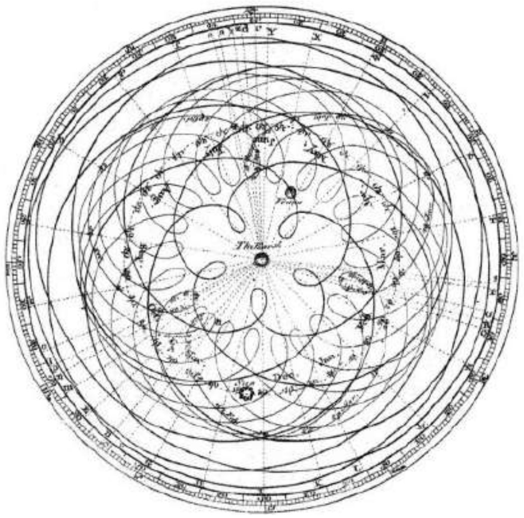
Physics Honors:
Gravity

A Short History of Gravity

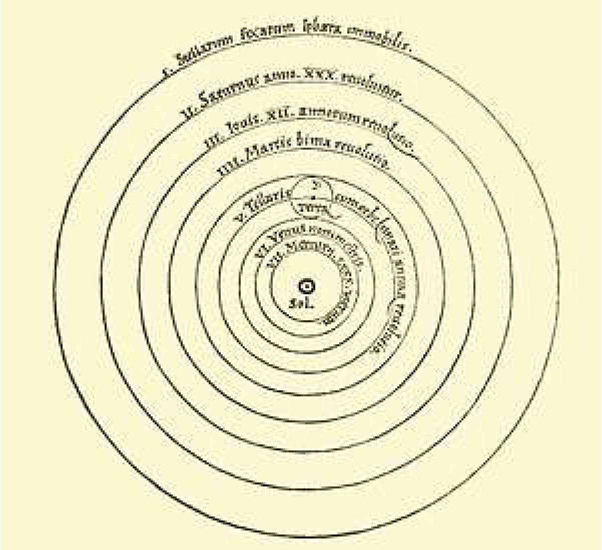
- The earliest observations of the way that the moon and stars moved suggested that they went around the Earth
- As they took more observations, the paths of the planets got really complicated trying to make it work so that the earth was the center of the solar system



A Short History of Gravity

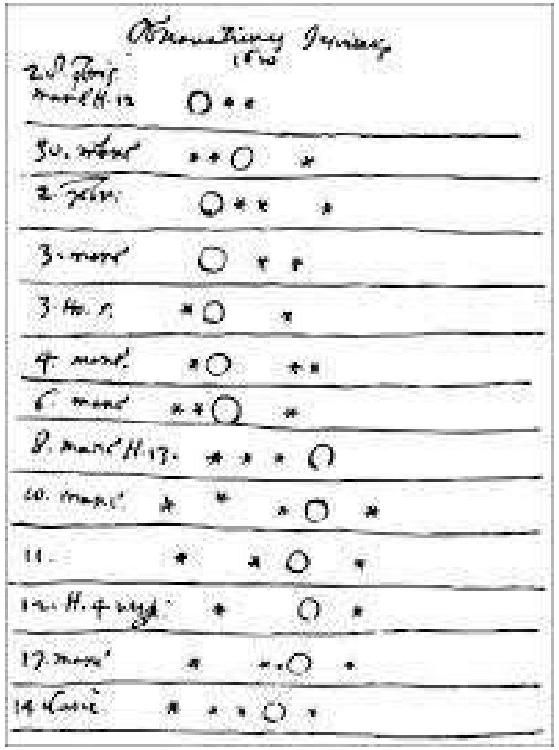
- Nicolas Copernicus took careful and detailed observations of the planets.
- When he did so, he realized he could make a much simpler model of the solar system if he put the sun in the center

- In science, we always say that the simplest solution is the best, so that idea suggested Copernicus was right



A Short History of Gravity

- In 1610, Galileo observed Jupiter with his brand-new telescope. He saw that Jupiter had moons that orbited around Jupiter.
- This was the first hard evidence that there were objects that orbited something other than the sun.



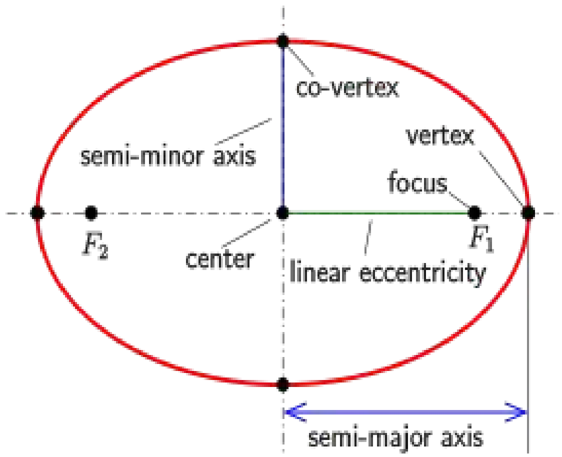
A Short History of Gravity

- Tycho Brahe was a meticulous astronomer who took the most precise measurements of the stars and planets ever seen. (In the 1600’s)

- He was really good at measurements but his student, Kepler, was able to take his measurements and use them to create three laws about the way that planets move around the sun.

Kepler’s First Law

- Kepler’s First Law states that planets orbit the sun in **ellipses.**



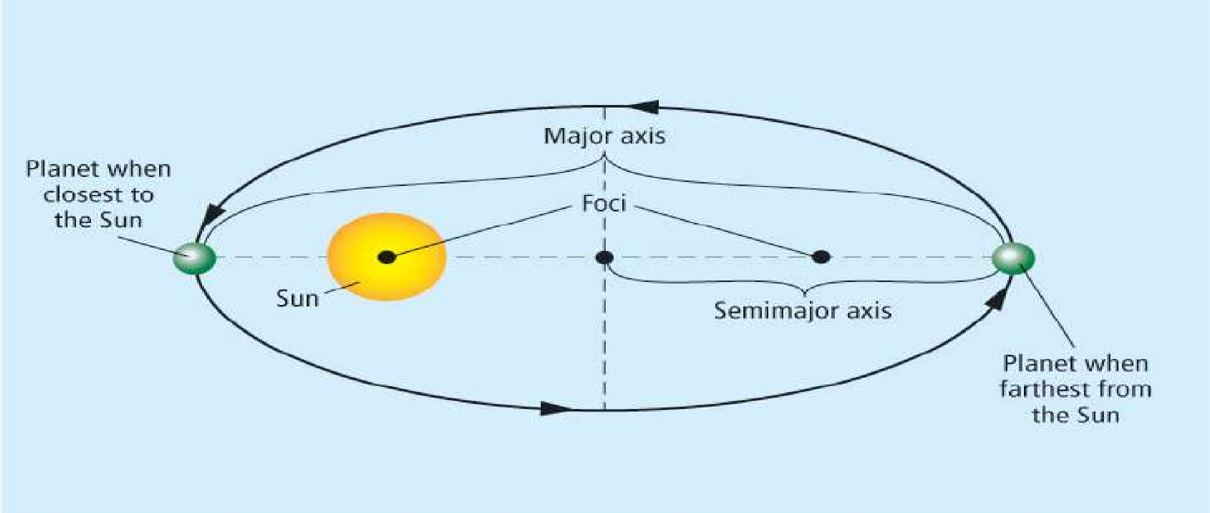
- Before Kepler, it was thought that planets orbited in circles

Kepler’s First Law

The two points in an ellipse are called the foci. (singular: focus)

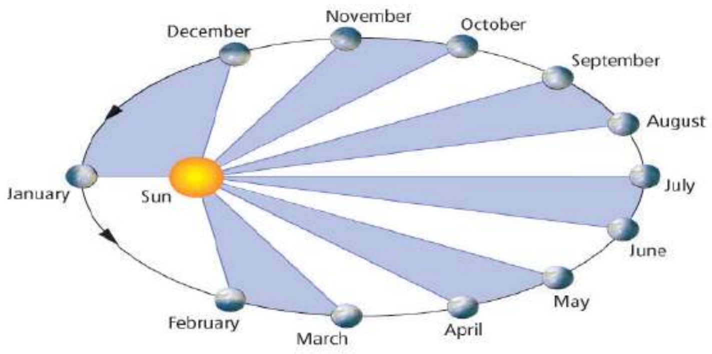
The major axis is the line that runs through both foci at the longest part of the ellipse.

The shape of a planet’s elliptical orbit is defined by **eccentricity**, which is the ratio of the distance between the foci to the length of the major axis.



Kepler’s Second Law

- Kepler’s Second Law states that an imaginary line from the sun to the planet sweeps out equal areas in equal time periods



- What this means is that planets is that planets will move faster when they are closer to the sun, and slower when they are further away

Kepler’s Third Law

- Kepler’s Third Law is an equation that related how long it takes a planet to orbit the sun to how far away the planet is.

$$P^2 = A^3$$

P = Period of the planet’s orbit (in Earth years)

A = The length of the semi major axis (in Astronomical Units)

1 Astronomical Unit = The distance that the Earth is from the Sun

Kepler’s Third Law

- Kepler’s Third Law works for any planet in our solar system

- If we want to use this equation for planets in other solar systems, we need to include a constant that accounts for gravity and differences in the mass of the sun

$$P^2 = \frac{4\pi^2}{k^2(M_{\rm tot})}a^3$$

Newton’s Law of Gravitation

- Just a few years after Kepler published his 3 planetary laws, Isaac Newton began working with the concept of gravity.

- He put together an equation that accounted for the gravity between any two objects and the distance between them.

$$F_g = \frac{G M_1 M_2}{r^2}$$

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- Fg = Force due to Gravity (Newtons)
- G = Universal Gravitational Constant $(6.67 * 10^{-11} \frac{Nm^2}{kg^2})$
- M1 = Mass of object 1 (kg)
- M2 = Mass of object 2 (kg)
- r = distance between the objects (m)

Universal Gravitation Practice

- What is the force of gravity between two students who each weigh 70 kg if they are stand 2 meters away from each other?

Universal Gravitation Practice

- The mass of the Sun is 1.989×10^{30} kg. An astronaut on the ISS weights 75 kg. If the ISS is 1.5×10^{11}m from the sun, how much gravity is the sun exerting on the astronaut?

Wait…doesn't $F_g = mg$?

Cavendish's Experiment

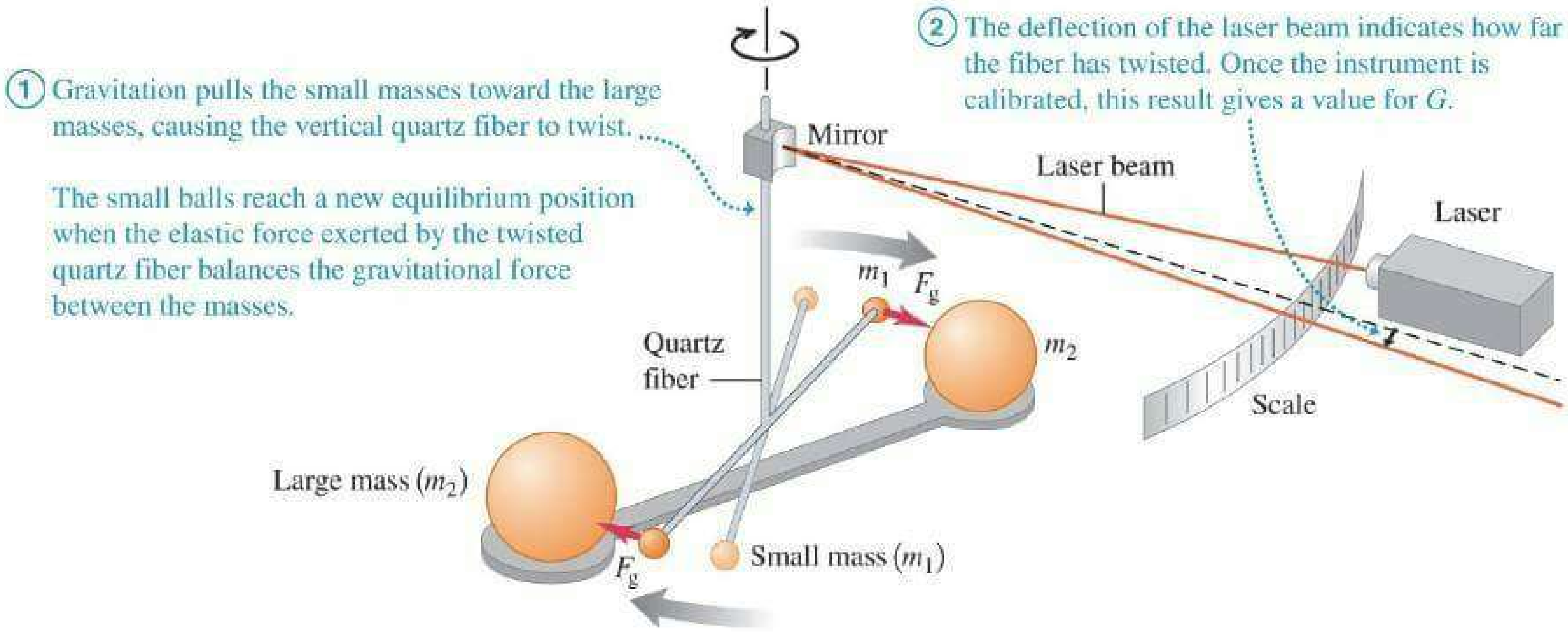
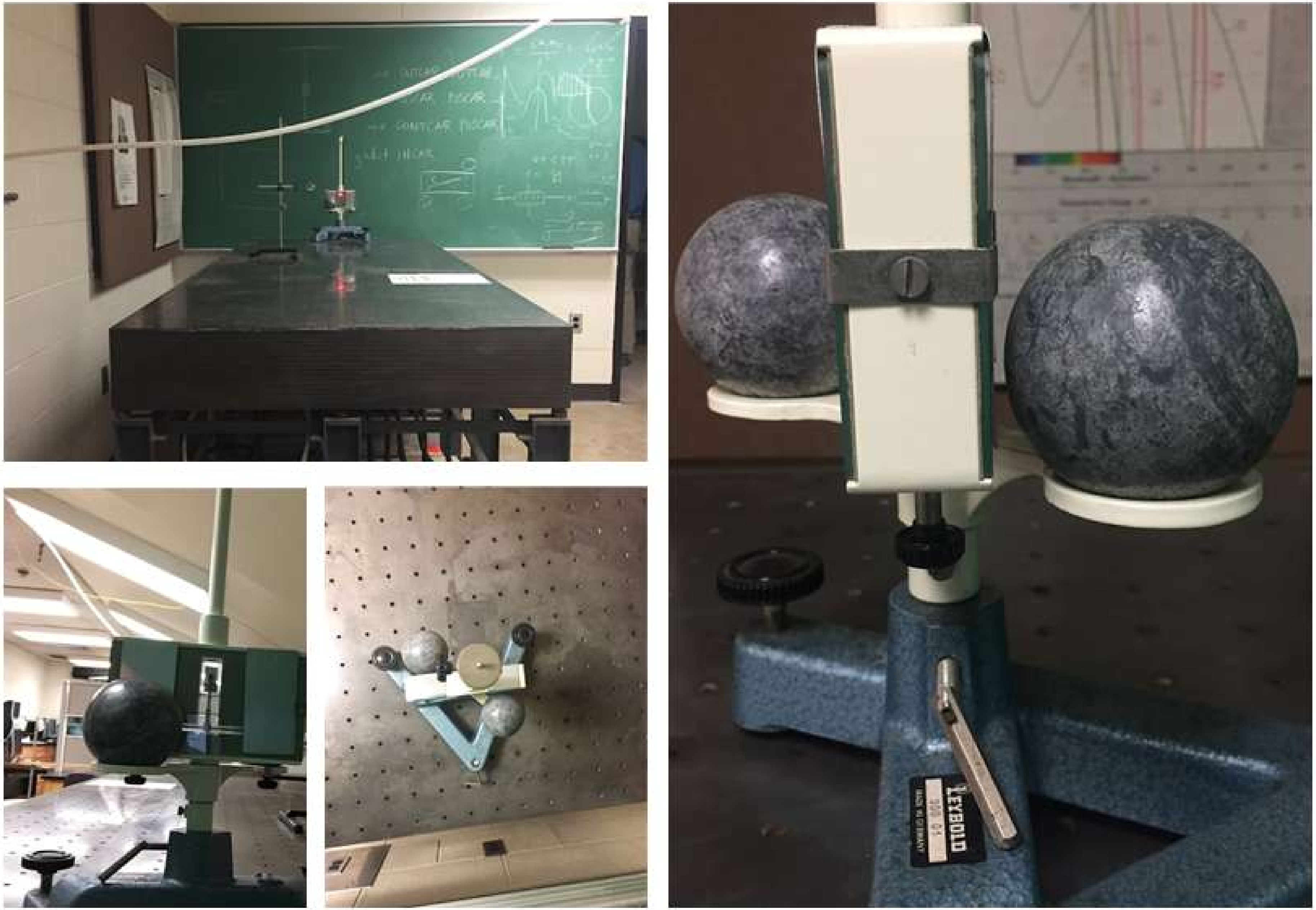


Figure 2 – The apparatus used by Cavendish to measure the magnitude of the universal gravitational constant.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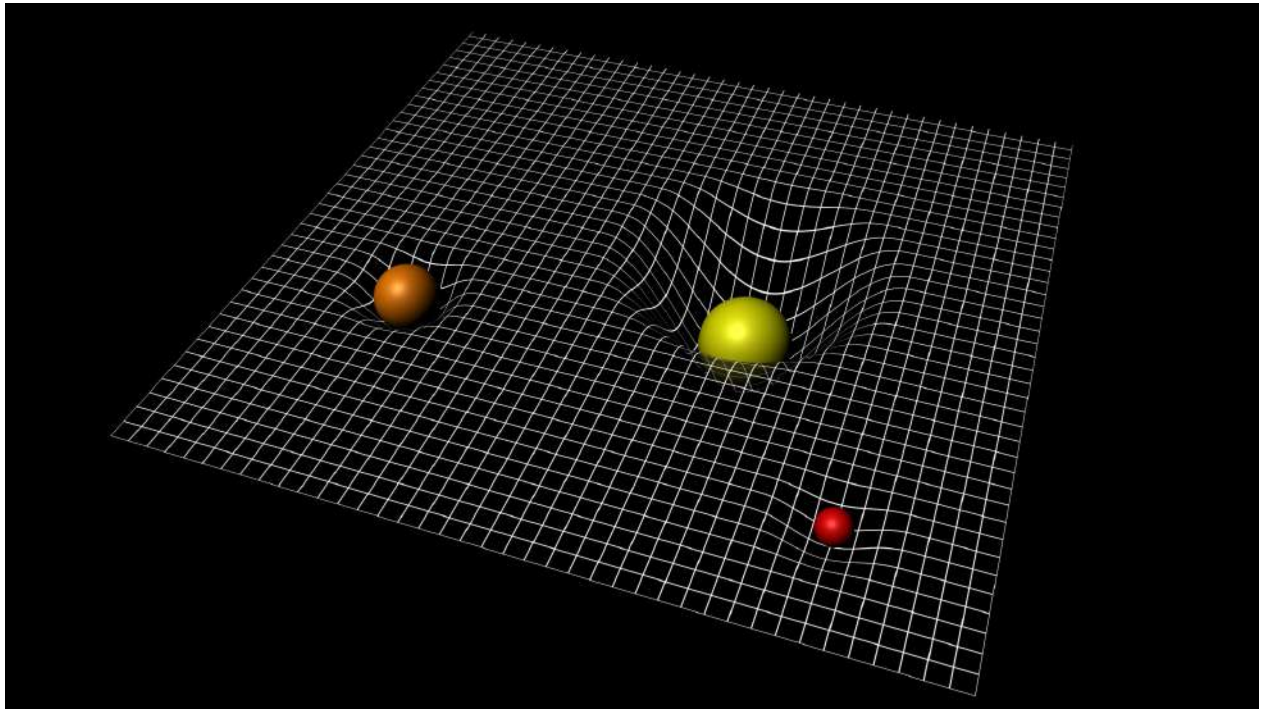
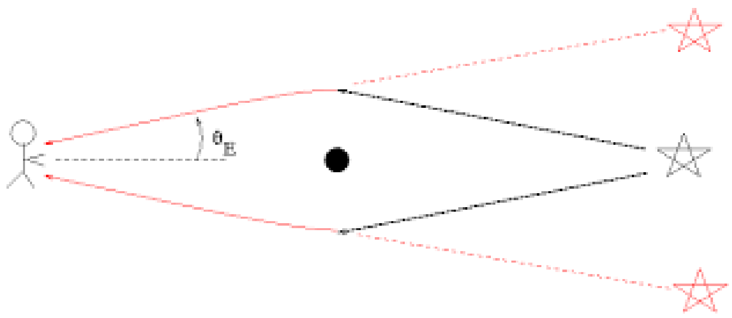
Einstein’s Theory of Gravity

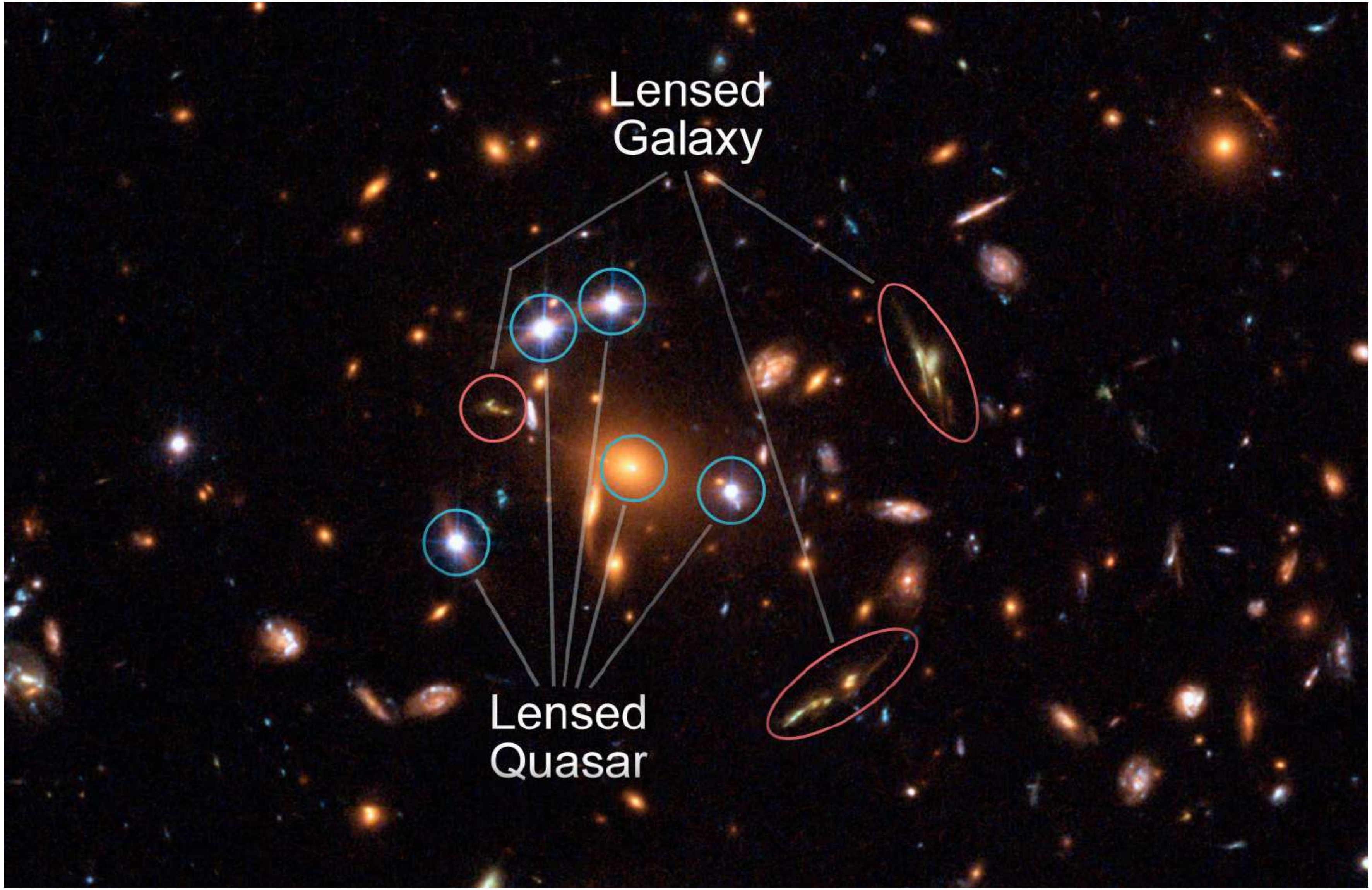
- Einstein suggested that Gravity might not be a force, but rather an effect of space itself.
- He theorized that mass bent space, like a heavy object on a sheet. The heavier the object, the more space gets curved.
- He called this theory General Relativity.



Deflected light

- Einstein's theory predicts that massive objects would deflect light, because light follows the curvature of space.

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