Catalysis of higher dimensional static black hole in metastable vacuum decay

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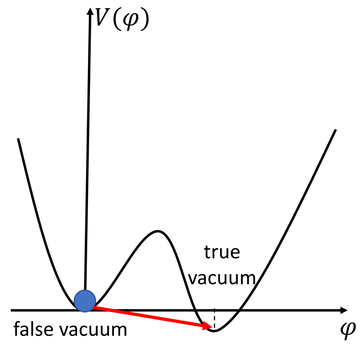
1. Background

- Recent studies suggest that our universe exist in the false vacuum and have the possibility to decay to true vacuum.
- Previous study showed that 4 dimension static black hole induces the catalysis in vacuum decay.

[Gregory et.al arXiv:1401.0017]

- As the first step for the application to the string theory, we extended the number of dimensions and showed the catalysis of higher dimension static black hole.



2. Purpose

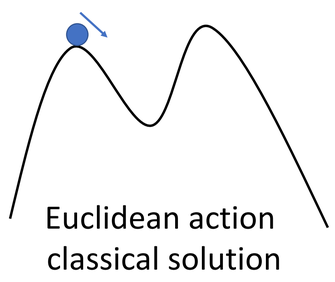
- To study the vacuum decay in the early universe and the catalysis of very small mass back hole, we need to take effect of the quantum gravity.
  →applying to the string theory, we try to take in the effect of quantum gravity.
- String theory is 10 dimension theory, so we extended the previous study to higher dimensions.

3. Mehod-1

- no black hole → Coleman,de Luccia (1980)

$$\Gamma \sim e^{-B} \qquad B = -S_E(\phi_B) \qquad B = I - I_{SdS}$$

decay rate; bounce action; Euclidean action; classical solution



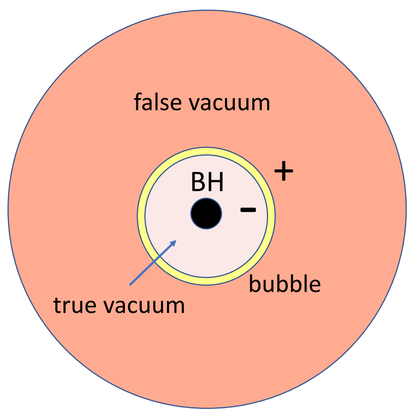
The Euclidean action, which is substituted into its classical solution dominate the decay.

- black hole → horizon

$$ds^2 = -f(r)dt^2 + \frac{dr^2}{f(r)} + r^2 d\Omega_{D-2}^2$$

$$f(r) = 1 - \frac{\mu}{r^{D-3}} - \frac{r^2}{l^2}$$

$$\mu = \frac{16\pi GM}{(D-2)\Omega_{D-2}} \qquad l^2 = \frac{(D-1)(D-2)}{2\Lambda}$$



3. Mehod-2

- horizon + Euclidean action → singularity in classical solution
- connect the BH solutions on boundary

$$I_{\mathcal{S}} = -\frac{1}{4G}(\mathcal{A}_h + \mathcal{A}_c) \qquad K_{ab}^{+} - K_{ab}^{-} = -\frac{8\pi G}{D-2}\gamma_{ab}\sigma$$

area of horizon; induced metric; bubble tension

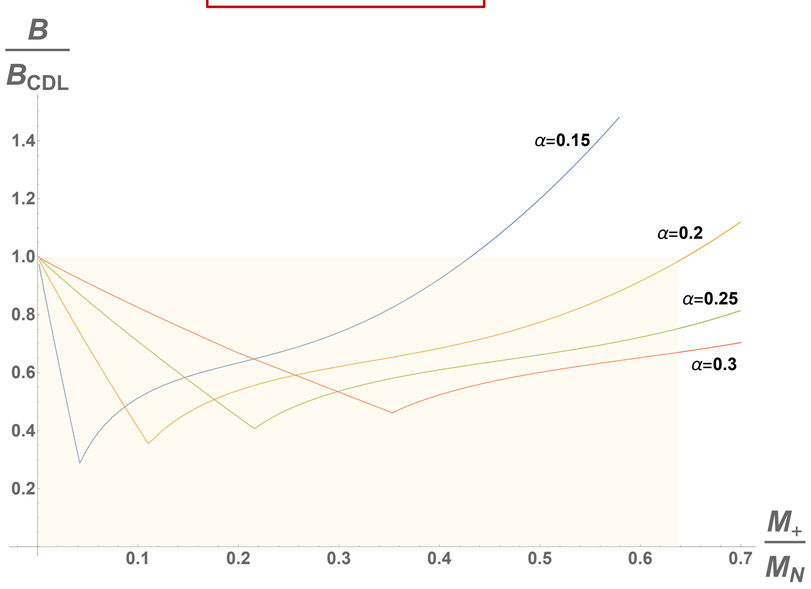
SdS→Minkowski $(\Lambda_+ \neq 0, \Lambda_- = 0)$

$$\mathcal{L} = \frac{1}{16\pi G}\mathcal{R} + \mathcal{L}_m(g,\phi)$$

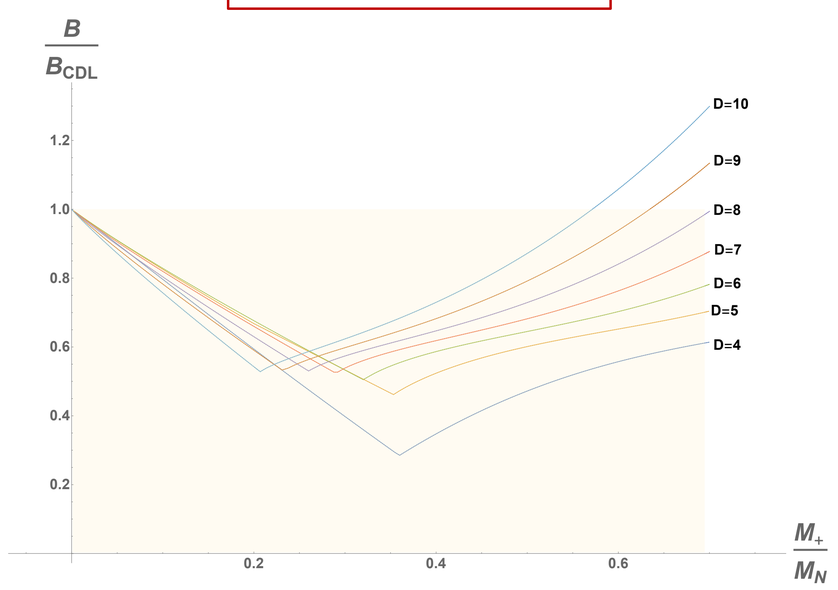
$$B = \frac{\mathcal{A}_h}{4G} + \frac{2\pi^{\frac{D-1}{2}}}{16\pi G\Gamma(\frac{D-1}{2})}\int d\lambda\Big[\left(2R^{D-3} - \mu(D-1)\right)\dot{\tau}_+ - 2R^{D-3}\dot{\tau}_-\Big]$$

5. Result

5 dimension



4～10 dimension



$\frac{B}{B_{CDL}} < 1$ show the catalysis

M_N : Nariai mass (maximum mass)

M_+ : BH mass

B_{CDL} : bounce action whiout BH

6. Summary

- Results show higher dimension black holes also induce catalysis.
- The power of catalysis become weak as the number of dimensions grow.

7. Future work

- Study the catalysis of { rotating black hole. / new objects that exist string theory.
- Propose the new scenario about the evolution of the universe.