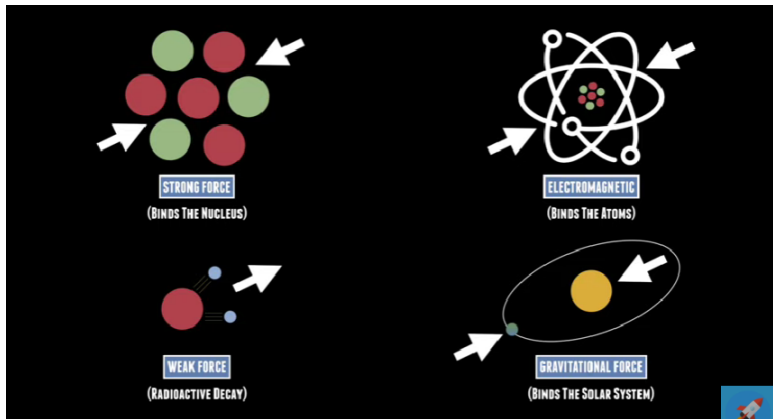


A Brief History of Gravity

Harsha Sreekumar

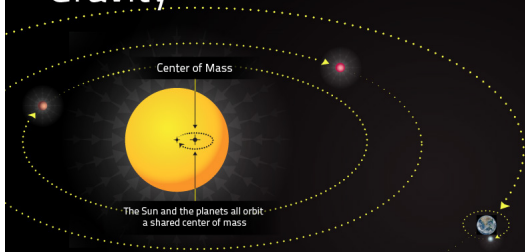
June 2023

The Four Fundamental Forces of Nature



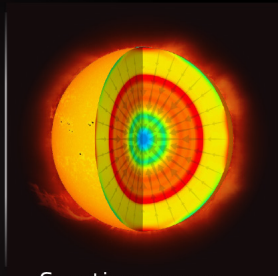
Gravitational Force

Gravity



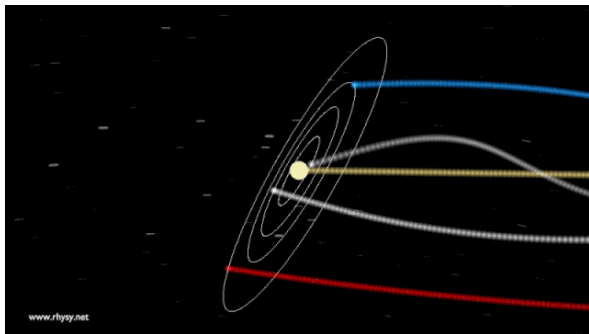
Adding motion to the Universe

Gravity forms stars, planets, and moons, and forces these objects to spin on an axis and move along an orbital path. The planets appear to be orbiting the center of the Sun, but the Sun and planets all orbit a shared center of mass. Planets with enough mass can develop orbiting moons or rings of debris.



Creating energy

Gravity is the force that creates pressure and fusion energy in the core of stars allowing them to burn for millions of years.

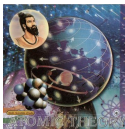


A Bit of History !!

600 BCE

Acharya Kanada

“Guruthva-prayatna-samyoganam-utkshepanam” .



400 BCE

Aristotle

Objects moved toward their “natural place” .



300 BCE

Archimedes

Discovered fundamental theorems concerning the center of gravity of plane figures.



600s-690s

Brahmaputra

“Guru-thv-akarshanam”.

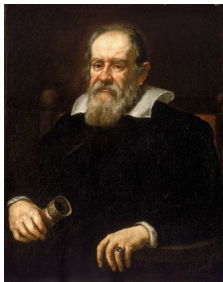
900s-990s

Al-Biruni

proposed that heavenly bodies have mass, weight, and gravity, just like the Earth..



Galileo Galilei(16th Century)



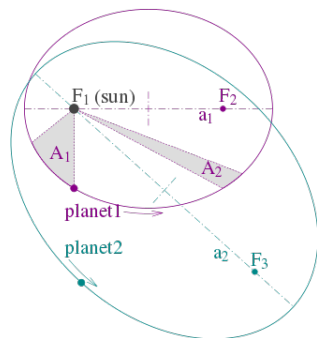
- Italian astronomer, physicist and engineer.
- Conducted experiments to show two different balls hit the ground at the same time no matter what their masses were.
- Calculated the acceleration because of gravity to be constant at around $10m/s^2$.

Johannes Kepler(16th Century)



- German astronomer, mathematician, astrologer, natural philosopher.
- Described the motion of planets around the Sun improving on Copernicus's ideas
- His works also provided one of the foundations for Newton's theory of gravitation.

Kepler's Laws of Planetary Motion



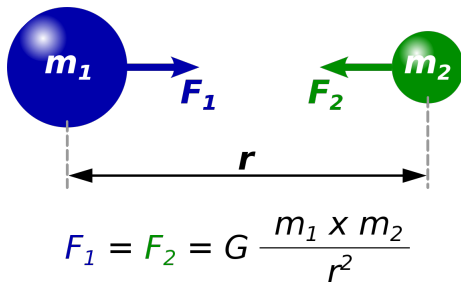
- The laws modified the heliocentric theory of **Nicolaus Copernicus** explaining the motion of planets around the Sun.
- The laws state that:
 - 1 The orbit of a planet is an **ellipse** with the Sun at one of the two foci.
 - 2 A line segment joining a planet and the Sun **sweeps out equal areas during equal intervals of time**.
 - 3 $T^2 \propto a^3$
 $T \rightarrow$ planet's orbital period
 $a \rightarrow$ length of the semi-major axis of its orbit

Isaac Newton(1687)



- English mathematician, physicist, astronomer, alchemist, theologian.
- His pioneering book *Philosophiæ Naturalis Principia Mathematica* (Mathematical Principles of Natural Philosophy), first published in 1687, consolidated many previous results and established classical mechanics.
- Newton formulated the laws of motion and universal gravitation that formed the dominant scientific viewpoint for centuries.

Newton's Law of Gravitation



In his own words:

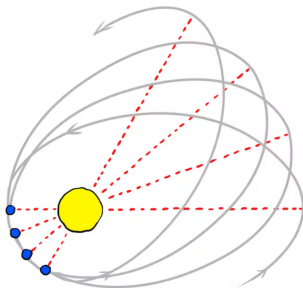
I deduced that the forces which keep the planets in their orbs must be reciprocally as the squares of their distances from the centres about which they revolve; and thereby compared the force requisite to keep the moon in her orb with the force of gravity at the surface of the earth; and found them to answer pretty nearly.

Success of Newton's Law

- First test of Newton's Law was **Cavendish Experiment** by English scientist Henry Cavendish in 1797-98.
- It was used to predict the existence of Neptune based on motions of Uranus that could not be accounted by the actions of the other planets.
- Calculations by **John Couch Adams** and **Urbain Le Verrier** both predicted the general position of the planet.
- In 1846, Le Verrier sent his position to Johann Gottfried Galle, asking him to verify it.
- The same night, Galle spotted Neptune near the position Le Verrier had predicted.

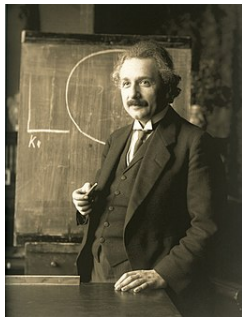
Slight Hiccup in the Law!!

- All planets' orbits precess – with the closest point of their orbit moving slightly with each revolution – due to the gravitational tugs from other planets.



- The issue with Mercury's orbit was that the amount of precession did not match what Newton's theory predicted.

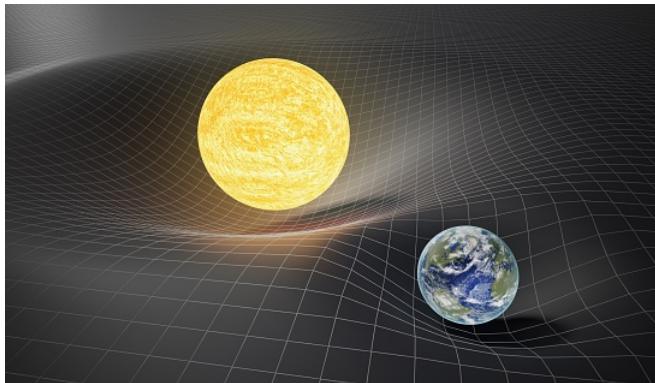
Albert Einstein(1905)



- German-born theoretical physicist.
- In 1905, Einstein published four groundbreaking papers. These outlined the theory of the photoelectric effect, explained Brownian motion, introduced **special relativity**, and demonstrated mass–energy equivalence($E = mc^2$).
- In 1917, he applied the **general theory of relativity** to model the structure of the universe.

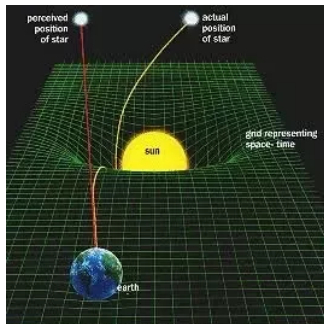
Theory of Relativity

Encompasses two interrelated theories by Einstein, Special Theory and **General Theory of Relativity**(1905, 1915).

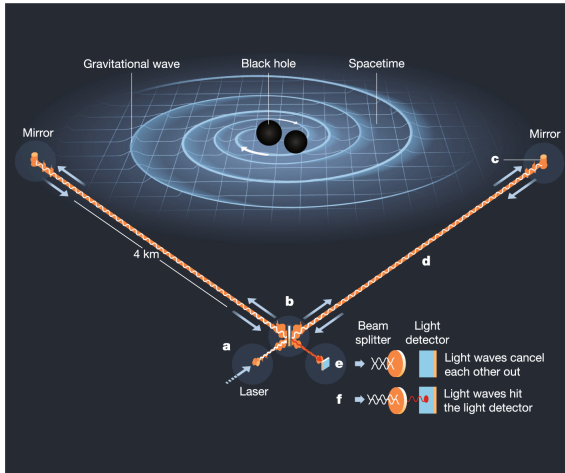


Tests of General Relativity

- GR agrees closely with the observed **precession in the orbit of Mercury**.
- **Gravitational Lensing** → First observed by Arthur Eddington in 1919.

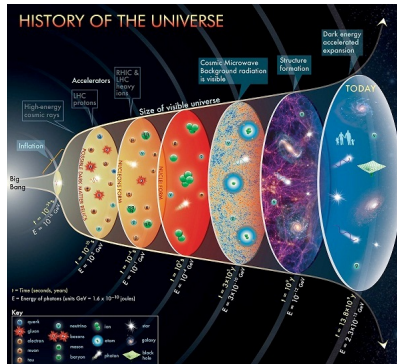


■ **Gravitational Waves** → Successfully detected in 2015.





Is the Theory of Gravity complete?

- It is not!! Since the theory is incompatible with **quantum mechanics**.
- But Why do we need quantum mechanical description of Gravity?



Theories of Quantum Gravity

- String Theory
- Loop Quantum gravity
- Causal Set Theory
- **Noncommutative Geometry**
- Twister Theory

-  History of gravitational theory — Wikipedia,. https://en.wikipedia.org/wiki/History_of_gravitational_theory, 2023. [Online; accessed 09-June-2023].
-  Geraint Lewis. Timeline: the history of gravity ,. <https://theconversation.com/timeline-the-history-of-gravity-54528>, 2016. [Online; accessed 09-June-2023].

Thank You