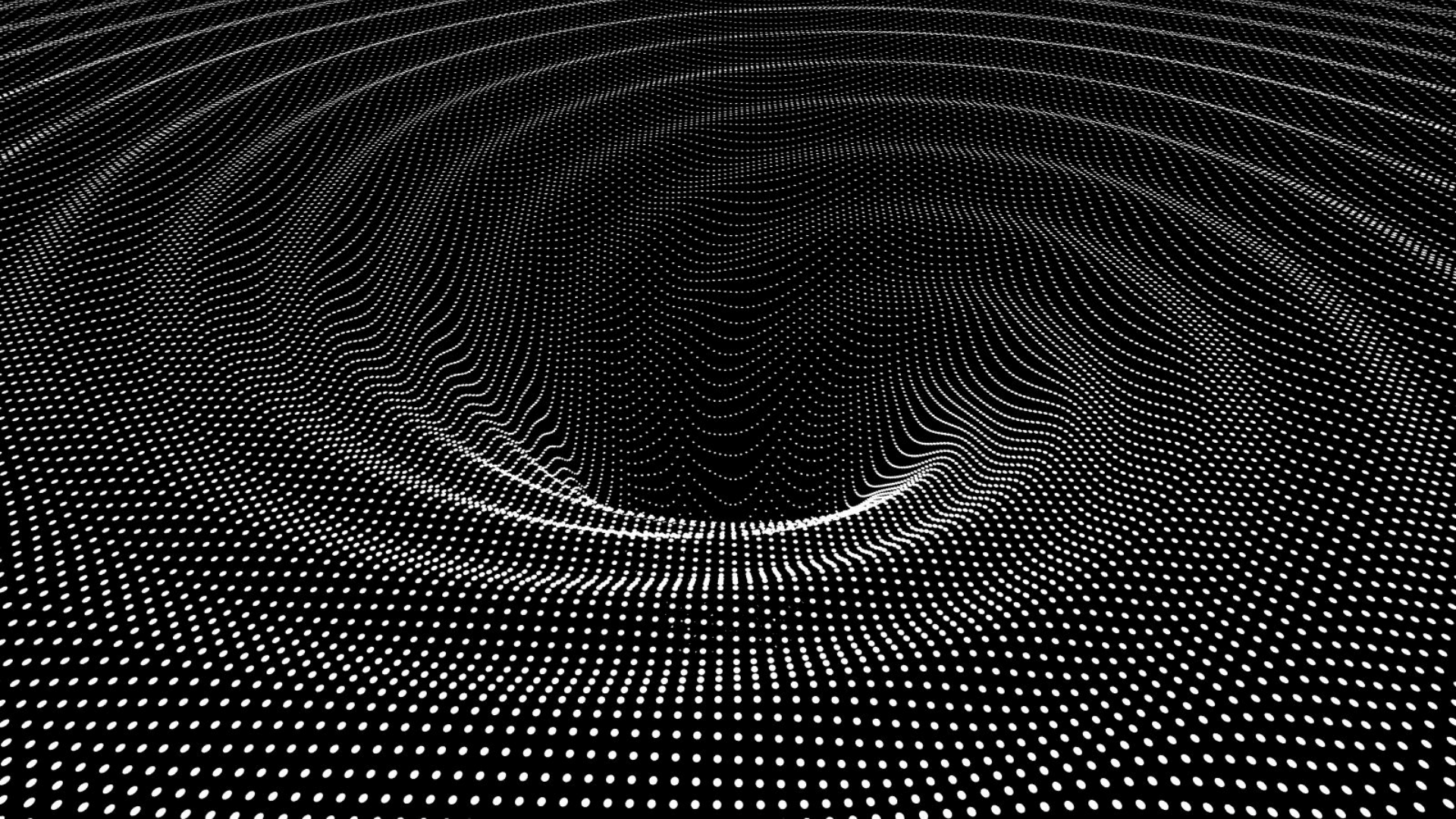
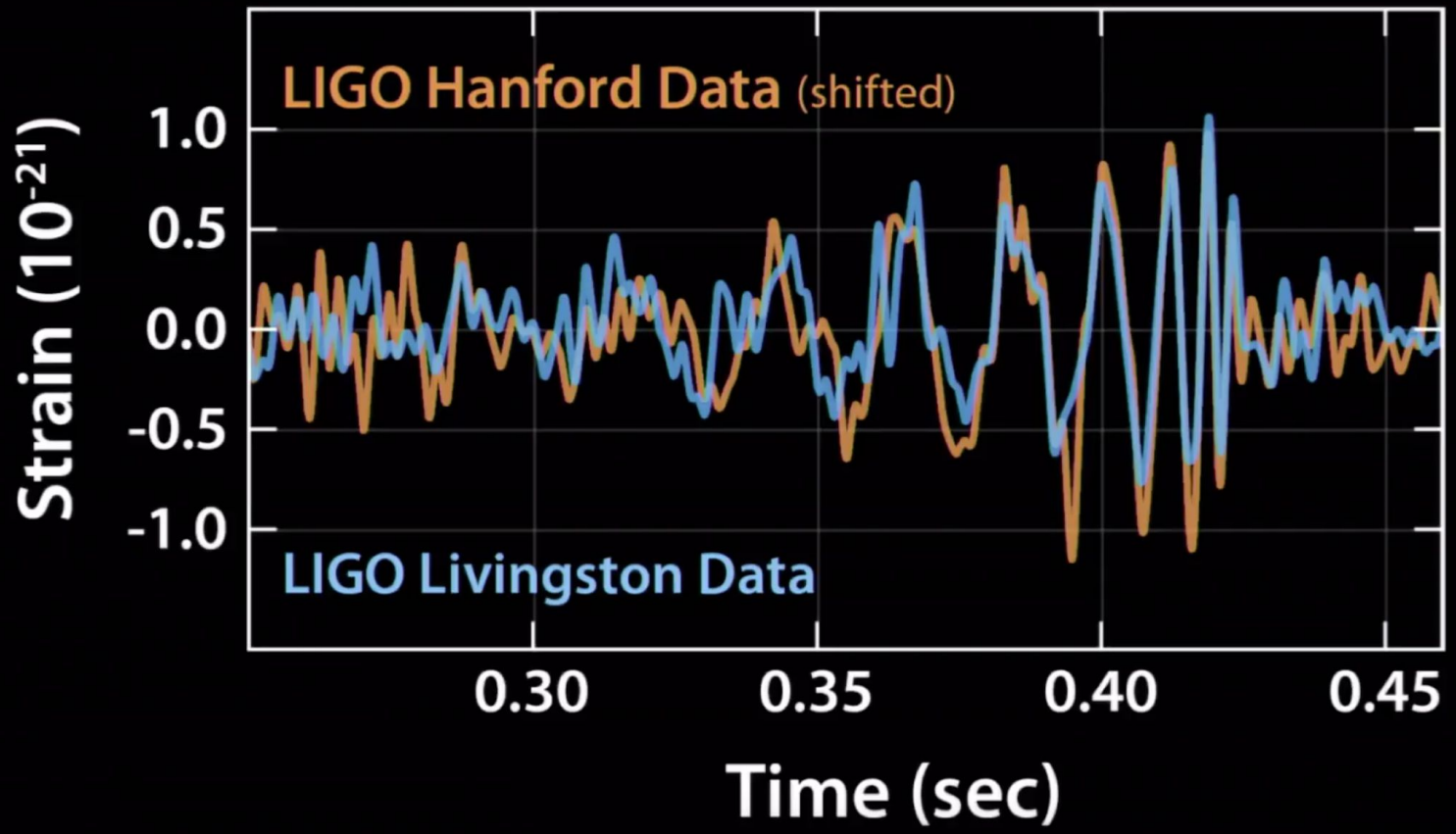
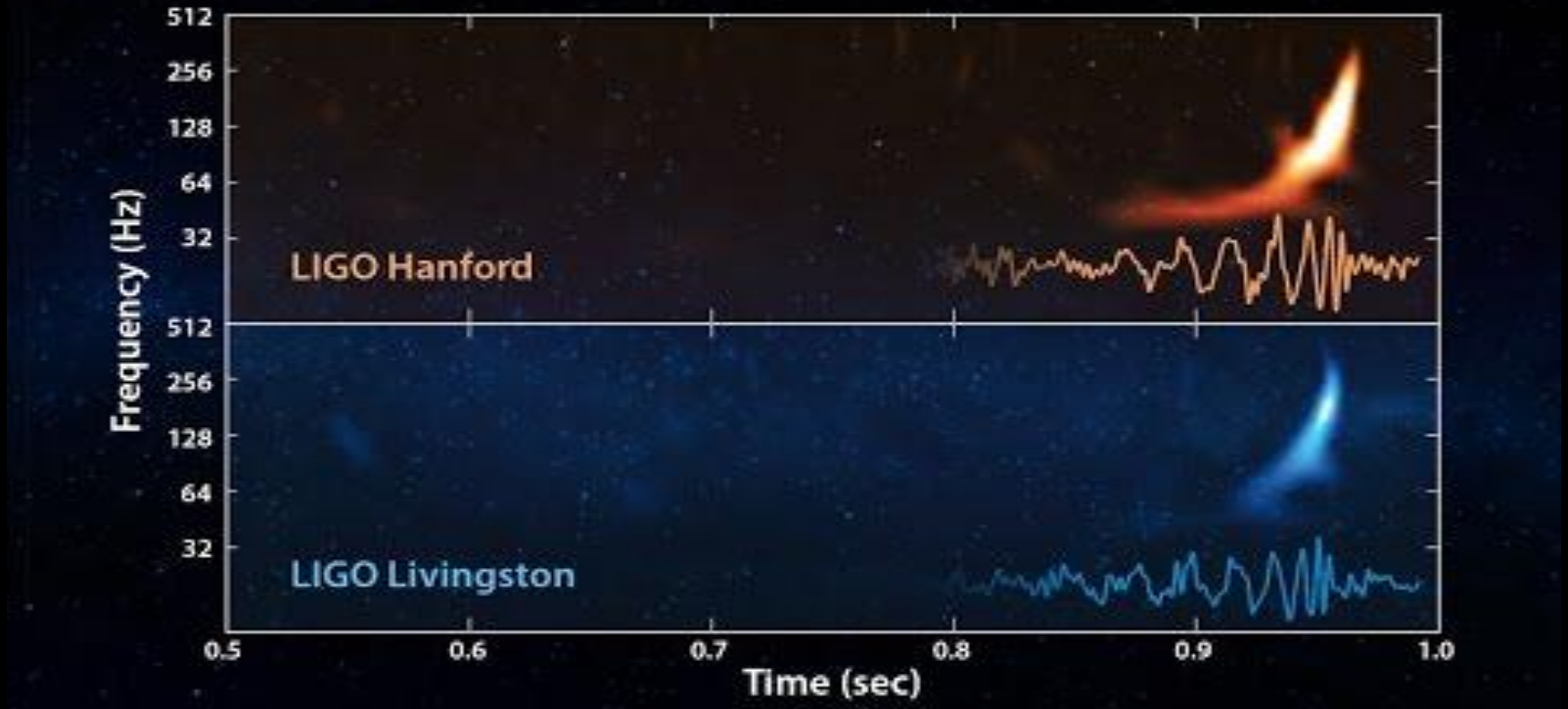
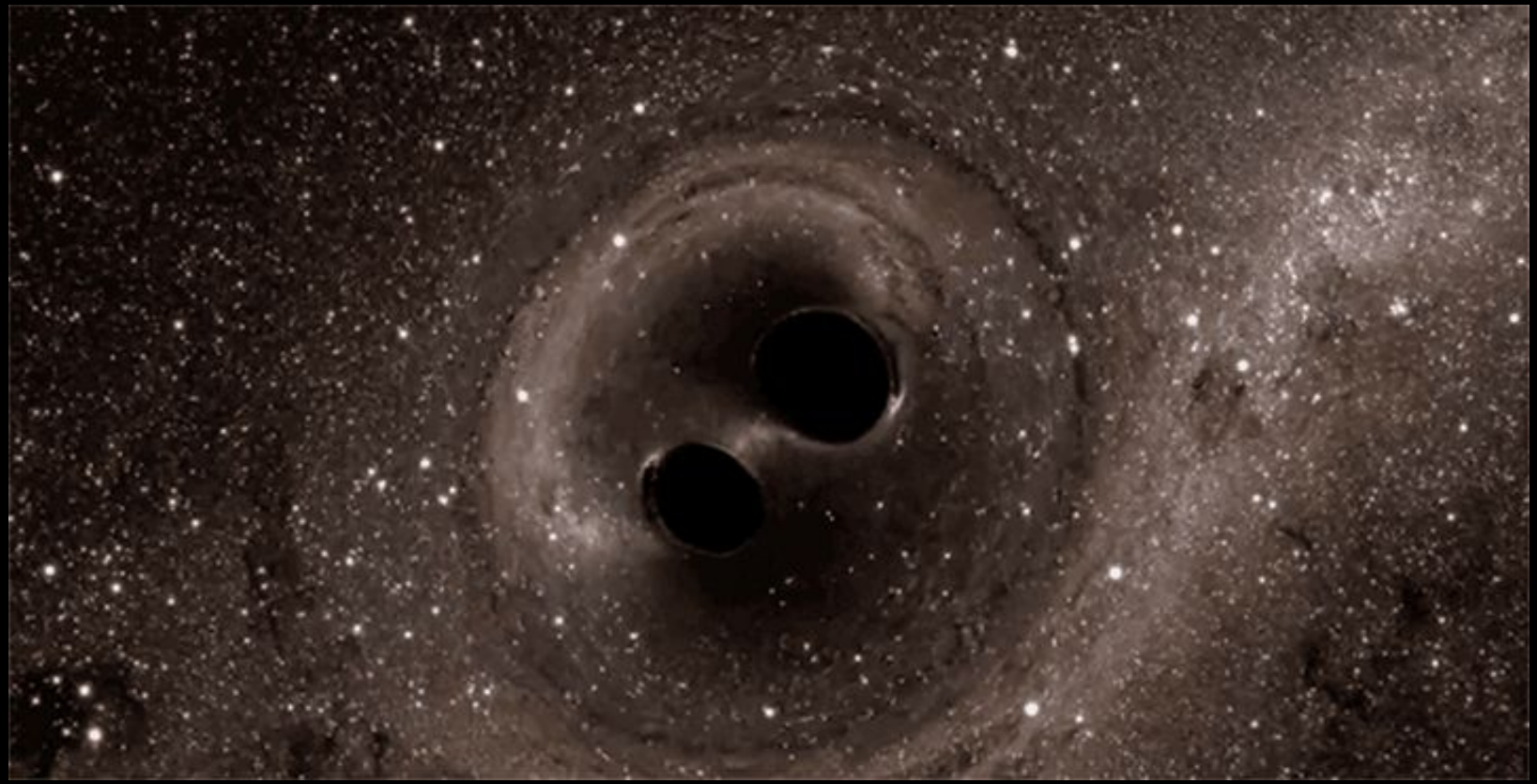


black holes!

splash 2019


LIGO Hanford Data (shifted)
LIGO Livingston Data
Strain (10-21)
1.0
0.5
0.0
-0.5
-1.0
0.30
0.35
0.40
0.45
Time (sec)


512
256
128
64
32
LIGO Hanford
512
256
128
64
32
LIGO Livingston
Frequency (Hz)
0.5
0.6
0.7
0.8
0.9
1.0
Time (sec)



what is a black hole??

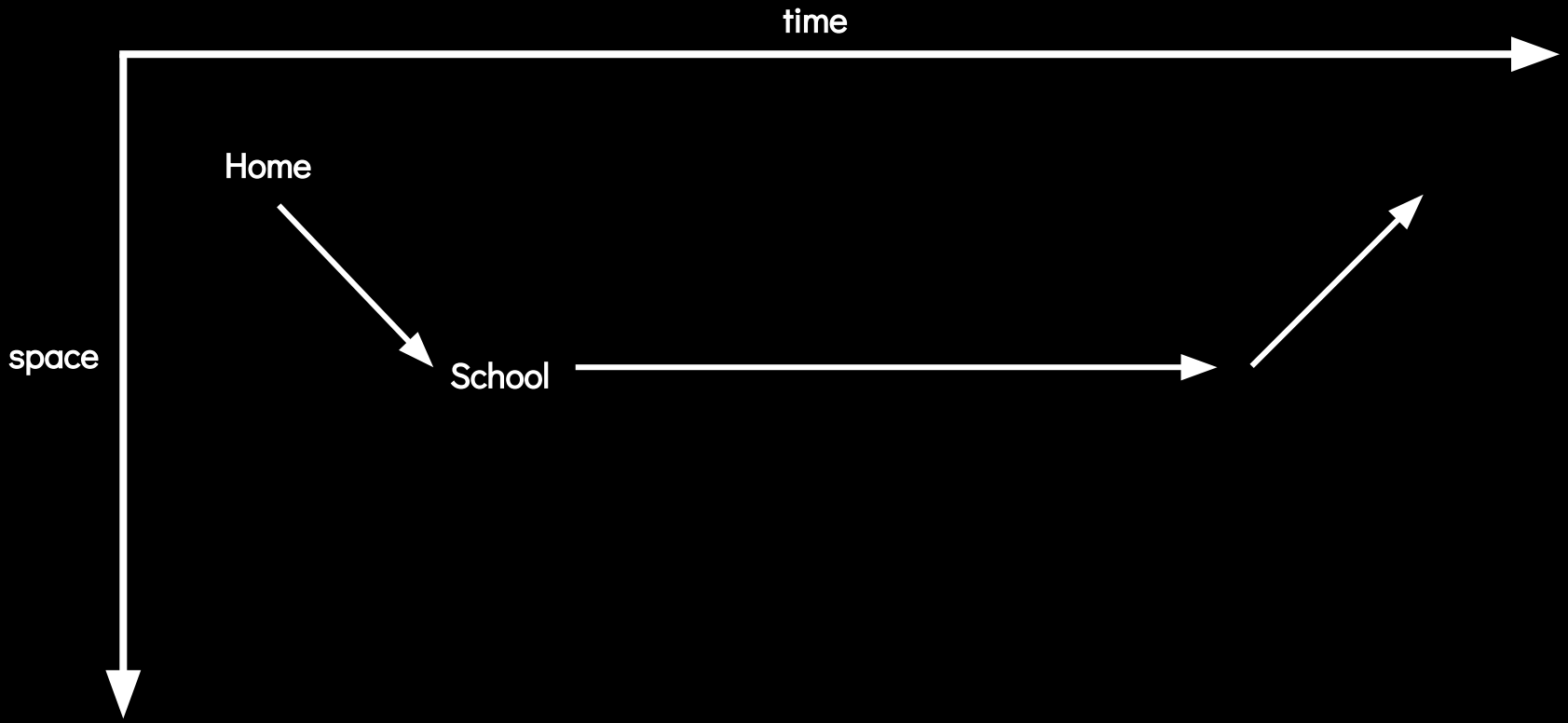
a black hole is a region of spacetime where the force of gravity is so strong that nothing, not even light, can escape.

let’s talk about relativity!

299 792 458 m/s

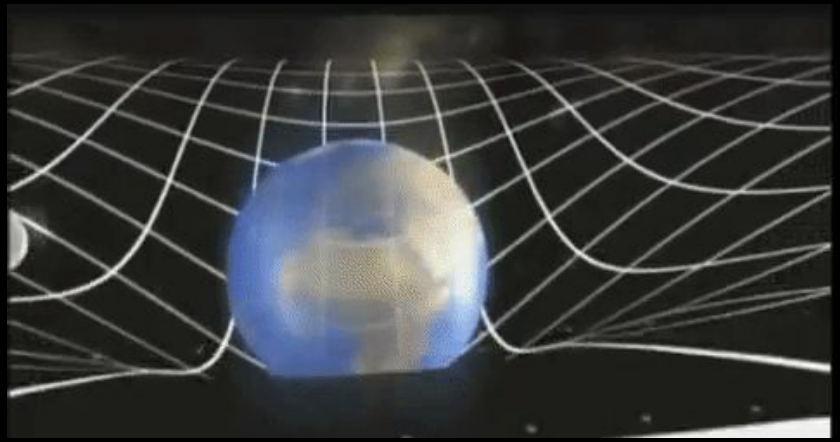
consider a train.

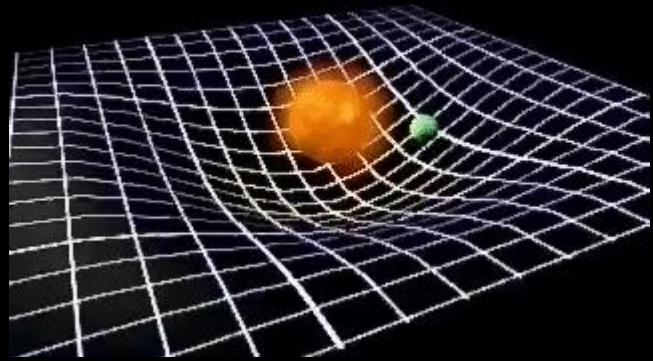
but it turns out that space and time
LINKED TOGETHER
still have meaning.

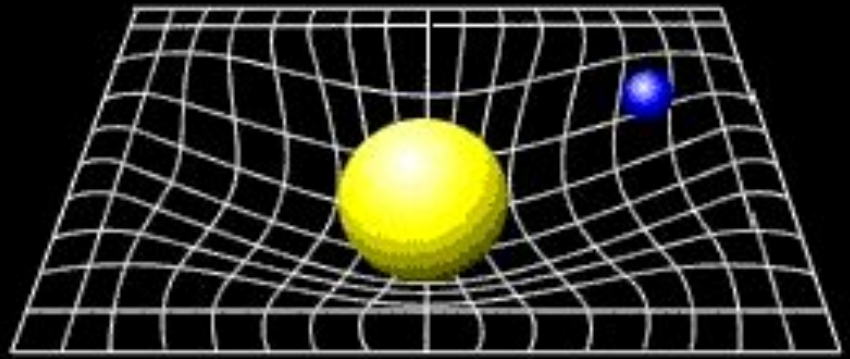

time
space
Home
School

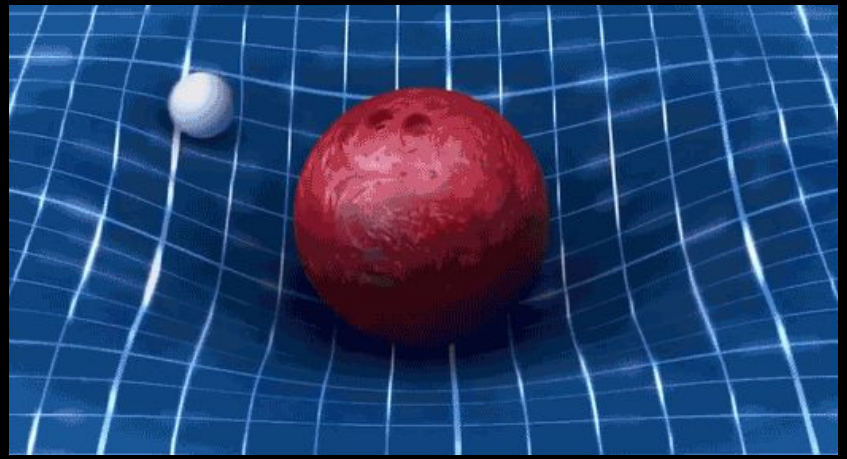
$$E = mc^2$$

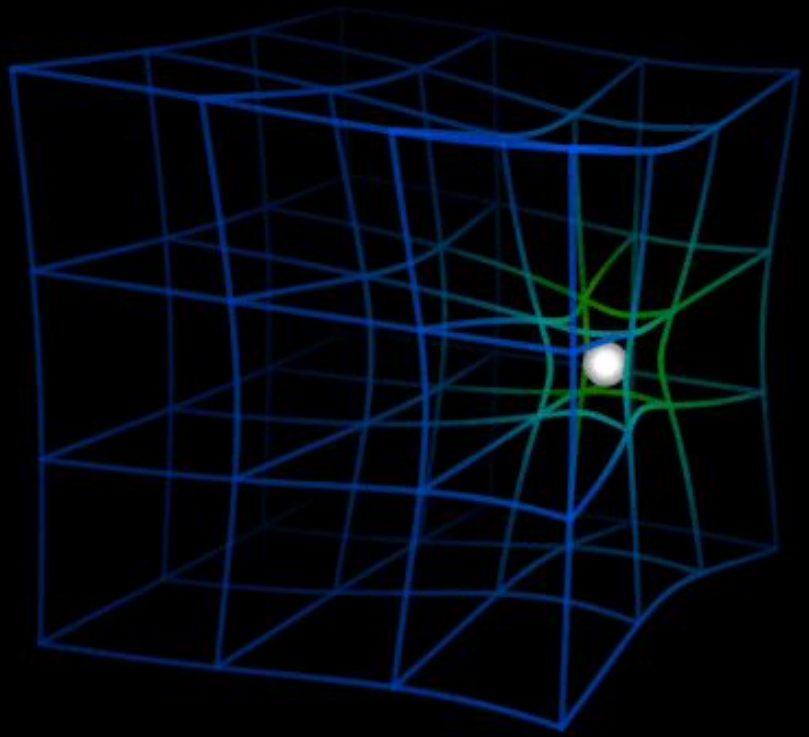
$$E = \gamma mc^2$$











$$G_{\alpha\beta} = \frac{8\pi G}{c^4} T_{\alpha\beta}$$

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amount of curviness

$$G_{\alpha\beta} = \frac{8\pi G}{c^4} T_{\alpha\beta}$$

amount of curviness

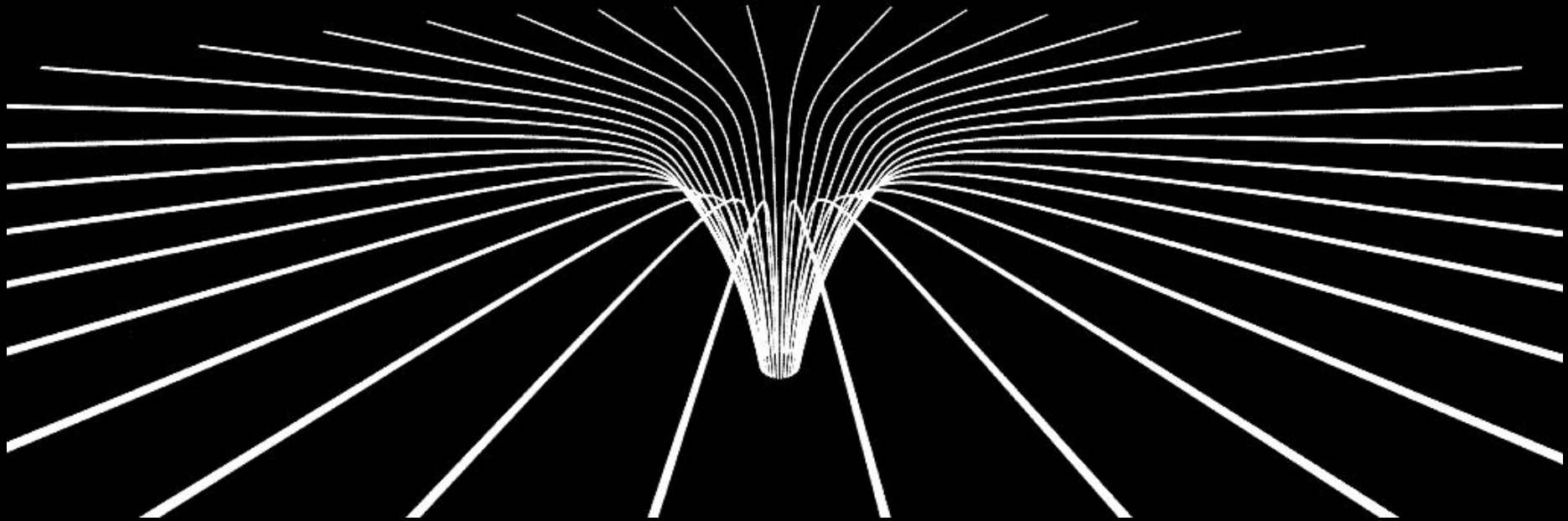
amount of stuff
in space

not important for us!

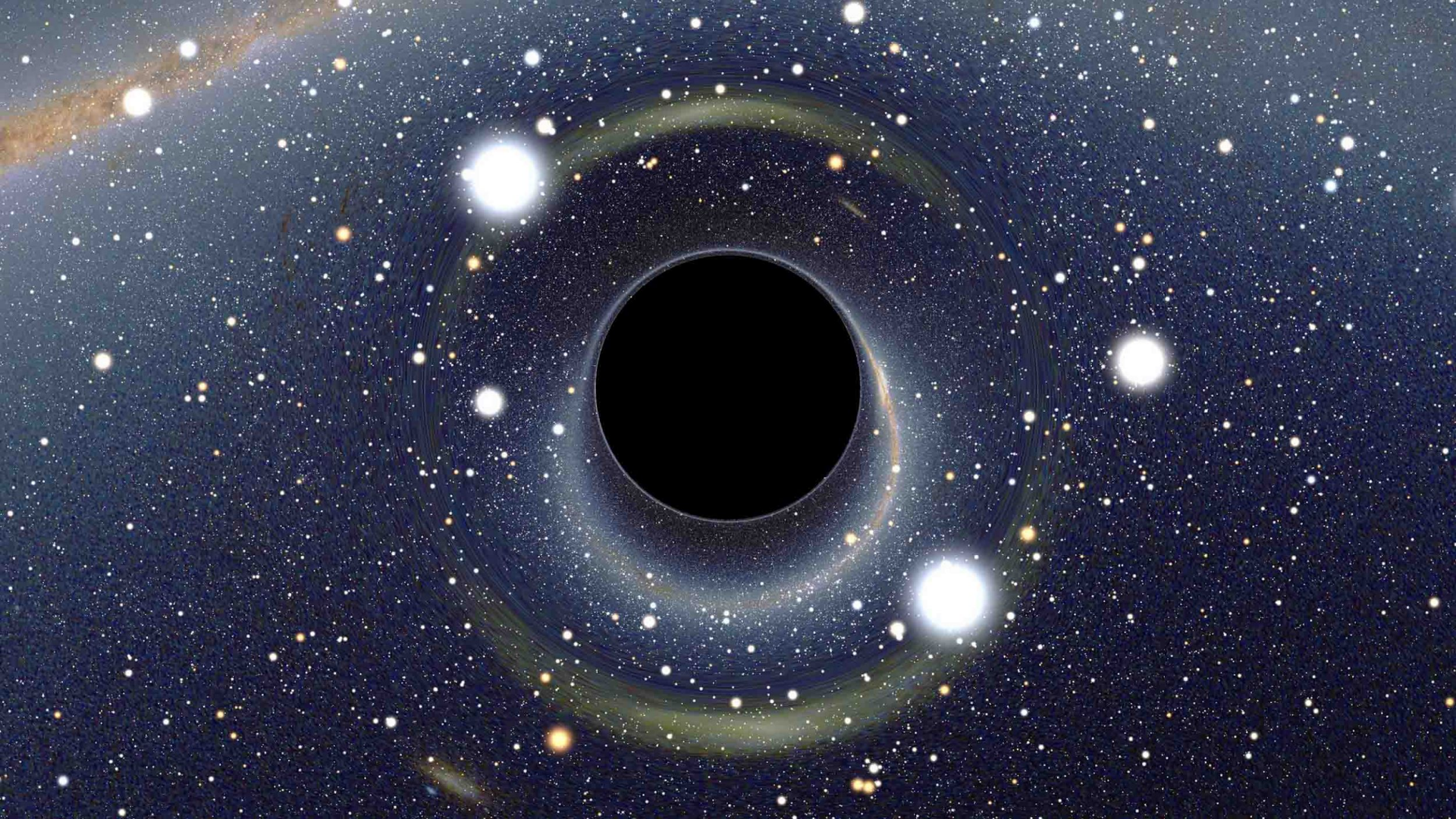
$$G_{\alpha\beta} = \frac{8\pi G}{c^4} T_{\alpha\beta}$$

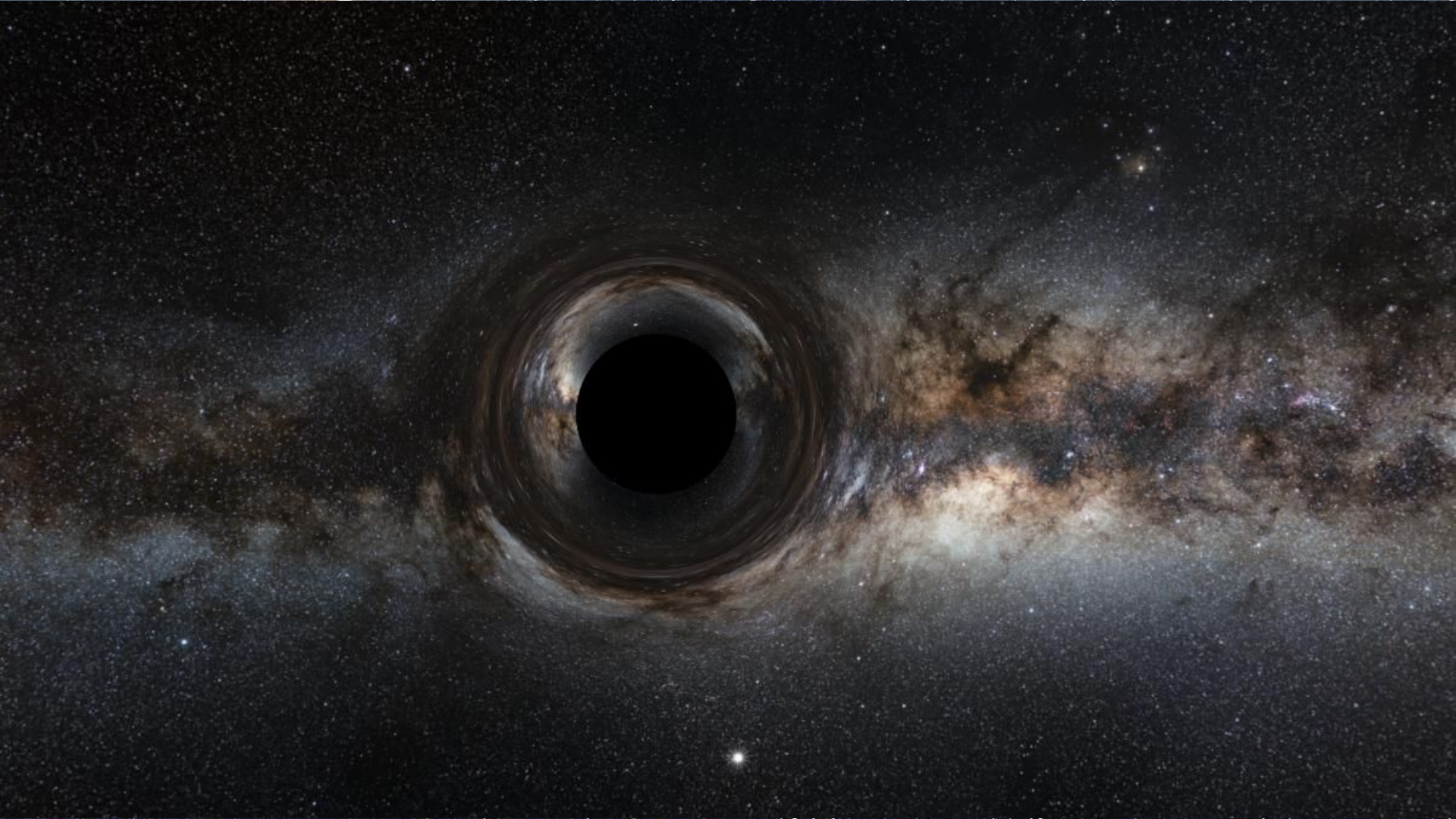
amount of curviness

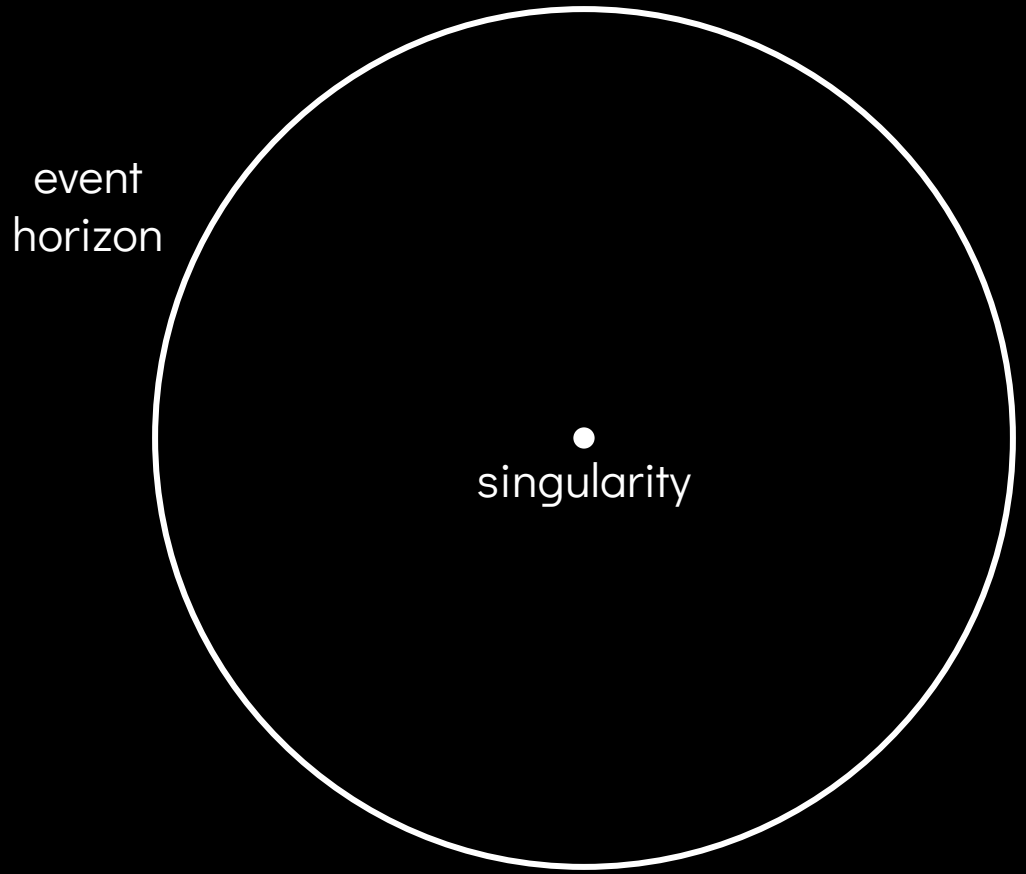
amount of stuff
in space



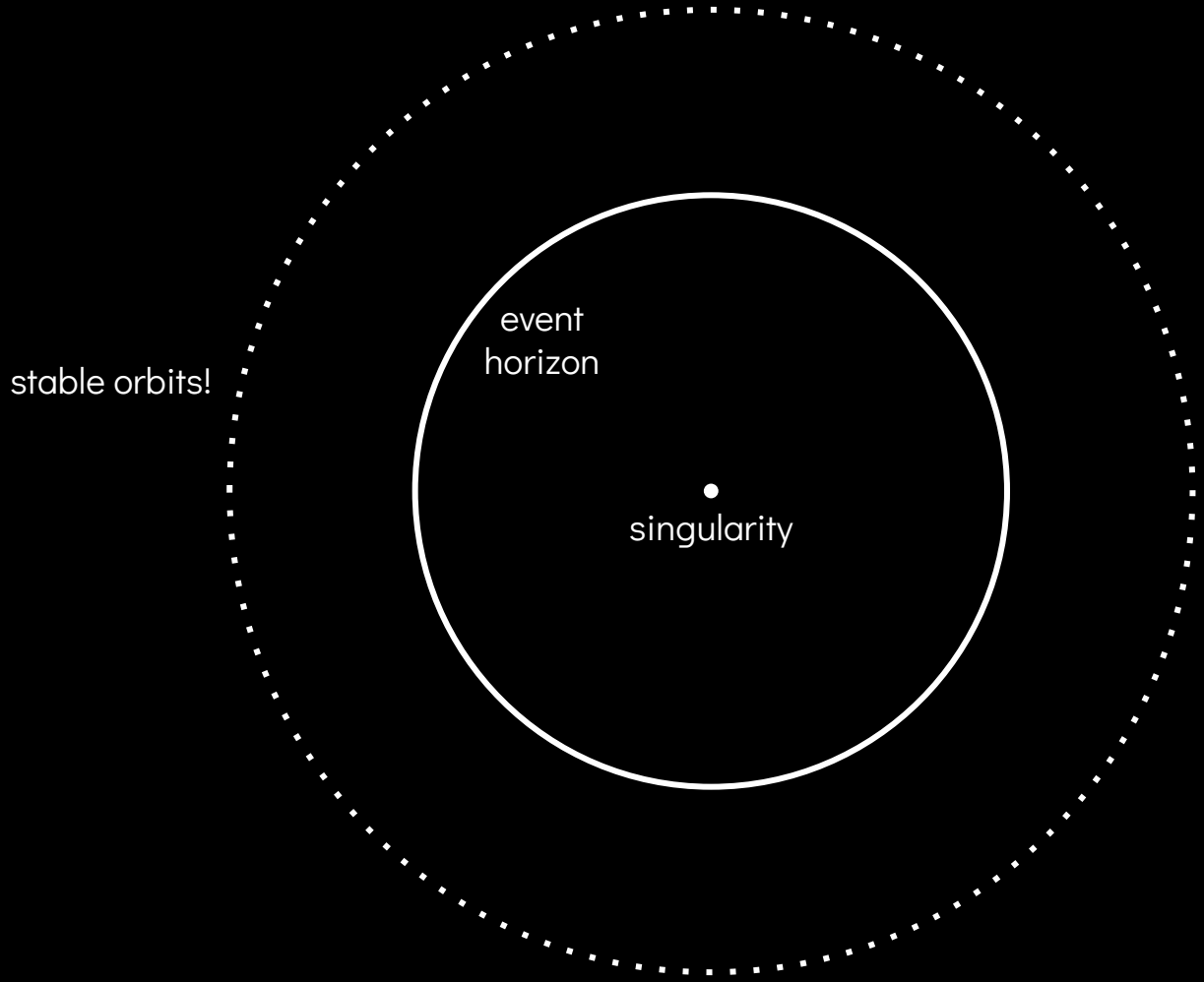
so what are black holes like?






event
horizon
singularity

earth’s event horizon is 9mm


stable orbits!
event
horizon
singularity

mass

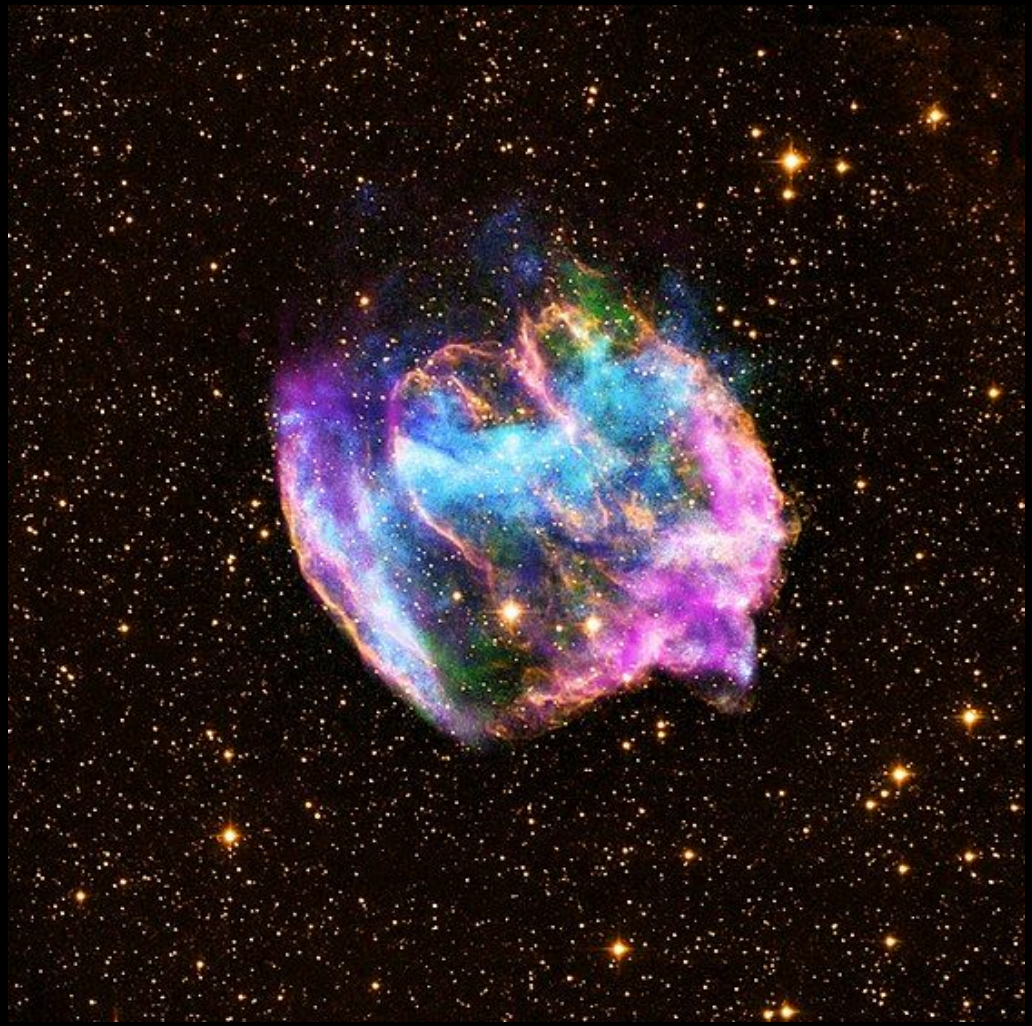
mass
charge

mass
charge
spin

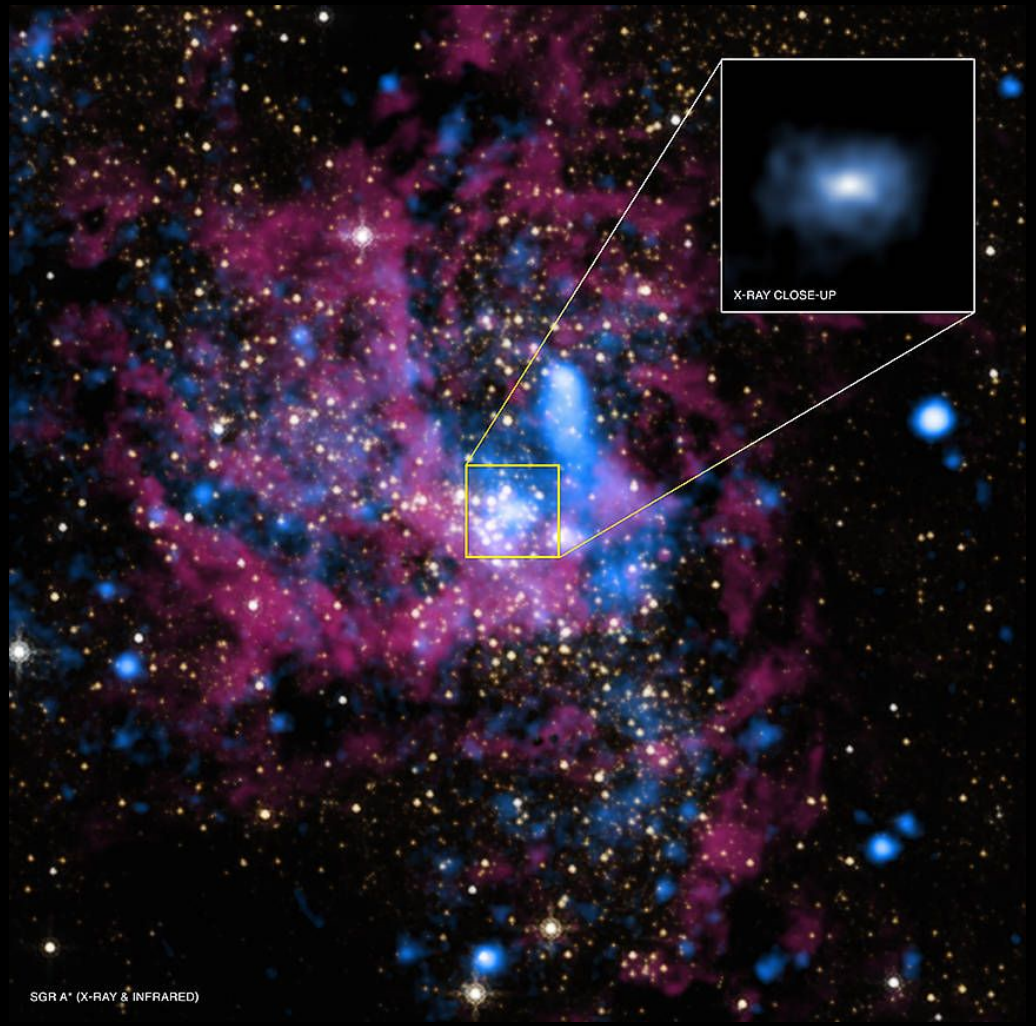

FORMATION

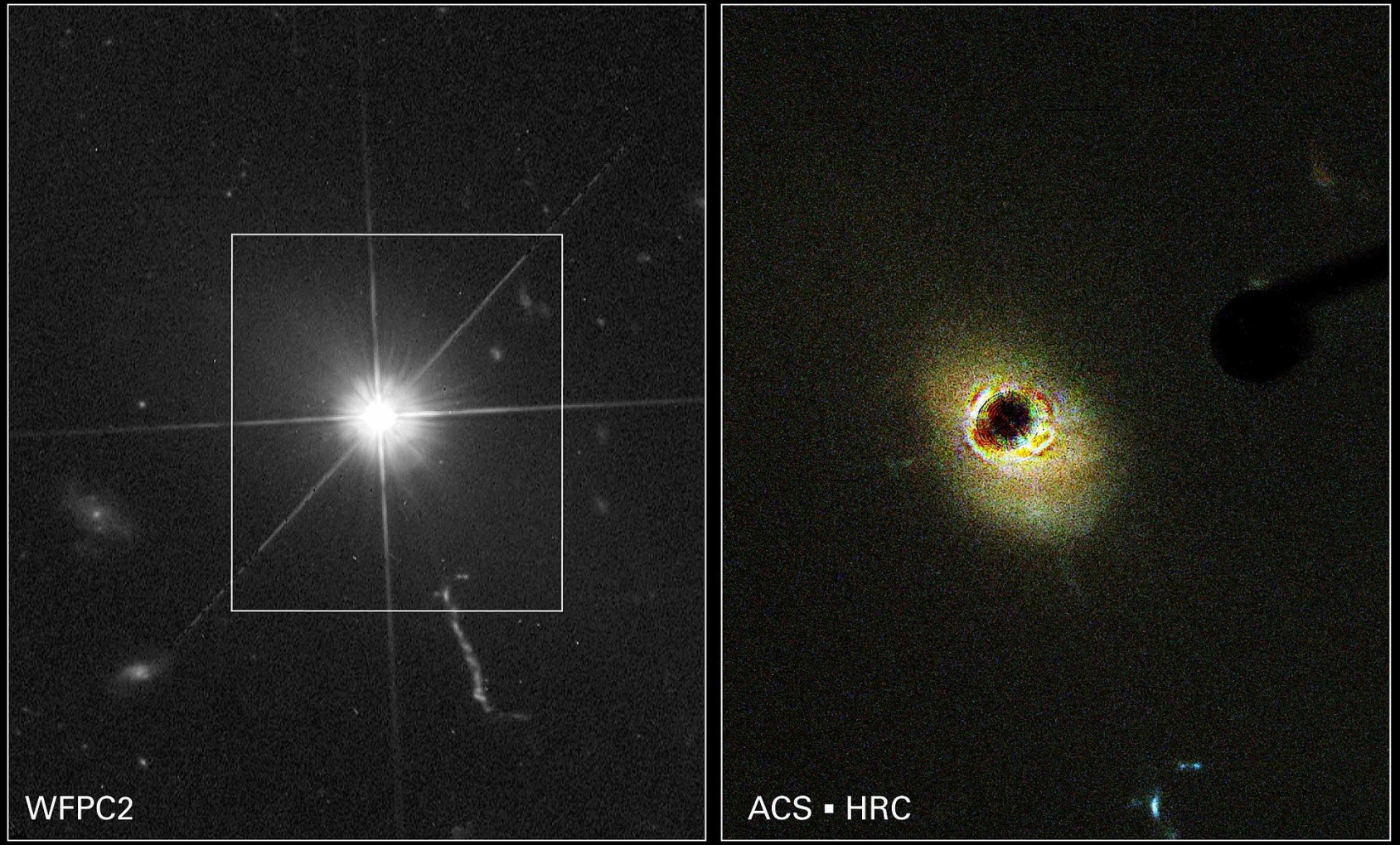

formation

supernovae can make black holes!

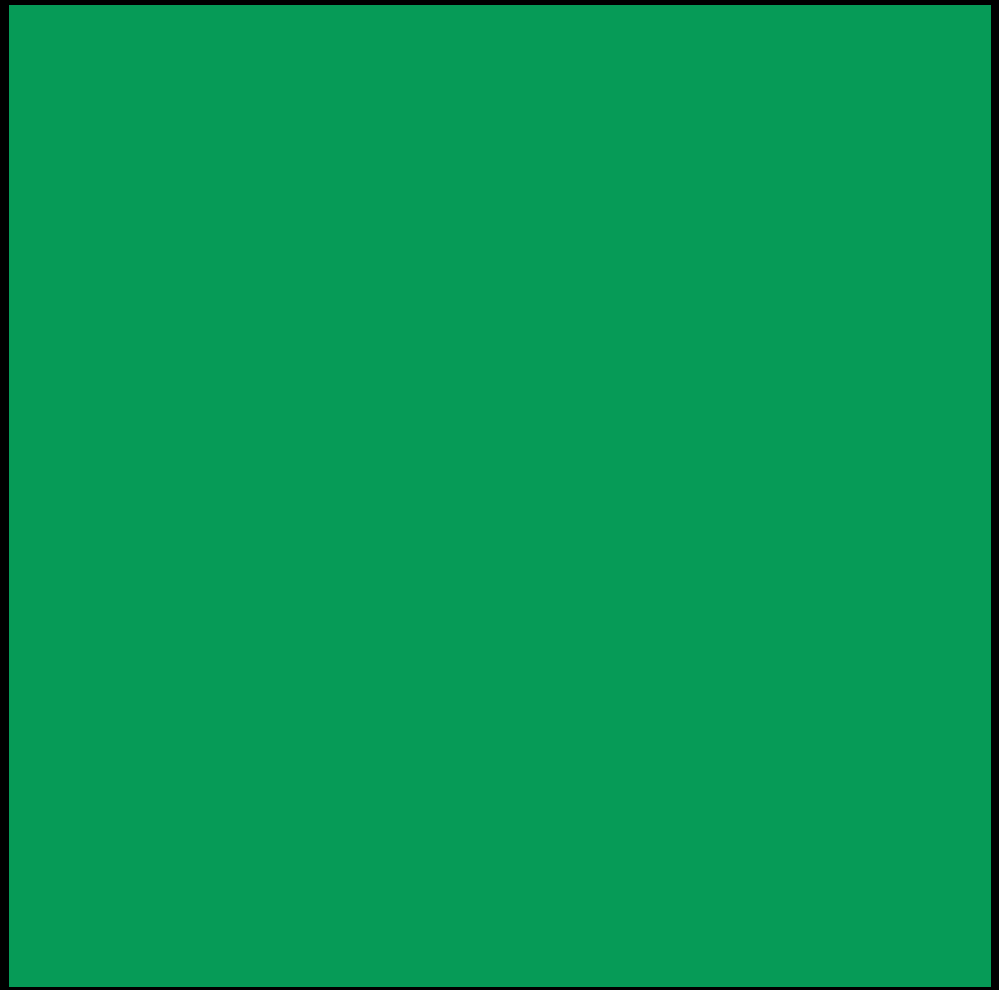


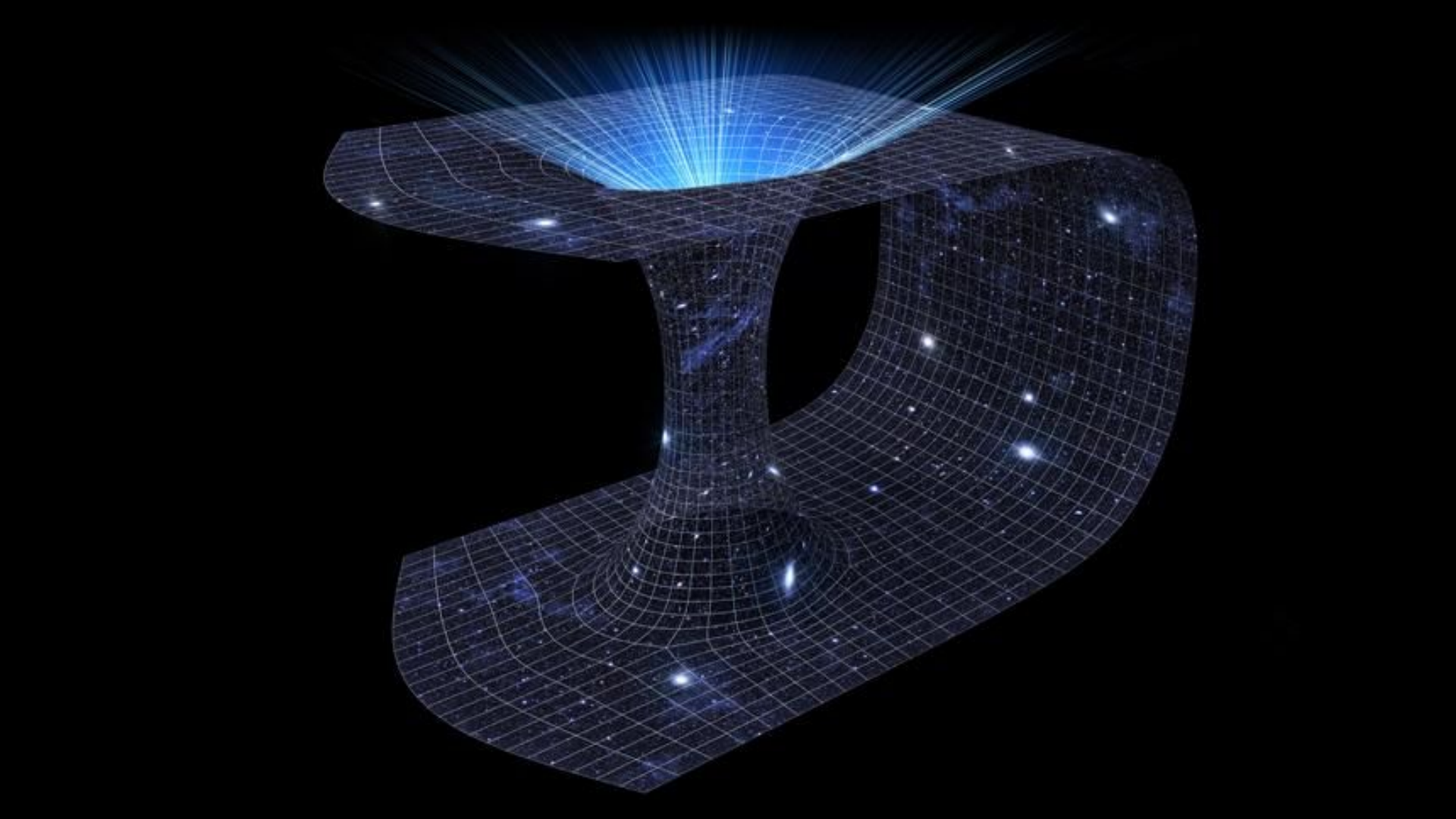
* as long as the star is big enough


X-RAY CLOSE-UP
SGR A* (X-RAY & INFRARED)


WFPC2
ACS ▪ HRC

black holes are ~weird~





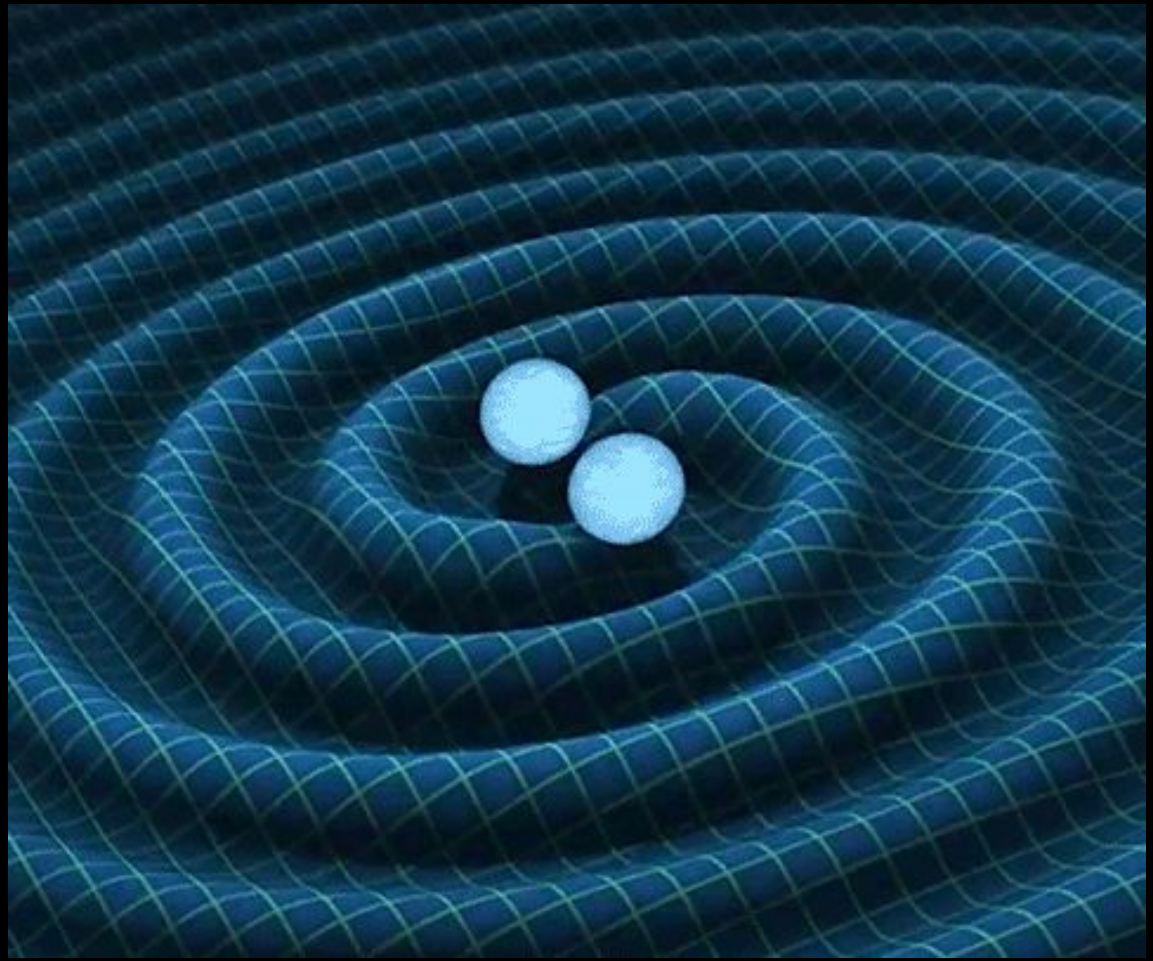
let’s talk about ligo

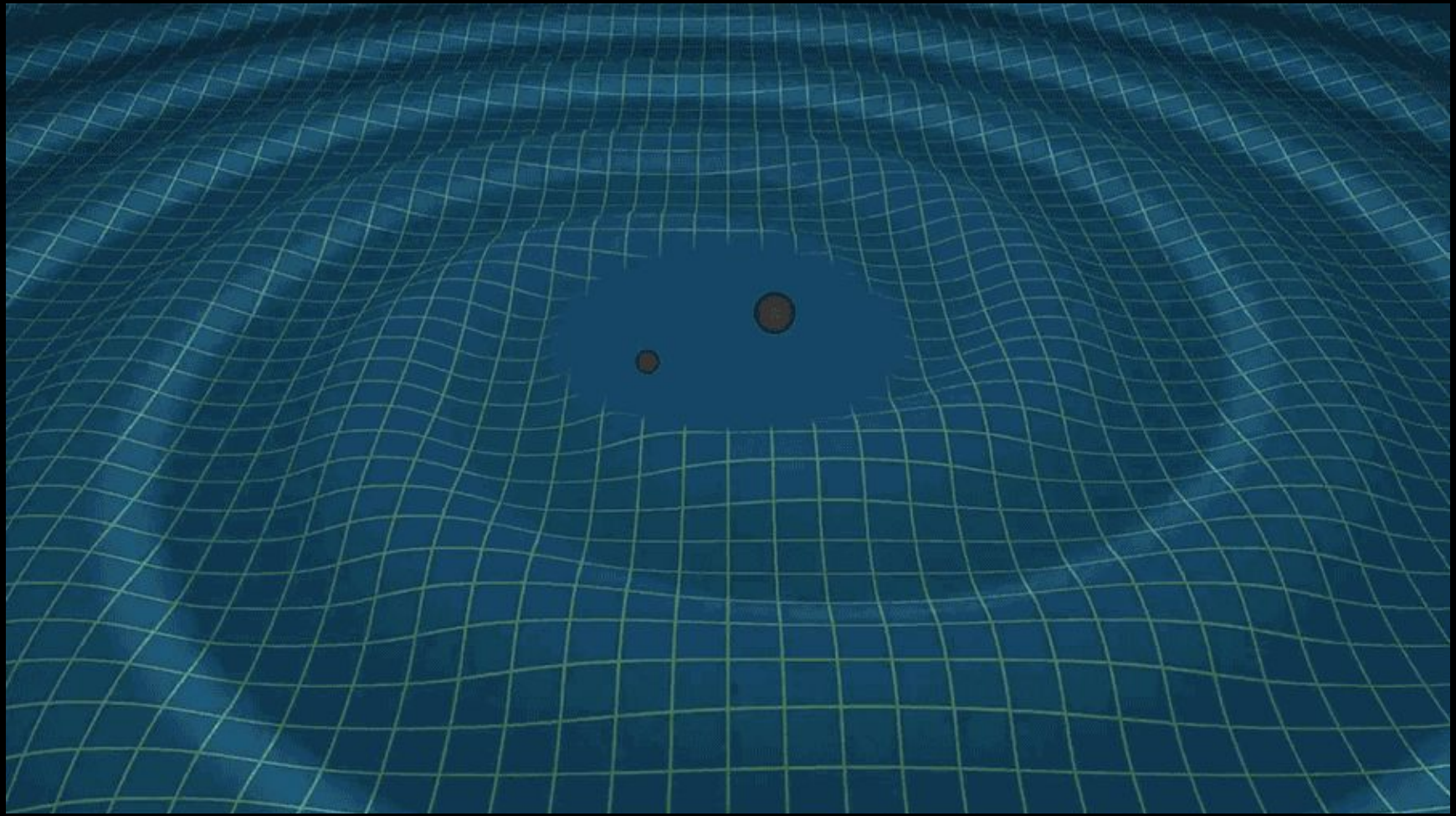
L laser

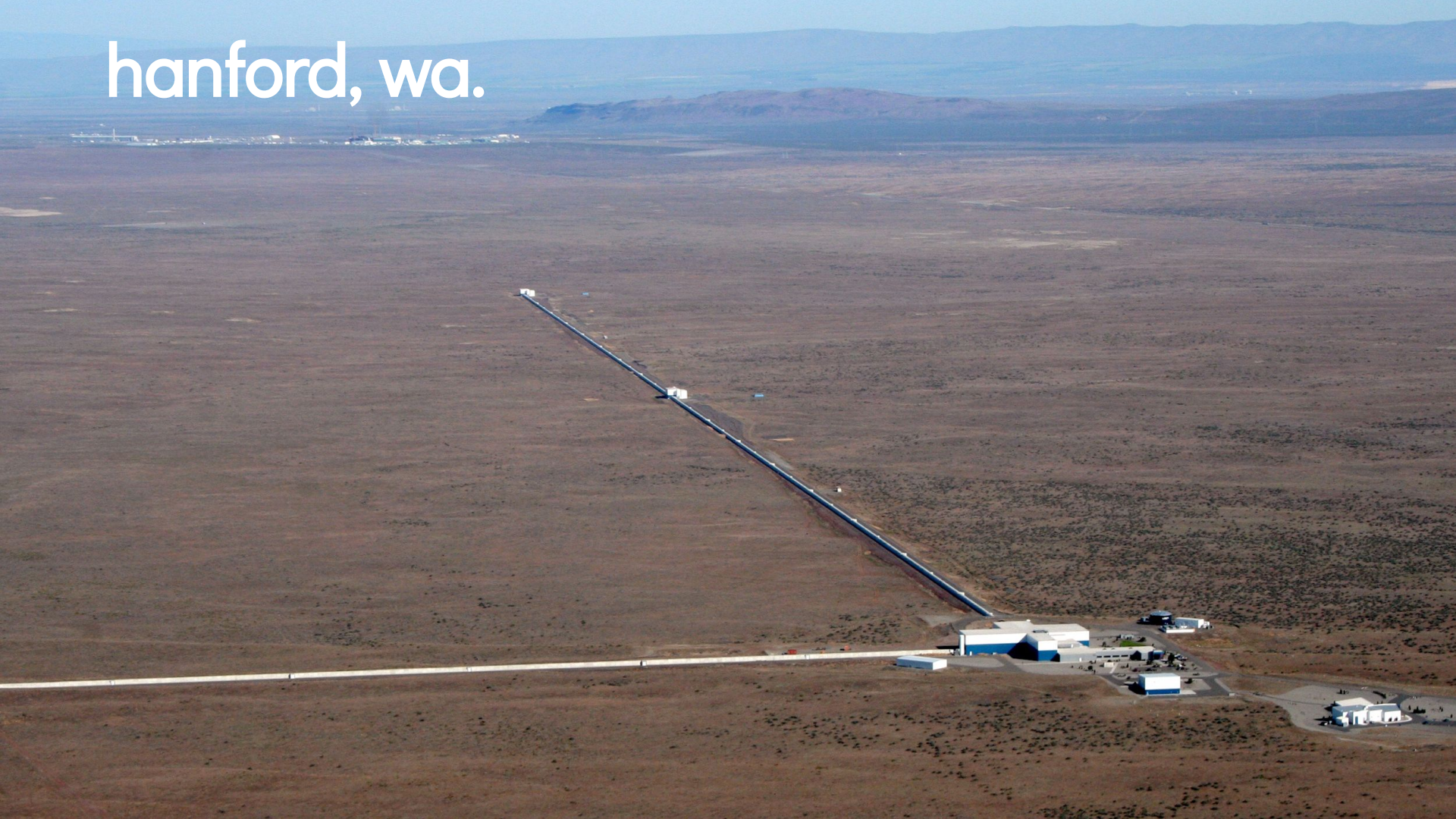
I interferometer

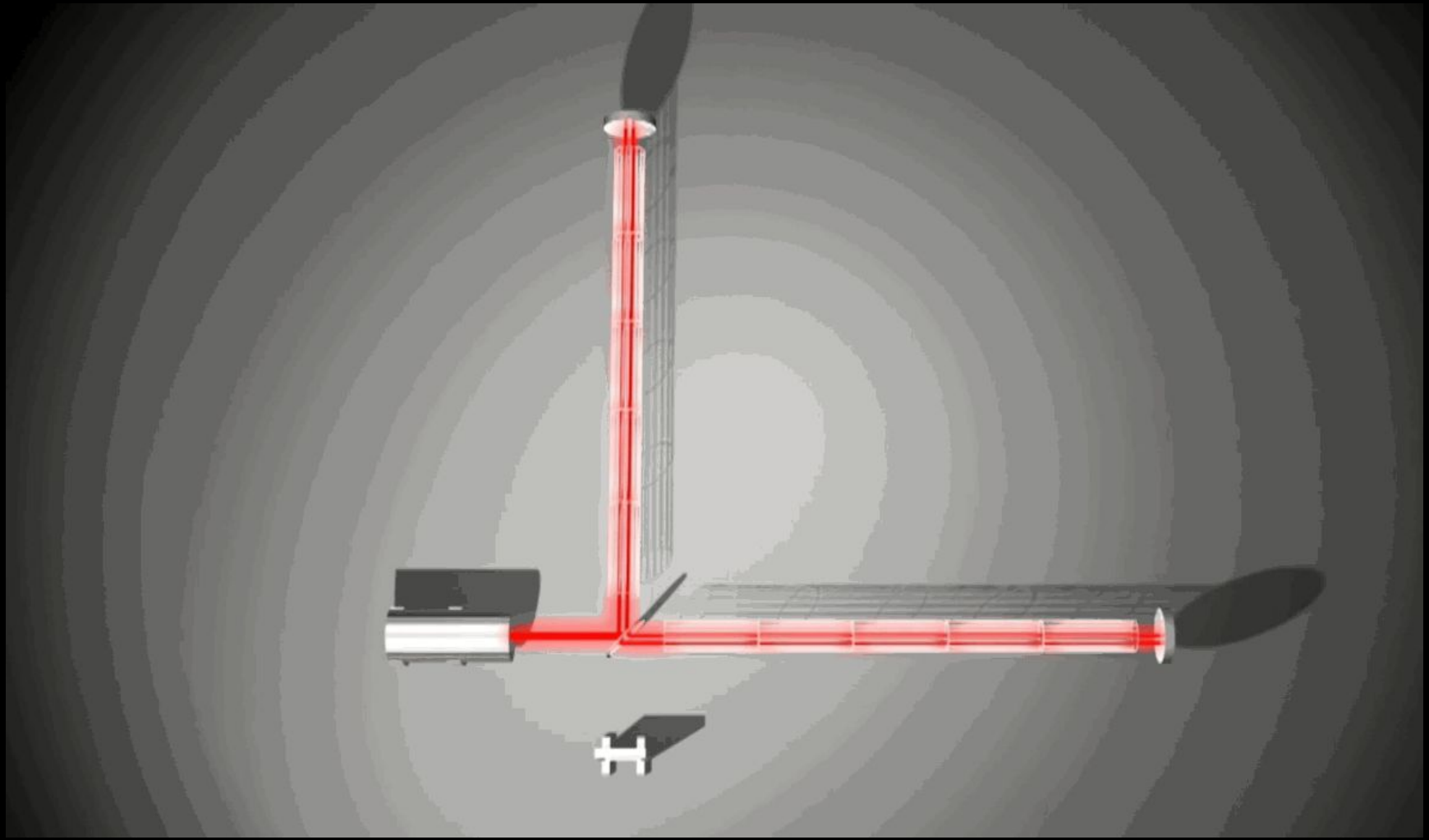
G gravitational-wave

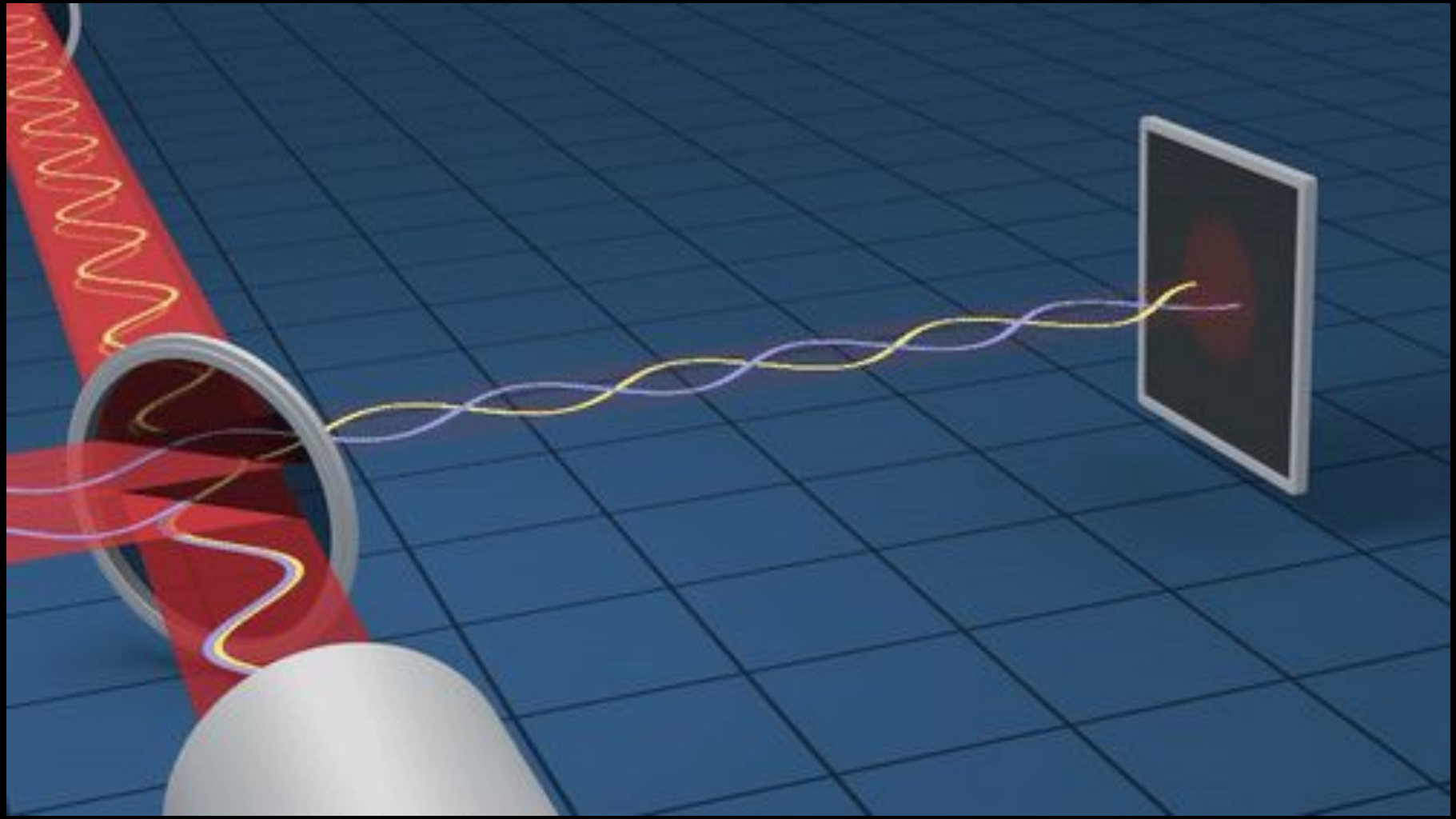
O observatory

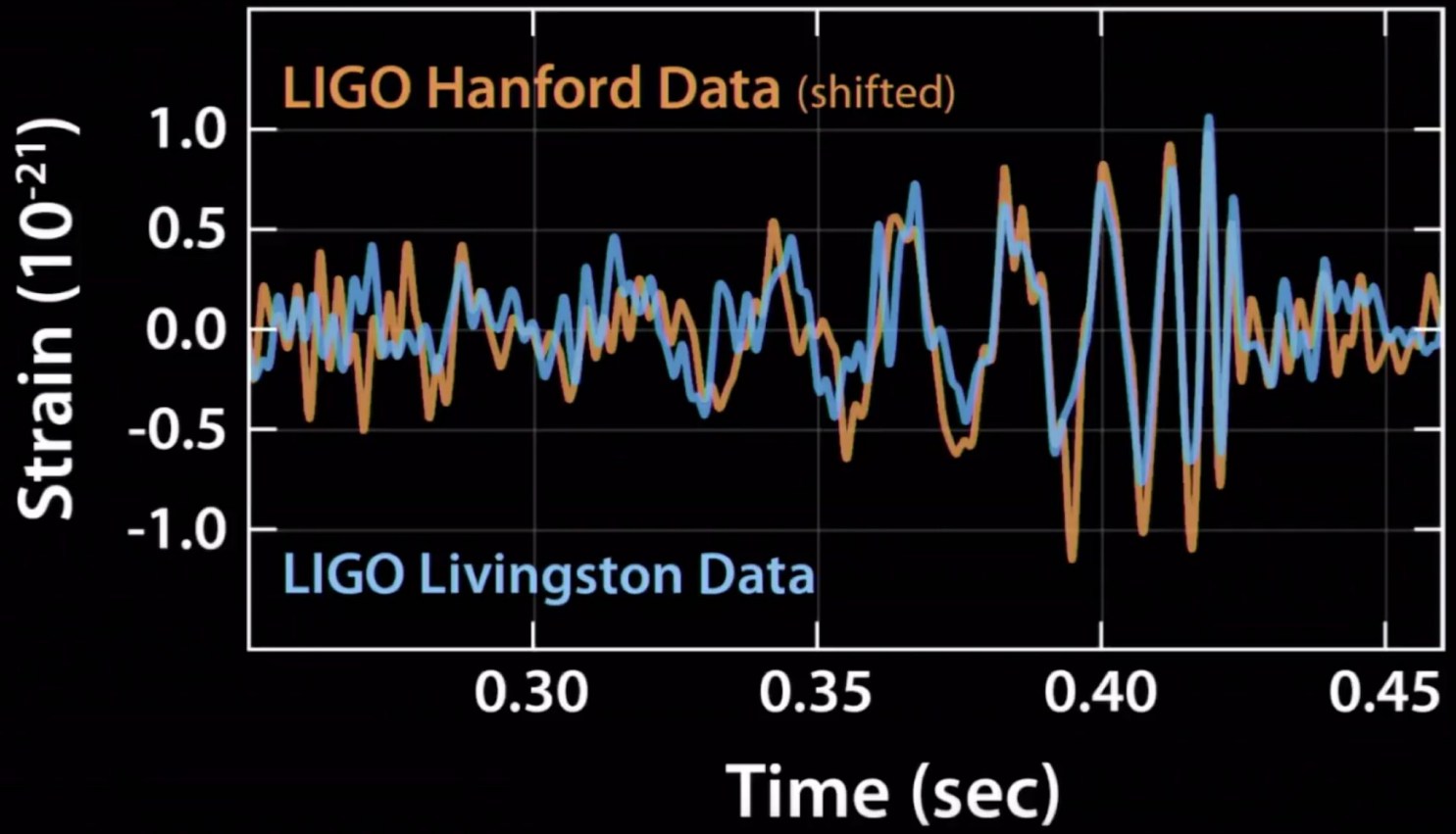





hanford, wa.



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0.40
0.45
Time (sec)


thank you! questions?