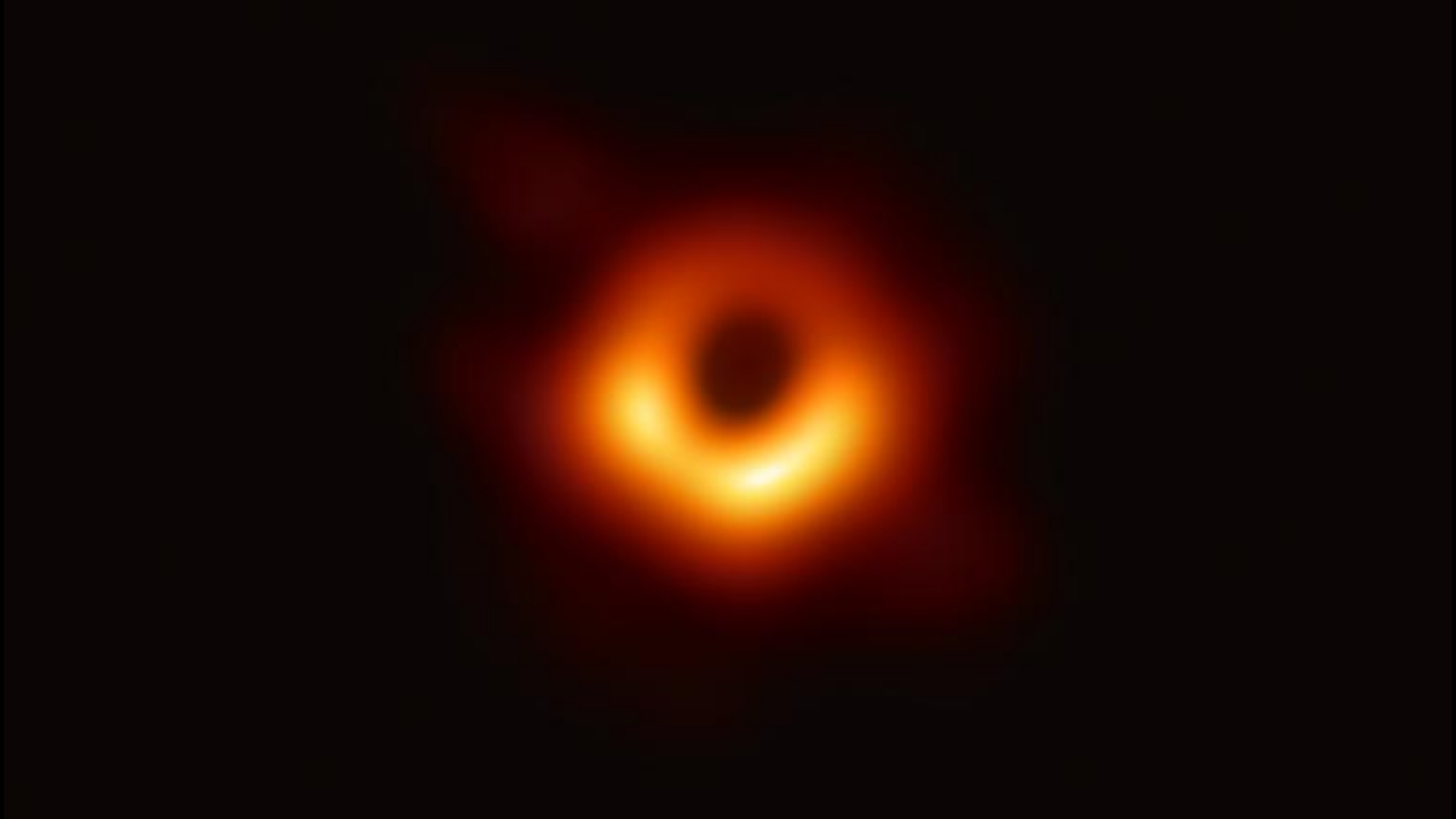
Event Horizon Telescope

Imaging a Black Hole

Adam Swinton



Introduction

- What are black holes?
- What are we looking at?
- How was this done?
- Why it is important?

What are they?

- Region of spacetime at which the escape velocity is greater than the speed of light.
- Escape velocity of an object is defined by it's *mass* and *distance to centre.*
- Radius at which a mass has escape velocity equal to c is the Schwarzchild radius.
- Event horizon is point at which light can no longer escape.

$$v = \sqrt[2]{\frac{2GM}{r}}$$

$$R_{sch} = \frac{2GM}{c^2}$$

$r = Radius$

$M = Mass$

$G = Gravitational\ Constant$

$c = Speed\ of\ Light$

$v = Escape\ Velocity$

$R_{sch} = Schwarzchild\ Radius$

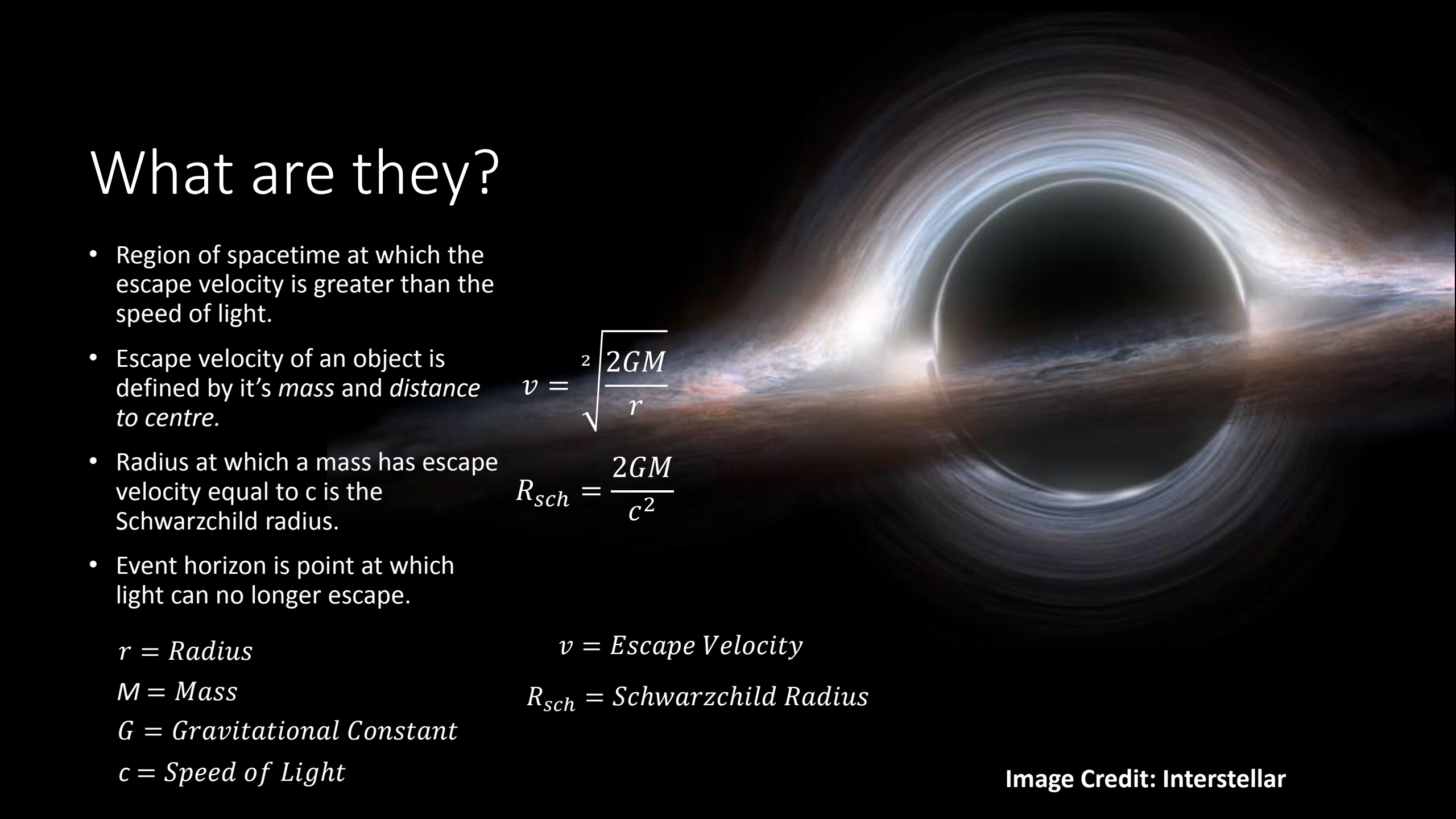


Image Credit: Interstellar

Formation

- Form when very massive stars collapse at the end of their life cycle in a supernova.
- Imbalance between radiation and gravitational pressure.
- Continues to grow by absorbing matter from it's surroundings.
- By 'eating' stars and other black holes, supermassive black holes with billions of solar masses may form.

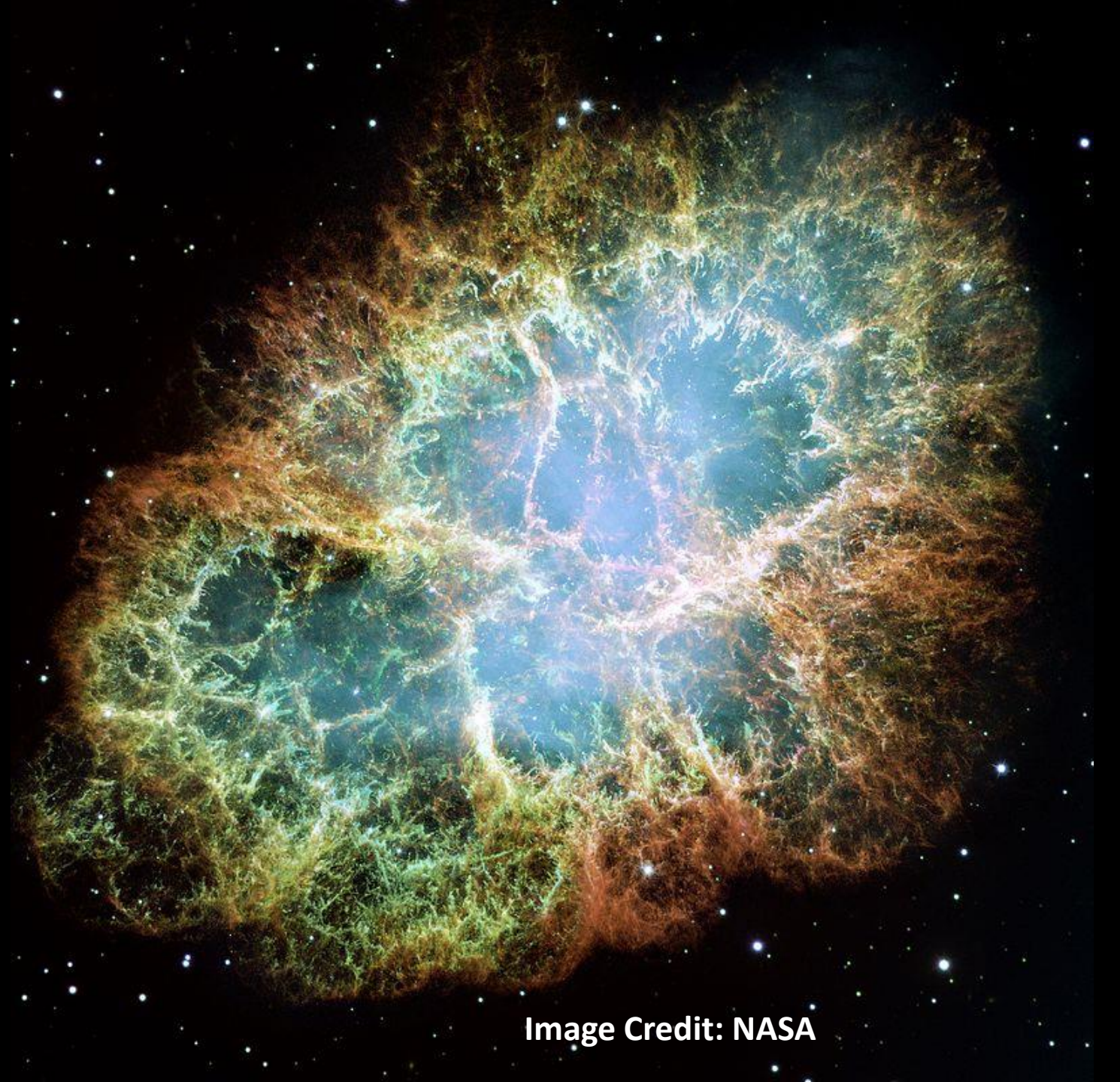
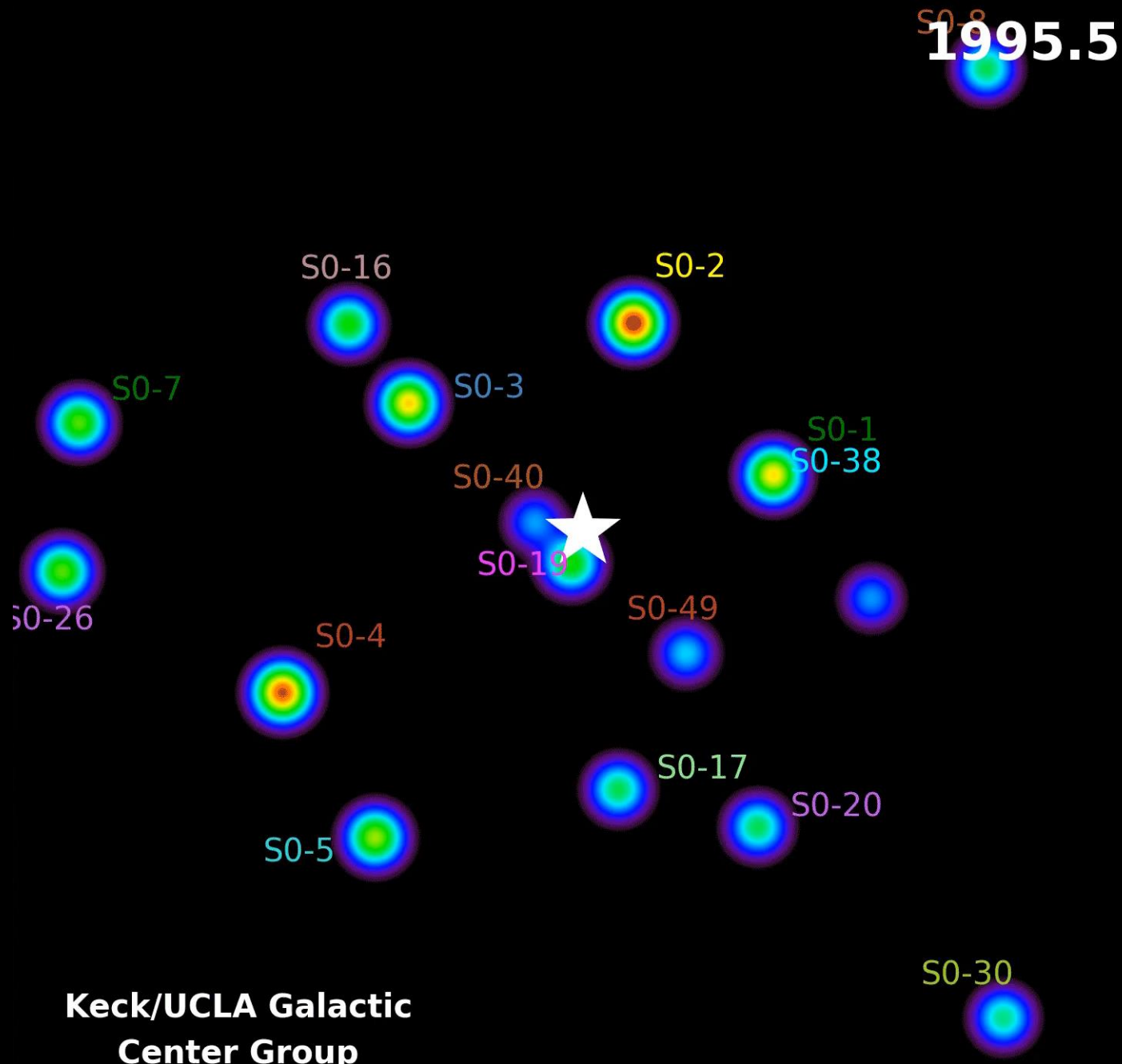


Image Credit: NASA

Observational Evidence

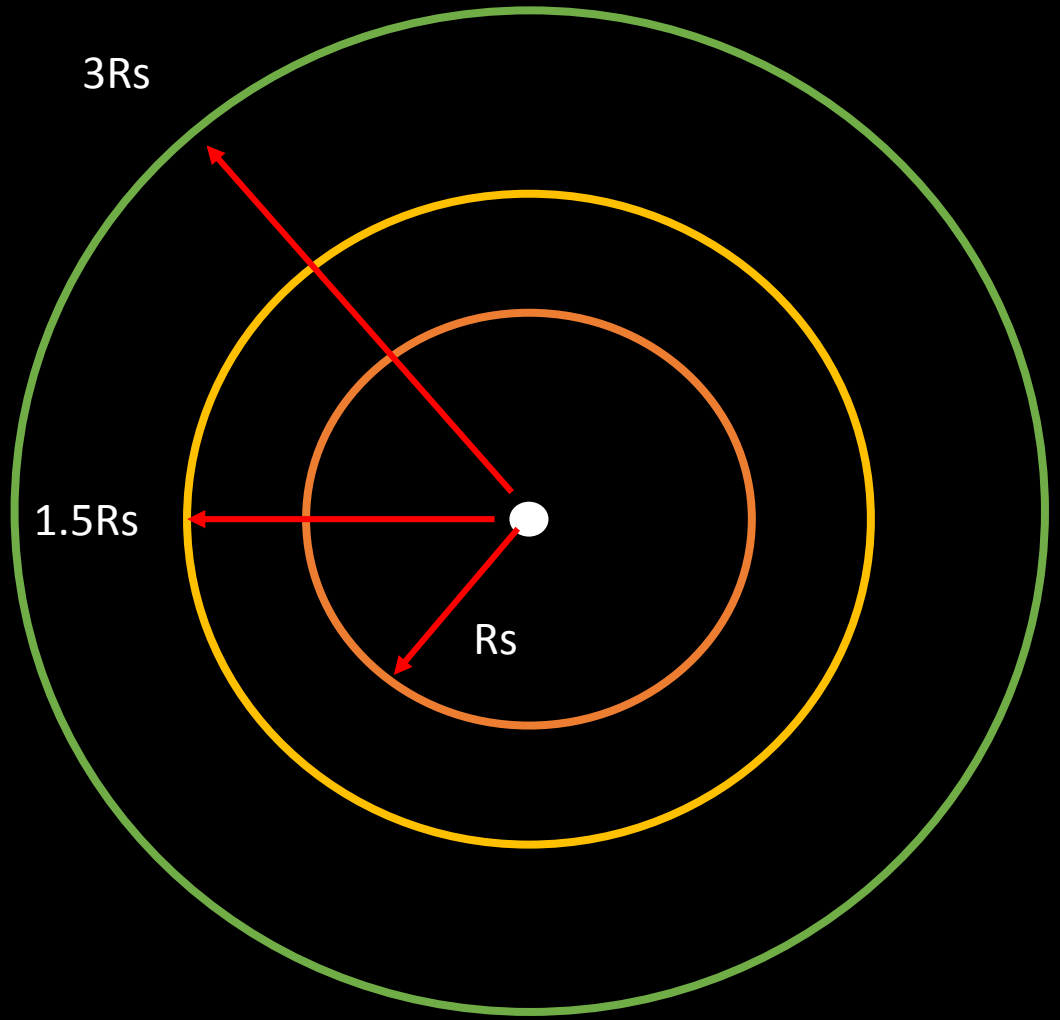
- First suggested as a by-product of General Relativity.
- Motions of stars orbiting Sagittarius A*.
- LIGO gravitational wave observatory observed waves consistent with theoretical predictions.



Video Credit: **Keck/UCLA Galactic Center Group**

What are we looking at?

- Rs = Event Horizon.
- 1.5Rs = Photon sphere (Innermost sphere of stable photon orbits).
- 3Rs = Stable orbit of accretion disk.



What are we looking at?

- Accretion disk is a disk-shaped structure formed by material in orbital motion around a black hole.
- Gravitational and frictional forces compress the material causing the emission of X-rays.
- Extreme curvature of spacetime allows us to see *behind* the black hole!

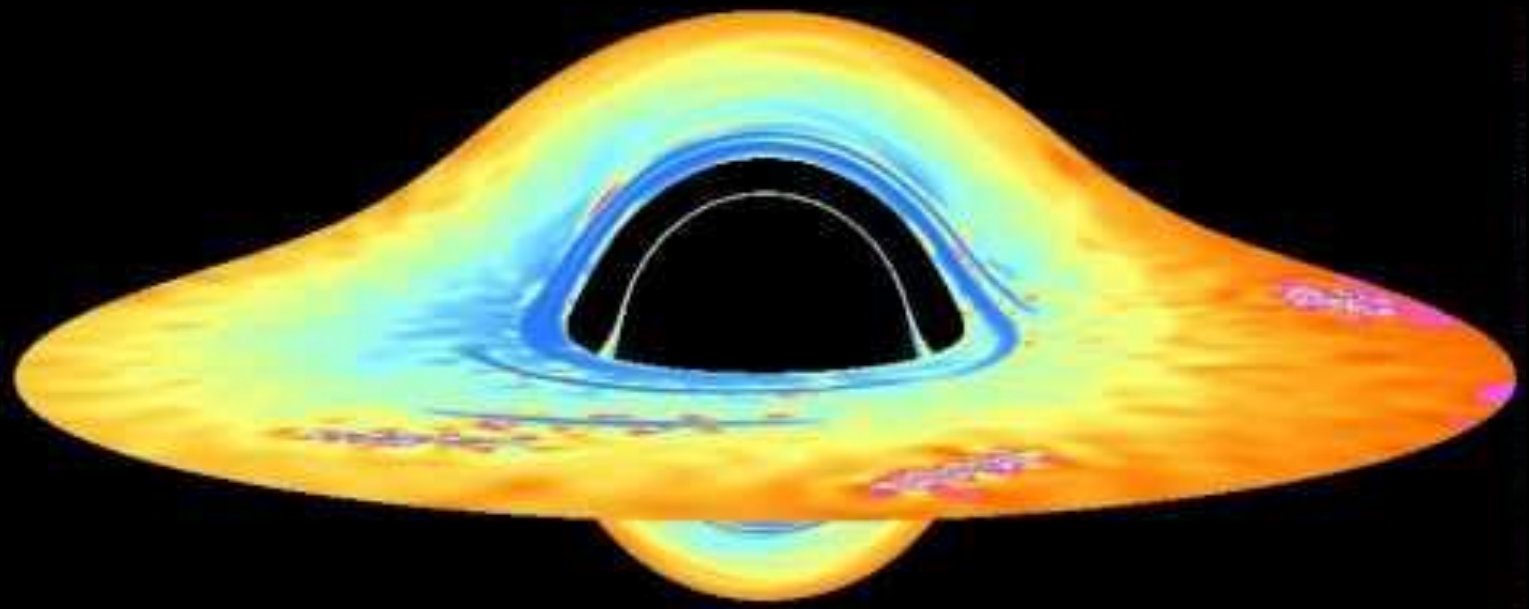
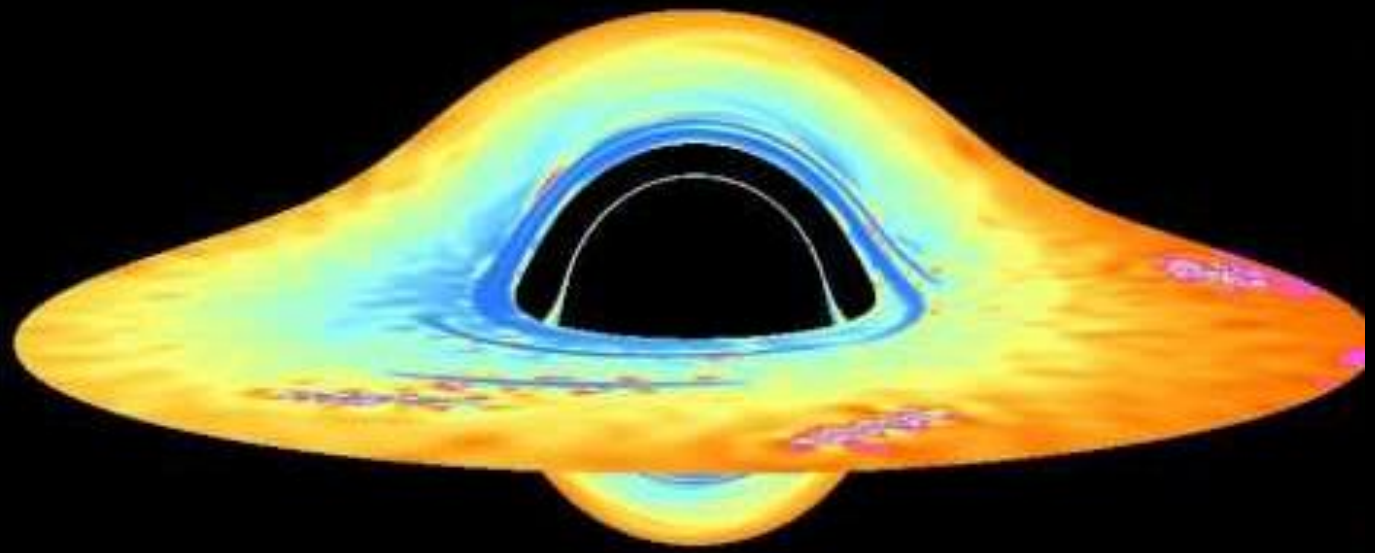
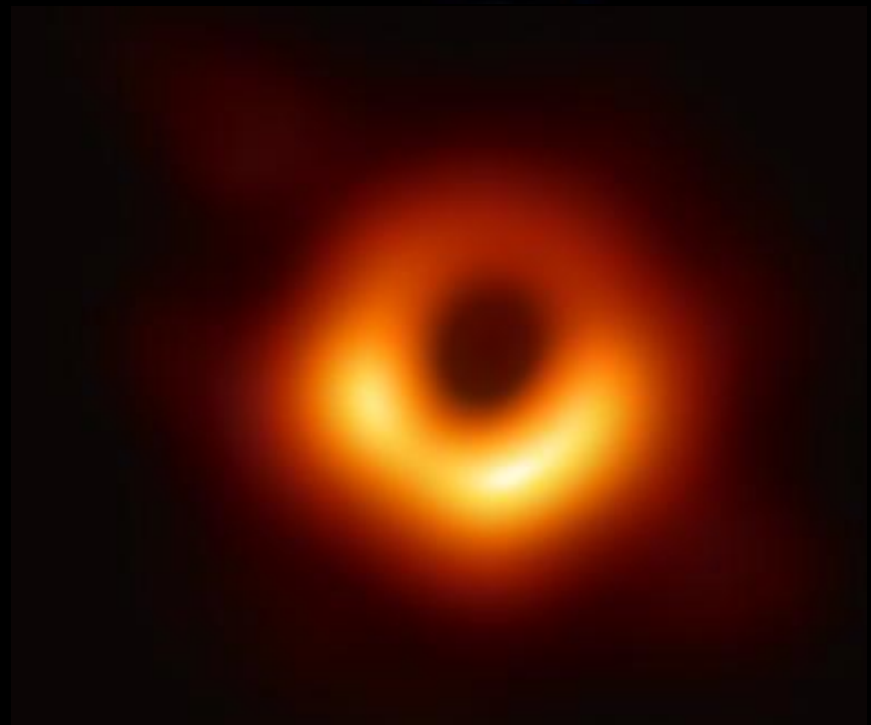


Image Credit: Thomas Müller

What are we looking at?

- Shadow cast over the surrounding material.
- Event horizon larger than solar system.
- Around 40 microarcseconds wide.
- 1 arcsecond = 1/3600th of a degree.
- Equivalent of reading a newspaper in New York from a café in Paris!





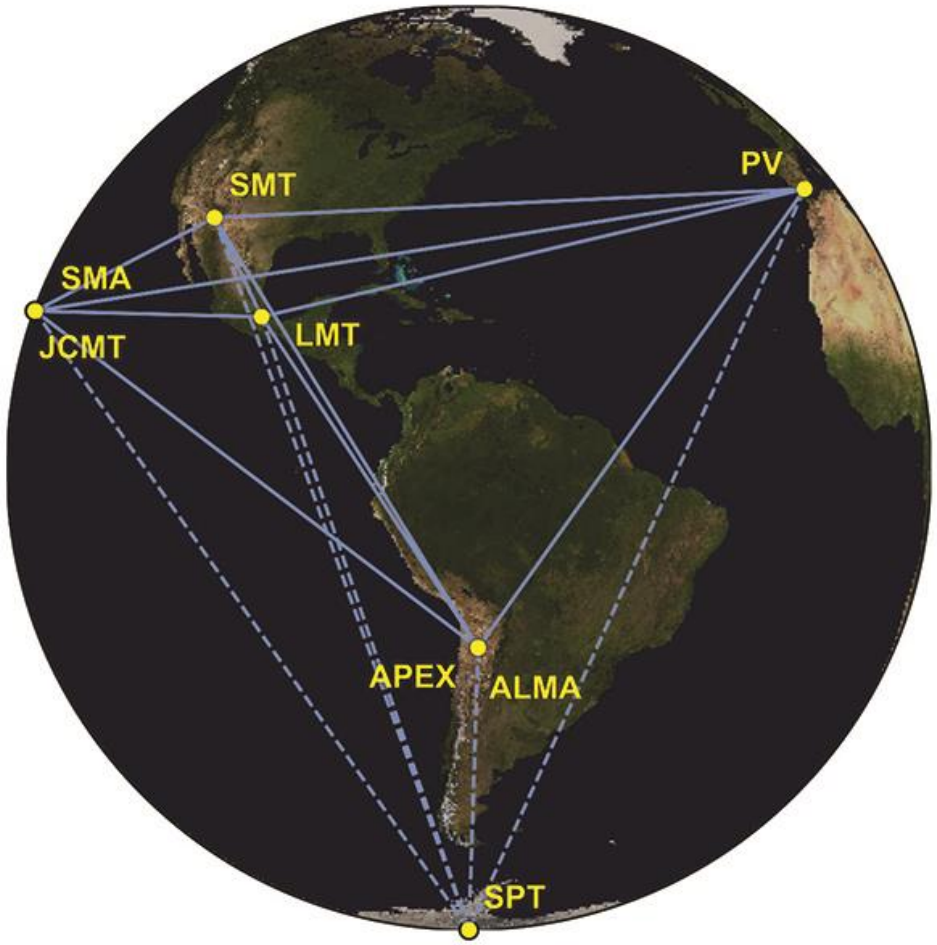


Image Credit: Event Horizon Telescope

Event Horizon Telescope

- Worldwide collaboration of telescope arrays, consisting of:
- *Arizona Radio Observatory*
- *Atacama Pathfinder Experiment*
- *James Clerk Maxwell Telescope (Spain)*
- *Submillimeter Array (Hawaii)*
- *Large Millmeter Telescope (Mexico)*
- *Atacama Large Millimeter/Submillimeter Array*
- *South Pole Telescope*

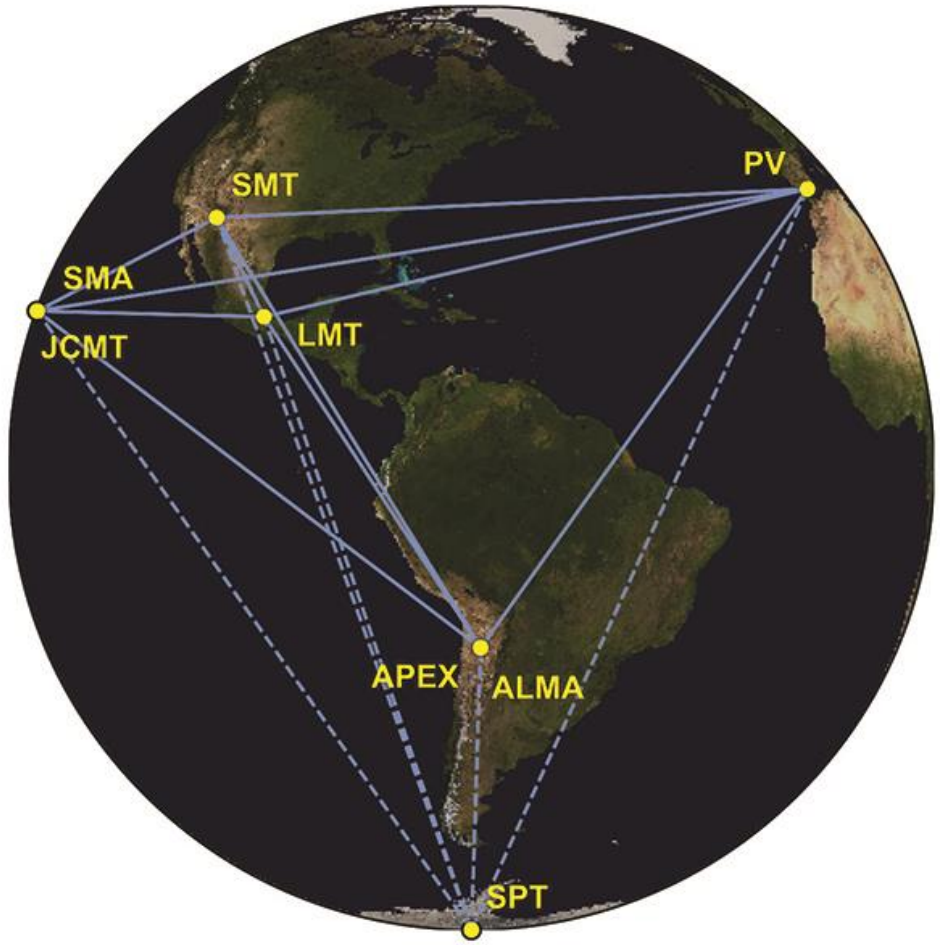


Image Credit: Event Horizon Telescope

Very Long Baseline Interferometry (VLBI)

- Mathematical method of feasibly increasing resolution without building massive telescopes.
- Combining light taken multiple telescopes to improve resolution.
- Effectively the same as having a telescope as wide as their distance apart.

Very Long Baseline Interferometry (VLBI)

- VLBI requires synchronisation at the level of 1 millionth of a second.
- Achieved by atomic clocks that lose 1 second every 100 million years.
- Data from each site is correlated together.

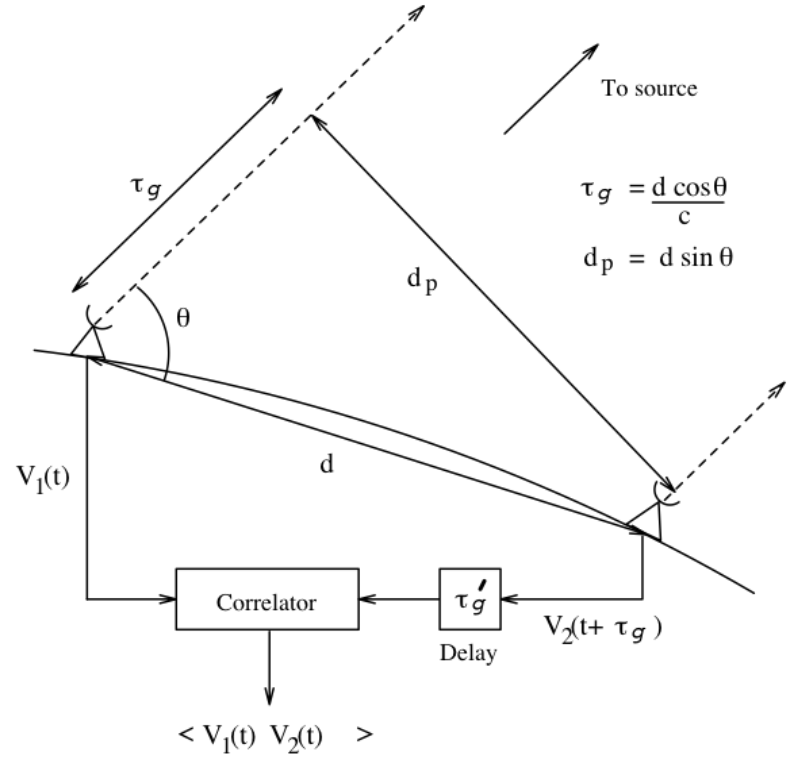


Image Credit: Event Horizon Telescope

Very Long Baseline Interferometry (VLBI)

- However, there are an infinite number of images that are consistent with the measured data.
- The algorithms rank the images by how reasonable they look.

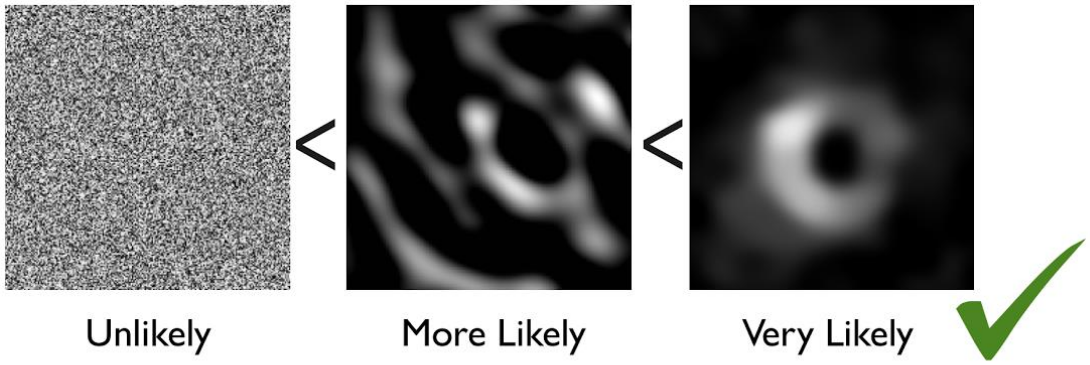
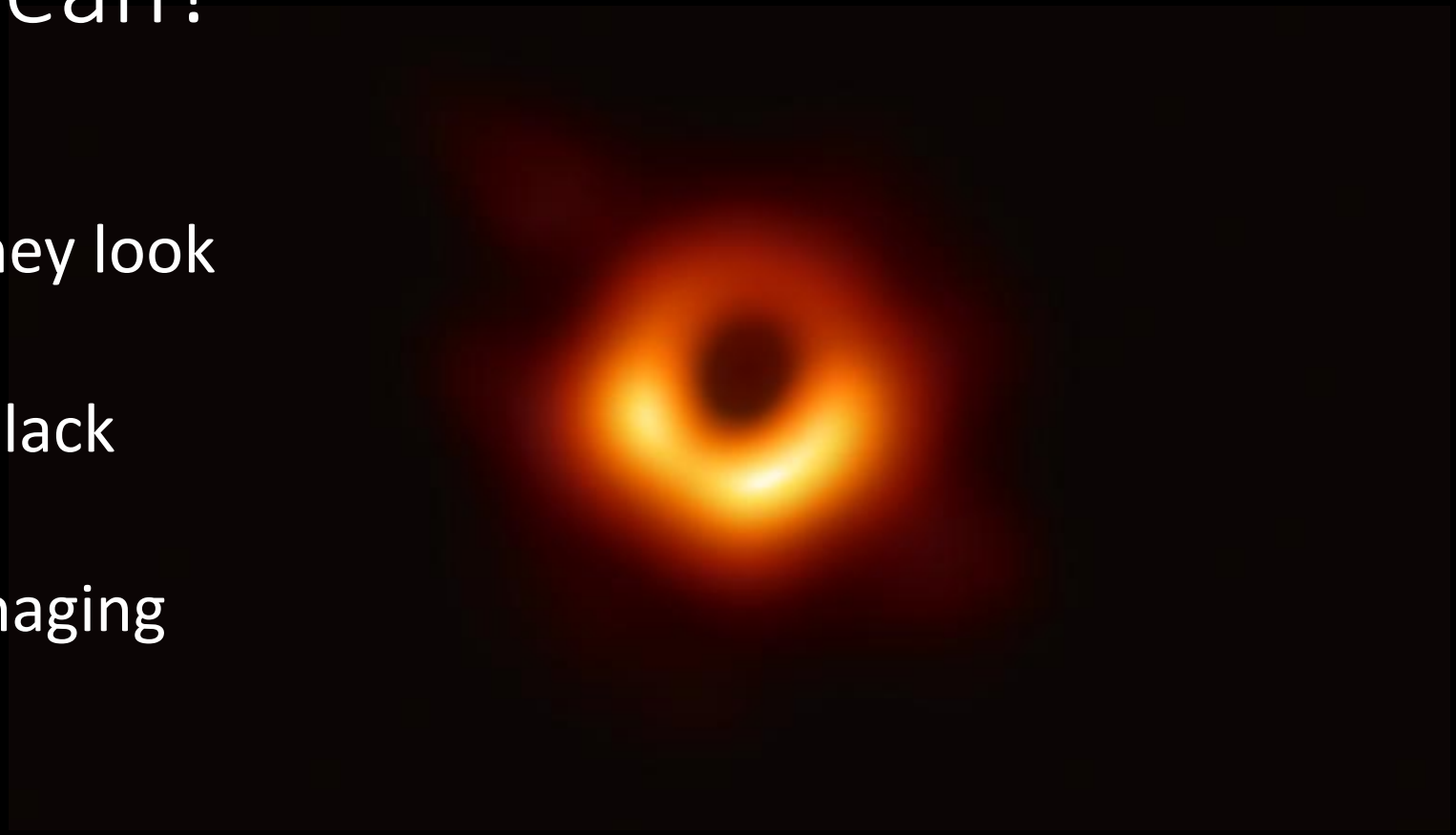


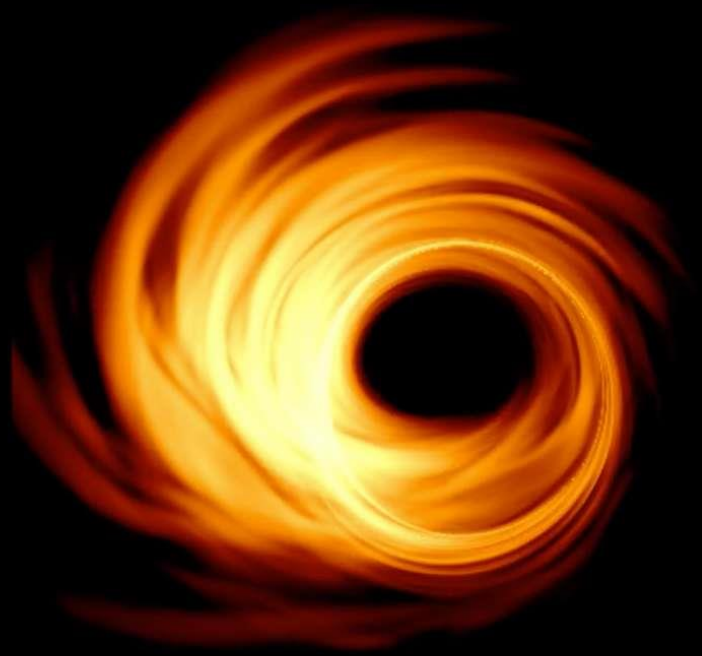
Image Credit: Katie Bouman/Event Horizon Telescope

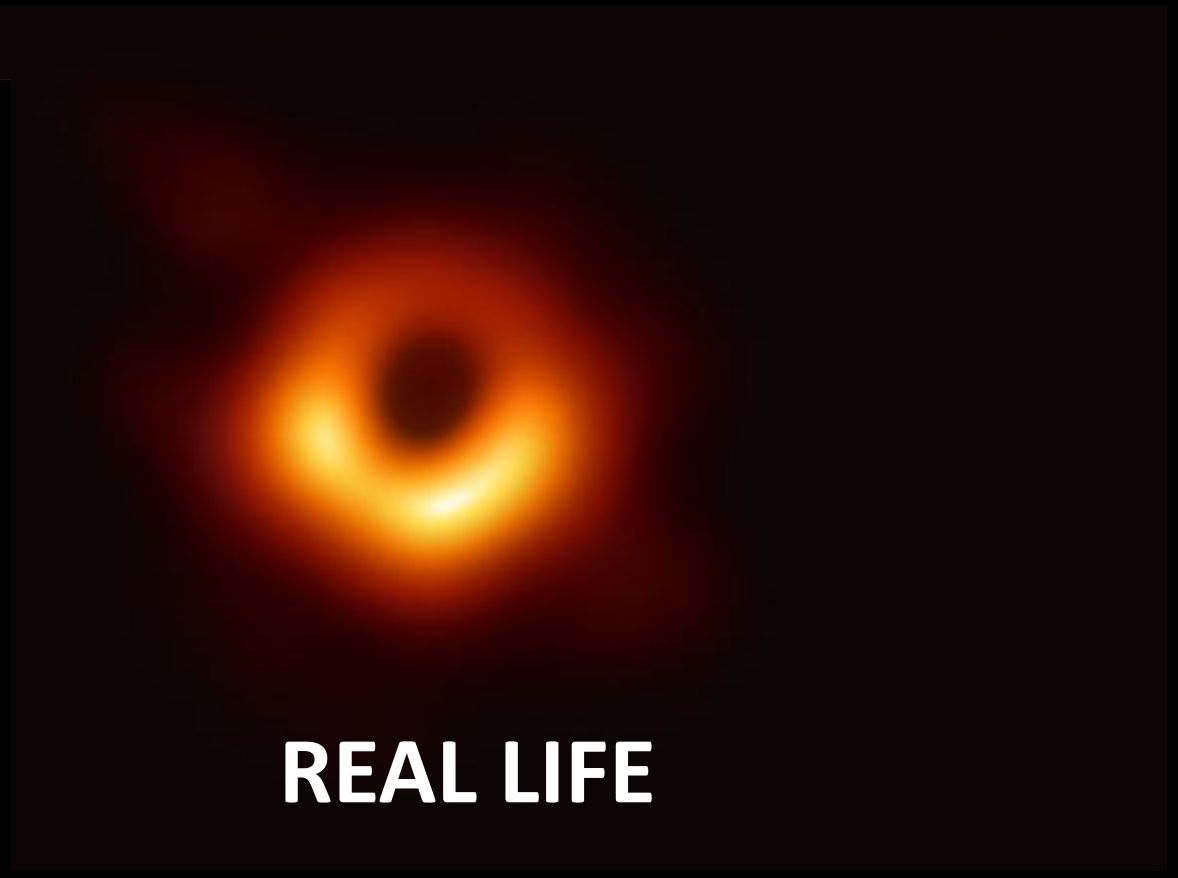
What does this mean?

- Einstein is right! (Again)
- We know for sure what they look like.
- Better understanding of black holes and laws of gravity.
- Advancements in radio imaging technology.



INSTAGRAM





REAL LIFE

Image Credit: Hotaka Shiokawa

Thank You For Listening

Image Credit: Event Horizon Telescope