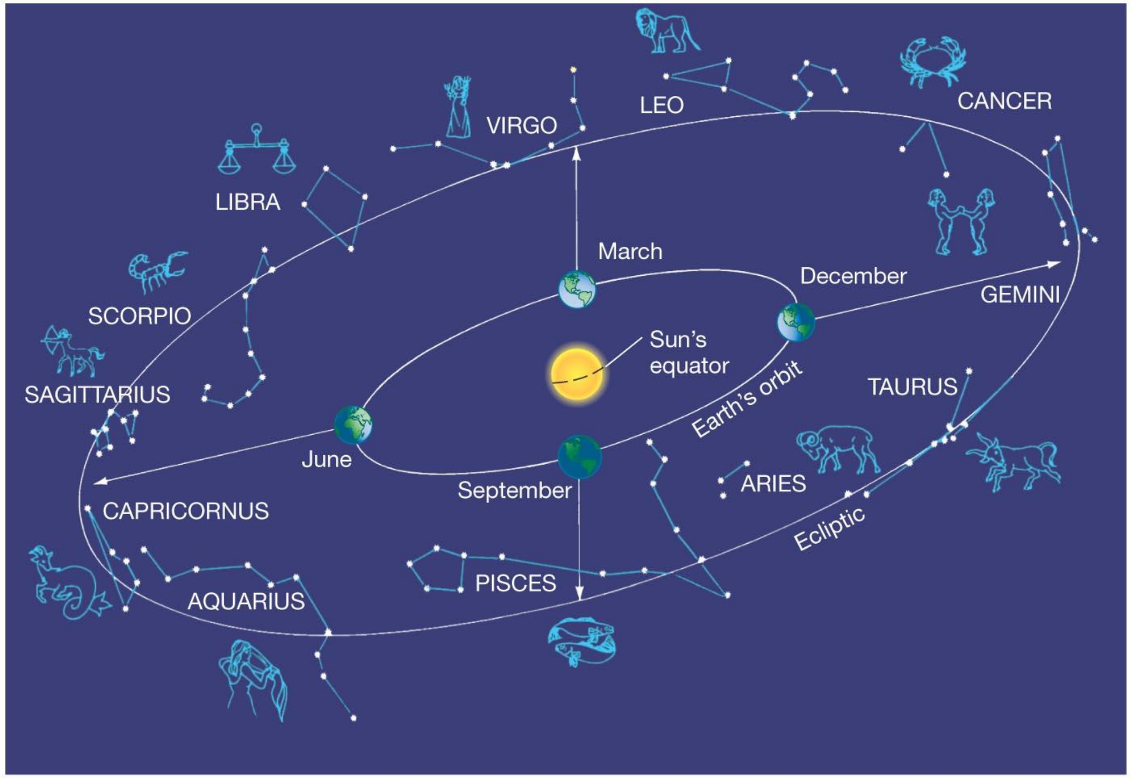
Part 2

- Heliocentric model
  - Inferior & superior planets
    - Orbital periods
  - Superior planets
    - Relative distances
      - Assignment
    - Order of the planets from the Sun
- Celestial coordinate systems
  - Celestial motions

Sidereal period

- The amount of time necessary to make one complete orbit relative to the background stars is referred to as the sidereal period (P).



Synodic period

- Stellarium Web Online Star Map
- The time interval between successive oppositions or conjunctions is known as the synodic period (*S*).
- The relative orbital motions of Earth and the other planets mean that the synodic period can differ significantly from the sidereal period.

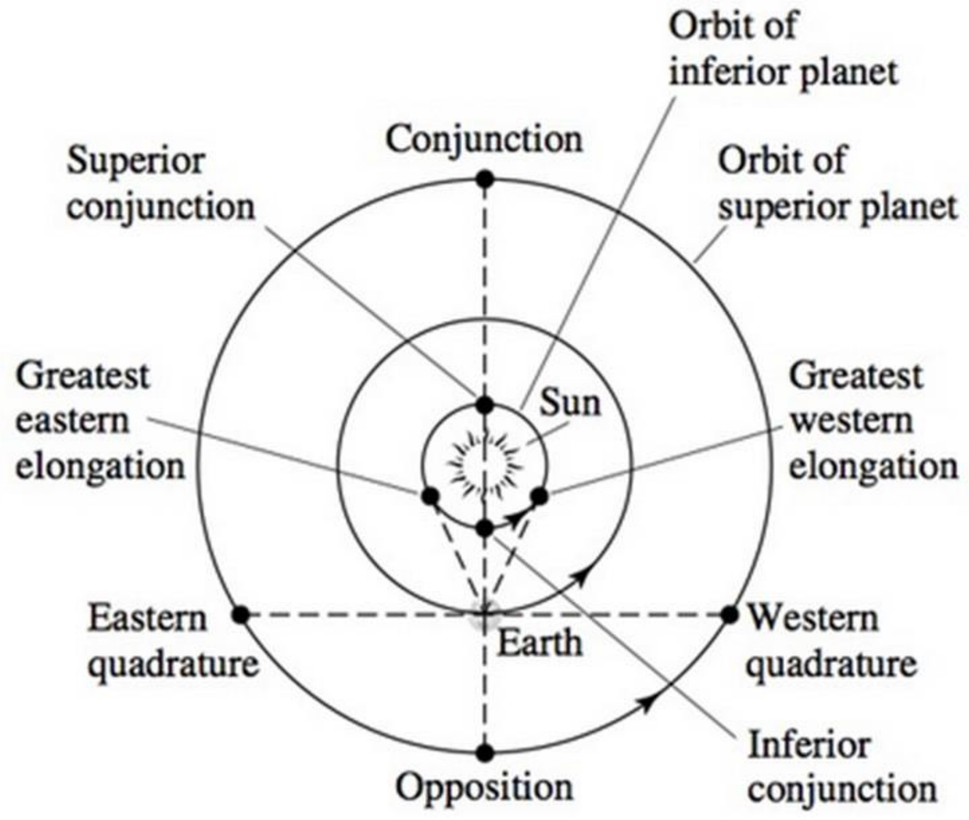


FIGURE 5 Orbital configurations of the planets.

Relationship

- The relationship between the two periods is given by

$$\frac{1}{S} = \begin{cases} \frac{1}{P} - \frac{1}{P_\oplus} & \text{(inferior)} \\ \frac{1}{P_\oplus} - \frac{1}{P} & \text{(superior)} \end{cases}$$

when perfectly circular orbits and constant speeds are assumed; $P_\oplus$ is the sidereal period of Earth's orbit (365.26 d).

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Coordinate systems

- To catalog the locations of objects, coordinates must be specified.
- The Copernican revolution has shown us that the notion of a geocentric universe is incorrect. Nevertheless, our observations of the heavens are still based on a reference frame centered on Earth.

Two coordinates

- Viewing objects in the night sky requires only directions to them, not their distances.
- We can imagine that all objects are located on a celestial sphere, just as the ancient Greeks believed.
- It then becomes sufficient to specify only two coordinates.

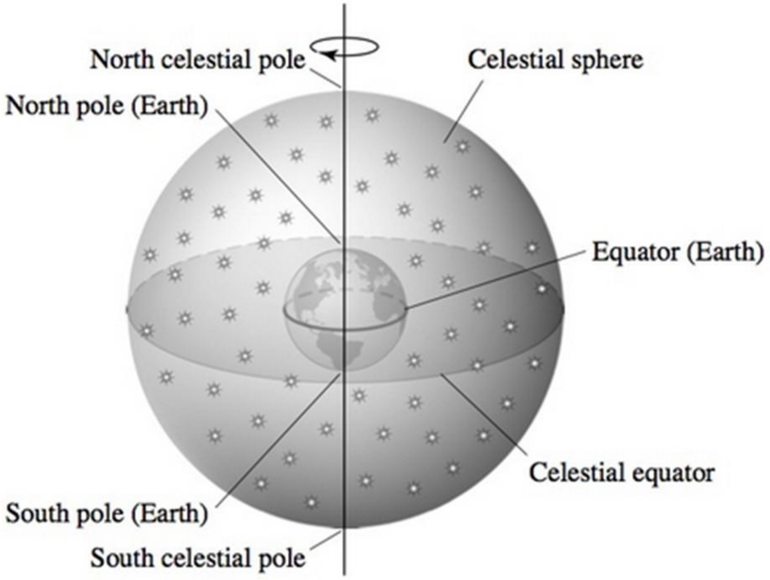

FIGURE 1 The celestial sphere. Earth is depicted in the center of the celestial sphere.

Horizontal coordinate system

- The altitude–azimuth (or horizontal) coordinate system is a straight-forward coordinate system based on the observer’s local horizon.
- It is based on the measurement of the azimuth angle along the horizon together with the altitude angle above the horizon.

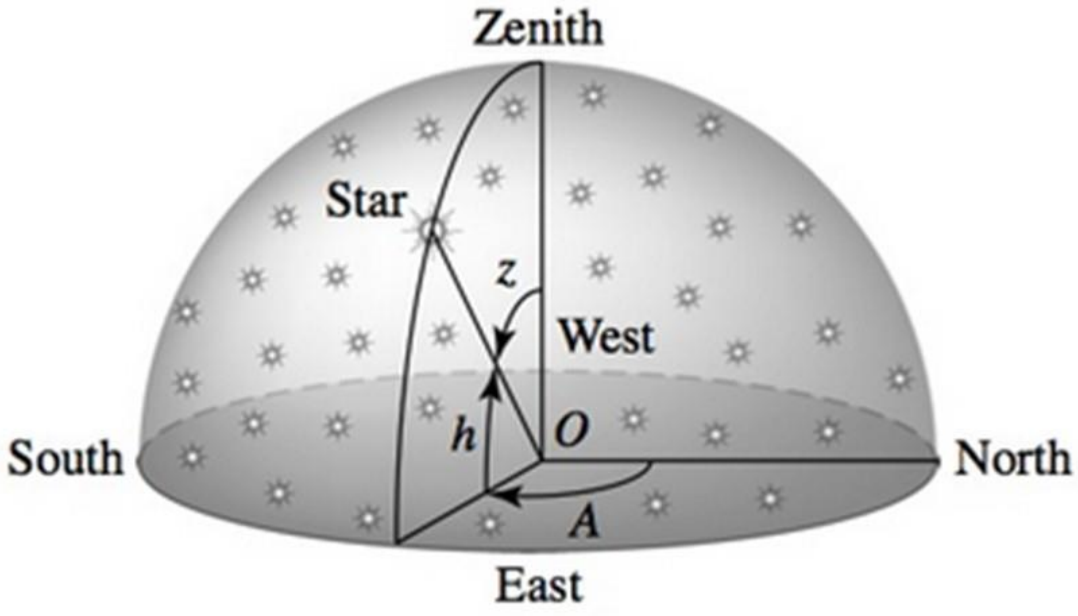

FIGURE 8 The altitude–azimuth coordinate system. h, z, and A are the altitude, zenith distance, and azimuth, respectively.

Altitude & azimuth

- The zenith is a point on the celestial sphere directly above the observer.
- The altitude h is defined as that angle measured from the horizon to the object along a great circle that passes through the object and the zenith.
- The azimuth A is the angle measured along the horizon eastward from north to the great circle.

Defined by the observer's local horizon

- Since the horizontal system is defined by the observer's local horizon, the same object viewed from different locations on Earth at the same time will have different values of altitude and azimuth.

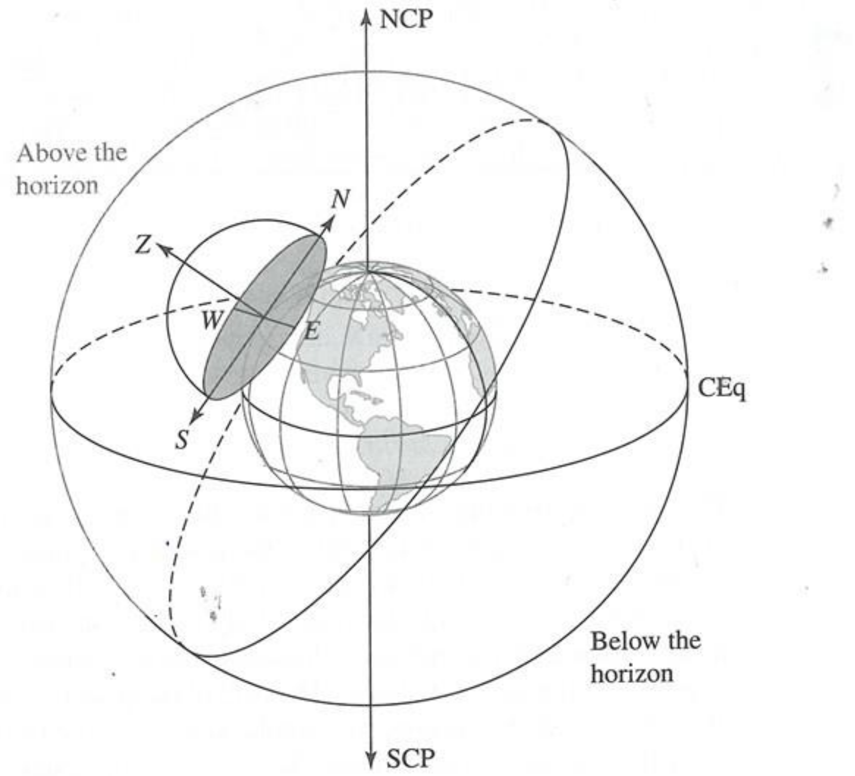

FIGURE 1.1 The celestial sphere surrounding the Earth. The Earth's north pole, south pole, and equator project onto the north celestial pole (NCP), south celestial pole (SCP), and celestial equator (CEq), respectively. For any observer, the horizon plane is tangent to the observer's location, and the zenith (Z) is directly overhead.

Earth is rotating

- Since Earth is rotating, stars appear to move constantly across the sky, meaning that the coordinates of each object are constantly changing, even for the local observer.

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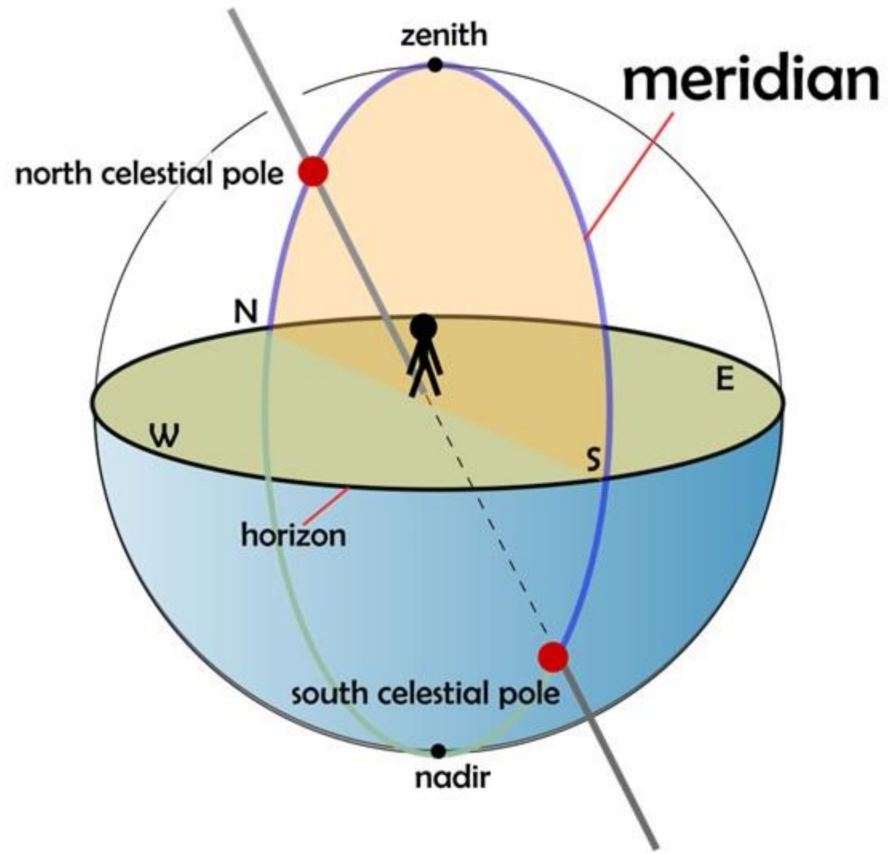
Meridian

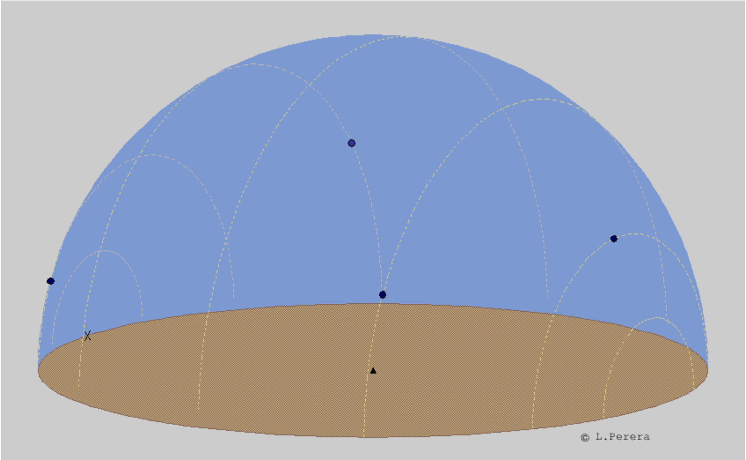
- The meridian is another frequently used great circle; it is defined as passing through the observer's zenith and intersecting the horizon due north and south.

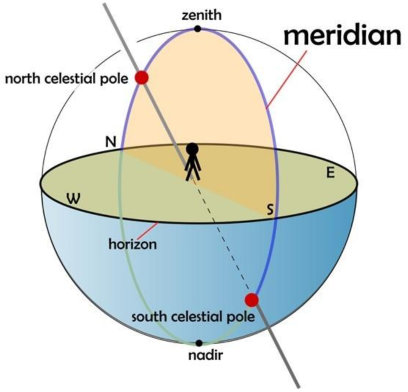


Transit the upper meridian & culmination

- On any given day/night, a celestial object will appear to drift across, or transit, the observer's upper meridian as Earth rotates.
- At culmination, the object contacts the upper meridian and reaches its highest point in the sky.

https://www.phy.olemiss.edu/~perera/animations/sky_equator.html





Earth’s orbital motion about the Sun

- Earth has an orbital motion about the Sun.

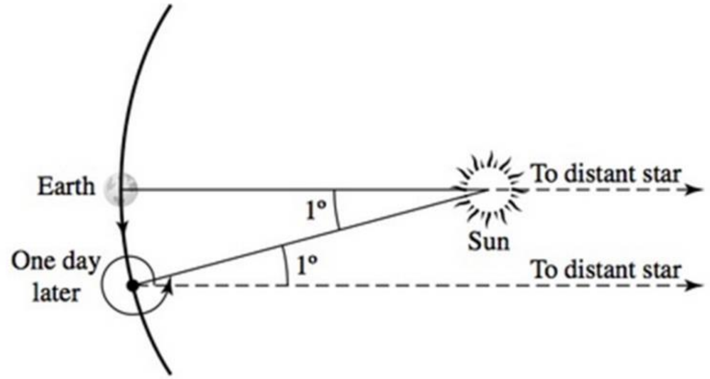


FIGURE 10 Earth must rotate nearly 361° per solar day and only 360° per sidereal day.

Meridian crossings of the Sun

- Since Earth completes one sidereal period in approximately 365.26 days, it moves slightly less than 1° around its orbit in one day.
- Thus Earth must actually rotate nearly 361° to bring the Sun to the meridian on two successive days.

Meridian crossings of a star

- Because of the much greater distances to the stars, they do not shift their positions significantly as Earth orbits the Sun.
- As a result, placing a star on the meridian on successive nights requires only a 360° rotation.

Solar time & sidereal time

- Solar time is defined as an average interval of 24 hours between meridian crossings of the Sun.
- Sidereal time is based on consecutive meridian crossings of a star.
  - A sidereal day is approximately 23 hours 56 minutes.
  - It takes approximately 4 minutes for Earth to rotate the extra 1°.

Stars’ coordinates change from day to day

- The stars rise approximately 4 minutes earlier on each successive night, so that even when viewed from the same location at a specified time, the coordinates change from day to day.

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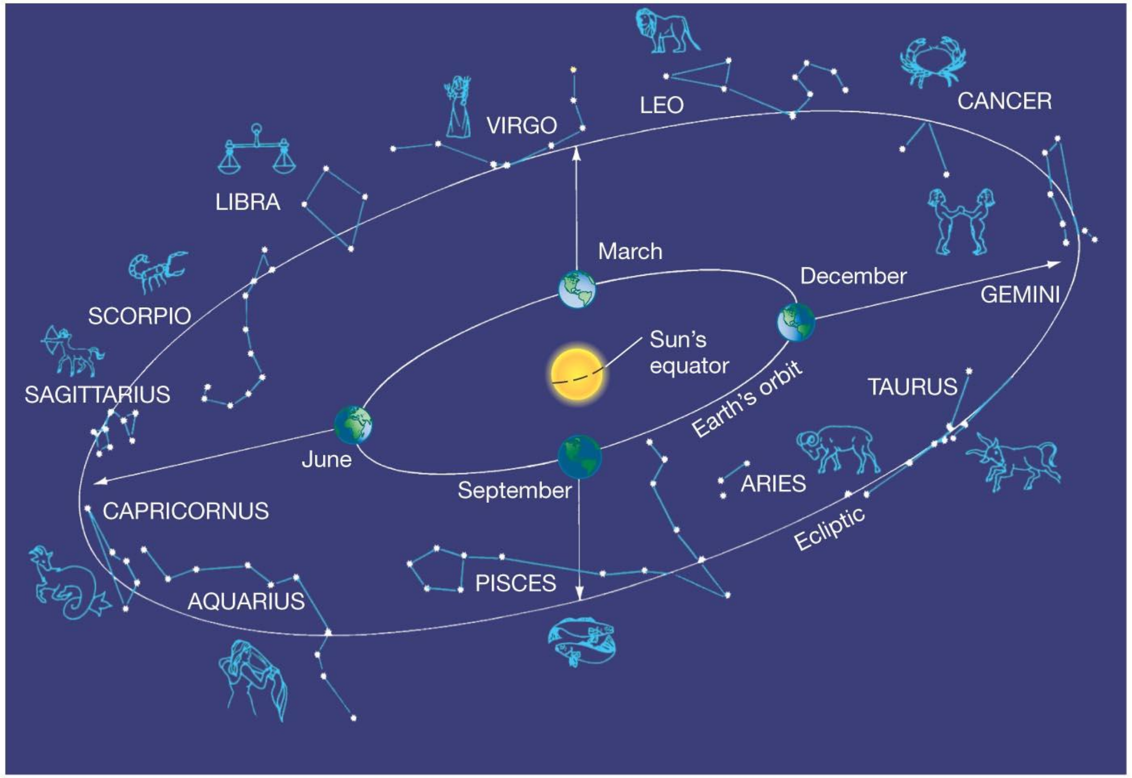
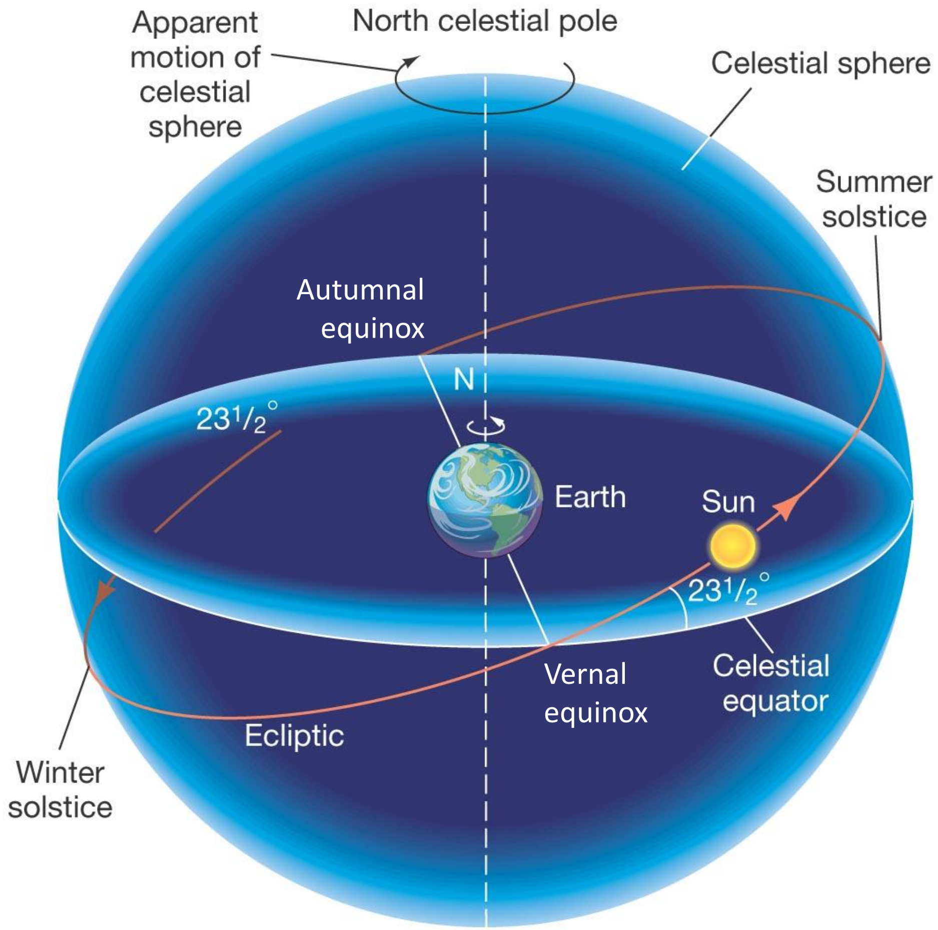
Sun’s apparent motion

- As Earth orbits the Sun, our line of sight to the Sun sweeps through the constellations during the seasons.



Ecliptic

- Consequently, we see the Sun apparently move through those constellations along a path referred to as the ecliptic.



Celestial equator

- The celestial equator is defined by passing a plane through Earth at its equator and extending that plane out to the celestial sphere.

Tilt of Earth’s rotation axis

- There is an approximately 23.5° tilt of Earth’s rotation axis.
- As a result of the tilt, the ecliptic moves north and south of the celestial equator.

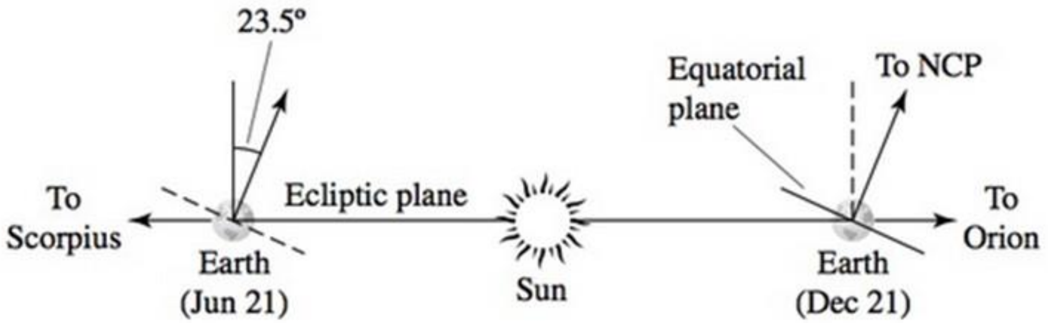


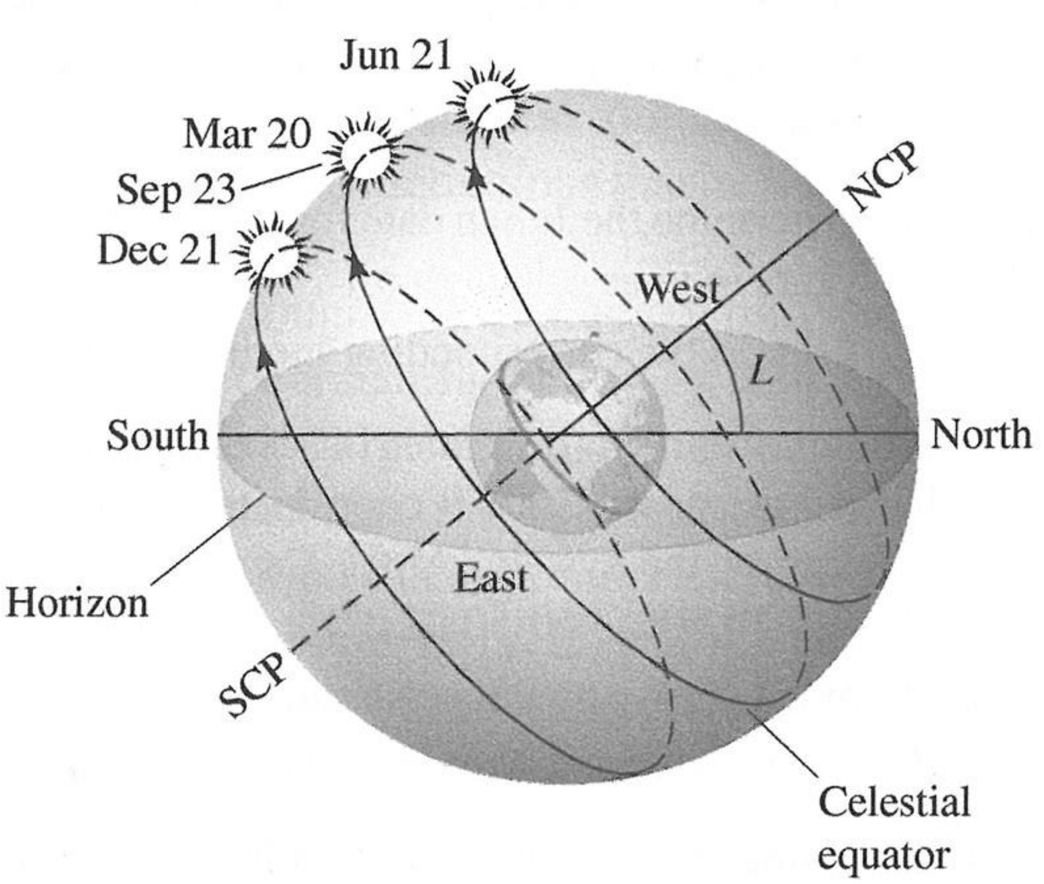
FIGURE 9 The plane of Earth’s orbit seen edge-on. The tilt of Earth’s rotation axis relative to the ecliptic is also shown.

Equinoxes & solstices

- The Sun, in its apparent motion along the ecliptic, crosses the celestial equator at two points known as the equinoxes. The crossing from south to north is known as the **vernal equinox**. The crossing from north to south is the **autumnal equinox**.
- The most northern excursion of the Sun along the ecliptic occurs at the **summer solstice**, and the southernmost position of the Sun is defined as the **winter solstice**.

Sun’s position relative to the celestial equator

- The seasonal variations in weather are due to the position of the Sun relative to the celestial equator.



Seasonal variations in weather

- During the summer months in the Northern Hemisphere, the Sun’s northern position causes it to appear higher in the sky, producing longer days and more intense sunlight.
- During the winter months the position of the Sun is below the celestial equator, its path above the horizon is shorter, and its rays are less intense.

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