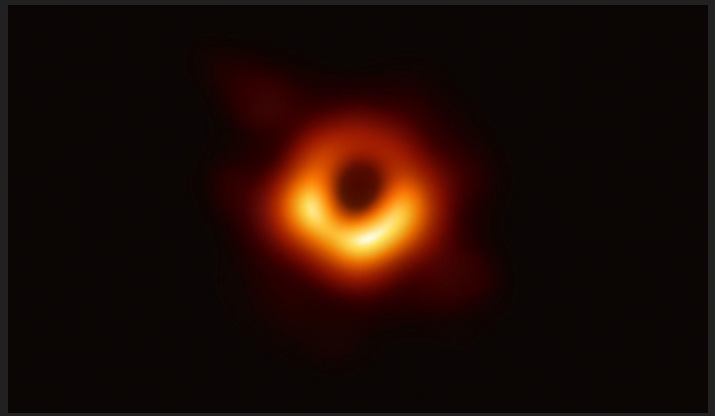
Hawking Radiation from Black holes



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Summary

I) Blackholes

- a) History
- b) Formation
- c) The oversimplified common explanation

II) The science

- a) Quantum Field Theory
- b) Event horizon perturbation
- c) Different perspectives
- d) Unruh effect
- e) Black hole evaporation

III) Ongoing Problems

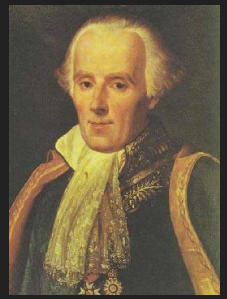
- a) Entropy
- b) Information

IV) A depressing potential end of everything : Heat death

I) Blackholes

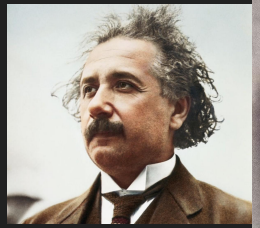
History

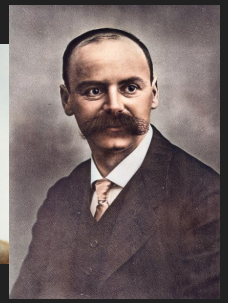
1784



John Michell

1915





A.Einstein
K.Schwarzschild

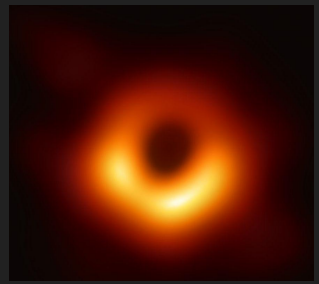
1974-1975

Sir S.Hawking

11 February 2016

LIGO Scientific Collaboration (LSC)

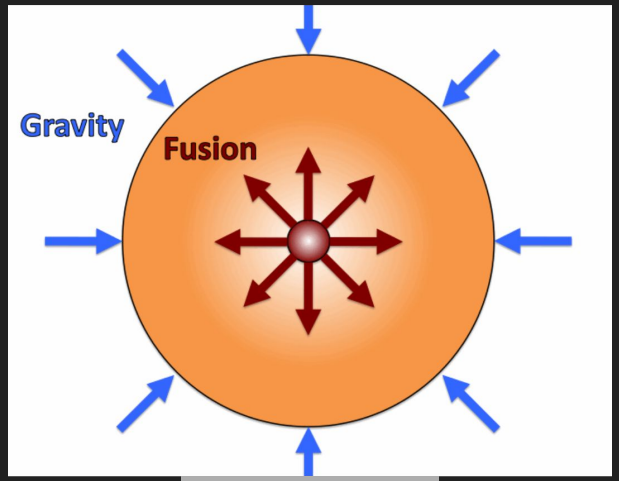
10 April 2019



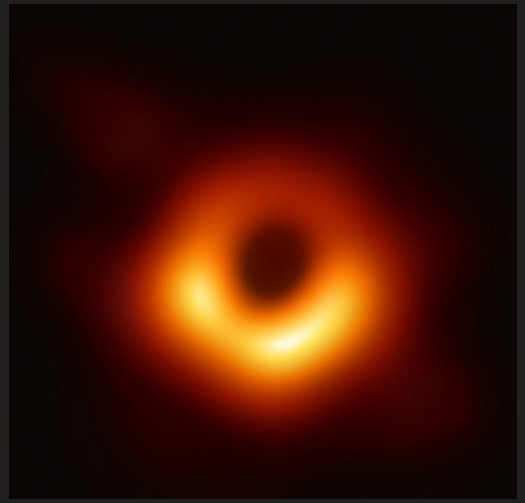
Event Horizon Telescope (EHT)

Formation

Common blackholes



$R = 15 - 20M_{\odot}$



$3 - 4M_{\odot} = (6 - 8) * 10^{30}kg$

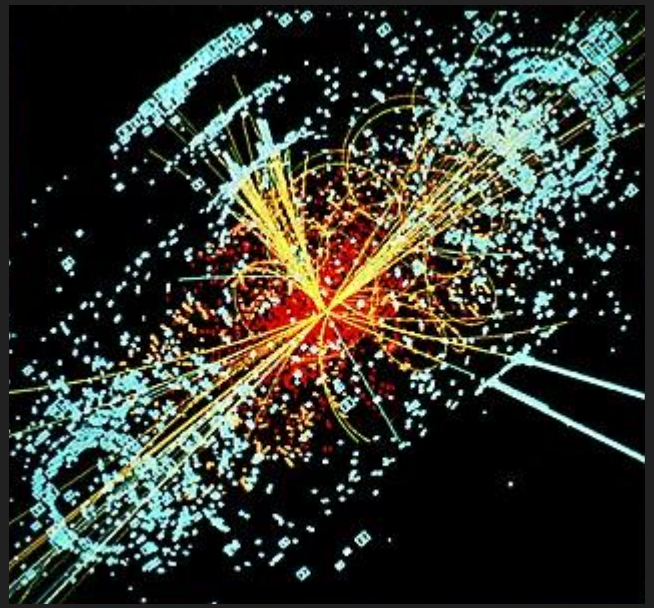
$\approx 2.5 * 10^{19} Human\ population = 10^{11} Moons$

$\approx 1.2 * 10^{29}\ (Ethan - weightUnits)$

$\approx (5 - 8)km \approx (2.5 - 4) Europe$

$\approx (2.8 - 4.5) * 1000\ (Ethan - heightUnits)$

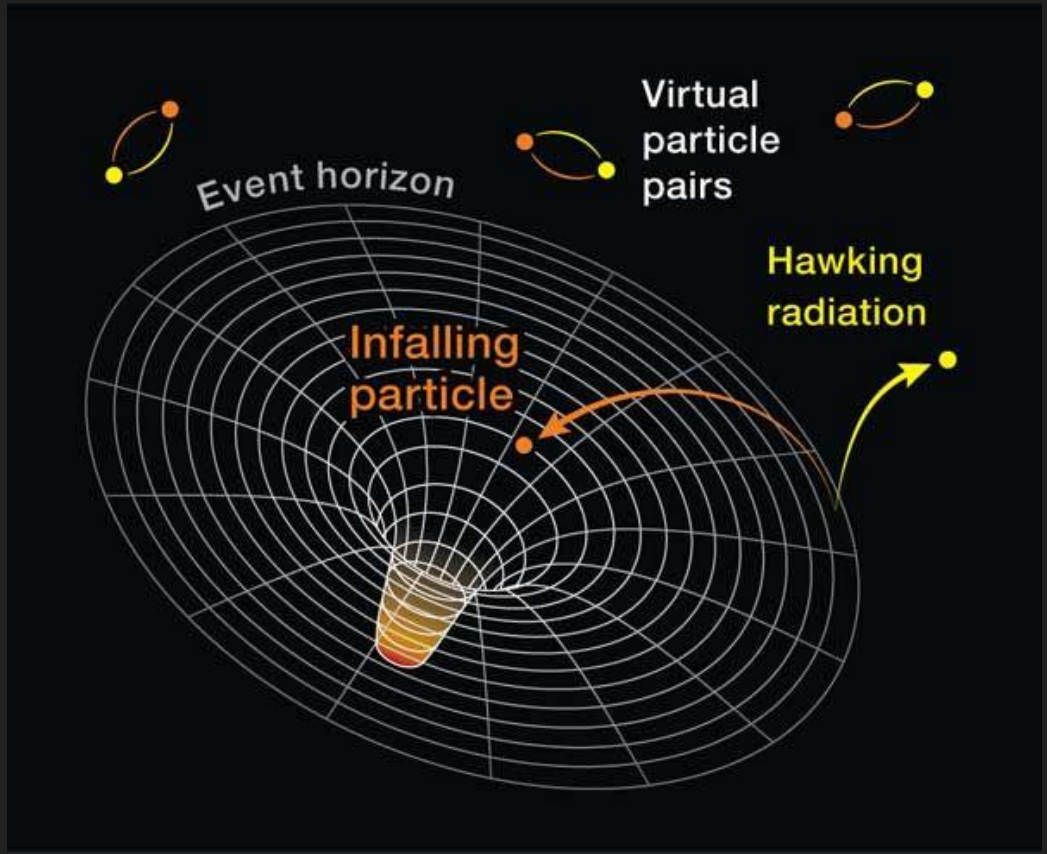
High energy collisions



Primordial Blackholes

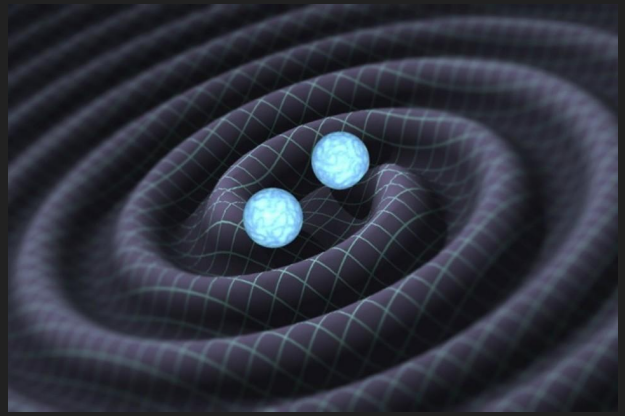
Formed <1s before Big Bang

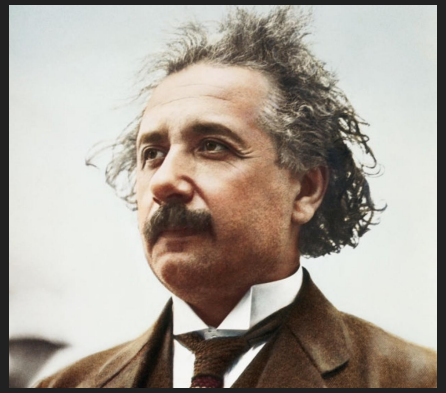
Oversimplified Solution



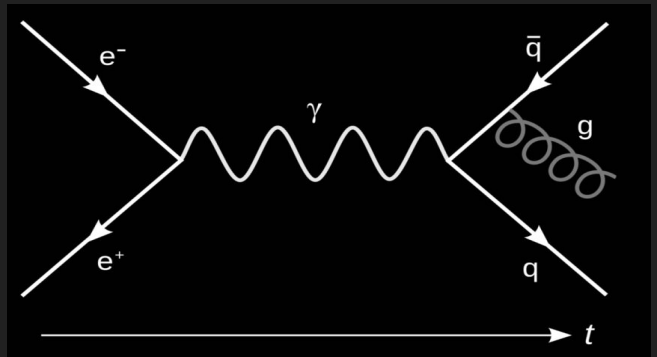
II) The Science

Quantum Field Theory

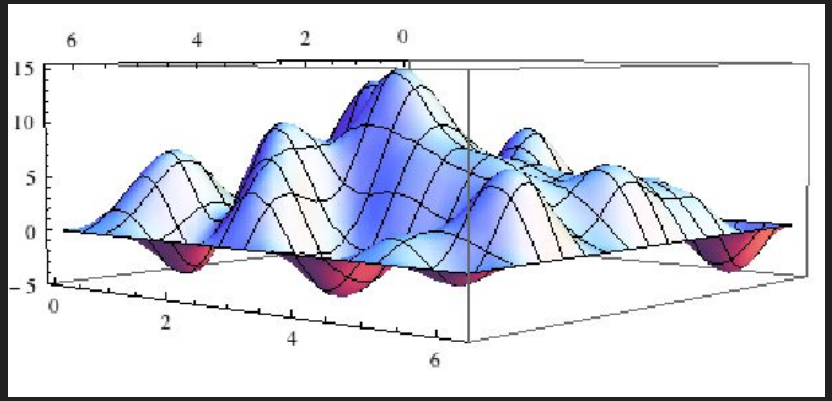




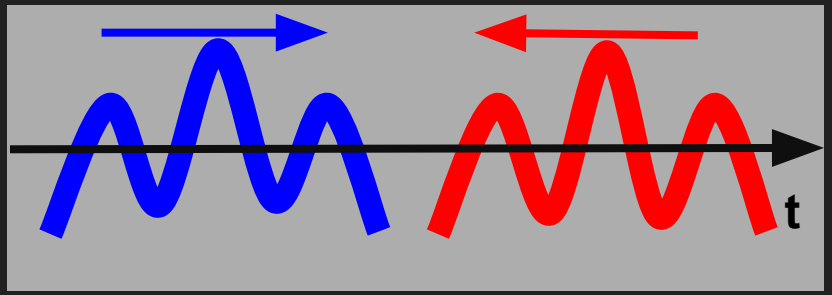
$$-\frac{\hbar^2}{2m}\nabla^2\psi + V(\boldsymbol{x})\psi = E\psi$$



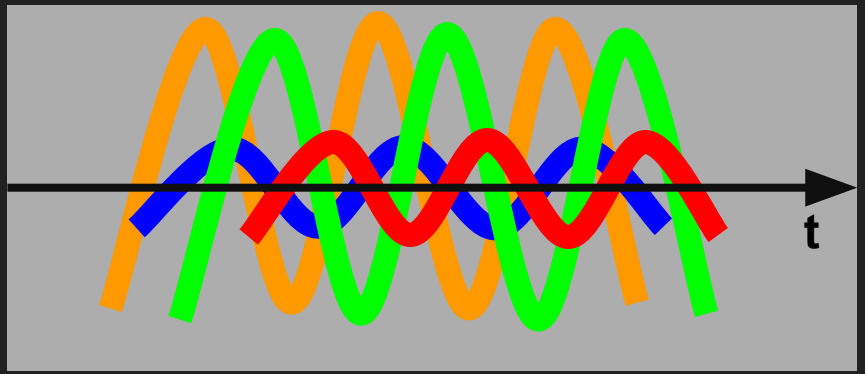
Particles as field excitations



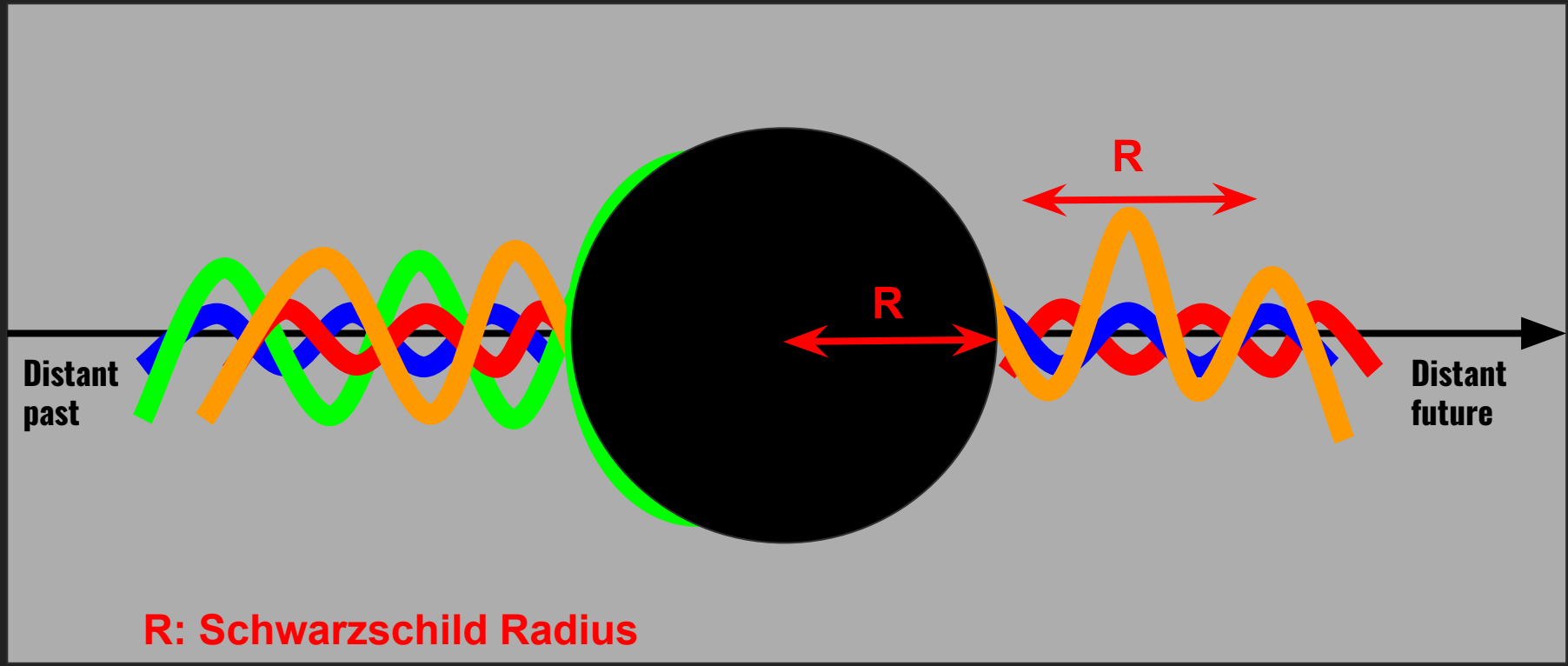
Matter and Antimatter



Vacuum



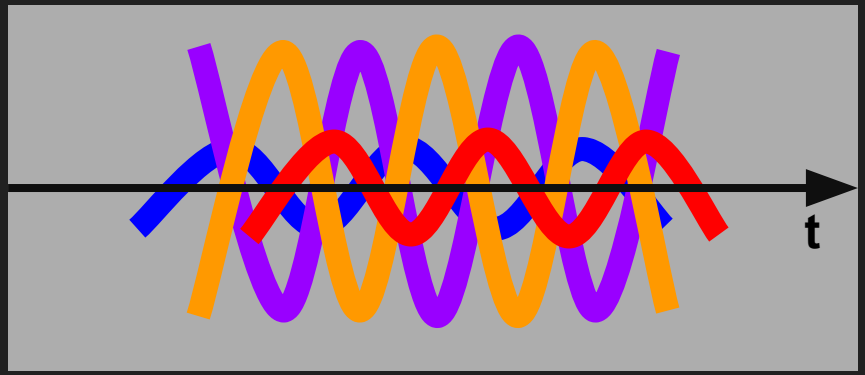
Event horizon perturbation



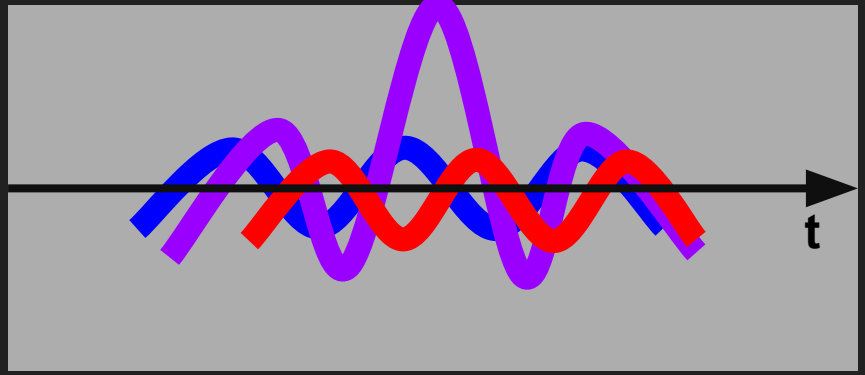
Different perspectives

Different observers can disagree about which state is the vacuum state(lowest energy)

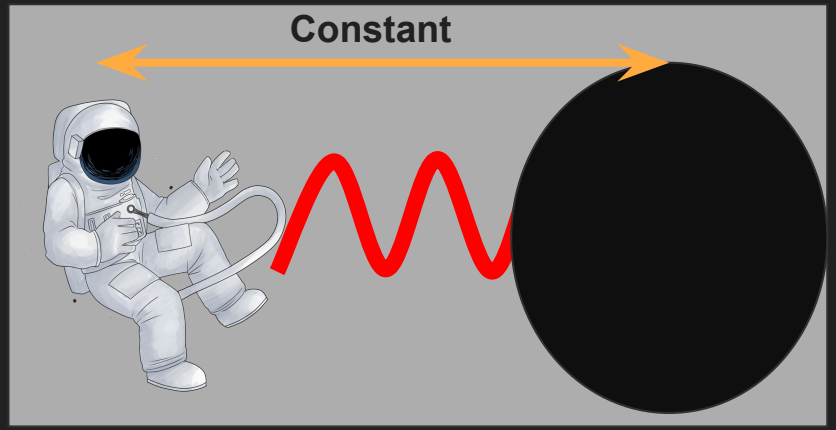
Observer 1
Falling into blackhole
E1±=E0*sin(±w*t)
E2±=E0*sin(±w*t)



Observer 2
Far from blackhole
E1=E0*sin(w*t)
E2=E0*sin(-w*t)*



Unruh effect

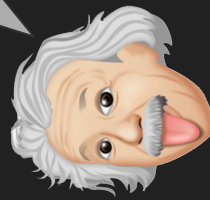


Hawking temperature

$$T_{\mathrm{H}} = \frac{\hbar g}{2\pi c k_{\mathrm{B}}}$$

g: the surface gravity of a black hole

German Accent Gravity and Acceleration are equivalent!



Unruh temperature

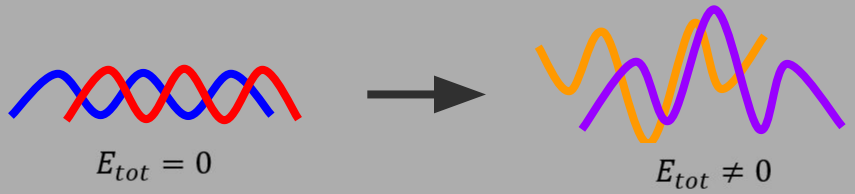
$$T = \frac{\hbar a}{2\pi c k_{\mathrm{B}}}$$

a: the local acceleration

Black Hole Evaporation

$$T = \frac{\hbar g}{2\pi c k_B}, Planck\ units: (\hbar, c, k_B) = 1 \rightarrow \frac{g}{2\pi} = \frac{1}{8\pi M}$$

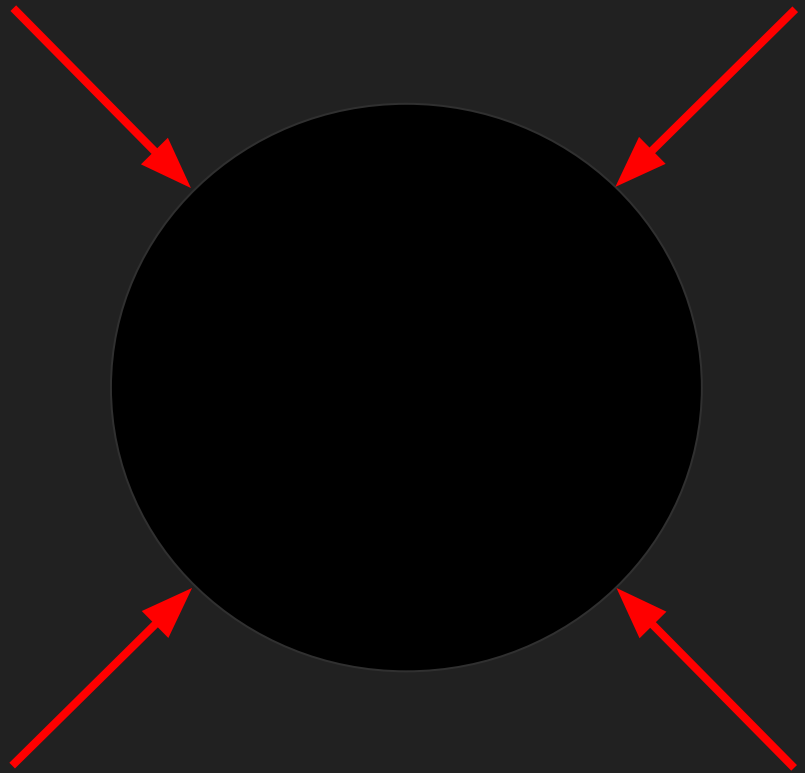
$$T = \frac{1}{8\pi M} \qquad M \searrow \longrightarrow T \nearrow \longrightarrow E \nearrow$$



$$T_{\odot} \approx 10^{-8} K \qquad T_{CMB} = 2.7K$$

$$T_{Earth} \approx 0.02K \qquad T_{4\odot} \approx 10^{-8} K$$

$$T_{plancklength} \sim Gamma\ rays!$$



Ongoing Problems?

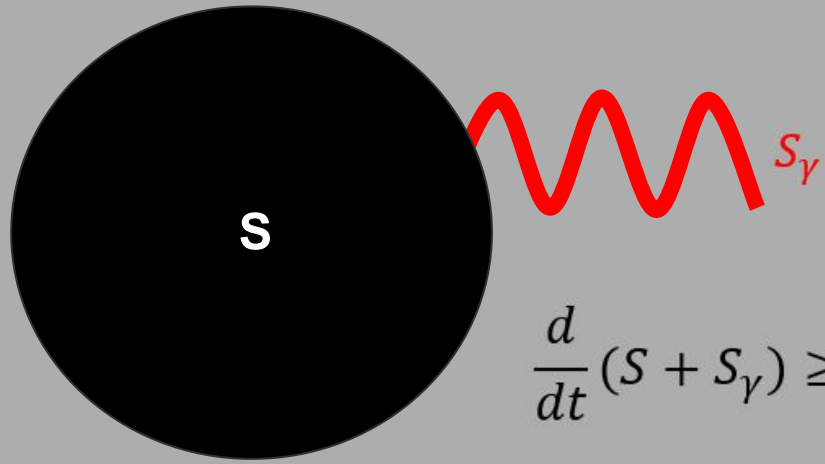
Entropy

$$T = \frac{1}{8\pi M}$$

$$dS = \frac{dQ}{T} = dQ * 8\pi M = 8\pi M dM = d(4\pi M^2)$$

$$R = 2M$$

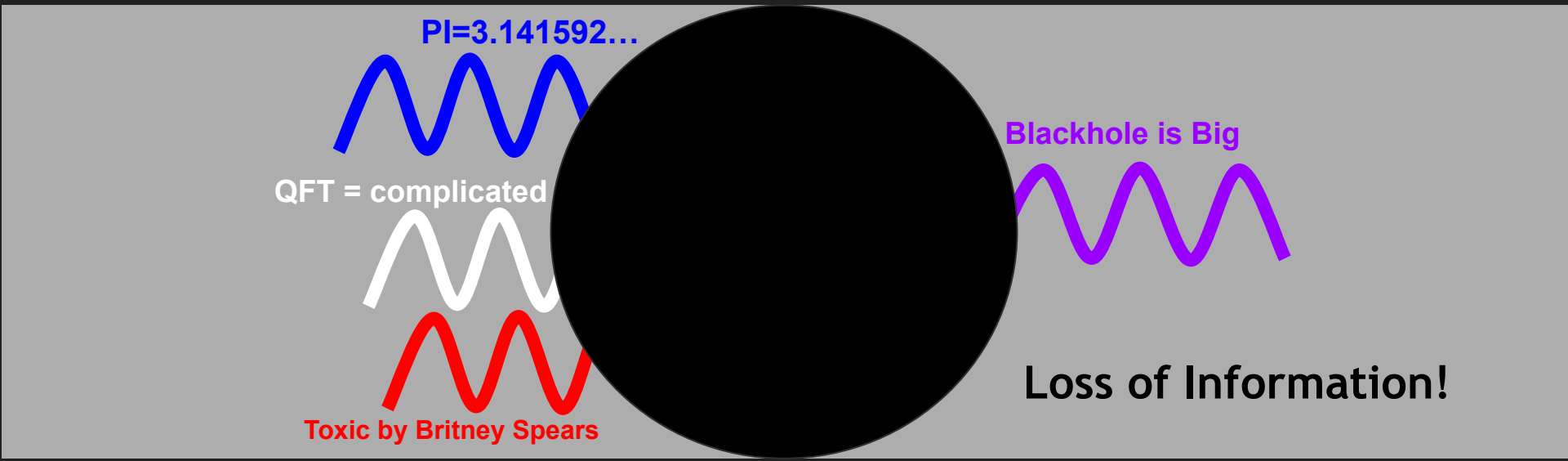
$$S = 4\pi M^2 = \pi R^2 = \frac{A}{4}$$



Solved?

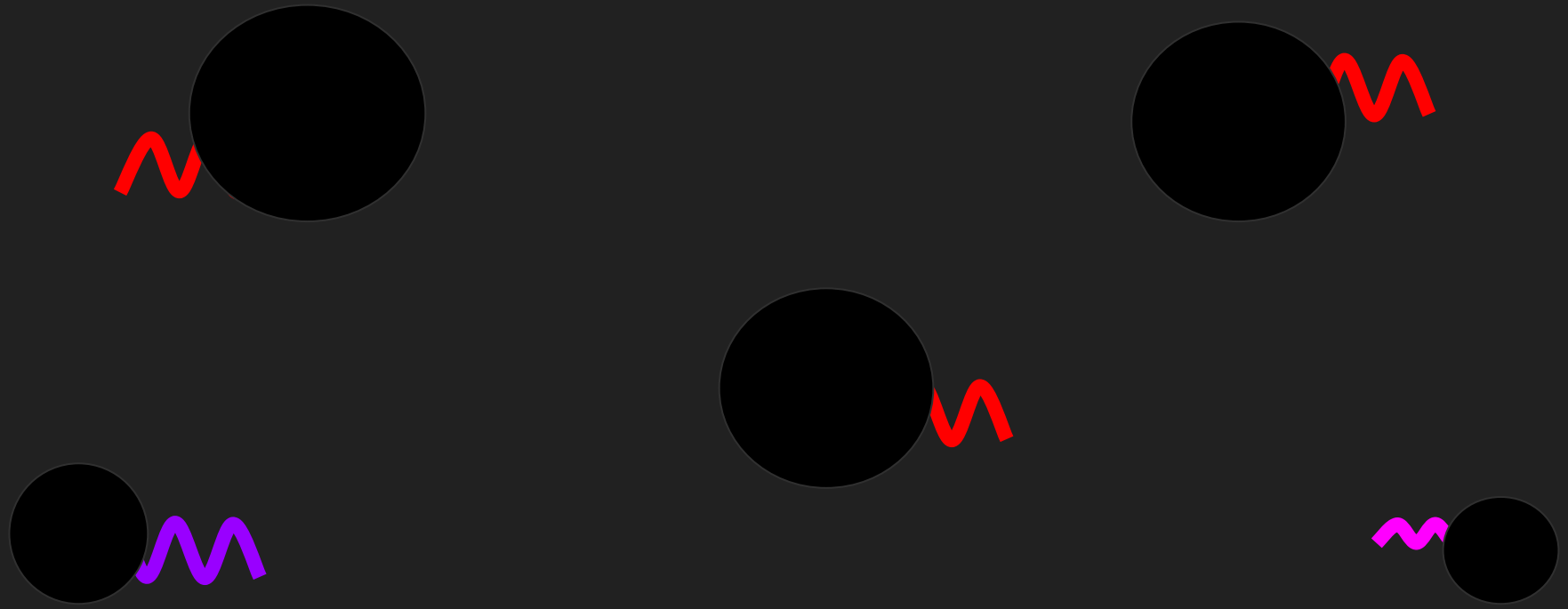
(hint:Nope !)

Information



Black hole information paradox

Heat death



Heat death