A Brief History (and Future) of Black Holes

Vikram Manikantan, Space Drafts #107

What is a black hole **not**?

1. It is not a vacuum
2. It is not a wormhole

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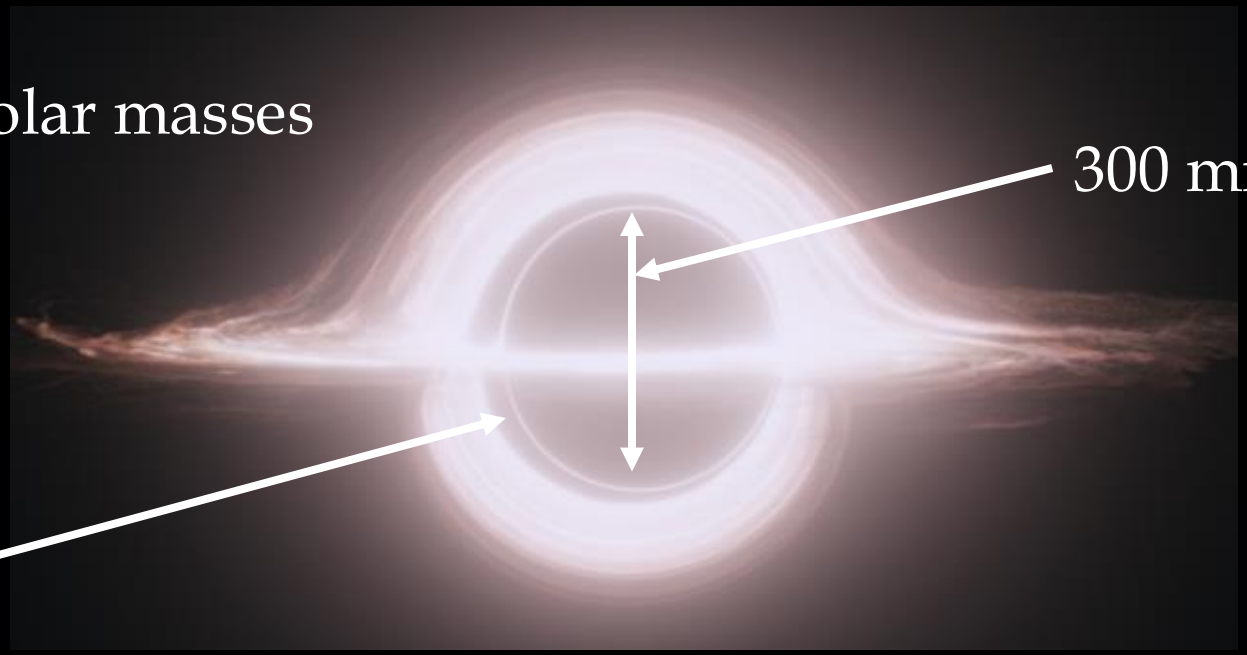
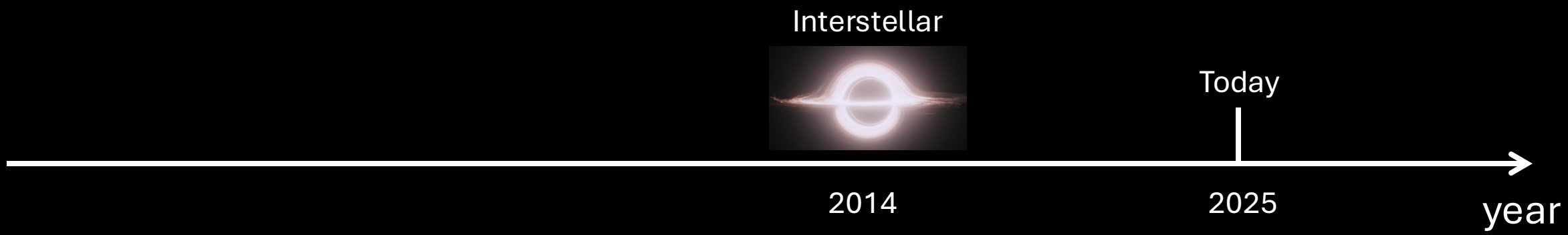
A black hole is…

A region in space where gravity is so strong, not even *light* can escape



Gargantua, from Interstellar (2014)

Black hole timeline



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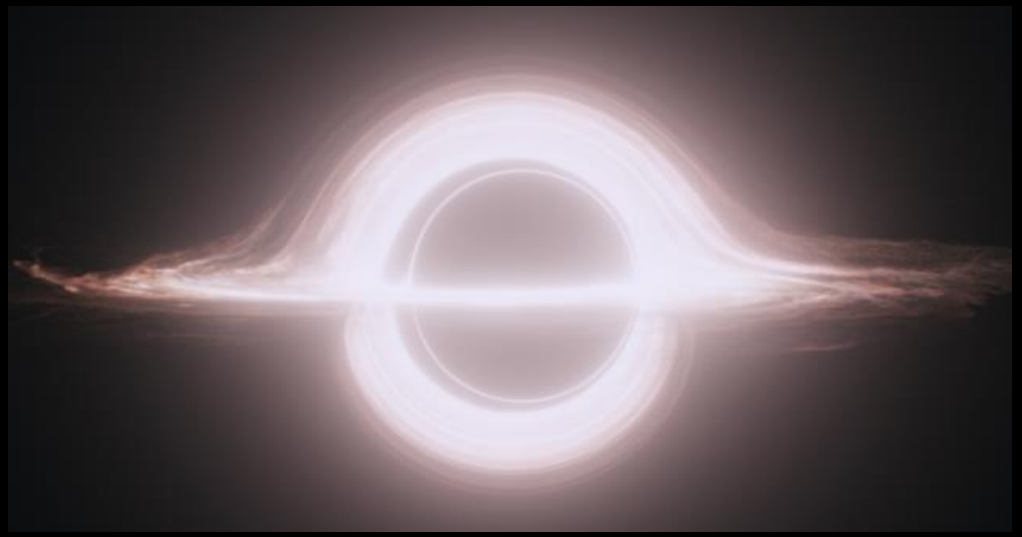
Trivia: Who first came up with the idea of black holes?

a) John Wheeler
b) Albert Einstein
c) Brahmagupta
d) John Michell
e) Jocelyn Bell Burnell



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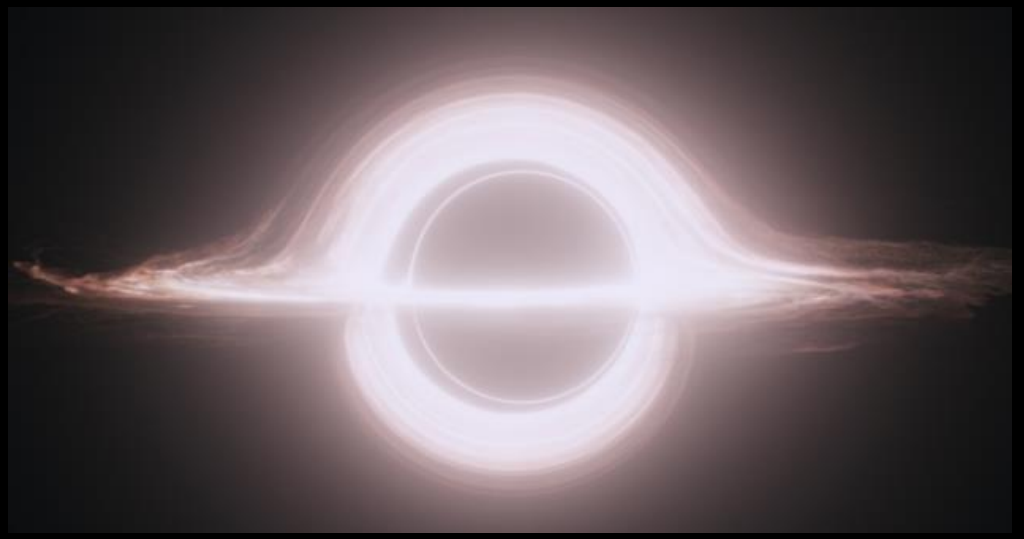

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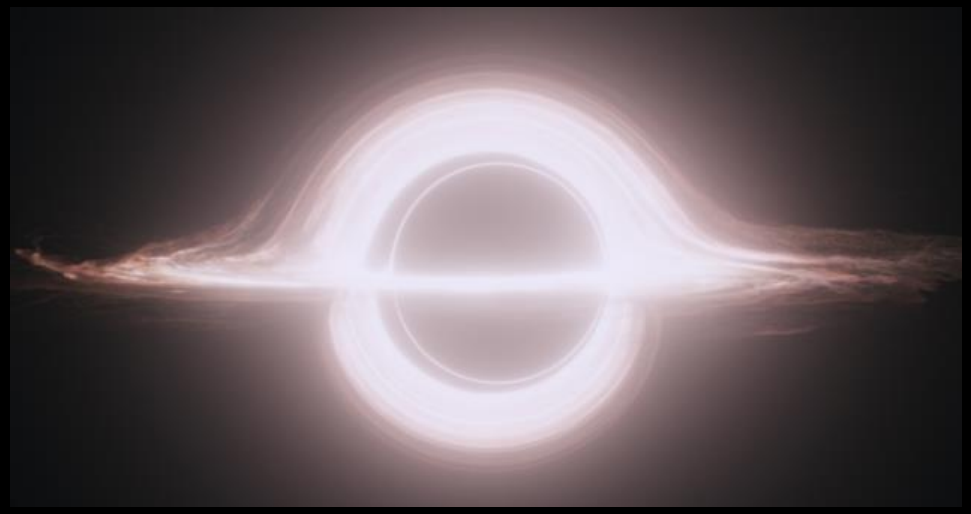

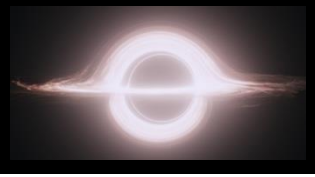

2014

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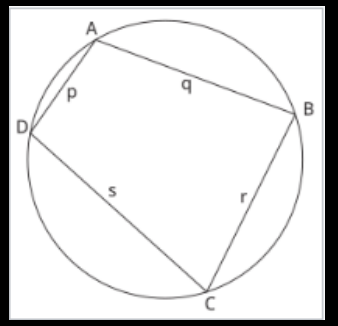
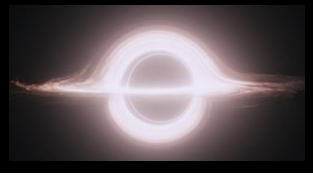
628: Brahmagupta and Gravity

- Described gravity as an attractive force
- Described a lot of geometrical theories
- First to use zero as a number
- First known astronomer to throw shade at other astronomers*

Drawing by Andreas Strick





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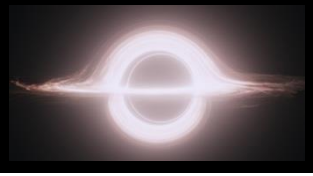
1684: Newton's Principia Mathematica

- Described gravitation as a "universal force"
- Explained elliptical orbits in the solar system



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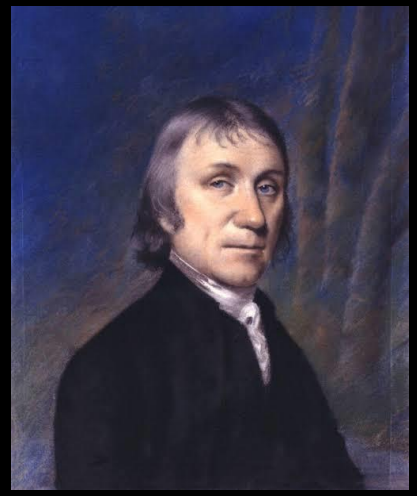
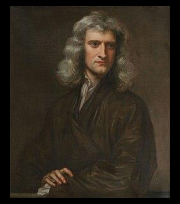
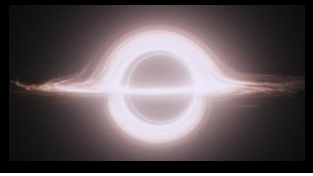
1784: John Michell describes a black hole

- Philosopher and clergyman
- Proposed the idea of black holes
- Predicted how we could find them (and was correct!)







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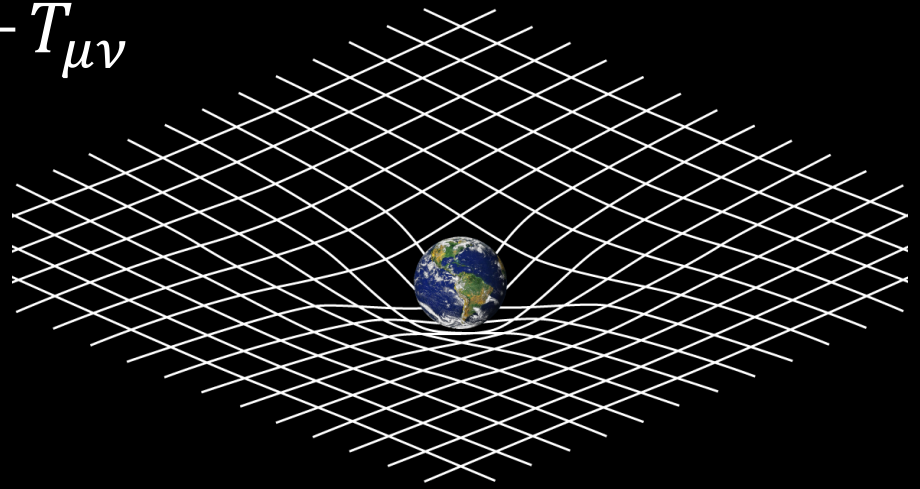
1915: Einstein's General Relativity

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$



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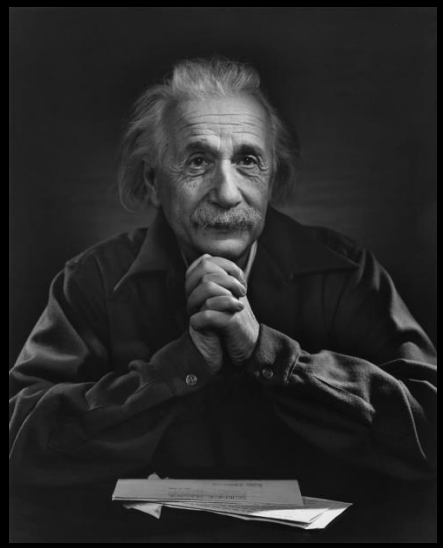

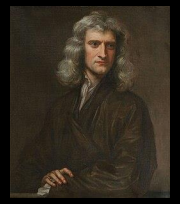

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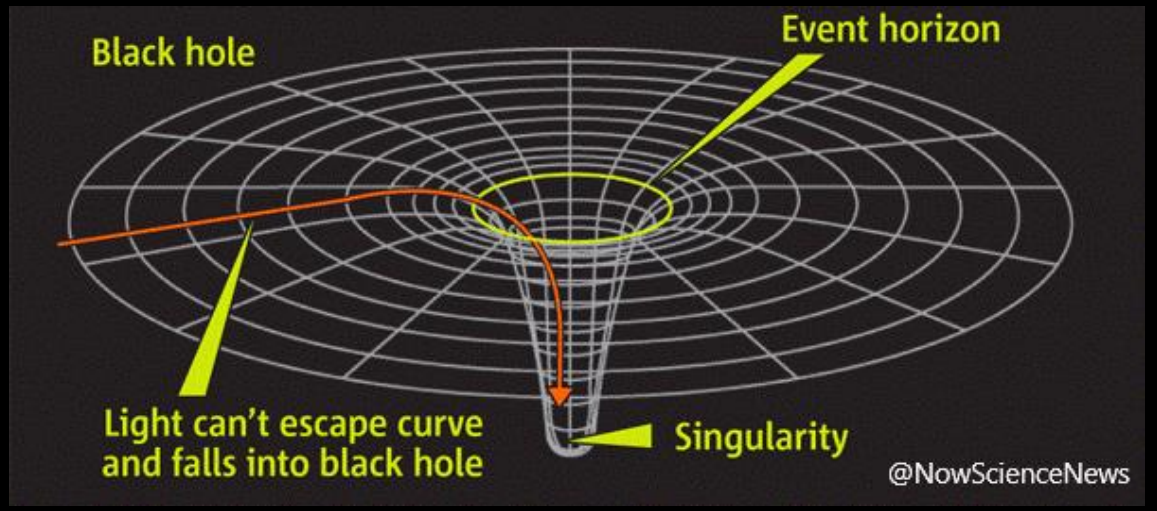
Schwarzschild, Finkelstein, and the event horizon

- Schwarzschild found a solution to Einstein's equations (1916)
- Finkelstein identified the 'event horizon' (aka the point of no return) (1958)

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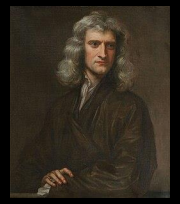
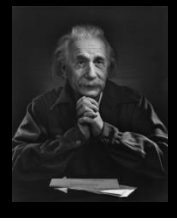
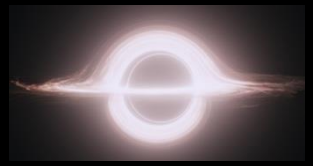

1684


1784


1915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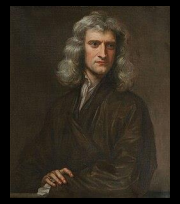
1967: Jocelyn Bell, the first neutron star

- Discovered the first neutron star
- A star so dense, that a teaspoon of its material would weigh 10 trillion pounds



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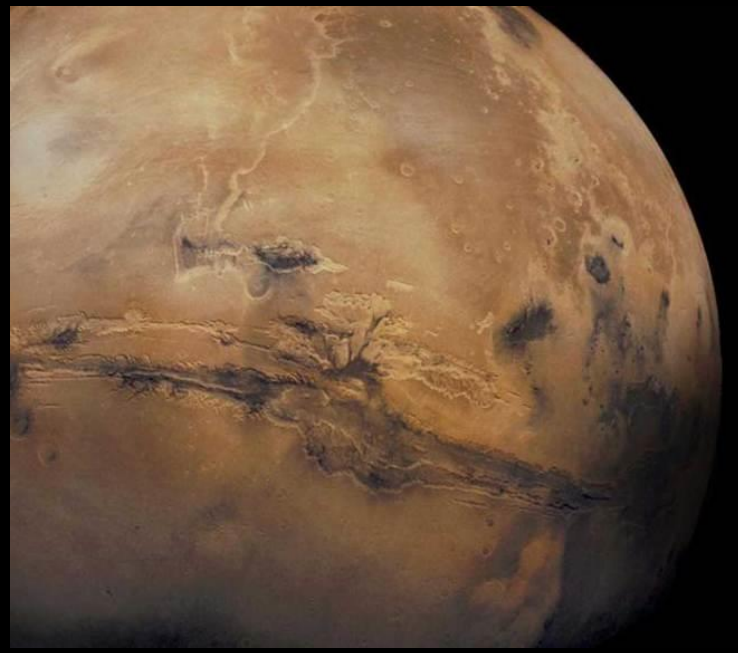
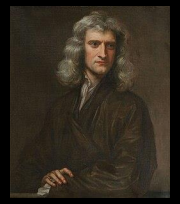
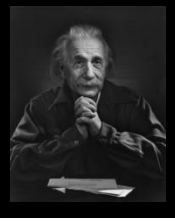
For context

- A cat made of neutron star would weigh about the same as Mars's moon, Phobos







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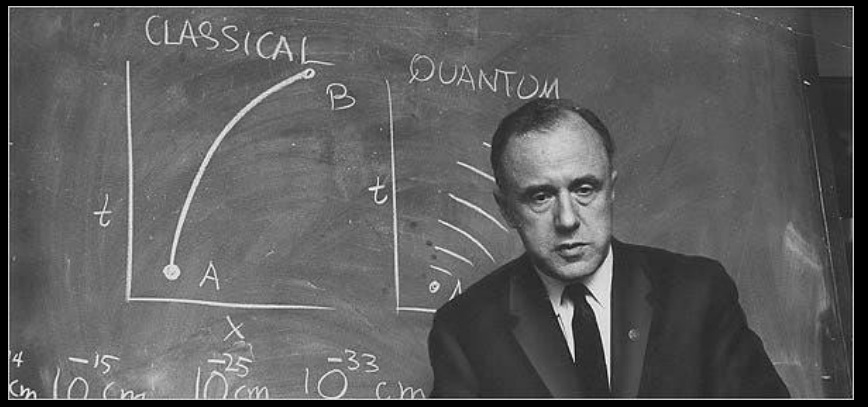
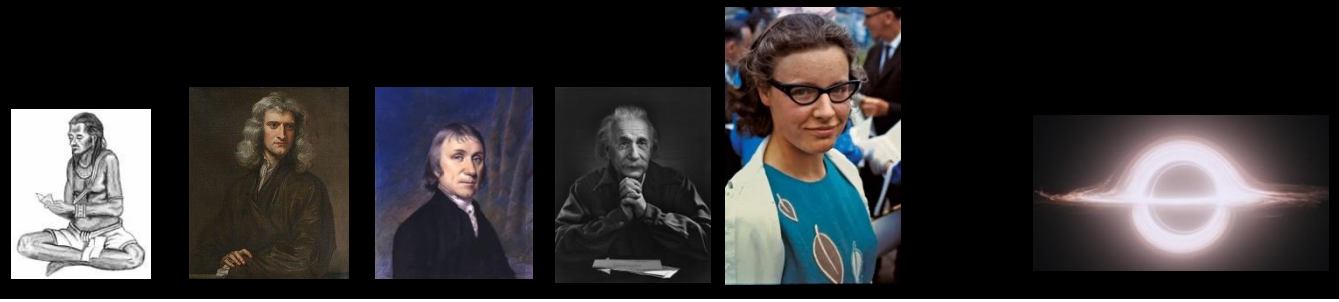
1967: First use of the phrase ‘Black Hole’

- Suggested by a student during John Wheeler’s lecture
- Wheeler continued to use it, as it was catchy





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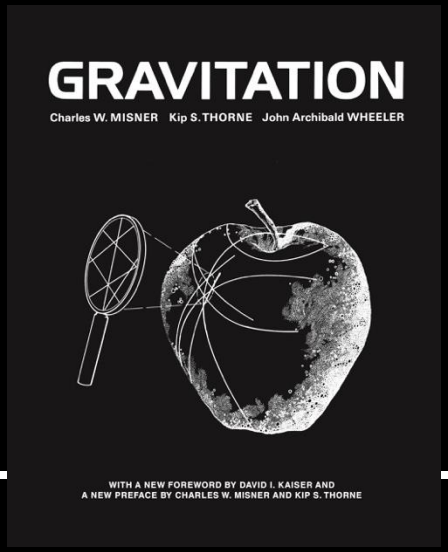

1971: Cygnus X-1, the first black hole

- Found by multiple scientists at the same time
- X-ray emission from a very small region
- Dark companion (as predicted by Michell) – must be a black hole!


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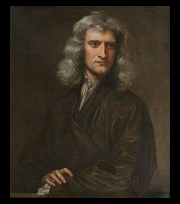
1684


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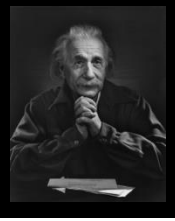
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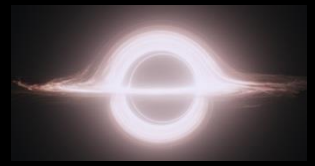
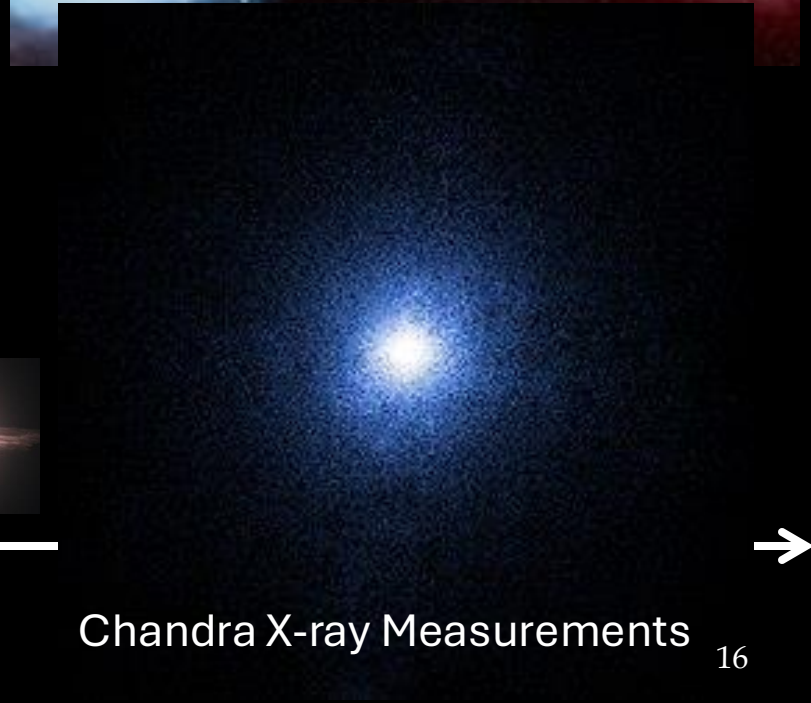
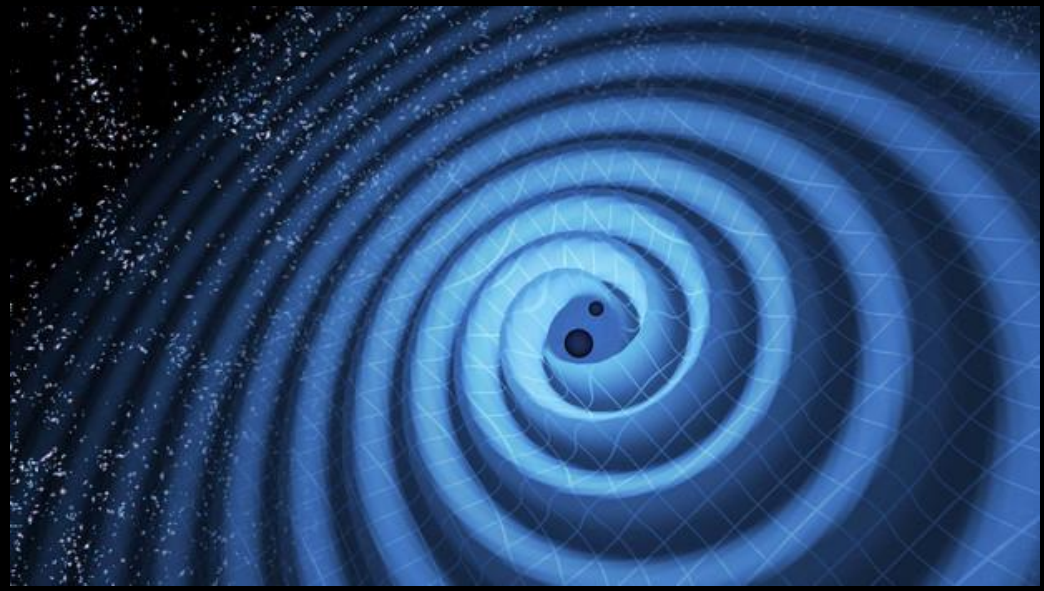
1967


2014


Chandra X-ray Measurements

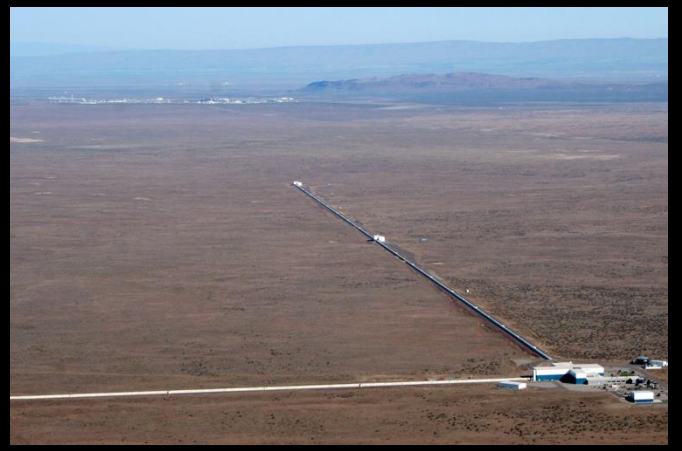
Einstein's prediction of gravitational waves

- Accelerating objects would create 'ripples' in spacetime
- The ripples would be tiny!
- Measuring a change of 1 part in 10^{20}
- That is like the distance from earth to the sun changing by 1000th the width of a hair

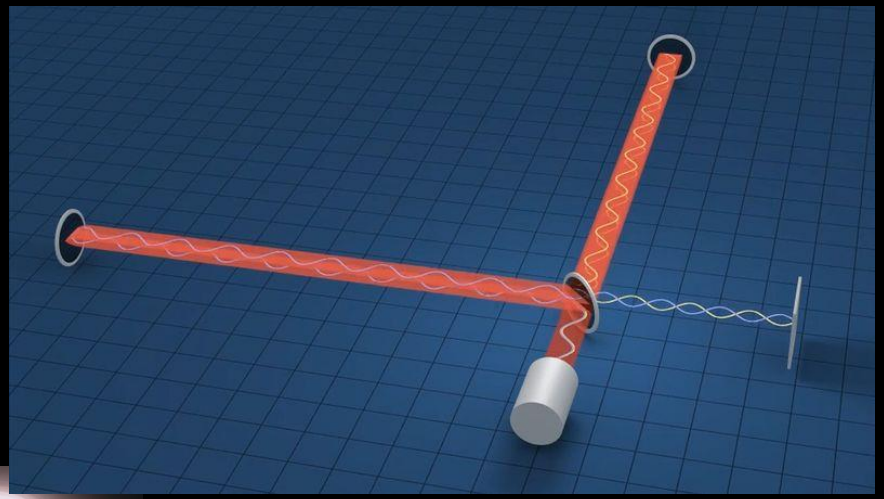


1992: Lasers on Earth

- In 1992, the NSF made their biggest ever investment into the Laser Interferometer Gravitational-wave Observatory (LIGO)
- Interfering lasers measured how spacetime was changing



LIGO Hanford



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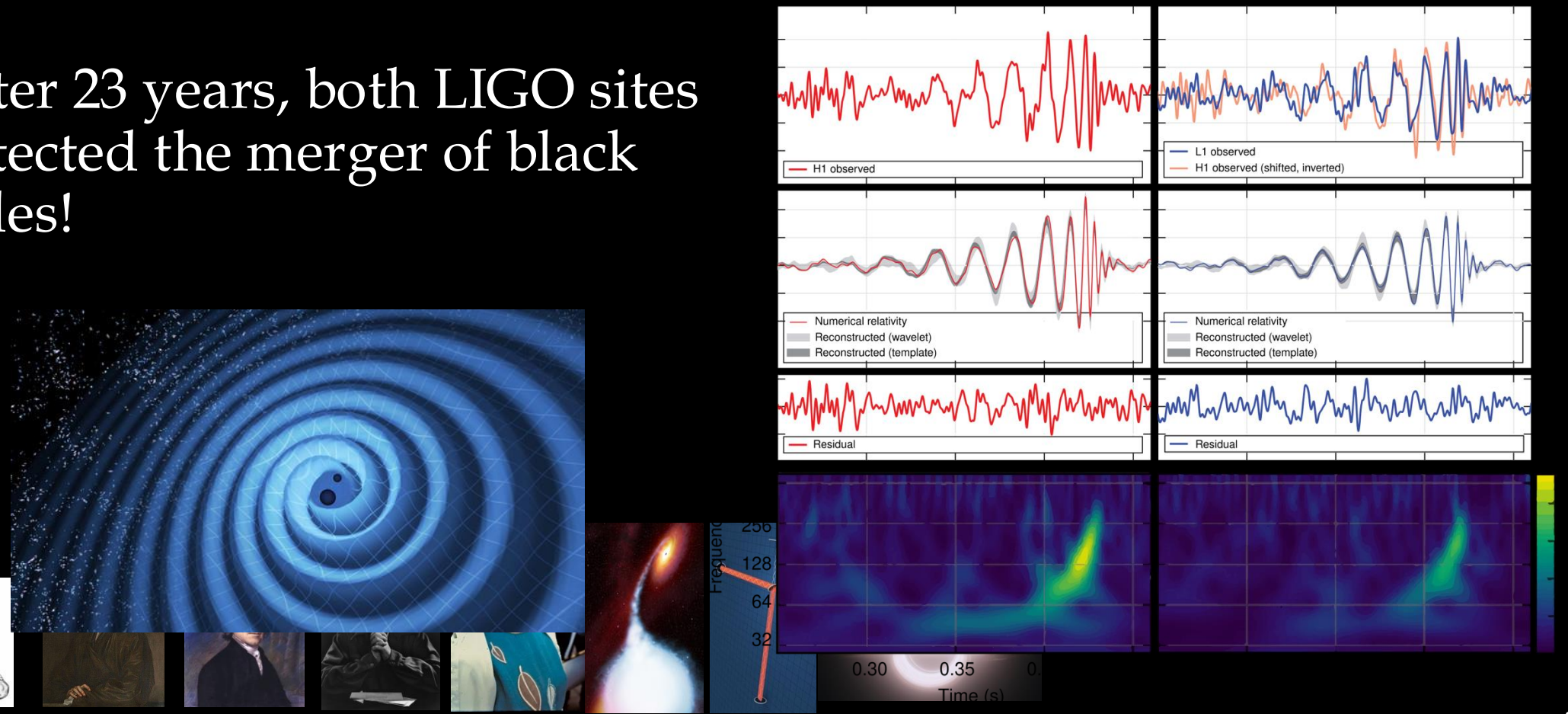
“the National Science Foundation is the agency that takes these kinds of risks. We support fundamental science and engineering at a point in the road to discovery where that path is anything but clear. We fund trailblazers. It’s why the U.S. continues to be a global leader in advancing knowledge.” - France Cordova, NSF Director

2015: The first black hole merger detection

- After 23 years, both LIGO sites detected the merger of black holes!



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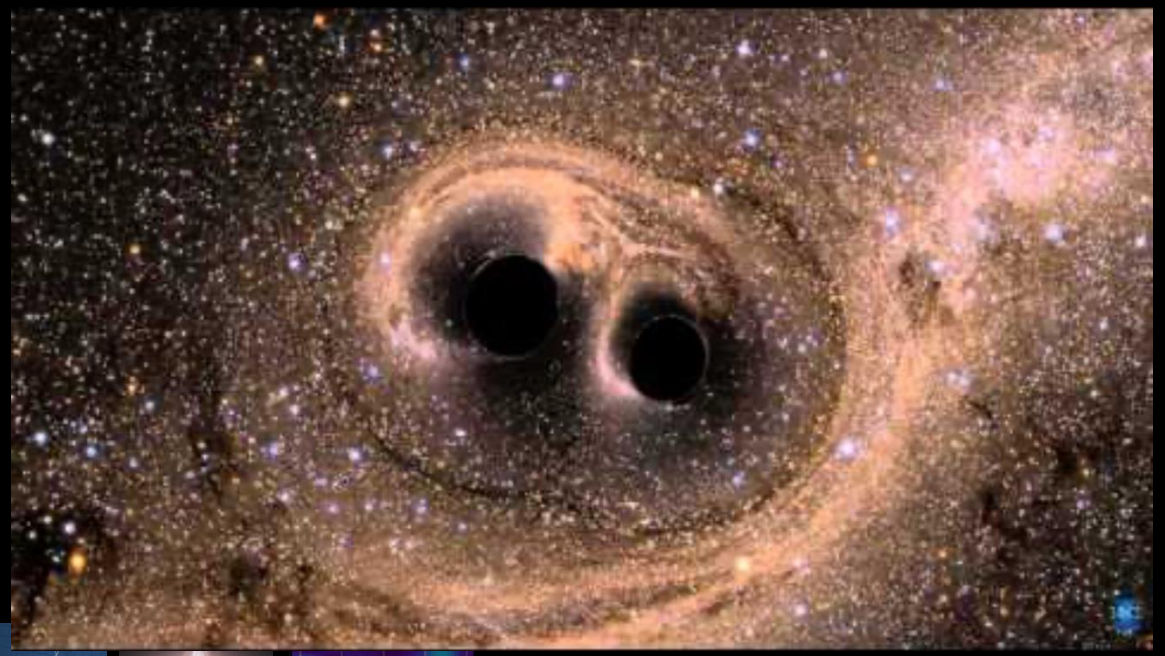
- Now, over 290 detections!



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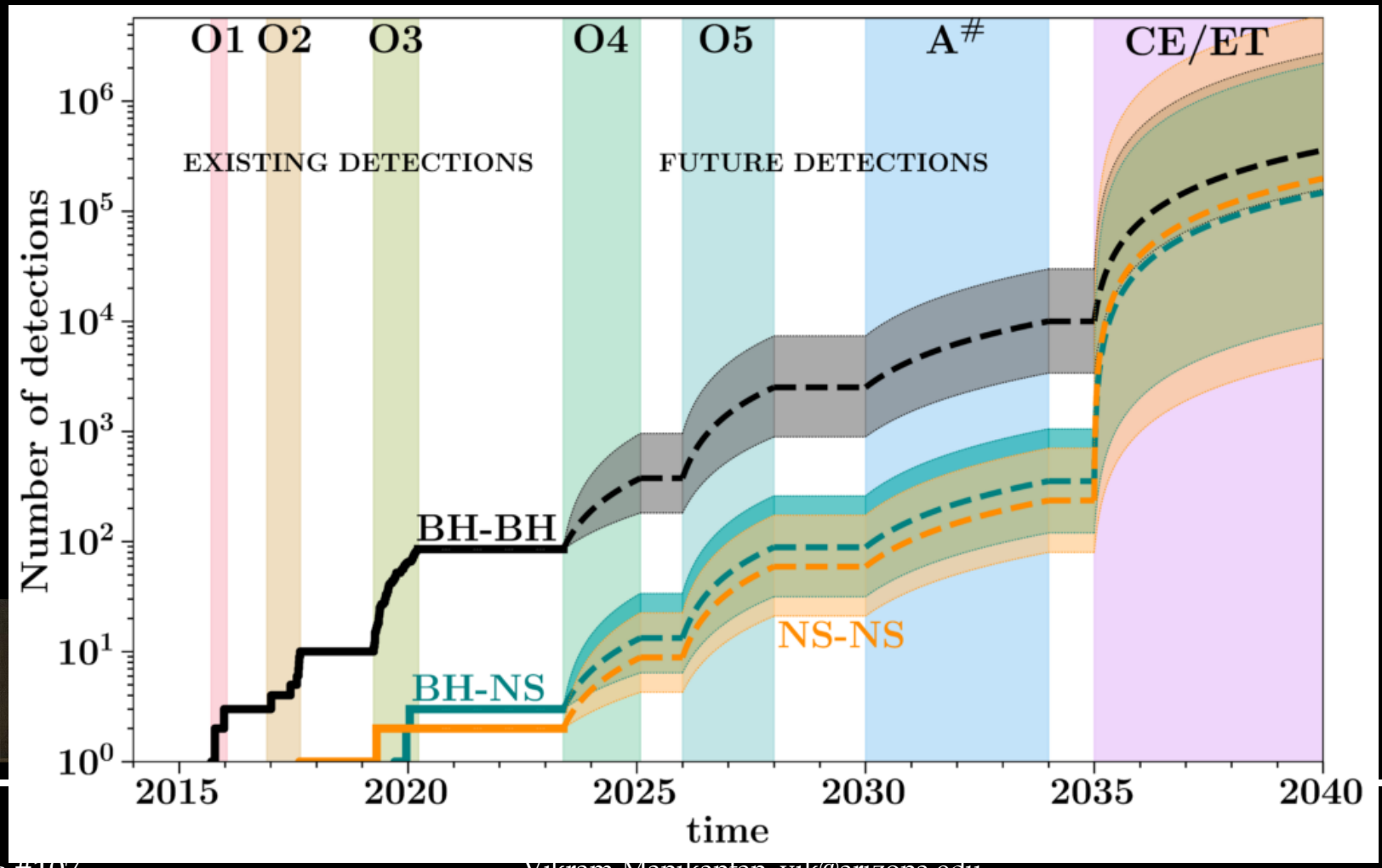
Future of Gravitational Waves



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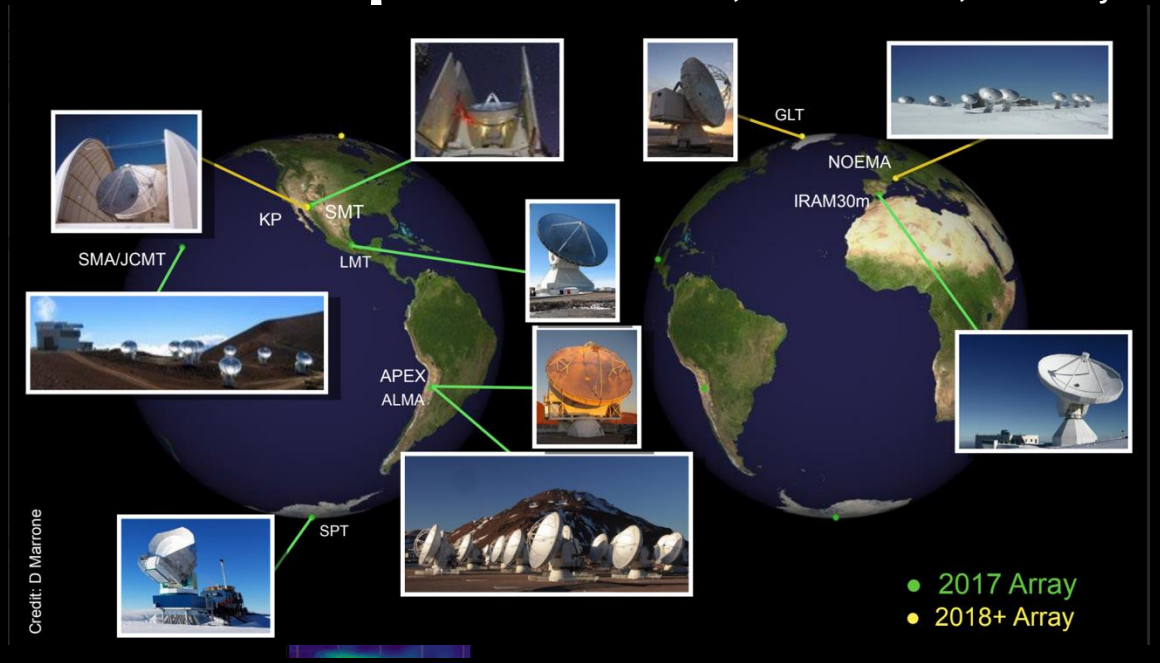
Credits to Floor Broekgaarden

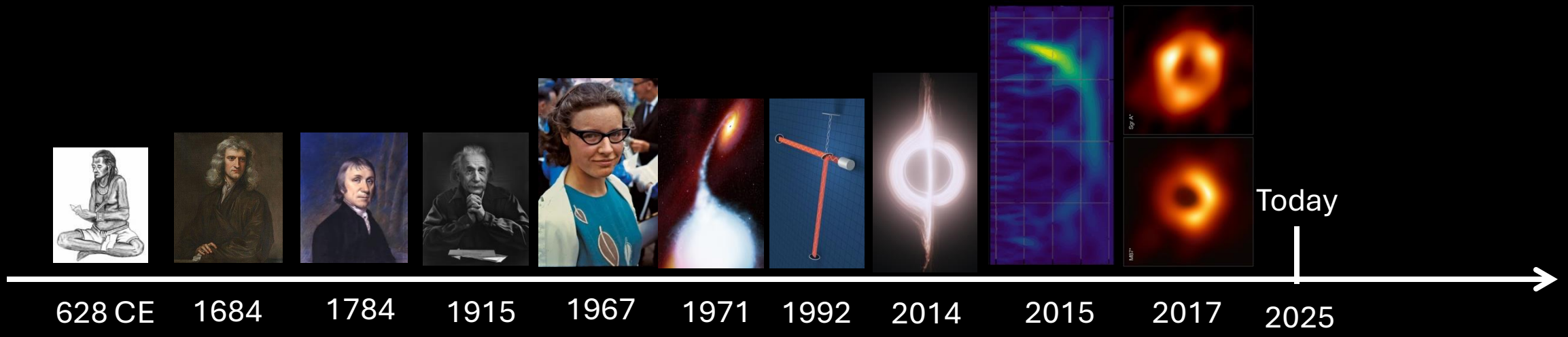
2017: Event Horizon Telescope

Credits: EHT, Dan Marrone, and Amy Lowitz

- Direct imaging of a supermassive black hole, M87* and Sag A*



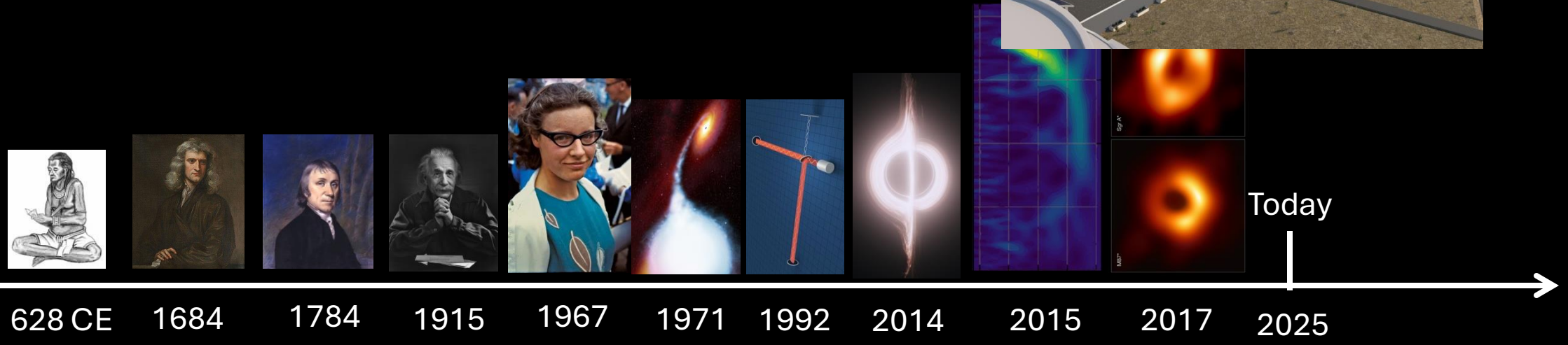
What next?


Today
628 CE
1684
1784
1915
1967
1971
1992
2014
2015
2017
2025

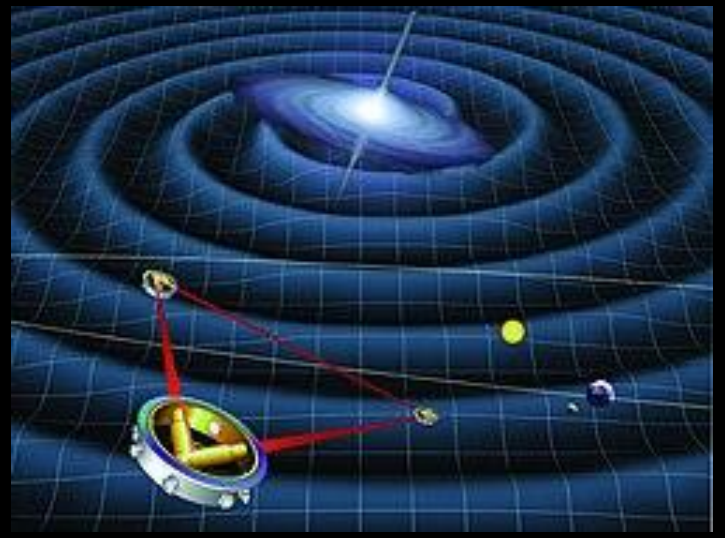
What next? More lasers on earth

- Cosmic Explorer with 40km long arms!
- Will observe every single stellar compact object merger in the visible universe (>100,000 a year)

Mockup of Cosmic Explorer

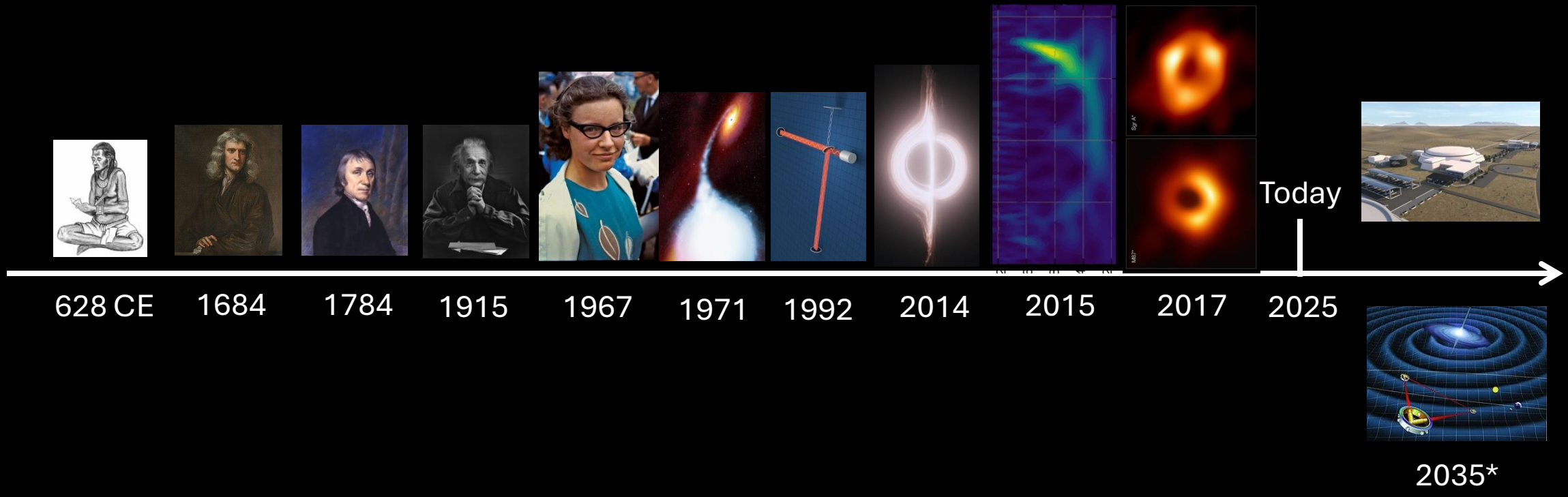


What next? Lasers in Space



- Laser interferometer Space Antenna, planned launch 2035
- Arms are 2.5 million kilometers in length
- Observe binary stars in our galaxy
- The merger of supermassive black holes

A Brief History and Future of Black Holes



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