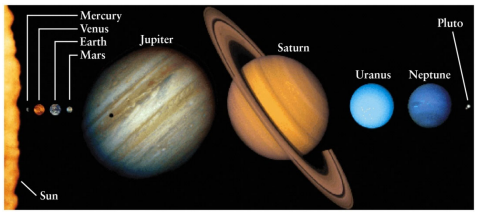
Distances and Angles



Distances

Many people find the Heavens to be incomprehensible because of the great range in sizes and distances. Even astronomers have a difficult time coming to grips with quantities like the distance from the Earth to the Sun when it is expressed as 93,000,000 miles (150,000,000 km). The way to comprehend sizes and distances is to use meaningful measurement units.

Distances

Here is an example. The distance from my house in Atlanta to my parents' house north of Nashville is about **17,740,000 inches** – the number is correct but it is completely meaningless because we do not have a real-world feel for numbers that large.

I could state that the distance is about **280 miles**. The number 280 is just on the verge of our ability to comprehend its magnitude.

An even better way of relating the distance between the houses is to say it takes me **4 hours** to drive from one to the other. In expressing it that way, two things have happened: (1) the quantity of 4 hours is easily comprehensible and (2) the measurement units were switched from distance to time. Hopefully by this change in measurement units, you get a better feel for the distance between these two homes.

What is a Good Distance Unit?

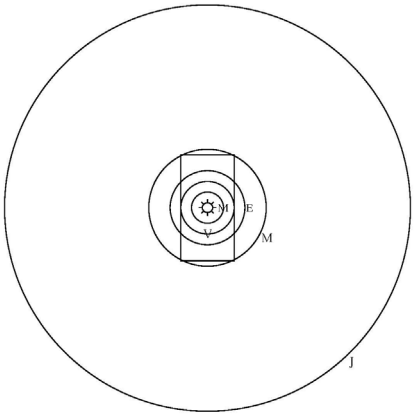
Astronomers recognized the need for better distance measurement units in the Solar System, Galaxy, and the Universe, since the mile is just too short to be useful. The unit for the **Solar System** is based on the average distance from the Earth to the Sun.

Instead of using 93 million miles (150 million km), this distance is defined as equal to 1 and is called the **Astronomical Unit** (AU).

$$1 \text{ AU} = 1.5 \times 10^8 \text{ km}$$

With this relative scale, we would say that the distance from the Sun to Mercury is 0.4 AU, to Mars it is 1.6 AU, to Jupiter it is 5.2 AU, and to Pluto it is on average about 40 AU.

Scale of the Solar System

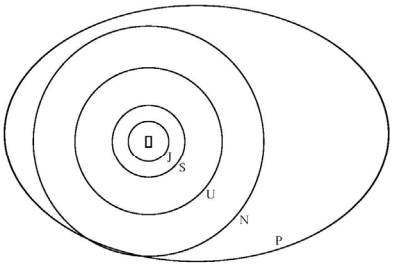


Shrink the Sun down to the size of a basketball.

Put it on the 50 yard line of the GT football field.

Note the spacing of the inner planets – all would fit on the football field.

Scale (cont.)



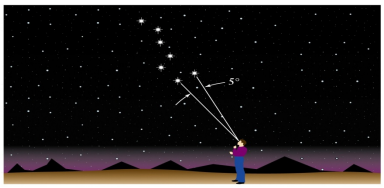
Note the spacing of the outer planets – much larger than the football field.

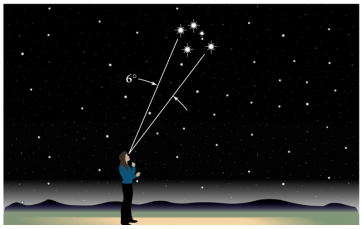
PLANET	DISTANCE		DIAMETER		MASS
	(AU)	(yd)	(E=1)	(mm)	(E=1)
Mercury	0.39	10	0.38	1	0.06
Venus	0.72	18	0.95	2	0.81
Earth	1.00	25	1.00	2	1.00
Mars	1.52	37	0.53	1	0.11
Jupiter	5.20	128	11.20	22	317.8
Saturn	9.54	235	9.41	18	94.3
Uranus	19.18	472	4.11	8	14.6
Neptune	30.06	740	3.81	7	17.2
Pluto	39.44	971	0.17	0	0.01

What About Angles on the Sky?

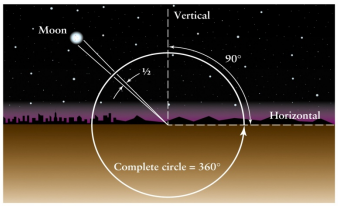
Angular Diameters

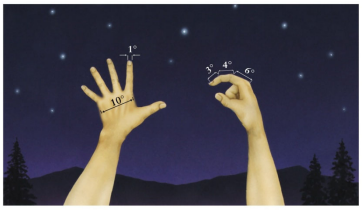
Full Moon = Sun
= 0.5°
= 30 arcmin
= 1,800 arcsec





Measuring Angles





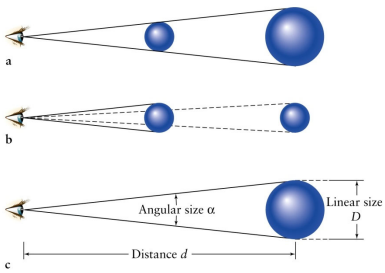
Circle

360º in Circumference

$$\frac{\alpha}{360^o} = \frac{x}{2\pi R}$$

For the Sunset project, calculate the angular size of your fist.

Angular Measurements



Skinny Triangle

$\tan \alpha = D / d$

[Diameter / distance]

$d \tan \alpha = D$

Ancient Astronomers

Questions

How much could the Ancients do without having a telescope?

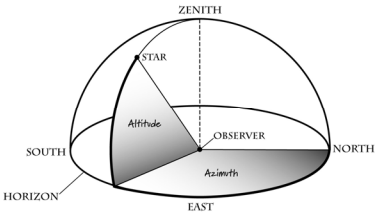
Did the Ancients distinguish between Science and Philosophy?

Observations and Theories

The Ancient Greeks and Egyptians developed theories to explain their observations. However, they maintained several postulates (e.g., circular motion), which prevented a truly impartial theory.

A. Geocentric Cosmology

1. Earth appears to be flat.
2. Celestial Sphere appears to be above the Earth.
3. Celestial Sphere moves around the Earth.
   Stars are fixed, except for meteors.
   Stars rise in East, set in the West.



Observations and Theories

B. The Sun's Motion

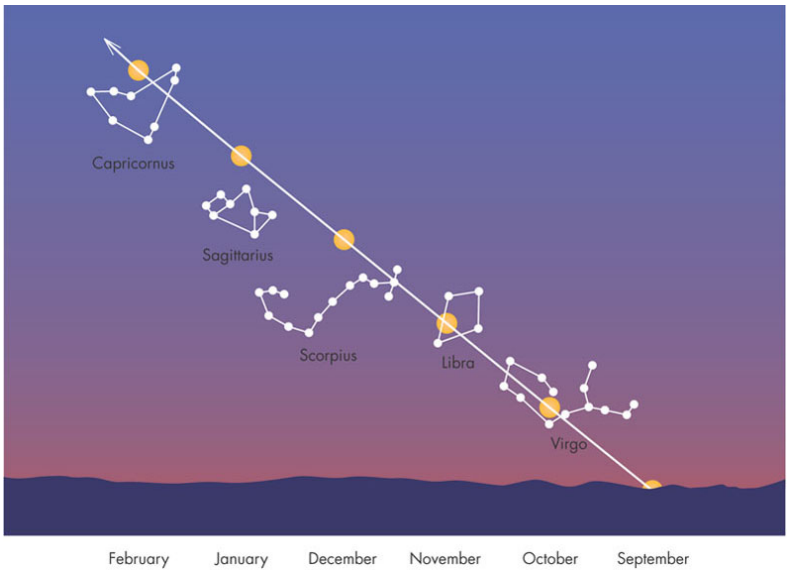
Sun travels on the ecliptic. There is a 4 minute difference per day of the Sun's position against the stars. The angle between the Earth's orbit and the Earth's rotation axis is 23.5° (obliquity).

C. Wanderers

Sun, Moon, Mercury, Venus, Mars, Jupiter, Saturn

D. Zodiac along the Ecliptic

Constellations are groups of stars. Today, there 88.



Key Individuals

Pythagoras [d. 497 BC, Italy]

Aristotle [384 - 322 BC]

Eratosthenes [276 - 195 BC, Alexandria, Egypt]

Hipparchus [160 - 127 BC, Alexandria, Egypt]

Claudius Ptolemy (or Ptolemaeus) [AD 140]

Pythagoras [d. 497 BC, Italy]

A. Pictured a series of concentric spheres, in which the 7 wanderers were carried by separate spheres from the one that carried the stars.

B. Motions gave rise to harmonic sounds, which only the most gifted could hear.

C. Heavenly bodies are spherical. Curved terminator on the Moon; therefore, all of the heavenly bodies are spherical.

Aristotle [384 - 322 BC]

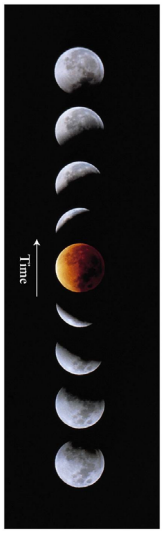
A. Shape of the Earth is a sphere.

During a lunar eclipse, the shape of the shadow seen on the Moon is always round.

Traveling North or South, one sees different positions of the stars with respect to the horizon.

B. Earth could be rotating (rejected this hypothesis).

C. Earth could be revolving around the Sun (no parallax).

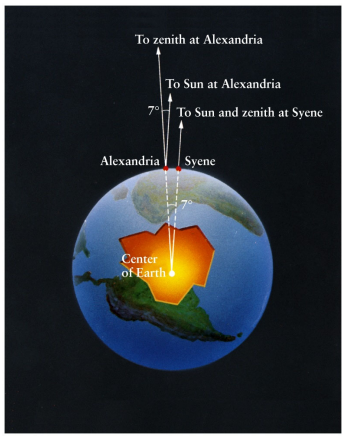


Eratosthenes [276 - 195 BC]

He noted that on the first day of summer, sunlight hit the bottom of a deep, vertical well at Syene, Egypt. On that same day in Alexandria (5000 stadia away) the angle of the sunlight in another deep well was 7°. He calculated the circumference of the earth:

360 / 7 x 5000 = 250,000 stadia.

The length of the stadia is no longer known, but some estimates put an error on his value of 1%.



Hipparchus [160 - 127 BC]

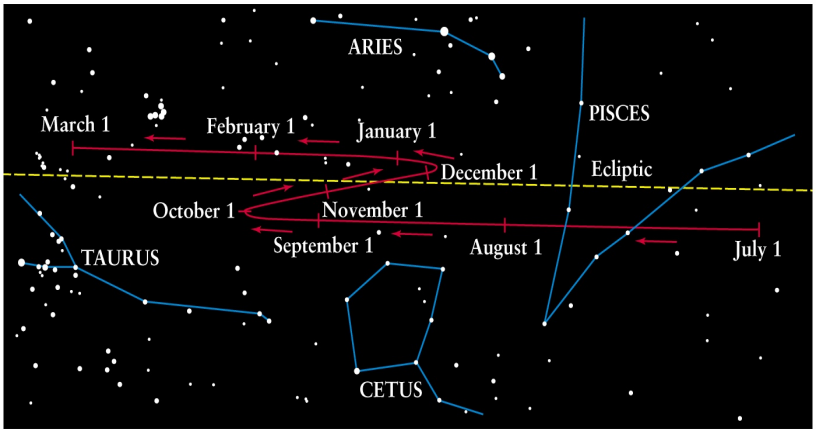
A. He cataloged 850 stars by position and by magnitude.

Claudius Ptolemy [AD 140]

A. He compiled the *Almagest* − 13 volumes on astronomy.

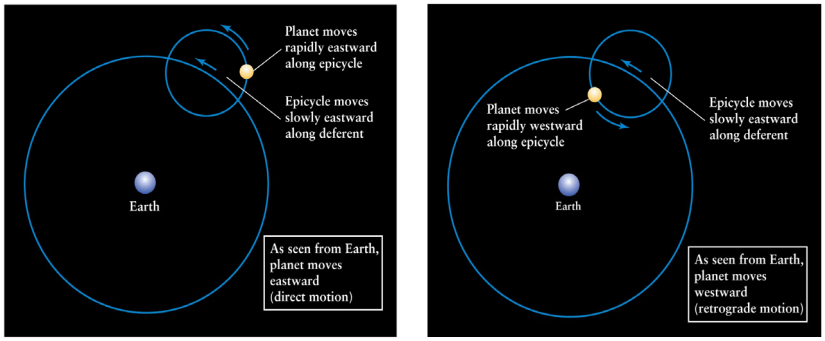
Not all of the *Almagest* deals with Ptolemy's own work, for it includes a compilation of the astronomical achievements of the past, principally those of Hipparchus. It is our main source of information about Greco-Roman astronomy.

Retrograde Motion



Apparent, but not physical, backwards motion demonstrated by all planets.

Ptolemaic Model



Geocentric Model

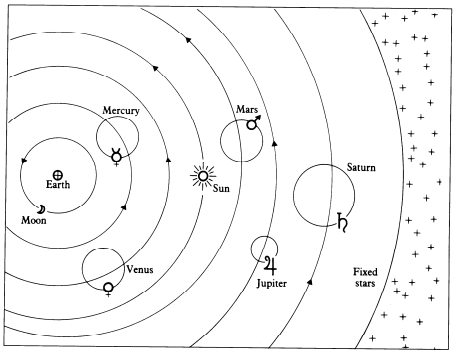


FIGURE 1.10 Earth-centered, or Ptolemaic, system, developed in antiquity to explain the apparent motions of the Sun and planets. Each object except the Earth must move in small epicycles in addition to its circular motion about the Earth.