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Gravitovacuum Effect

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ABSTRACT

When gravitational wave is absorbed by a black hole, for the energy of gravitational wave greater than the critical energy of the black hole, there is flow of quantum vacuums away from the black hole. We can define the critical energy of the black hole as the energy state after which if it absorbs energy in the form of gravitational waves, there is flow of quantum vacuums away from the black hole, which will lead to the enhancement in the curvature of space. The critical energy which we have calculated as E_{n0} =9.71×10^{-13} GeV.

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Introduction

In the collision of two black holes gravitational waves are produced and black hole remnant is left. The final black hole is characterized by its mass, spin and recoil velocity while the additional complexities are dissipated away in the form of gravitational waves which are ripples in space-time [1-4]. The detection of gravitational waves in 2015 confirms the need for the quantization of General Relativity [5-8]. When two black holes merge together, there is disturbance in space due to which there is compression and expansion of space itself. This compression and expansion of space is really the gravitational wave which moves uniformly in all directions of the universe. Suppose there is existence of fourth black hole very far distance from this event place, the gravitational waves moving in the universe may reach the fourth black hole. Recently, gravitational waves are quantized using Loop Quantum Gravity. The wavelength, time period and energy of the gravitational wave can be quantized as $\lambda_n=n2\pi L_p, T_n=n2\pi T_p, E_n=\frac{1}{n}E_p$ n=1,2,3… where L_p, T_p and E_p are Planck Length, Planck Time and Planck Energy respectively, and $E_p=M_pc^2$ in which M_p is defined as Planck mass [5,9,10]. Considering the energy density of quantum vacuums as the zero-point energy density which is defined as the lowest energy of the ground state, we have done our calculations [11-14].

Loop Quantum Gravity (LQG) has emerged as a promising candidate for quantum theory of gravity in the last 15 years [6-8]. Further, LQG which is based on canonical quantization of general relativity [15-32]. The numerical result for the eigenvalue of the volume operator can be given as [27-29],

$$\lambda_{min} = L_P^3\sqrt{|Z.\sigma(123)|.2.j_{max}(j_{max}+1)} \qquad (1)$$

where, $Z=i,\sigma(123)=0,\pm2,\pm4$ and are contributed by the spin configuration $j_1=j_2=1/2$ and $j_3=j_4=j_{max}$.

The space is quantized as superfluid quantum vacuums [33-39]. The variable density of vacuum gives rise to vacuum fluctuations which is the cause of gravity. According to General Relativity, the variable density of vacuum can be described by curvature in space. For the larger curvature of space, we have lesser vacuum density.

This paper is organized as follows: In section 2, we have discussed about the Gravitovacuum Effect: flow of quantum vacuums away from the black hole by absorbing gravitational waves. In section 3, we have gone through results and discussions. Finally, we present our conclusions in section 4.

Gravitovacuum Effect: Flow of Superfluid Quantum Vacuums away from the Black Hole by Absorbing Gravitational Waves

The phenomenon in which, there is flow of superfluid quantum vacuums away from the black hole by absorbing the gravitational waves by it is defined as Gravitovacuum Effect. The main phenomenology behind the Gravitovacuum Effect is that when gravitational waves are absorbed by the black hole, the overall energy of the black hole may increase rapidly. As a result of this, there is flow of superfluid quantum vacuums away from the black hole which leads to the enhancement in the curvature of space. We consider the energy density of quantum vacuums as the zero-point energy density. The zero-point energy density of vacuum is defined as the lowest energy of the ground state is given by [11-14]:

$$\rho_{zpe} = \frac{\hbar c k_{max}^4}{16\pi^2}, \qquad (2)$$

Where, $k_{max}=1/l_p$ is cut-off wave-number and l_p, Planck length. But the observable energy density of vacuum is at least 10^{60} times lesser than ρ_{zpe} [40-44]. The critical energy is defined as the energy state of the black hole after which if it absorbs gravitational waves, there is flow of superfluid quantum vacuums away from it. So, the energy of the gravitational waves absorbed by the black hole must be greater than the critical energy. We can write the critical energy the black hole as,

$$E_{n_0} = \frac{1}{n_0} E_P, \qquad (3)$$

where, E_{n0} is critical energy for the black hole and n_0 is critical number. In order to get quantum vacuums flowing away from the black hole, we should have $En > En_0$ and hence $n < n_0$. finally, we can write the equation for Gravitovacuum Effect as,

$$\frac{1}{n} E_P = \frac{1}{n_0} E_P + E_{qv}, n < n_0 \qquad (4)$$

Hence, in Gravitovacuum Effect the energy of the quantum vacuum flowing away from the black hole is given by,

$$E_{qv} = \left(\frac{1}{n} - \frac{1}{n_0}\right) E_P, n < n_0 \qquad (5)$$

In equation (5), taking

$$E_{qv} = 10^{-60} \rho_{zpe} \times l_p^3 \qquad (6)$$

as the energy of the quantum vacuum flowing away from the black hole taking greatest value of n that is $n=n_0 - 1$ and solving we find $n_0=4\pi \times 10^{30}$ and critical energy as $En_0 = 9.71\times10^{-13}$ GeV. For, $n<4\pi\times10^{30}$, there will be flow of superfluid quantum vacuums away from the black holes after absorbing gravitational waves by it. We have taken l_p^3 as the volume of the quantum vacuum in calculating the critical energy of the black hole since the volume of quantum vacuum cannot be less than l_p^3.

Results and Discussions

Taking, $n_0=4\pi\times10^{30}$, for $n=n_0-2$, there is flow of quantum vacuums away from the balck hole having energy upto 1.545×10^{-34} eV. For, $n=n_0-3$, there is flow of quantum vacuums away from the black hole having energy upto 2.318×10^{-34} eV. For, $n=n_0-4$, there if flow of quantum vacuums away from the black hole having energy unto 3.1×10^{-34} eV. For, $n = n_0-5$, there is flow of quantum vacuums having energy up to 3.863×10^{-34} eV. For, $n=n_0-6$, there is flow of quantum vacuums having energy upto 4.635×10^{-34} eV. For, $n=n_0-7$, there is flow of quantum vacuums away from the black hole having energy up to 5.41×10^{-34} eV. Table 1 given below correlates σ(123) and j_{max} in Gravitovacuum Effect for different values of n, while Tables 2 and 3 describe the energies of the quantum vacuums flowing away from the black hole corresponding to definite values of j_{max} and $\sigma(123)$ using equation (1).

Table 1: The values of σ(123) and j_{max} of the volume operator of quantum vacuums which flow away from black hole in Gravitovacuum Effect for different values of *n*

n	σ(123)	j_{max}
$4\pi\times10^{30}-2$	±2	1⁄2
$4\pi\times10^{30}-3$	±2 ±4	1,3⁄2 1
$4\pi\times10^{30}-4$	±2 ±4	2,5⁄2,3,7⁄2 3⁄2
$4\pi\times10^{30}-5$	±2 ±4	4,9⁄2,5,11⁄2 2,5⁄2
$4\pi\times10^{30}-6$	±2 ±4	6,13⁄2,7,15⁄2,8,17/2 3,7⁄2,4
$4\pi\times10^{30}-7$	±2 ±4	9,19⁄2,10,21⁄2,11,23⁄2 9⁄2,5,11⁄2

Table 2: For the value of σ(123)=±2, the value of j_{max} for the corresponding energy of the quantum vacuum flowing away from the black hole in Gravitovacuum Effect

j_{max}	Eqv (×10^{-34} eV)
1⁄2	1.433
1	1.83
3⁄2	2.143
2	2.41
5⁄2	2.65
3	2.866
7⁄2	3.068
4	3.257
9⁄2	3.435
5	3.6
11⁄2	3.765
6	3.92
13⁄2	4.069
7	4.213
15⁄2	4.35
8	4.486
17⁄2	4.616
9	4.74
19⁄2	4.87
10	4.987
21⁄2	5.105
11	5.22
23⁄2	5.332
12	5.443

Table 3: For the value of σ(123)=±4, the value of j_{max} for the corresponding energy of the quantum vacuum flowing away from the black hole in Gravitovacuum Effect.

j_{max}	Eqv (×10^{-34} eV)
1⁄2	2.027
1	2.59
3⁄2	3.031
2	3.41
5⁄2	3.746
3	4.054
7⁄2	4.34
4	4.61
9⁄2	4.858
5	5.1
11⁄2	5.325
6	5.544

For, $n= 4\pi\times10^{30}-1$, using equation (5), we can get quantum vacuums having energy upto 0.773×10^{-34} eV. But from table 2, we see that energy of the first quantum vacuum is given by $E_{qv}=1.545\times10^{-34}$ eV. From table 1, we see that first quantum vacuum is for σ(123)=±2 and j_{max}=1⁄2. using equation (1), we will have quantum vacuums having energy 0 for *σ*(123)=0, that is there will be no quantum vacuum for *n*= $4\pi\times10^{30}-1$.

Conclusions

Finally, we have come to the conclusion that, for different values of *n*, i.e. for different values of energies of the gravitational waves as given in equation (5) which is absorbed by the black hole, there is flow of quantum vacuums having different energies away from the black hole which can be calculated from equations (1) and (5) for definite volume of quantum vacuums for some particular values of *σ*(123) and j_{max} as given in Table 1. For the value of *σ*(123)=±2, the value of j_{max} for the corresponding energy of the quantum vacuum flowing away from the black hole in Gravitovacuum Effect has been given in Table 2. For the value of *σ*(123)=±4, the value of j_{max} for the corresponding energy of the quantum vacuum in Gravitovacuum Effect has been given in Table 3. Considering the energy density of quantum vacuum as the zero-point energy density which is defined as the lowest energy of the ground state [11-14], we studied Gravitovacuum Effect that is, if the gravitational waves are absorbed by the black holes, then for energy of the gravitational wave greater than the critical energy of the black hole, there is flow of superfluid quantum vacuums away from the black hole. The critical energy which we have calculated as $E_{n0}=9.71\times10^{-13}$ GeV and the mass of the neutrinos are around $m_\nu=10^{-6}$ eV[45,46]. So, at $E_n=10^{-3}$ eV, there will be emission of neutrinos from the black hole. The energy of the quantum vacuum flowing away from the black hole is comparatively less or comparable to the mass of gravitons which is about $m_g=10^{-23}$ eV–10^{-34} eV[47-67]. Thus we see that if the black hole absorbs energy in the form of gravitational waves which is greater than its critical energy calculated by us there is flow of quantum vacuums away from the black hole which will lead to the enhancement in the curvature of space. Hence, we can describe gravity with the flow of quantum vacuums without considering gravitons[33].We hope that our results will be proved experimentally in the near future.

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