Inside Black Holes

Why do we care? By definition:

- no observer *outside* the horizon can learn anything about what is going on inside

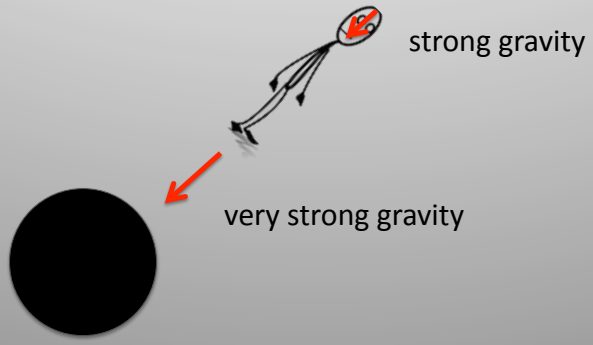
Inside Black Holes

Why do we care?

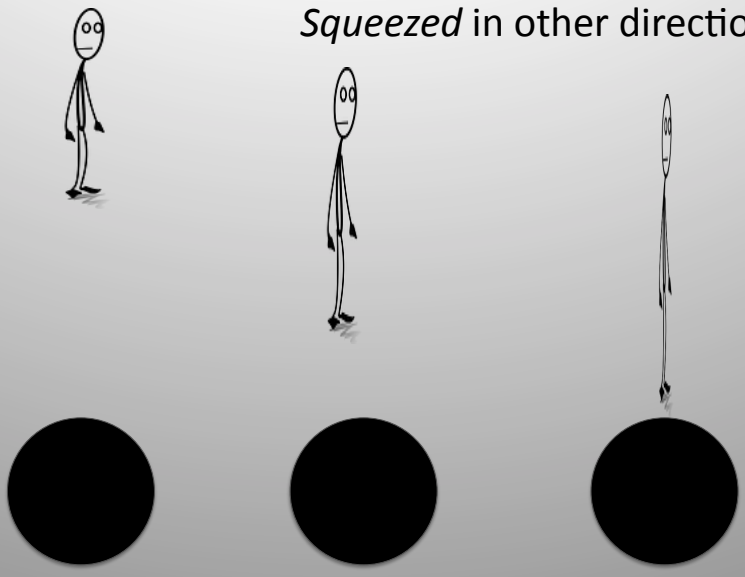
- conditions inside a black hole are more extreme than anywhere else in the Universe
- Hawking radiation: black hole will (in principle) cease to exist, inside is not permanently sealed off

Dangers of falling into a black hole (apart from not being able to get back out!):

1. Tidal gravity



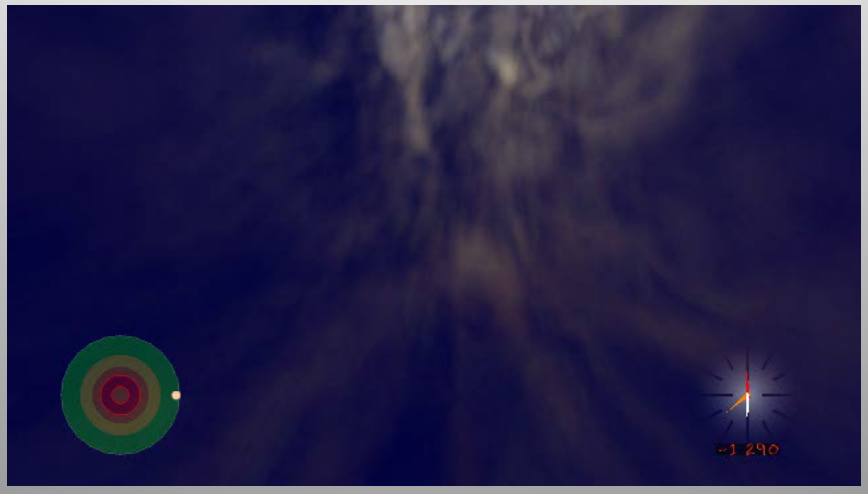
Stretched in one direction
Squeezed in other direction



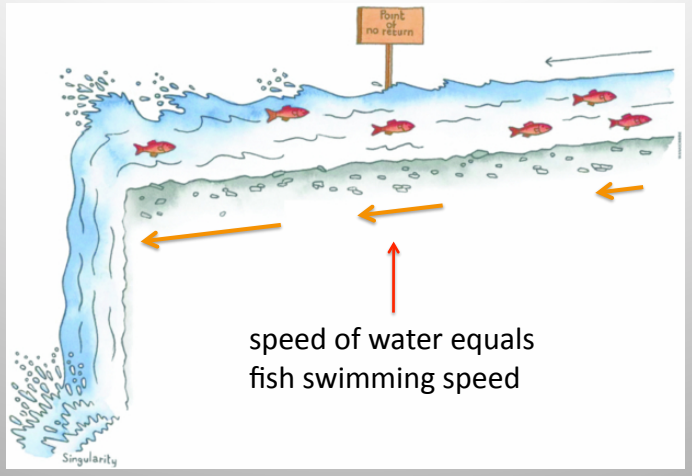
Hazard depends on the black hole mass:

- stellar mass black hole – tidal forces will kill you *before* you cross the horizon
- supermassive black hole – tidal forces are weaker… can cross the horizon into the interior without any problem (in classical general relativity)

Nothing special or remarkable to see as the event horizon is crossed



Visualization: Andrew Hamilton



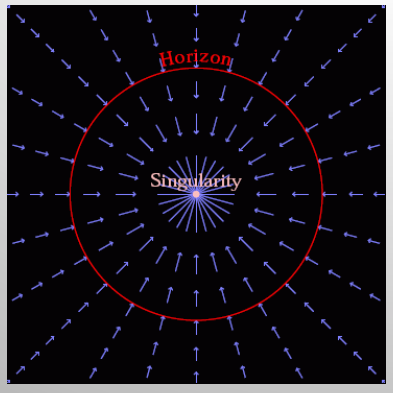
Imagine space is "flowing" into the black hole: event horizon is where inflow speed = c – can't "swim" upstream and out no matter what you do

Dangers of falling into a black hole (apart from not being able to get back out!):

2. Encountering a singularity

Singularity = place where known laws of physics break down, e.g.

- curvature becomes infinite
- infinite energy density
- …

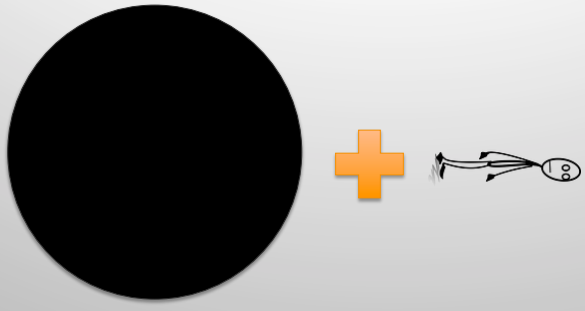


Perfectly spherical black hole (Schwarzschild solution)

Visualization: Andrew Hamilton

Singularity is a simple point, where tidal forces become infinite

Impossible to avoid: if you fall into the black hole, reach the singularity in a finite time



Not realistic – if you fall into a perfectly spherical black hole, it's no longer perfectly spherical!

Singularity theorem

Trapped surface: surface within which all light rays (ingoing or outgoing) converge

Every trapped surface must contain a singularity

Proved by Roger Penrose – means every black hole must contain a singularity, even in complex cases where it's hard to work out where and of what type

Cosmic censorship

("inverse" argument) **Every singularity is hidden behind an event horizon**

Only a hypothesis, though if counter-examples exist seems very unlikely they would be realized in any naturally occurring process

Cosmic censorship

Whereas Stephen W. Hawking firmly believes that naked singularities are an anathema and should be prohibited by the laws of classical physics,

And whereas John Preskill and Kip Thorne regard naked singularities as quantum gravitational objects that might exist unclothed by horizons, for all the Universe to see,

Therefore Hawking offers and Preskill/Thorne accept, a wager with odds of 100 pounds sterling to 50 pounds sterling, that

When any form of classical matter or field that is incapable of becoming singular in flat spacetime is coupled to general relativity via the classical Einstein equations, the result can never be a naked singularity.

The loser will reward the winner with clothing to cover the winner's nakedness. The clothing is to be embroidered with a suitable concessionary message.

Stephen W. Hawking, John P. Preskill, Kip S. Thorne
Pasadena, California, 24 September 1991

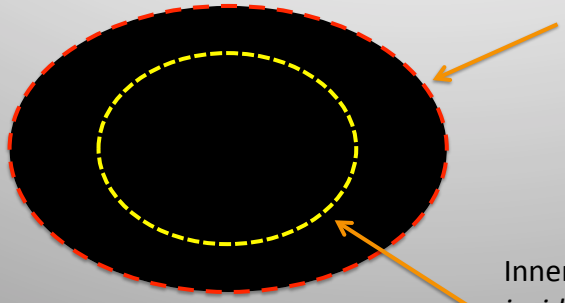
Conceded on a technicality by Stephen W. Hawking, 5 February 1997

Inside real black holes

- rotating
- charged
- with matter and radiation falling in

Must be a singularity but it need not be a point, physics inside can be very complex *even ignoring quantum gravity effects*

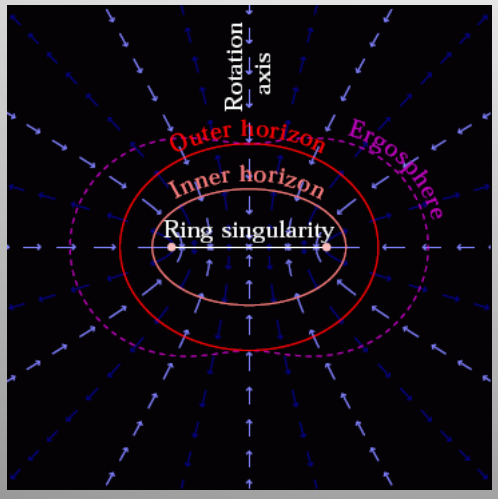
Inside real black holes



Event horizon: surface beyond which matter, radiation, information from inside cannot pass

Inner (Cauchy) horizon: *inside* here the singularity is visible and we need to know what happens at the singularity to predict what happens

Inside real black holes

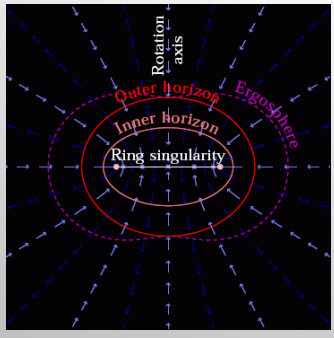


Visualization: Andrew Hamilton

Can imagine all manner of weird and wonderful stuff inside the inner horizon (wormholes, white holes, portals to other universes)

Inside real black holes

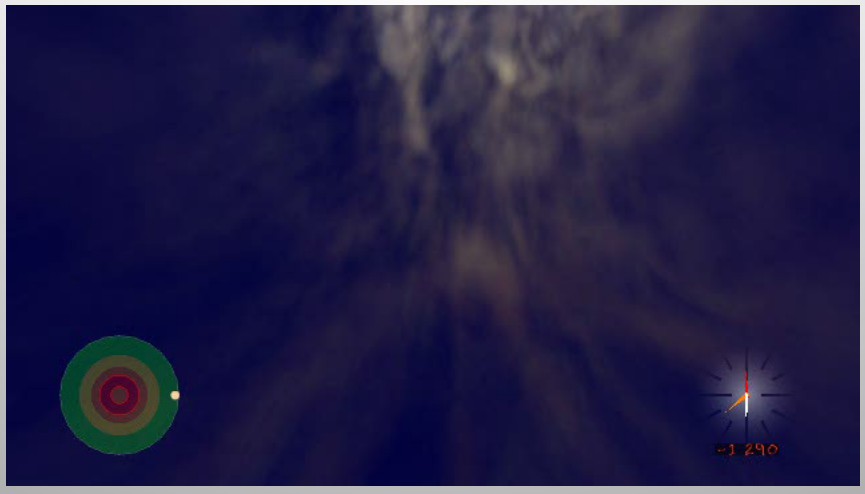
Formal / idealized / *unrealistic* mathematical solutions to equations of general relativity ☹



Energy density becomes infinite at the inner horizon

(still inside the event horizon, so this doesn't affect what an external observer measures)

- would kill you
- destroys the idealized solutions with the cool stuff going on further inside



- Low mass BH: tides "spaghettify" you
- 10^9 Solar mass BH: survive for some hours inside before being vaporized by infinitely bright flash of radiation

Irrespective of whether you could make it inside…

- predict regions inside a black hole where general relativity must break down – spacetime curvature or energy becomes so large that quantum effects become important
- usually assumed that the classical solutions are a good "first guess" to what really happens