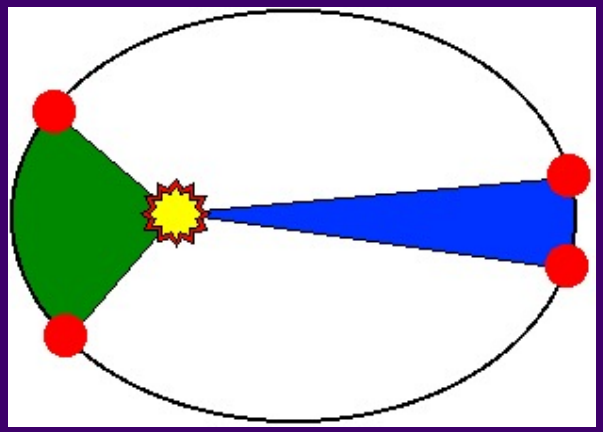
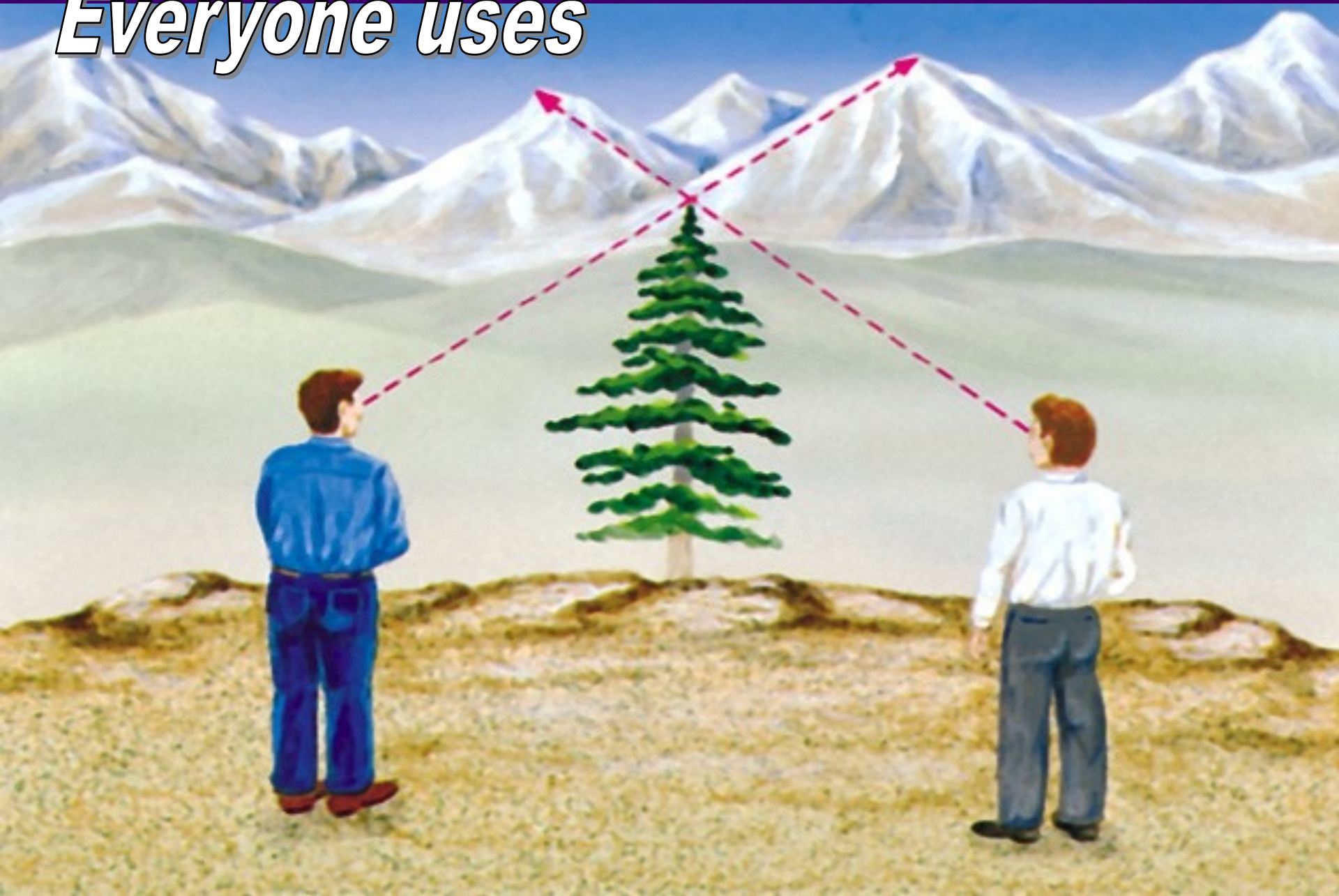
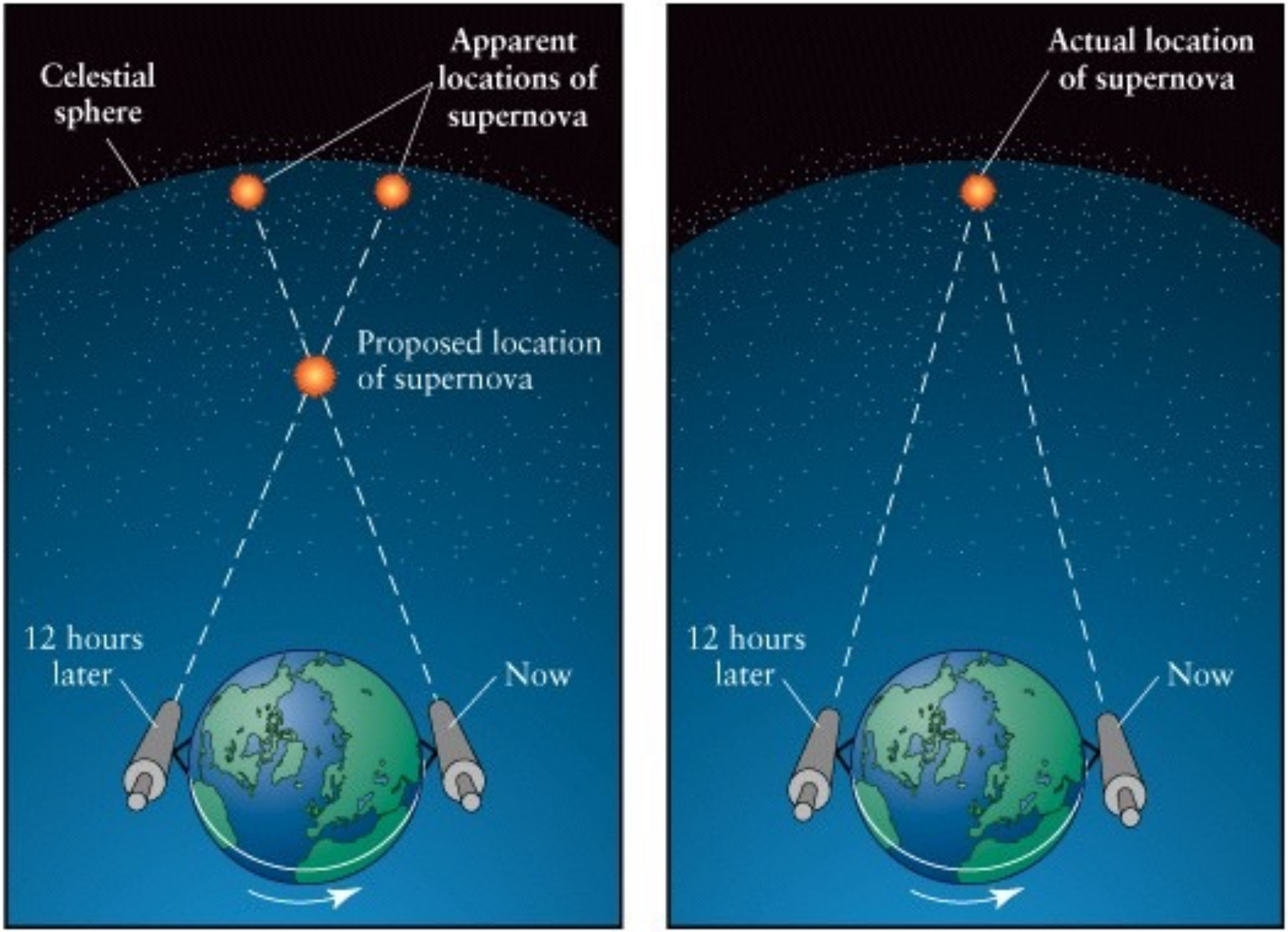


Kepler's Laws

~~Scientists~~ use parallax to measure distances.

Everyone uses




Celestial sphere
Apparent locations of supernova
Proposed location of supernova
12 hours later
Now
a
Actual location of supernova
12 hours later
Now
b

Tycho Brahe measured distances using parallax that disproved ancient ideas about the heavens

- A supernova in 1572 was shown to exist in the distant heavens; this troubled scholars who previously thought the heavens were unchanging.
- He showed that comets were objects that occurred in the region of the planets, not in Earth's atmosphere.

Galileo Galilei (1564-1642)

- First man to build and point a telescope at the sky
- wanted to connect physics on earth with the heavens
- *Dialogue Concerning the Two Chief World Systems* [written in Italian]

This book got him in trouble with the Church!

Hans Lipperhey was a spectacle maker in Middleburg (The Netherlands) who applied for a patent from the States General of the Netherlands on 25 September 1608. The petition states "a certain device by means of which all things at a very great distance can be seen as if they were nearby, by looking through glasses which he claims to be a new invention."

The States General eventually denied the patent because it was felt that the device could not be kept a secret, Lipperhey made several binocular telescopes for the States General and was paid handsomely for his services.

Thomas Harriot (1560-1621)

He was employed by Sir Walter Ralegh and in 1585 went with the expedition to Virginia organized by Ralegh as cartographer and one versed in the theory of navigation. Harriot returned in 1586 and wrote an account of Virginia and its natives, *A Briefe and True Report of the New Found Land of Virginia* , published in 1588. In the meantime, Harriot had joined Ralegh in Ireland, which the English were colonizing at that time. Ralegh granted Harriot a former abbey, where Harriot lived for a few years.

In 1598 he left Ralegh and entered the service of William Percy, the 9th Earl of Northumberland, who gave him a pension and living quarters (and later a separate house – where he lived until he died). Harriot was briefly imprisoned along with Northumberland as a result of the Gunpowder Plot.

Except for A Brief and True Report, Harriot published no books.

At his death he left a large number of manuscripts on various scientific subjects, and over the past three centuries these have slowly come into the mainstream of historical research.

Harriot studied optics (about which he corresponded with Johannes Kepler) and had discovered what is now known as Snell's Law of refraction before Snell did, he made important contributions to algebra, and, from 1609 to 1613, he made numerous telescopic observations. His telescopic drawing of the Moon of early August 1609 is the first on record and preceded Galileo's study of the Moon by several months.

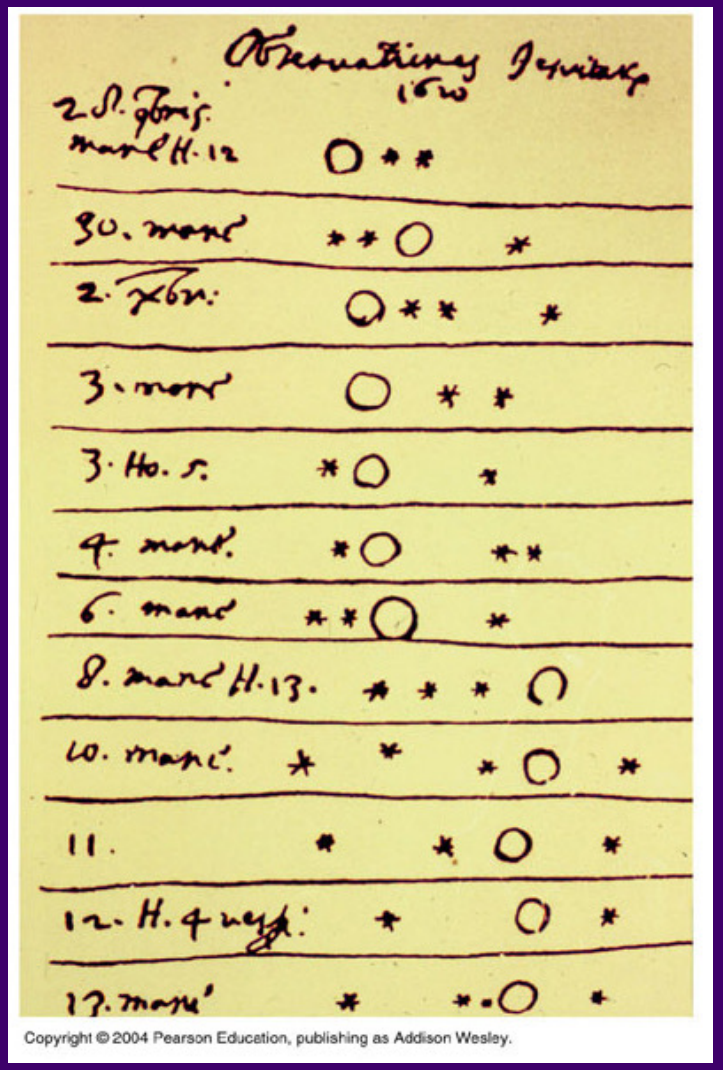
Harriot's telescopic observation of sunspots of December 1610 is also the first on record. But although Harriot shared his observations with a group of correspondents in England, he did not publish them.

Galileo's Observations

- Galileo saw shadows cast by the mountains on the Moon.
- He observed craters.
- The Moon had a landscape; it was a "place", not a perfect heavenly

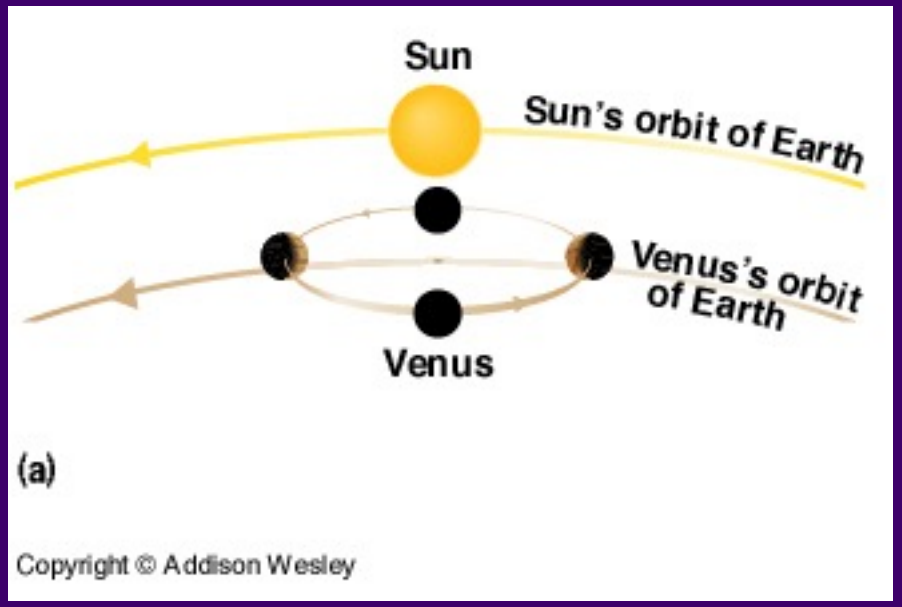
Galileo's Observations

- Galileo discovered that Jupiter had four moons of its own.
- Jupiter was the center of its own system.
- Heavenly bodies existed which did not orbit the earth.

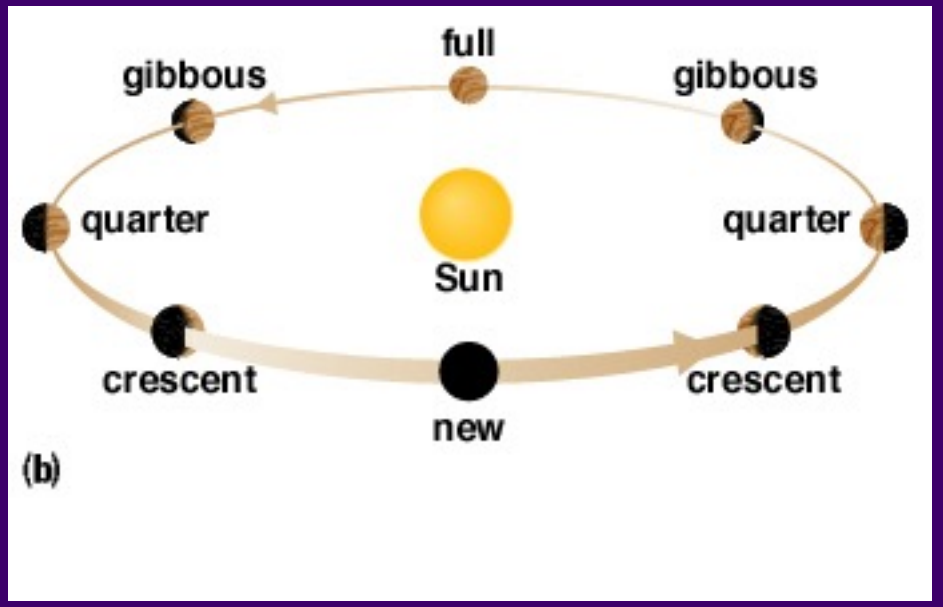


Galileo's observation of the phases of Venus was the final evidence which buried the geocentric model.

GEOCENTRIC



HELIOCENTRIC



No gibbous or full phases!

All phases are seen!

Galileo observed **all** phases!

The Scientific Method

1 Question

2 Hypothesis

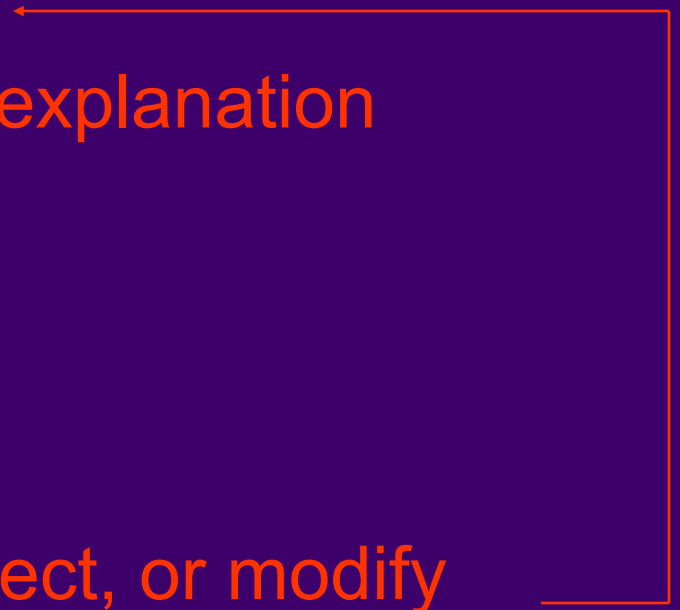
– a tentative explanation

3 Prediction

4 Test

5 Result

– confirm, reject, or modify



should be the same no matter who conducts the test

Hallmarks of Good Science

- Science seeks explanations for *observed* phenomena that rely solely on natural causes.
- Science progresses through the creation and testing of models of nature that explain the observations as simply as possible.
  - ! Occam's Razor
- A scientific model must make testable predictions that could force us to revise or abandon the model.

Theory-- a model which survives repeated testing

Bad Scientific Practice

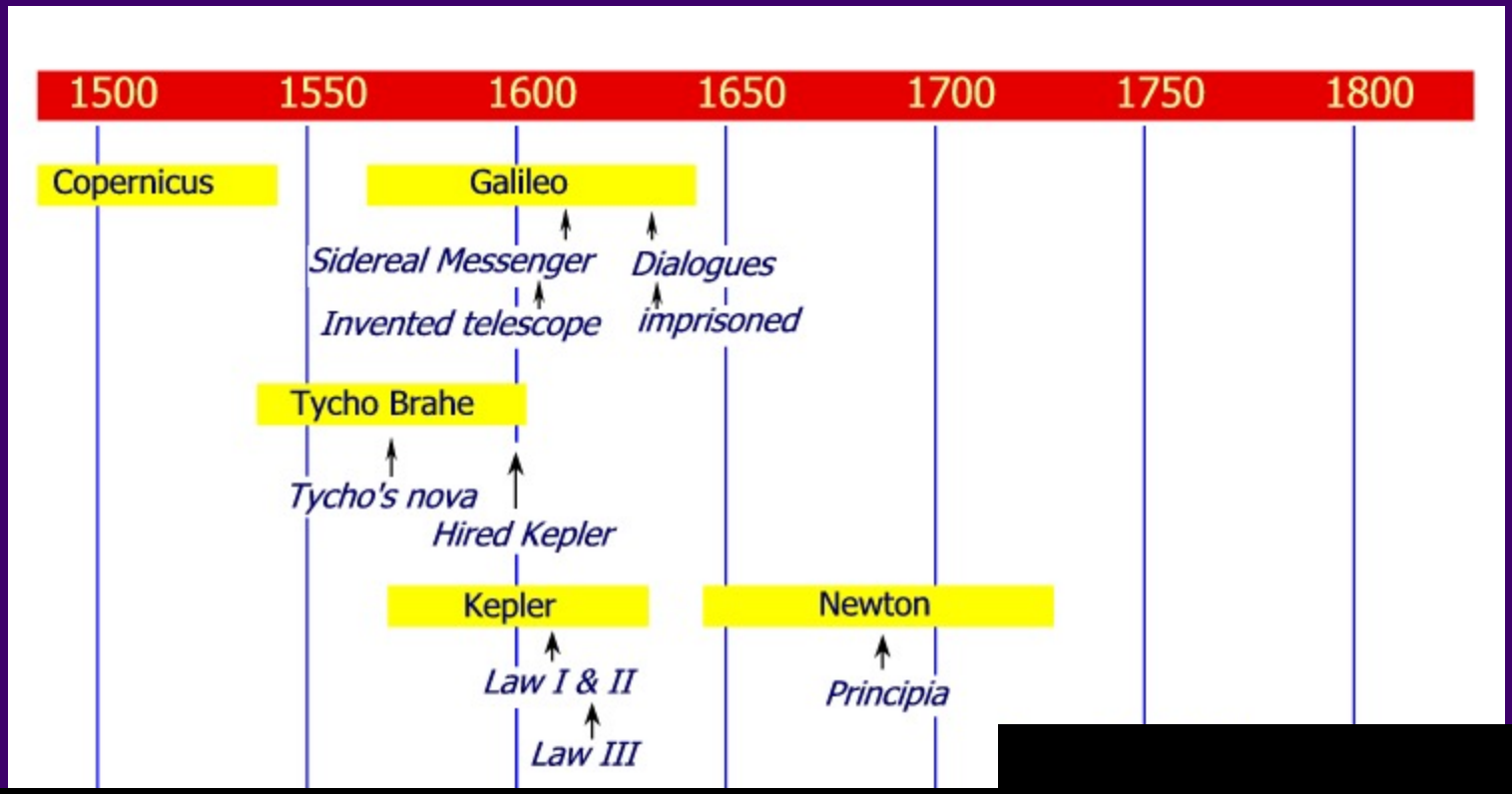
- **pseudoscience** – masquerades as science, but does not follow the scientific rules of evidence
- **nonscience** – establishes "truths" through belief

Astrology

- claims to study how the positions of the Sun, Moon, & planets among the stars influence human behavior
- was the driving force which advanced ancient astronomy
- Kepler & Galileo were the last astronomers to cast horoscopes… since then astronomy grew apart from astrology into a modern science
- modern scientific tests of astrology fail …it is a *pseudoscience*

A scientific theory is a collection of ideas that seem to explain the phenomenon under study in a way that is consistent with observations and experiments.

Important years for astronomy



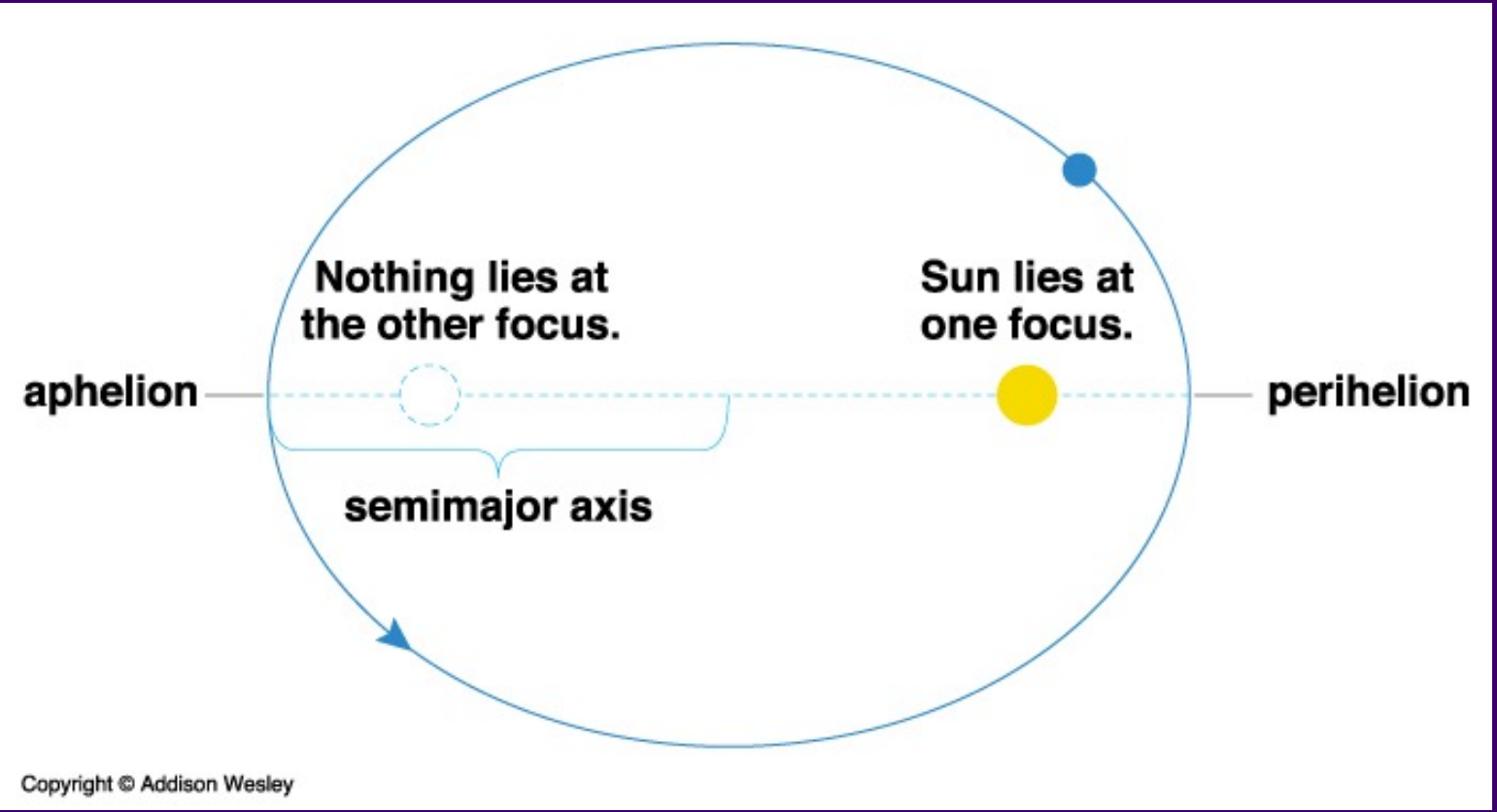
Johannes Kepler (1571-1630)

- Greatest theorist of his day
- a mystic
- there were no heavenly spheres
- *forces* made the planets move

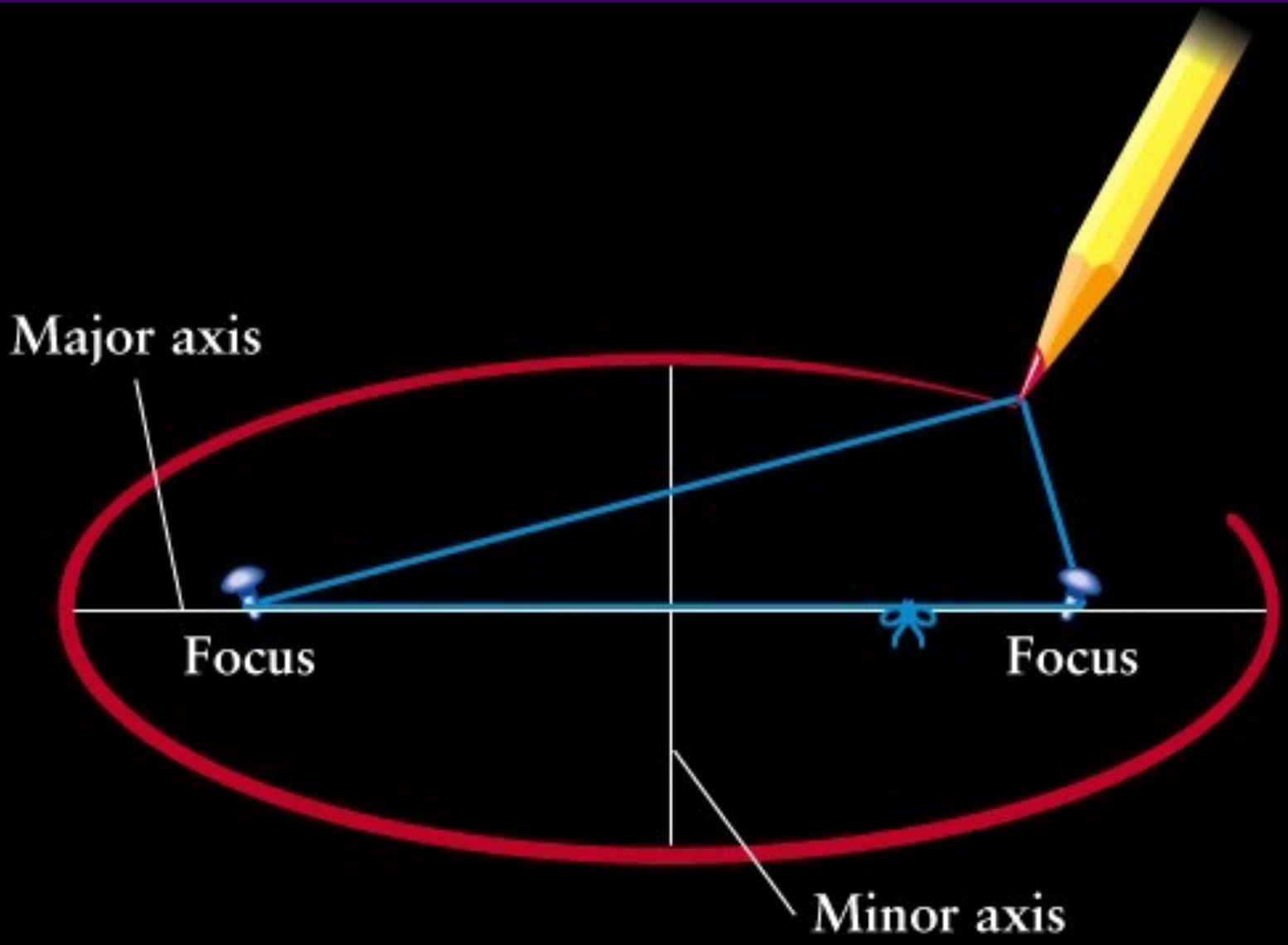
Mathematician ***Johannes Kepler*** created laws of planetary motion that describe the orbital shapes, changing speeds, and the lengths of planetary years

Kepler's Laws

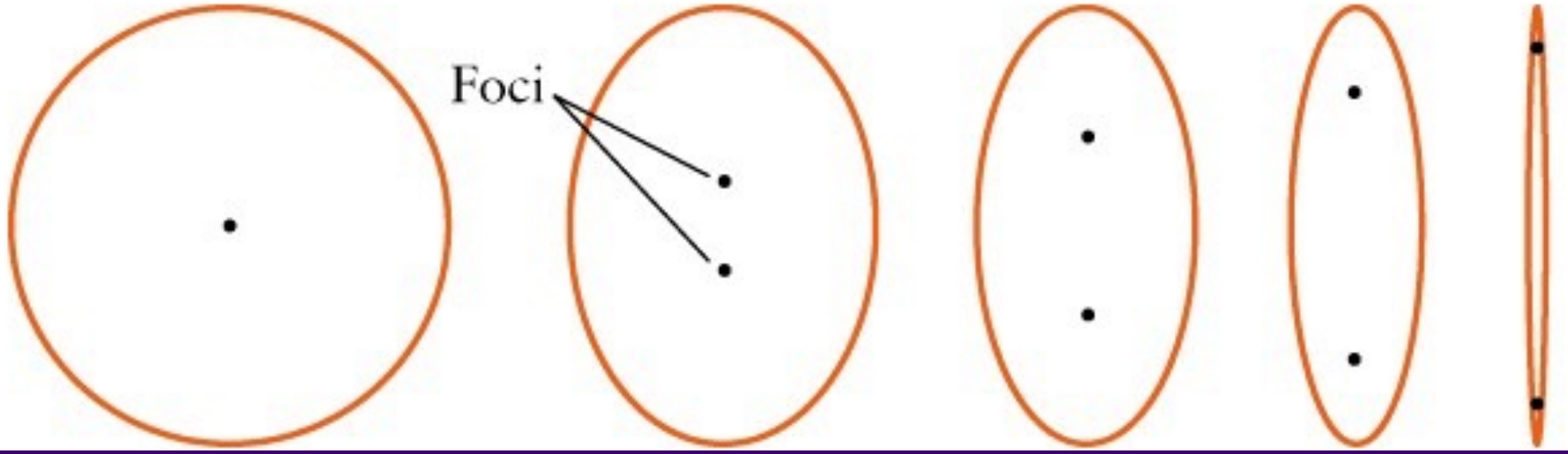
1 **Each planet's orbit around the Sun is an ellipse, with the Sun at one focus.**



Kepler's First Law: The orbit of a planet about the Sun is an ellipse with the Sun at one focus.

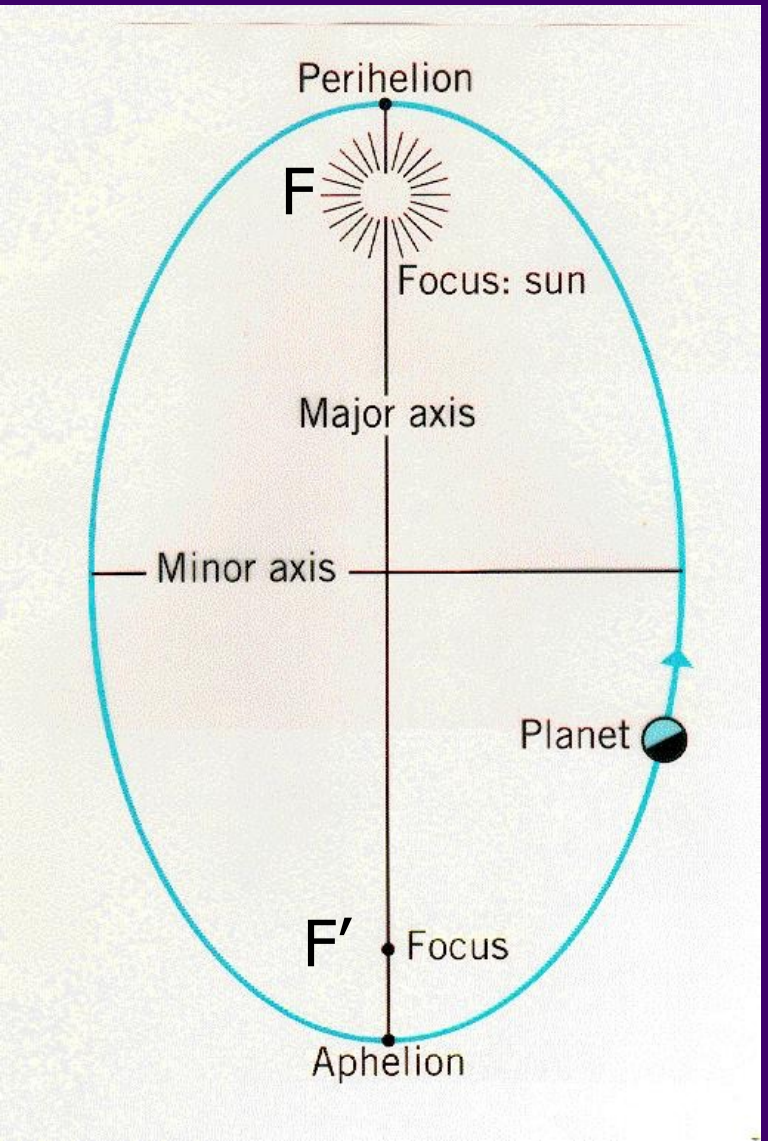


The distance between the two foci impact the eccentricity of the ellipse's shape.

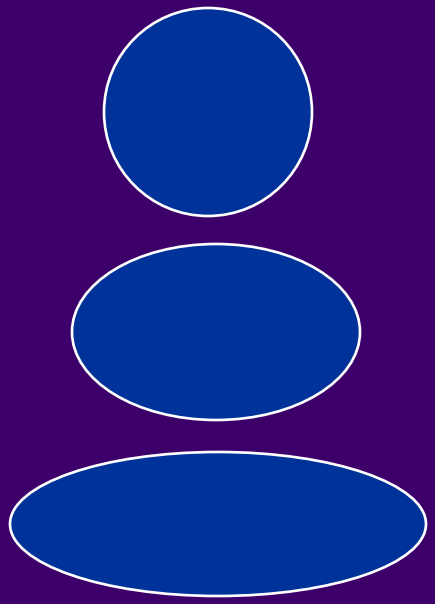


Eccentricity, e

- how squashed or out of round the ellipse is
- a number ranging from 0 for a circle to 1 for a straight line



(e = FF′/2a)

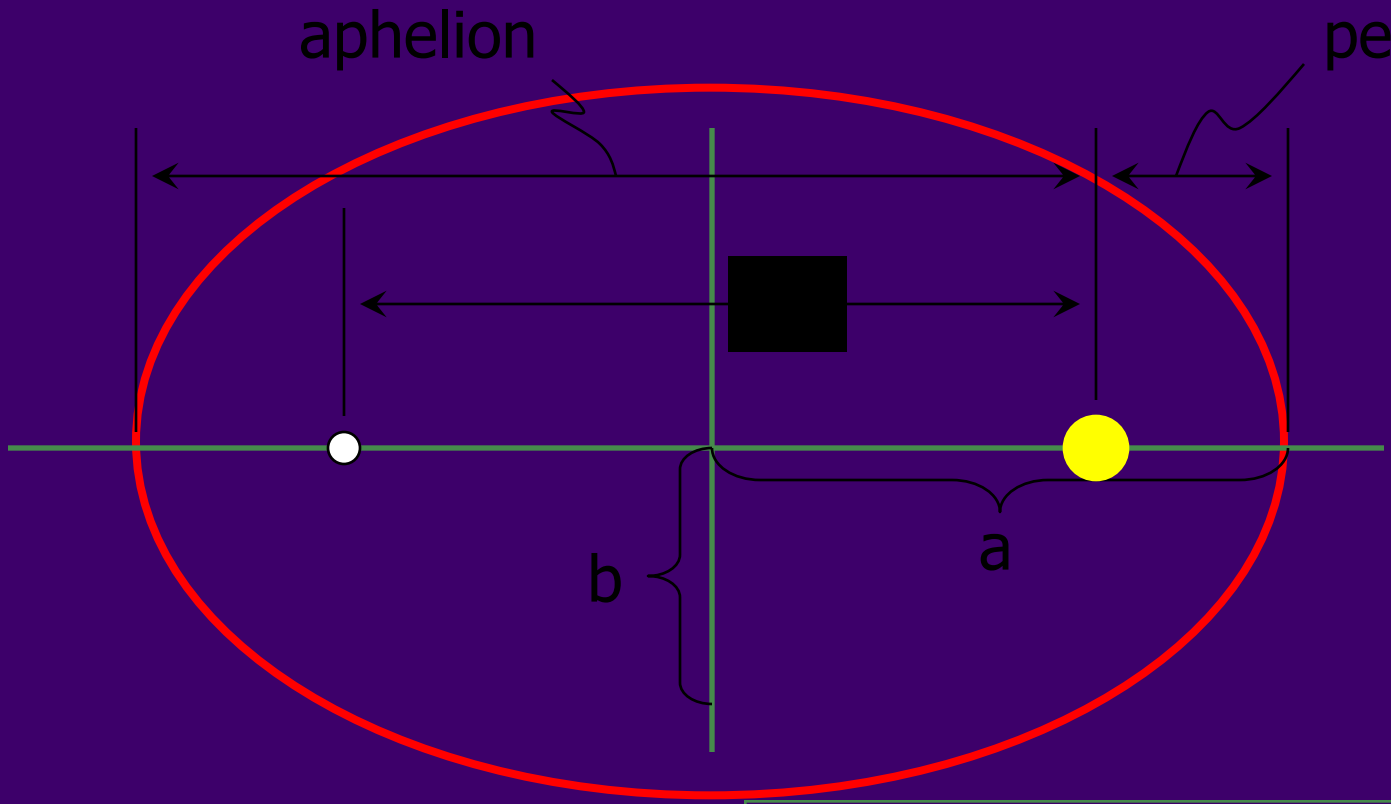


e = 0.0

e = 0.4

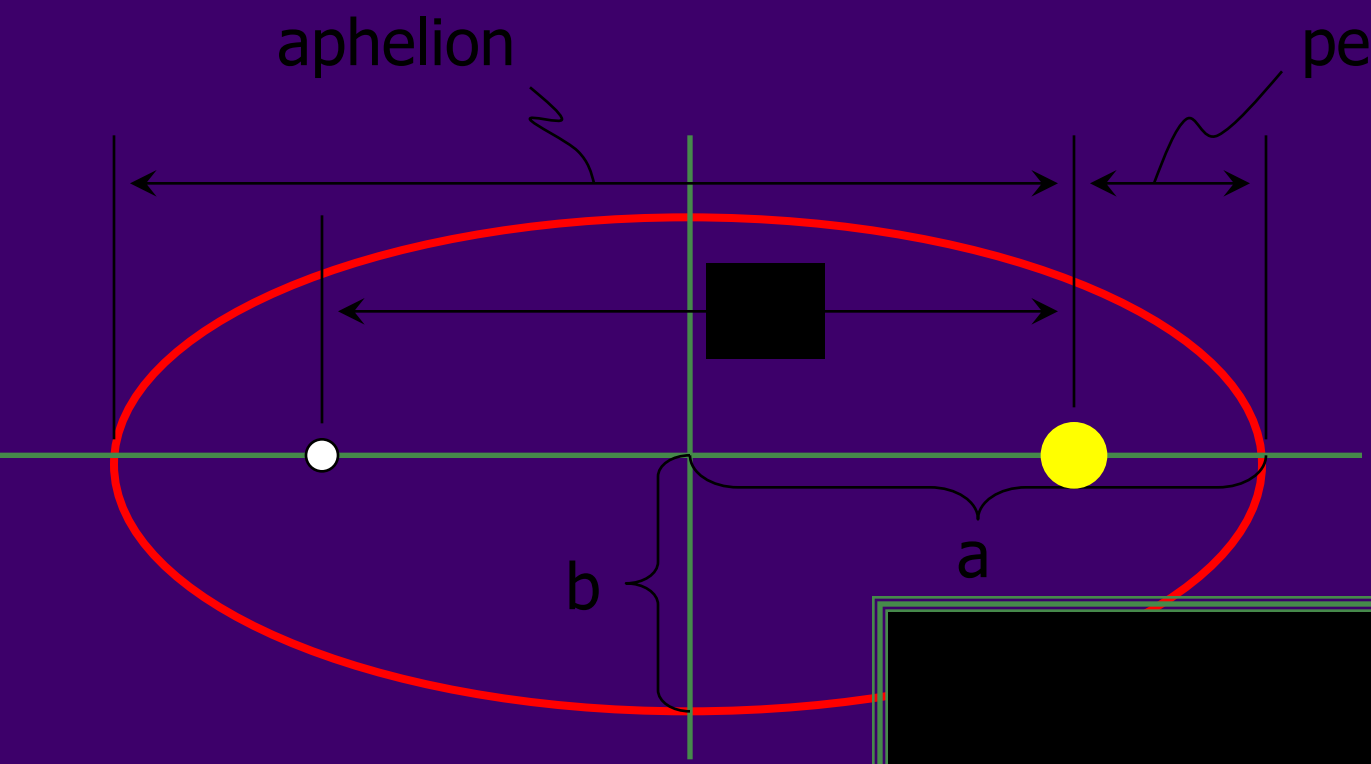
e = 0.7

e = 1.0


aphelion
perihelion
b
a

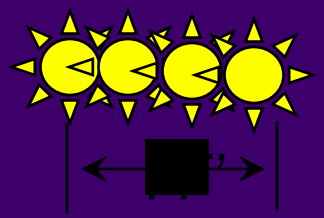
FIRST LAW

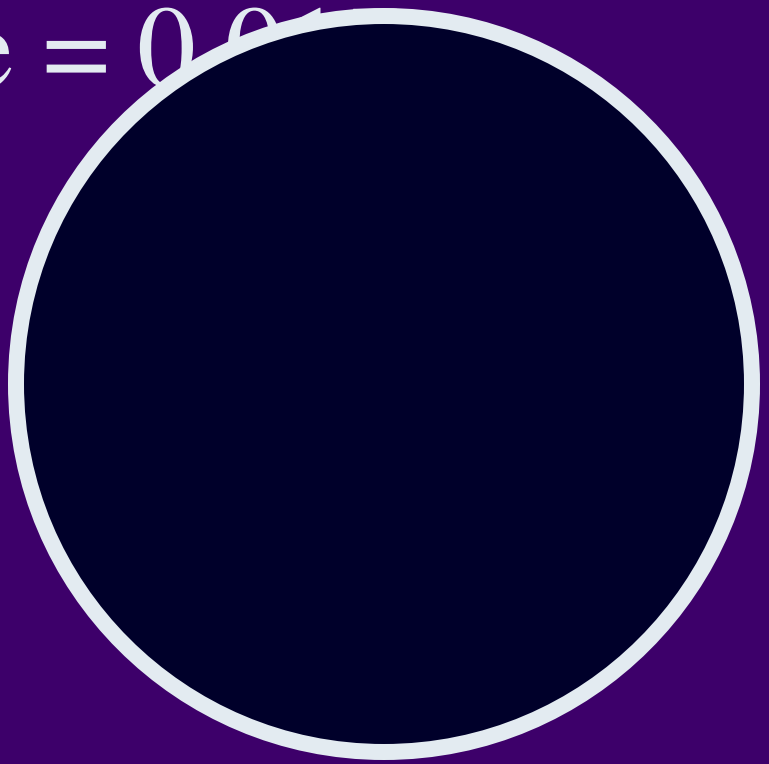
- **The planets move precisely in elliptical paths around the Sun; with the Sun at one focus.**



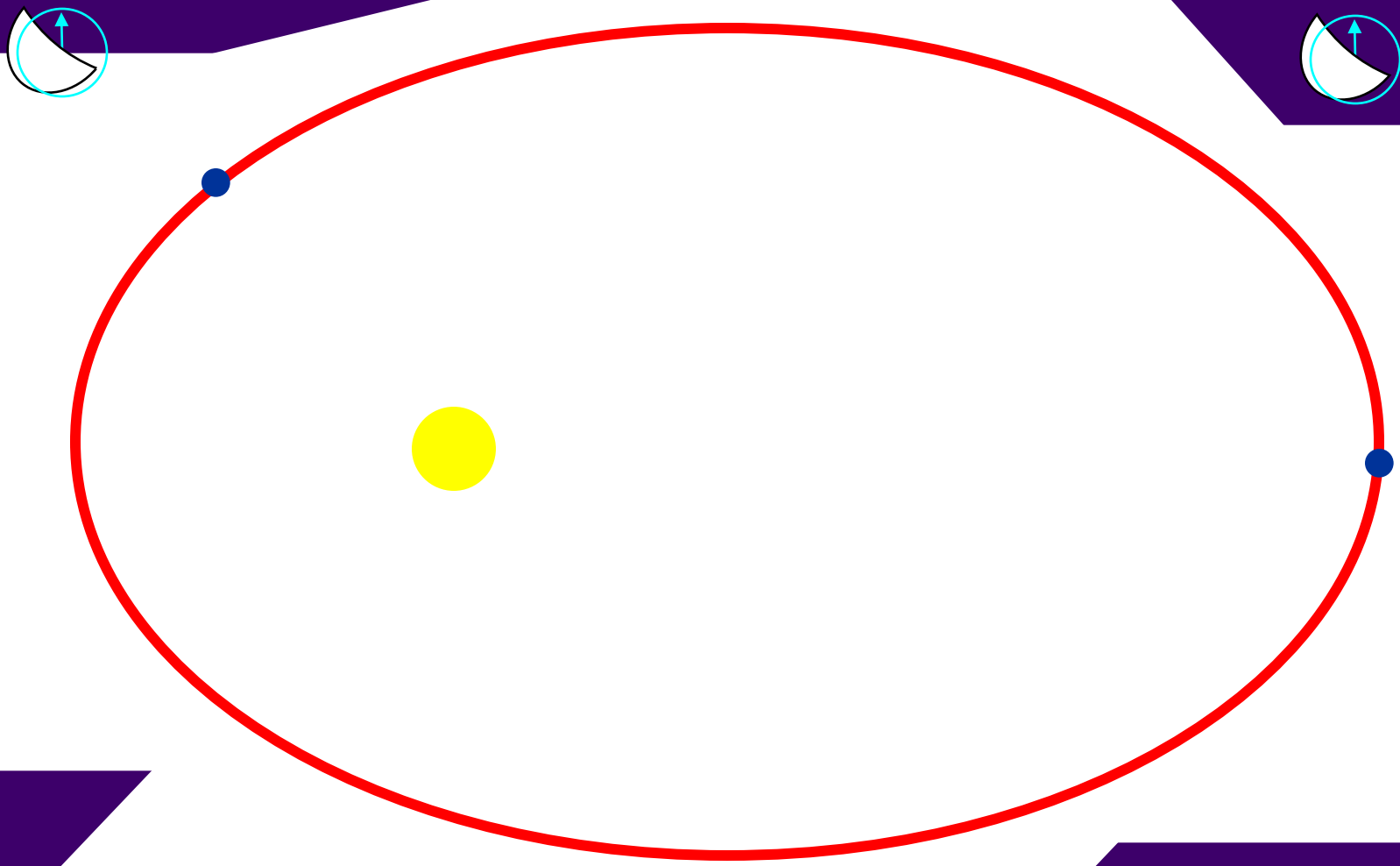
What is the shape of Earth's orbit around the Sun?

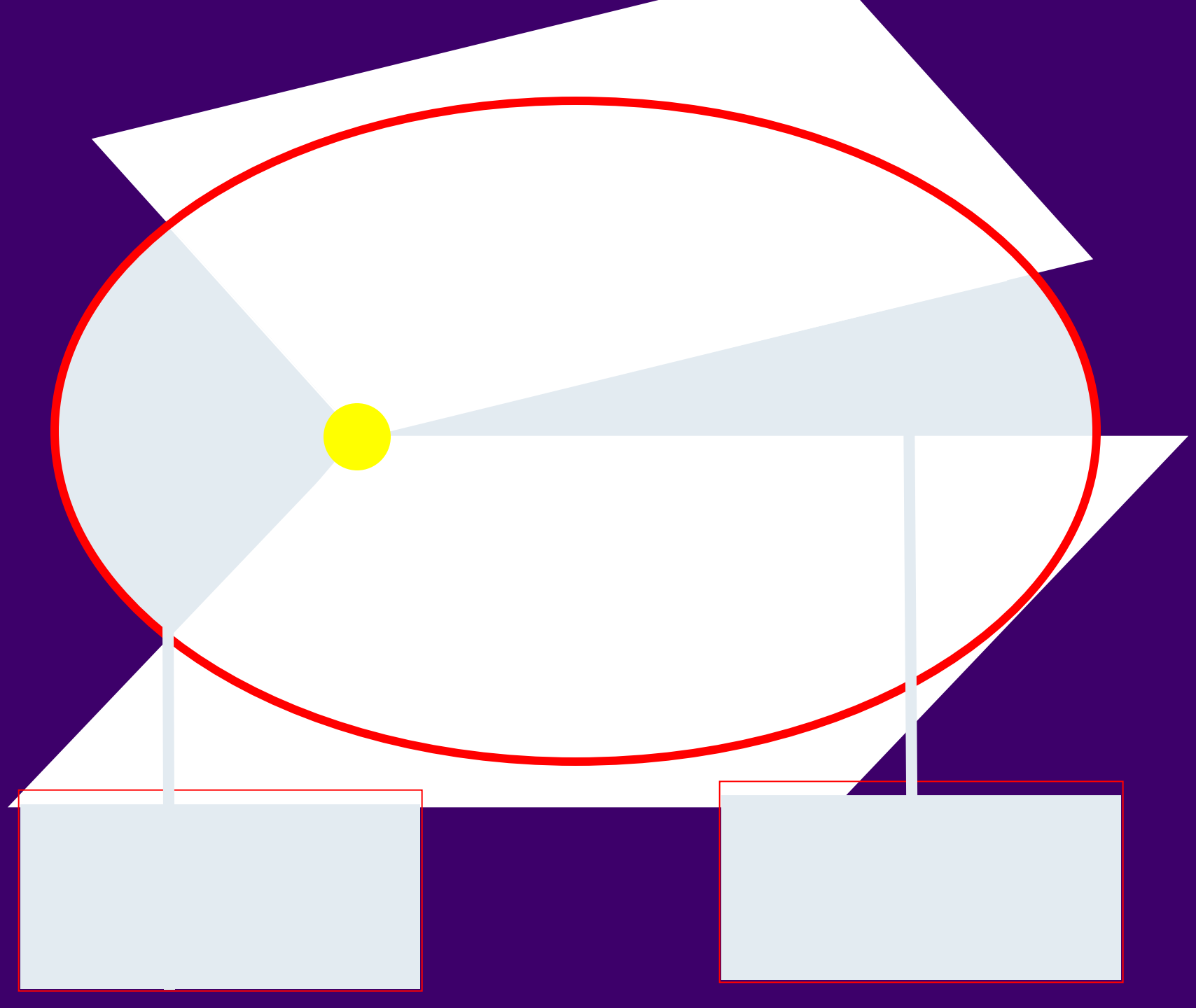
Earth, e = 0.0





<u>Kepler's Second Law</u>: A line joining a planet and the Sun sweeps out equal areas in equal intervals of time.





SECOND LAW

- A line drawn from the planet to the Sun sweeps out equal areas in equal times
  - orbital speed is not constant
  - planets move faster when near the Sun (perihelion)
  - planets move slower when they are far from the Sun (aphelion)

Kepler's Third Law: The square of a planet's sidereal period is proportional to the cube of the length of its orbit's semimajor axis ($p^2=a^3$).

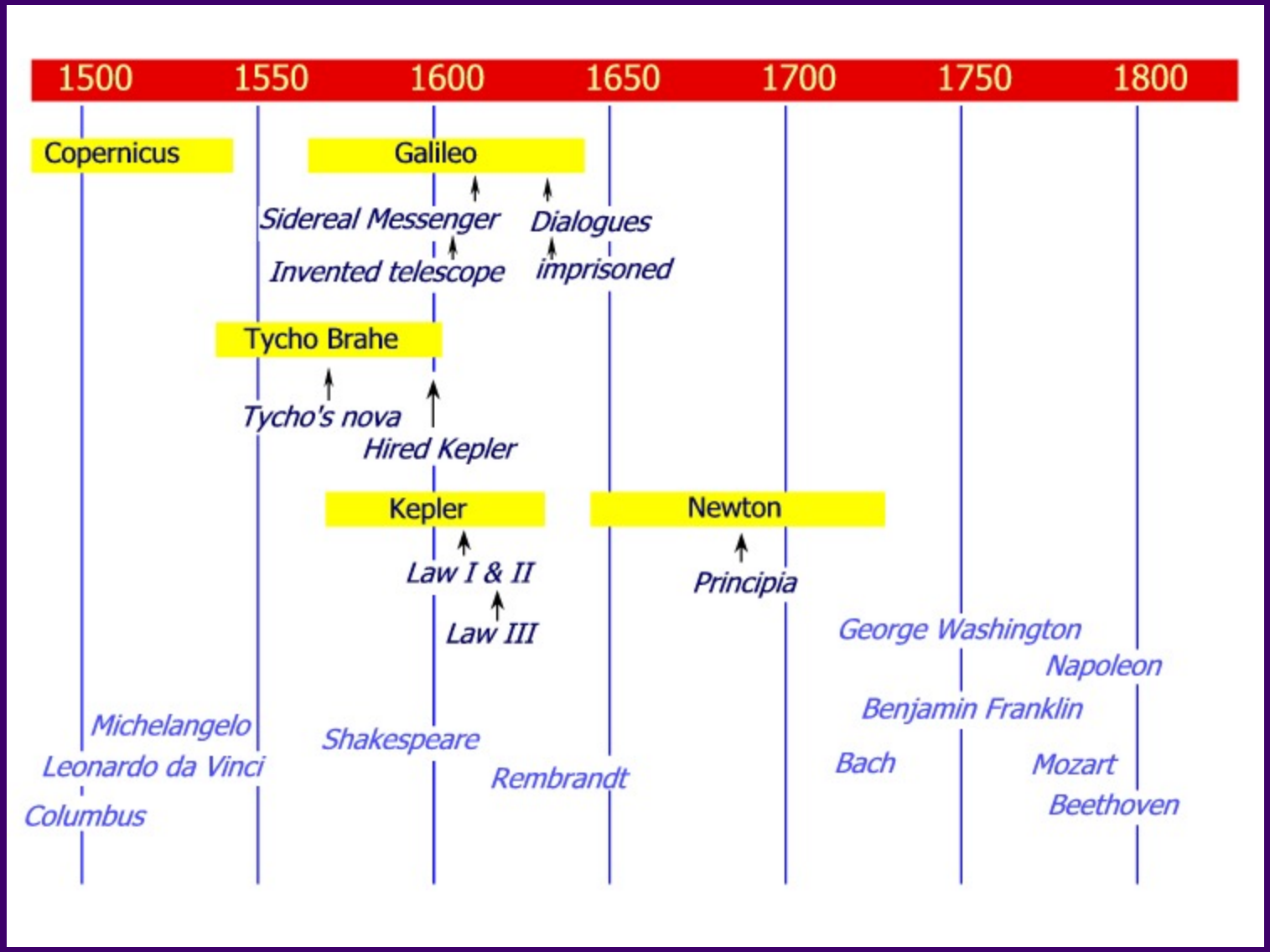
	Sidereal period P (yr)	Semimajor axis a (AU)	P^2	=	a^3
Mercury	0.24	0.390	.06		0.06
Venus	0.61	0.72	0.37		0.37
Earth	1.00	1.00	1.00		1.00
Mars	1.88	1.52	3.53		3.51
Jupiter	11.86	5.20	140.7		140.6
Saturn	29.46	9.54	867.9		868.3
Uranus	84.01	19.19	7,058		7,067
Neptune	164.79	30.06	27,160		27,160
Pluto	248.54	39.53	61,770		61,770

THIRD LAW

$$a^3_{AU} = P^2_{years}$$

- **The size of the orbit determines the period of revolution**
  - **planets that orbit near the Sun orbit faster than planets that are far from the Sun**

Important years for astronomy



A Universe of Matter and Energy

"*The eternal mystery of the world is its comprehensibility. The fact that it is comprehensible is a miracle.*"

Albert Einstein (1879 – 1955)
Physicist

What are Matter and Energy?

matter – is material such as rocks, water, air.

energy – is what makes matter move!

Energy is measured in many different units.

The metric unit of energy used by scientists is:

Joule

4,184 Joules = 1 kilocalorie

= 1 “food” calori

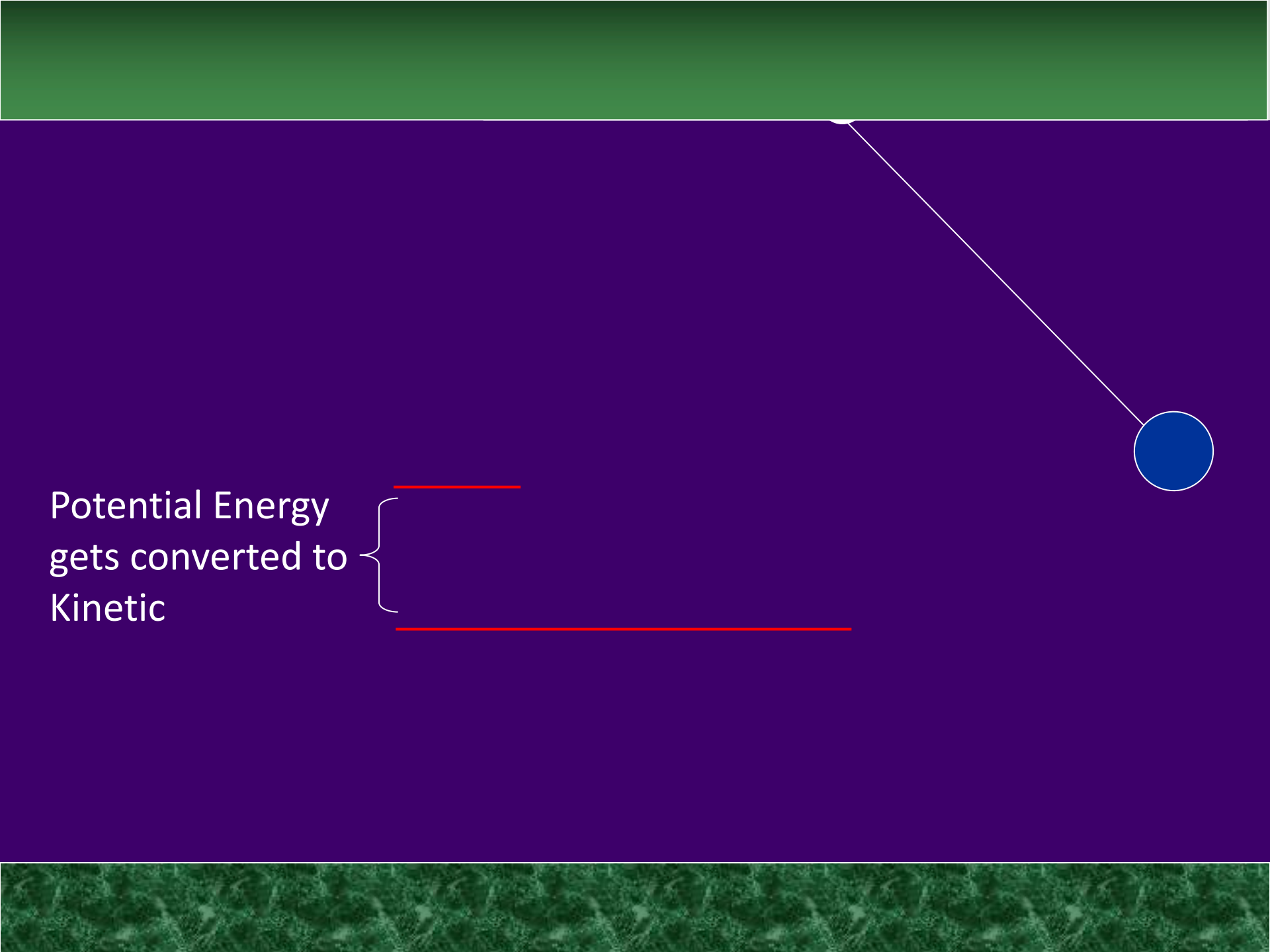
Table 4.1 Energy Comparisons

Item	Energy
Average daytime solar energy striking Earth, per m^2 per second	1.3×10^3
Energy released by metabolism of one average candy bar	1×10^6
Energy needed for 1 hour of walking (adult)	1×10^6
Kinetic energy of average car traveling at 60 mi/hr	1×10^6
Daily energy needs of average adult	1×10^7
Energy released by burning 1 liter of oil	1.2×10^6
Energy released by fission of 1 kg of uranium-235	5.6×10^{13}
Energy released by fusion of hydrogen in 1 liter of water	7×10^{13}
Energy released by 1-megaton H-bomb	5×10^{15}
Energy released by major earthquake (magnitude 8.0)	2.5×10^{16}
U.S. annual energy consumption	10^{20}
Annual energy generation from the Sun	10^{34}
Energy released by supernova (explosion of a star)	10^{44}–10^{46}

Three Basic Types of Energy

- **kinetic**
  - energy of motion
- **potential**
  - stored energy
- **radiative**
  - energy transported by light

Energy can change from one form to another.


Potential Energy
gets converted to
Kinetic

Kinetic Energy

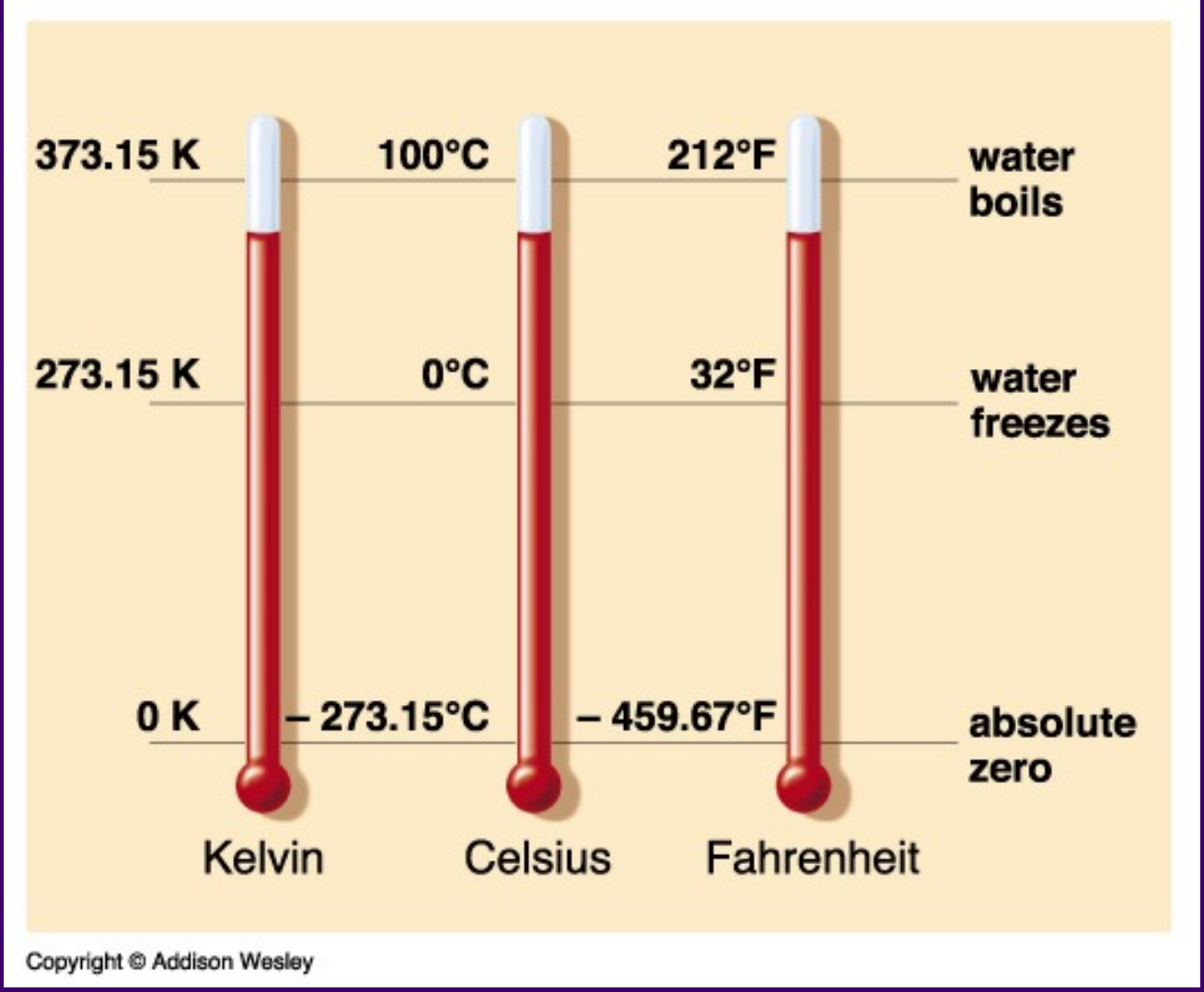
- Amount of kinetic energy of a moving object

  $= 1/2\ mv^2$

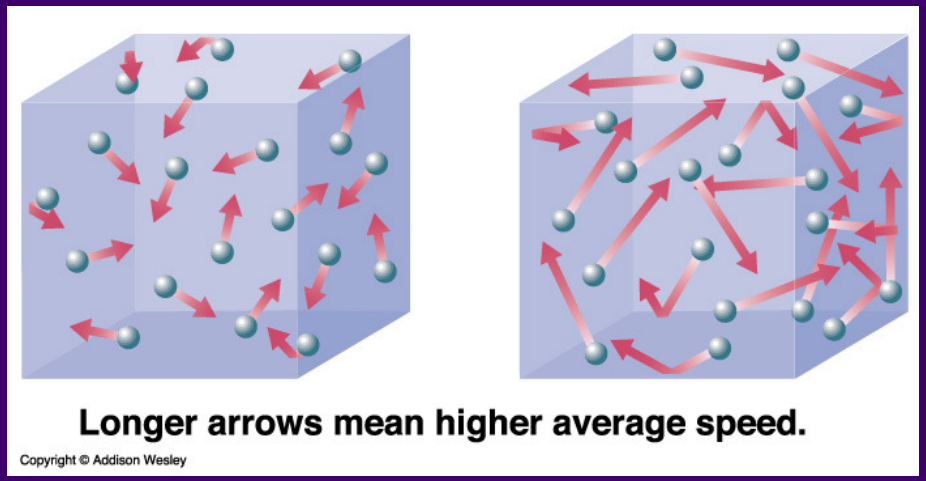
[if mass (m) is in kg & velocity (v) is in m/s, energy is in Joules]

- On the microscopic level
  - the average kinetic energy of the particles within a substance is called the **temperature**.
  - it is dominated by the velocities of the particles.

Temperature Scales



Temperature vs. Heat



- Temperature is the <u>average</u> kinetic energy.
- Heat (thermal energy) is the <u>total</u> kinetic energy.

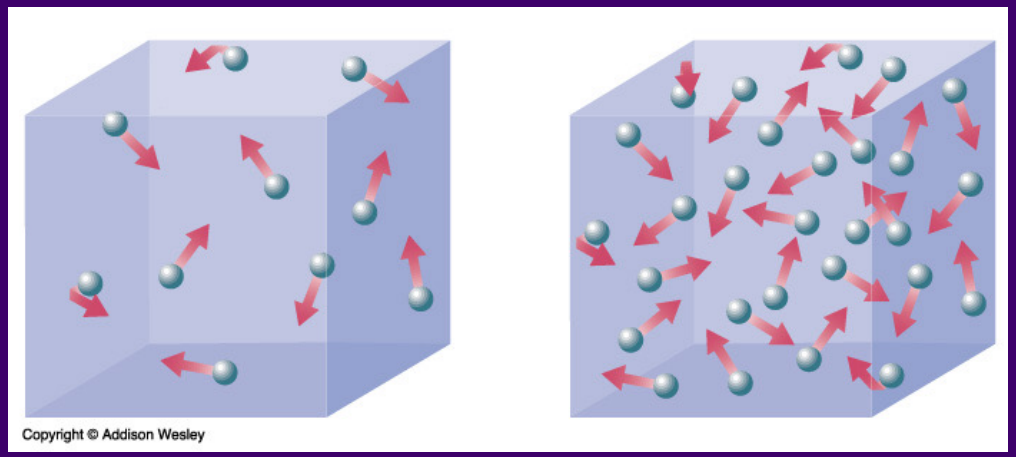
lower T

higher T

same T

less heat

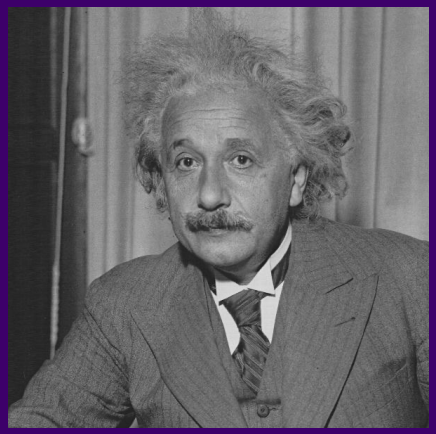
more heat



Another kind of Potential Energy

- energy is stored in matter itself
- this *mass-energy* is what would be released if an amount of mass, m, were converted into energy

$$E = mc^2$$

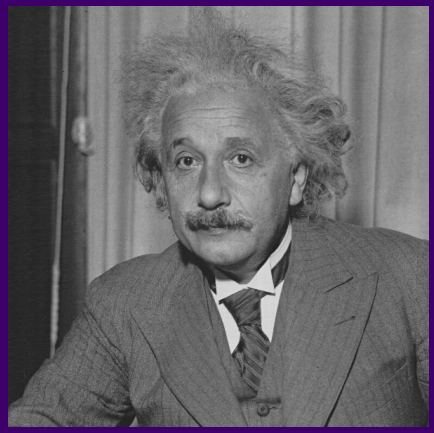


[c = 3 x 10^8 m/s is the speed of light; m is in kg, then E is in Joule

Radiative Energy

- energy is carried by light
- The amount of energy depends on the frequency (or wavelength) of the light

$$E = h\nu = hc/\lambda$$



[h=Planck's constant = 6.63×10^{-34} J s]

Conservation of Energy

- Energy can be neither created nor destroyed.
- It merely changes it form or is exchanged between objects.
- This principle (or *law*) is fundamental to science.
- The total energy content of the Universe was determined in the Big Bang and remains the same today.