

Hawking Radiation via Tunneling

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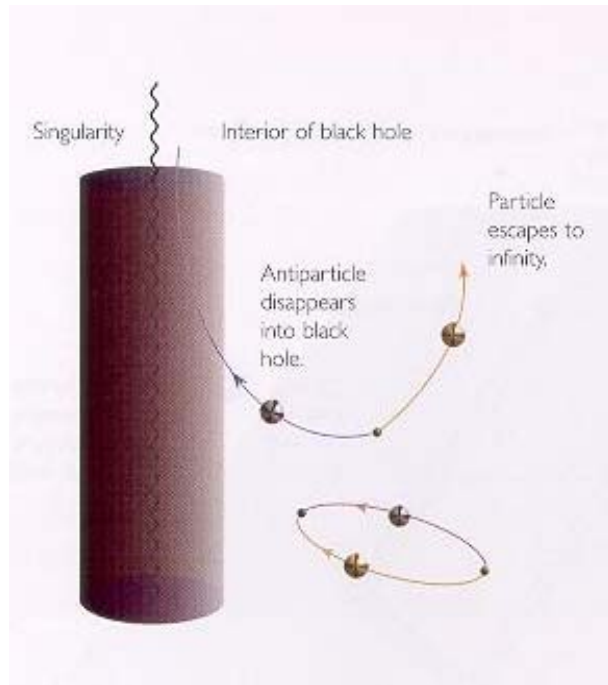
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A Secret Tunnel Through The Horizon

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In WKB limit, the probability of tunneling is related to the imaginary part of the action of the classically forbidden trajectory :

$$\Gamma \sim \exp(-2 \operatorname{Im} I)$$

$$\operatorname{Im} I = \operatorname{Im} \int_{r_{\text{in}}}^{r_{\text{out}}} p \, dr$$

The Schwarzschild Black Hole

Introduce a time coordinate : $t = t_s + 2\sqrt{2Mr} + 2M \ln \frac{\sqrt{r} - \sqrt{2M}}{\sqrt{r} + \sqrt{2M}}$

Painlevé-Gullstrand coordinates

$$ds^2 = - \left(1 - \frac{2(M - \omega)}{r} \right) dt^2 + 2 \sqrt{\frac{2(M - \omega)}{r}} dt dr + dr^2 + r^2 d\Omega^2$$

$$\text{Im } S = \text{Im} \int_{r_{\text{in}}}^{r_{\text{out}}} p_r dr = \text{Im} \int_{r_{\text{in}}}^{r_{\text{out}}} \int_0^{p_r} dp'_r dr$$

$$= \text{Im} \int_M^{M-\omega} \int_{r_{\text{in}}}^{r_{\text{out}}} \frac{dr}{\dot{r}} dH = \text{Im} \int_0^{+\omega} \int_{r_{\text{in}}}^{r_{\text{out}}} \frac{dr}{1 - \sqrt{\frac{2(M-\omega')}{r}}} (-d\omega')$$

$$= +4\pi\omega \left(M - \frac{\omega}{2} \right)$$

$$\Gamma \sim e^{-2 \text{Im } S} = e^{-8\pi\omega \left(M - \frac{\omega}{2} \right)}$$

$$\Gamma \sim \exp(\Delta S)$$

Is there information loss ?

*In 1976, Hawking said “ **Yes** ”.*

*In 2004, “ **No** ”, said by Hawking.*

Let's go ahead !

References

- *M. K. Parikh, “Energy Conservation and Hawking Radiation,” hep-th/0402166.*
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- *M. K. Parikh and F. Wilczek, “Hawking Radiation as Tunneling,” Phys. Rev. Lett. 85 (2000) 5042, hep-th/9907001.*



Thank you