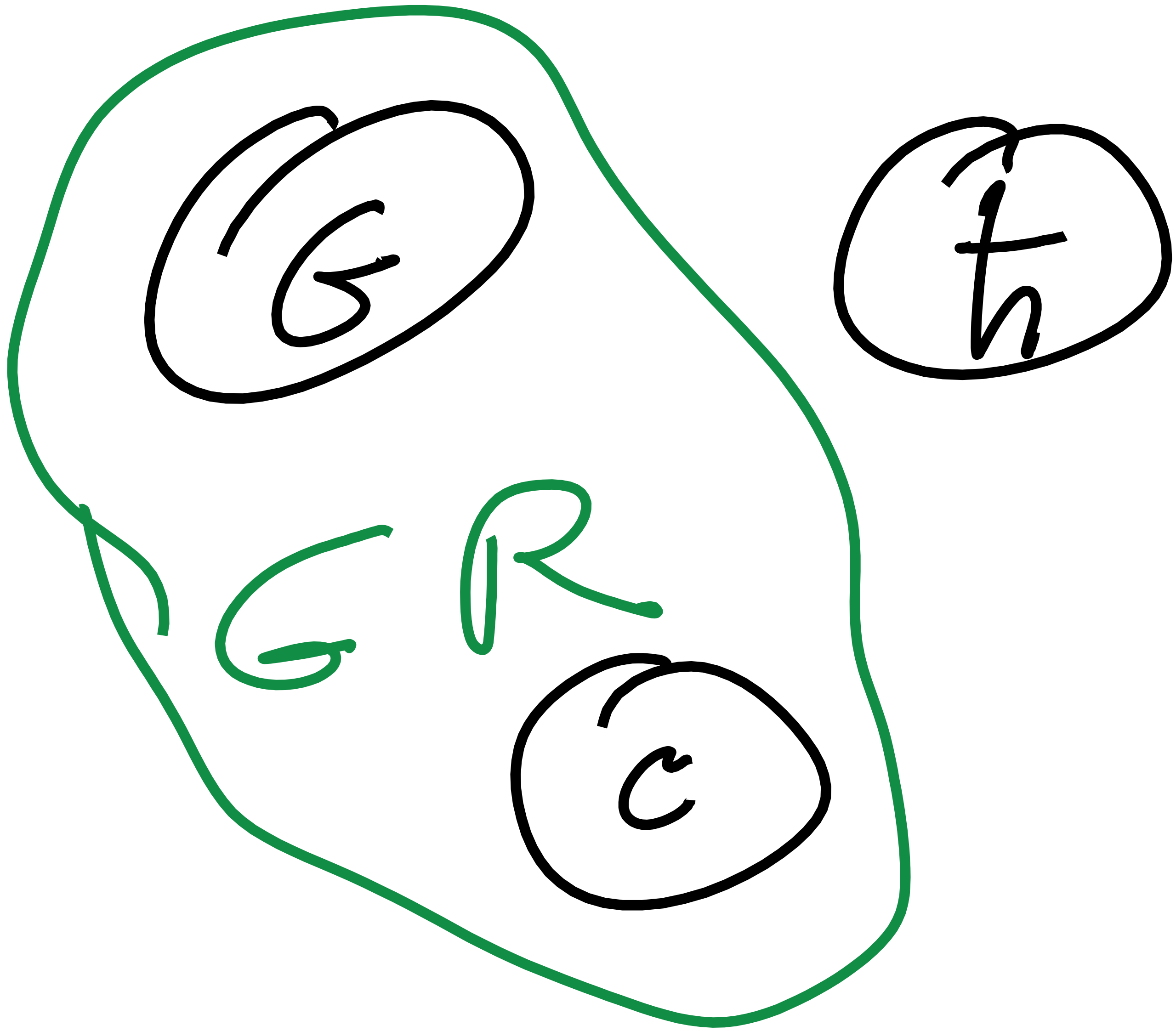
G $\hbar$

c


G
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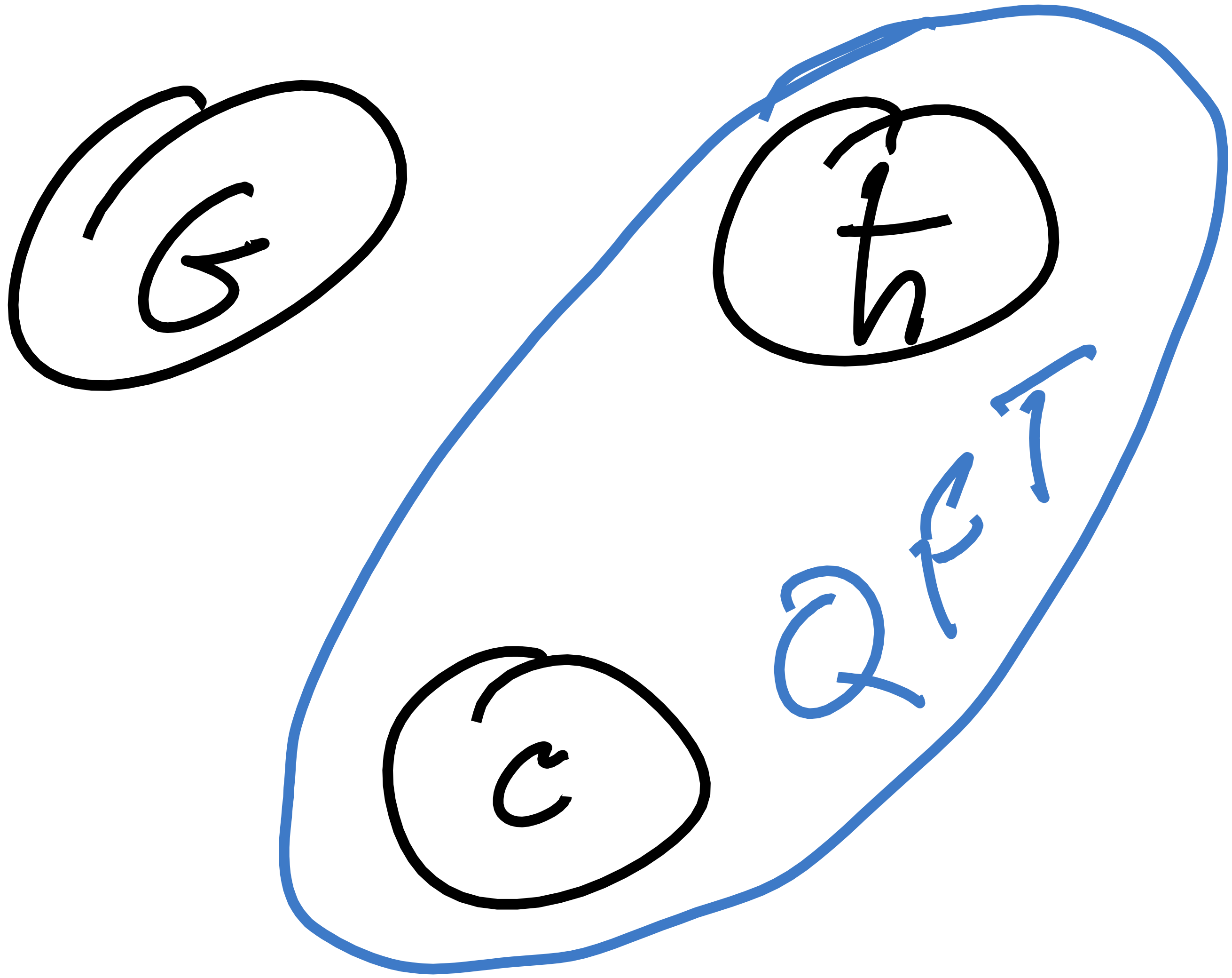
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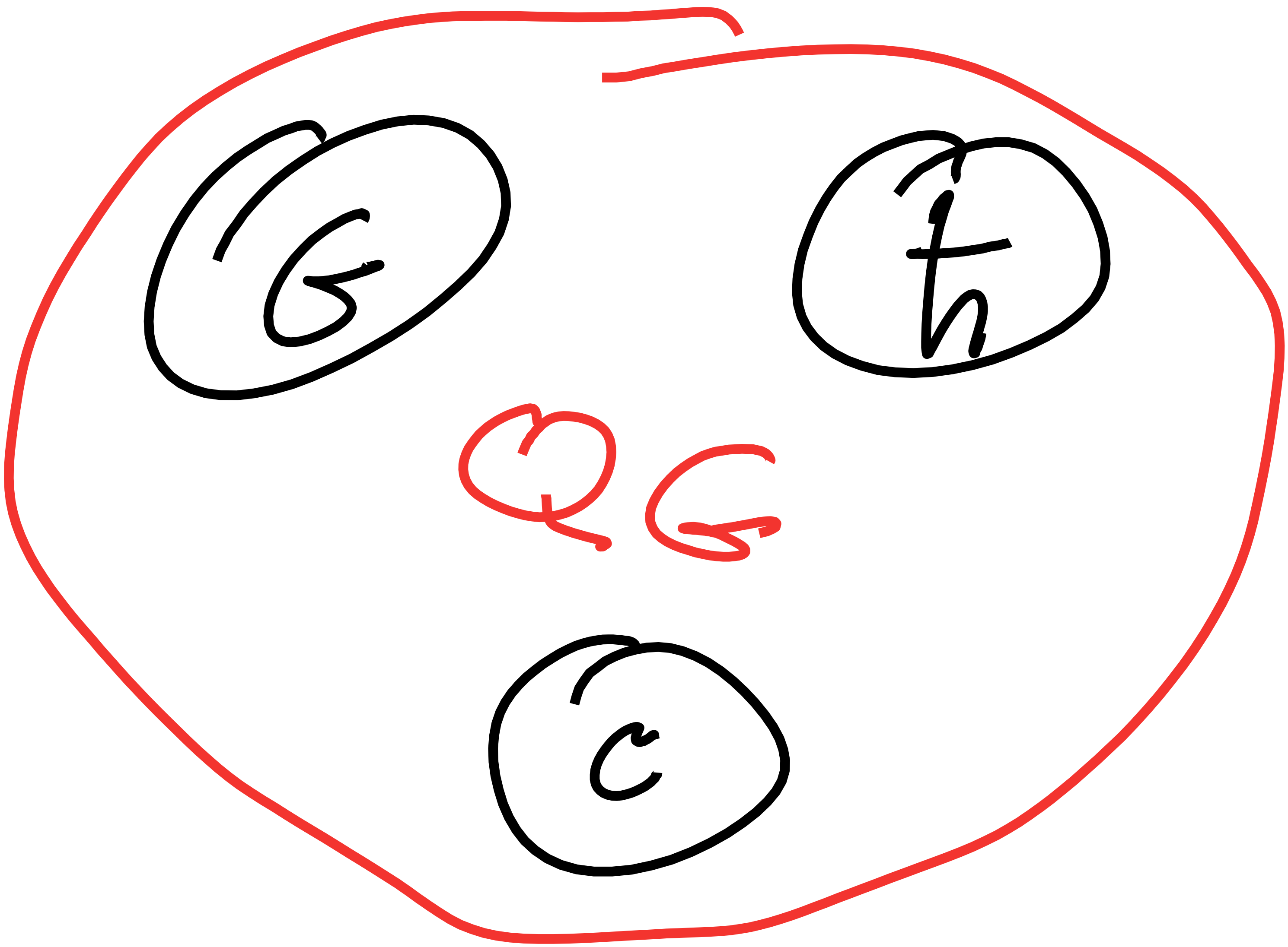
G
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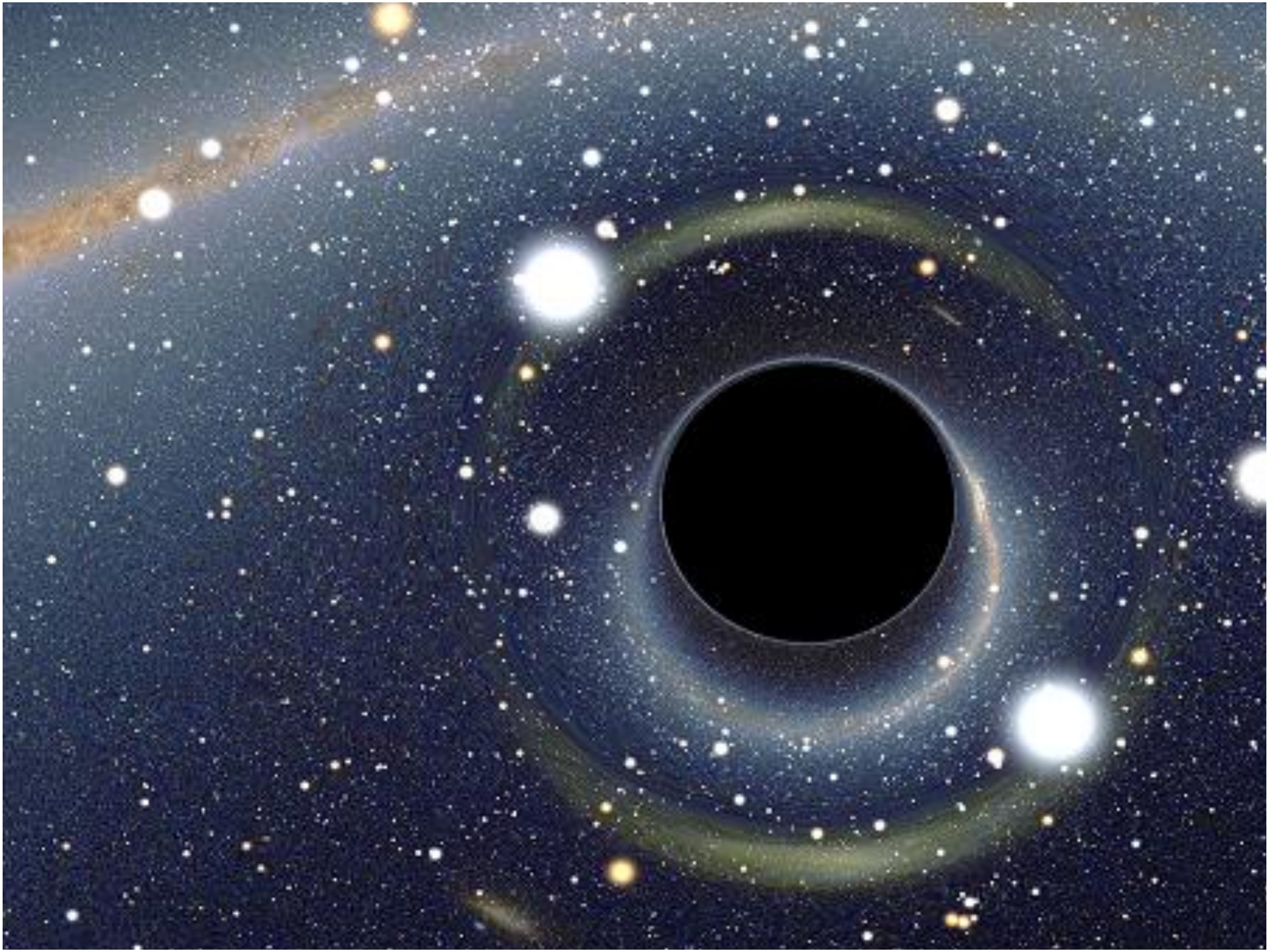
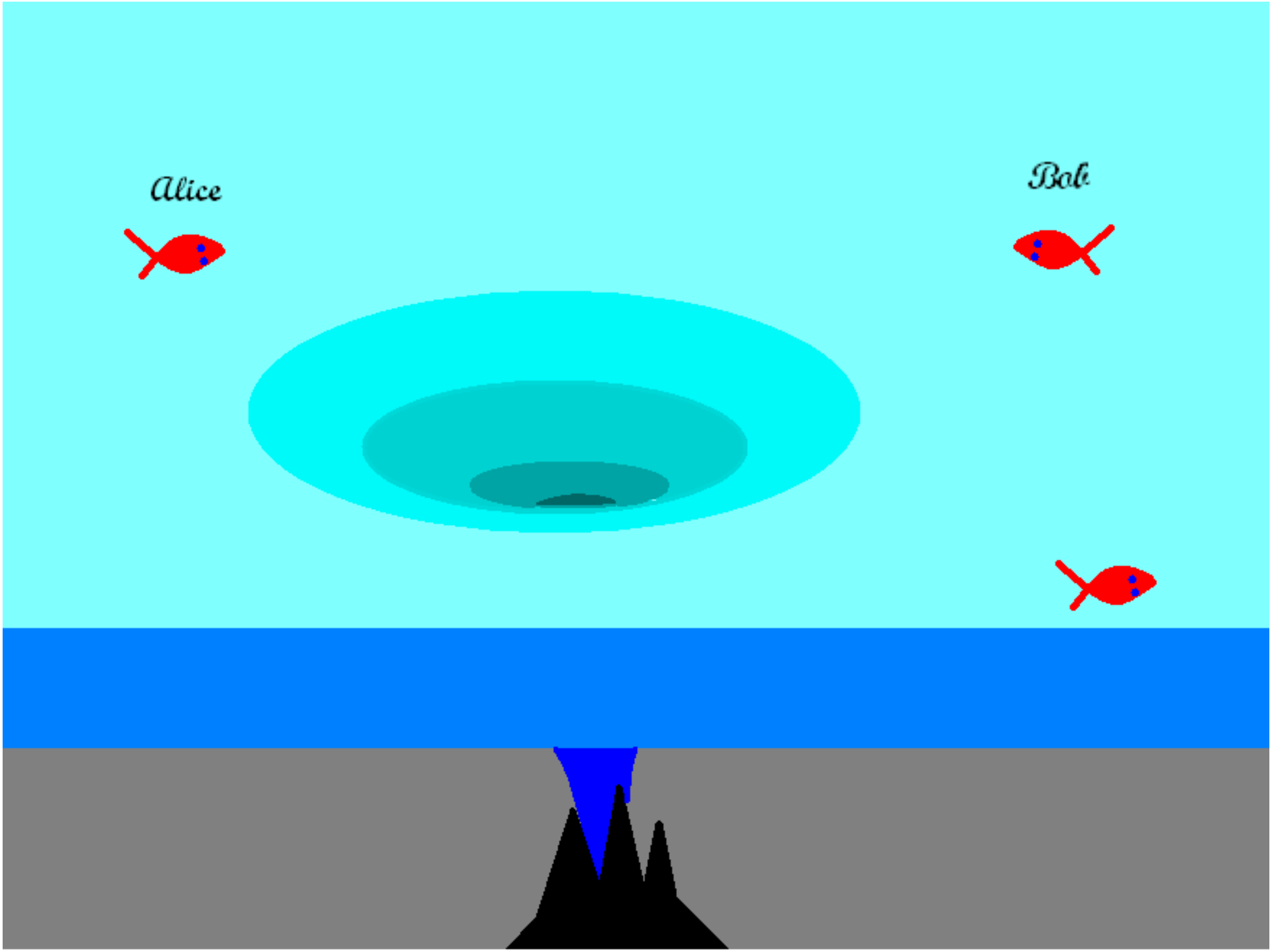
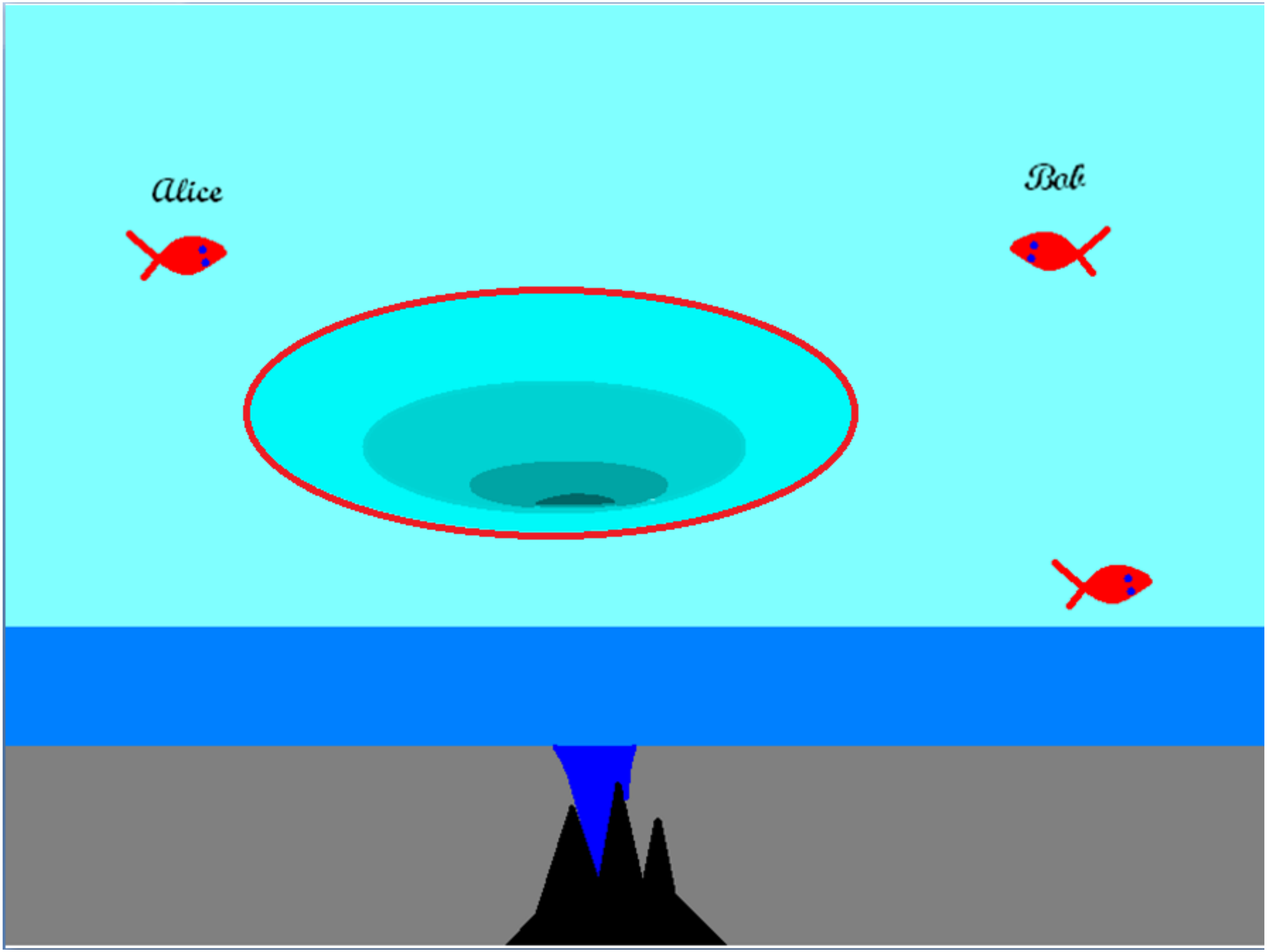
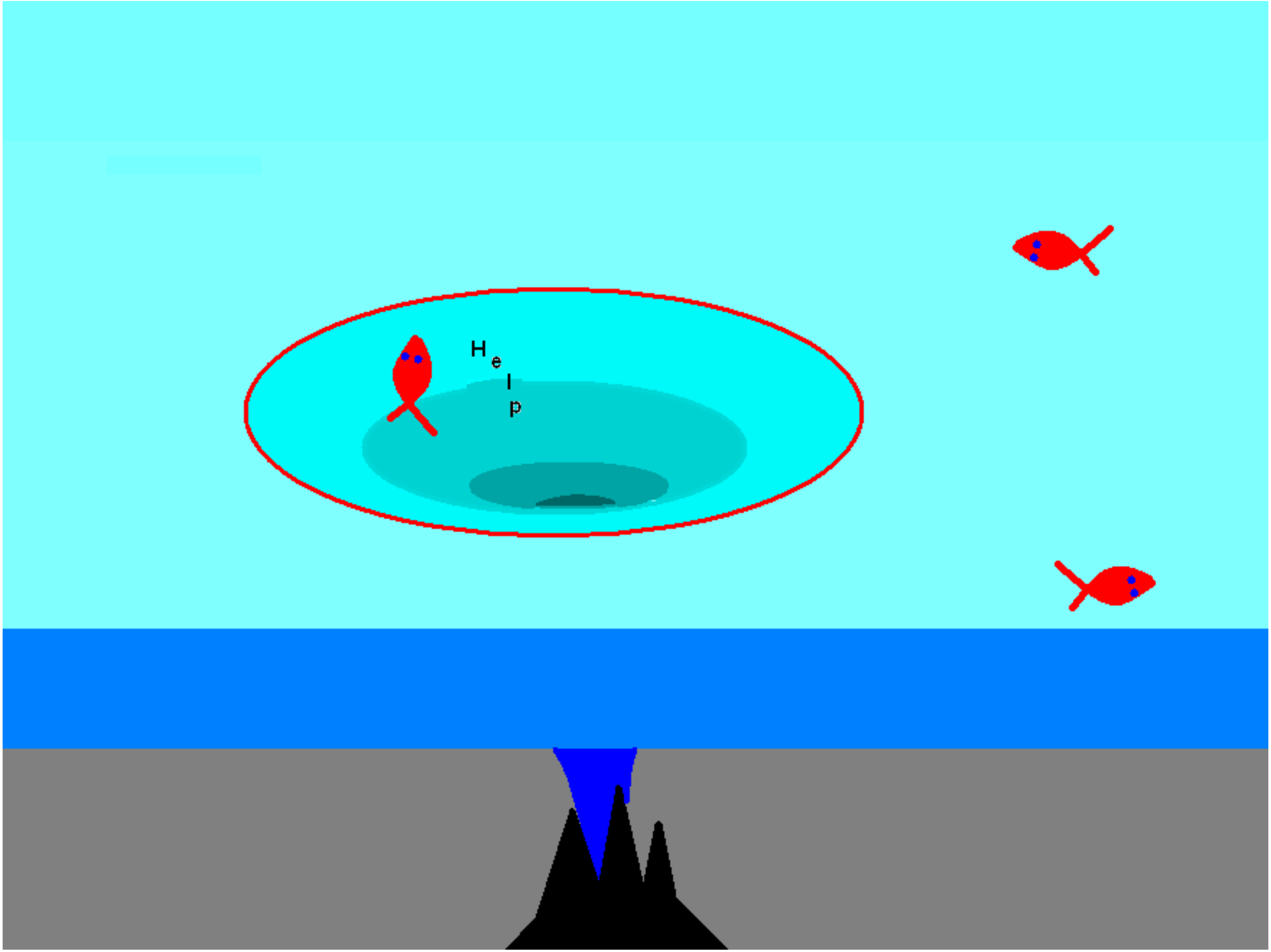


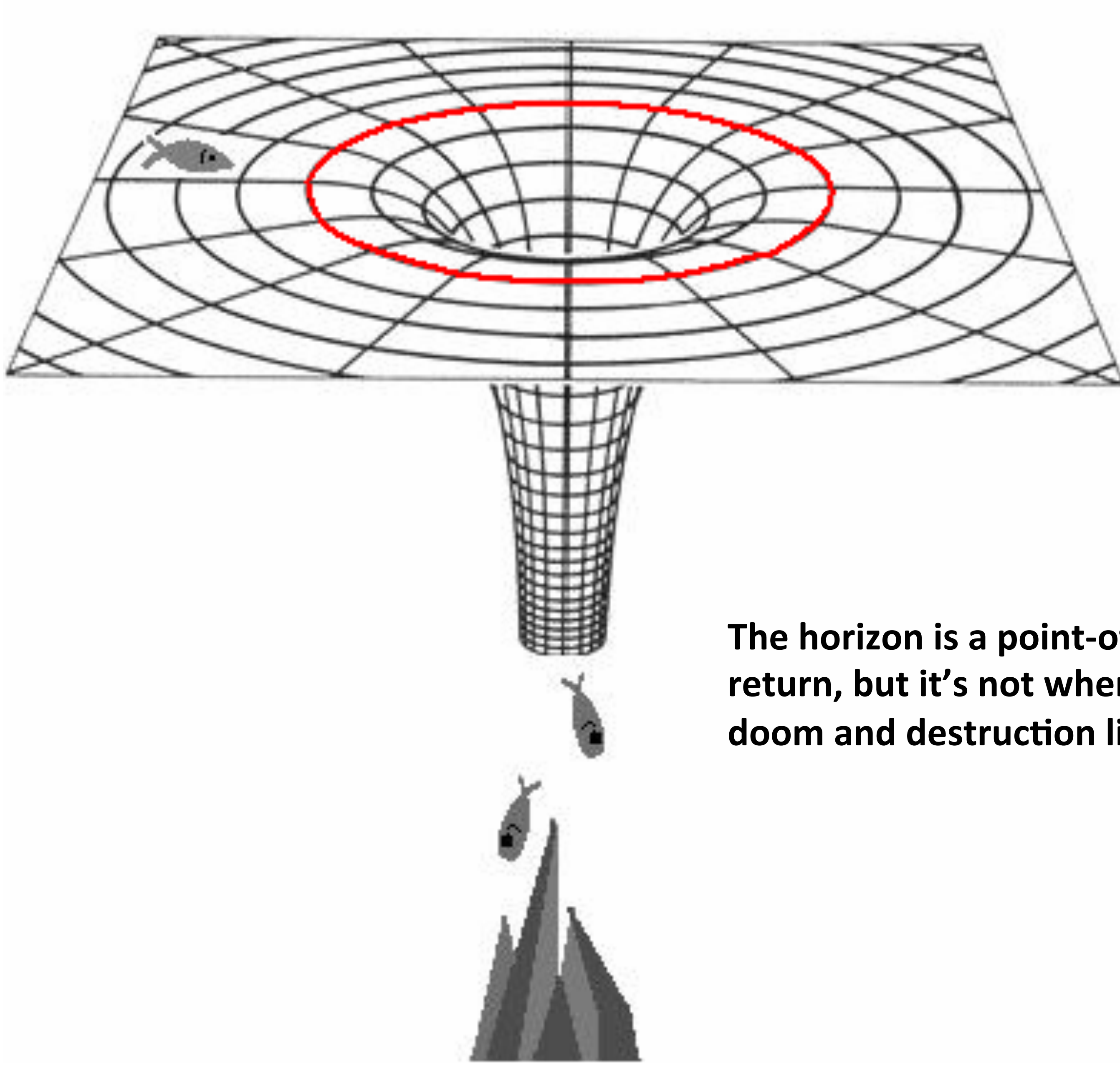

IN GOD WE TRUST
LIBERTY
2010

$$R_s = \frac{2MG}{c^2}$$

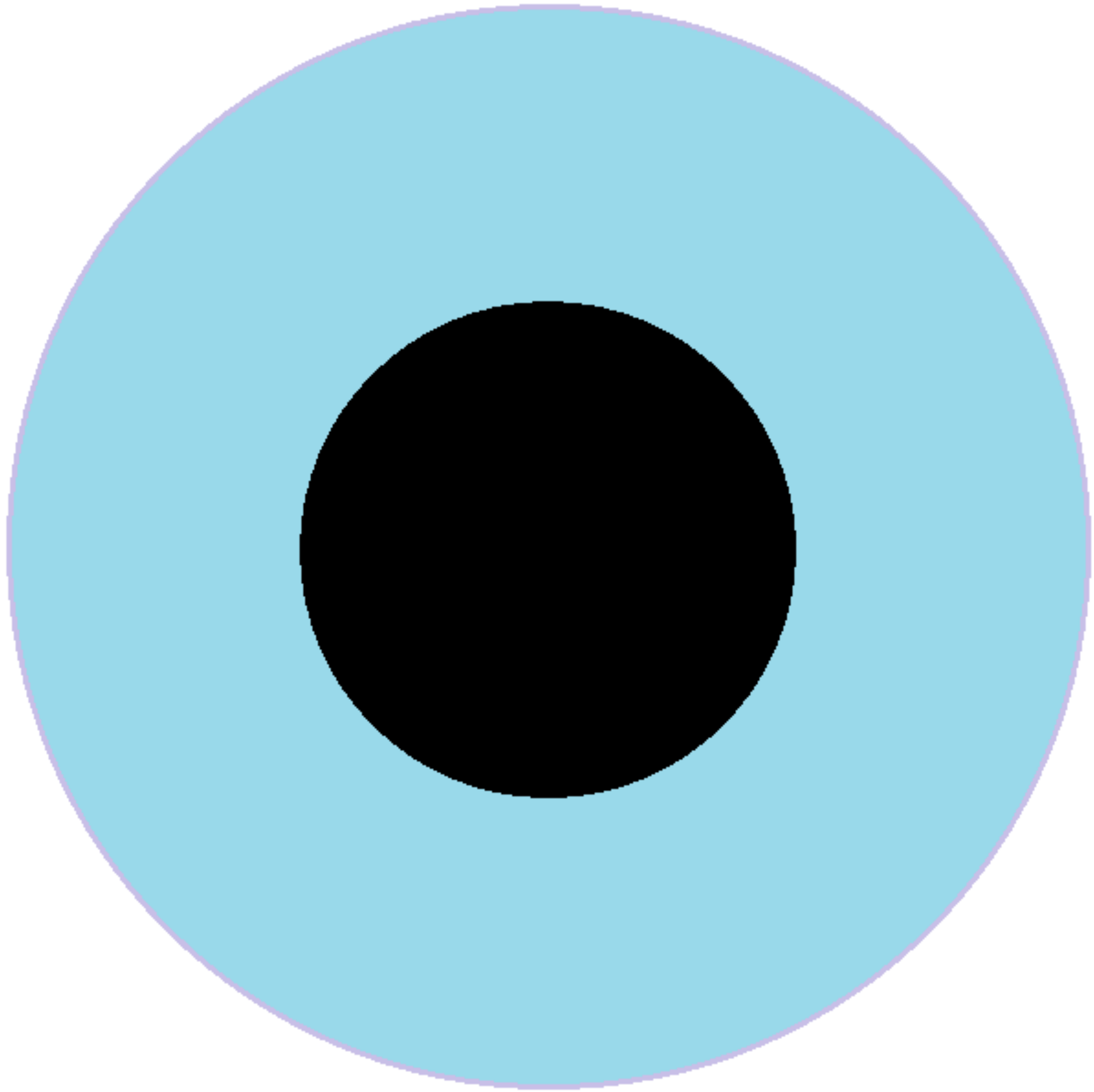

Alice
Bob

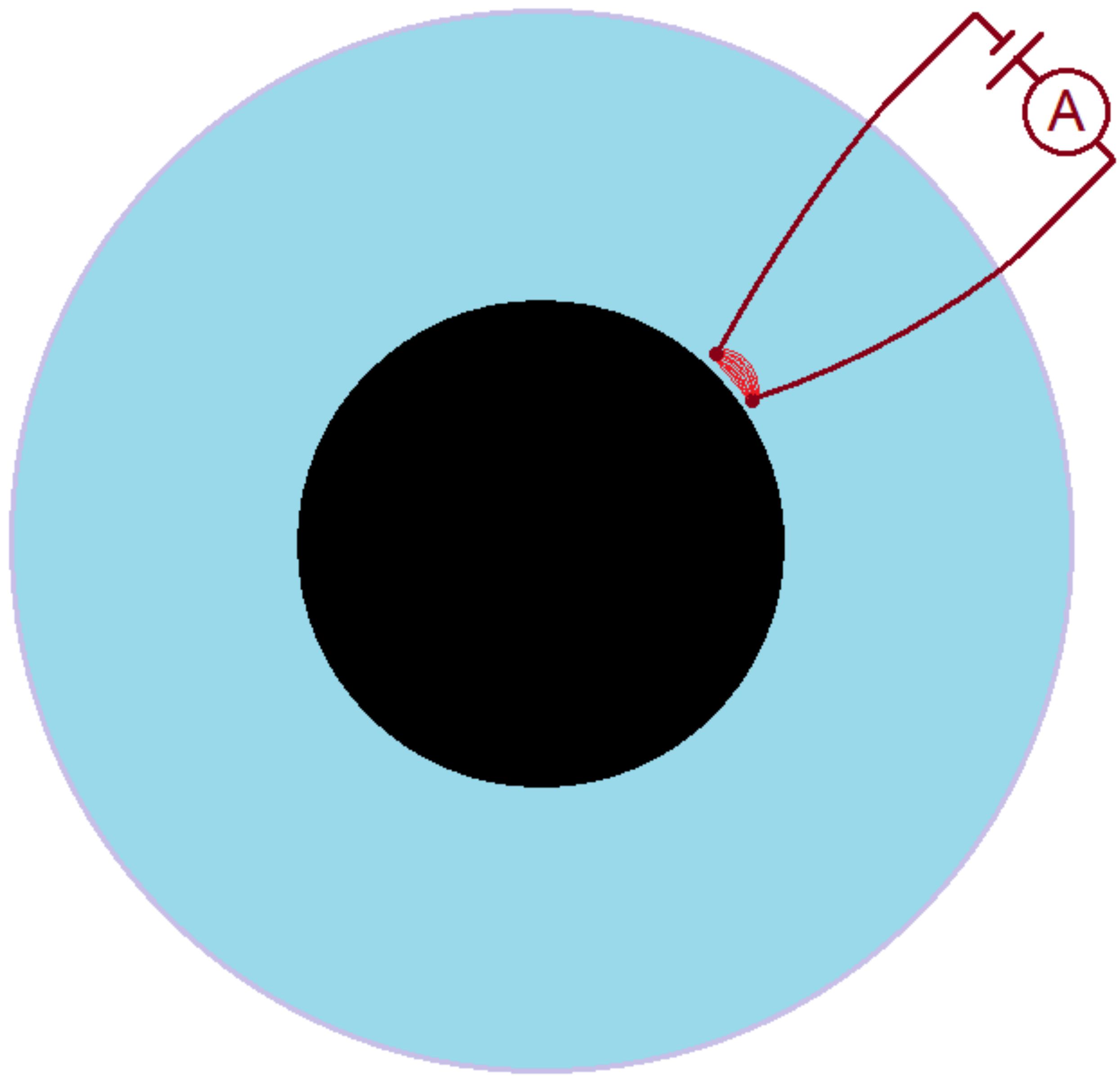

Alice
Bob


Help

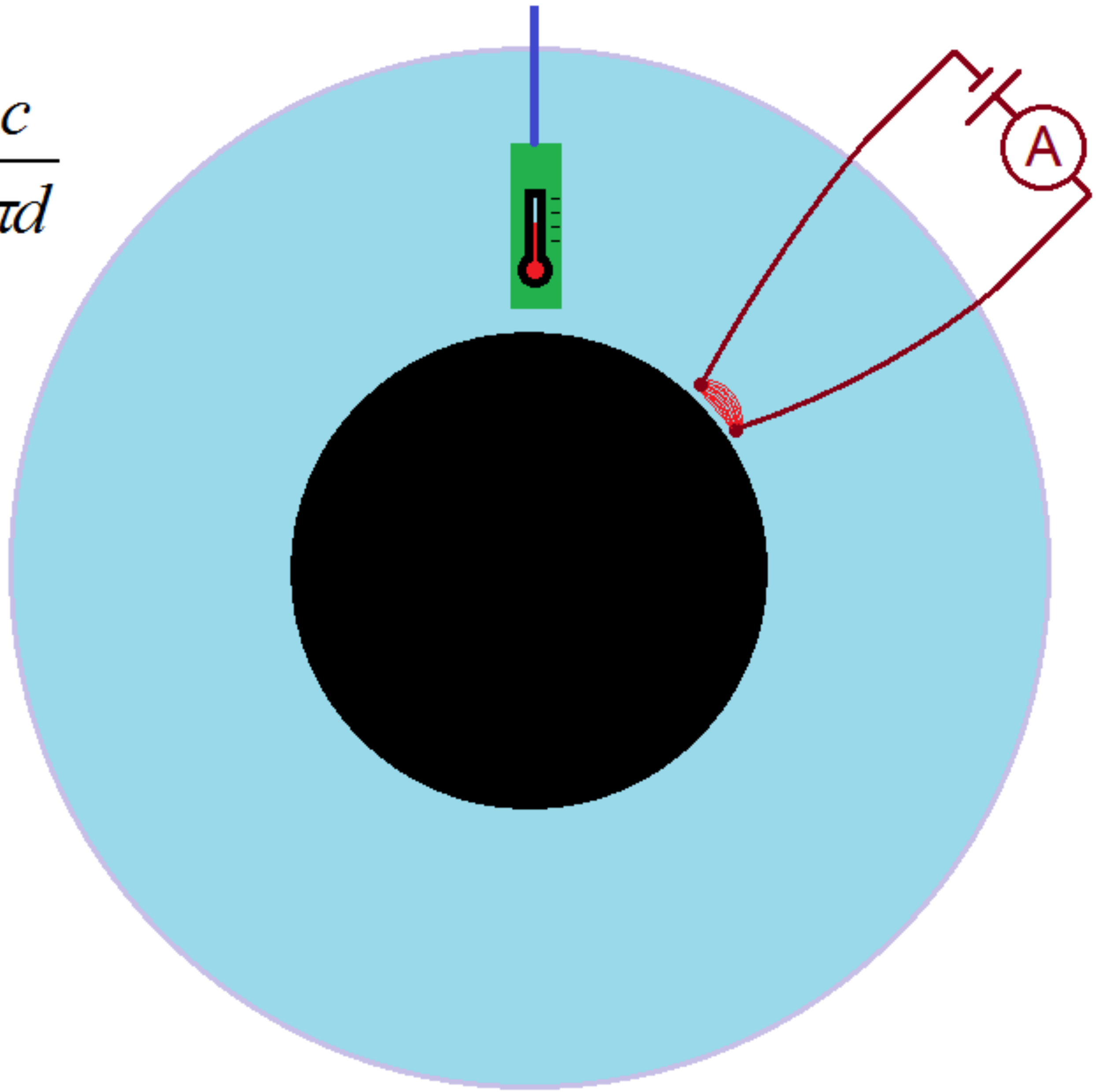


The horizon is a point-of-no-return, but it's not where the doom and destruction lie.

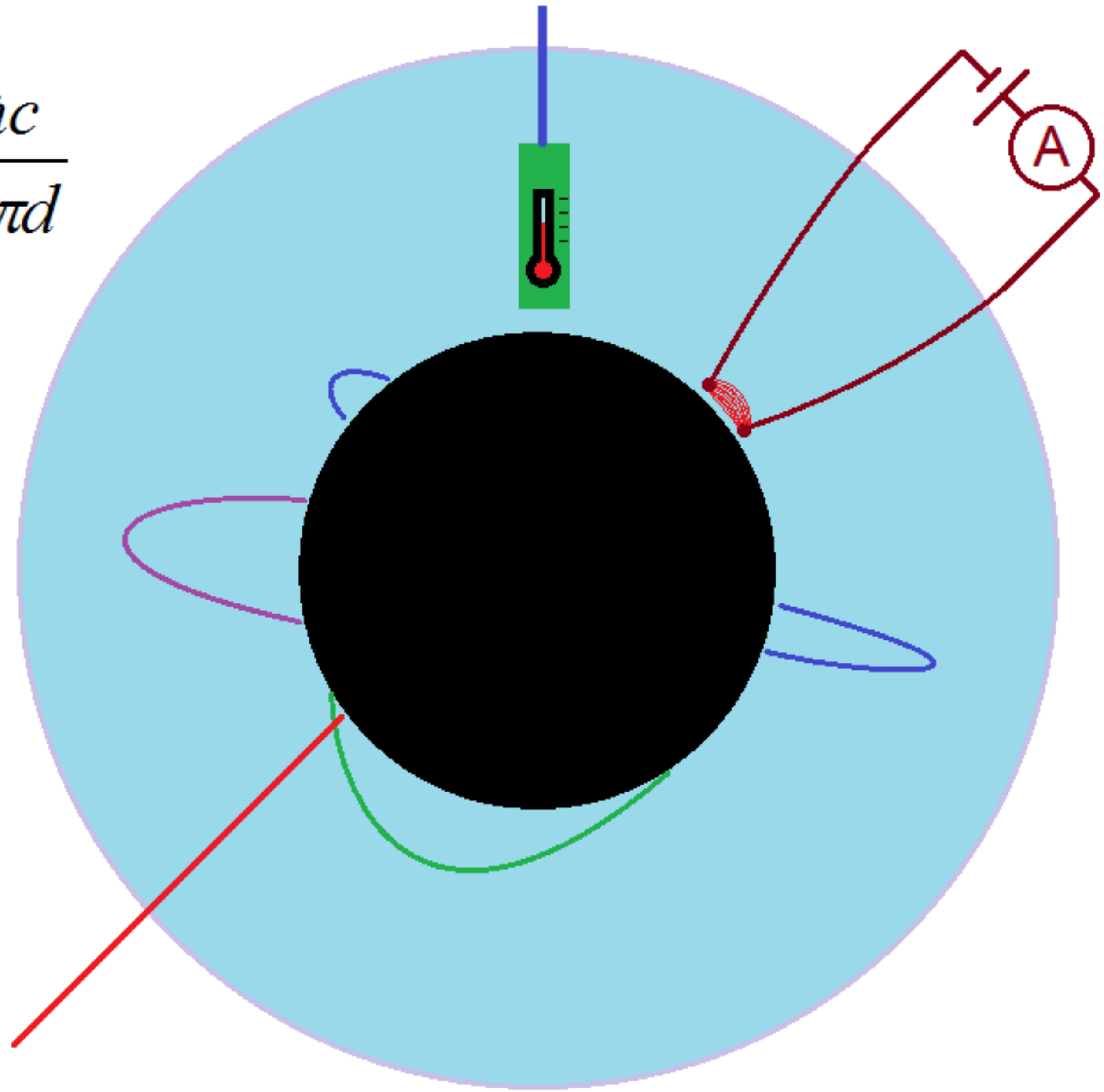


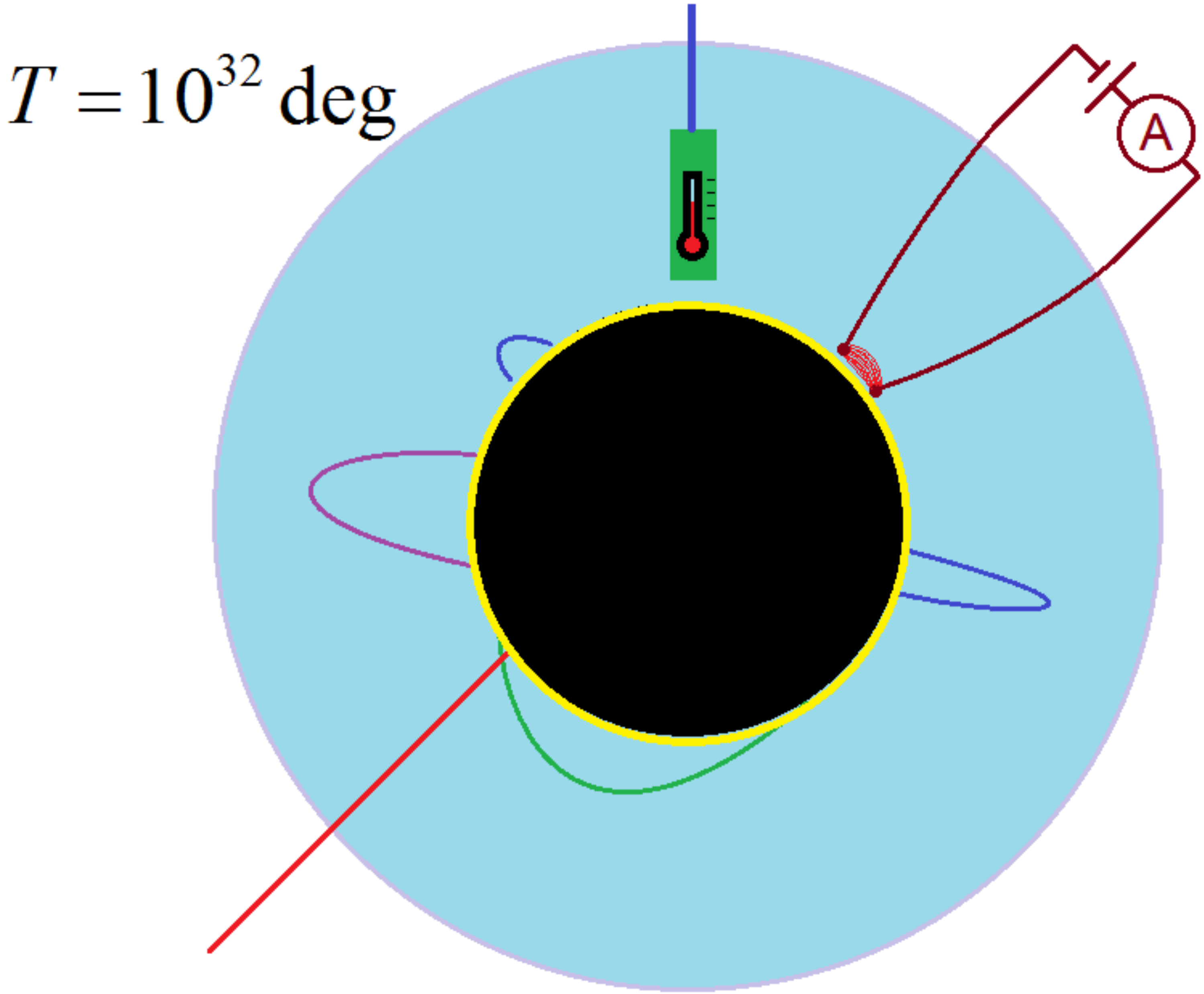

A

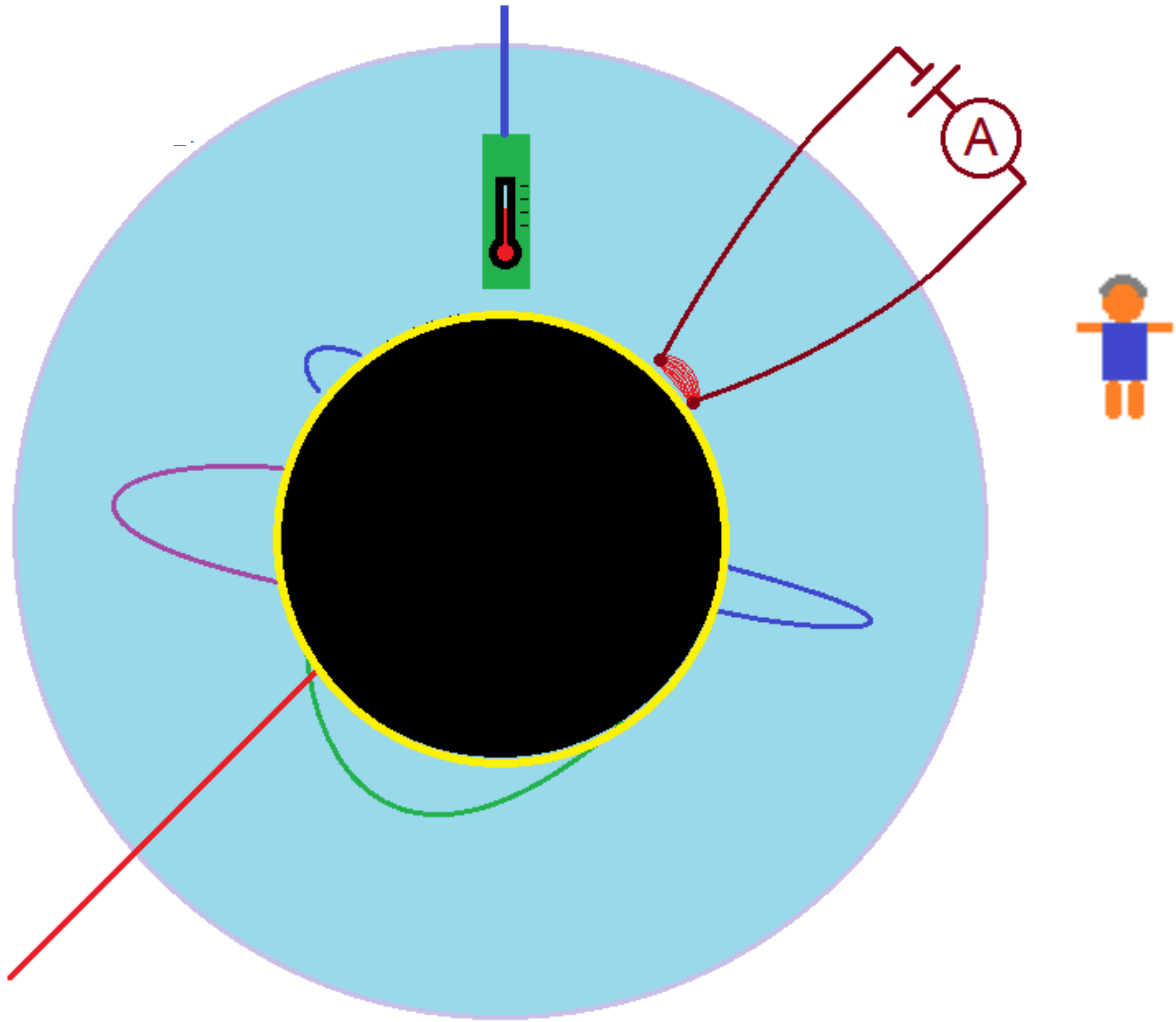
$$T = \frac{\hbar c}{2\pi d}$$

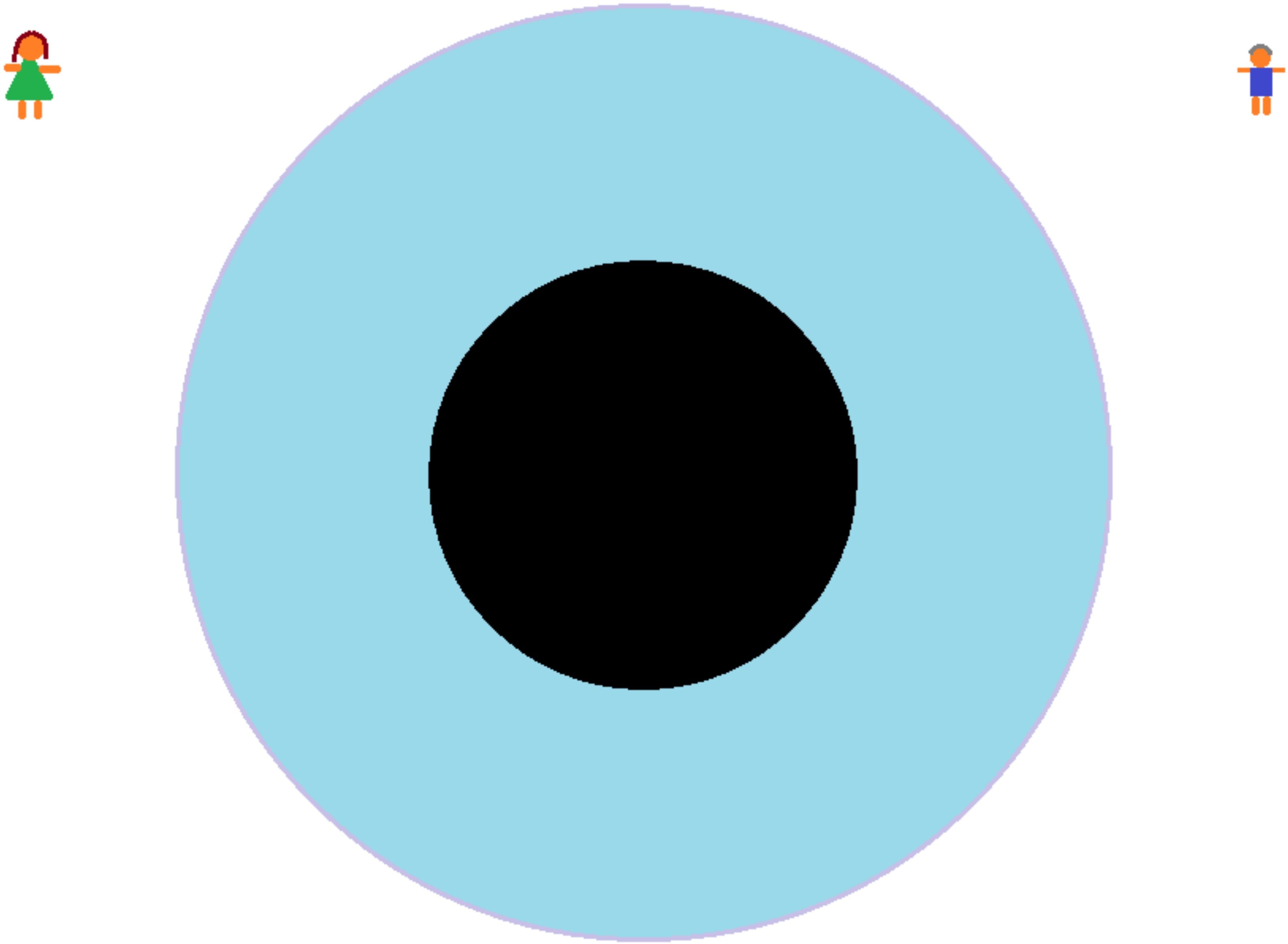


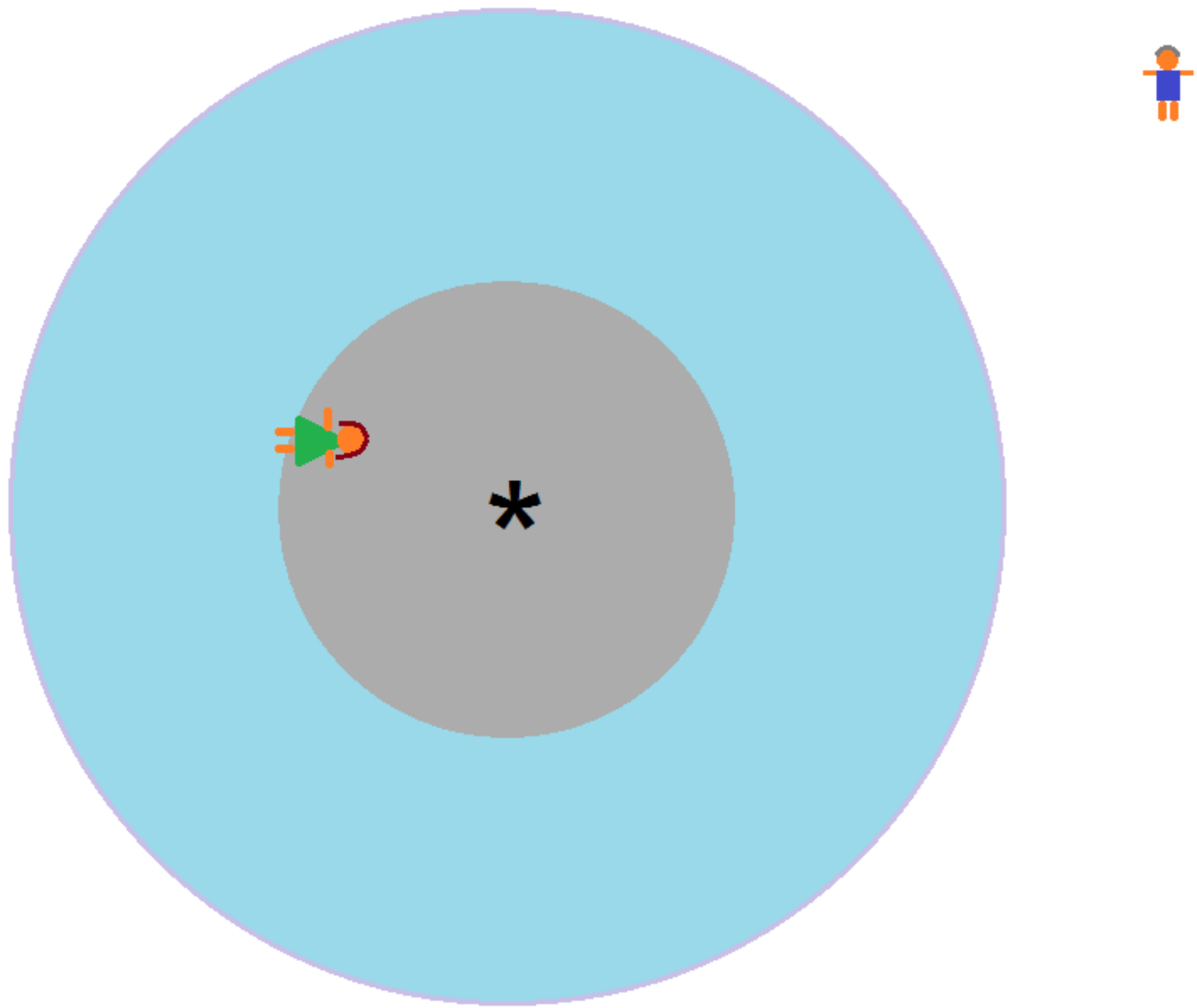
$$T = \frac{\hbar c}{2\pi d}$$



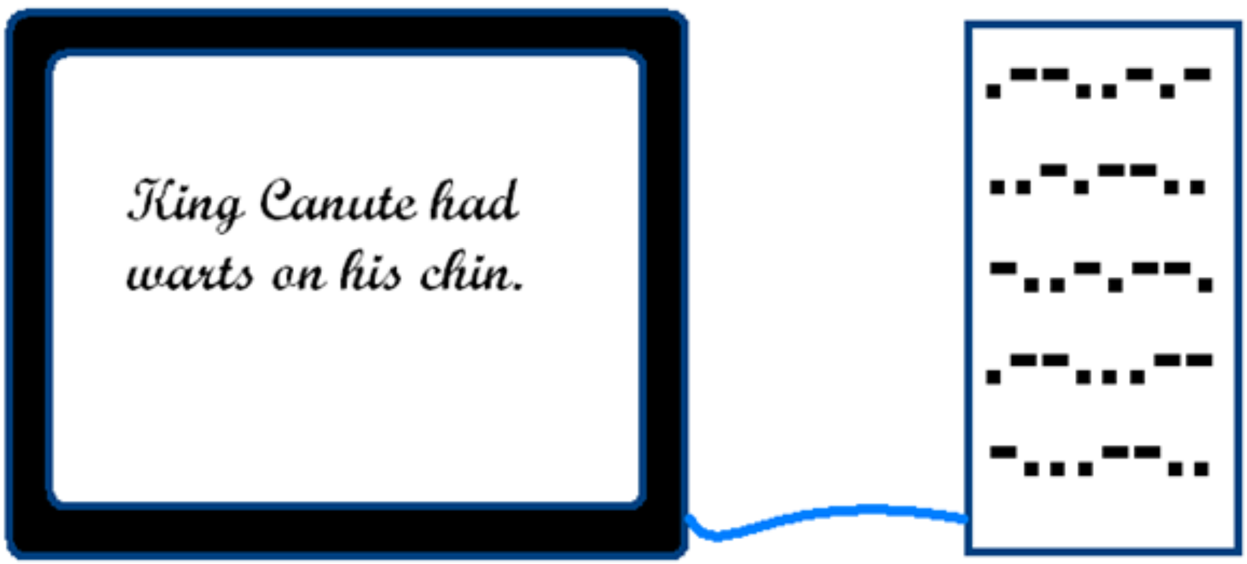

$T = 10^{32}$ deg
A


A

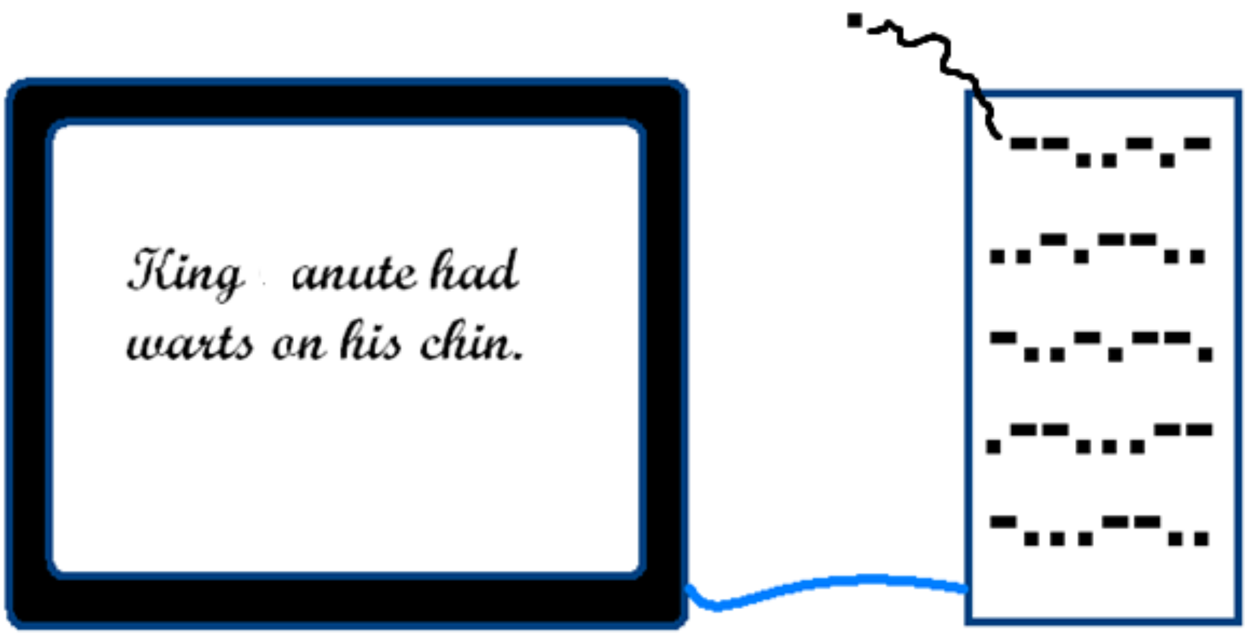




Information comes in bits.



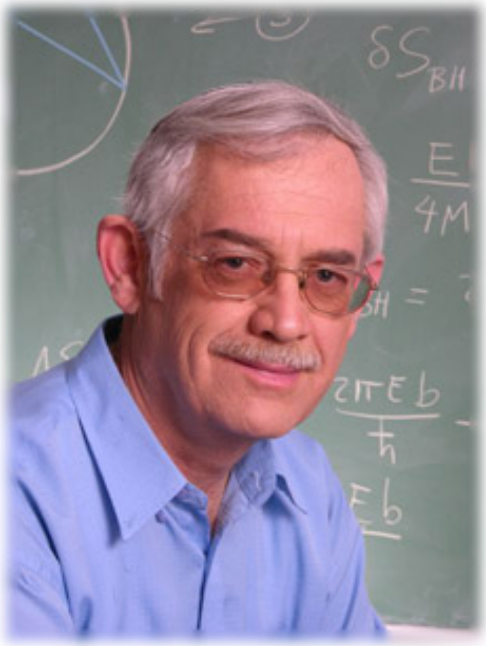
Bits are indestructible.



What happened to Alice’s bits?

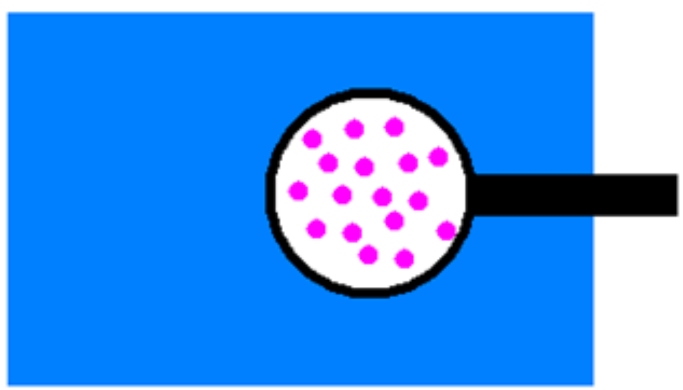
Are they gone?

Where are they hiding?



1972 Jacob Bekenstein

Black holes have entropy.

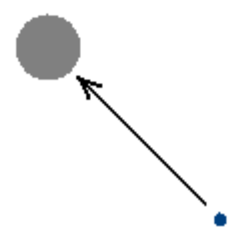


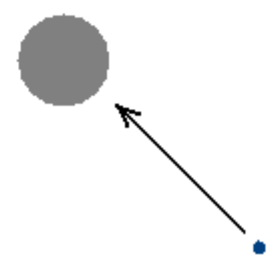
Entropy is hidden information.

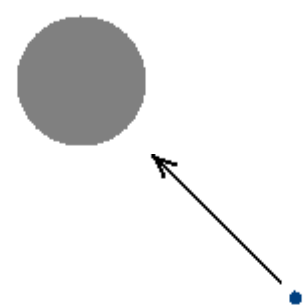
What information and how much?

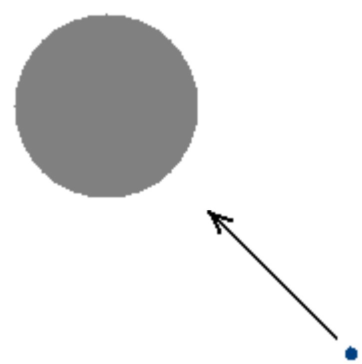
What are the microscopic objects that play the role of atoms in the bathtub?

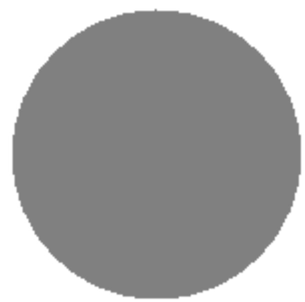
Where are they located?

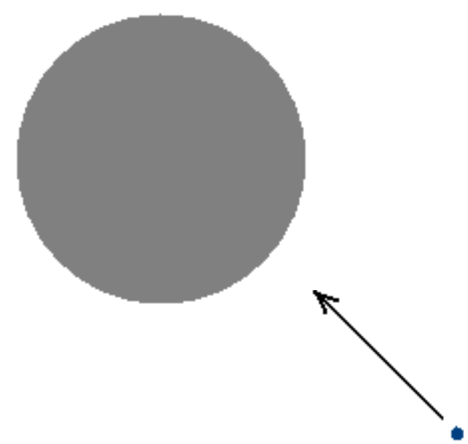








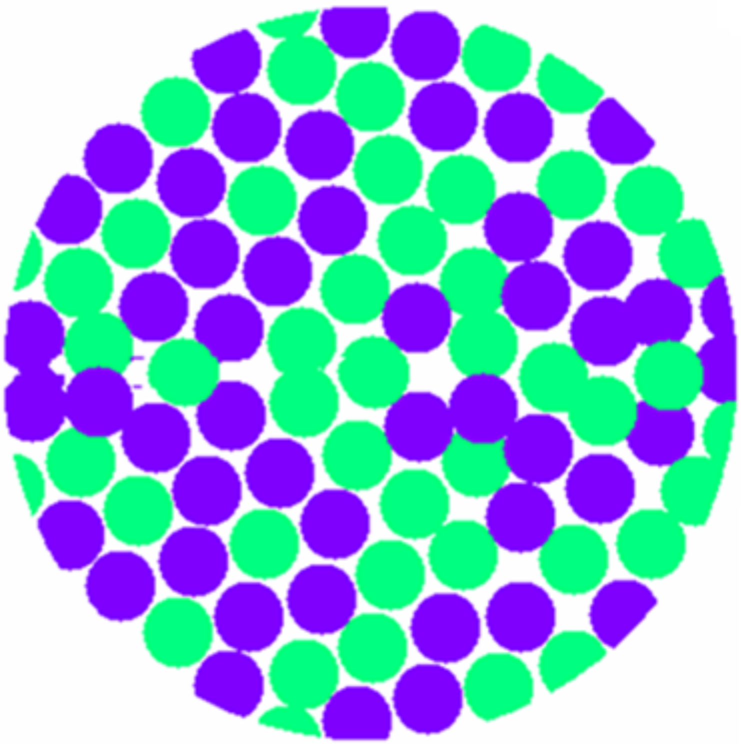




$$\delta E = \frac{\hbar c}{R}$$

$$E = mc^2$$

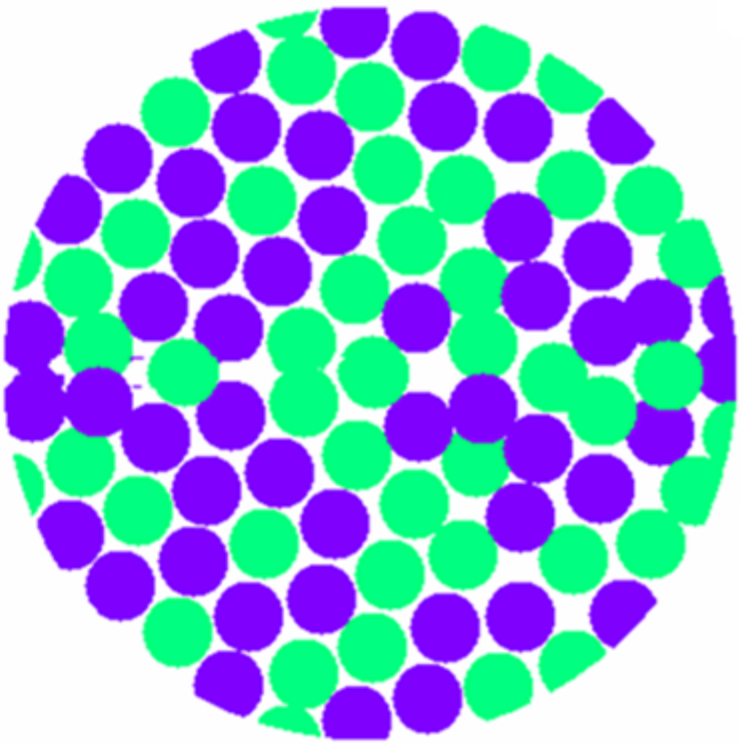
$$R = \frac{2MG}{c^2}$$



The number of hidden bits is proportional to the area of the horizon.

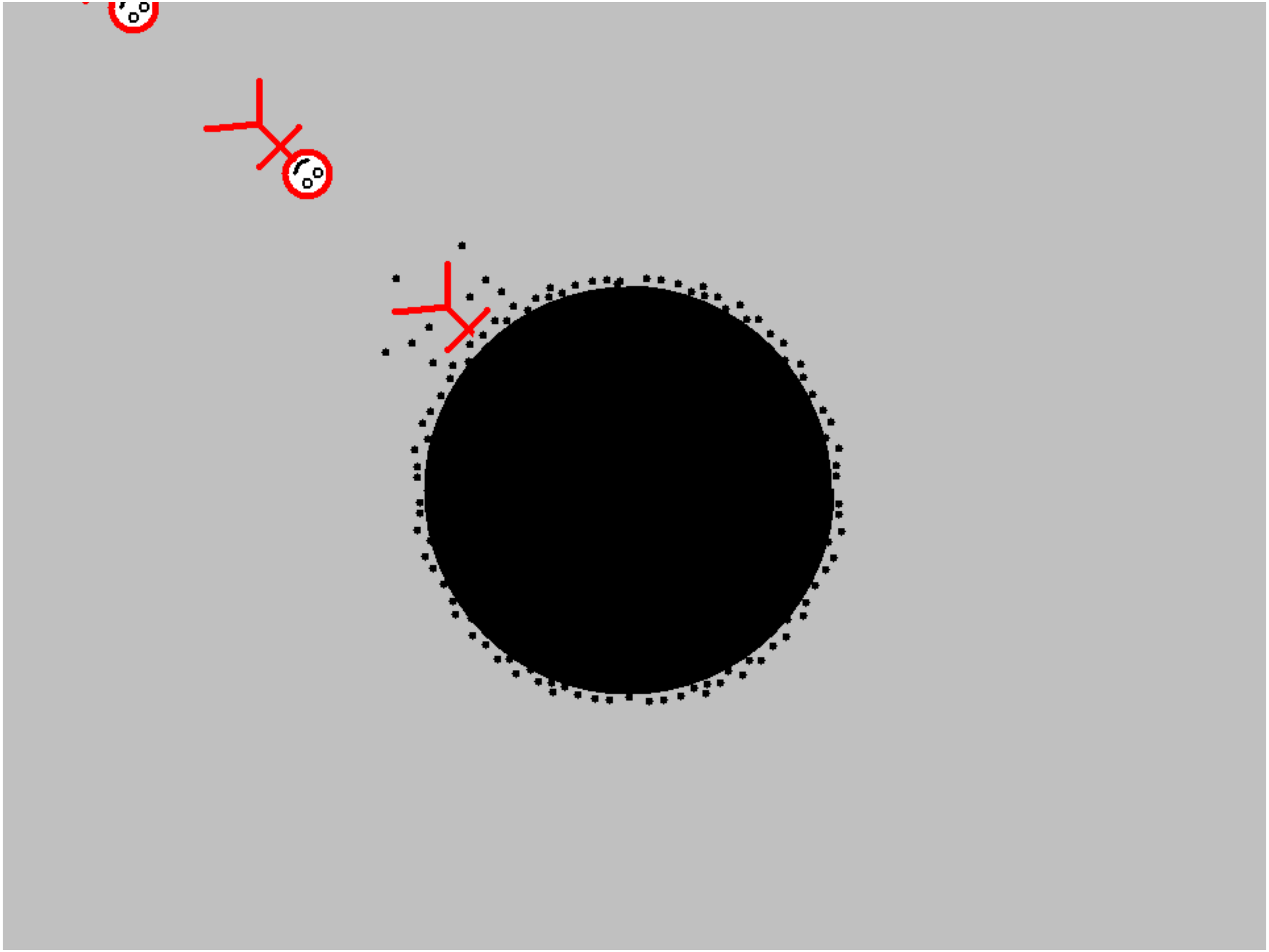
$$S = \frac{Ac^3}{4\hbar G}$$

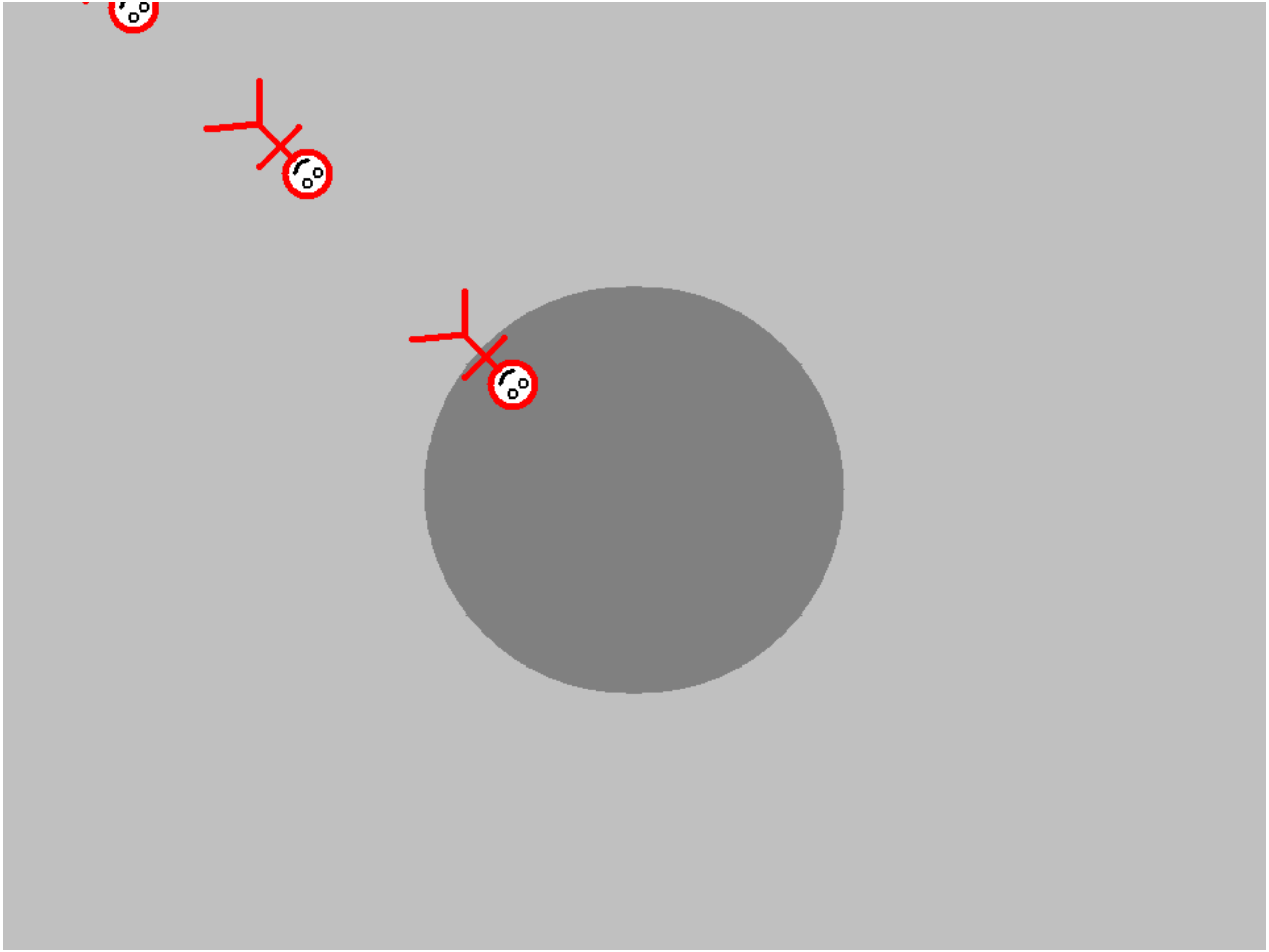
10^{70} bits per square meter.



Entropy implies heat.

$T = 10^{32}$ degrees

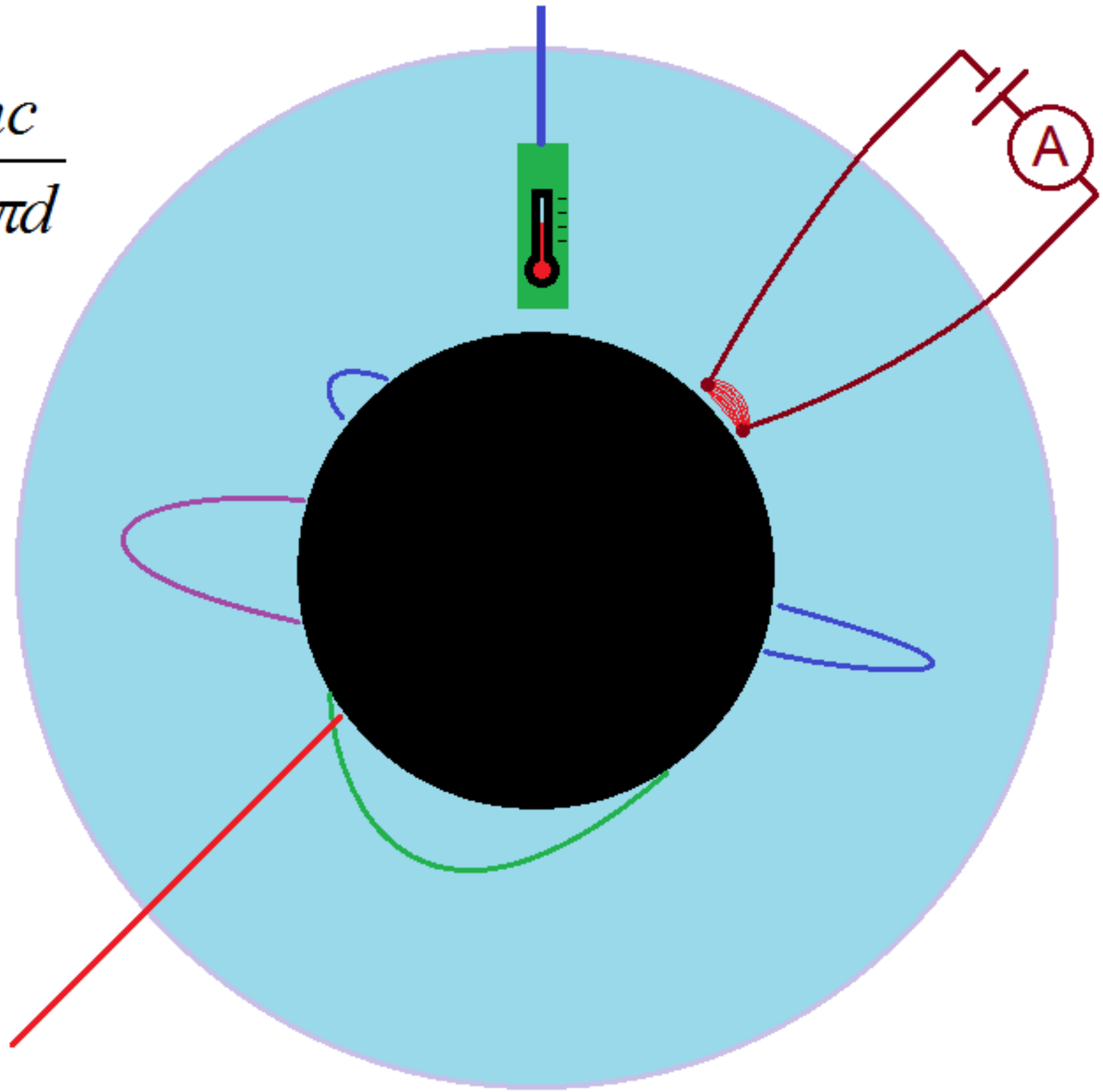




To make things even more confusing,

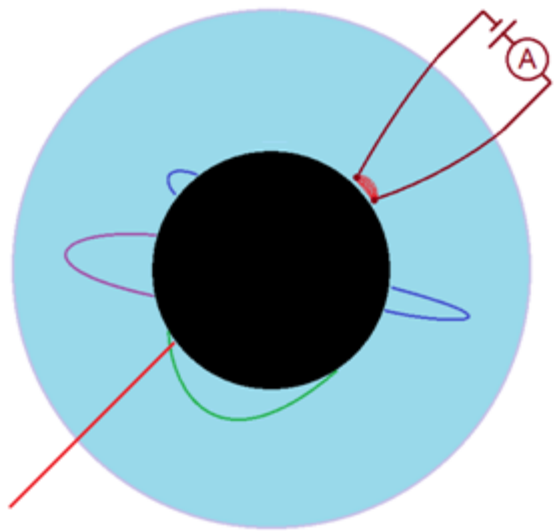
Black holes evaporate: Hawking (1974)

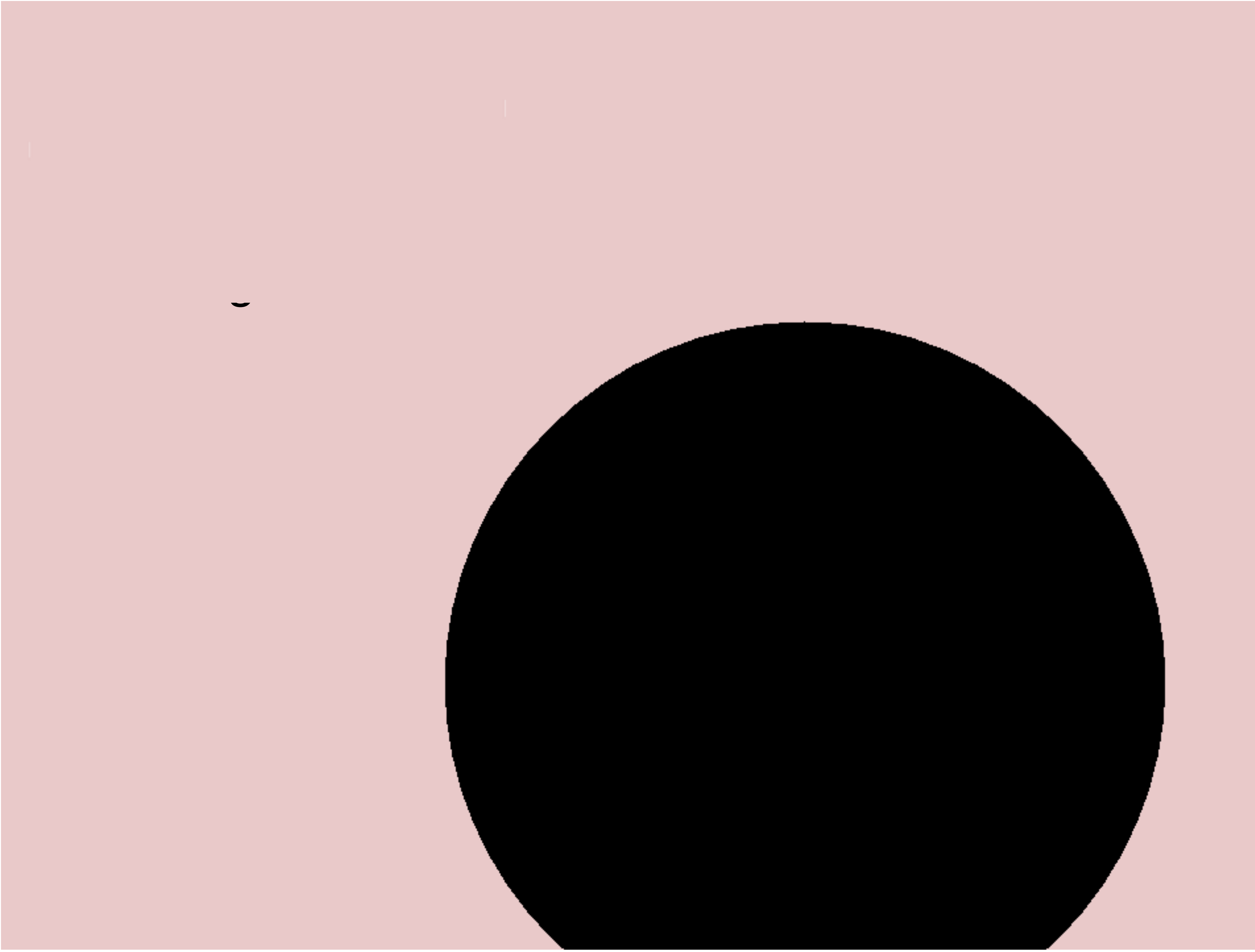
$$T = \frac{\hbar c}{2\pi d}$$

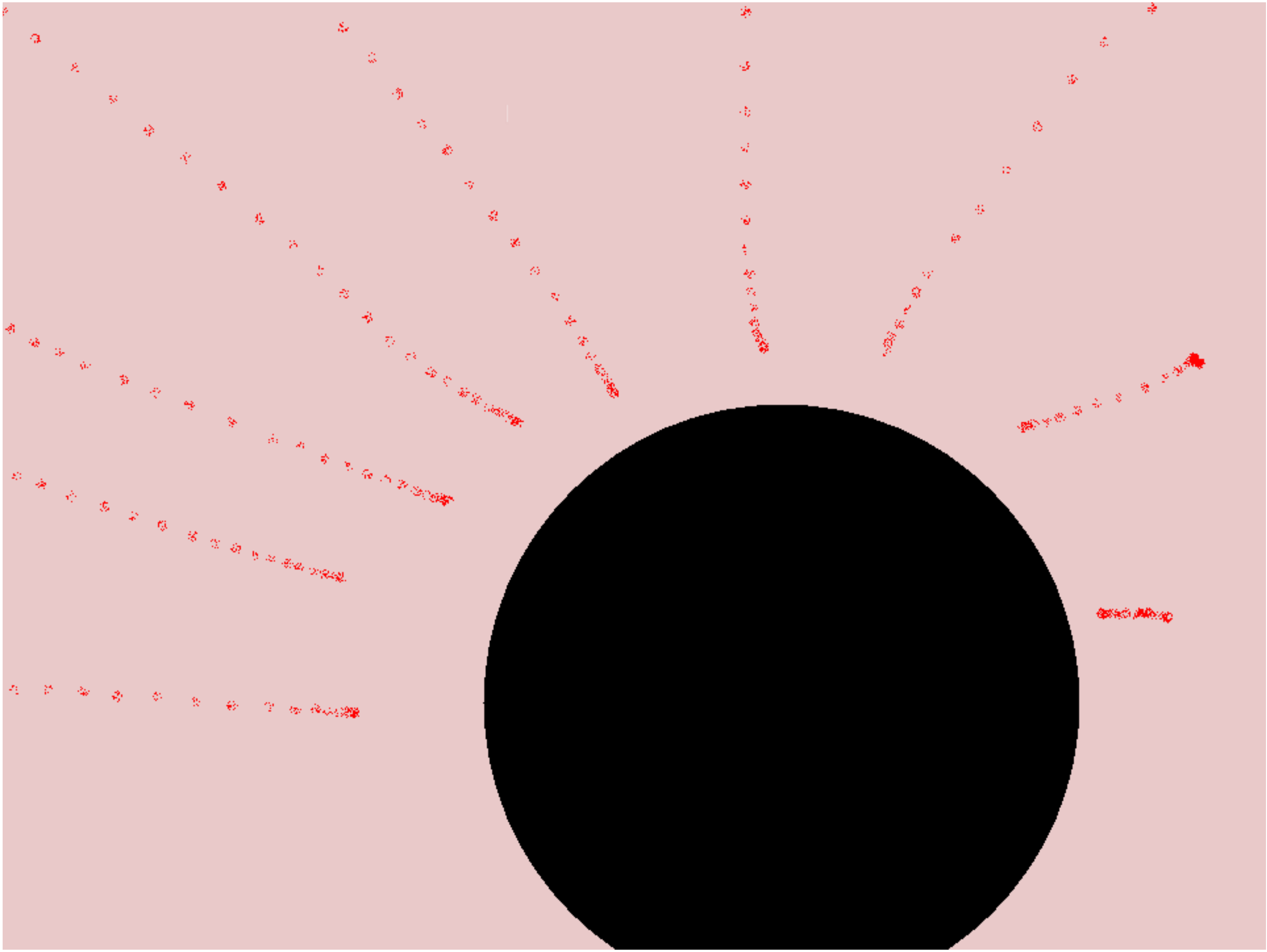


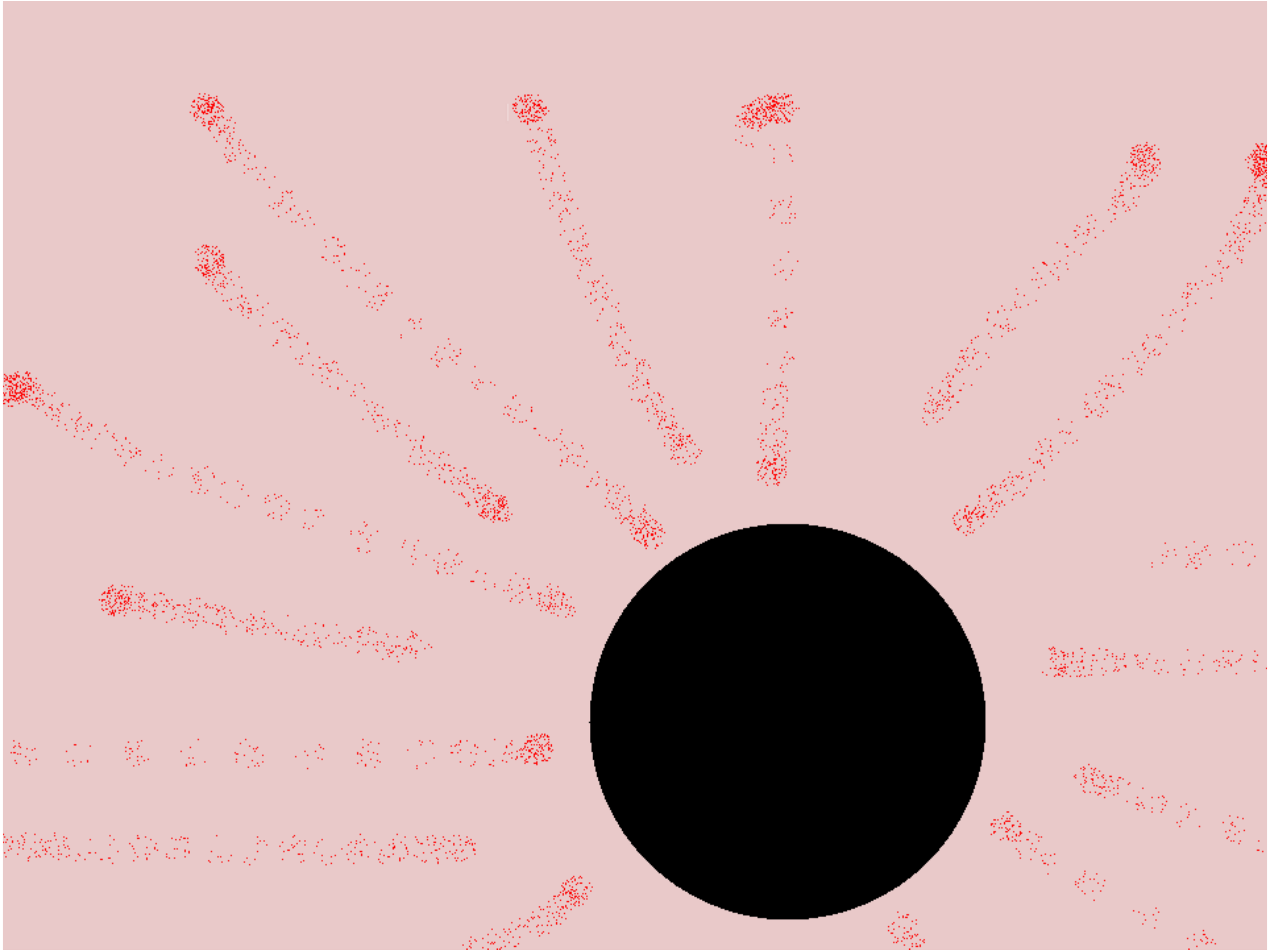
$$T = \frac{\hbar c}{4\pi R_s}$$

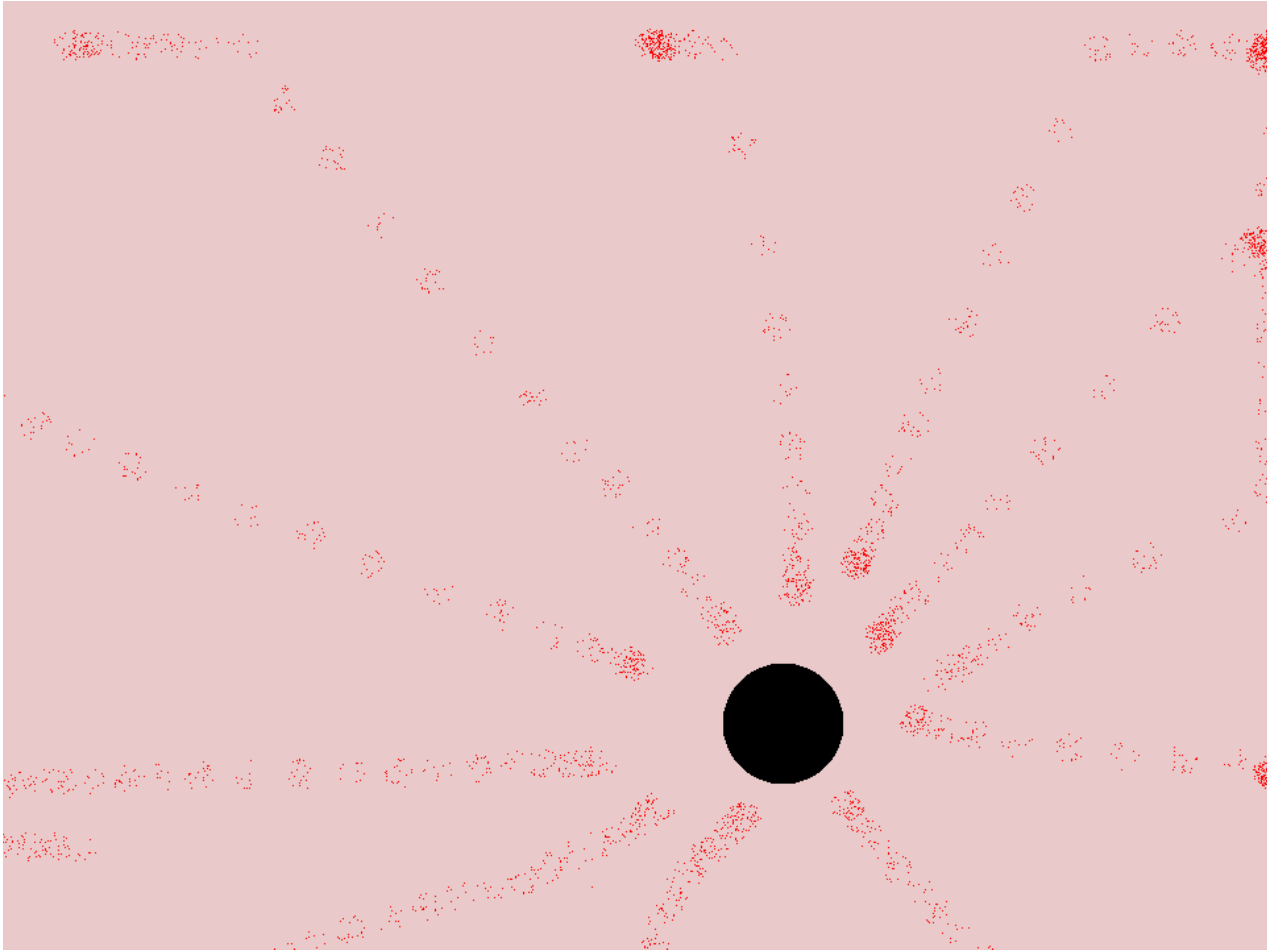
10^{-8} deg

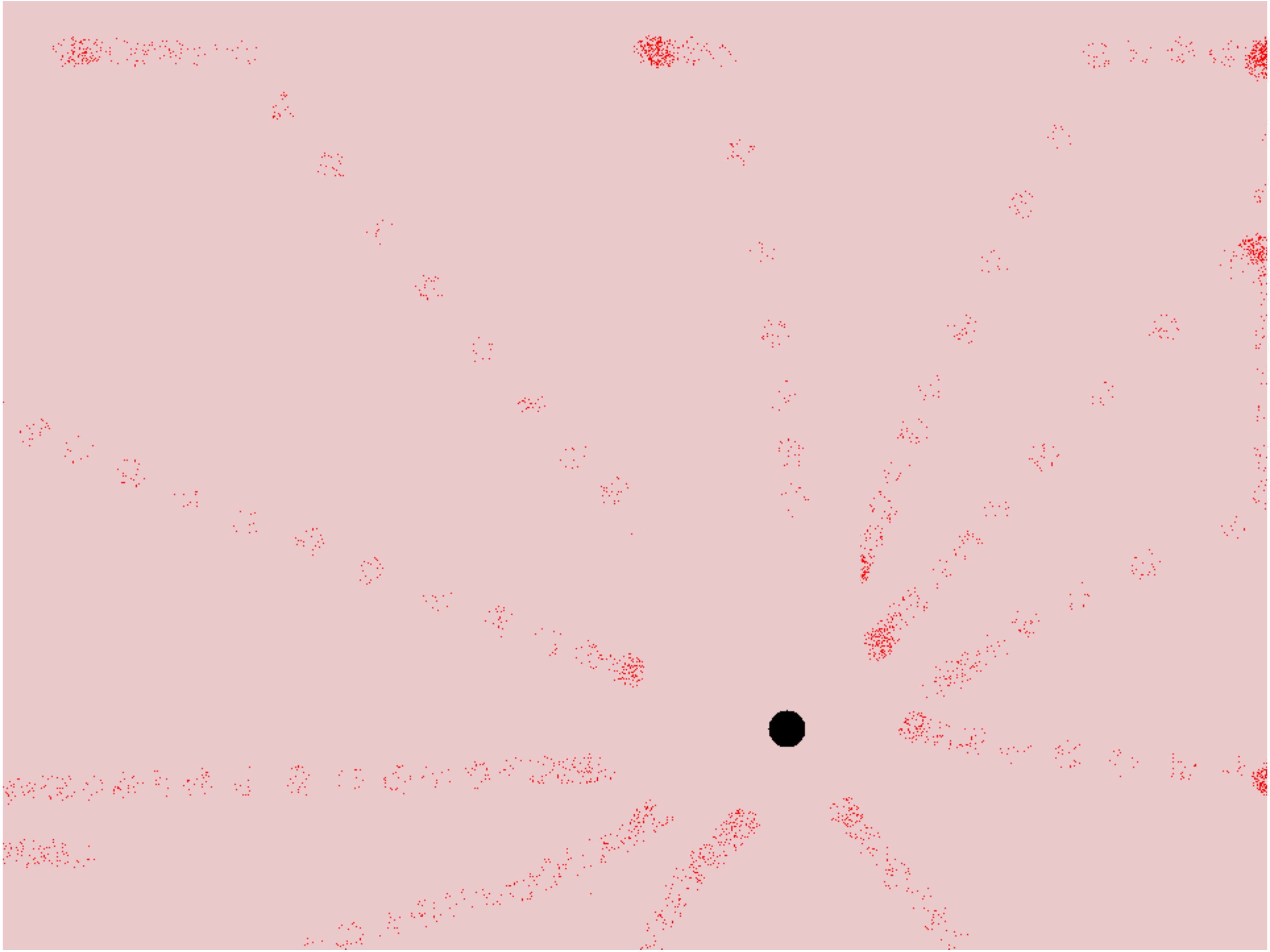








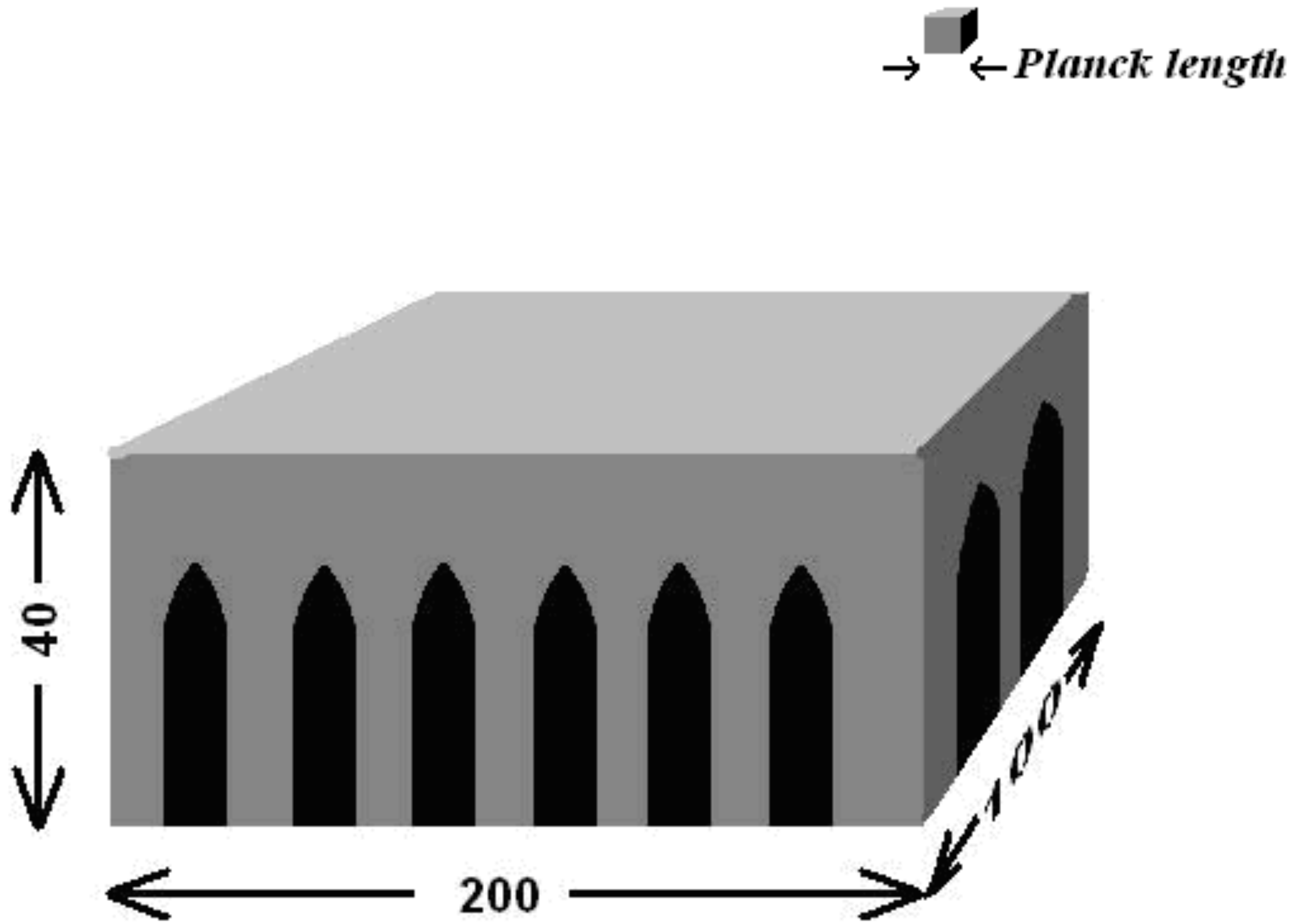




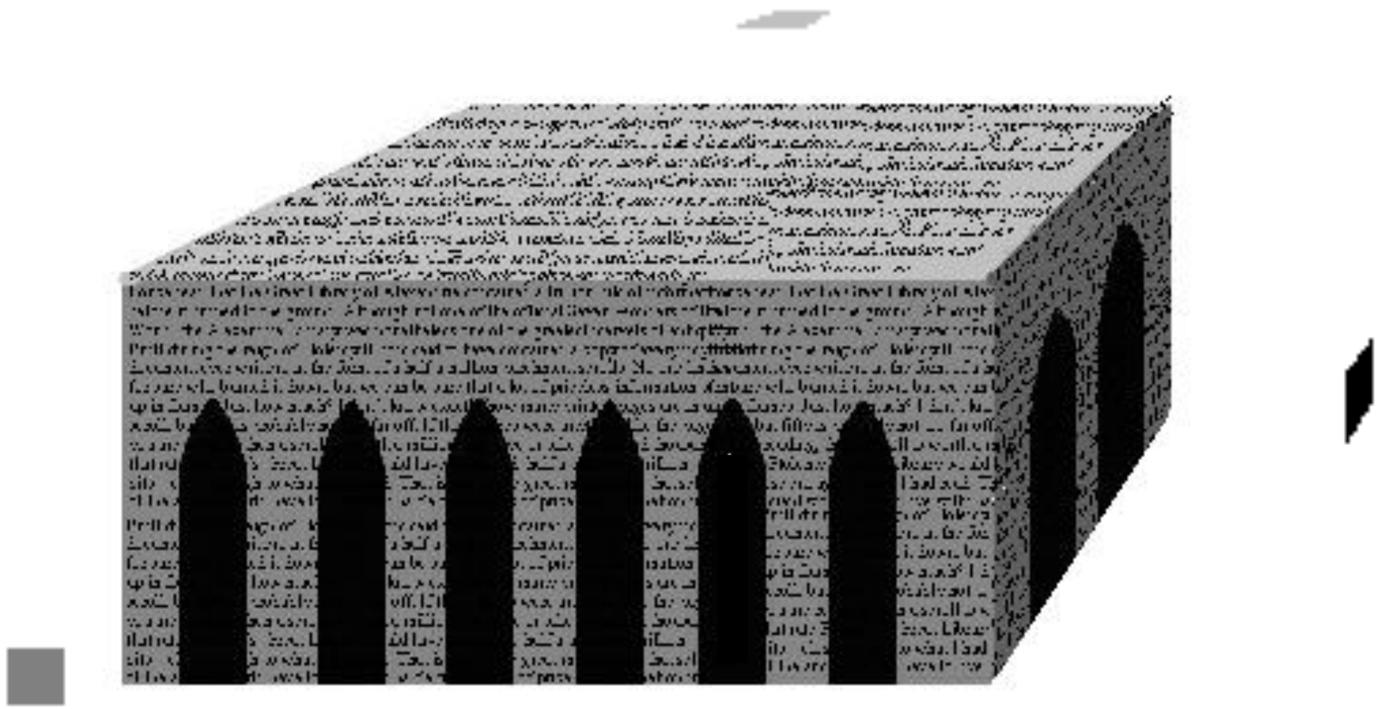
Where is Alice?

Where are her bits?

The horizon is a hologram.

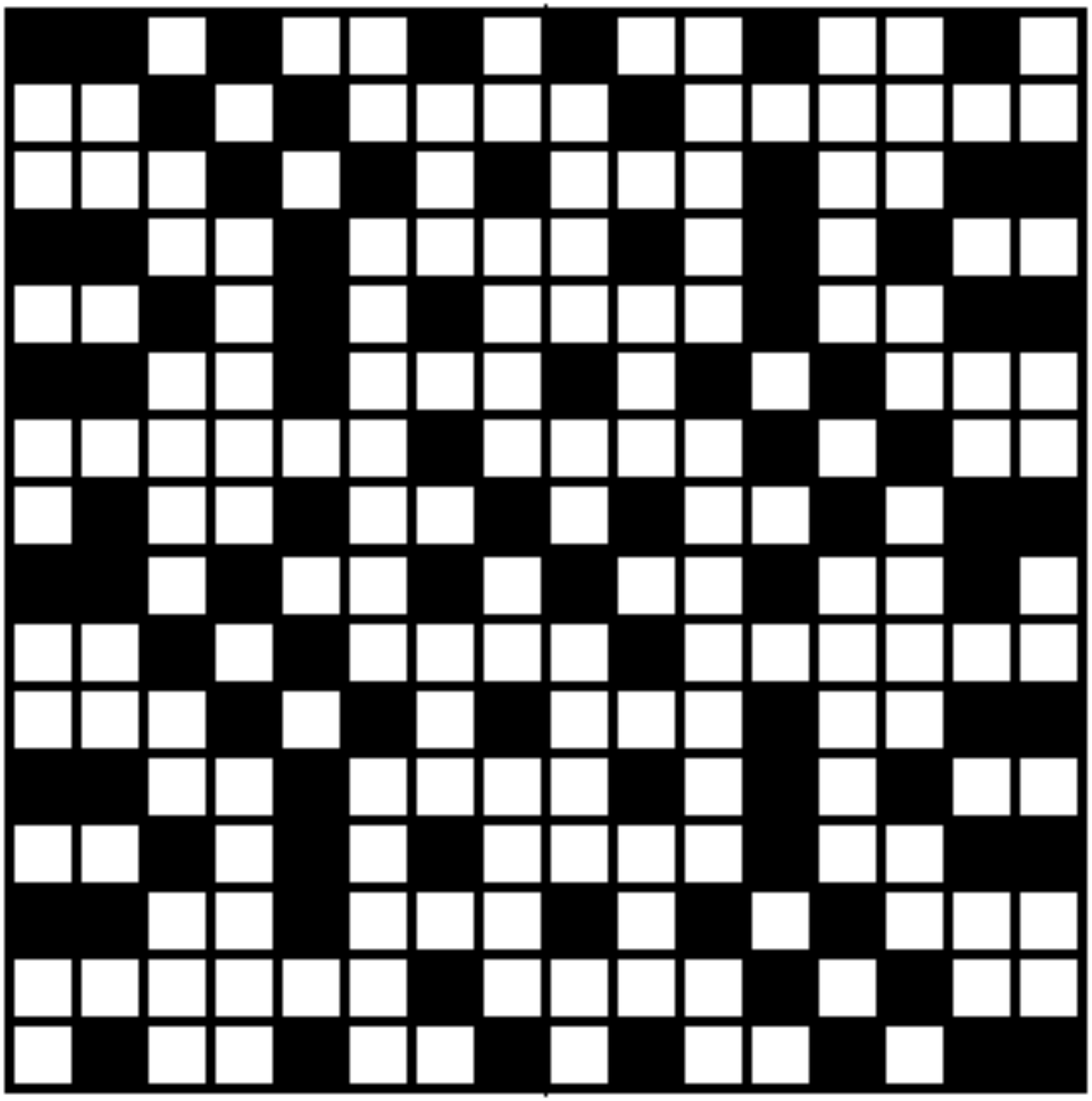


This library can hold 10^{108} bits of information.

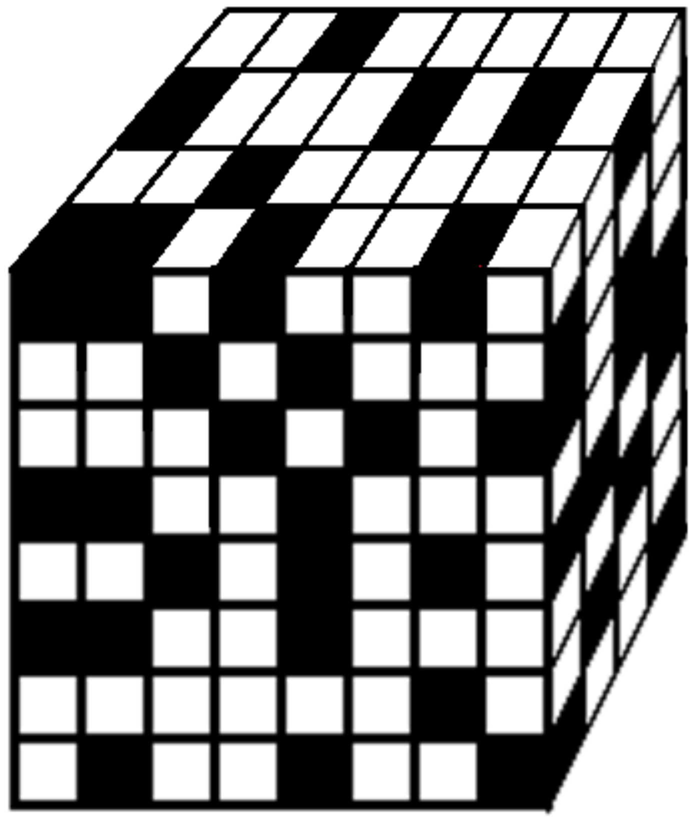


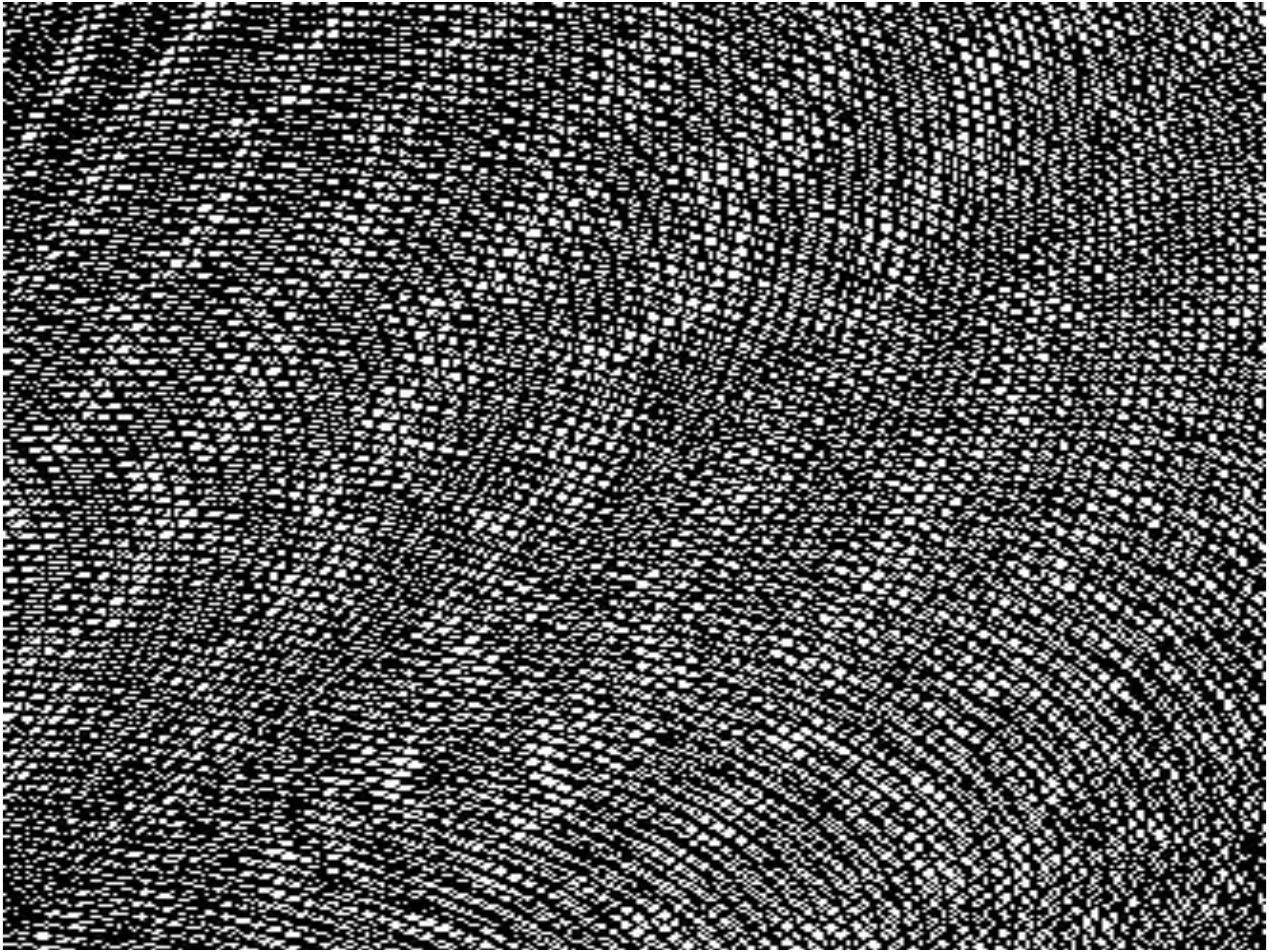
This library can only hold 10^{72} bits of information.

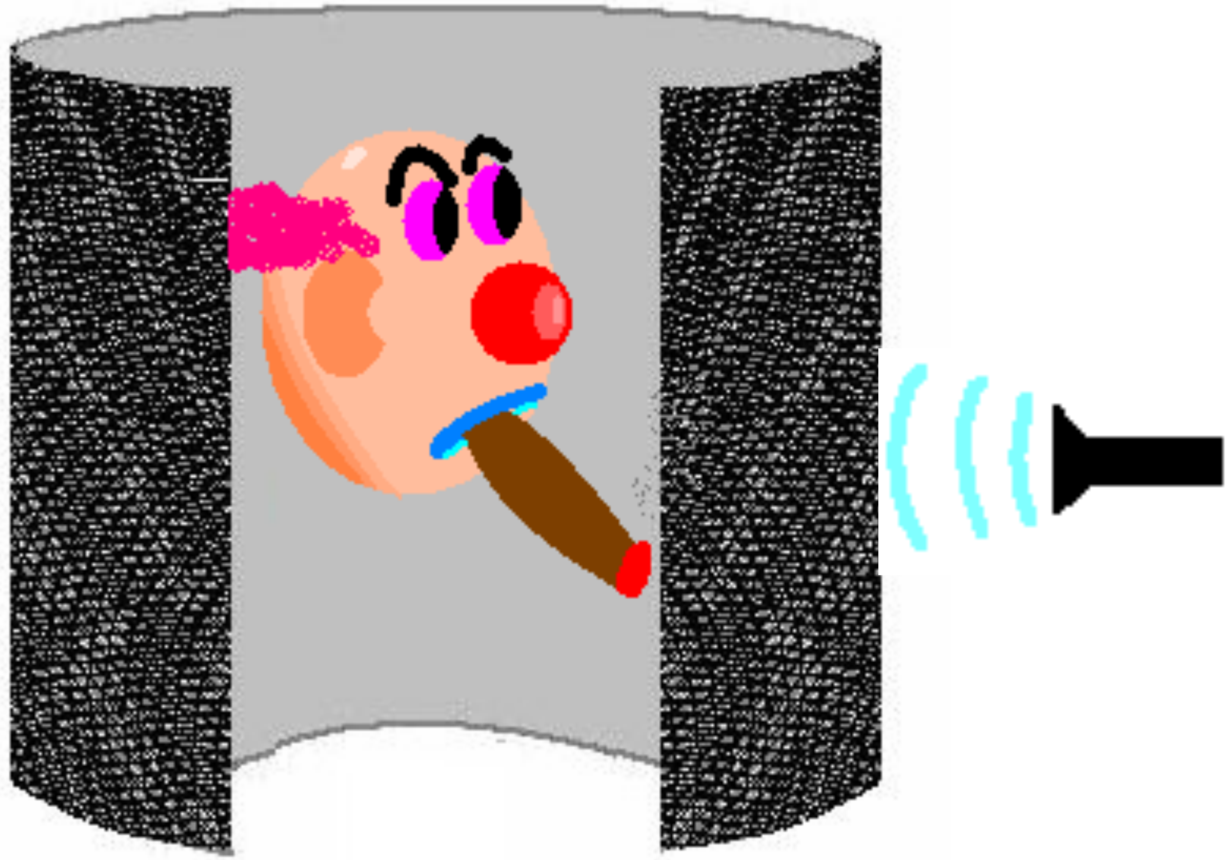
Pixels

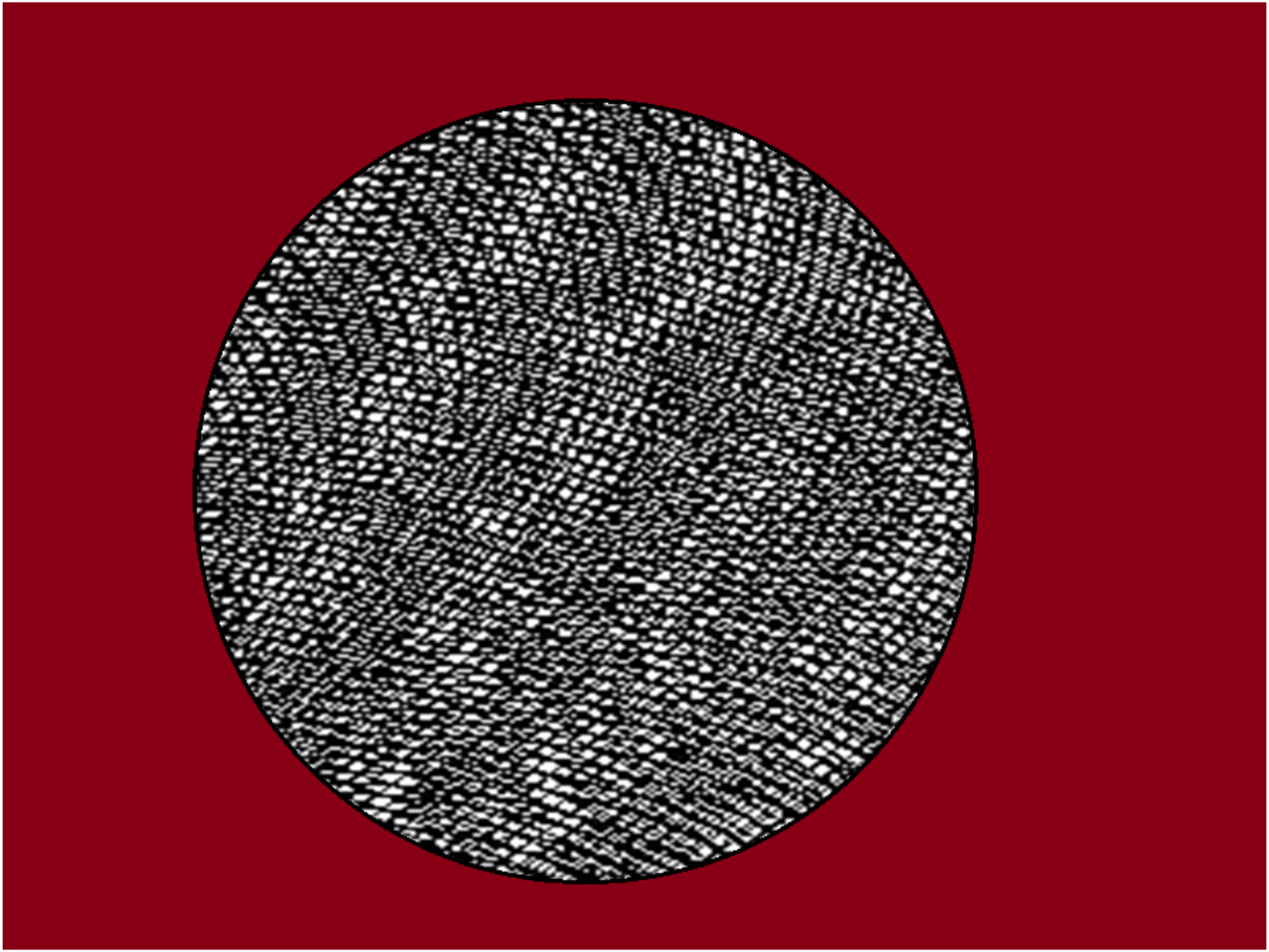


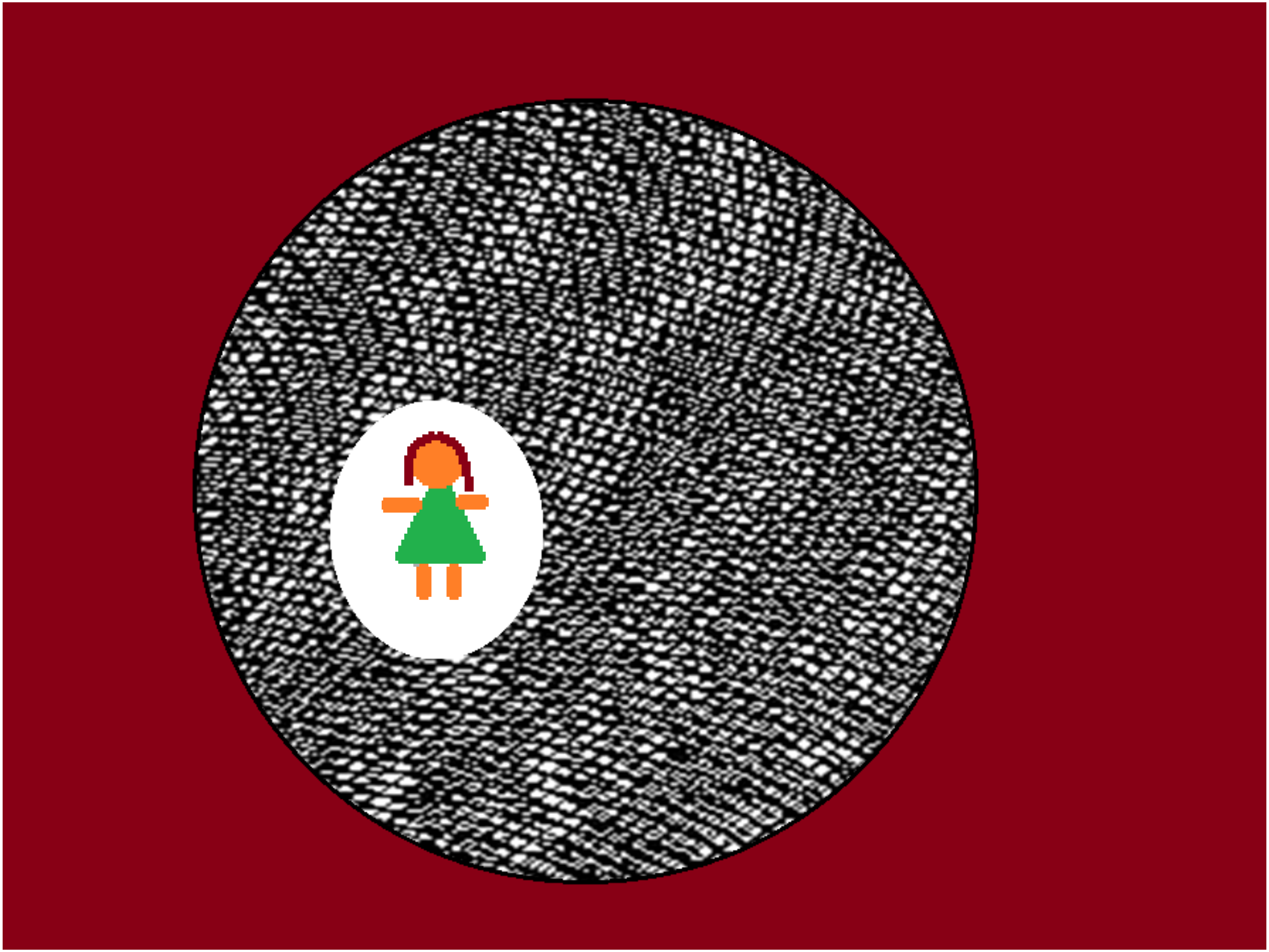
Voxels

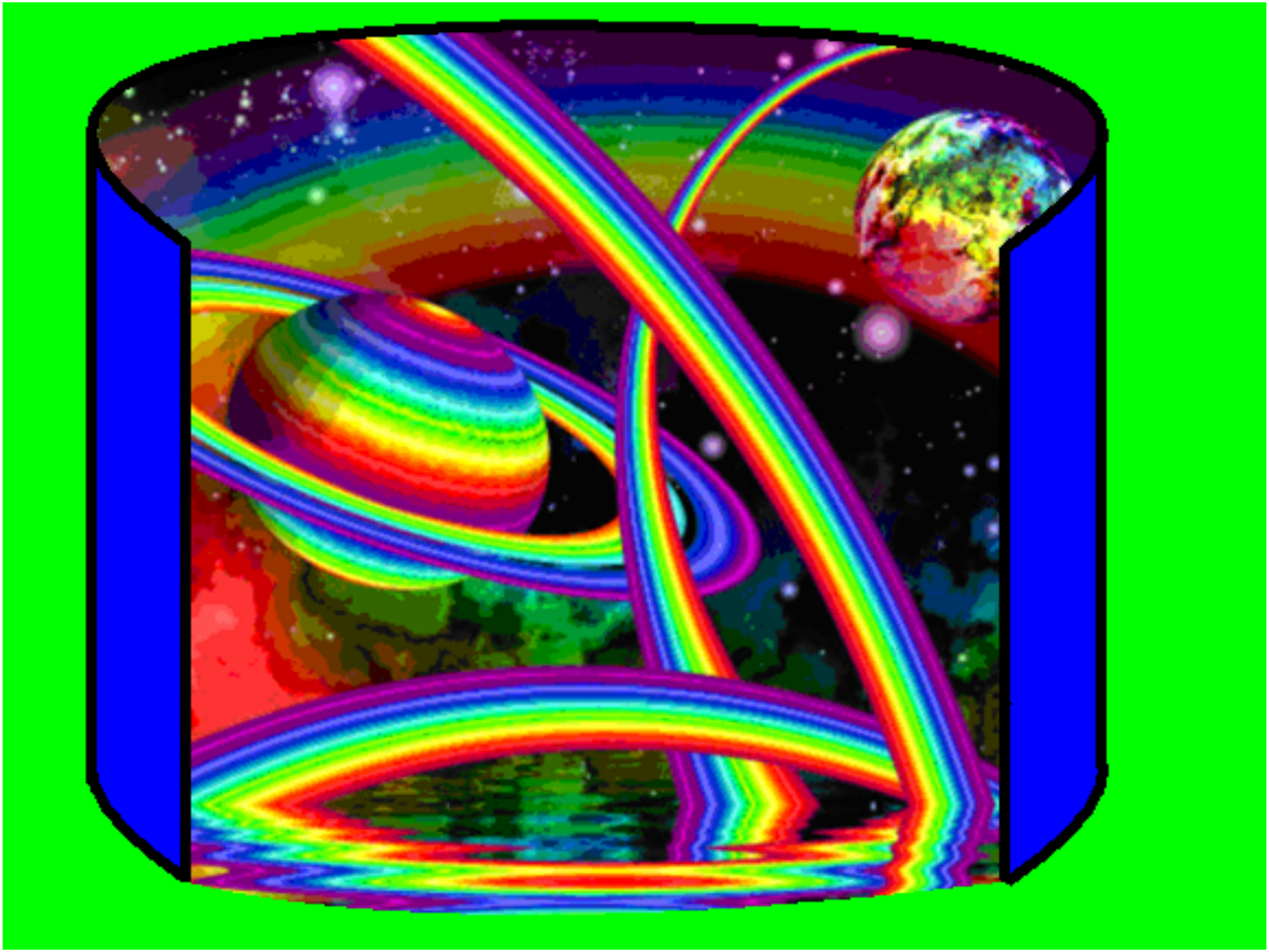












Juan Maldacena (1998)


Expect surprises

arXiv:1207.3123v2 [hep-th] 22 Aug 2012

Black Holes: Complementarity or Firewalls?

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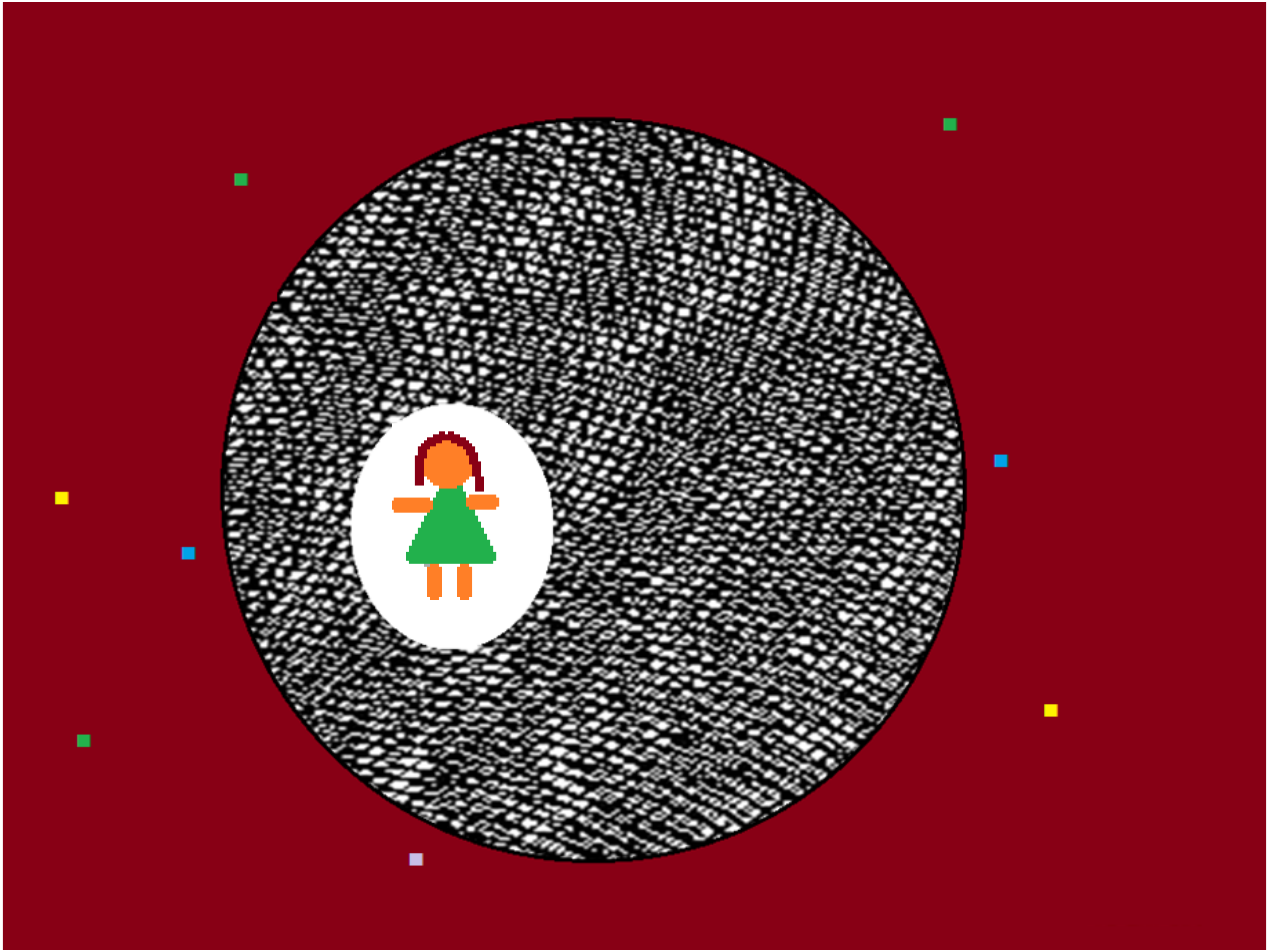
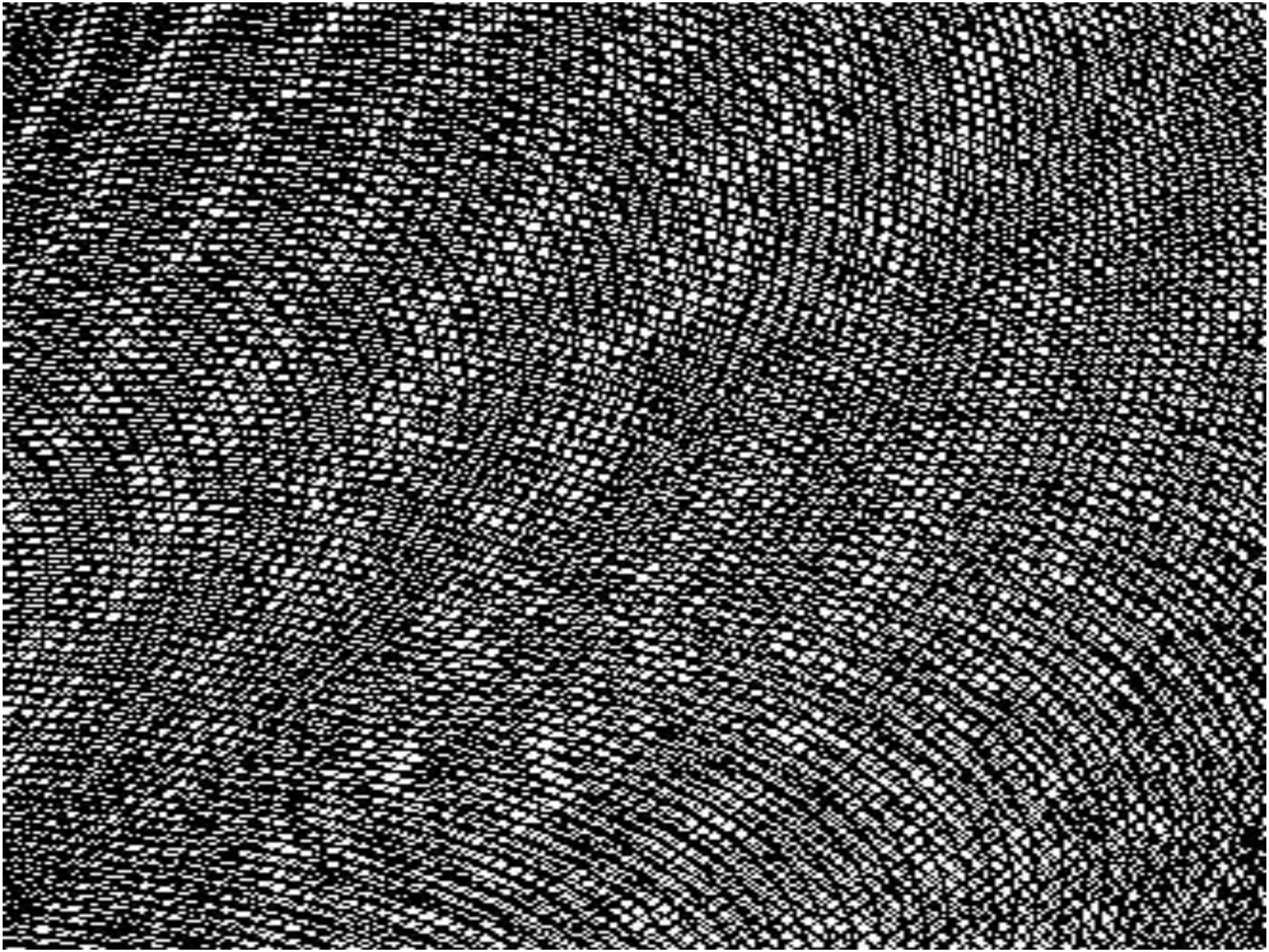
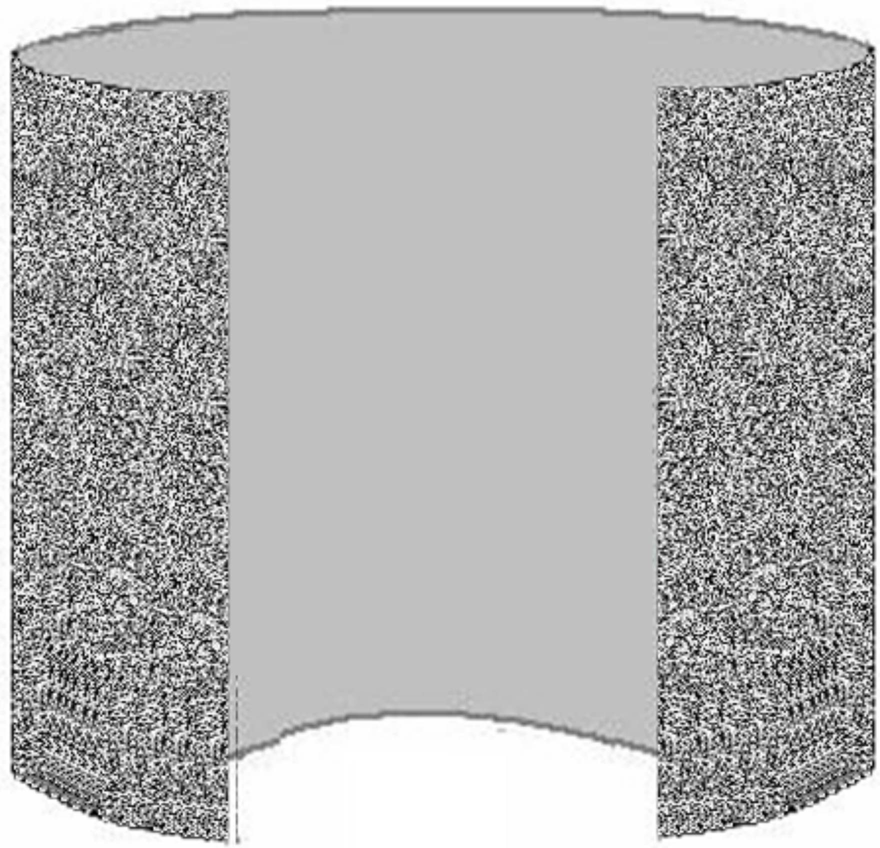
Abstract

We argue that the following three statements cannot all be true: (i) Hawking radiation is in a pure state, (ii) the information carried by the radiation is emitted from the region near the horizon, with low energy effective field theory valid beyond some microscopic distance from the horizon, and (iii) the infalling observer encounters nothing unusual at the horizon. Perhaps the most conservative resolution is that the infalling observer burns up at the horizon. Alternatives would seem to require novel dynamics that nevertheless cause notable violations of semiclassical physics at macroscopic distances from the horizon.

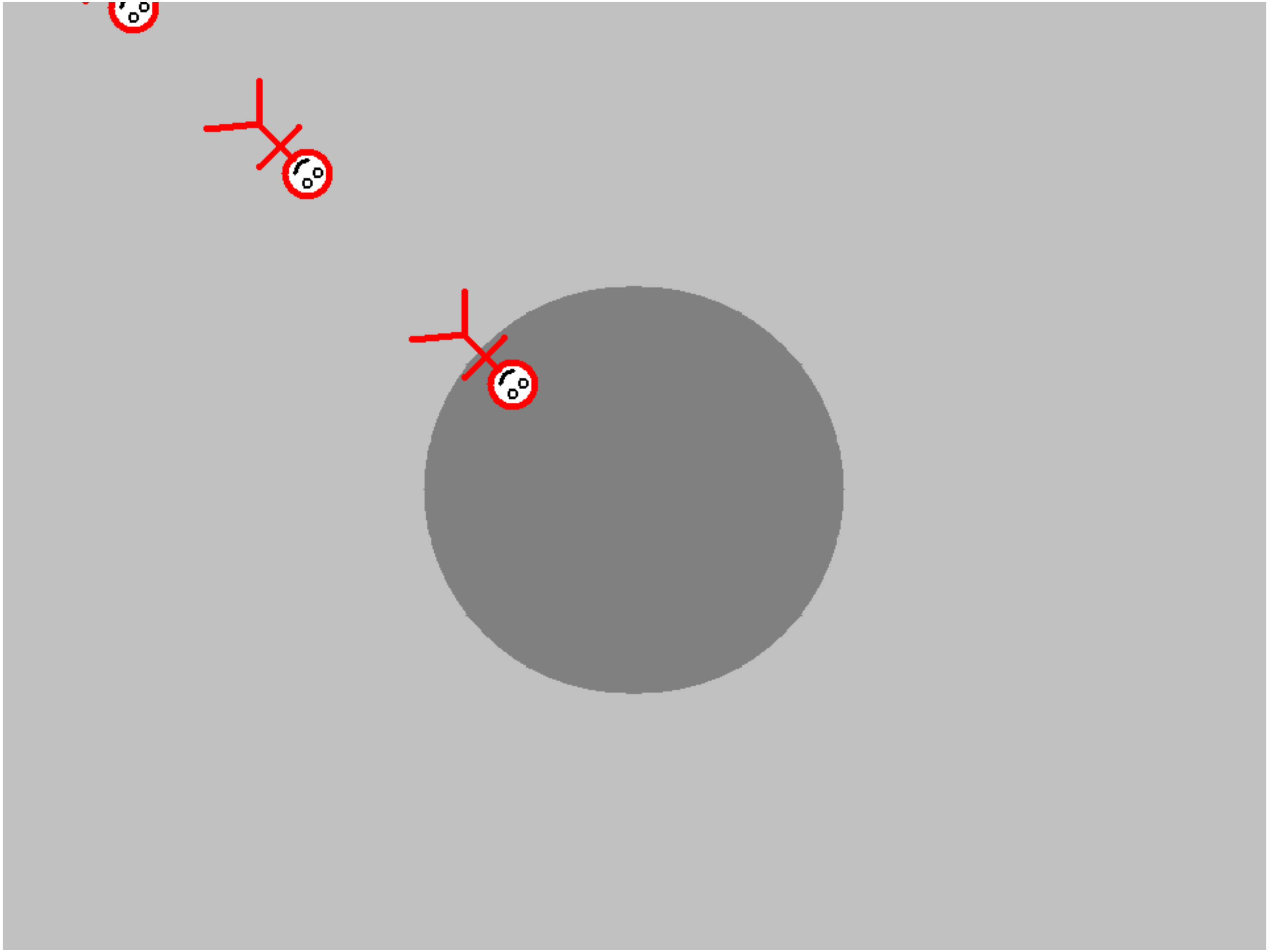


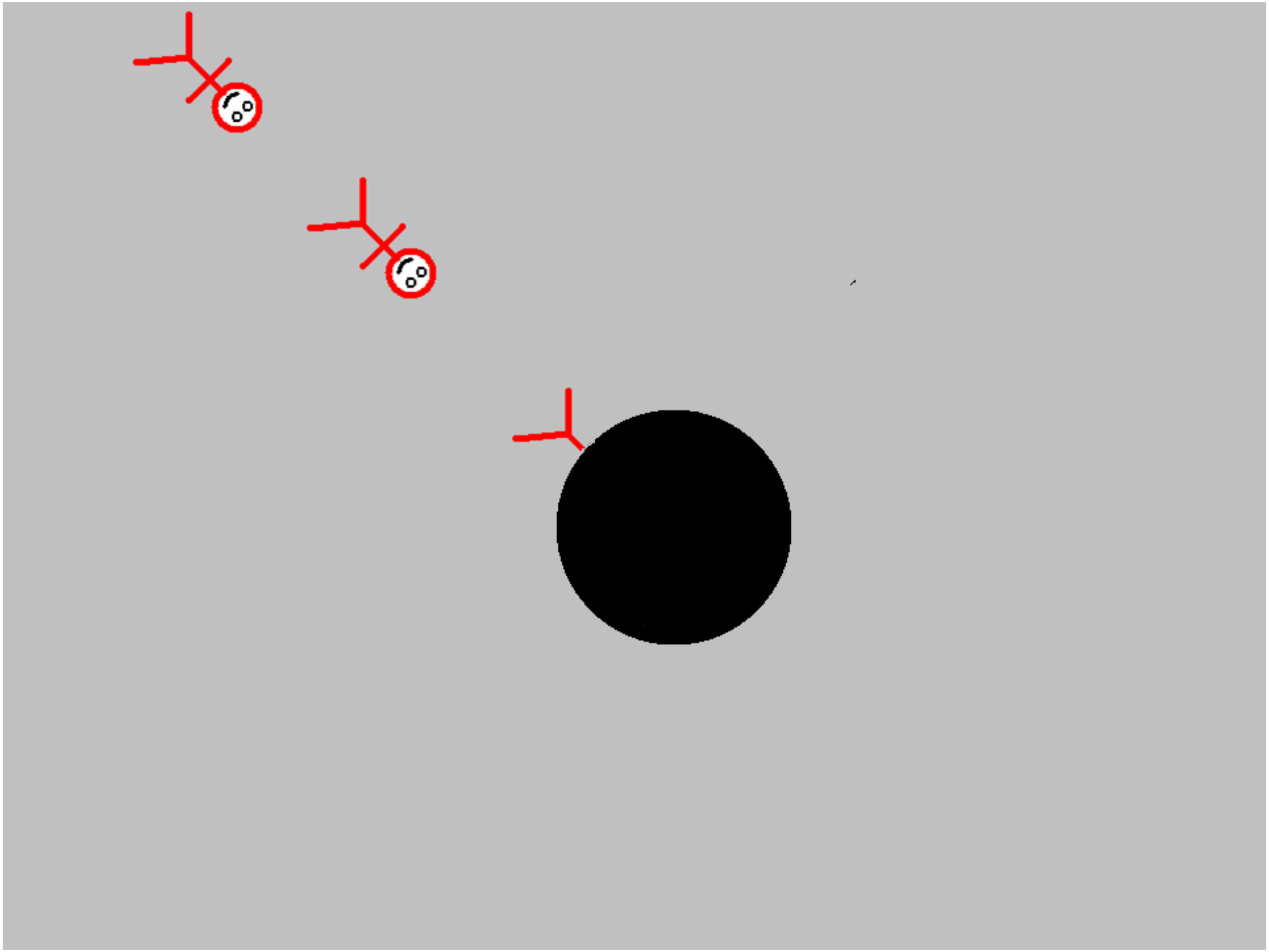




If AMPS are right how long does it take for the hologram to degrade?

$$t = \frac{R_s^{\,3} c^2}{\hbar G} = 10^{72}\, yr$$





The Firewall (end of space) is a violent breakdown of General Relativity. Is it right?

Something much more subtle?

We just don't know.

Hubble Law

V = H D