\[ R_s = \frac{2MG}{c^2} \]
The horizon is a point-of-no-return, but it’s not where the doom and destruction lie.
\[ T = \frac{\hbar c}{2\pi d} \]
\[ T = \frac{\hbar c}{2\pi d} \]
$T = 10^{32} \text{ deg}$
Information comes in bits.

*King Canute had warts on his chin.*
Bits are indestructible.
What happened to Alice’s bits?

Are they gone?

Where are they hiding?
Black holes have entropy.

1972 Jacob Bekenstein
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.

\[ T = 10^{32} \text{ degrees} \]
To make things even more confusing,

Black holes evaporate: Hawking (1974)
\[ T = \frac{\hbar c}{2\pi d} \]
\[ T = \frac{\hbar c}{4\pi R_s} \quad 10^{-8} \text{ deg} \]
Black holes evaporate.
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.
Voxels
Expect surprises
Black Holes: Complementarity or Firewalls?

Ahmed Almheiri,¹* Donald Marolf,²*† Joseph Polchinski,³† and James Sully⁴*  

*Department of Physics  
University of California  
Santa Barbara, CA 93106  

†Kavli Institute for Theoretical Physics  
University of California  
Santa Barbara, CA 93106-4030  

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?

\[ t = \frac{R_s^3 c^2}{\hbar G} = 10^{72} \text{ yr} \]
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

\[ V = H D \]