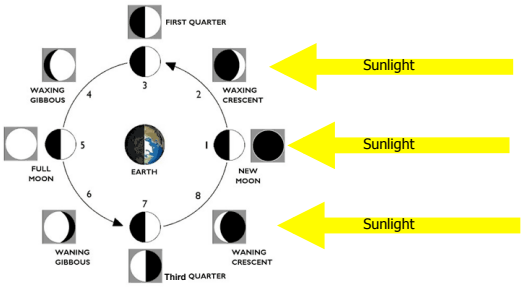
Where is the Moon in the orbit?



The full moon rises at approximately:

A. Midnight
B. Sunset
C. Sunrise
D. 9 PM
E. It rises at different times during the year

Which phase of the Moon rises at 9 AM?

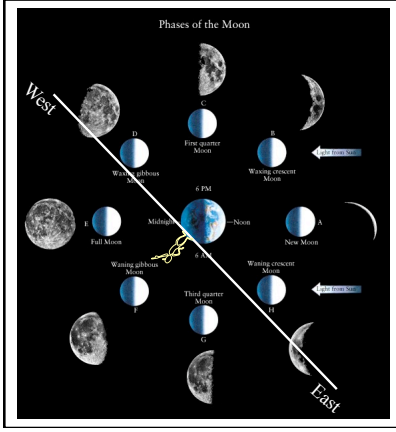
A. Waning gibbous
B. Third quarter
C. First quarter
D. Waxing crescent
E. None of the above

If the moon is in the Full phase today, how many of the moon phases shown above would the moon go through during the next 11 days.

A. only one
B. two
C. three
D. more than three
E. none

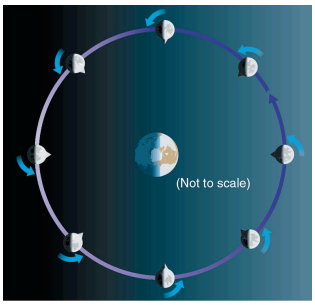
Which of the following groups of moon phases can be seen (above the horizon) at 3:00 am?

A. Third Quarter, Waning Crescent, and Waxing Crescent
B. New Moon, First Quarter, and Waxing Gibbous
C. Third Quarter, Full Moon, Waning Gibbous
D. Waxing Crescent, First Quarter, Waxing Gibbous
E. None of the above is correct



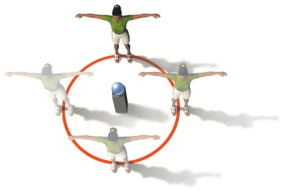
The Face of the Moon

- Have you noticed that we only see one face of the Moon?
- Does this mean the moon doesn't rotate?
- *No,* the Moon rotates so that the same face is always pointed at the Earth

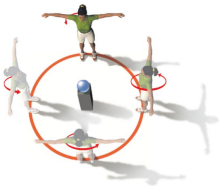


A lunar day equals a lunar orbit!

We see only one side of Moon



a If you do not rotate while walking around the model, you will not always face it.

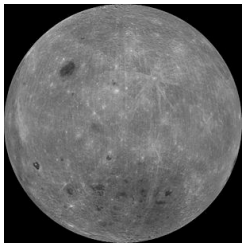


b You will face the model at all times only if you rotate exactly once during each orbit.

Synchronous rotation: the Moon rotates exactly once with each orbit

The Far Side of the Moon

The Moon has synchronous rotation:
period of rotation = period of orbit



Eclipses

Solar Eclipses

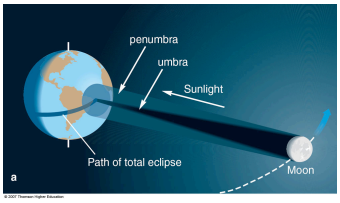
Lunar Eclipses

Eclipses of the Sun

- From Earth, you can see a phenomenon that is not visible from most planets.
- The Moon is just about the right size to cover the bright disk of the sun and cause a **solar eclipse**

What causes eclipses?

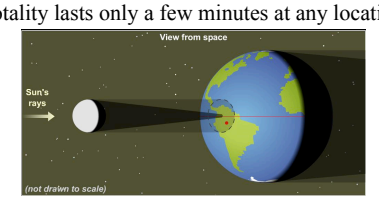
- A shadow consists of two parts:
  - **umbra -** part of the shadow where the Sun is completely obscured
  - **penumbra -** the Sun is only partly obscured



In the umbra:
Total Solar Eclipse

Small Shadow

- Moon's shadow is too small too cover all the Earth
  - Black dot – umbra
  - Gray area – penumbra
- Shadow moves across the Earth
  - Totality lasts only a few minutes at any location



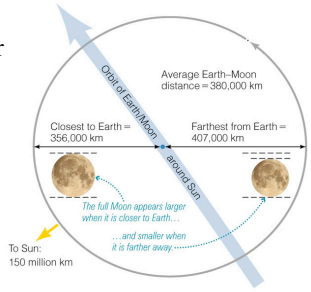
Annular Solar Eclipses

- Sometimes, when the moon crosses in front of the sun, it is too small to fully cover the sun
- Then, you would witness an **annular eclipse**

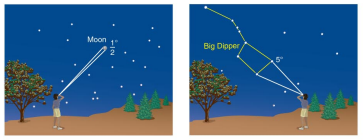
In an annular eclipse, a ring of the sun's disk is visible around the disk of the moon

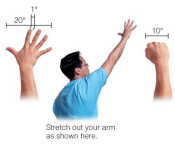
Why are some solar eclipses annular?

- The Moon's orbit is not perfectly circular
- When the Moon is *closer to the Earth* - ***total solar eclipse!***
- When the Moon is *farther from the Earth* - ***annular solar eclipse!***



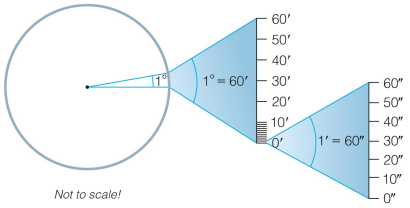
We measure the sky using *angles*





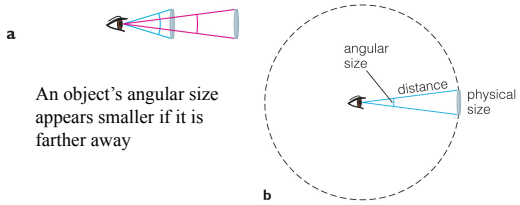
Angular Measurements

- Full circle = 360º
- 1º = 60′ (arcminutes)
- 1′ = 60″ (arcseconds)



Angular Size

$$\text{angular size} = \text{physical size} \times \frac{360 \text{ degrees}}{2\pi \times \text{distance}}$$

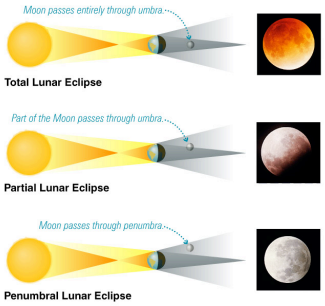


What must the phase of the moon be for a solar eclipse to occur?

A. New moon
B. First or Third quarter
C. Full moon
D. An eclipse can happen at any phase

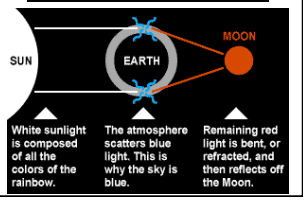
Eclipses of the Moon

- Occur when the Moon passes into the Earth's shadow
- Can occur only at **full moon**
- Three types of lunar eclipses



Red Moon

- During a total lunar eclipse, the Moon turns a dark red-orange color
- Some sunlight is bent by the Earth's atmosphere into the umbra
- Atmosphere scatters blue light away, so Moon is dimly illuminated in red



Recent and upcoming eclipses

Table 2-1 | Total and Annular Eclipses of the Sun, 2007–2010

Date	Total/ Annular (T/A)	Time* of Mid-eclipse (GMT)	Maximum Length of Total or Annular Phase (MinSec)	Area of Visibility
2008 Feb. 7	A	4h	2:14	S. Pacific, Antarctica
2008 Aug. 1	T	10h	2:28	Canada, Arctic, Siberia
2009 Jan. 26	A	8h	7:56	S. Atlantic, Indian Ocean
2009 July 22	T	3h	6:40	Asia, Pacific
2010 Jan. 15	A	7h	11:10	Africa, Indian Ocean
2010 July 11	T	20h	5:20	Pacific, S. America

There are no total or annular eclipses of the sun in 2007. The next major total solar eclipse visible from the United States will occur on August 21, 2017.

*Times are Greenwich Mean Time. Subtract 5 hours for Eastern Standard Time, 6 hours for Central Standard Time, 7 hours for Mountain Standard Time, and 8 hours for Pacific Standard Time.

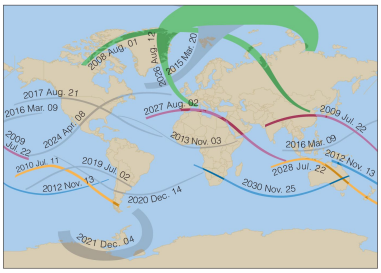
Table 2-2 | Total and Partial Eclipses of the Moon, 2007–2010

Date	Time of Mid-eclipse (GMT)	Length of Totality (Min)	Length of Eclipse (Hr:Min)
2007 Mar. 3	23:22	74	3:40
2007 Aug. 28	10:38	90	3:32
2008 Feb. 21	3:27	50	3:24
2008 Aug. 16	21:11	Partial	3:08
2009 Dec. 31	19:24	Partial	1:00
2010 June 26	11:40	Partial	2:42
2010 Dec. 21	8:18	72	3:28

*Times are Greenwich Mean Time. Subtract 5 hours for Eastern Standard Time, 6 hours for Central Standard Time, 7 hours for Mountain Standard Time, and 8 hours for Pacific Standard Time. From your time zone, lunar eclipses that occur between sunset and sunrise will be visible, and those at midnight will have the moon highest in the sky.

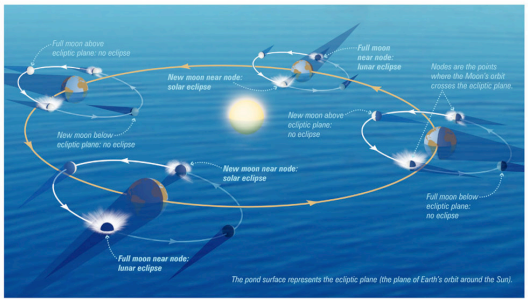
Predicting Eclipses

- Eclipses recur with the 18 yr, 11 1/3 day **saros cycle**, but type (e.g., partial, total) and location may vary.



Why don't we have an eclipse at every new and full moon?

- The moon's orbit is tipped about 5 degrees to the ecliptic
- So, most full moons cross the sky north or south of Earth's shadow and there is no lunar eclipse that month
- For the same reason, solar eclipses always occur at new moon but not at every new moon



The moon's orbit is tipped about 5 degrees to the Earth's orbit around the Sun

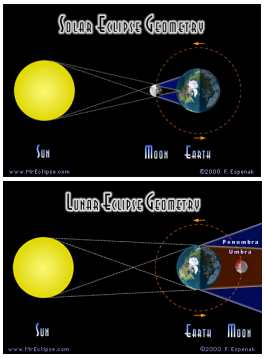
Two conditions must be met to have an eclipse

- It must be full moon (for a lunar eclipse) or new moon (for a solar eclipse)
- The Moon must be at or near one of the two points in its orbit where it crosses the ecliptic (the plane of the Earth's orbit around the Sun)

Moon crossing the Ecliptic at new or full moon = Eclipse!

Eclipses

- Solar eclipses
  - Occur when the Moon shadow falls on the Earth
  - Can occur only at **new moon**
- Lunar Eclipses
  - Occur when the Moon passes into the Earth's shadow
  - Can occur only at **full moon**



Why have more people seen an eclipse of the Moon than an eclipse of the Sun?

A. Eclipses of the Sun are much rarer than eclipses of the Moon

B. The shadow of the Moon is smaller than the shadow of the Earth

C. Anyone on the night side of the Earth can see a total eclipse of the Moon

D. Anyone on the day side of the Earth can see a total solar eclipse

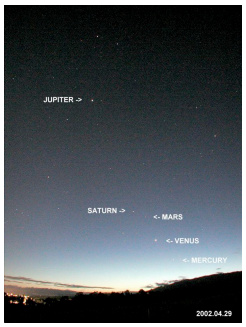
E. B and C

The Planets

In ancient times, people noted five bright "stars" that moved through the constellations of the Zodiac over time

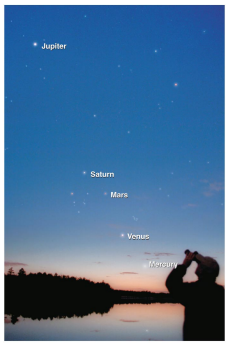
These "stars" were called **planets**, from Greek for "wanderers"

Mercury, Venus, Mars, Jupiter, Saturn



Planets Known in Ancient Times

- Mercury
  - difficult to see; always close to Sun in sky
- Venus
  - very bright when visible; morning or evening "star"
- Mars
  - noticeably red
- Jupiter
  - very bright
- Saturn
  - moderately bright

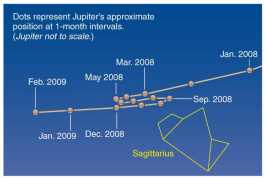


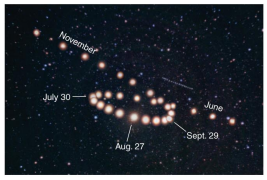
Celestial Origins of the Days of the Week

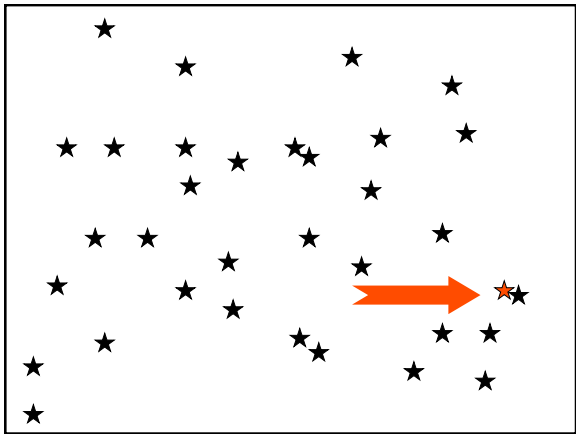
Object	Teutonic Name	English	French	Spanish
Sun	Sun	Sunday	dimanche	domingo
Moon	Moon	Monday	lundi	lunes
Mars	Tiw	Tuesday	mardi	martes
Mercury	Woden	Wednesday	mercredi	miércoles
Jupiter	Thor	Thursday	jeudi	jueves
Venus	Fria	Friday	vendredi	viernes
Saturn	Saturn	Saturday	samedi	sábado

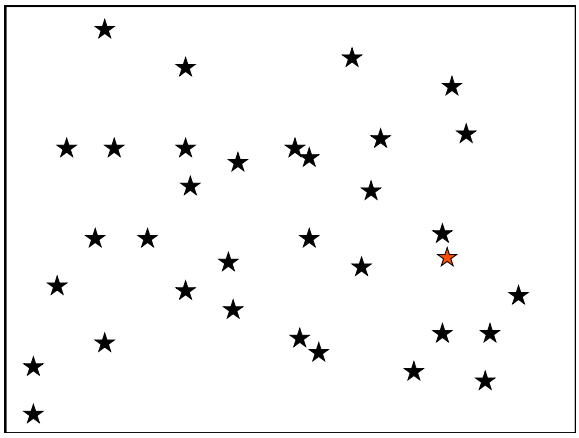
What was once so mysterious about planetary motion in our sky?

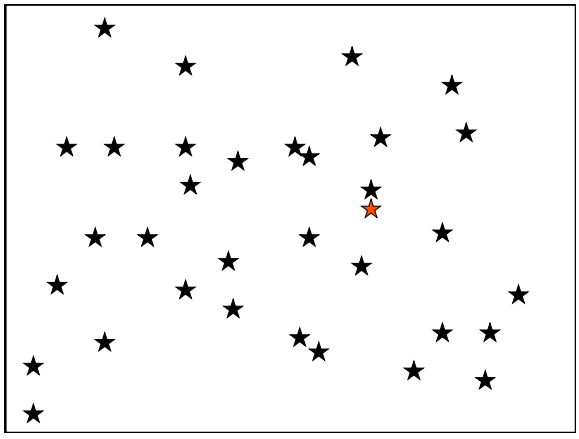
- Planets usually move slightly *eastward* from night to night relative to the stars. You cannot see this motion on a single night.
- But sometimes they go *westward* relative to the stars for a few weeks: **apparent retrograde motion**

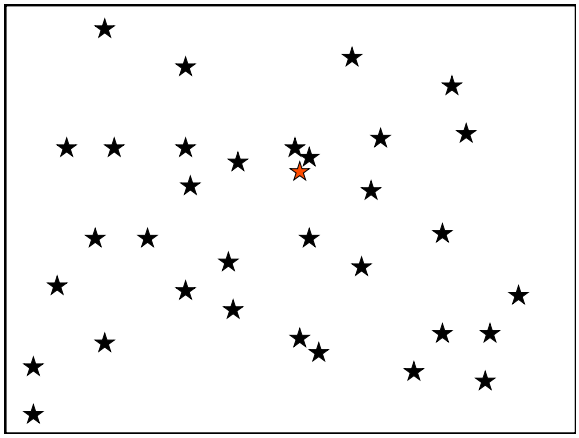


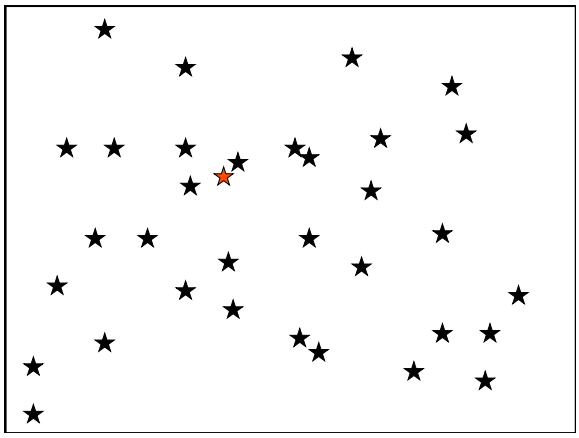


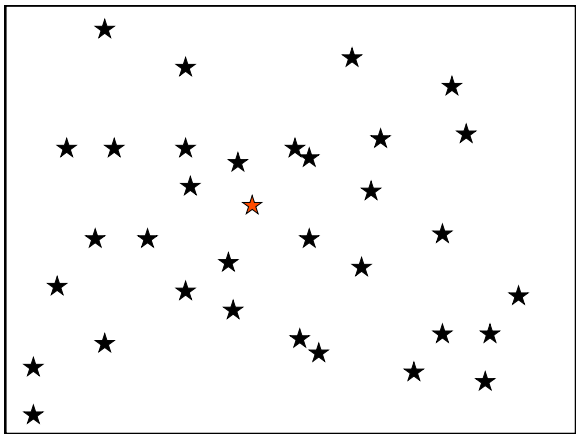


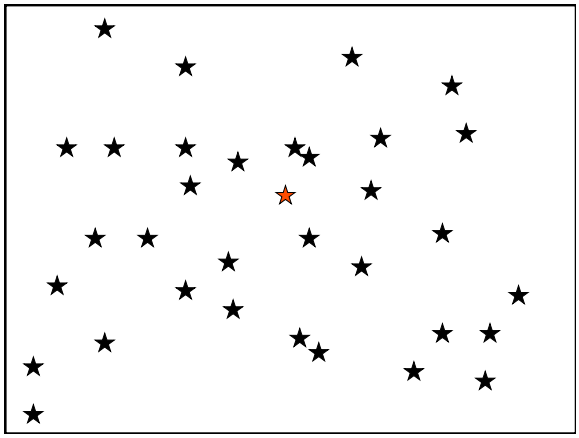


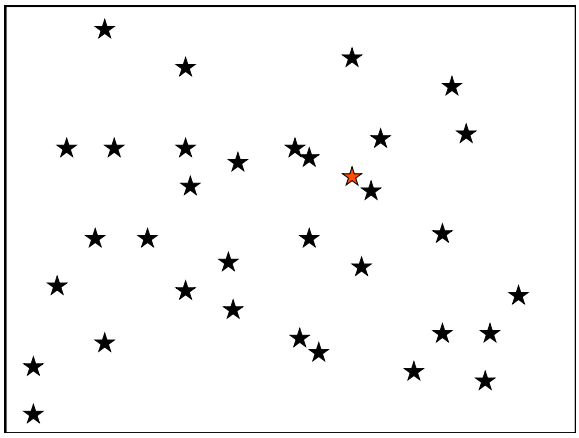


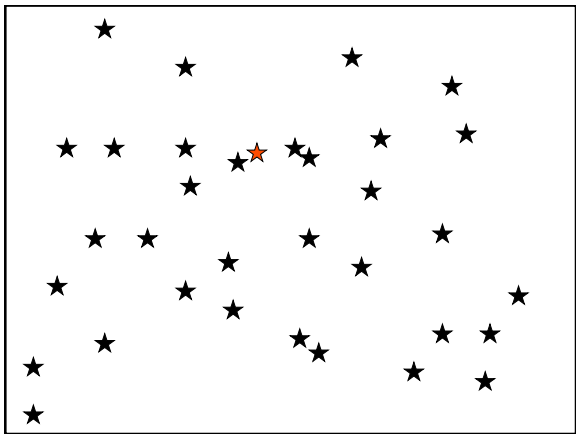


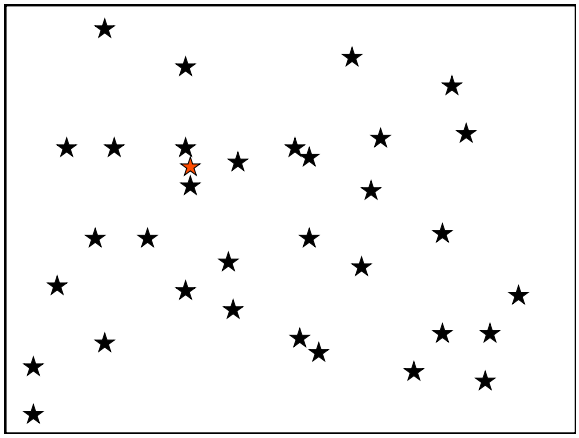


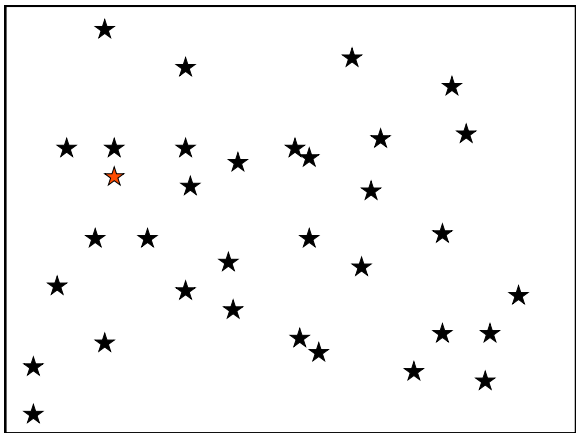


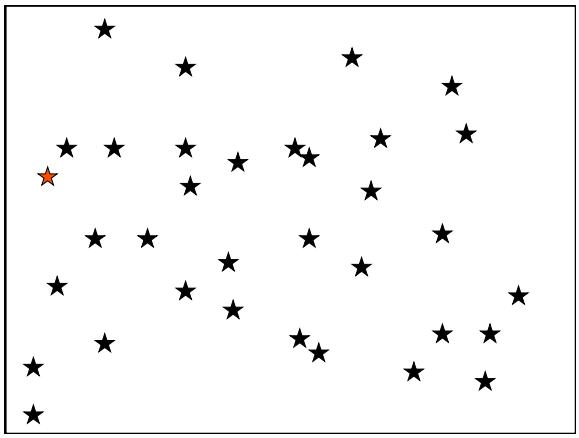


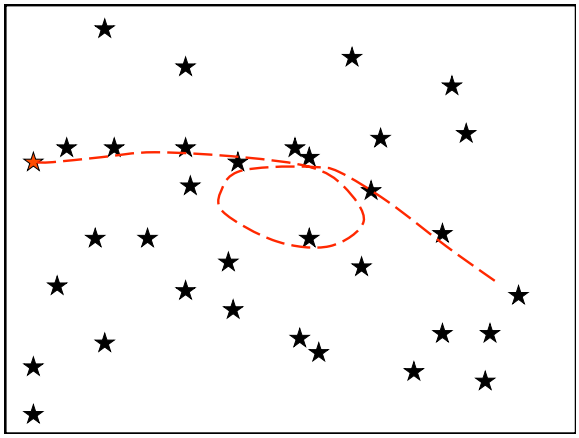






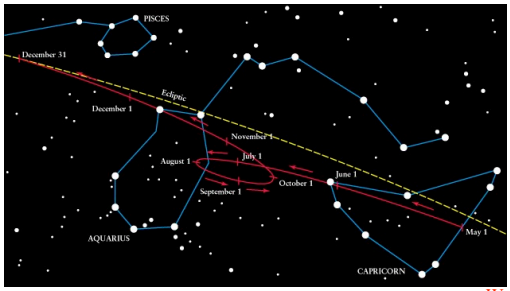






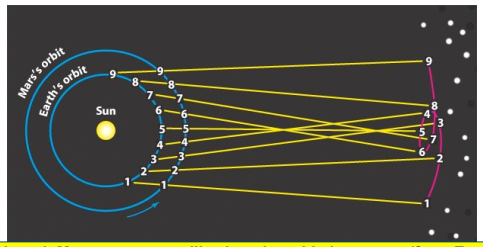
Prograde and Retrograde Motion

- Prograde Motion (normal motion) – The apparent West to East motion of objects (over many nights) as compared to the stationary background stars.
- Retrograde Motion - The apparent East to West motion of objects (over many nights) as compared to the stationary background stars.



East South West

We see apparent retrograde motion when we pass by a planet



Although Mars moves steadily along its orbit, it appears (from Earth's perspective) to slow to a stop and move westward (retrograde) relative to the background stars as Earth passes it

A planet moving in retrograde motion will, over the course of one night, appear to move *across the sky*

a) east to west.

b) west to east.

c) not at all, as planets do not move with the stars.

d) randomly, as planets move differently than the stars.

A planet is moving in retrograde motion. Over the course of several nights, how will the planet appear to move *relative to the background stars?*

a) It will move east to west.

b) It will move west to east.

c) It will not move at all, as planets do not move with the stars.

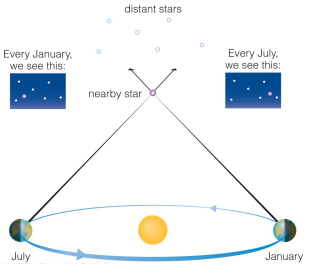
d) It will move randomly, as planets move differently than the stars.

Explaining Apparent Retrograde Motion

- Easy *for us* to explain: occurs when we "lap" another planet (or when Mercury or Venus laps us)
- But very difficult to explain if you think that Earth is the center of the universe!
- *In fact, ancients considered but rejected the correct explanation*

Why did the ancient Greeks reject the real explanation for planetary motion?

• Their inability to observe **stellar parallax** was a major factor.



The Greeks knew that the lack of observable parallax could mean one of two things:

1. Stars are so far away that stellar parallax is too small to notice with the naked eye
2. Earth does not orbit Sun; it is the center of the universe

With rare exceptions such as Aristarchus, the Greeks rejected the correct explanation (1) because they did not think the stars could be *that* far away

Thus setting the stage for the long, historical showdown between Earth-centered and Sun-centered systems.