimatter.

As we will argue later the energy ε_m with which an infalling particle of mass m hits the target (and consequently the upper limit for energy of products of collision) is

$$\varepsilon_m \approx \sqrt{\frac{R_s}{\lambda_e}} mc^2 \tag{4}$$

where $R_s = \frac{2GM}{c^2}$ and λ_e are respectively the Schwarzschild radius of the black hole and the reduced Compton wavelength of electron. Consequently, a supermassive black hole with mass of about 10^{10} solar masses may emit antiprotons and antineutrons with energies up to a few $10^{12} GeV$! Of course this kind of radiation is independent from the existence of the quantum vacuum.

In addition to the above irregular creation and emission of antiparticles, there is a second mechanism of creation of particle-antiparticle pairs, mainly limited to neutrino-antineutrino pairs. Namely, virtual particle-antiparticle pairs from the quantum vacuum might be converted into real ones by a sufficiently strong gravitational field deep inside the horizon of a black hole (this is the gravitational analog of the Schwinger mechanism in quantum electrodynamics).

According to the Schwinger mechanism in quantum electrodynamics [8], a virtual electron-positron pair can be converted to a real one by an external field which, during their short lifetime, can separate particle and antiparticle to a distance of about one reduced Compton wavelength.

For a constant acceleration a (which corresponds to a constant electric field) the particle creation rate per unit volume and time (for particles with mass m), can be written as [5, 9]

$$\frac{dN_{m\overline{m}}}{dtdV} = \frac{c}{\lambdabar_m^4}\left(\frac{a}{a_{cr}}\right)\sum_{n=1}^{\propto}\frac{1}{n^2}exp\left(-n\frac{a_{cr}}{a}\right),\ \lambdabar_m \equiv \frac{\hbar}{mc},\ a_{cr} \equiv \pi\frac{c^2}{\lambdabar_m} \tag{5}$$

If there are virtual gravitational dipoles, equation (5) is valid for gravity; consequently instead of Hawking radiation there is a radically different, *non-thermal radiation*, based on the gravitational version of the Schwinger mechanism.

Equation (5) contains a sum of exponential functions with negative exponents; hence, the particle creation rate is significant only for a gravitational field a greater than the critical value a_{cr}. Let us compare the critical acceleration $a_{cr}(m)$ with the gravitational acceleration $g_s = GM/{R_s}^2 = c^2/R_s$ at the Schwarzschild radius of a black hole with mass M; the comparison leads to the conclusion $a_{cr} \gg g_s$, i.e. a virtual pair can be converted to a real one only deep inside the horizon of a black hole.

Instead of considering the mass collapsed to singularity, let us consider a black hole as a "ball" of a small size $r_H \ll R_s$, and let us define a critical radius $r_{Cm} \ll R_s$, as the distance at which the gravitational acceleration $g = GM/r^2$, produced by a Schwarzschild black hole (according to equation (3)), has the critical value $a_{cr}(m) = \pi c^2/\lambdabar_m$. Consequently,

$$r_{Cm} = \sqrt{\frac{\lambdabar_m R_s}{2\pi}} \tag{6}$$

Hence a spherical shell with the inner radius r_H and the outer radius r_{Cm} acts as a "factory" for creation of particle-antiparticle pairs with mass m. It is evident that there is a series of decreasing critical radiuses r_{Cm}. For instance, according to (6), the critical radius $r_{C\nu}$ corresponding to neutrinos is nearly four orders of magnitude greater than the critical radius r_{Ce} for electrons.

Integration of Eq. (5) over the shell determined by r_H and r_{Cm} (and taking $r_{Cm} \gg r_H$) leads to the following approximation

$$\frac{dN_{m\overline{m}}}{dt} \approx \left(\frac{R_s}{\lambdabar_m}\right)^2\frac{c}{r_H} \equiv \left(\frac{2GM}{\lambdabar_m c^2}\right)\frac{c}{r_H} \tag{7}$$

According to (7), the particleantiparticle creation rate per unit time depends on both mass M and radius r_H. If r_H (i.e. the size of a black hole) is very small, the conversion of matter into antimatter is very fast! At first sight, this looks to be the demise of the existence of black holes as objects with extremely long lifetimes. However, it is obvious that the first production of the lightest charged particles (electron-positron pairs) is accompanied with a phase transition from the Schwarzschild metric to the Reissner-Nordstrom metric (i.e. metric of a negatively charged black hole). The negative electric charge of the black hole opposes both [9] the further collapse and the further creation of electron-positron pairs by the gravitational field (it is because the electric and gravitational force on a positron, have opposite directions; hence, after some time the ejection of positrons should be stopped, and, as a final result, a black hole made from matter should emit mainly antineutrinos). Consequently, the size of a black hole and the critical radius for production of the electron-positron pairs should be of the same order of magnitude; we may use the approximation $r_H \approx r_{Ce}$ which leads to equation (4) as the upper bound for the energy of ejected antiparticles with mass m.

According to the approximation $r_H \approx r_{Ce}$ and equation (6), the size of the supermassive black hole in the center of the Milky Way (with $M_{MW} = 4 \times 10^6 M_{Sun}$) is $r_H \approx 3cm$; the size of a tennis ball but not a singularity! The number of the ejected antineutrinos (equation (7)) is of the order of 10^{41}

antineutrinos per second with maximal energy (equation (4)) of a few GeV. These numbers suggest that antineutrinos created by black hole from the quantum vacuum, might be detectable with a future generation of the neutrino telescopes.

The fact that radiation caused by the Schwinger mechanism is not a thermal one makes our theory of black hole radiation free of the information loss paradox which is inherent shortcomings of Hawkings theory because of its thermal nature [2].

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