Ch. 1 Charting the Heavens
The Moon and Eclipses
1.5 Motion of the Moon

The Moon is a natural satellite of the Earth. It is about 2160 miles in Diameter and about 239,000 miles away from the Earth, on average. → 110 x its diam away

Its distance changes because the orbit is elliptical. (e=.055)

The Moon's orbital plane is tilted by 5.15 degrees with respect to the ecliptic plane.

The Moon and Earth interact tidally.

→ The Moon – Earth system is a complex one!

We have no less than 5 different months all based on the time it takes for the Moon to go around the Earth.
Tilt of the Moon’s orbit

Top View:

Side View:

Side View of Solar System

Ecliptic (Earth’s orbital plane)

Enlarged Side View of Earth-Moon System

© 2011 Pearson Education, Inc.
1.5 Motion of the Moon

1) Sidereal Month: time to orbit relative to stars = 27.3 days.

2) Synodic Month: time to orbit relative to Sun = 29.5 days. Same as the “phase month”.

Why is the synodic month longer?

How fast does Moon move relative to stars?
Q: Does the Moon rotate? (Relative to stars, Earth?)
Q: Is there a “dark side” of the Moon, or a “far side”? 

See Moon globe, and YouTube videos about libration.
Phases are due to different amounts of sunlit portion being visible from Earth.

Q: Seen from Earth, what angle (ccw) is between the Sun and the Full Moon?

Q: Place a stick figure on Earth representing an observer experiencing morning.

Q: What time would a 1st quarter Moon rise?
Eclipse Basics – the shadow cone geometry.
Eclipse Basics.

Solar Eclipses – the shadow of the Moon falls on the Earth. We (on Earth) see the Sun get obscured.

**TYPES:**
- Partial
- Annular
- Hybrid or mixed (e.g. start annular, end total)
- Total

Lunar Eclipses – the shadow of the Earth falls on the Moon. We see a shadow pass over the Moon.

**TYPES:**
- Penumbral
- Partial
- Total

Q: What phase does the Moon have to be in, if any, during a solar eclipse? During a lunar eclipse?
Eclipses occur when Earth, Moon, and Sun form a straight line (syzygy).
Eclipses don’t occur every month because Earth’s and Moon’s orbits are not in the same plane.
1.5 Motion of the Moon

Moon’s orbit intersects ecliptic plane at a \textit{line of nodes}.

The line of nodes connects two points: an ascending node and a descending node.
ECLIPSE A/

Desc. node

5°

18.7° MAX.
REFERENCE
STAR

Full Moon (d=0.5°)

Penumbra (d=2.3°)

THE NEXT MONTH...
(29.5 days later)

Desc. node

1.5°

29.1° STAR

Penumbra

Full Moon

TWO PENUMBRAL'S IN ONE MONTH!

Degrees and distances 
(Not to scale.)

© 2011 Pearson
Lunar eclipses – Earth is between Moon and Sun

- Types determined by maximum immersion
- *Partial* if Moon only partially enters Umbra
- *Total* if Moon completely enters Umbra
- *Penumbral* when Moon only enters penumbra
Lunar eclipses – Earth is between Moon and Sun
Lunar Eclipses!

Total Lunar Eclipse, 1/20-21/2019
Lunar Eclipses!

My Pics from Jan 20-21, 2019 TLE

What's wrong with the labels?
Lunar Eclipses!

Total Lunar Eclipse, 2008

What’s wrong with the labels?
Solar Eclipses!

Total, 1999

Annular 1994

Phobos eclipses Sun, Aug 17, 2013
Solar eclipses - Moon is between Earth and Sun

A-E = possible positions of the Earth

- Observer at A sees: Sun obscured (total)
- Observer at B sees: Sun just obscured (total)
- Observer at C sees: Sun Moon (annular)
- Observer at D sees: Sun Moon (partial)
- Observer at E sees: Moon Sun (partial)
Solar eclipses - Moon is between Earth and Sun

- Partial when only part of Sun is blocked
- Total when it is all blocked
- Annular when Moon is too far from Earth for total
Solar Eclipse Paths

PATH OF ANNULAR ECLIPSE across Mexico, the United States, New Brunswick, and Nova Scotia.

May, 1994
Predicting Eclipses

Eclipses happen during *Eclipse Seasons* which are ...

34.5 days in duration (on average, range 31-37 d)
5.7 months apart
(2x5.7=11.4 months in a Draconic year)

Every 18 yrs 11.33 days an eclipse of the same type will repeat on the same node (ascending or descending) and in the same part of the Moon’s orbit (perigee, apogee, etc). This is a *saros*.

Every 54 yrs 34 days, an eclipse will repeat as above but also on about the same place(s) on Earth. This is an *exeligmos*. 
Saros 136 will produce 71 eclipses over 1262 yrs (8part, 6annul, 6hyb, 44tot, 7part)

© 2011 Pearson Education, Inc.
Predicting Eclipses

Lunar nodal precession period: 18.6 yrs for the L.O.N. to rotate CW. Draconic year 346.6 days
Lunar apsidal precession period: 8.85 yrs for the line between perigee and apogee to rotate CCW.

This figure does not show the rotation of the L.O.N.!
1.5 Predicting Eclipses

Eclipse Seasons.

There are a minimum of 4, and a maximum of 7 eclipses per year (all types included).

There is a minimum of 2, and a maximum of 5 lunar eclipses per year. Same for solar.

A lunar and solar eclipse are often 2 weeks apart.

Ohio's next solar eclipses:
Oct 14, 2023 - Annular
Apr 8, 2024 – Total
1.5 Predicting Eclipses

Total solar eclipses occur somewhere on Earth about 2 times every 3 years (0.67/year).

Total solar eclipses happen at a given location (like a small town) about once every 370 years, on average. Some spots will have to wait over 1000 years for their next total solar eclipse, while other lucky spots have two separated by 1.5 years.

Total lunar eclipses happen at a given location about once per year because a TLE can be seen by half of the Earth at a given moment.

1 Saros = 6585.32 d (18 yrs 11 d 8 hrs)
   ~ 223 synodic months
   ~ 239 anomalistic months
   ~ 242 draconic months
1.6 The Measurement of Distance

**Triangulation:**
Measure baseline and angles, can calculate distance.
Parallax: Similar to triangulation, but look at apparent shift of object against distant background from two vantage points.

Change your POV to the object. \( \theta = \frac{LD}{D} \) becomes parallax = \( \frac{\text{Baseline}}{D} \)
Summary of Chapter 1

• Astronomy: Study of the universe

• Scientific method: Observation, theory, prediction, observation, …

• Stars can be imagined to be on inside of celestial sphere; useful for describing location

• Plane of Earth’s orbit around Sun is ecliptic; at 23.5° to celestial equator

• Tilt of Earth’s axis causes seasons

• Moon shines by reflected light, has phases
Summary of Chapter 1 (cont.)

• Solar day $\neq$ sidereal day, due to Earth’s revolution around Sun

• Synodic month $\neq$ sidereal month, also due to Earth’s revolution around Sun

• Tropical year $\neq$ sidereal year, due to precession of Earth’s spin axis

• Eclipses of Sun and Moon occur due to alignment; only occur occasionally as orbits are not in same plane

• Distances can be measured through triangulation and parallax