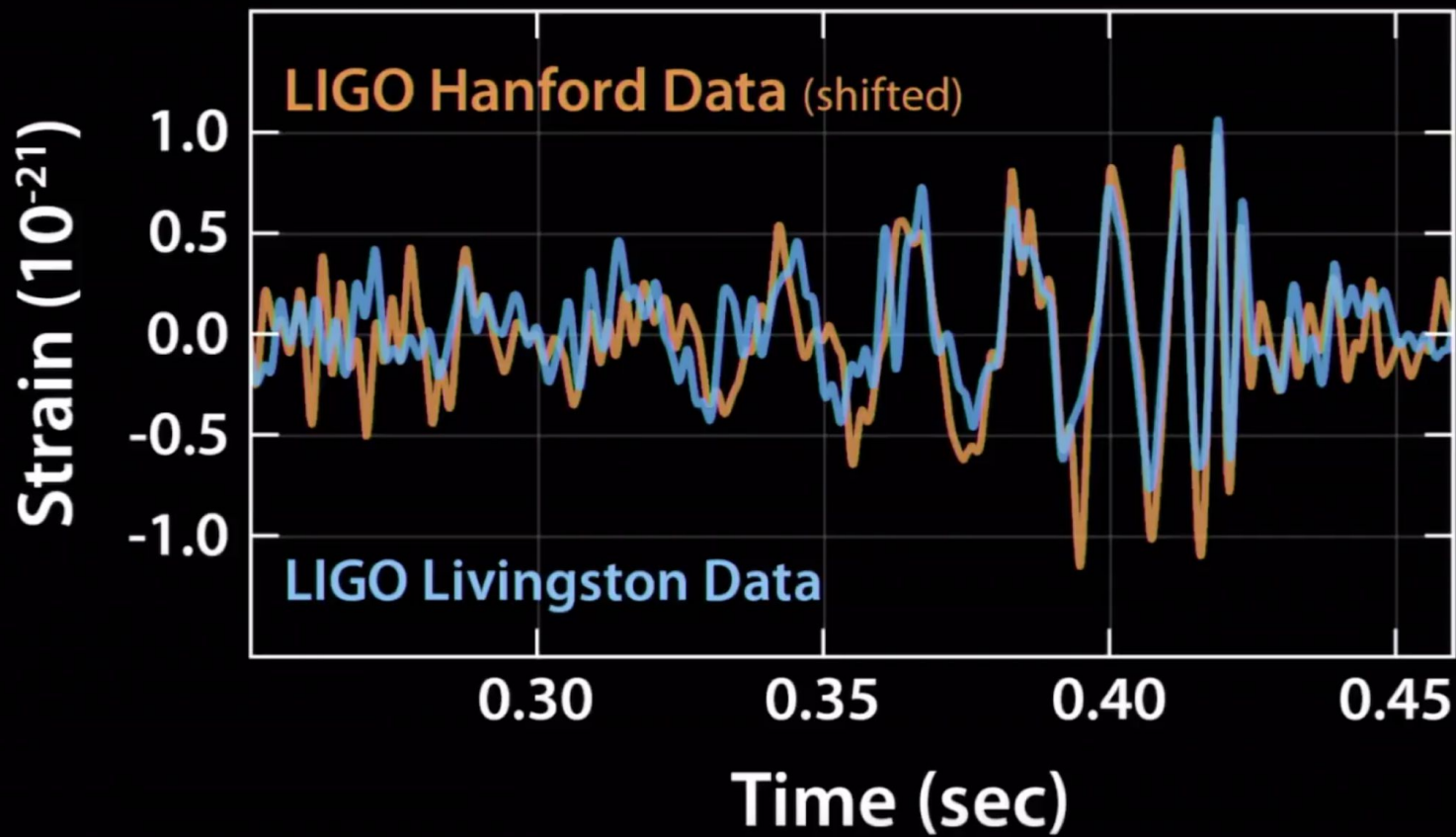
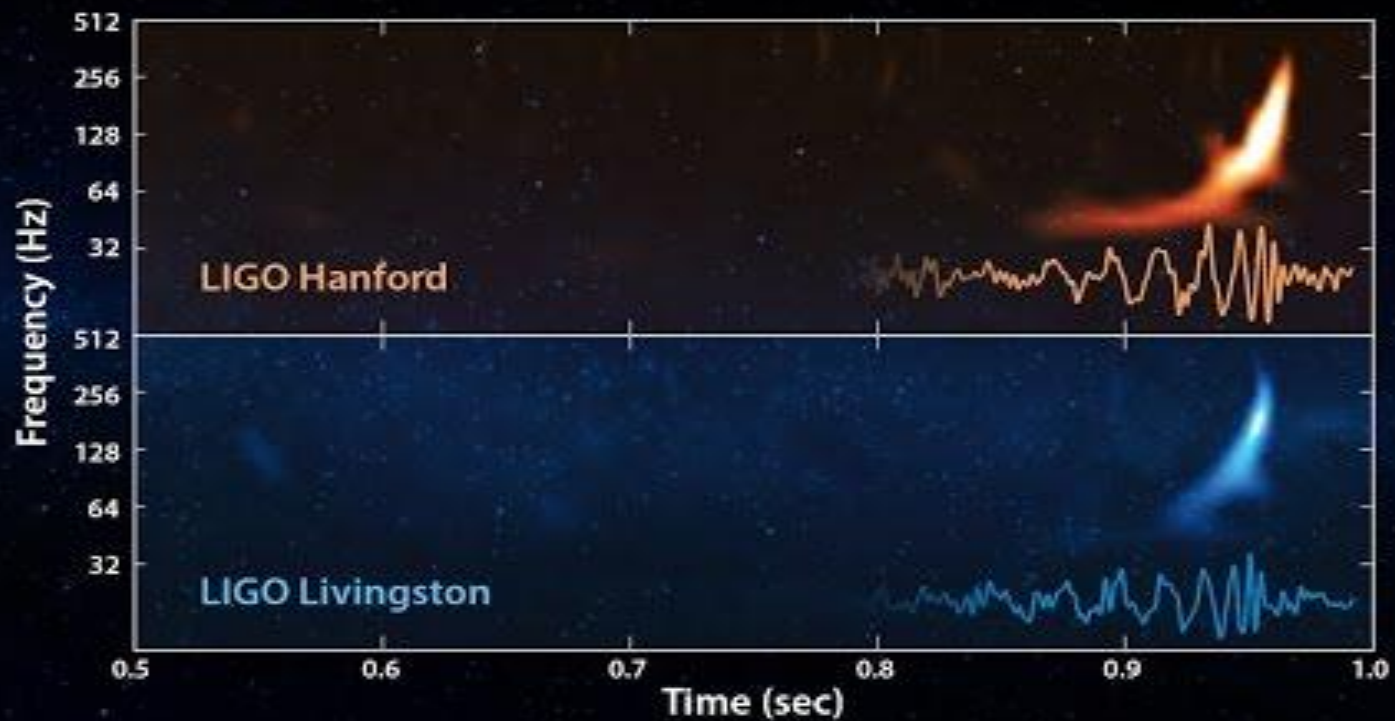
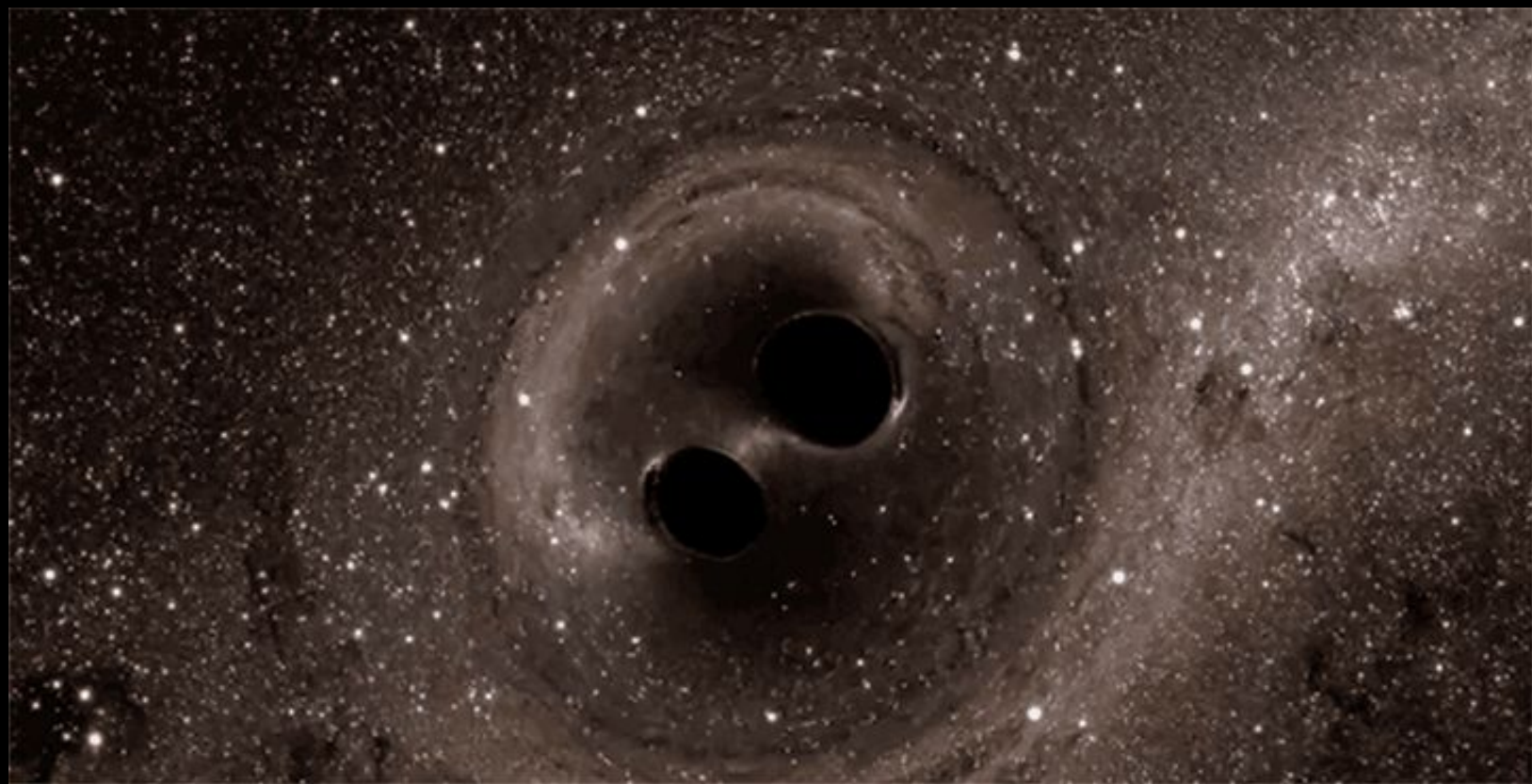


**black holes!**

spark 2019







**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.

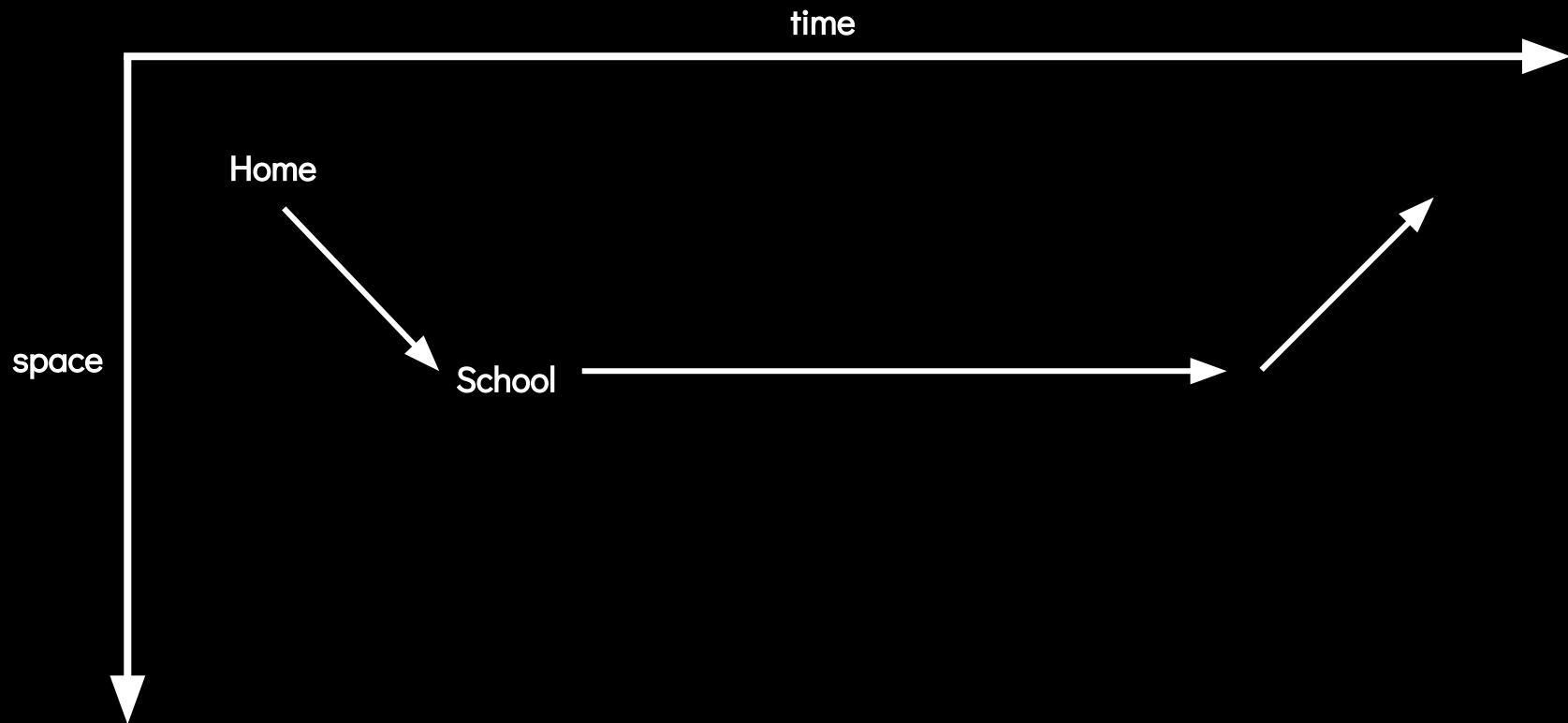
**let's talk about relativity!**



299 792 458 m/s

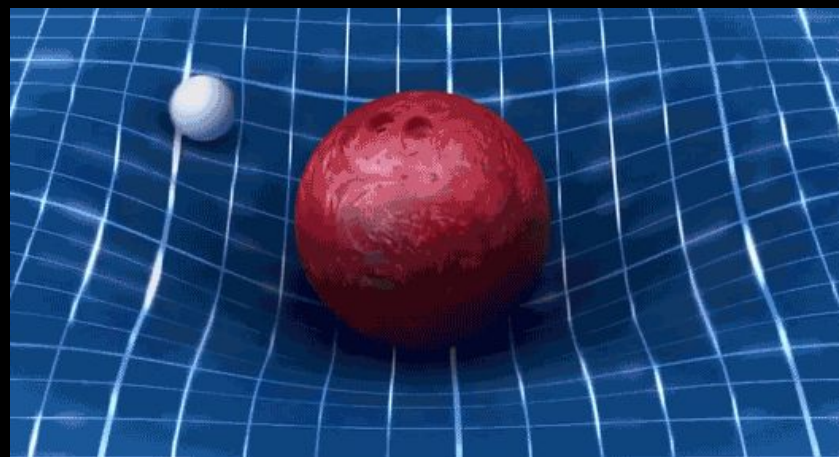
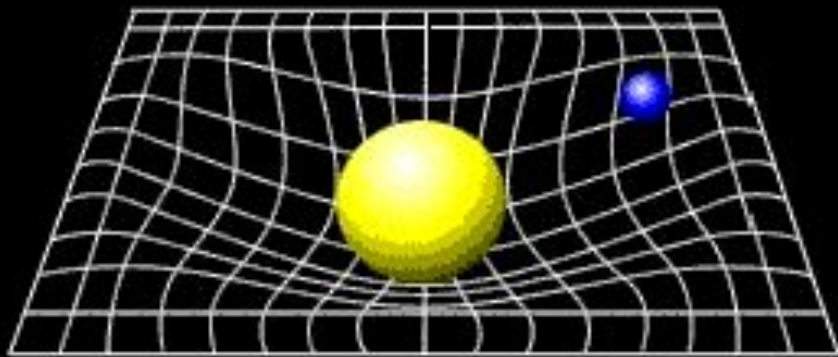
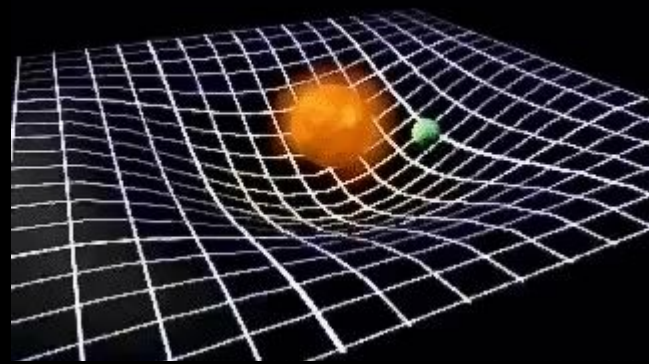
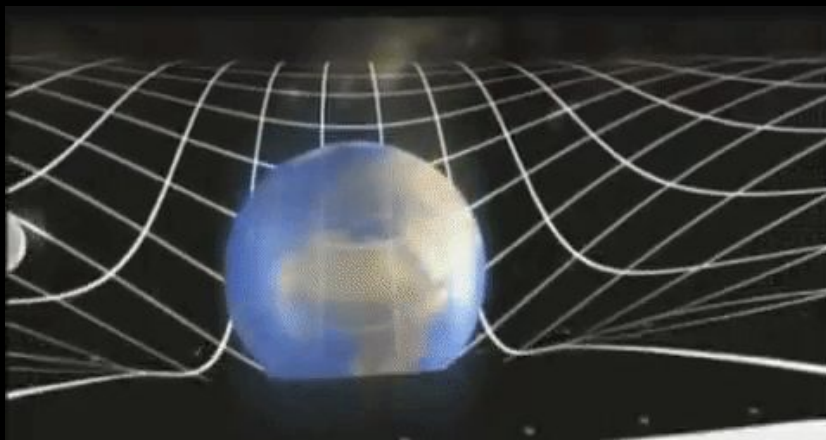
**consider a train.**

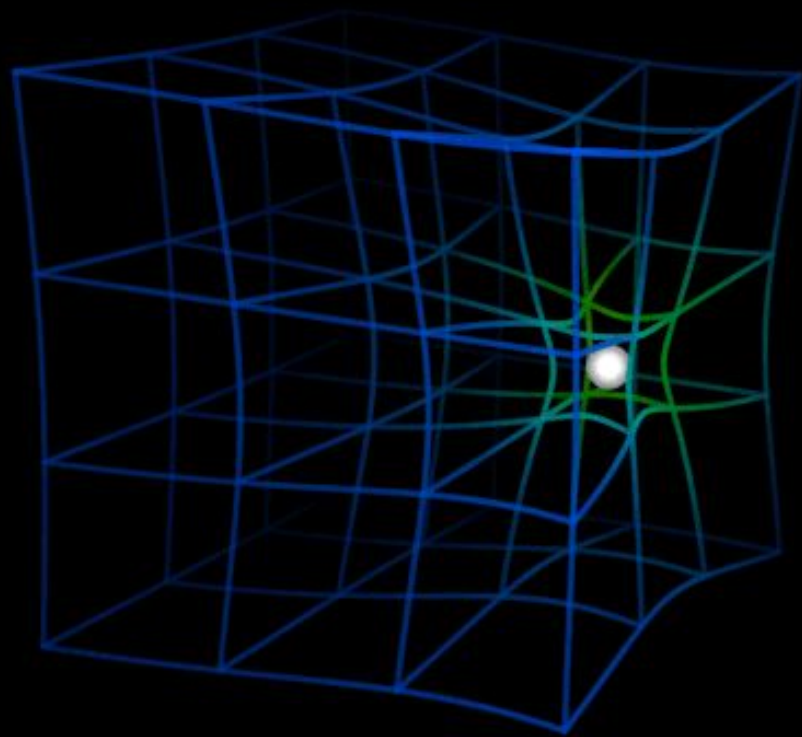
but it turns out that space and time  
**LINKED TOGETHER**  
still have meaning.



$$E = mc^2$$

$$E = \gamma mc^2$$







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

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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

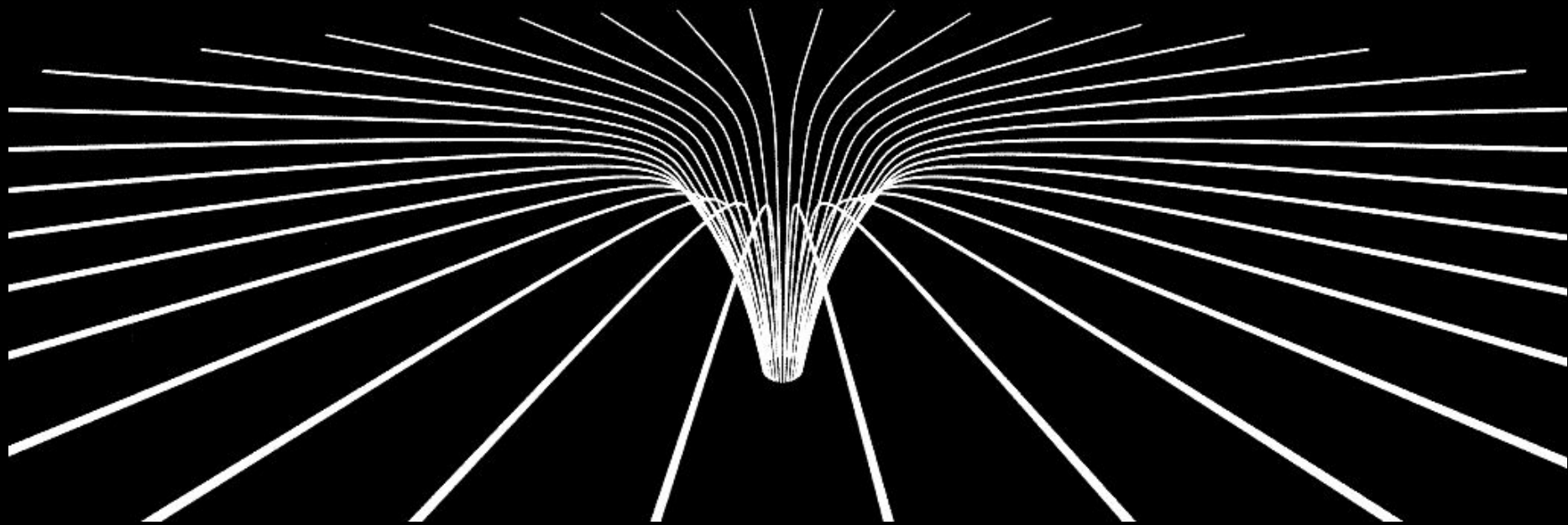
$$G_{\alpha\beta} = \frac{8\pi G}{c^4} T_{\alpha\beta}$$

not important for us!

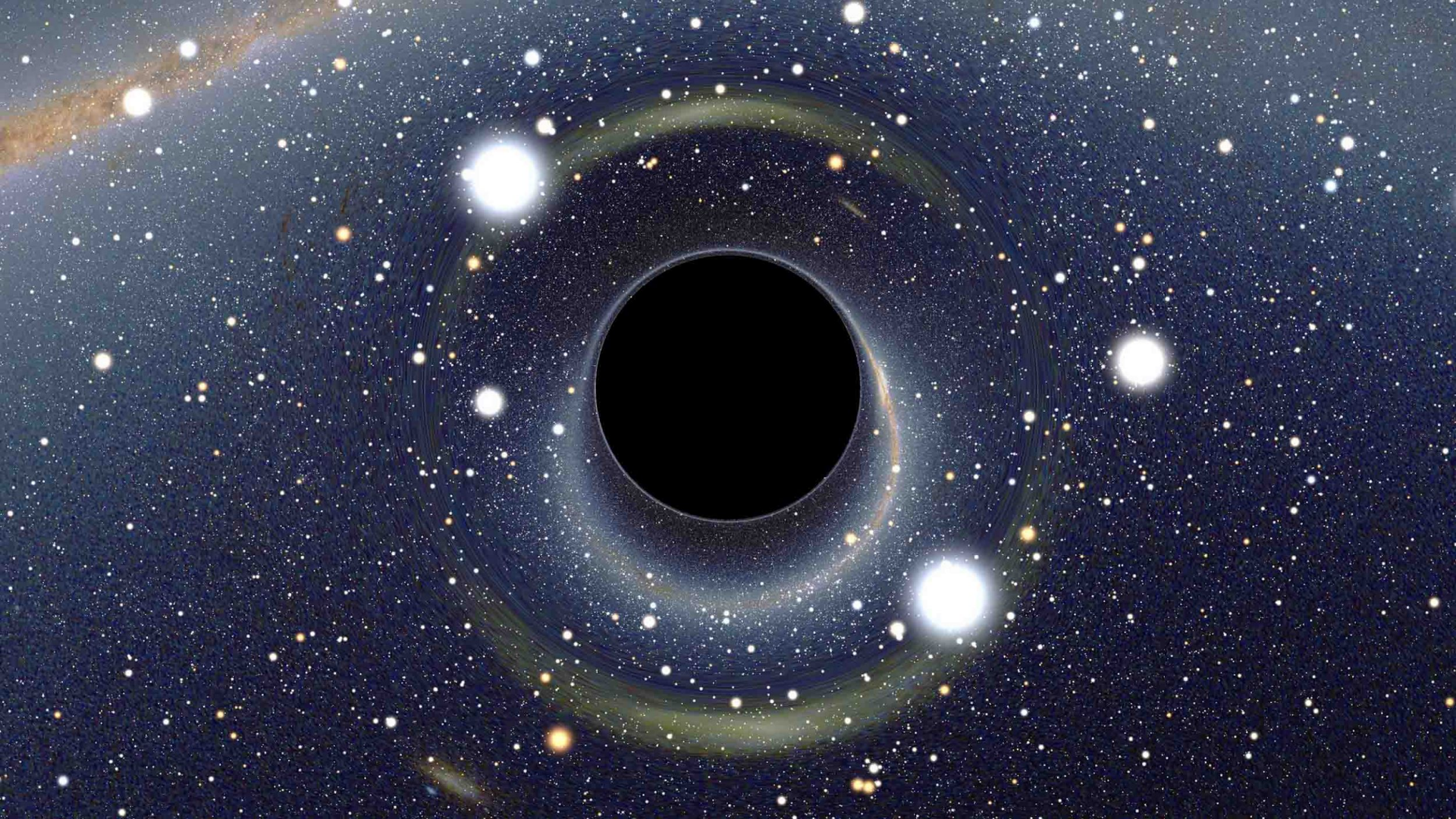
amount of curviness

amount of stuff in space

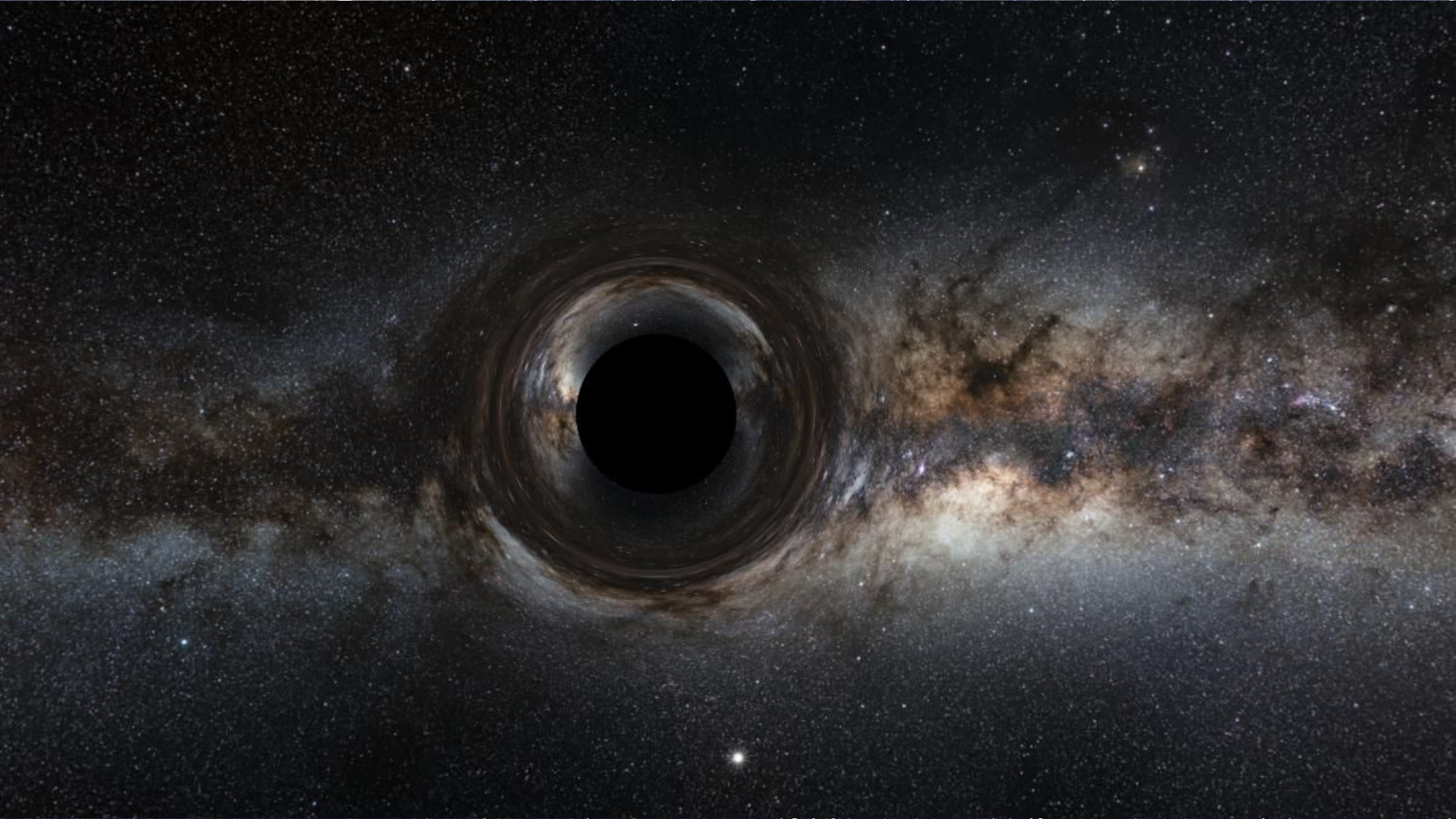
The image shows the Einstein field equation  $G_{\alpha\beta} = \frac{8\pi G}{c^4} T_{\alpha\beta}$  centered on a black background. Three white arrows point from text labels to parts of the equation: one from 'amount of curviness' to  $G_{\alpha\beta}$ , one from 'amount of stuff in space' to  $T_{\alpha\beta}$ , and one from 'not important for us!' to the fraction  $\frac{8\pi G}{c^4}$ .



**so what are black holes like?**

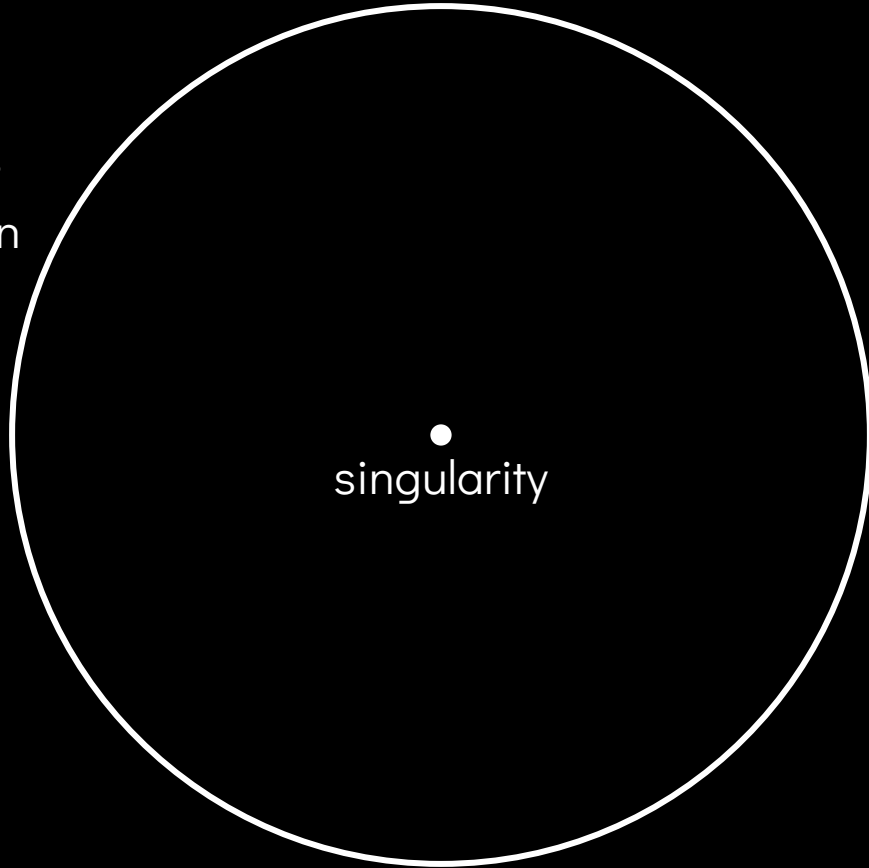








event  
horizon



singularity

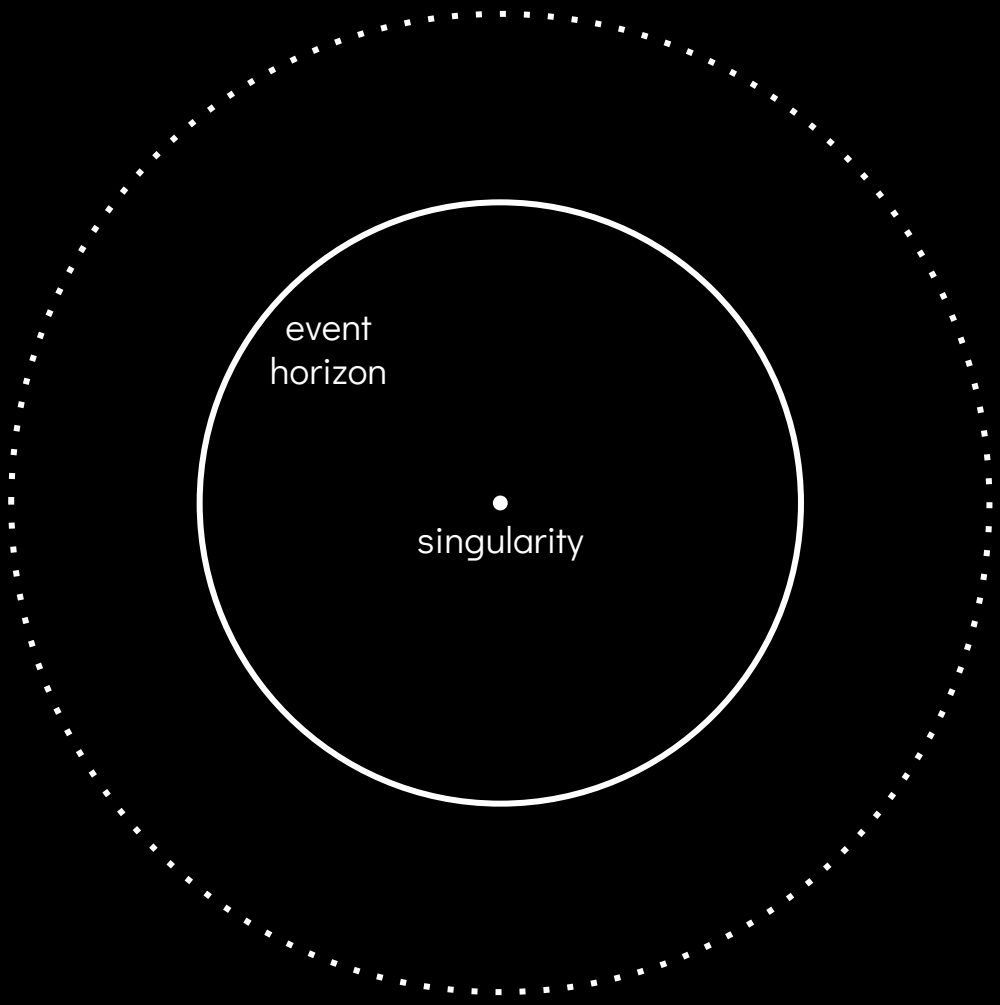
earth's event horizon is 9mm



stable orbits!

event  
horizon

•  
singularity





**mass**

mass  
charge

mass  
charge  
spin



A woman wearing a voluminous white fur coat and a long, dark, fringed necklace is leaning her arms on the hood of a light blue classic car. Her head is tilted back, and she appears to be looking up at the sky. The car is parked in an outdoor setting, possibly a parking lot, with a building and trees in the background. The word "FORMATION" is overlaid in white, bold, sans-serif capital letters across the center of the image.

**FORMATION**



formation





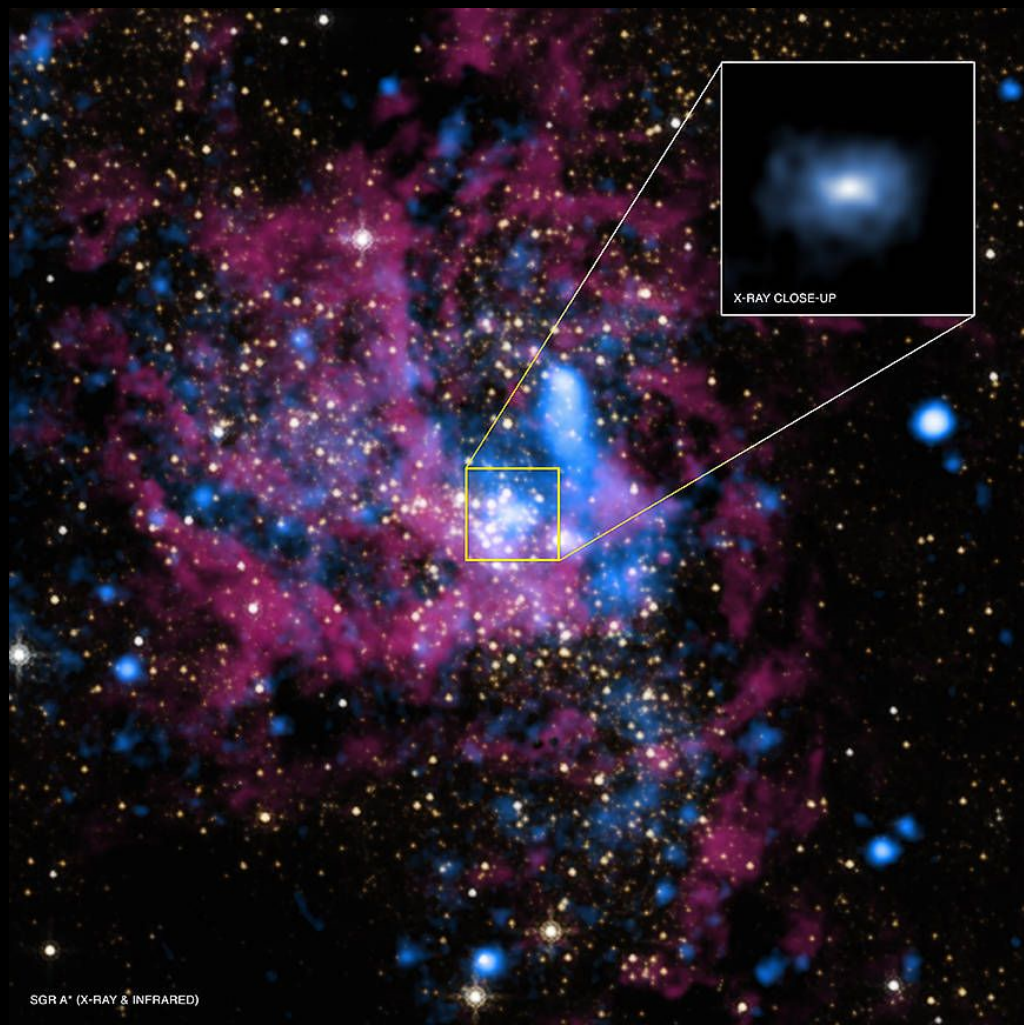
**supernovae can  
make black holes!**



\* as long as the  
star is big enough





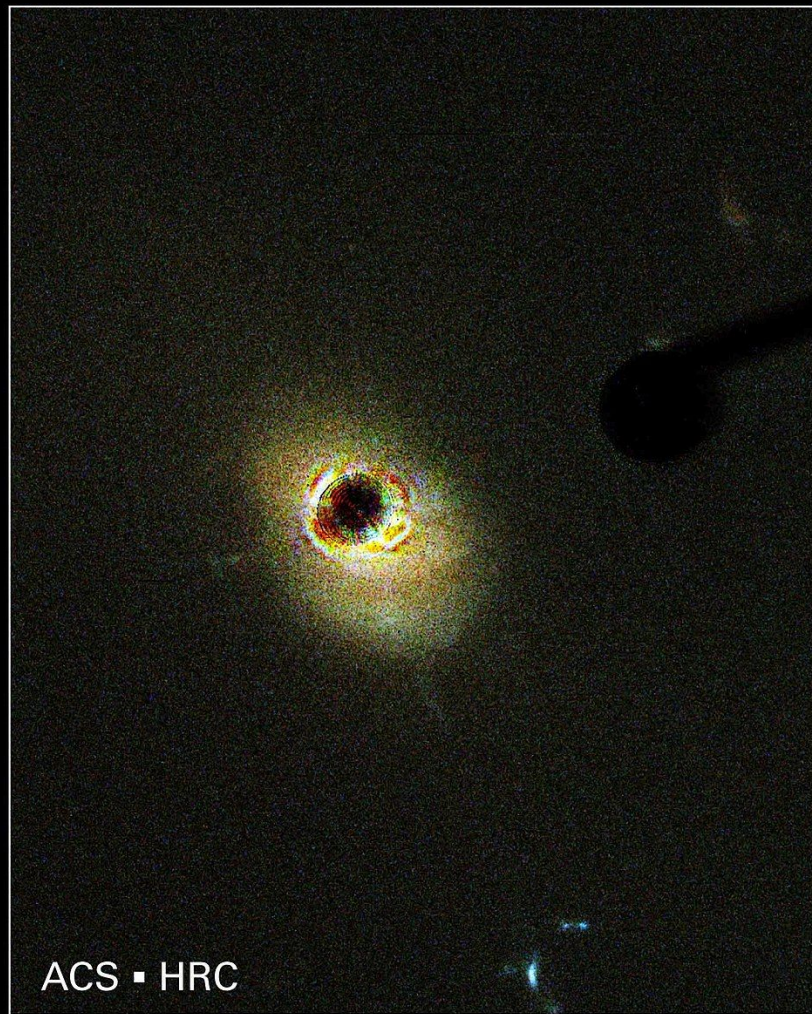
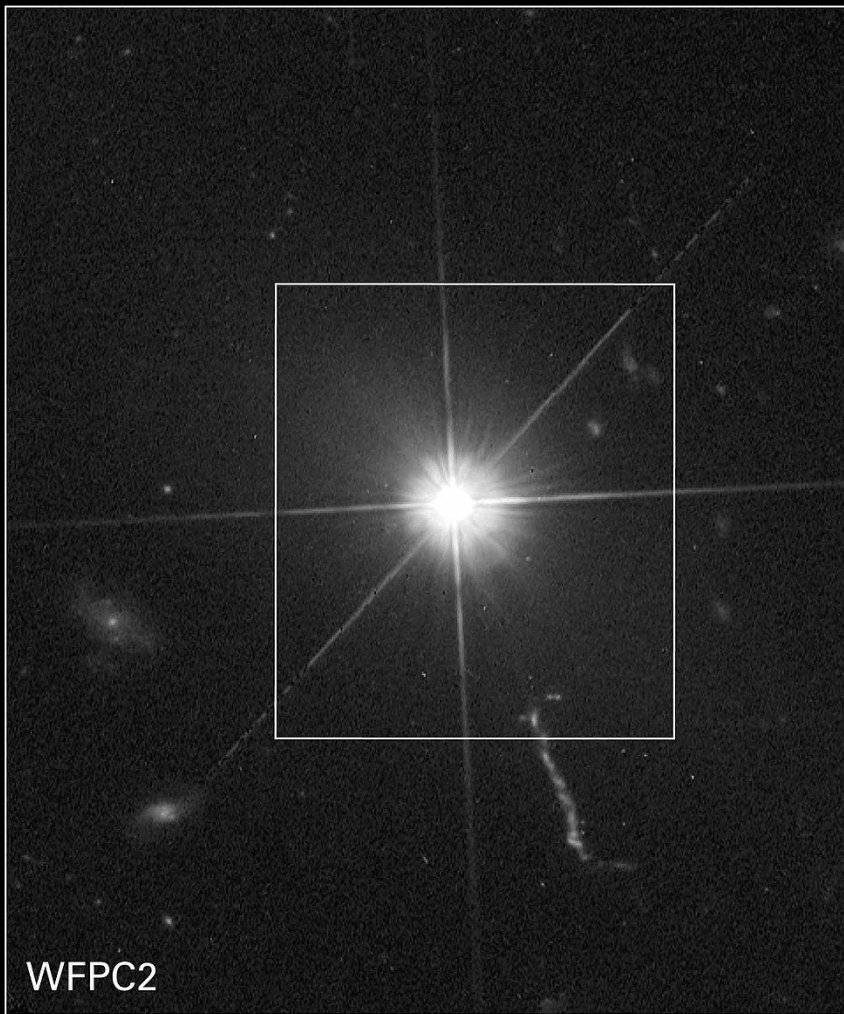


SGR A\* (X-RAY & INFRARED)







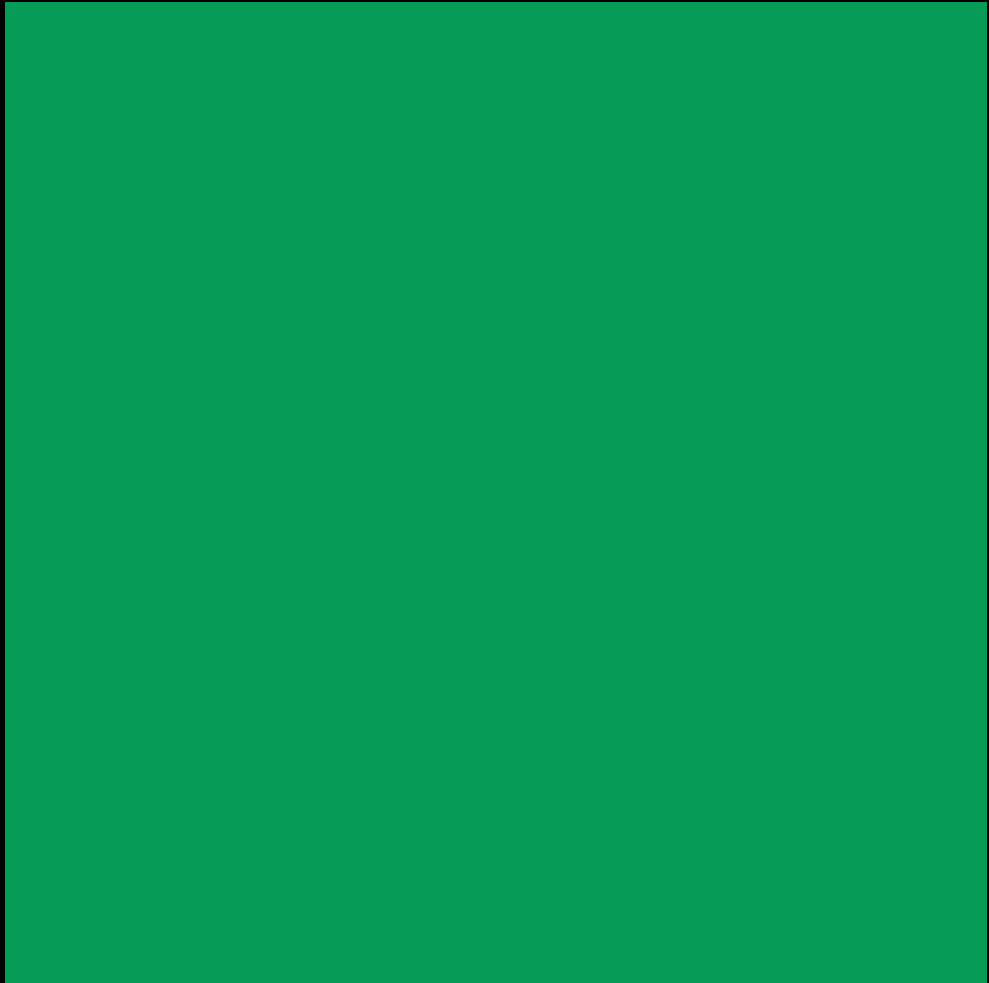


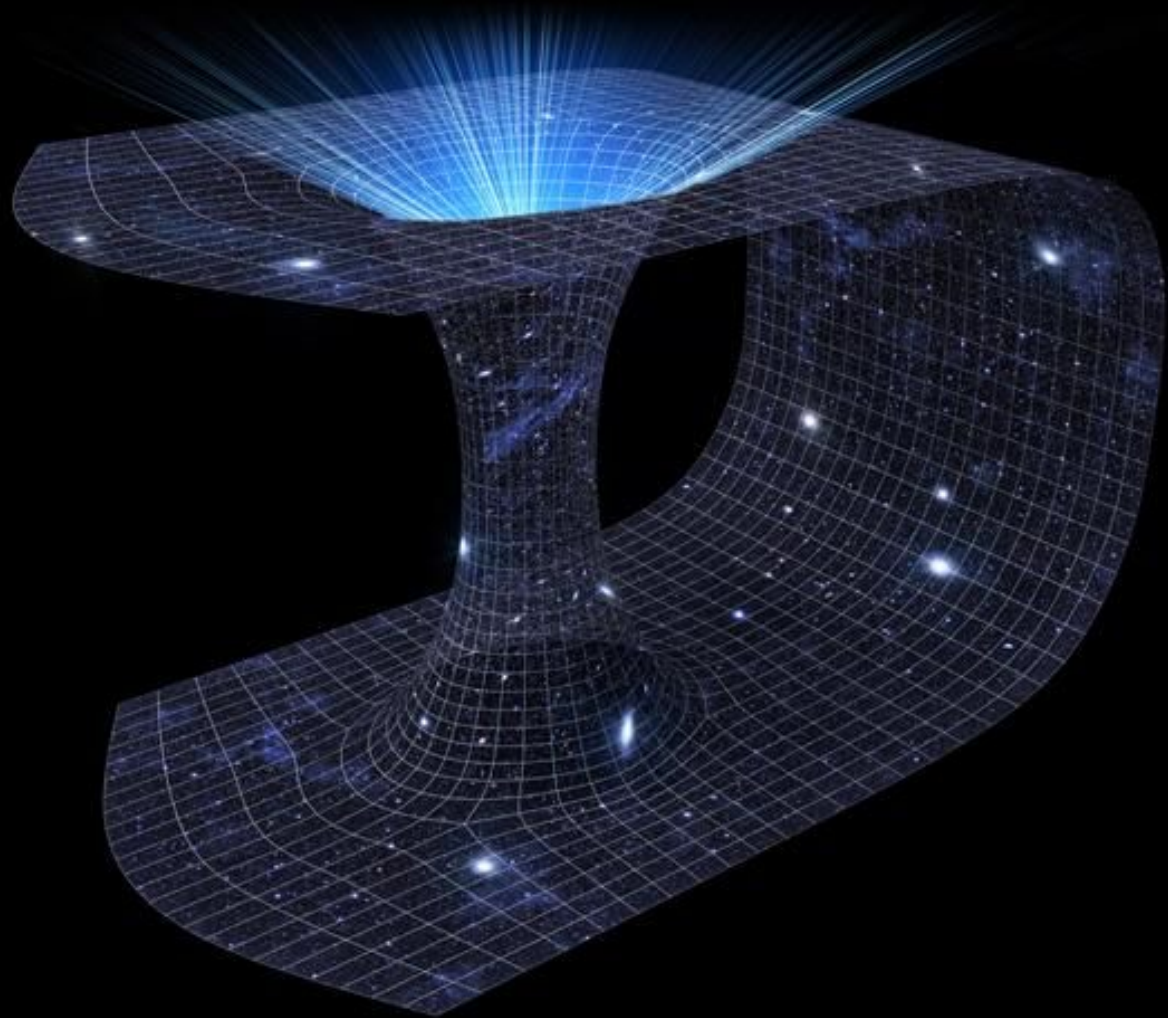






black holes are ~weird~









let's talk about ligo

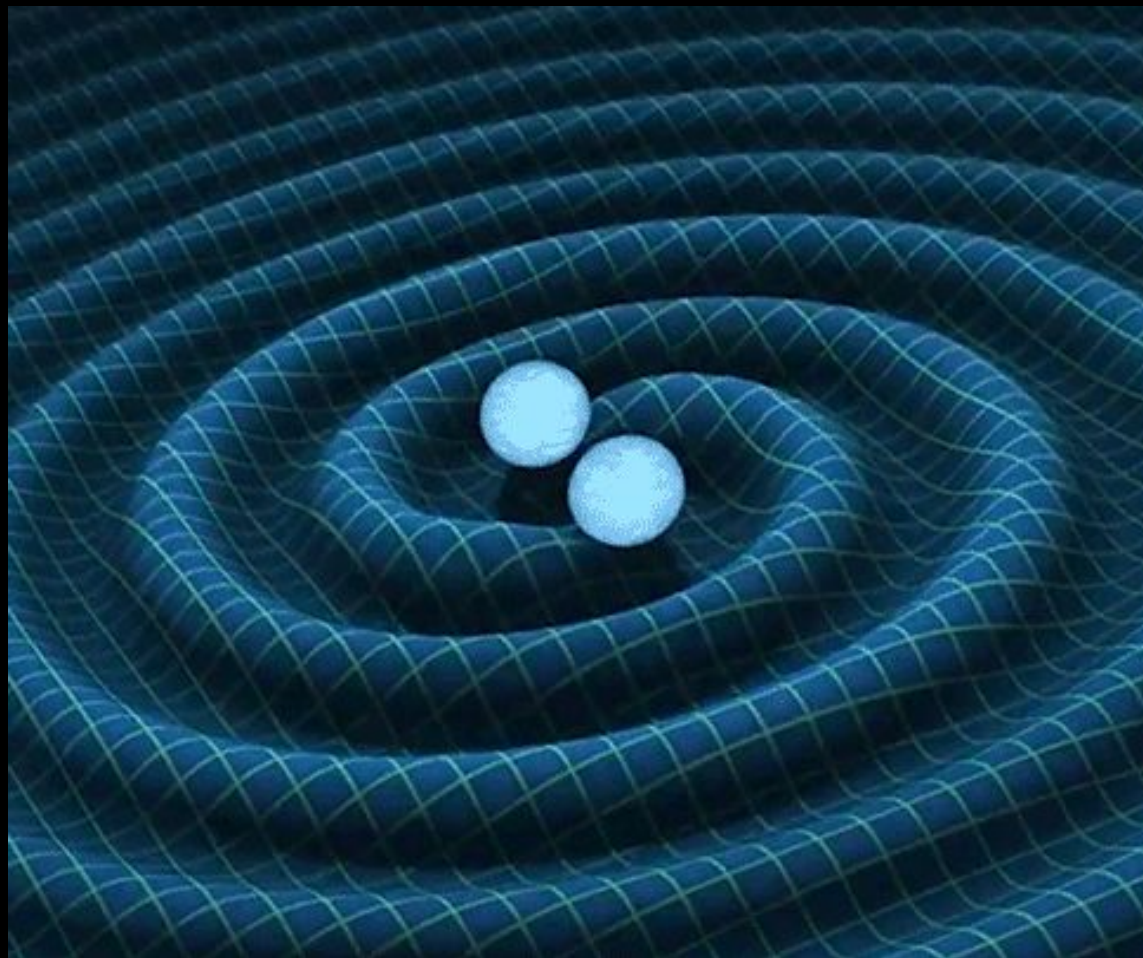
L laser

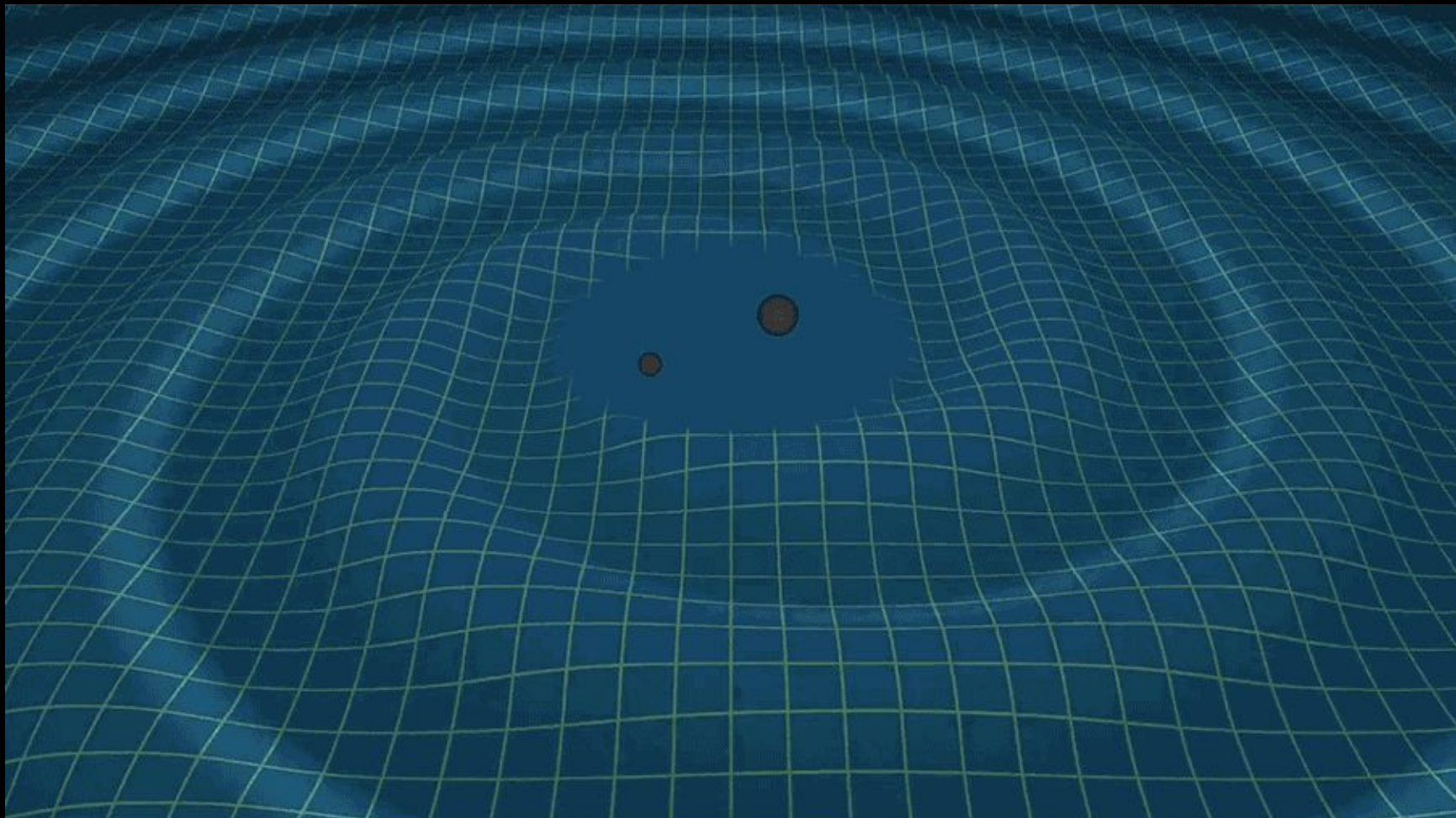
I interferometer

G gravitational-wave

O observatory

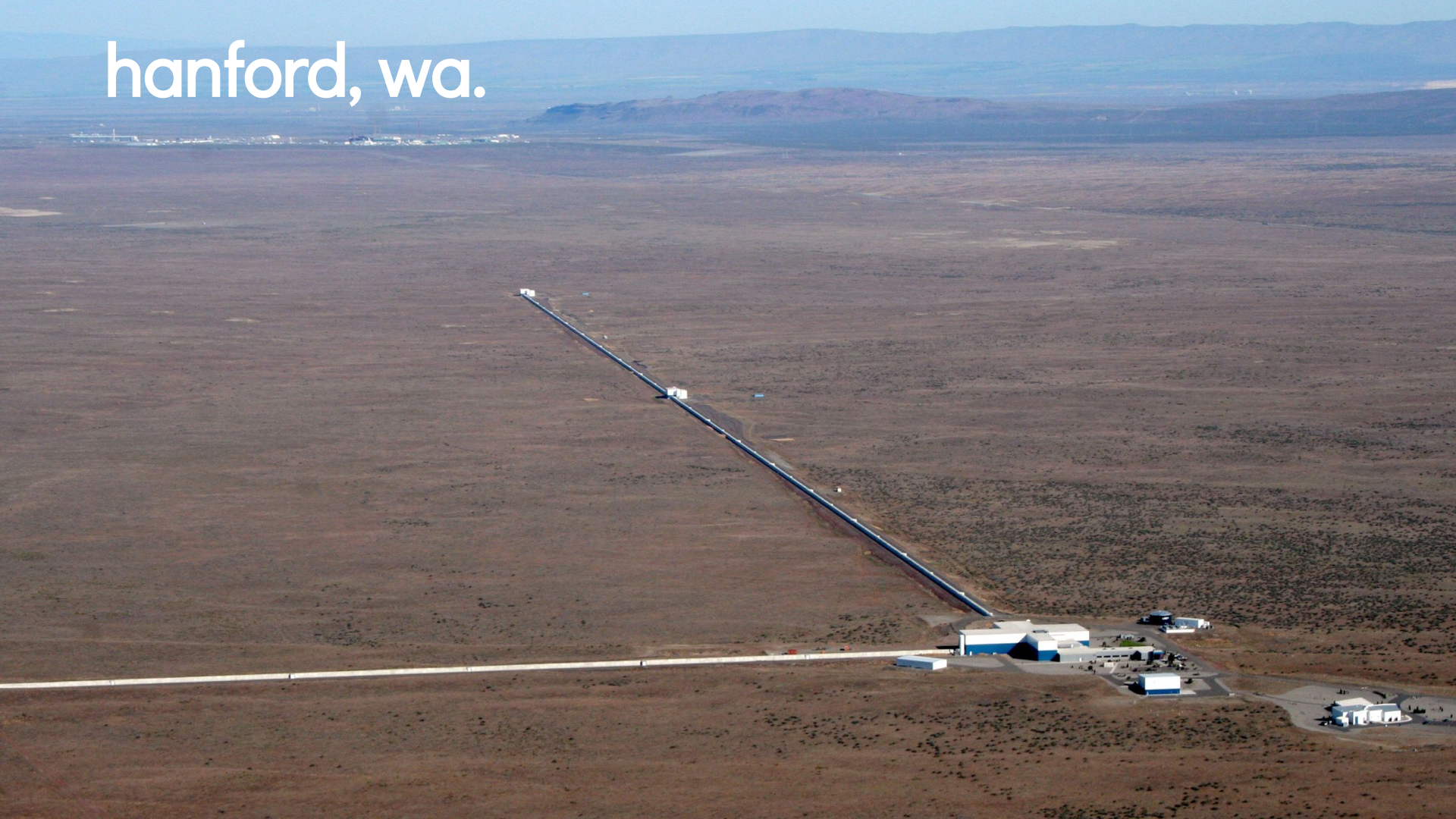


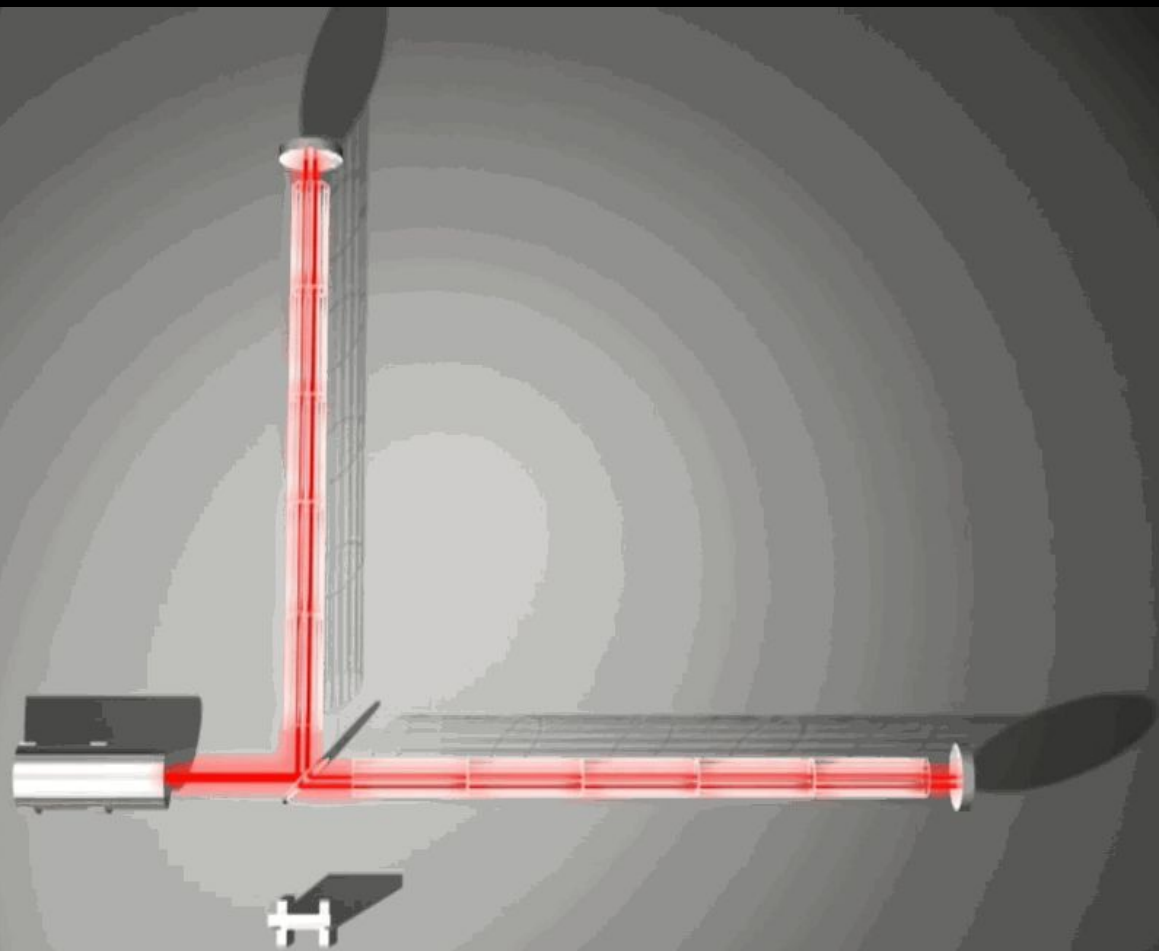


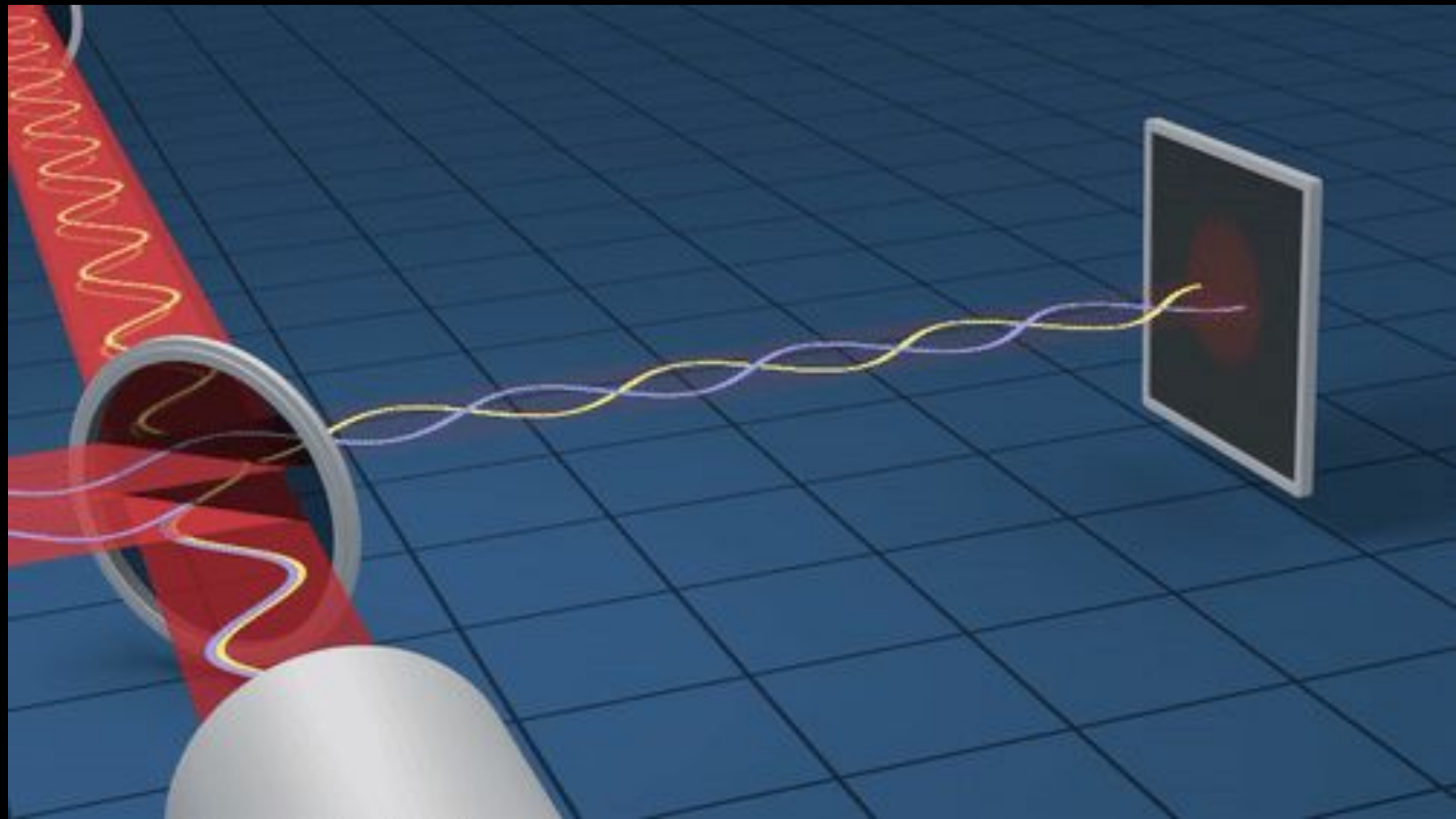




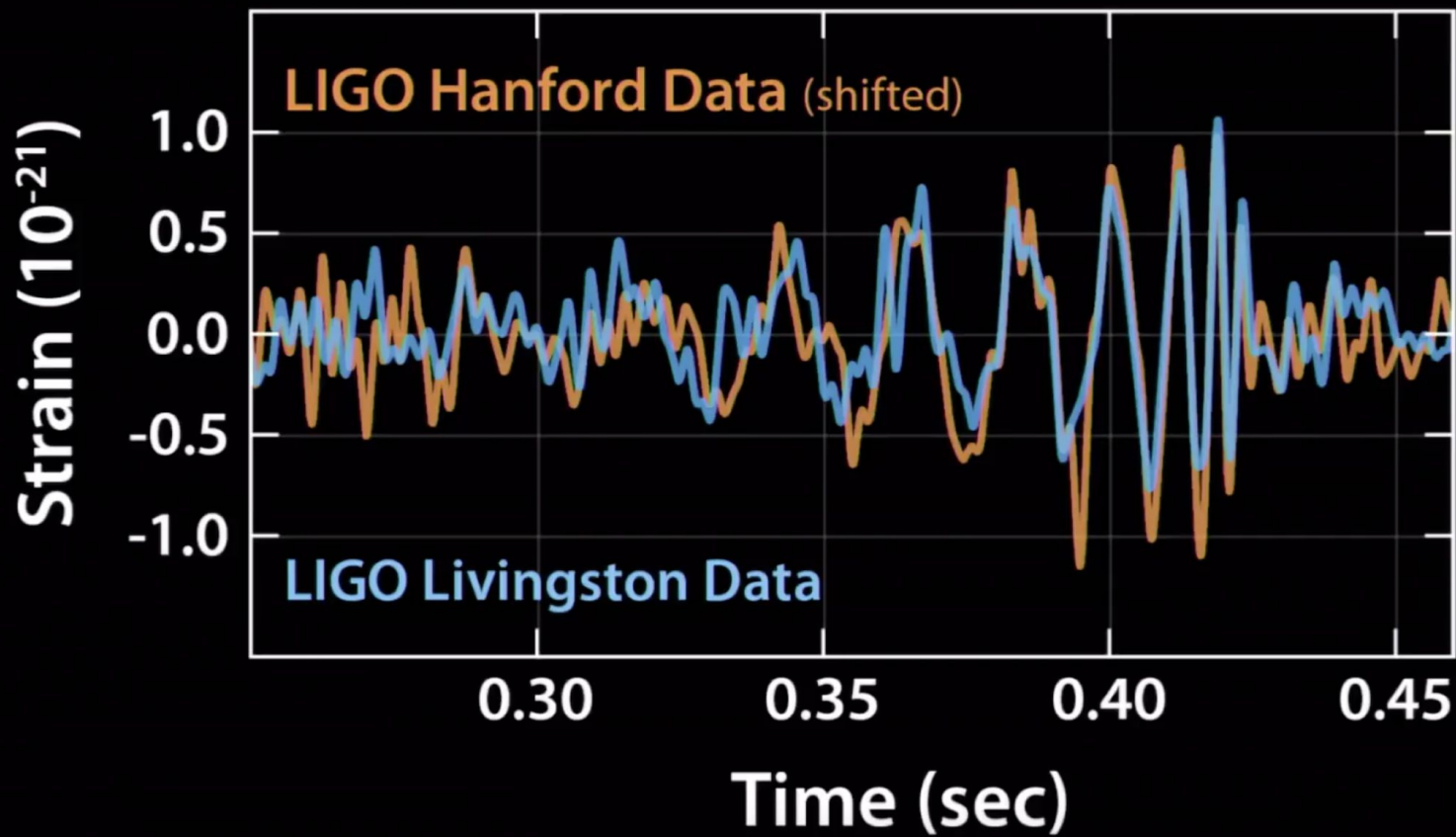
hanford, wa.













thank you! questions?