The Road to Modern Astronomy

Galileo and Newton

When last we met…

- Kepler had finally gotten the idea
- 3 laws of planetary motion
- Heliocentric Cosmos suspected but not yet proven
- Big changes are coming!



Galileo Galilei

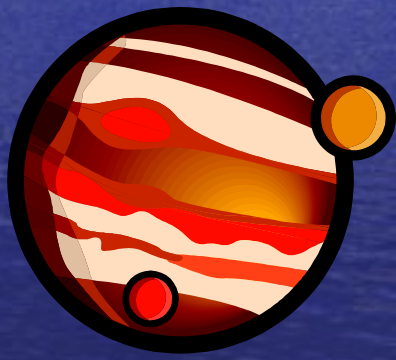
- 1564-1642
- Contemporary of Kepler
- Didn't invent telescope, but put it to very good use!
- Published many of his findings in books

Sidereus Nuncius

- ***The Starry Messenger* (1610)**
- Written in Italian, accessible to public
- Reported observing many imperfections in the heavens
- Sold like hotcakes! First 'pop' science book

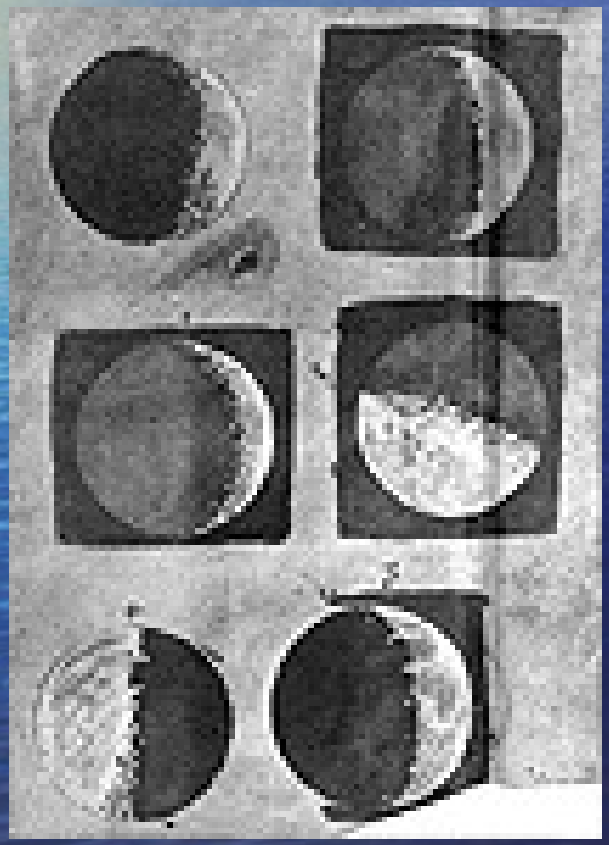
What he saw…

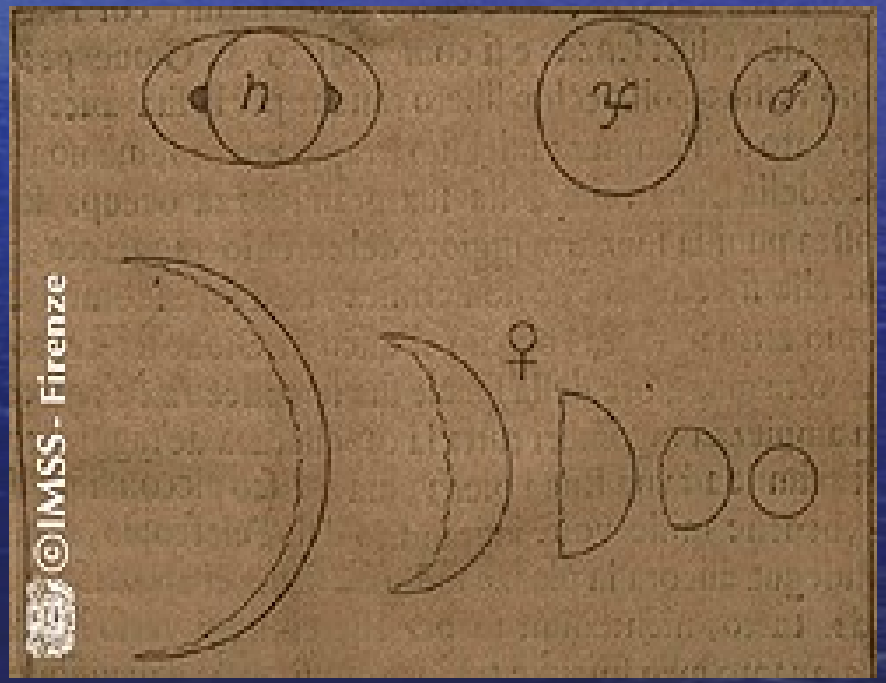
- ***Moon's surface was imperfect***
- ***Many, many stars in Milky Way***
- ***4 "things" orbiting Jupiter***



- Still didn't publicly proclaim to be a "Copernican"
- Kepler's work helped verify observations

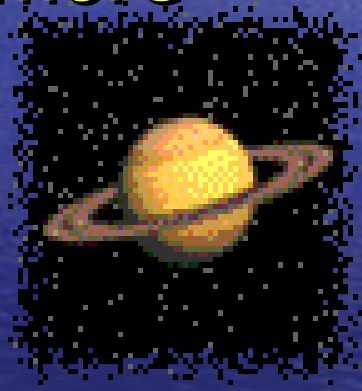
Galileo's Work





More discoveries

- Encouraged by Kepler, Galileo does more
- ***Sunspots, Sun's rotation***
- ***Phases of Venus***
- ***Rings of Saturn***
- Publicly declares his "Copernicanism" in 1613 in ***The Letters on Sunspots***



Galileo's Scientific Method

- He didn't prove the Copernican model "true"
- His work proved that the Ptolematic/Aristotlian model was "false"
- It didn't support the experimental observations

Back on Earth…

- Galileo tried to lend credence to his work by improving the laws of motion
- Father of Mechanics (a branch of Physics)
- Studied motion caused by forces
- Began by looking at the motion of falling objects

A Bit of Mechanics

Vectors and Scalars

- **Vector** has magnitude and direction
- Takes two numbers to describe

- **Scalar** has magnitude only
- Takes one number to describe

You know Physics!

- Speed and Velocity

Speed is Scalar

Velocity is Vector

My speed is 65 miles per hour

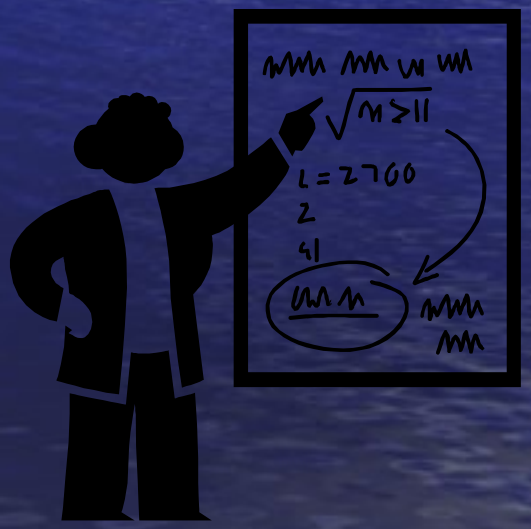
My velocity is 65 miles per hour North

Changing a Vector

- You can change a vector many ways
- You can change its magnitude (length)
  - Increase your speed from 30mph to 60mph
- You can change its direction
  - Turn a corner, go around a curve, top a hill

Acceleration

- Any time velocity changes, there is an acceleration that causes this change!
- Speeding up
- Slowing down
- Changing Direction



Acceleration is Important

- Galileo was interested in how objects accelerate here on Earth
- Specifically, do falling objects accelerate?
- What causes them to accelerate?

Galileo Vs. Aristotle

- Reversed Aristotlian ideas about forces
- May seem to be opposite to what should be true, but on closer inspection make sense!
- Galileo's Motions

Falling-Caused by a Force

Constant Velocity Motion-Natural

Inertia

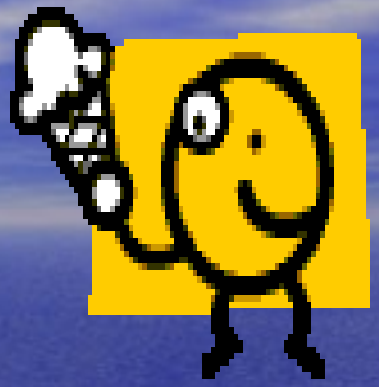
- An object that is experiencing constant velocity motion
  - Constant speed
  - Moving in a straight line

will continue to do so unless acted on by an outside force

Gravity for Galileo

- Viewed objects that are falling as a "forced" motion
- Some unknown force was puling the objects downward
- Today we know the force is **Gravity**
- Objects that are "falling" due to gravity are in ***free fall***

Gravity



- Galileo's experiment at Pisa
- Dropped objects speed up!
- All objects speed up at the same rate (they have the same accleration)
- Must be experiencing an acceleration so same force must be acting on everything

Galileo's Cosmos

- ***Dialogue on the Two Chief World Systems*** (1632)
- No evidence of Kepler's influence
- A Copernican model with no "earthly" physics applied
- Stellar Sphere still existed, but with some doubts

Newton Saves the Day

- Isaac Newton (1642-1727)
- Invented a telescope configuration that is still used today (Reflecting)
- Began working on Kepler's Laws
- Gravity is the driving force

Principia

- Published in 1687
- Defines velocity, acceleration, mass
- Presents 3 laws of Motion
- ***Mass is not Weight***

Mass and Weight

- Here on Earth we use them interchangeably
- Mass is a measure of how much "stuff" (matter) the object is made of
- It is always present
- Weight is a measure of gravity's affect on the object
- Is it always present?

Newton's Laws

- First Law- Law of Inertia

A body at rest or in motion w/ a constant velocity will continue in that state unless acted on by a <u>net external force</u>

Newton's Laws

- Newton's Second Law- the Force Law

The acceleration an object experiences is directly proportional to the force applied and inversely proportional to the object's mass

$$F=ma$$

Newton's Laws

- Newton's Third Law-Action/Reaction Law

  For every action (force) there is an equal and opposite reaction (force)

Newton's Law of Gravitation

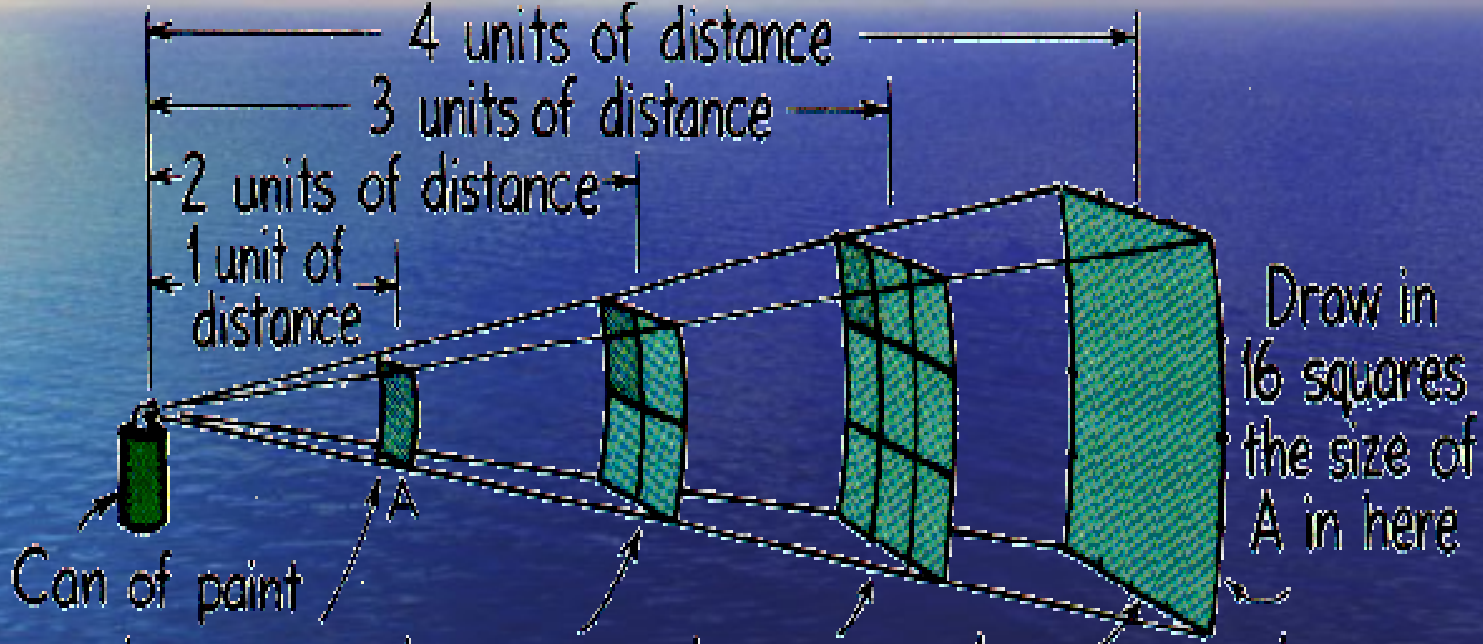
- Kepler's 2nd law, force had to be a "central force"
- Kept planets from flying off into space
- Explains changes in speed
- Force got weaker as planets got more distant
- Mass dependent

Newton's Law of Gravitation

- An inverse-square law (think spray paint)

$$F = G\frac{m_1 m_2}{R^2}$$

Inverse Square Law



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Long Arm of Gravity

- Confirms Kepler's Laws
- Explains tides
- Interactions on a cosmic scale
- Satellites
- Binary Stars

We can reduce its effect but…

We never get away from Gravity!

Centripetal Force

- Any "center seeking" force
- Everyday experience while driving
- Gravity is the centripetal force of objects in orbit
- Causes a centripetal acceleration

Escape Velocity

- Newton’s Mountain illustrates this
- Newton's Mountain animation
- Orbits of satellites depend only on object being orbited
  - Mass
  - Radius
- These determine the gravitational force
- The properties of the satellite do not matter!

Summary

- Kepler put our feet on the road to Modern Astronomy
- Galileo confirmed Kepler's heliocentric cosmos by observation
- Newton mathematically proved Kepler's Laws and described the fundamental Laws of Physics