

THE MOON

The background of the slide is a composite image. The upper portion shows a dark night sky with a series of small, crescent-shaped moons arranged in a curved path from the top left towards the center. Below the sky, a range of rugged mountains is visible, their peaks illuminated with a warm, orange-red glow from a low sun. The foreground consists of dark, silhouetted evergreen trees against the base of the mountains.

*Professor Daniel Dale
Department of Physics & Astronomy
University of Wyoming*

Photo: Tyler Nordgren

A Trip to the Moon [Le Voyage Dans la Lun](#)
by Georges Méliès (1902)



Apollo 11, 12, 14, 15, 16, 17
July 1969 – December 1972
12 men

A Trip to the Moon [Le Voyage Dans la Lun](#)
by Georges Méliès (1902)



Apollo 11, 12, 14, 15, 16, 17
July 1969 – December 1972
12 men

17 December 1903
Kitty Hawk, NC

A Trip to the Moon [Le Voyage Dans la Lun](#)
by Georges Méliès (1902)



Apollo 11, 12, 14, 15, 16, 17
July 1969 – December 1972
12 men

17 December 1903
Kitty Hawk, NC



Outline

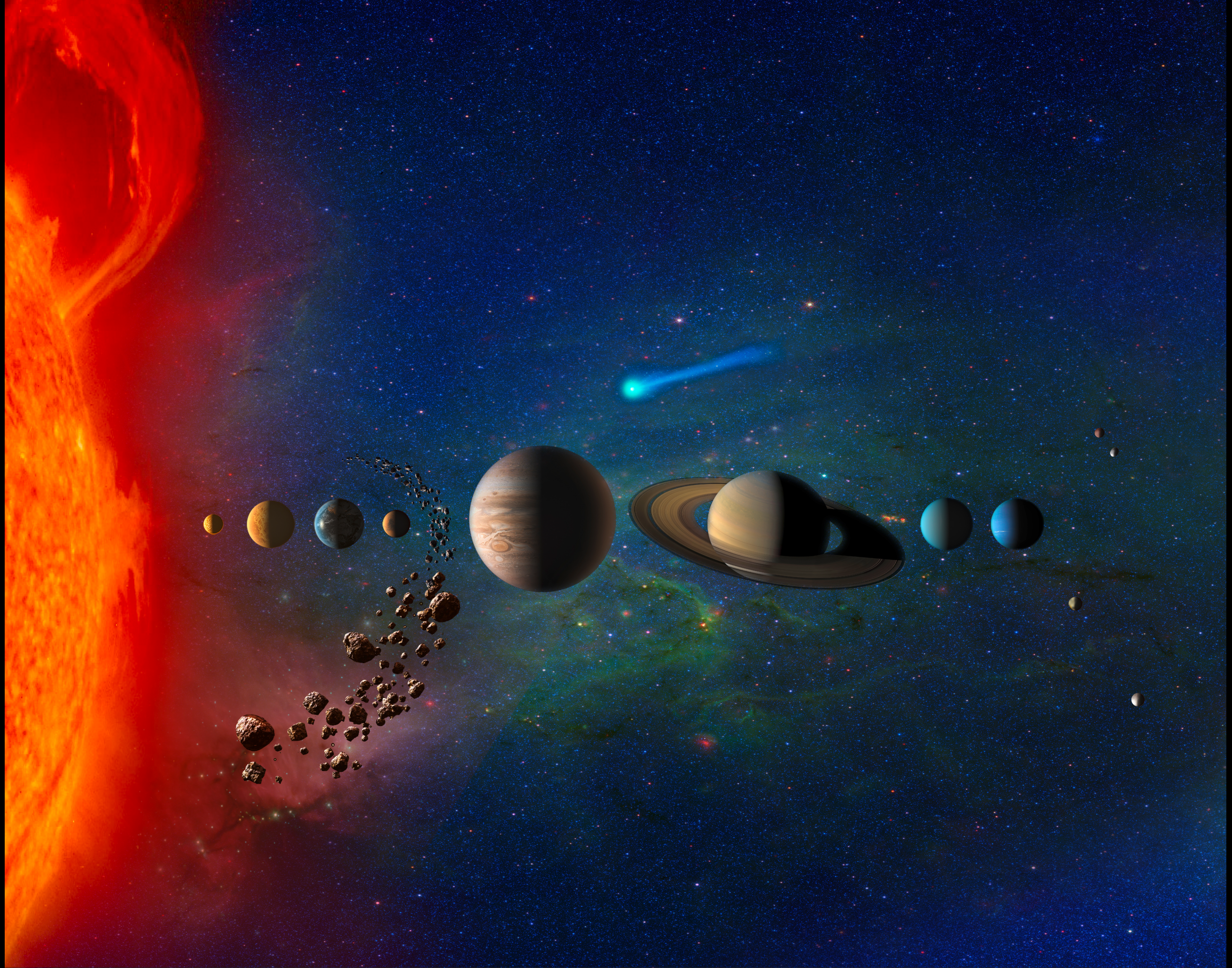
Origin

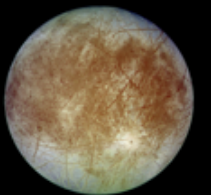
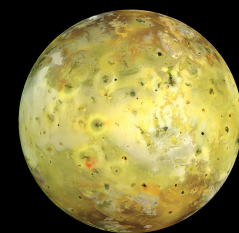
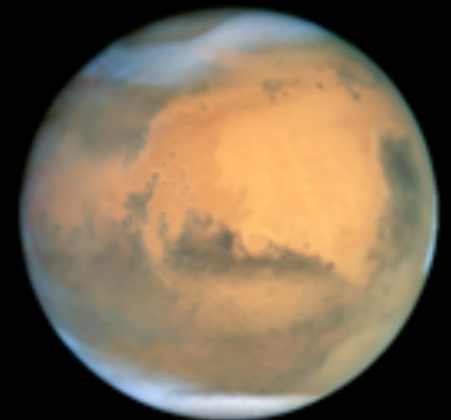
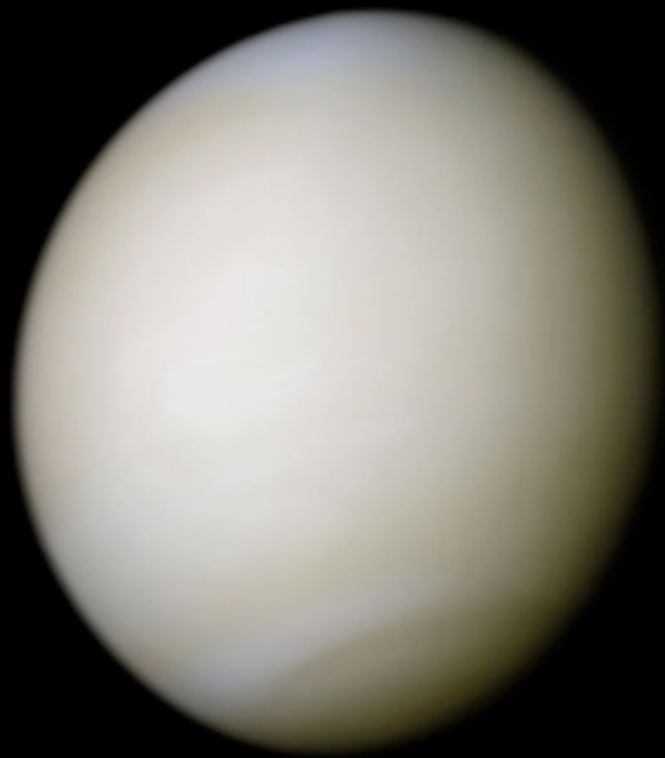
Fun Facts & Misconceptions

Science Today



Copyright Tyler Nordgren





5th largest natural satellite
What's a 'natural satellite'?

***Lunar rocks retrieved
from the Apollo missions***



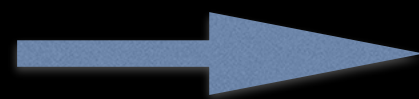
***The Moon is
thought to have
originated from
a glancing collision
with the Mars-size
planet Theia***



***The Moon is
thought to have
originated from
a glancing collision
with the Mars-size
planet Theia***



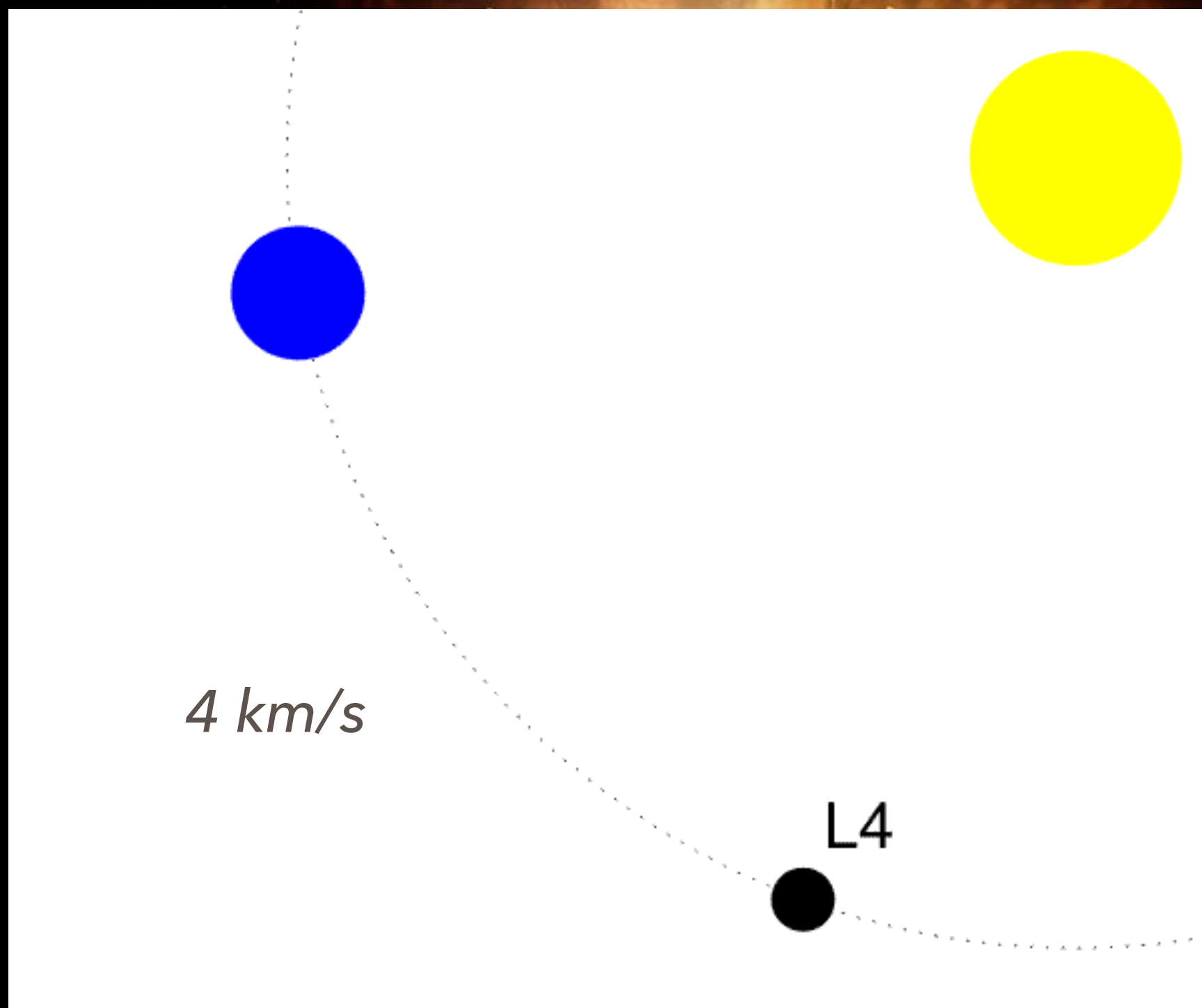
***The Moon is
thought to have
originated from
a glancing collision
with the Mars-size
planet Theia***



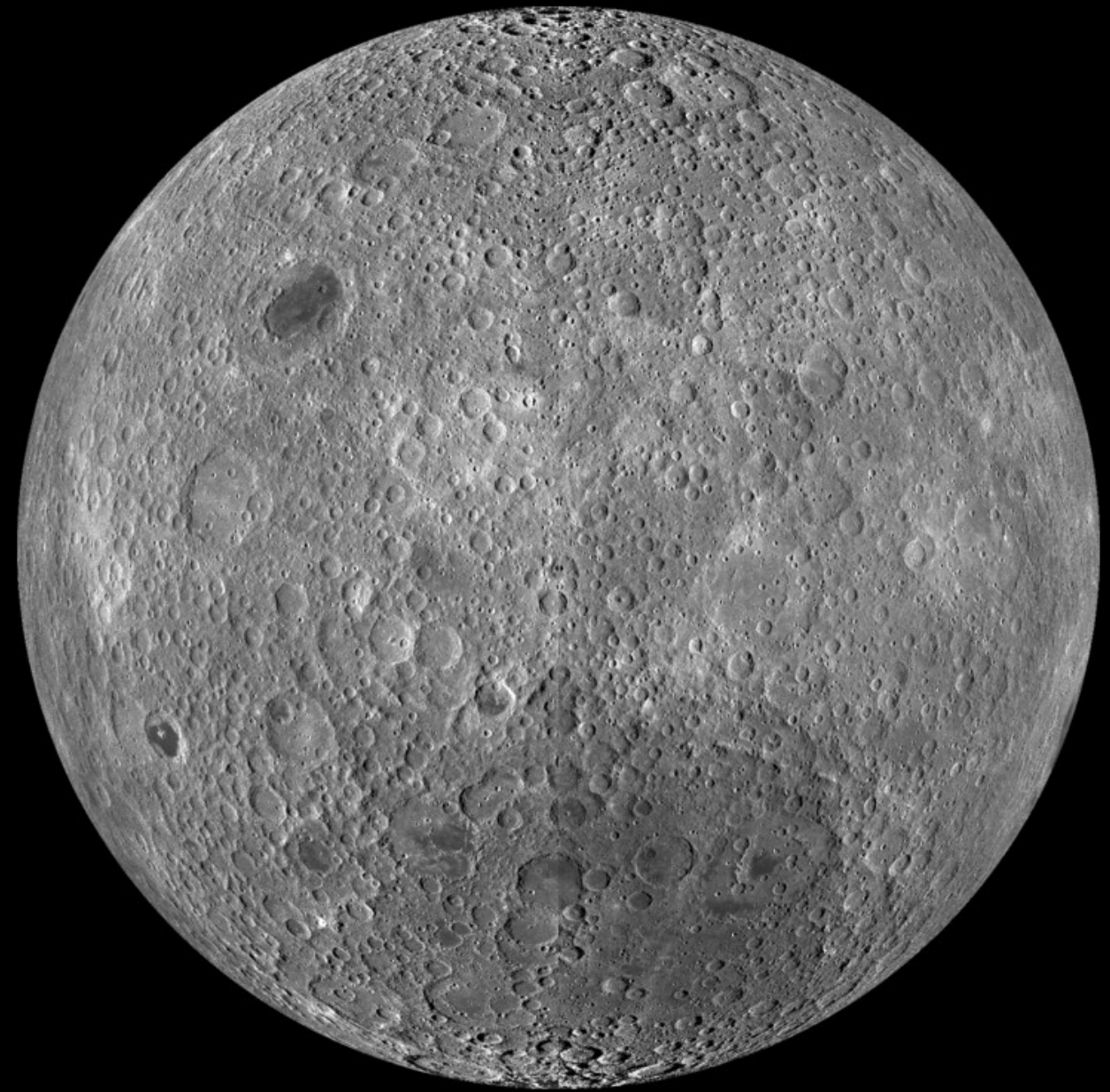
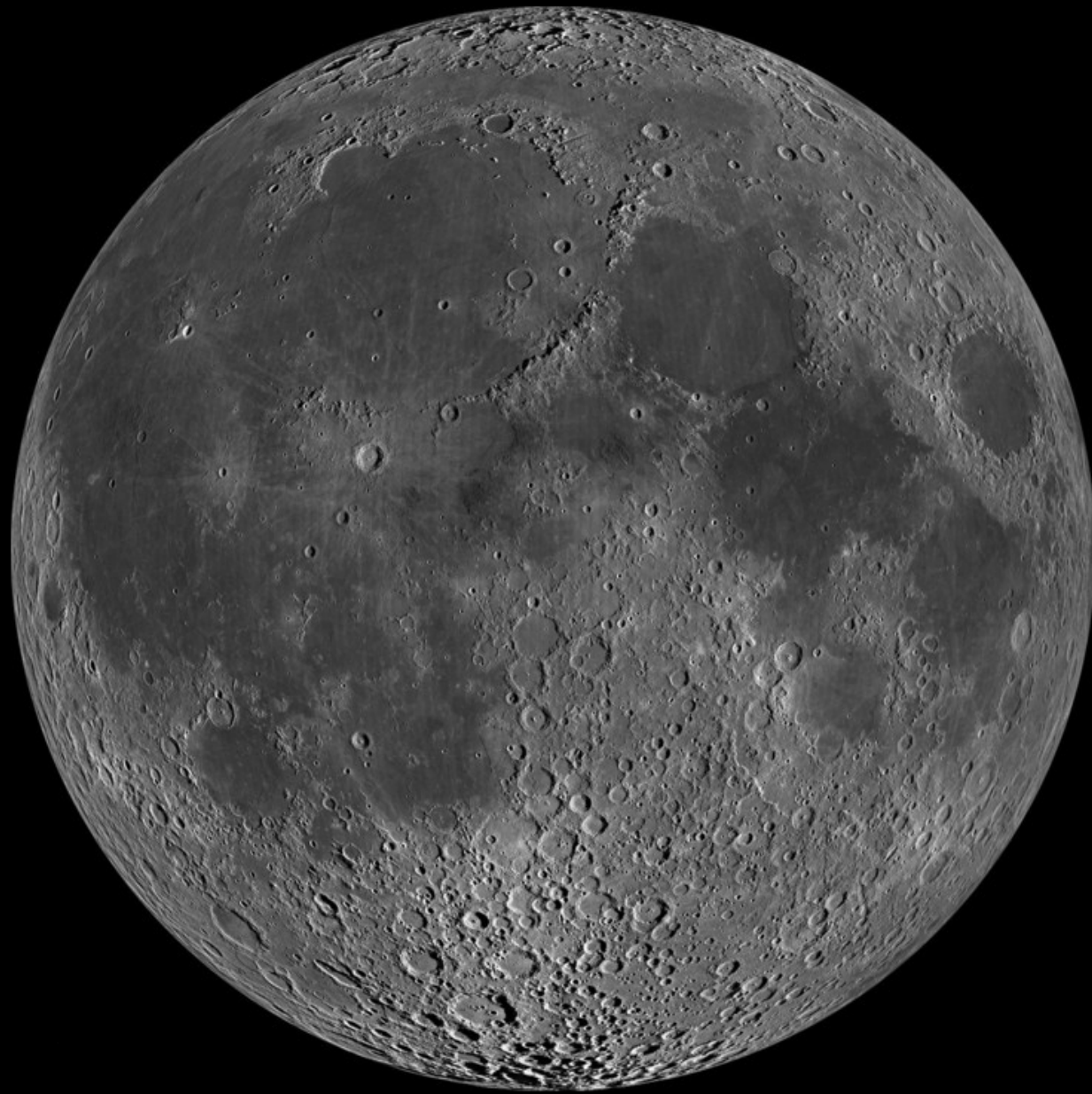
***23.5 degree tilt
Identical isotopes
1/10th the current distance***



***The Moon is
thought to have
originated from
a glancing collision
with the Mars-size
planet Theia***



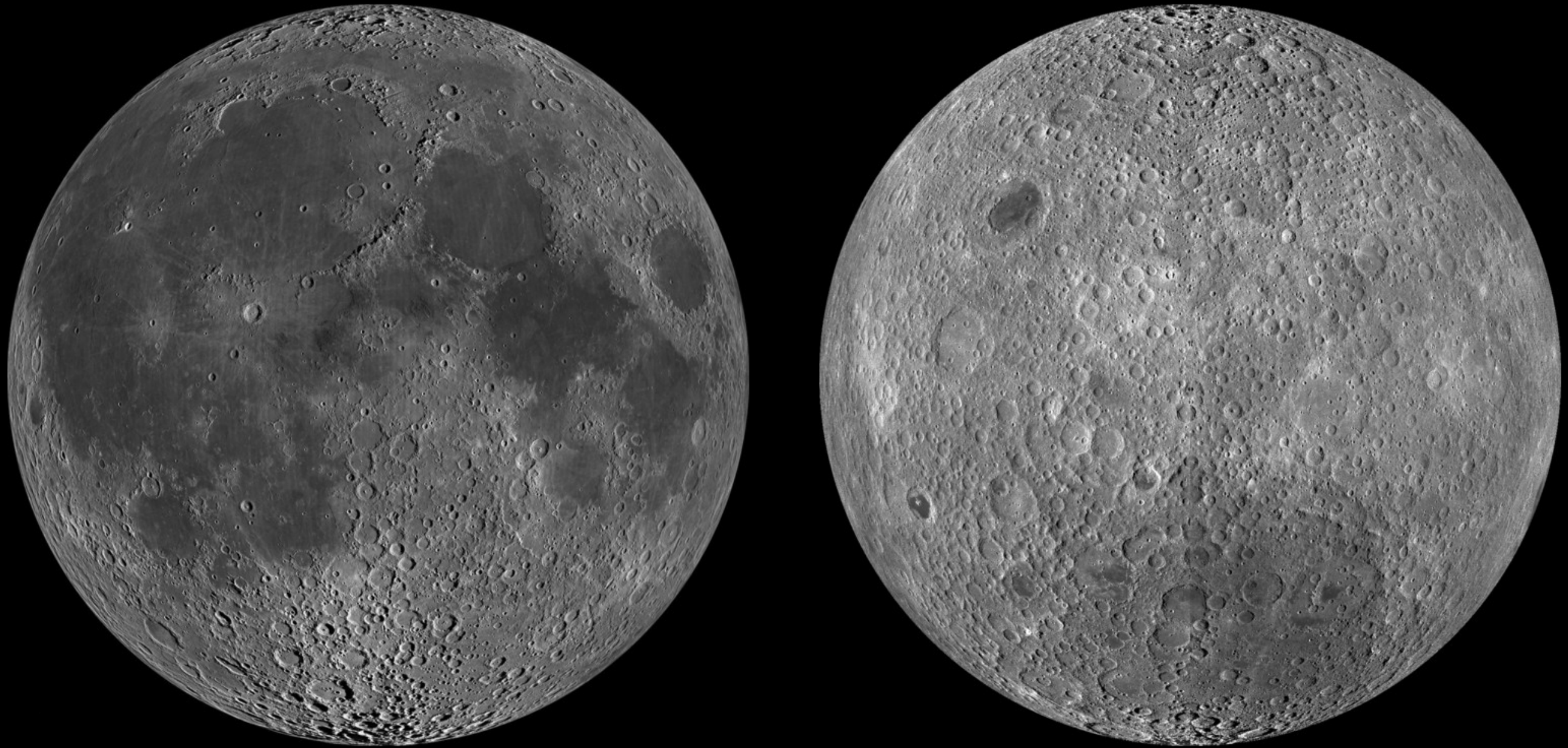
***The moon is 'tidally locked' to the Earth.
Which side do we see?***



Dark side of the moon

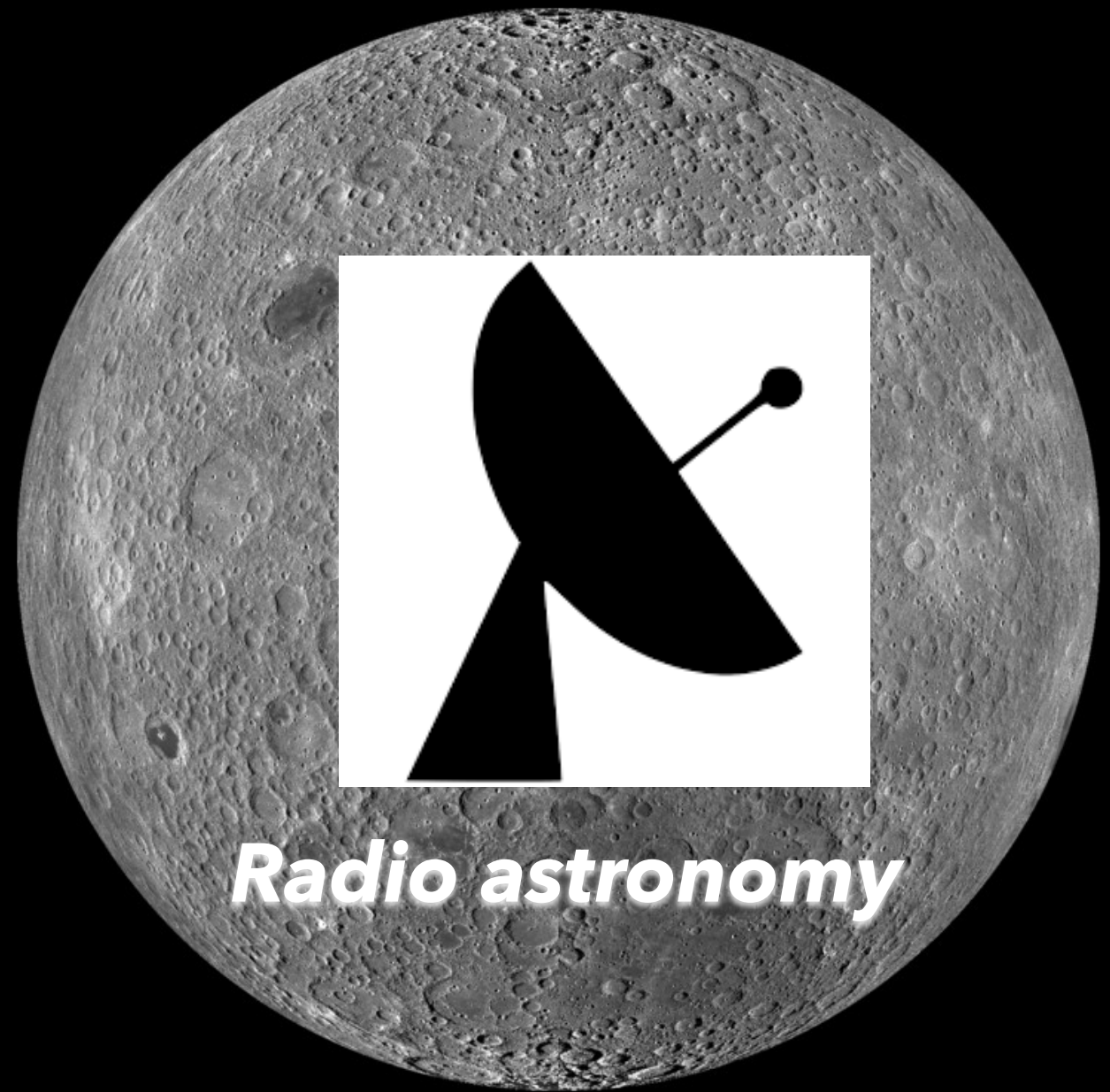
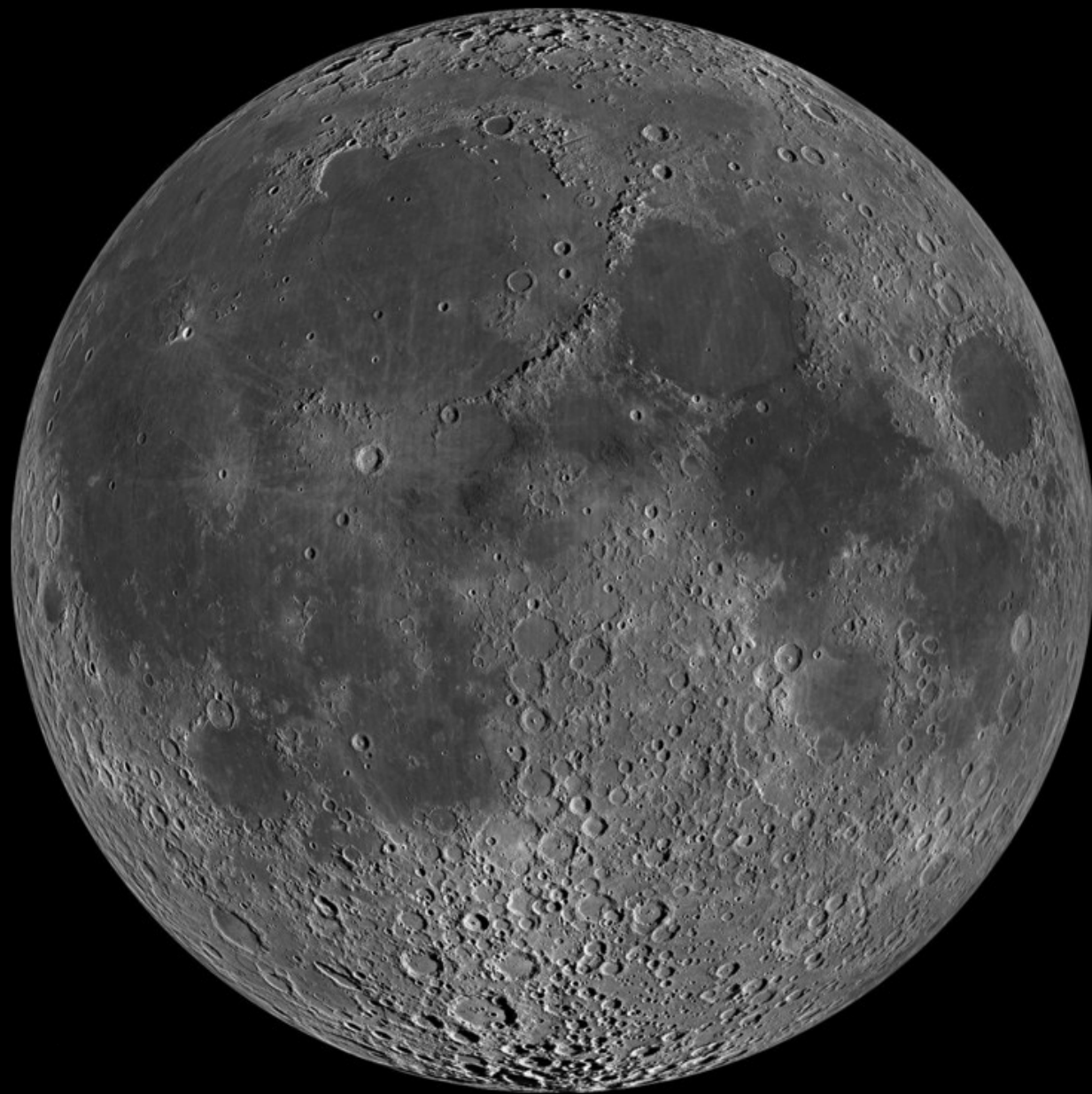


Far side of the moon

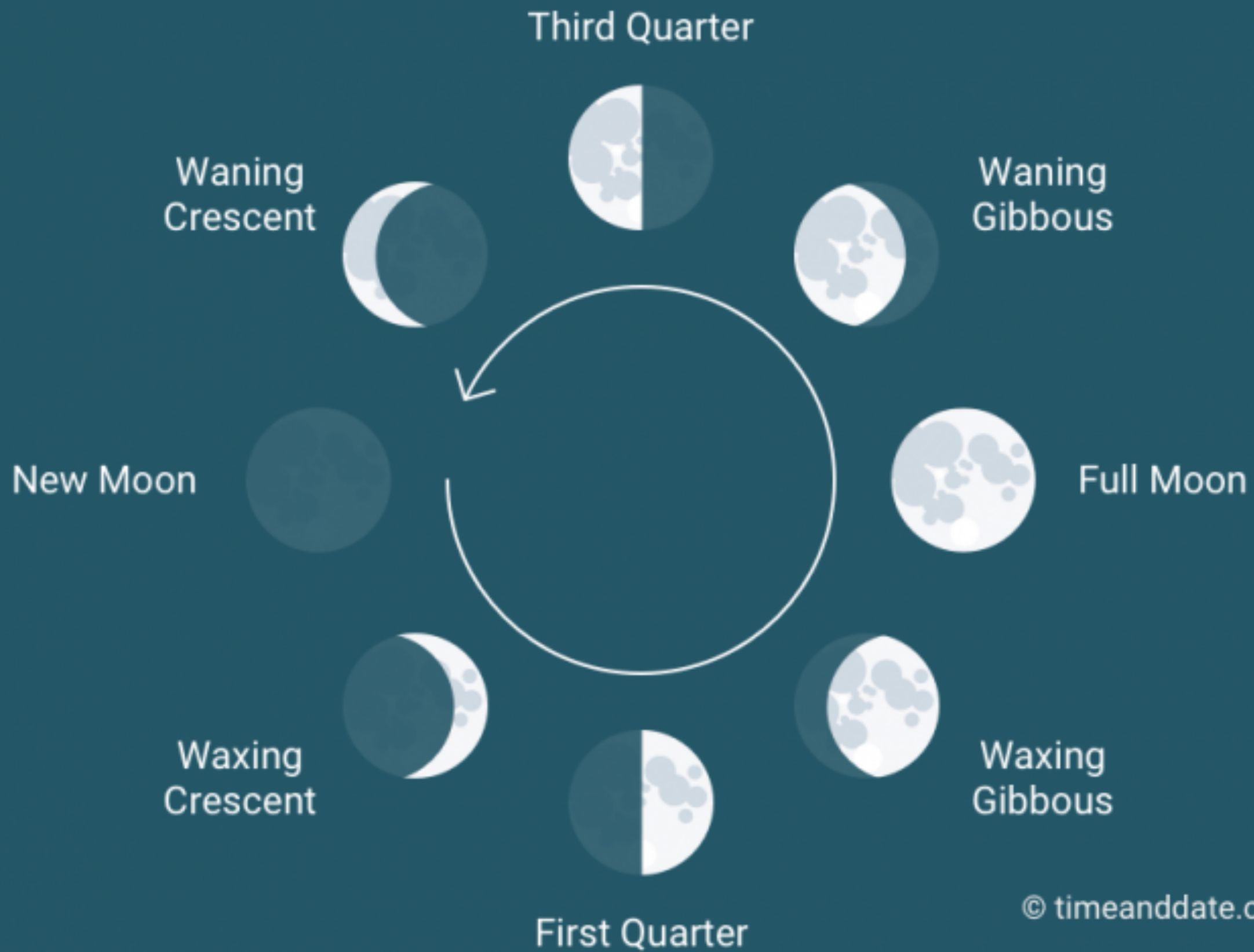


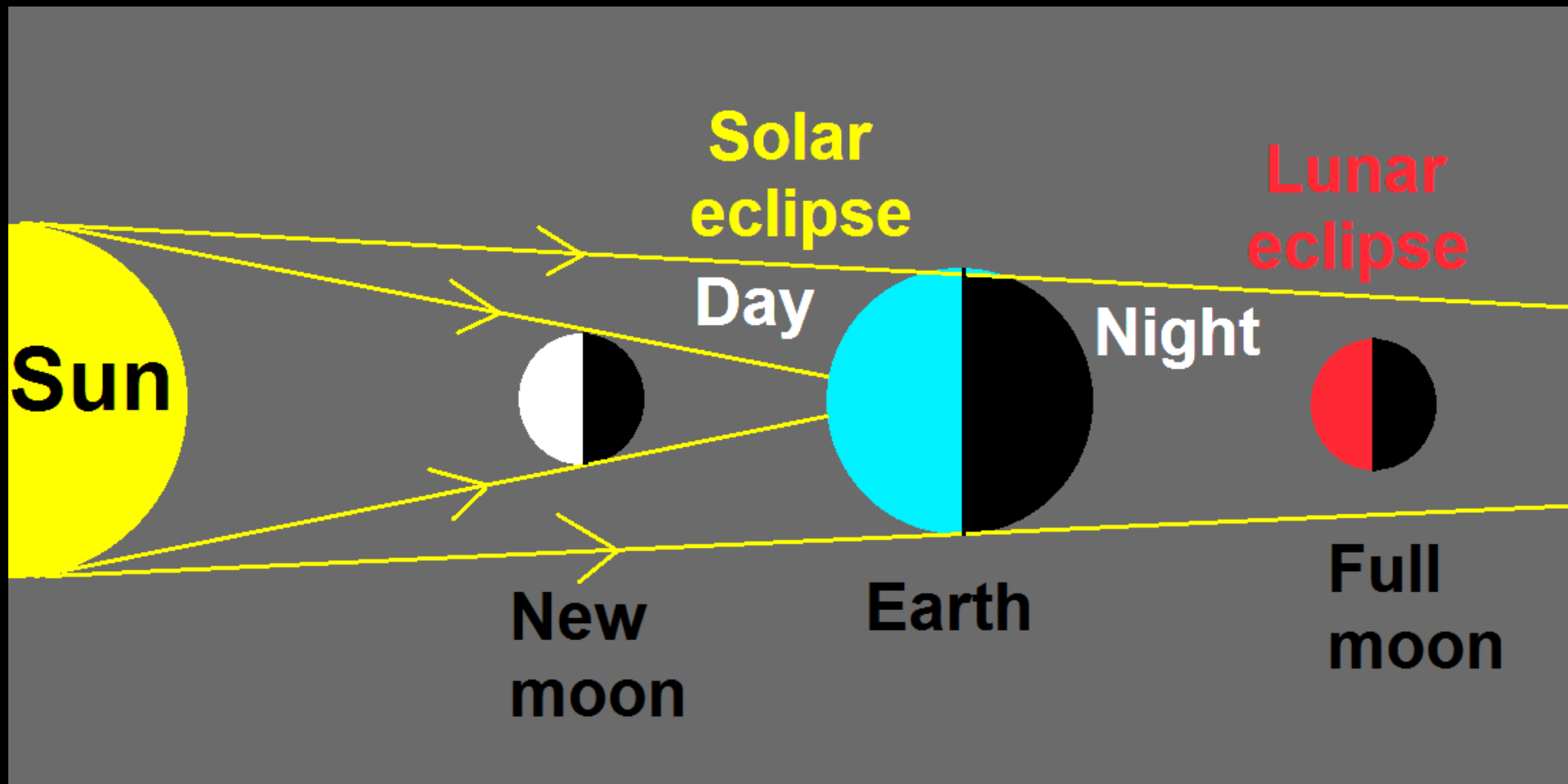
***Lunar rocks from Apollo: Late Heavy Bombardment ~3.9 billion years ago
100 million years after Solar System formation***

Far side of the moon



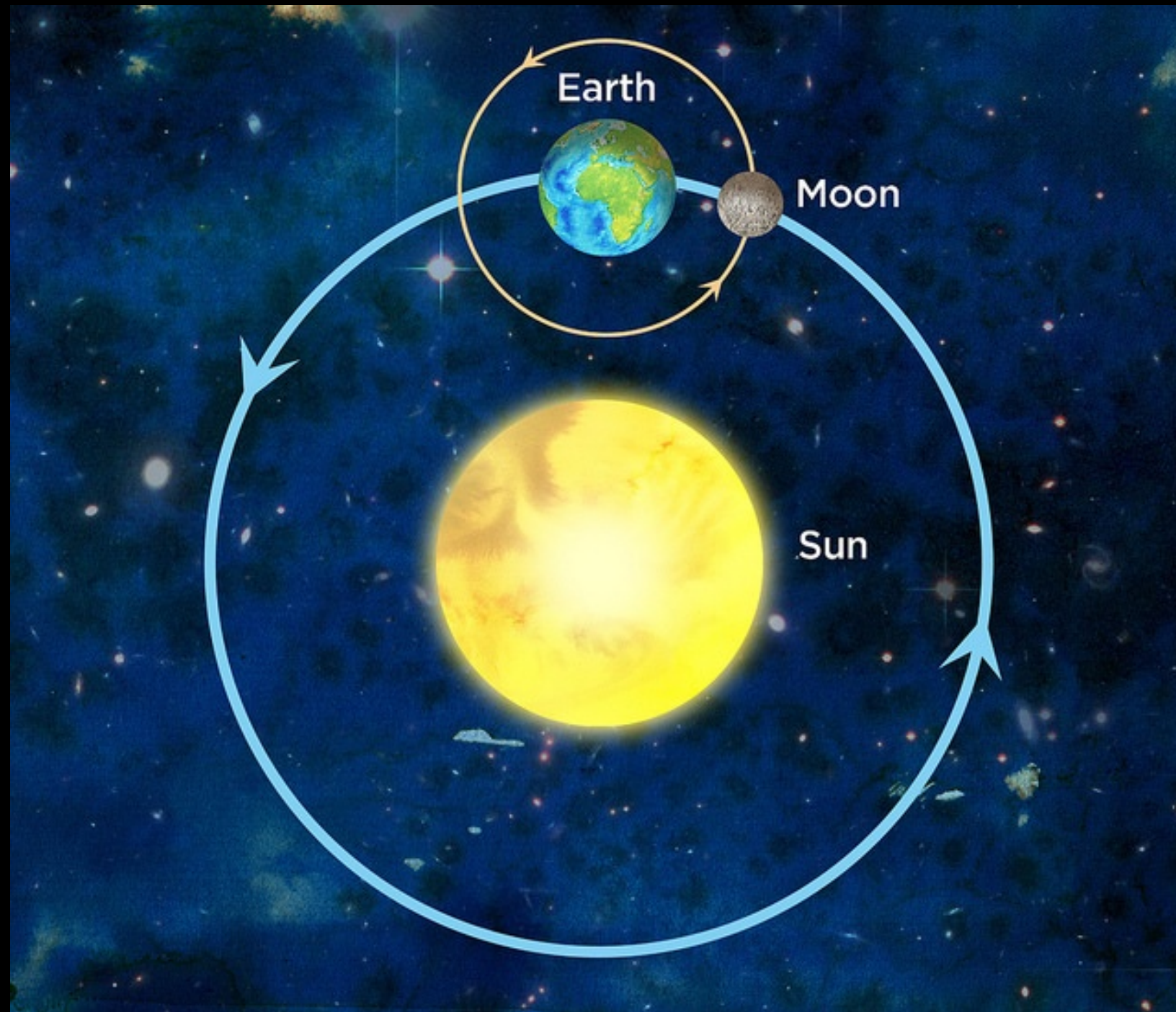
Radio astronomy





A lunar eclipse occurs when the Earth passes between the Sun and the Moon. What is the moon phase during a lunar eclipse?

- a. First quarter***
- b. Third quarter***
- c. Full moon***
- d. New moon***
- e. Green cheese moon***



Suppose tonight is new Moon and you are a Space X employee working on the side of the Moon facing the Earth. What Earth phase do you see?

- a. You can't see the Earth because it is eclipsed by the Sun.***
- b. new Earth***
- c. first quarter Earth***
- d. full Earth***
- e. third quarter Earth***

As seen from the Moon, how often does the Sun rise?

- a. never***
- b. every ~24 hours***
- c. ~once per week***
- d. ~once per month***
- e. ~once per year***

The Power of the Supermoon

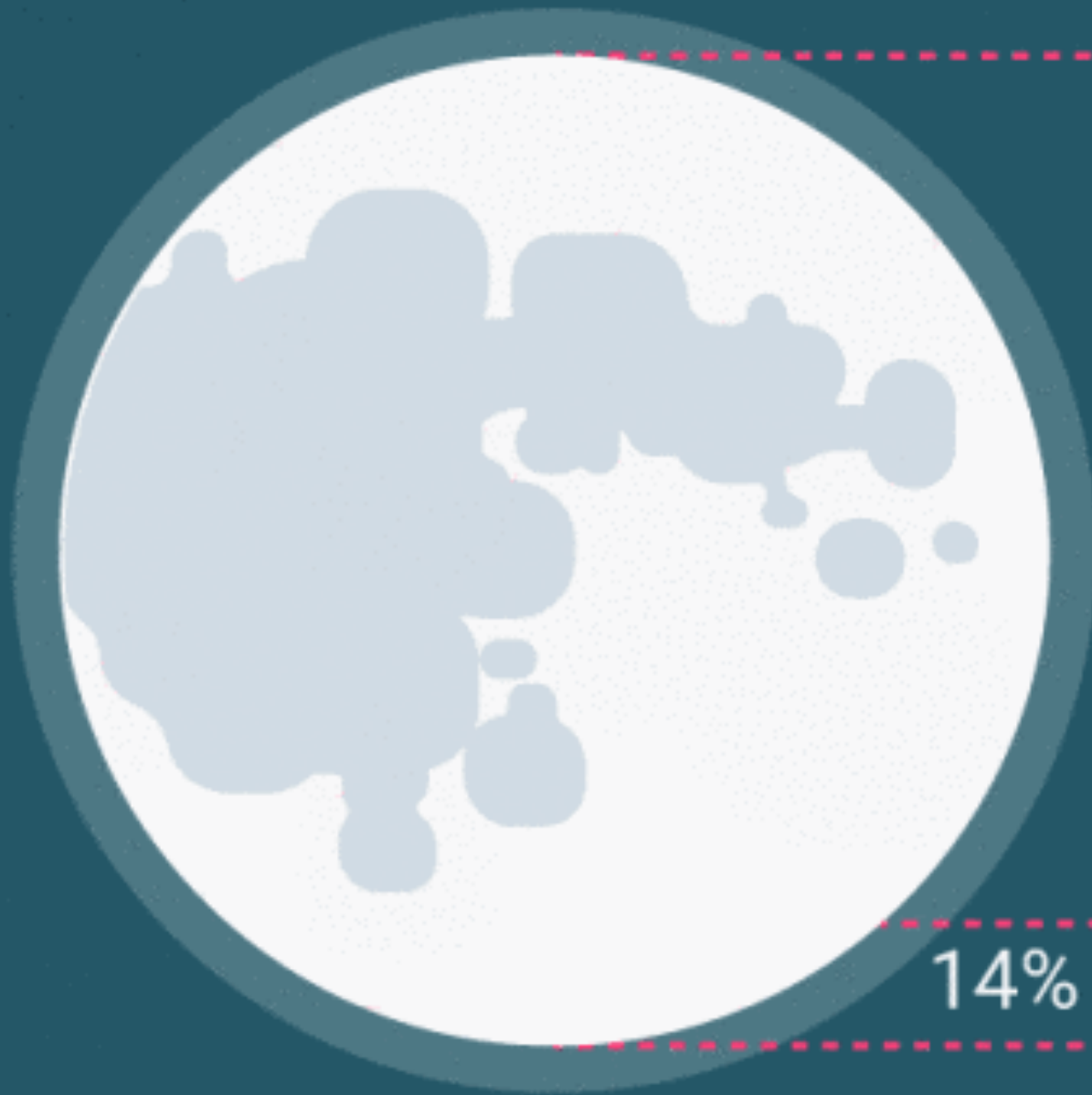
Makes you crazy!

Induces natural disasters!



Supermoon (Perigee)

Micromoon (Apogee)



14% Bigger

30% Brighter

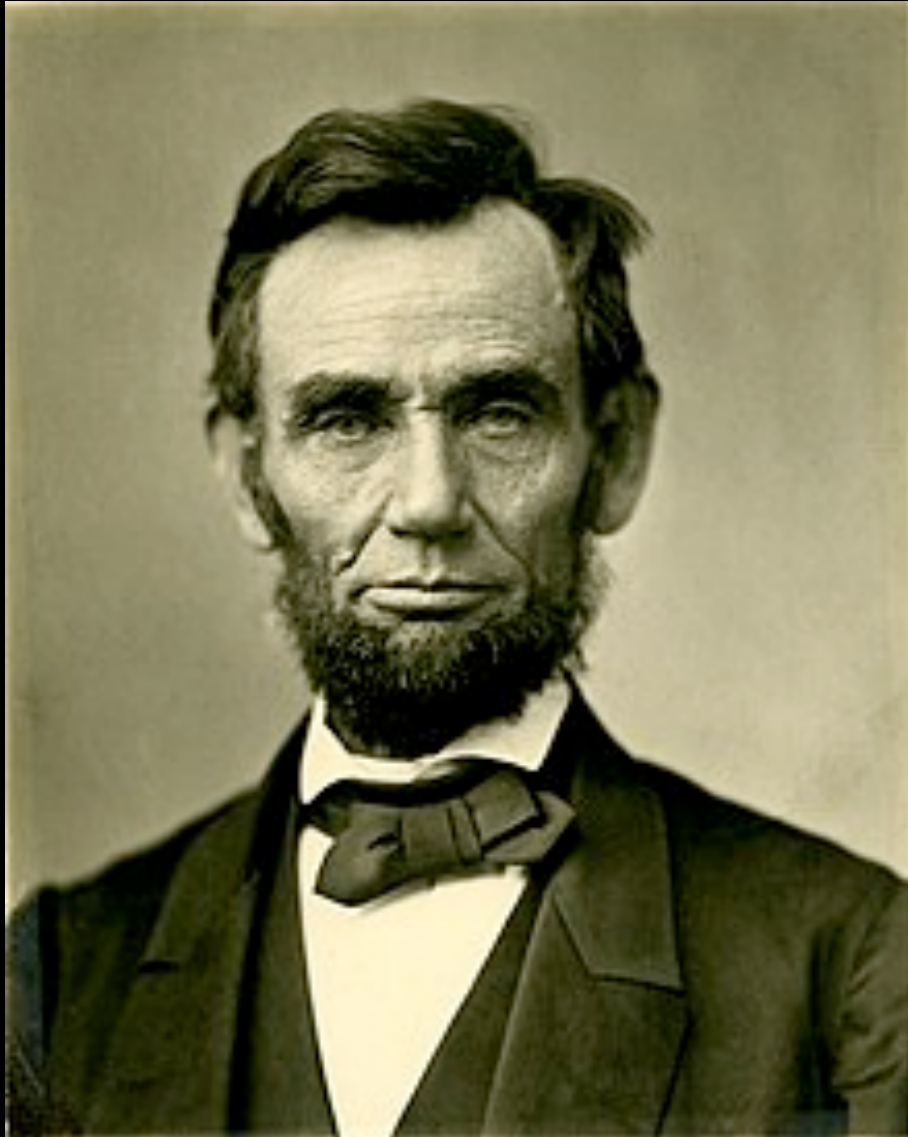
5% closer than average

5% further than average

The Moon isn't larger when near the horizon

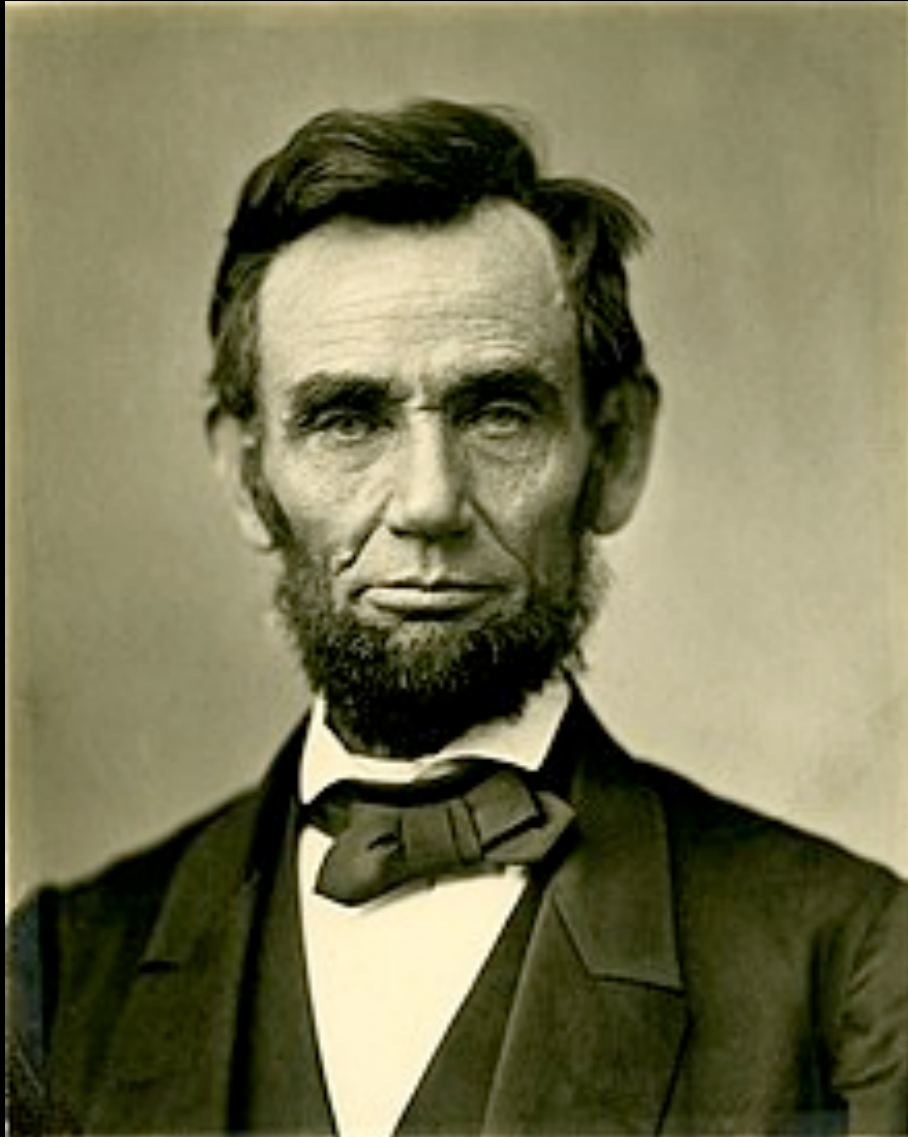


Abraham Lincoln & the Moon



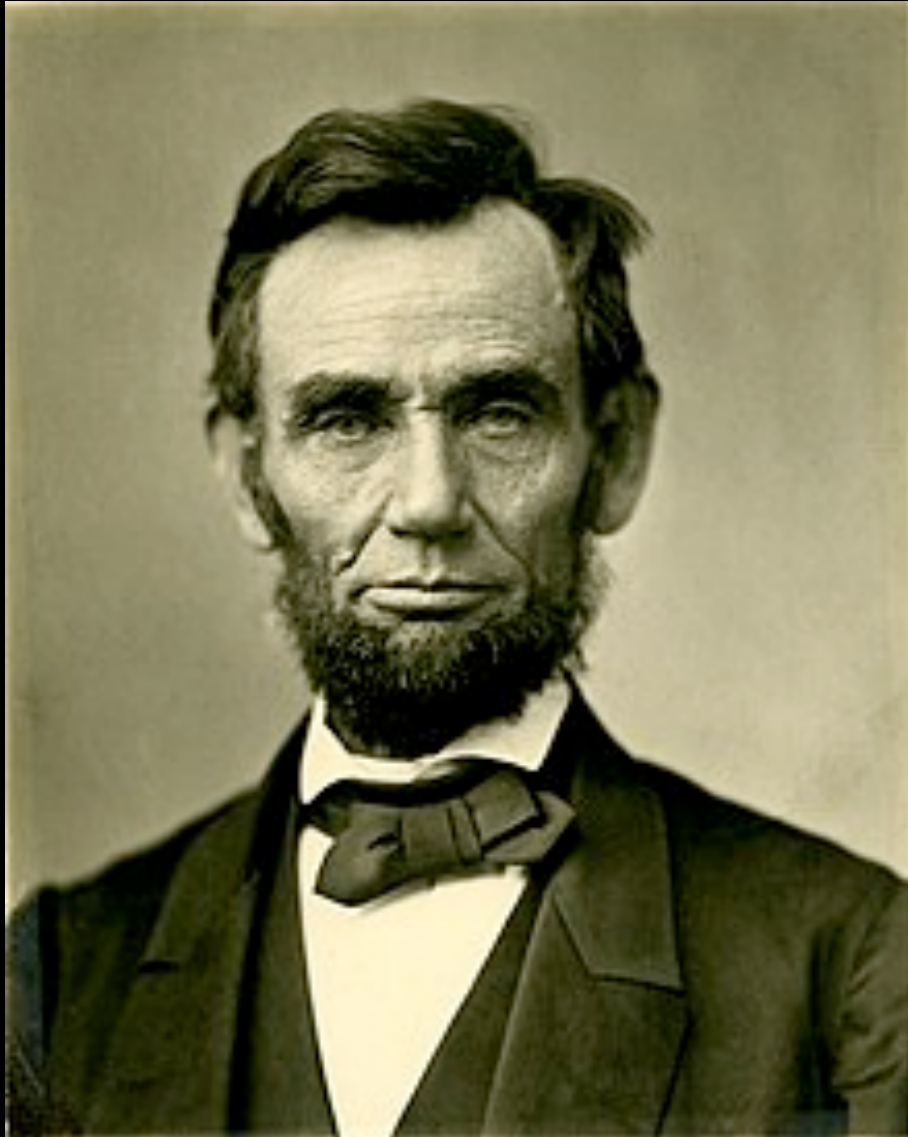
- ***The 1858 Armstrong Murder Trial***

Abraham Lincoln & the Moon



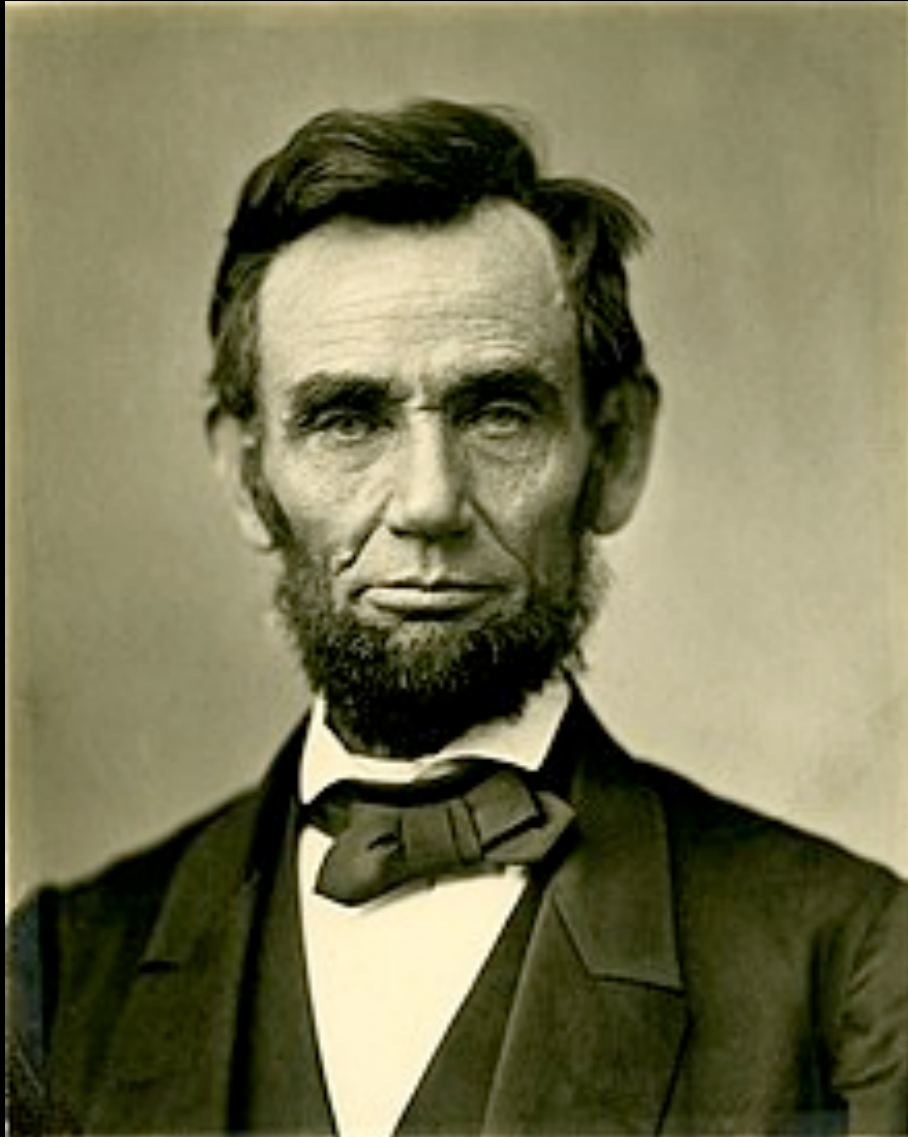
- ***The 1858 Armstrong Murder Trial***
- ***Allegedly witnessed @ 150' using a slungshot***

Abraham Lincoln & the Moon



- ***The 1858 Armstrong Murder Trial***
- ***Allegedly witnessed @ 150' using a slungshot***
- ***11:00 pm full moon "nearly in mid-heavens"***

Abraham Lincoln & the Moon



- ***The 1858 Armstrong Murder Trial***
- ***Allegedly witnessed @ 150' using a slungshot***
- ***11:00 pm full moon "nearly in mid-heavens"***
- ***The Farmer's Almanac: 1st quarter; 10 degrees from horizon***

Testing the ideas behind gravity with the help of the moon

Gravity compared to Earth's: 1/6th

$$g = G \frac{M}{r^2}$$

Apollo 15 and Commander David Scott



Equivalence Principle

→ Are the Sun and Moon “falling” toward the Sun at the same rate?

$$g = G \frac{M}{r^2}$$

Equivalence Principle

→ Are the Sun and Moon “falling” toward the Sun at the same rate?

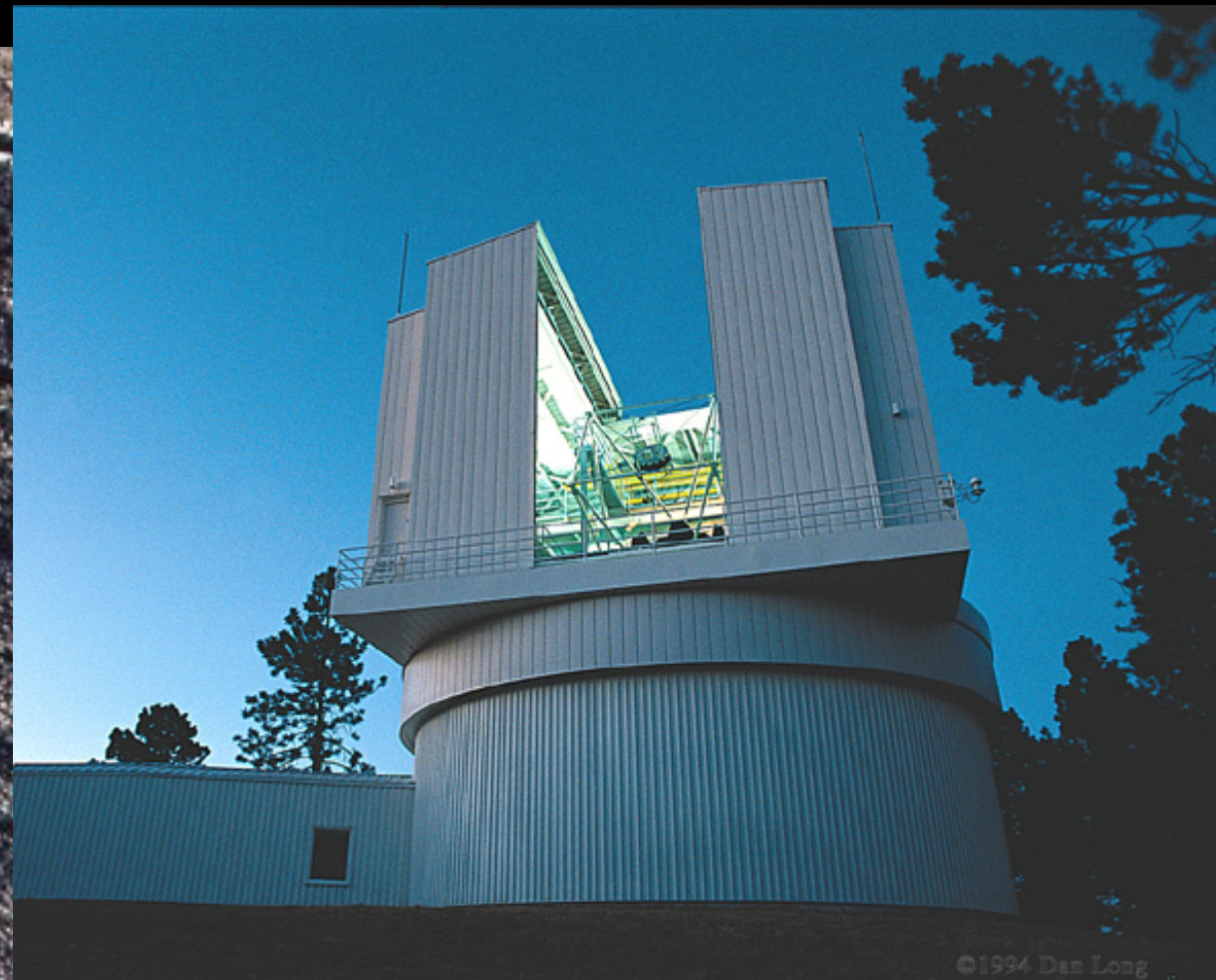
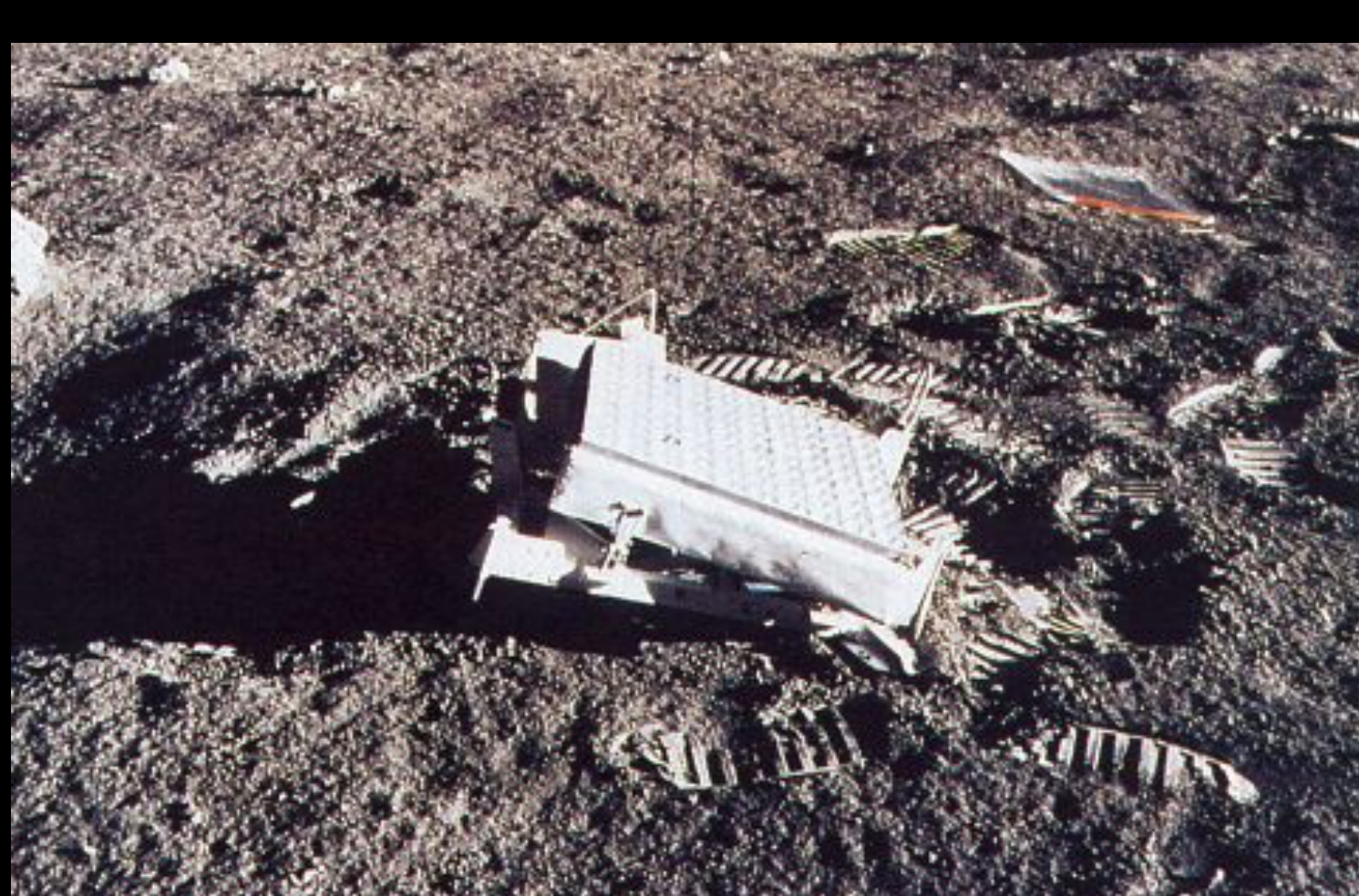
$$mg = G \frac{M_m}{r^2}$$

Equivalence Principle

→ Are the Sun and Moon “falling” toward the Sun at the same rate?



$$mg = G \frac{M_m}{r^2}$$



HUMANITY'S FIRST PICTURE OF A BLACK HOLE

*Professor Daniel Dale
Department of Physics & Astronomy
University of Wyoming*

Photo: Tyler Nordgren

Outline

Einstein & Relativity

Black holes

Event Horizon Telescope



Copyright Tyler Nordgren

Outline

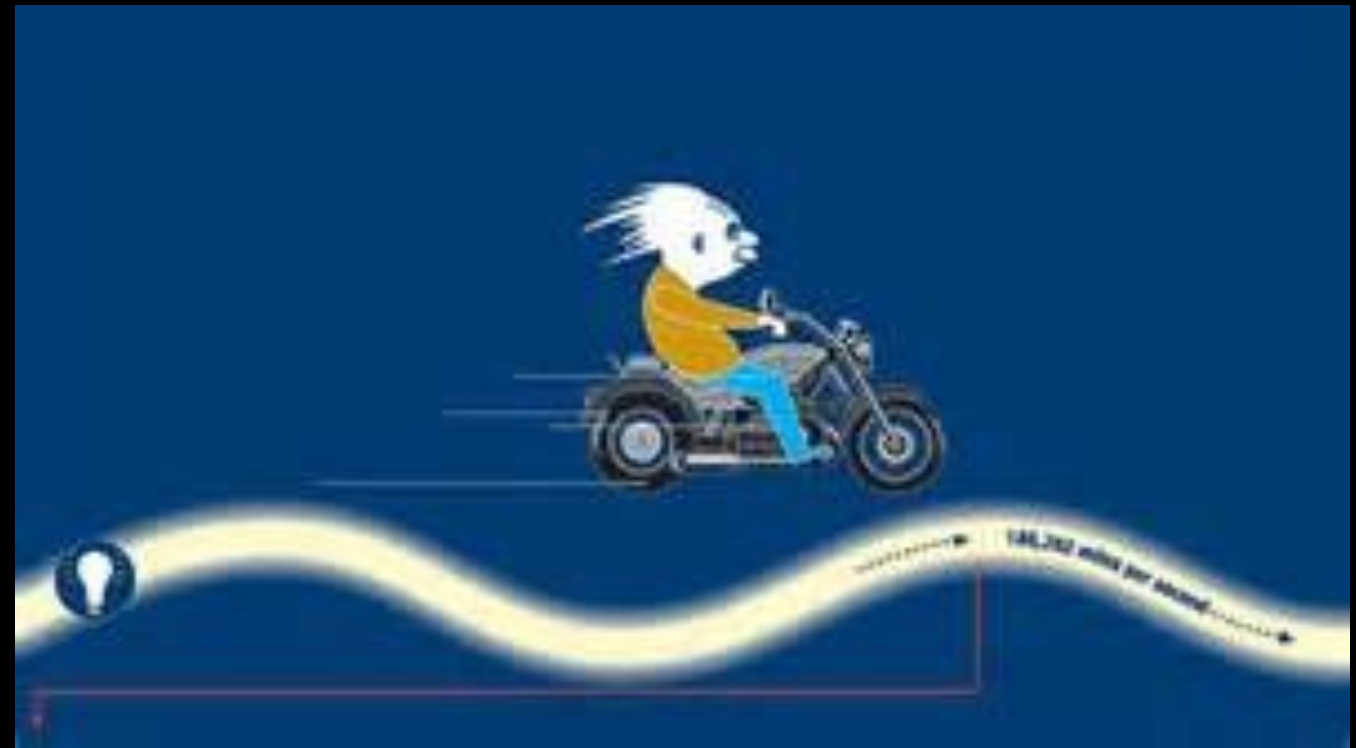
Einstein & Relativity

Black holes

Event Horizon Telescope



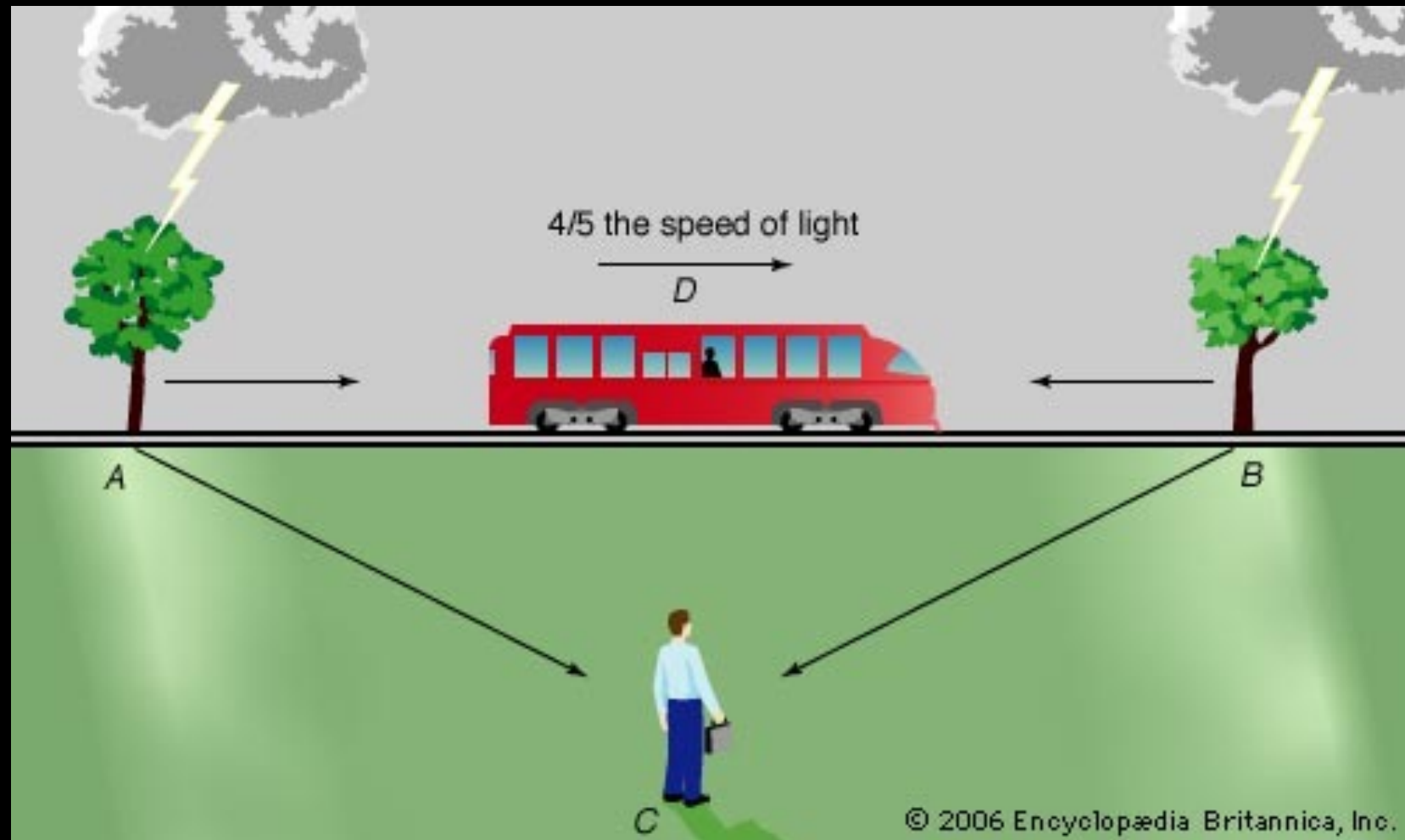
Copyright Tyler Nordgren



- 1. The laws of physics are the same for all observers in uniform motion (non-accelerating).***
- 2. The speed of light (in a vacuum) is the same for all such observers.***

Special Relativity

- **time dilation**
- **relativistic mass**
- **length contraction**
- **$E=mc^2$**
- **speed of light is maximum possible**

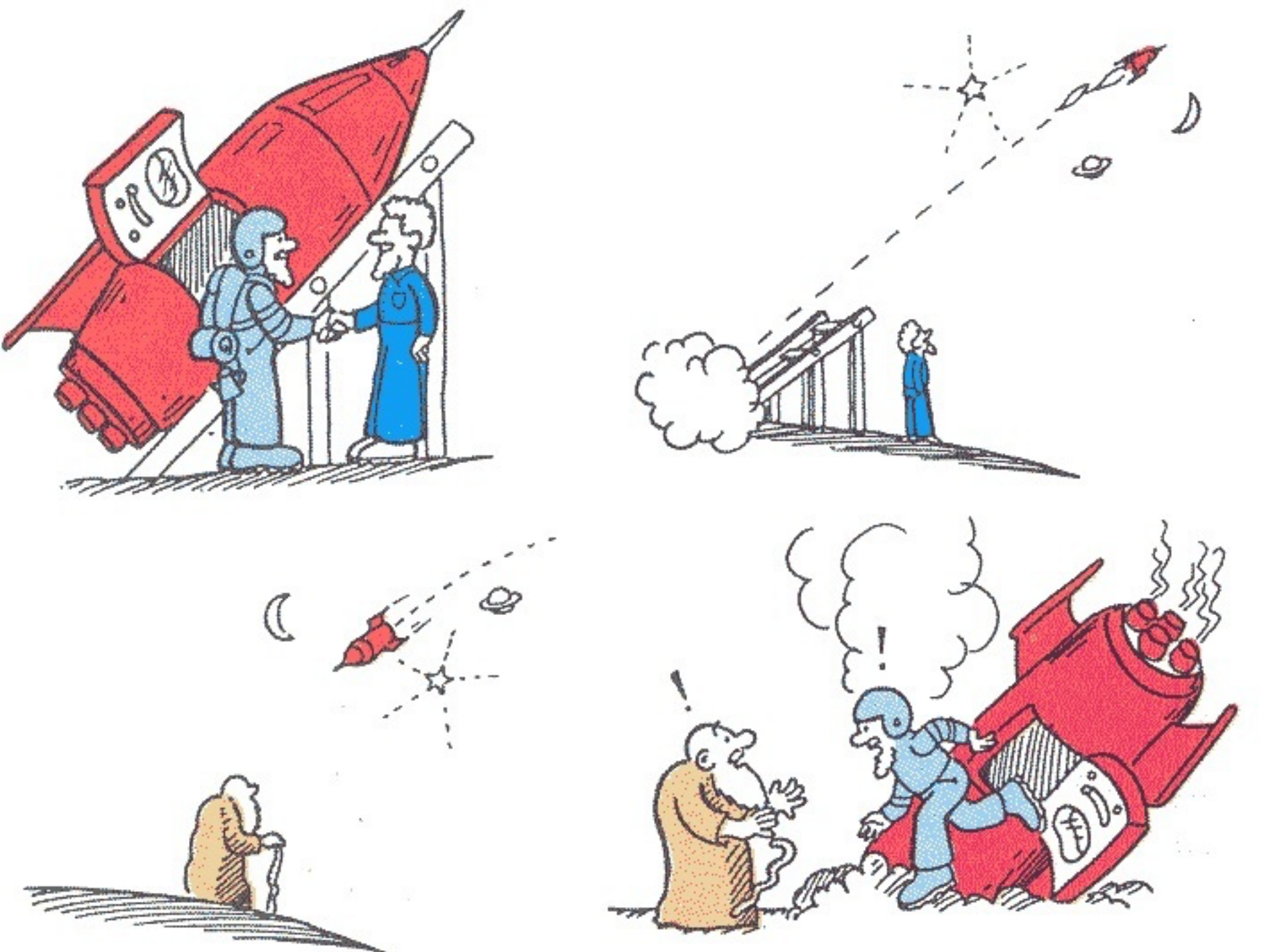


General Relativity

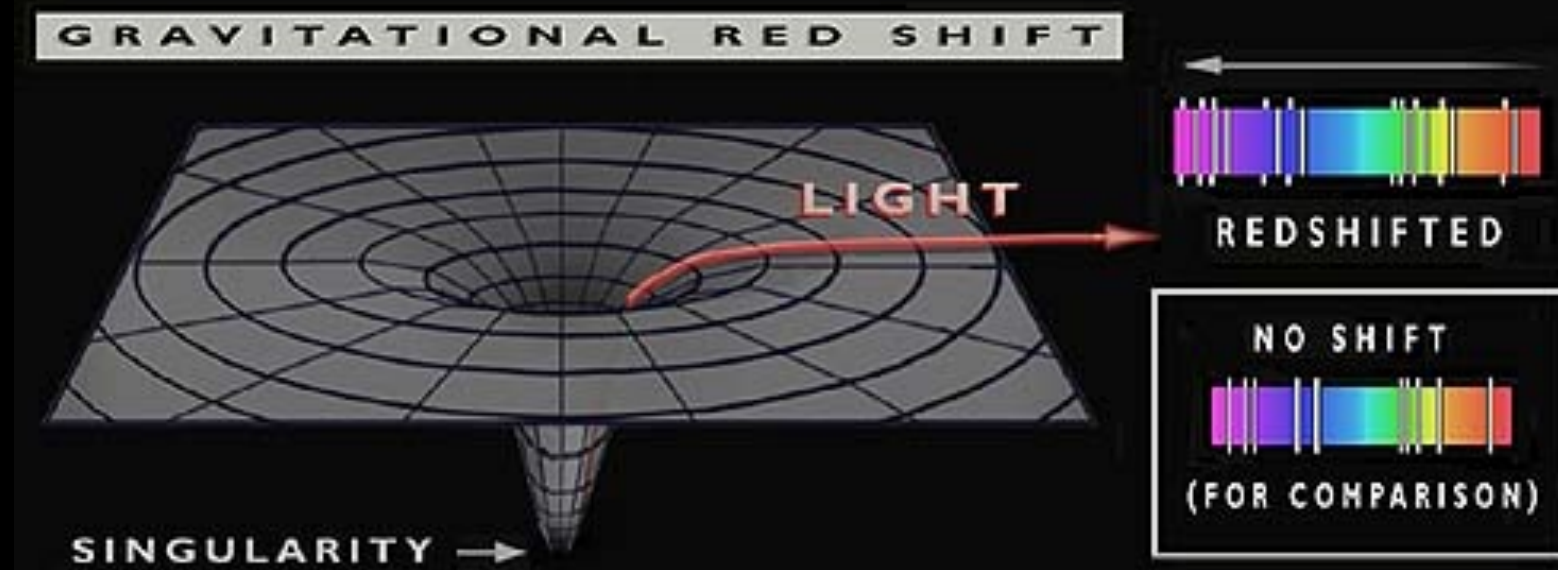
- **gravitational time dilation**
- **orbital precession**
- **frame dragging**
- **expansion of the Universe**
- **light deflection**
- **gravitational redshift**
- **gravitational waves**

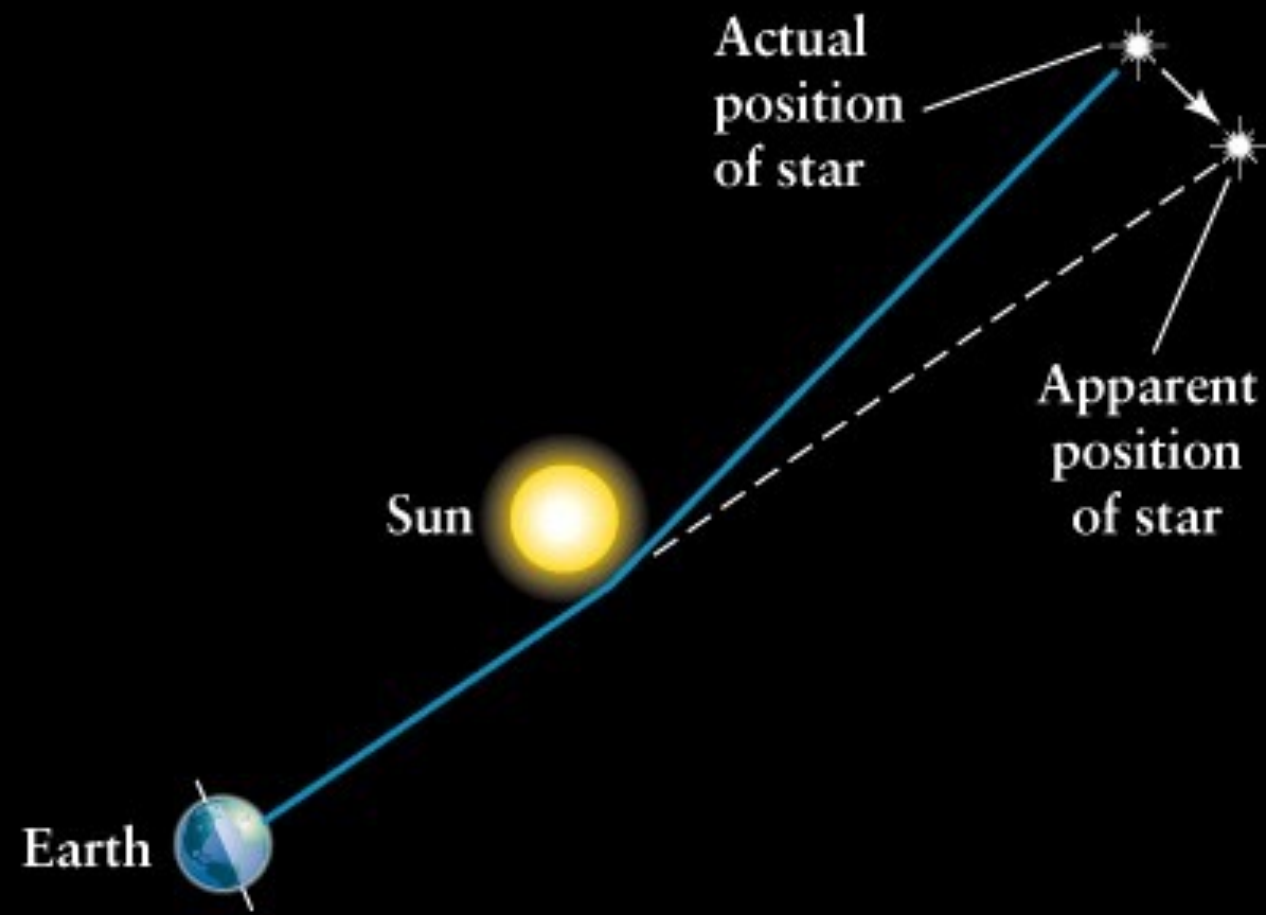


Time dilation

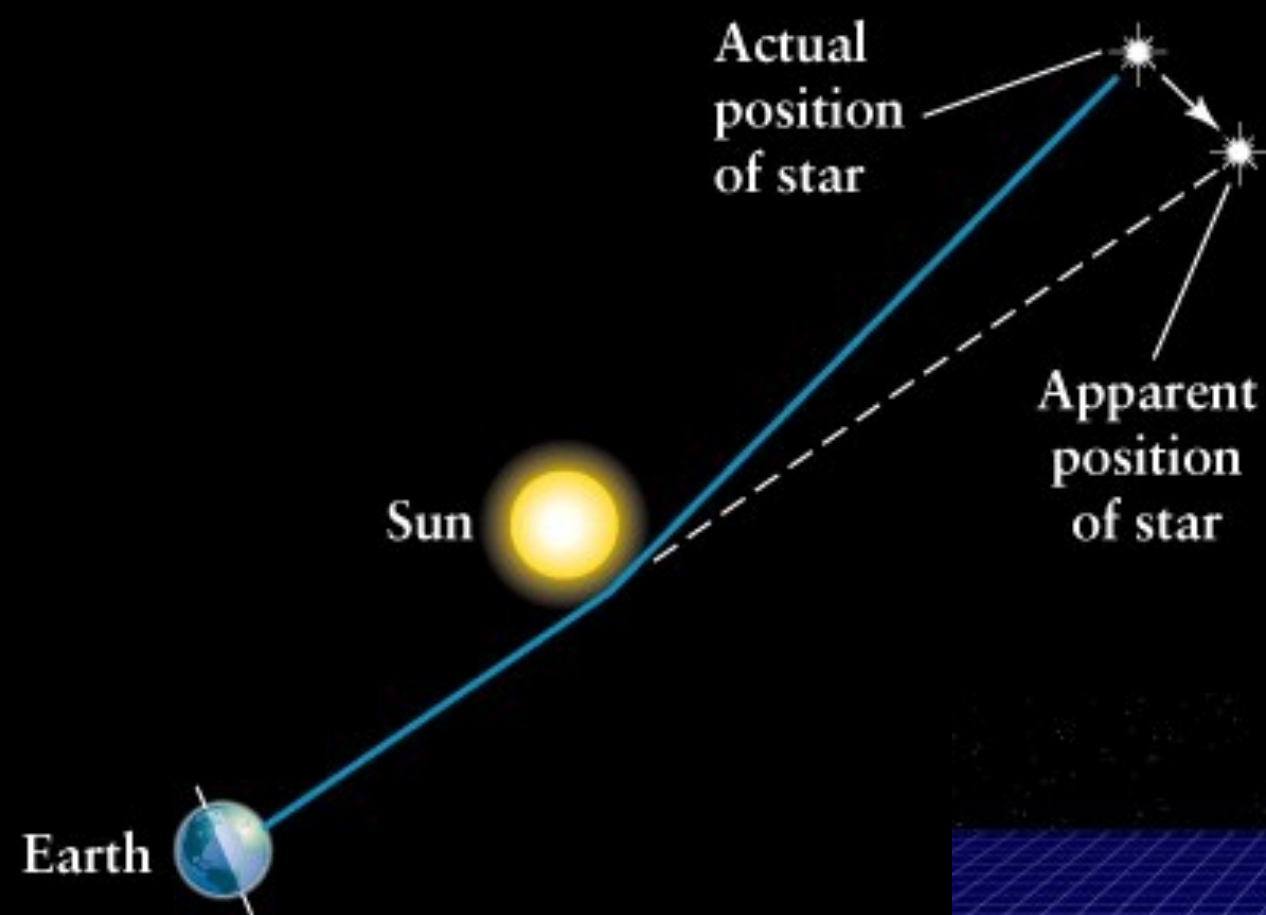


Gravitational redshift

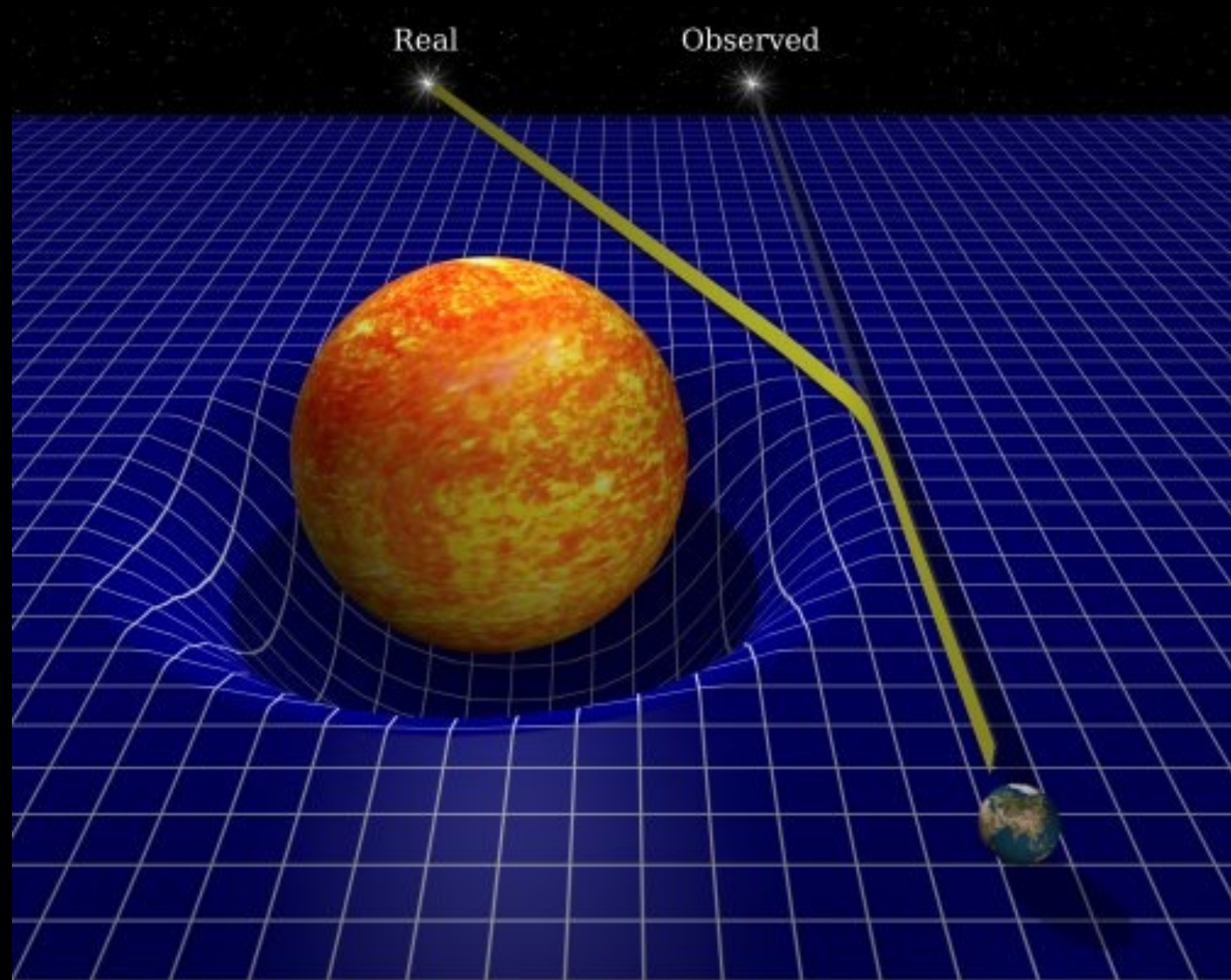


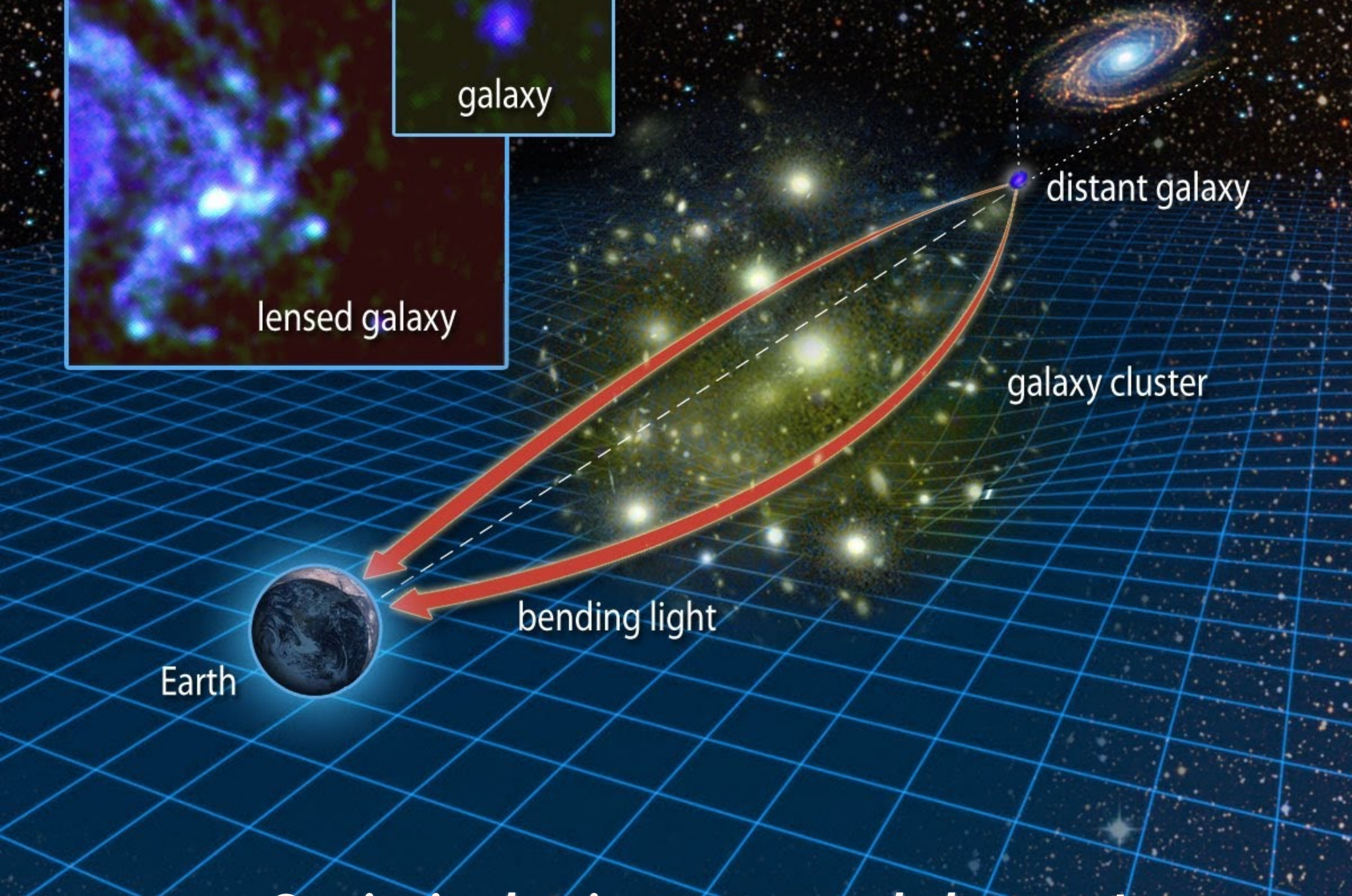


The deflection of light

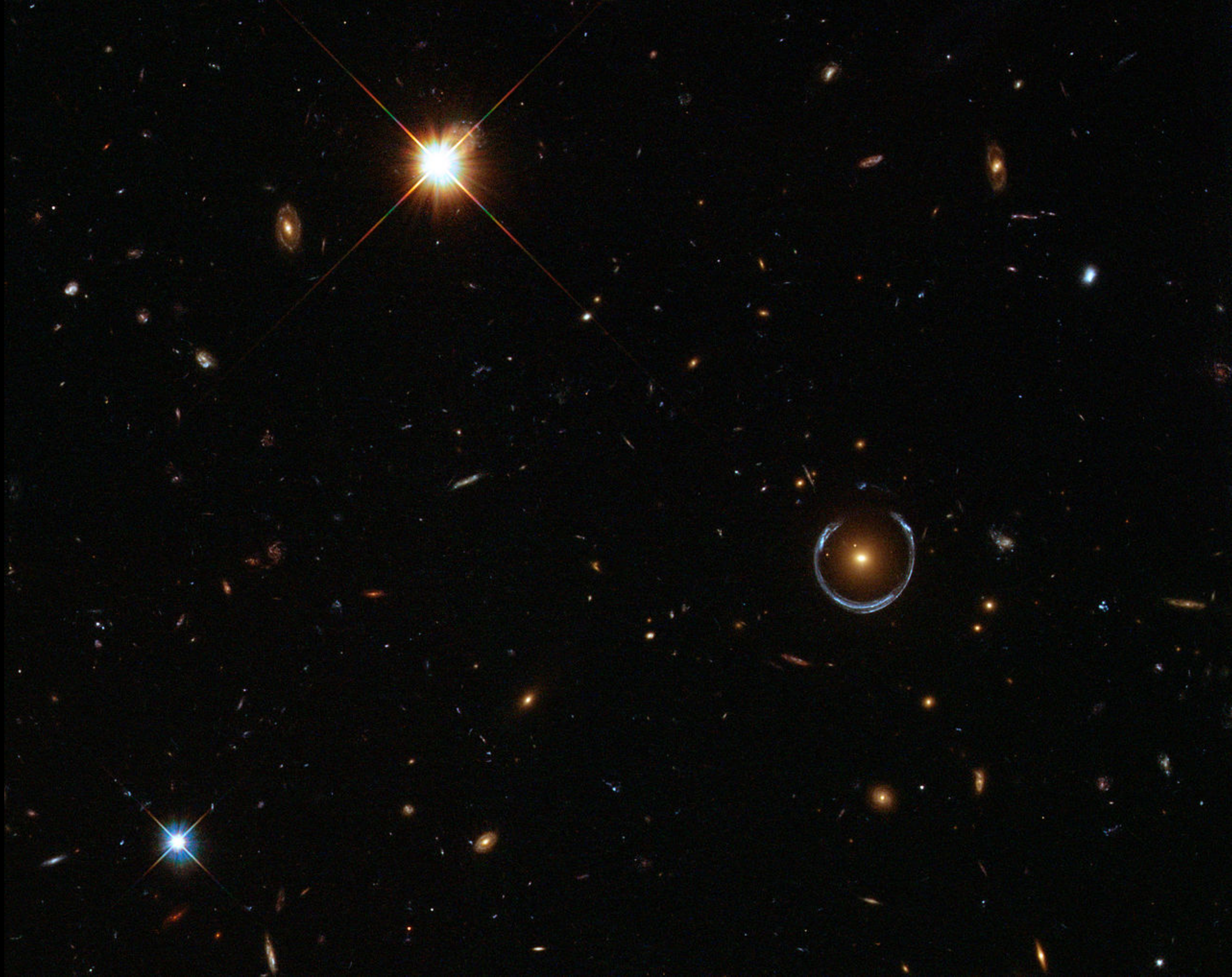


The deflection of light





Gravitation lensing: maps out dark matter!



Outline

Einstein & Relativity

Black holes

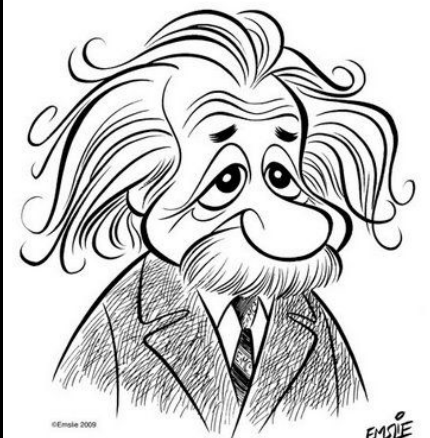
Event Horizon Telescope



Copyright Tyler Nordgren

***Einstein's field equations: curvature of spacetime
and how it depends on mass and energy***

$$R_{\mu\nu} - \frac{1}{2}R g_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$



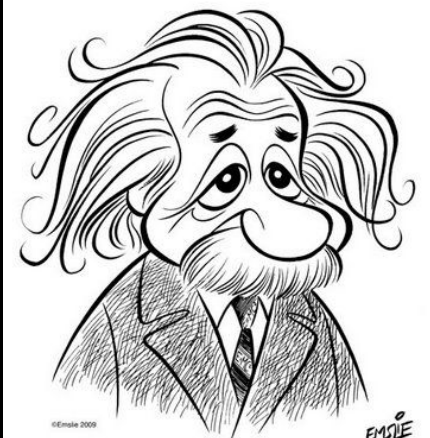
Einstein's field equations: curvature of spacetime and how it depends on mass and energy

$$R_{\mu\nu} - \frac{1}{2}R g_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Diagram illustrating Einstein's field equations with labels and arrows:

- cosmological constant** points to Λ .
- Newton's gravitational constant** points to G .
- curvature** points to $R_{\mu\nu}$.
- metric** points to $g_{\mu\nu}$.
- stress-energy** points to $T_{\mu\nu}$.

(actually 10 equations)

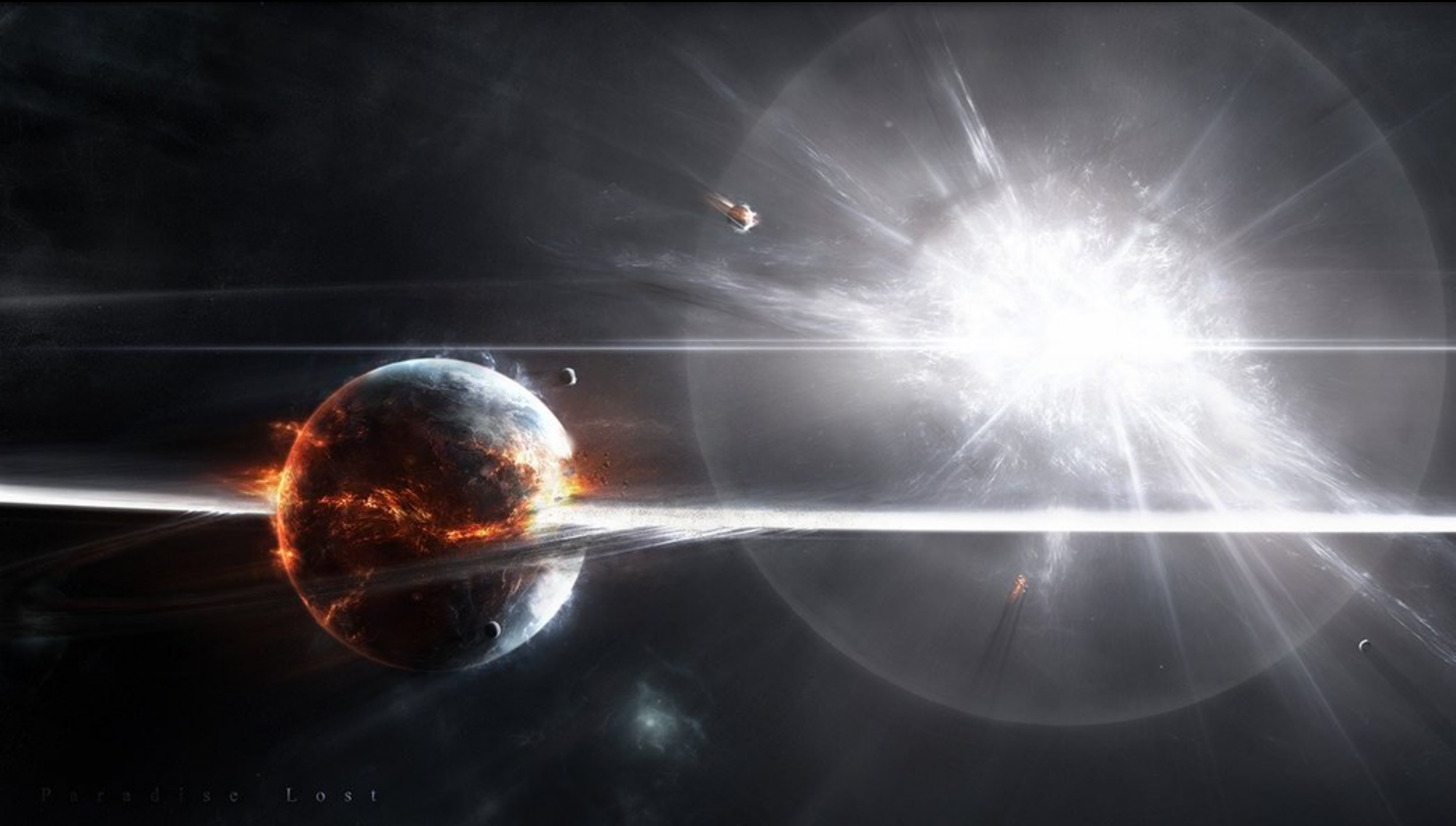




Karl Schwarzschild
1873-1916

***First exact solution
to Einstein's field
equations, for a
spherical non-
rotating mass***

"Stellar mass black holes" form from supernovae



P a r a d i s e L o s t

spaghetti-fication



Outline

Einstein & Relativity

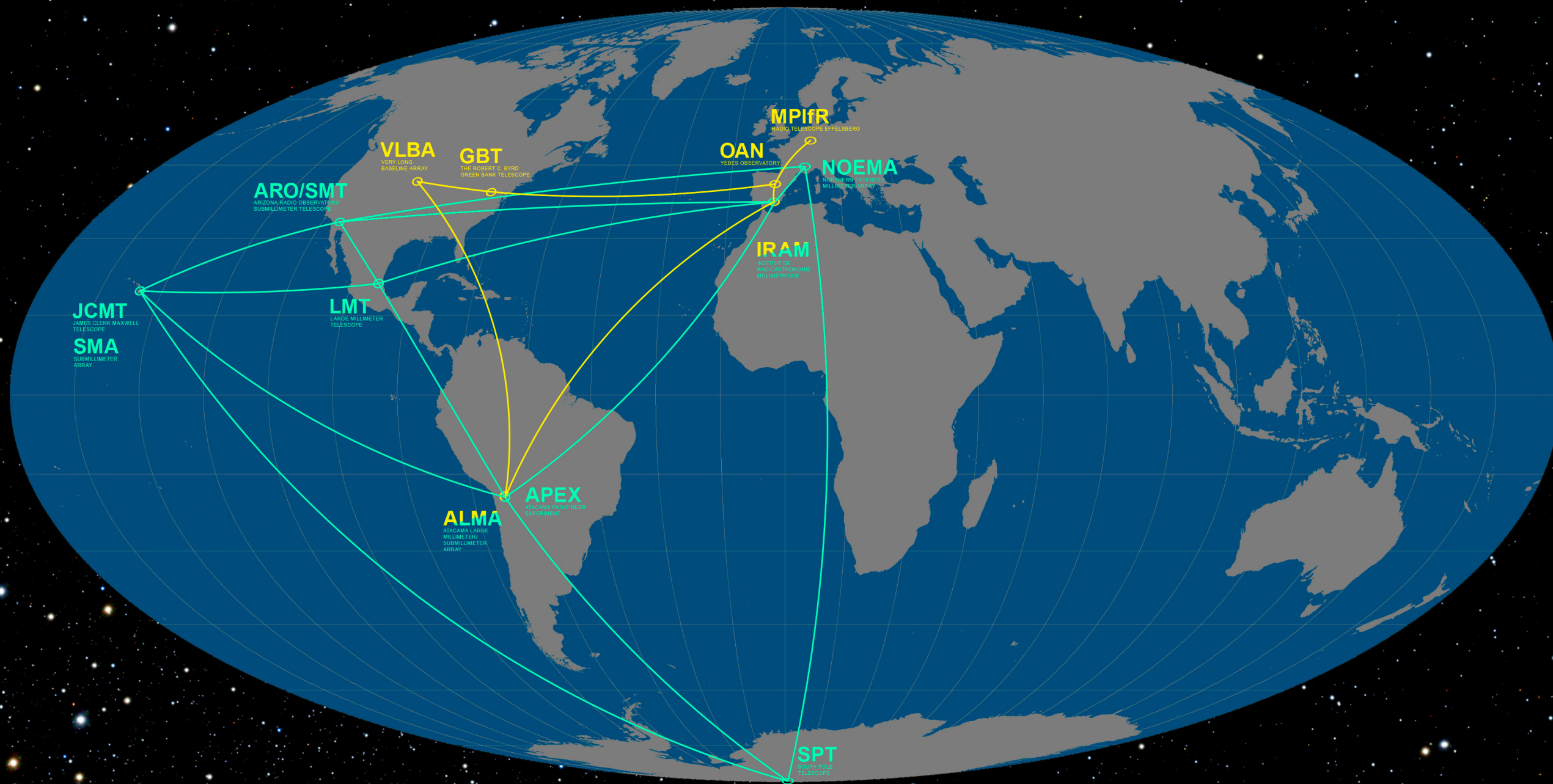
Black holes

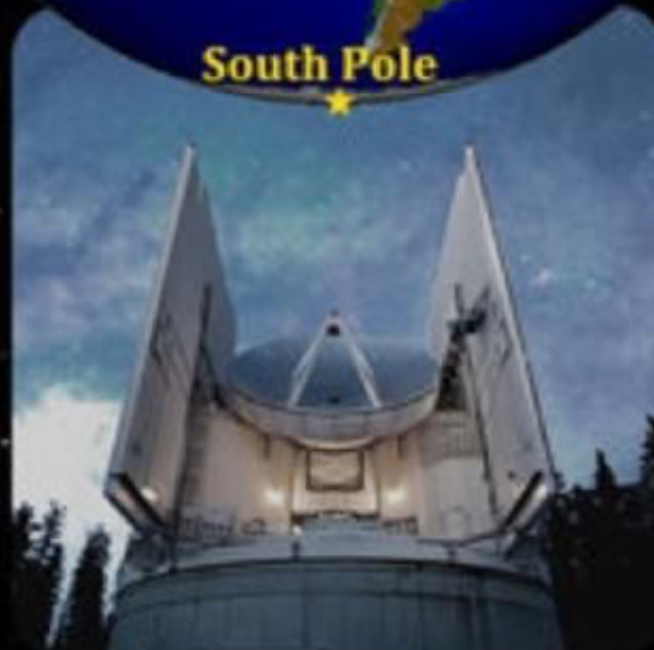
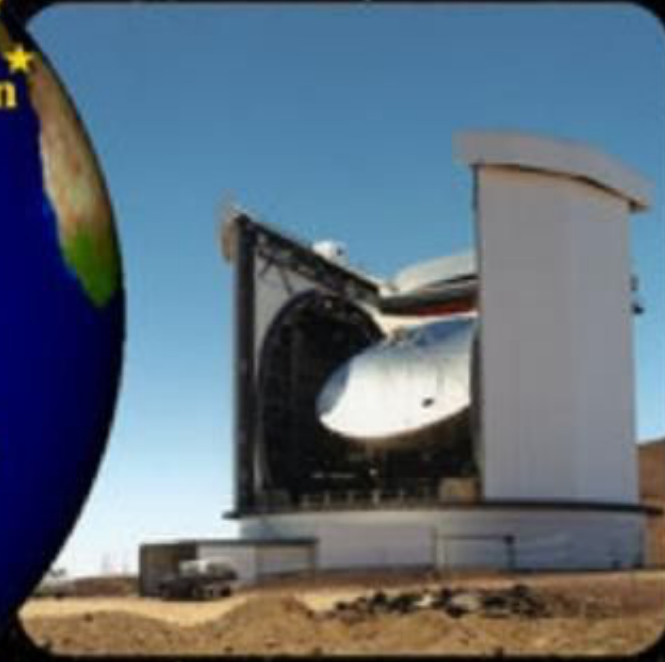
Event Horizon Telescope



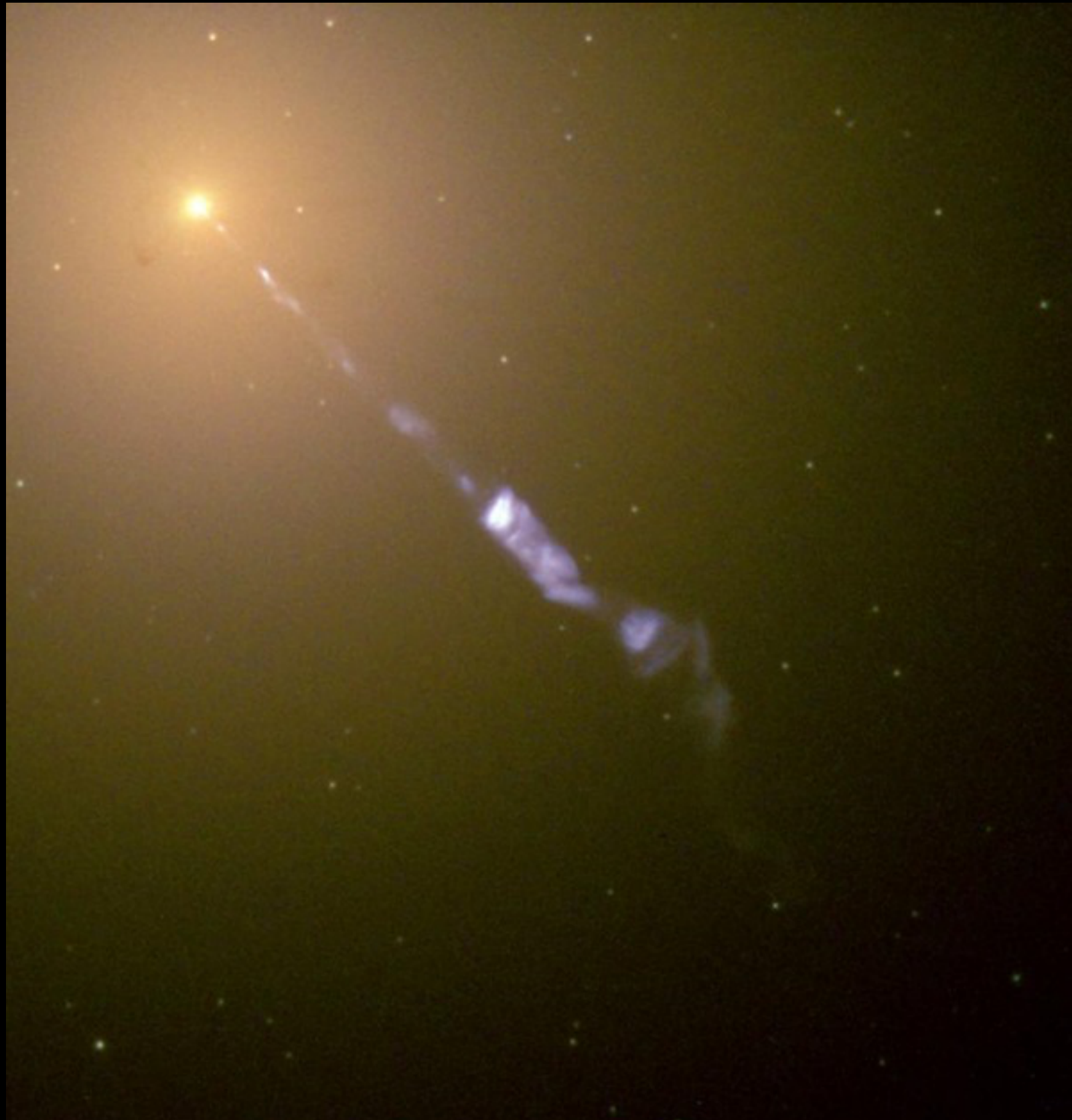
Copyright Tyler Nordgren

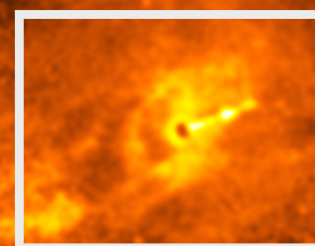
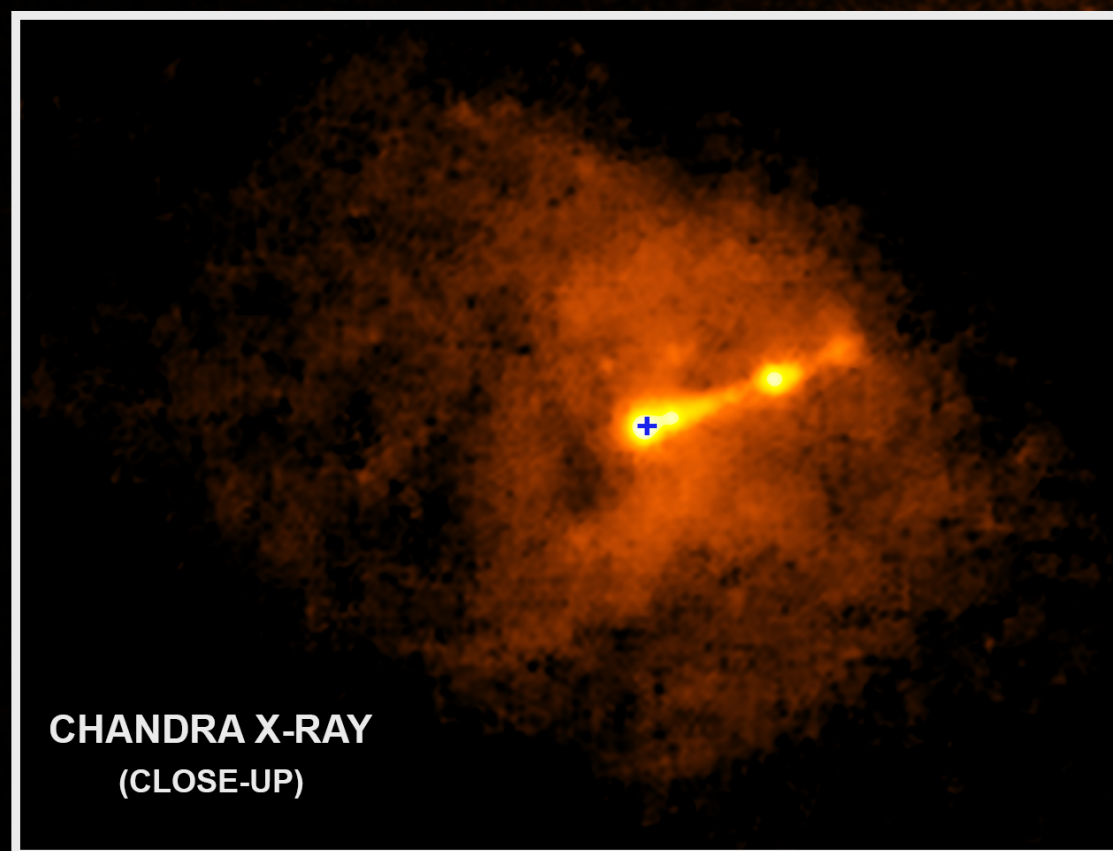
Event Horizon Telescope



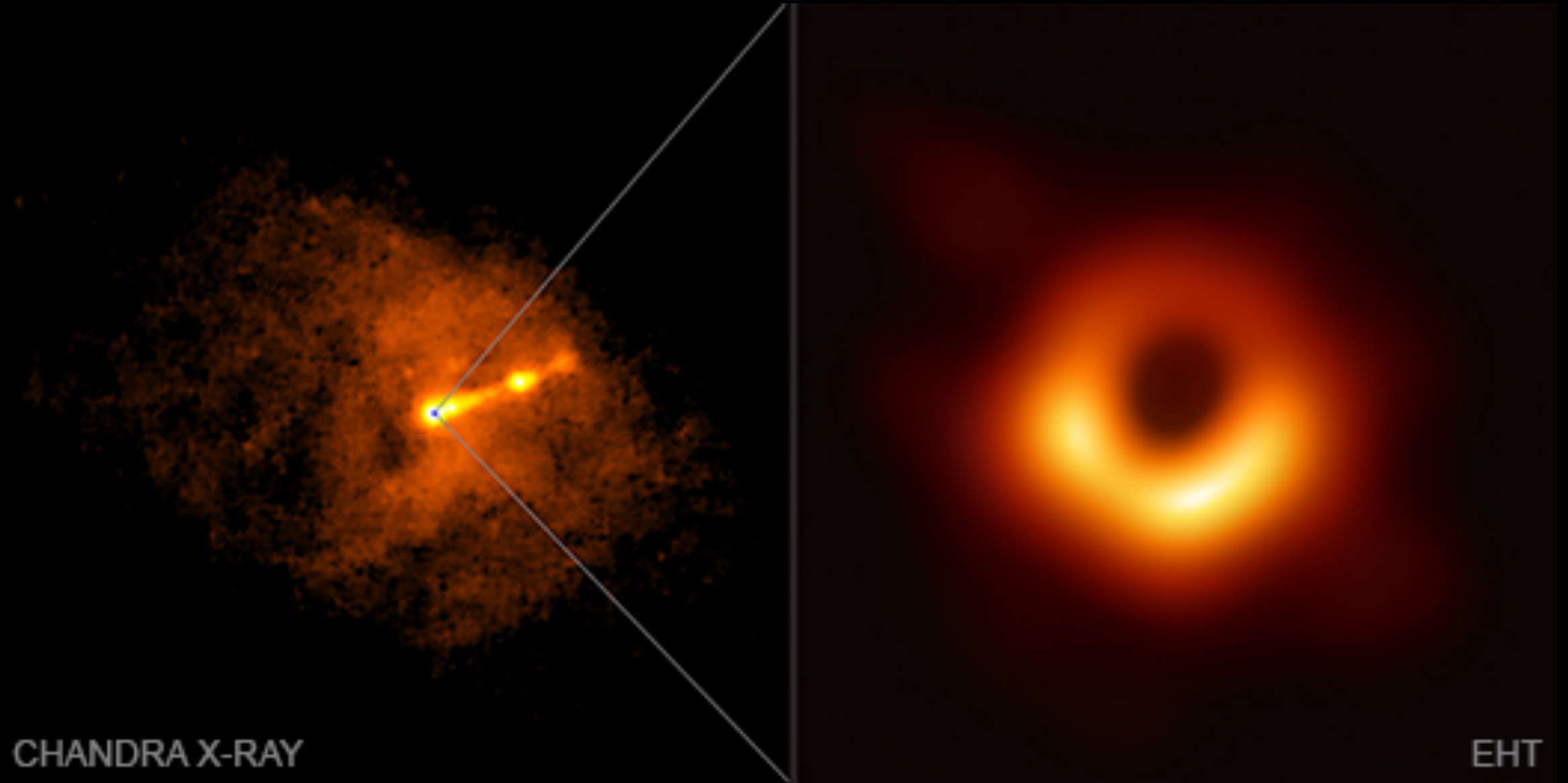


M87's jet





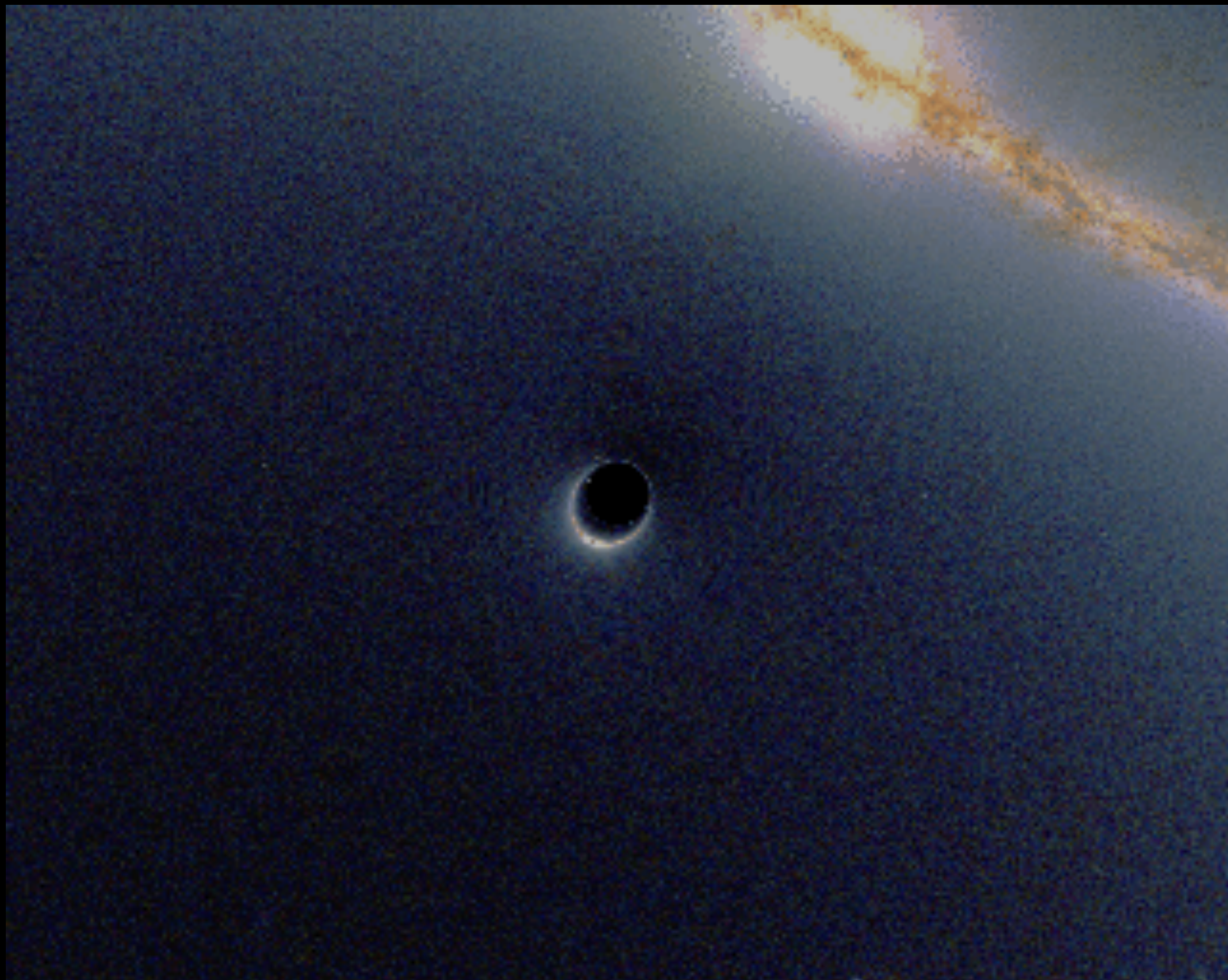
CHANDRA X-RAY
(WIDE-FIELD)



***6.5 billion times the mass of the Sun
(Sag A* is 4 million times M_{sun})***

Theoretical Physics & Hollywood





A composite image showing a geothermal landscape at night. In the foreground, there is a large, vibrant blue-green hot spring pool with white mineral deposits around its edges. To the right, a paved path leads towards other geothermal features. In the background, a dark line of evergreen trees is visible against the night sky. The sky is filled with stars, and the Milky Way galaxy is prominently displayed, arching across the upper half of the frame. The text "Thank You!" is centered in the sky area.

Thank You!