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On black hole information

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Abstract

In this paper we present a very simple estimate of the spreading time, showing that it is very smaller than the Hawking evaporation time for the black hole *i.e.* $t_{tunnel} | \ll t_{avap}$. String theory has given a set of states over which the wave function of the shell may spread.

Mathur[1] argued that bound states of branes have a size that is of the same order as the horizon radius of the corresponding black hole. Hence, the interior of a black hole is not empty space with central singularity, and Hawking radiation may pick up information from the degrees of freedom of the back hole. In view of Bekenstein[2] one may associate an entropy

(1) $$S = \frac{A}{4G}$$

with a black hole where A be the area of the horizon. Statistical mechanics leads that there should be e^s states of the black hole. Let us understand the states of the black hole *i.e.* the hair that differentiate different states of the black hole. The interior of the horizon is not described by empty space with a central singularity. e^s states are manifested throughout the interior of the horizon. Hence, there in general, no special point to play the role of singularity, and the horizon is the boundary of the region where the typical states differ from each other. Hence, e^s microstates should have no horizons individually and the notion of a horizons individually and the notion of a horizon should arise as the boundary of the region. Let us consider a shell which is collapsing through its horizon. The fuzzball describe a complete set of energy eigenstates of the system. So, one may put

$$|\psi\rangle = \sum_i C_i |E_i\rangle,$$

the wave function of the shell spread over this space of states. The tunneling amplitude $t_A \sim e^{S_{tunnel}}$ between the shell state and any one of the fuzzball states. Mathur (2008) presented

(2) $S_{tunnel} \sim \frac{1}{G}\int\sqrt{-g}R = \alpha GM^2, \alpha = O(1)$

which gives

(3) $t_A \sim \bar{e}^{S_{tunnel}} \sim \bar{e}^{\alpha GM^2}, \alpha = O(1)$ and the number of states that one may tunnel reads

(4) $N \sim e^{S_{Bek}} \sim e^{GM^2}$

which is very large.

One may hope that non perturbative quantum gravity effects such as tunneling may resolve the information paradox. String theory has given that there are a set of states to tunnel and the probability of tunneling to these states should be high enought[3-6].

2. The Tunneling time :

Let us consider a double-well potential. The wave function for left be a superposition of symmetric and anti symmetric wave function

(5) $|\psi\rangle_L = \frac{1}{\sqrt{2}}|\psi\rangle_s + \frac{1}{\sqrt{2}}|\psi\rangle_{AS}$

As the $|\psi\rangle_S$ and $|\psi\rangle_{AS}$ as different in energies, so, one may put

(6) $|\psi\rangle_L = \frac{1}{\sqrt{2}}\bar{e}^{iE_s t}|\psi\rangle_s + \frac{1}{\sqrt{2}}\bar{e}^{iE_{AS} t}|\psi\rangle_{AS}$

Hence, t_{tunnel} reads

(7) $t_{tunnel} = \frac{\pi}{E_A - E_{AS}} = \frac{\pi}{\Delta E}.$

The Hawking evaporation time t_{evap} for a Schwarzschild radius R reads

(8) $t_{evap} \sim MR^2$

where M be the mass of black hole.

Now let us consider the shell collapses to from a black hole, one must localise the matter in the shell with radius $\ll R,$ where R be the Schwarzschild radius of the shell, which requires a spread in radial momentum

(9) $\Delta p \gg \frac{1}{R}.$

But the energy of the shell

$$E \sim p^2/2M.$$

Hence, one obtains

(10) $\Delta E \sim 2p\frac{\Delta p}{2M} \gg \frac{(\Delta p)^2}{M} \gg \frac{1}{MR^2}$

But

(11) $t_{tunnel} \sim \frac{1}{\Delta E} \ll MR^2$

In view of eq. (8) and (11), one obtains

(12) $t_{tunnel} \ll t_{evap},$

showing that t_{tunnel} is smaller than the Hawking evaporation time[7].

Hayden and Preskill[6], Sekino and Susskind (2008) have given the estimates about information release times.

Strominger and Wafa (1996) have presented that string theory has provided in matching entropy and radiation rates of brane bound states with corresponding black holes. In view of this we have attempted to argue that bound states swell upto a horizon radius, so the interior the horizon is not an empty space with a central singularity. It is shown that $t_{tunnel} \ll t_{evap}$.

References

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