## Ancient Astronomy: beginning of science

Laws of motion

### **Measures of Motion**

- Gravity causes objects with mass to move. Examples include an apple falling toward the ground and the Earth going around the Sun. So, we need to understand a bit about motion.
- Velocity or speed is the rate of change of position of an object with time. The units of velocity are:

$$Velocity = \frac{Distance}{Time},$$

or meters per second (m/sec). When you are cruising down I-25 at the speed limit, your velocity is 65 miles/hr or 29.1 m/sec. This means that in 1 hr, you travel 65 miles or in 1 second, you travel 29.1 meters.

Acceleration is the rate of change of velocity with time. The units of acceleration are:

$$Acceleration = \frac{Velocity}{Time},$$

or meters per second per second (m/sec<sup>2</sup>). If you go from zero to 65 miles/hr (29.1 m/sec) in 10 seconds, your acceleration is 2.91 m/sec<sup>2</sup>. Gravity causes objects to accelerate toward the center of mass of planets or the Sun or other stars.

## Even in ancient times people were curious to know how everything works around us and how the Universe functions







## Stonehenge (UK)





## Medieval China



Scholar contemplates the moon beyond a plum tree. Attendant carries a musical instrument. By the master painter Ma Yüan.



Birds and rabbits in snow were painted by Hsüan-tê for one of his generals. The work reflects the style of the Sung Painting Academy, a source of his inspiration. Court painters of the Ming period tended to comply with imperial taste.



Fig. 54. The sefiratic tree from Paulus Ricius.



Map of the Greek World. From N. Hetberington, Addicate Astronomy and (Tucson, Arizona: Pachart Publishing House, 1987), 42.





Artists, poets, architects, philosophers, scientists, warriors, and statesmen -- ancient greeks made a significant contribution to our human civilization.



#### Plato: 427 - 350 B.C.

- Socrates's pupil and close friend. Socrates was executed by Athens (was forced to drink a fatal cup of hemlock. Reacting to shifting moral values of his time, Plato searched for UNCHANGING standards. He turned to the world of ideas (``Platonism"). The cause of the world coming into being is the idea. The world is generated to fulfill the idea.
- Do not trust your feelings. Allegory of the Cave.
- Saving the phenomena

#### Aristotle: 384-322 B.C

- Poetics: poetry comedy and tragedy. Tragedy: six factors scenic presentation, lyrical song, diction, plot, character, thought.
- Look for the cause of things. ``Why" is the main question.
- Final cause purpose of an action.
- Motion: not just changing places, but more general as fulfillment of Potential. (Growth of a plant, growth of a society ...).
- Every motion has its INTERNAL cause and purpose.
- Logic: reductio ad absurdum.
- Earth is a sphere in the center of the Universe.
- The universe does not change: everything is on circular motion.

According to Aristotle, celestial motions are perpetual: there is no reason for those motion to happen; constant motion of celestial objects is natural

- Ptolemy: Second century A.D., Alexandria. Author of Almagest
- Pythagoras: 585 495 B.C. The theorem. NUMBER. Beginning of Math.
- Ionian Cosmology (now Turkey and Greek Islands): search for fundamental elements. Beginning of chemistry.
  - What was difficult? ``To know thyself".
  - True philosopher pursues scientific inquiry for its own sake; others demand that science pay in practical results.
  - Ended in 494 B.C. : Persian invasion.



Ptolemy



Fundamental Premises Concerning the Earth and the Cosmos in Greek's cosmology

- The cosmos is a sphere
- The Earth is a sphere
- The Earth is at the middle of the cosmos
- The Earth is motionless



# Greeks reasoning why Earth is at the center of the Universe

would have a triangular shape.



Greeks reasoning why Earth is a sphere: the shape of the Earth shadow during lunar eclipses is round. Thus, the shape of the Earth is round too. **Parallax** is a displacement or difference in the apparent position of an object viewed along two different lines of sight, and is measured by the angle or semi-angle of inclination between those two lines. The term is derived from the Greek  $\pi\alpha\rho\dot{\alpha}\lambda\alpha\xi$  (*parallaxis*), meaning "alteration". Nearby objects have a larger parallax than more distant objects when observed from different positions, so parallax can be used to determine distances.

<u>Astronomers</u> use the principle of parallax to measure distances to celestial objects including to the <u>Moon</u>, the <u>Sun</u>, and to <u>stars</u> beyond the <u>Solar System</u>. (Wikipedia)



Earth's motion around Sun

Parallax and the ancient greeks' argument why the Earth is in the middle of cosmos. They tried to measure parallaxes of stars and found that they are zero. According to their logic, this can only happen of the Earth is at the center and stars are on a sphere around us.

We now know that parallaxes of stars are very small because of very large distances to stars. Ancient greeks could not measure those parallaxes.





## Motion of stars and planets on the sky

According to Aristotle, celestial motions are perpetual: there is no reason for those motion to happen; constant motion of celestial objects is natural



This is how the stellar motions are observed from the ground during the night. The stars rise in the east; go up in the sky and go down in the west. The night sky rotates around the polar axis.



### Aristotle/Ptolemy model of the Universe

Geo-centric model:

Earth is at the center Moon Mercury Venus Sun Mars Jupiter Saturn Sphere of stars

Terrestrial world is below the sphere of the Moon. Only here changes may happen. Only here motion must have a cause.

Celestial world: perpetual motion, which does not need to have a reason. Everything moves, but nothing happens



## Retrograde (backward) motion of some planets (especially Mars) made a problem for greek astronomers



According to Greeks, the retrograde motion is produced by a combination of two motions: Deferent and Epicycle



One must distinguish observational facts and explanations of the facts. The retrograde motion of planets on the sky is a fact. However, Greeks' explanation of the fact was wrong. It will take another 1000 years before astronomers find the correct explanation. Circular motions would finally succumb to the precision of Tycho Brahe's observations. But meanwhile, after the collapse of the *pax romana*, astronomers of civilizations unborn in Ptolemy's day would struggle to master the intricacies of the *Almagest*, against a background of philosophical disquiet at the devices Ptolemy had found it necessary to employ. the radii of the epicycles of Mars, Jupiter, and Saturn are parallel to the line from the Earth to the Sun. Following Copernicus, we realize that this reflects the fact that we Earth-dwellers observe the planets from a platform in orbit about the Sun.

