Chapter 1 Charting the Heavens
1.1 Our Place in Space

- **Earth** is unique because we live here
- **Universe**: totality of all space, time, matter, and energy
1.1 Our Place in Space

- **Astronomy**: study of the universe
- **Scales** are very large: measure in light-years, the distance light travels in a year—about 10 trillion miles
- **Powers of 10 Video**
1.1 Our Place in Space

- This galaxy is about 100,000 light-years across:
1.2 Scientific Theory and the Scientific Method

Scientific theories:

- Must be testable
- Must be continually tested
- Should be simple
- Should be elegant

Scientific theories can be proven wrong, but they can never be proven right with 100% certainty.
1.2 Scientific Theory and the Scientific Method

• **Observation leads to theory explaining it**

• **Theory leads to predictions consistent with previous observations**

• **Predictions of new phenomena are observed. If the observations agree with the prediction, more predictions can be made. If not, a new theory can be made.**
1.3 The “Obvious” View

**Simplest observation:** Look at the night sky

**About 3000 stars visible at any one time; distributed randomly but human brain tends to find patterns**
1.3 The "Obvious" View

Group stars into constellations: Figures having meaning to those doing the grouping

Useful: Polaris, which is almost due north

Not so useful: Astrology, which makes predictions about individuals based on the star patterns at their birth
1.3 The “Obvious” View

Stars that appear close in the sky may not actually be close in space.
1.3 The “Obvious” View

The celestial sphere:
Stars *seem* to be on the inner surface of a sphere surrounding the Earth

They aren’t, but can use two-dimensional spherical coordinates (similar to latitude and longitude) to locate sky objects
More Precisely 1-1: Angular Measure

- Full circle contains $360^\circ$ (degrees)
- Each degree contains 60′ (arc-minutes)
- Each arc-minute contains 60″ (arc-seconds)
- Angular size of an object depends on actual size and distance away
More Precisely 1-2: Celestial Coordinates

- **Declination**: degrees north or south of celestial equator
- **Right ascension**: measured in hours, minutes, and seconds eastward from position of Sun at vernal equinox

- [Celestial Sphere clip](#)
- [Rotating Sky Explorer](#)
1.4 Earth’s Orbital Motion

- **Solar Day**: Earth completes one rotation with respect to the sun = 24 hours

- **Stars aren’t in quite the same place 24 hours later due to Earth’s rotation around Sun; when they are, one sidereal day has passed**

- **Sidereal day**: Earth completes one rotation with respect to distant star = 24h 56m
Seasonal changes to night sky are due to Earth’s motion around Sun
12 constellations Sun moves through during the year are called the zodiac; path is ecliptic
Ecliptic – apparent path of the sun across the sky (really the earth in motion, not the sun)

- Ecliptic is tilted, because earth’s axis is tilted at $23.5^\circ$ to celestial equator
Seasons

• Tilt of axis creates changing seasons
• Distance from sun does not create seasonal changes
• Earth is marginally closer to sun in December than June, but December is not the hottest month in the N. hemisphere!

Motion of sun simulator

http://www.learner.org/jnorth/tm/mclass/eclipticsimulator.swf
Summer Solstice

• Usually 06/21 (may fall ± a calendar day)
• Longest day of the year (N hemisphere) because sun has maximum declination (+23.5°)
• N hemisphere is tipped toward the sun, more direct daylight makes the season summer
Winter Solstice

• Usually 12/21 (may fall ± a calendar day)
• Shortest day of the year (N hemisphere) because sun has minimum declination (-23.5°)
• N hemisphere is tipped away from the sun, less direct daylight makes the season winter
Equinoxes

- **Vernal (Spring) Equinox:** 03/21 (may fall ± a calendar day)
- **Autumnal Equinox:** 09/21 (may fall ± a calendar day)
- Equal length day & night because sun crosses celestial equator (declination = 0°)
The Earth’s Orbital Motion

• Earth’s axis wobbles slightly as it spins

• Today, N. Celestial Pole points almost perfectly at Polaris

• Wobble means that Polaris was not always the Pole Star, and will not be forever
The Earth’s Orbital Motion

Precession: rotation of Earth’s axis itself; makes one complete circle in about 26,000 years
Astronomical Timekeeping

- **Solar noon**: when Sun is at its highest point for the day
- **Drawbacks**: length of solar day varies during year; noon is different at different locations
Astronomical Timekeeping

• Mean (average) solar day—this is what clocks measure

• Time zones (24 total) around Earth - time the same in each one and then jumping an hour to the next
Astronomical Timekeeping

• Lunar month (complete lunar cycle) doesn’t have whole number of solar days in it

• Current calendar has months that are close to lunar cycle, but adjusted so there are 12 of them in a year
Astronomical Timekeeping

• Year doesn’t quite have a whole number of solar days in it—*leap years* take care of this.
  • Add extra day every 4 years
  • Omit years that are multiples of 100 but not of 400
  • Omit years that are multiples of 1000 but not of 4000
• This will work for 20,000 years.
Motion of the Moon – Lunar Phases

- **Phases** are due to different amounts of sunlit portion being visible from Earth
Motion of the Moon – Lunar Phases

• **New moon:** moon located between Earth and Sun (angle is 0°)

• **1st quarter:** moon makes a 90° angle

• **Full moon:** moon is 180° away from the sun in sky

• **3rd quarter:** moon makes a 90° angle
Motion of the Moon – Lunar Month

• **Sidereal Month**: 27.3 days for the moon to complete one full rotation with respect to a distant star

• **Synodic Month**: 29.5 days for moon to complete one full cycle of phases, or a complete rotation with respect to the sun (as seen from Earth)
Motion of the Moon

- Eclipses occur when Earth, Moon, and Sun form a straight line.
Eclipses don’t occur every month because Earth’s and Moon’s orbits are not in the same plane.
Motion of the Moon

- **Solar eclipse:**
  - Sun is eclipsed by the moon: moon passes in between Earth and sun
  - Can only happen when phase of the moon is new
  - Does not happen every month because moon’s orbit is tilted with respect to the ecliptic
- **Annular eclipse:** moon is farthest from Earth, making it appear slightly smaller (so it does not completely cover solar disk)
Motion of the Moon

- **Lunar eclipse:**
  - Shadow of the Earth eclipses the moon: Earth passes in between sun and moon
  - Can only happen when moon is full
  - More frequent than solar eclipse
  - Partial eclipses are common
Measurement of Distance

- **Triangulation:**
  - Measure distance to objects that are too far or inconvenient to be measured directly
  - Requires some geometry and trigonometry
  - Observe the same object from two different vantage points, compare
  - This works for stationary objects on Earth, but can also be used to locate planets
Measurement of Distance

- **Parallax:**
  - Apparent shift in the position of an object in the foreground with respect to the background
  - Result of changing point of observation, not the motion of the actual object
  - For close object, large parallax observed with relatively small baseline shift
  - The farther an object, smaller the parallax-increase baseline to increase parallax
Measurement of Distance

- **Measuring Earth’s radius:**
- **Done by Eratosthenes** about 2300 years ago; noticed that when Sun was directly overhead in one city, it was at an angle in another.
- **Measuring** that angle and the distance between the cities gives the radius.