The Black Hole Evaporation paradigm: A new Approach

Abstract: The author is considering 2 possible scenarios of Black Holes evaporation. First one coincide with well known S. Hawking's (1974,1975) scenarios, according to which actually Black Holes (created after the Big Bang, perhaps) with should evaporate, while another, which would take into account the occurency of Mass particles Bound states ([1]), especially Bose mass particles, of which the Higgs boson is of special interest. The second scenarios suppose a concurrence between the Hawking process and Bose mass particles exponentially fast accumulation with a rate of Black Hole's mass evolution. When the time is going to ∞ the mass of a Black Hole is going to 0. The time of diminishing by a half of the initial mass of a Black Hole is such, that it corresponds to ~ 54700 sec=15.19 hours for a Black Hole of mass nearly 1 mln tones in weight. This would occur due to generation of a Higgs boson (s=o) with mass m_Higgs=1Tev. If the Higgs boson mass is 125Gev, the time of diminishing by a half of the Black Hole's mass would be ~ 97 sec.

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INTRODUCTION

According to latest informations about 300 Black holes were discovered since the middle of 70-th. But all discovered Black Holes are Stellar Black Holes, Black holes in the Cluster of Stars Nucleus, or supermaissive Black Holes in the Nuclei of Galaxies. No primordial masses black Holes with

$M < (4-7) \cdot 10^{14} g$ has been discovered till nowadays. And nor Black Holes with masses in the range

$(4-7) \cdot 10^{14}\ g\ <\ M\ < 2.4\ M_{\odot}$

were discovered also. Let us recollect, that such Black Holes were formed during the earliest stages of the Universe's expansion from matter inhomogeneities and should evaporate, according to S. Hawking's [1] mechanism in a time:

$$\tau_H \sim t_{Pl} \left(\frac{M}{M_{Pl}}\right)^3 , \qquad (1)$$

which numerically coincides with estimation given above for Kerr Black Holes (the lower limit) and Schwrarzschild Black Holes (the upper limit).

What could be the explanation? In my opinion Hawking's investigation of Black Holes evaporation misregards a part of possible regimes of particles generation, which is related with occurrence of (quasi)bound states for mass particles. Hawking writes in the second article of the ref. [1] :

„if the intial and final states are asymptotically Schwarzschild or Kerr solutions, one can describe the ingoing and outgoing waves in a simple manner by separation of variables and one can define positive frequencies with respect to the time translation Killing vectors of these initial and final asymptotic space-times. In the asymptotic future there are will be no bound states: any particle will either fall through the event horizon or escape to infinity. Thus the unbound outgoing states and the event horizon states together form a complete basis for solutions of the wave equation in the region outside the event horizon".

This statement does not agree nor with a number of authors which followed the line of investigation by J.A. Wheeler [2](see appendix), while some of them just being interested in ordinary quantum mechanics of Bohr levels around Black Holes [3-5], nor with a number of authors ([9-16]) which examine the bound states for various spins mass paricles in a Kerr or weakly charged Kerr-Newman spacetimes, continuing the line of thought by J.A. Wheeler[2], nor with an investigation [10], proving that mass particles bound states in the Black Holes field can be computed as poles of the scattering matrix around a Black Hole, when the energies of particles $E < mc^2$.

1. Black Holes evaporation and mass partciles bound states.

To be complete in citations and in the history of the problem, I would like to mention a number of publications by Russian authors ,made during the 80-th in Black Holes Physics [16-19], but less observed out of the borders of Russia. These papers include also the investigation of vector mass field around a Schwarzschild Black Hole. To mention some of last papers, investigating superradiant instabilities of Black Holes due to mass spin-integer field, see [11], [12].

It is to mention , that the papers [12]-[22] were made independently of the paper by J.A. Wheeler [2]. This paper was known and cited only by Damour, Deruelle and Ruffini. It was unknown in the USSR during Soviet times, as it was absent in Soviet libraries. Only at the beginning of the XXI-st century prof. Bahram Mashhoon was kind to send me a copy of the article by J.A. Wheeler [2], published in 1971, which was immediately wide-spread to colleagues throughout the former USSR and other interested peoples.

Let us make a connection with Black Holes observations. Actually only Black Holes of stellar masses in close Binaries Systems and massive and supermassive Black Holes are observed by astronomers. Celestial mechanics of particles in such Black Holes was investigated since 1931 till 60-th. For an incomplete list see: Hagihara 1931, Kaplan, 1949, Ch. Darwin, 1959, Bogorodskii, 1962, Mielnik and Plebansky, 1962 and other. It is naturally in a case of bound orbits to formulate, at least, the problem of quantification of bound orbits, if not to solve them. In fact, this problem since the epochal works by evaporation physicists at the half of 70-th was marginalized. This problem became suddenly non-important, marginale, non-interesting for Black Holes physics.

First, Wheeler established, that the absorption by Black Holes is non-null in any $\frac{\lambda}{R_G}$ ratio regime, where λ- is the wavelength of the partciles, and $R_G = \frac{2GM}{c^2}$ – gravitational radius of the Black Hole (Central Body), in opposition with some authors [23], which obtained 0 for the absorption cross section of massless scalar waves in a Schwarschild background. Second, Wheeler established that the particles could accumulate on (quasi)bound states with null or non-null orbital momentum around Black Holes (see, especially the appendix of the conference article by J.A. Wheeler[2]). Subsequently this result was confirmed in [9]-[22] and [27]-[30].

Let us mention, that the case, when the energy of particles is less than the rest energy of particles in the field of Black Holes, was of interest for physicists since 1962, when two pupils of Wheeler [3] studied bound energies levels in a weak Schwarschild field, and independently of them, E. Schmutzer [4] and N.V.Mitskevich [5] studied the more complex cases, when the Black Holes could have spin and electric charge. But they limited themselves to estimations sometimes erroneus, but heuristically correct of Hamiltonians and energies of particles on the levels, including fine and hyperfine structure of the levels.

Why Hawking is neglecting bound states in Black Holes evaporation? This question was unclear for me till 1987 , when in a private discussion with Stephen Hawking [7] during the „Quantum Gravity" seminar, chaired by M.A. Markov, in Moscow he told me:

- Bound states would be evidently ionized by my (Hawking's) unbound radiation.

Then, is the reason for neglecting mass particles bound states the ionization of bound states by Hawking's radiation, or the fact of nonexistence of such states in asymptotic past or asymptotic future, as Hawking stated in his well known articles [7]? From a physical point of view this is absolutely another motivation to neglect bound states in black Holes evaporation. Later I have shown, that the private communication of Hawking is correct only for electrically charged particles, not also for neutral particles. However in such a manner Hawking is neglecting a lot of Physics which develope in the region of spacetime, where a potential well captures particles, and where gravitational field go as $\sim\frac{1}{r}$. Then, the processes ocuring on mass particles bound states are more important, than was estimated initially by followers of the Hawking's treatment of Black Holes evaporation. These processes are especially important in a spin integer regime, when the Bose – Einstein statistics allows the accumulation of an arbitrary large number of particles on bound states levels. Prinicpially, there is no interdiction for a Black Hole to be reversed totally into a shell localized in the region of potential well. Moreover, such processes could lead to some important termodynamical consequences, as self-organization of matter on bound levels. Paradoxically, but the title of one of the last books by S.Hawking „The Universe in a Nutshell" suggests us, that black Holes also could be placed in nutshells. The mass bosons, generated by Black Hole itself, could form „nutshells" around black holes.

In turn, the problem should be investigated in detail for various particles masses and in various mass ranges of Black Holes with taking account of (quasi) bound and unbound (scattering) states. No for the moment a general proof of the Hawking's oral statement exists . Such a proof exists only for electrically charged particles generated by electrically charged black Holes. In this case the ionization of bound states for electrically charged particles by electromagnetic Hawking radiation is sufficiently fast to leave some possible charge fluctuations of the order of 1 elementary charge into the Black Hole.

2. Mass particles accumulation on Bound levels in a Schwarzshid Black Hole Background.

The evaporation process of primordial Black Holes is determined by a concurrency of processes of mass spin-integer particles accumulation on (quasi) bound states and unbound massless or mass particles radiation with $E > mc$^2, as the process of accumulation of mass (electrically uncharged) Bose particles would be exponentially fast. The Heisenberg indetermination principle in a case when $\lambda > \sim R_G$ make the events horizon transparent in both directions. The events horizon would absorbe and would be penetrable by exponentially fast in time Bose particles accumulation which would diminish the total mass-Enbergy of a Black Hole and its angular momentum, transporting them onto the levels.

If Hawking process with $E > mc^2$ is stronger , then the shell would be very effectively ionized, and the mass of the shell would be neglectible. This is evident for electrically charged particles in a field of a Schwarschild Black Hole (see [24]), but need a special examination for mass neutral particles.

If Bose mass particles accumulation is stronger, then a shell of mass partciles should form around a Black Hole with a radius of 1-st (for s=0), 2-nd (for s=1), 3-rd(for s=2) , and so one Bohr's orbits

$$\langle r \rangle \sim \frac{(s+1)\hbar}{mc}\left(\frac{M_{Pl}^2}{mM}\right), \quad s - \quad \text{spin of particles} \qquad (2)$$

which could concentrate a great part of the evaporating Black Hole. Since this moment the evaporation process of a Mini-Black Hole drastically varies from the picture given by Hawking. The picture given by Hawking' s does not describes the total dynamics of Black Holes for Bose particles, as His description does not takes account of mass particles quasibound states. The Hawking's evaporation picture would be correct only for Dirac particles in the following sence. Due to Dirac exclussion principle, the mass of the shell of Dirac particle would be neglectible as compared with the Hawking's thermal flux from the Black Hole. Indeed, in a case of Dirac particles , when all the bound states were occupied by 2 electrons every, we had an infinite mass of partciles on bound levels. This is the result of papers [25, 26]. But, this is an absurd. Nor and never an infinite mass could arise from an initial finite mass of the Black Hole! The Initial Schwarschild Black Hole could generate only a finite mass shell. Such a result was obtained due to a simpified dynamics of Black Hole evaporation. But, if You will limit the number of bound states by a some principal quantum number, say $n = 1 + l + n_r < N_{max}$ the shell's mass would be finite and the result would be physicaly resonable. This is physically motivated by a very fast decrease of the the timelifes with l and domination of lowest l -waves in the thermal flux. But , in this case the shell's mass is neglectible as compared with mass transported by the unbound radiation in Hawking quanta. Only the case when an exponentially fast accumulation take place could be of interest. This is the case when mass Bose particles accumulate by self induction on bound levels. In other words, this is the case, when every partcile placed on a bound level near the Black Hole will induce the generation from a vaccum (from the Black Hole) of number of partciles proportional with the partciles number yet existig on the bound level. This is just the case of Black Hole bombe. Then , esentially, the discussion is about the question: what process is faster: the development of a Black Hole bomb, or the process of Hawking's unbound radiation? My answer is that both processes should be taken into account.

An improved dynamics was given in [15] and [17]. According to these claculations the shell's mass due to a superardiative instability of a Kerr Black Hole is finite and this is physically reasonable result.

Nor, the calculations by D.Page [8] for bosons give a correct picture of the evaporation process in a case of bosons, as these calculations does not account for bound states at all.

Physically such a Black Hole, endowed with a bosonic shell would be much more pleasant than the Black Hole itself, since the density inside it would be by many order of magnitudes less than the Plank density. There is need to consider nonlinear processes inside the shell,which could lead to the repulsion, as well as processes of particles decays inside a shell, as well as ionization of the shell in order to give final estimation for the timelife of Black Holes. Unfortunately, I would not do these bellow, since the nonlinear repulsion in a shell is a complicate from both mathematical and physcal point of views. Particles decays, which could lead to decay of the shell at all should be considered separately for every kind of Bose mass particle with taking account of timelifes of the particles and to their changes in the field of a Black Hole . There is a lot of elementary particles physics which should be revised, at least in the weak gravitational field approximation limit. No the transitions between bound levels would play the most important role . But, it is clear that the timelife varies from the formula (1).

Bellow, let us estimate the density of a Bose particles shell, taking into account that the radius of a shell is

$\langle r\rangle \sim \frac{(s+1)\hbar}{mc}\left(\frac{{M_{Pl}}^2}{mM}\right)$ and the width of the level is: $\Gamma = -m\frac{8(mM)^5}{(1+s)^3}$ [12]. The timelife of the s-bound level is:

$$\tau = \frac{\hbar}{mc^2}\frac{(1+s)^3 M_{Pl}^{10}}{(mM)^5} \quad (3)$$

For a Higgs boson of mass 125Gev this means $5.25 \cdot 10^{-27}\left(\frac{M_{Pl}^2}{mM}\right)^5$ s. The timelife of a boson (1.25 10^-22s) on a bound level is greater than the timedecay of a s- bound state for $\frac{mM}{M_{Pl}^2} \leq (0.297)^{-1/5}$.

The speed of particles accumulation on the s-level of spin 0 particles is [18], [19]:

$$\frac{dN}{dt} = \frac{\Gamma(N+1)}{exp\left(\frac{\hbar\omega}{kT}\right)-1} \sim \frac{\Gamma(N+1)kT}{\hbar\omega} \approx \frac{8(mM)^5(N+1)}{(1+s)^3}kT \quad (4)$$

$$\frac{d(Mc^2)}{dt} \cong -mc^2\frac{dN}{dt} = -\frac{(mM)^5}{M_{Pl}^{10}(1+s)^3}(N+1)\frac{m\hbar c^5}{16\pi GM} \quad (5)$$

I have especially cited [17] - [19] , as the ideea of induced mass Bose particles accumulation was suggested in a soft and very uncertain manner, being amplified in [13] and later being pronouncingly sustained in [15], [16], [20] and [22].

The above set of equations could be easily solved. One have

$$M = M_0\left(1 + \frac{m^6 {M_0}^3 t}{2\pi(1+s)^3}\right)^{-1/3} \quad (6)$$

When the time is going to ∞ the mass of a Black Hole is going to 0. The time of diminishing by a half of the initial mass of a Black Hole is:

$$t_{1/2} = \frac{14\pi(1+s)^3}{m^6 M_0^3} \quad (7)$$

which corresponds to ~ 54700 sec=15.19 Hours for a Black Hole of mass $M_0 \sim 2.25 \cdot 10^{11} g$ (which is nearly 1 mln tones in weight). This would occurr due to generating of a Higgs boson with mass $m_{Higgs} = 1Tev = 0.17(7) \cdot 10^{-20}\ g.$ with a shape just exactly described in the picture by J.A. Wheeler in [2]. Then in less than 1 day such a Black Hole would generate a Higgs bosonic shell of mass 1.125 10^5 t=0.125Mt, which is equivalent to an Iron cube of 25 m^3 in weight.

3 Conclussions

The main conclussion of the poaper is: mass integer spins particles bound states are very important in the process of quantum evolution (evaporation) of Black Holes, contrary to the statement of S. Hawking in the articles [1]. These states could lead to formation of long living shells of particles around Black Holes and modify drastically the evolution of a Black Hole. Particularly 1) the timelife of Black Hole would be modified 2) The nonlinear processes, particularly repulssion of particles forming the shell, could be important in drawing final conlcussions.

As black holes with masses $M \sim (4-7)10^{14}g$ should have shells of integer spins mass particles which would stops the evaporation, the timelife of Black Holes would be longer. Actually would evaporate Black Holes of considerably less masses only. Let us note the critical mass as

$$M_{crit} < (4-7)10^{14}g$$

Concerning absence of intermediary masses black Holes $M_{crit} < M < 2.4M\odot$ why we do not try to explain the dark matter by a portion of such Black Holes? They do not radiate by any mechanism, if $\frac{m_\nu M}{M_{Pl}^2} \geq \sim 1$, where m_ν - is the neutrino rest mass. In this case we have $M > \sim 10^{22}\, g$, while if we admit the photon's quantum electrodynamic mass as the smallest possible mass in nature, such Black Holes should evolve by process already mentioned of a self induced mass Bose particles generation on a Bohr's shell. Just such Black Holes should be an another area of true concurrence of both (Wheeler- Ruffini- Damour- Deruelle- Ternov et all.) quantum accumulation of particles on bound levels and Hawking's thermal generation.

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