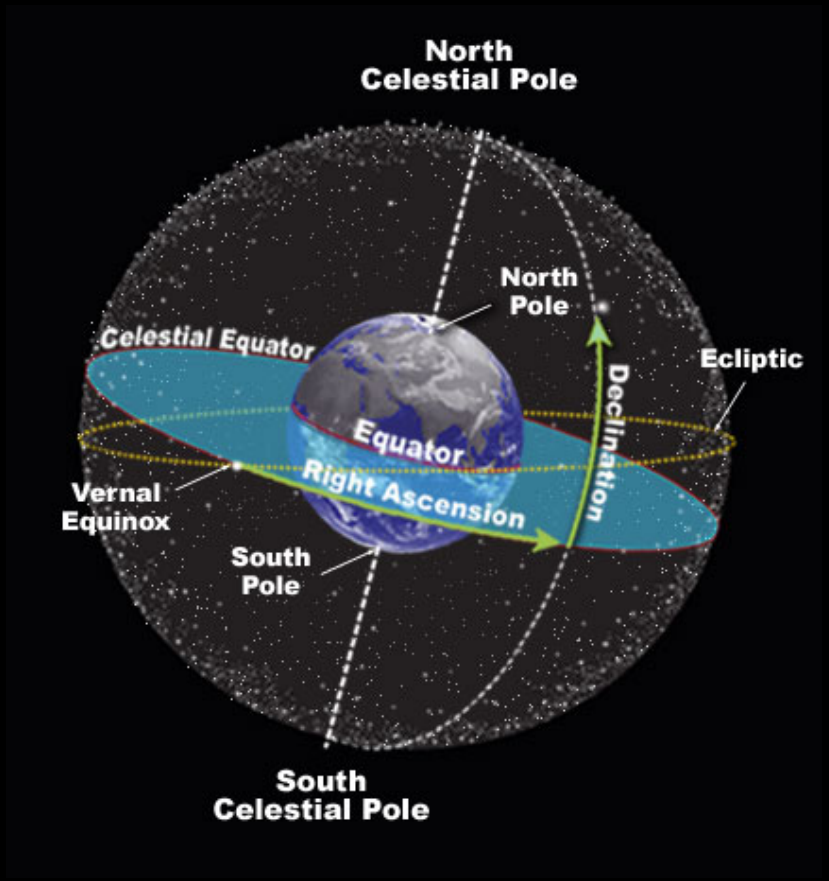
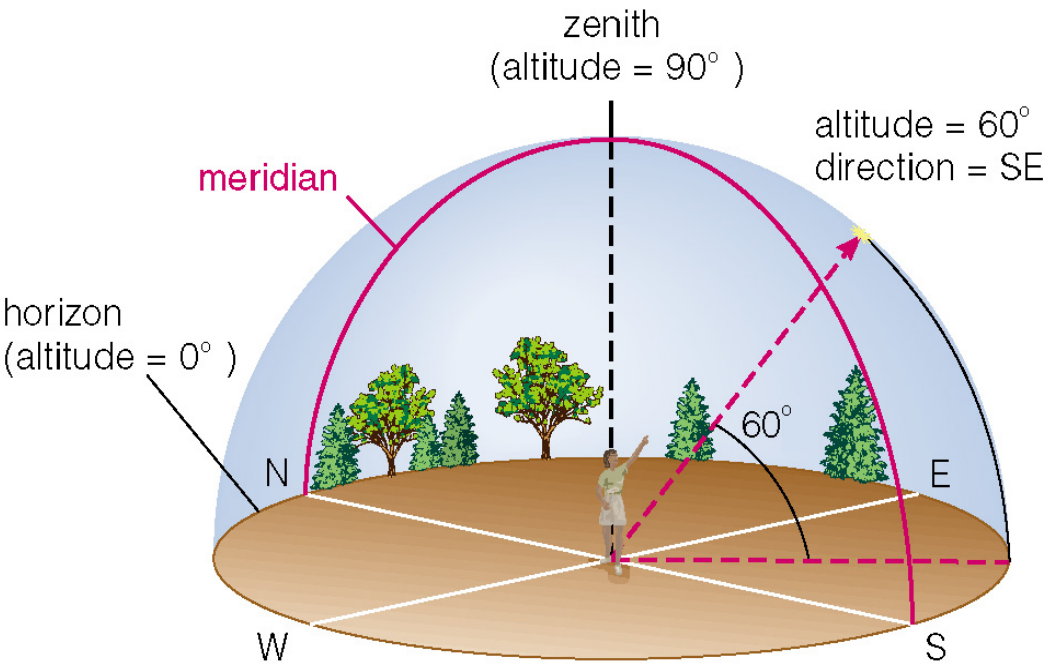
Lecture 2 – Observing the Sky



The Local Sky

We appear to be looking up inside an enormous sphere

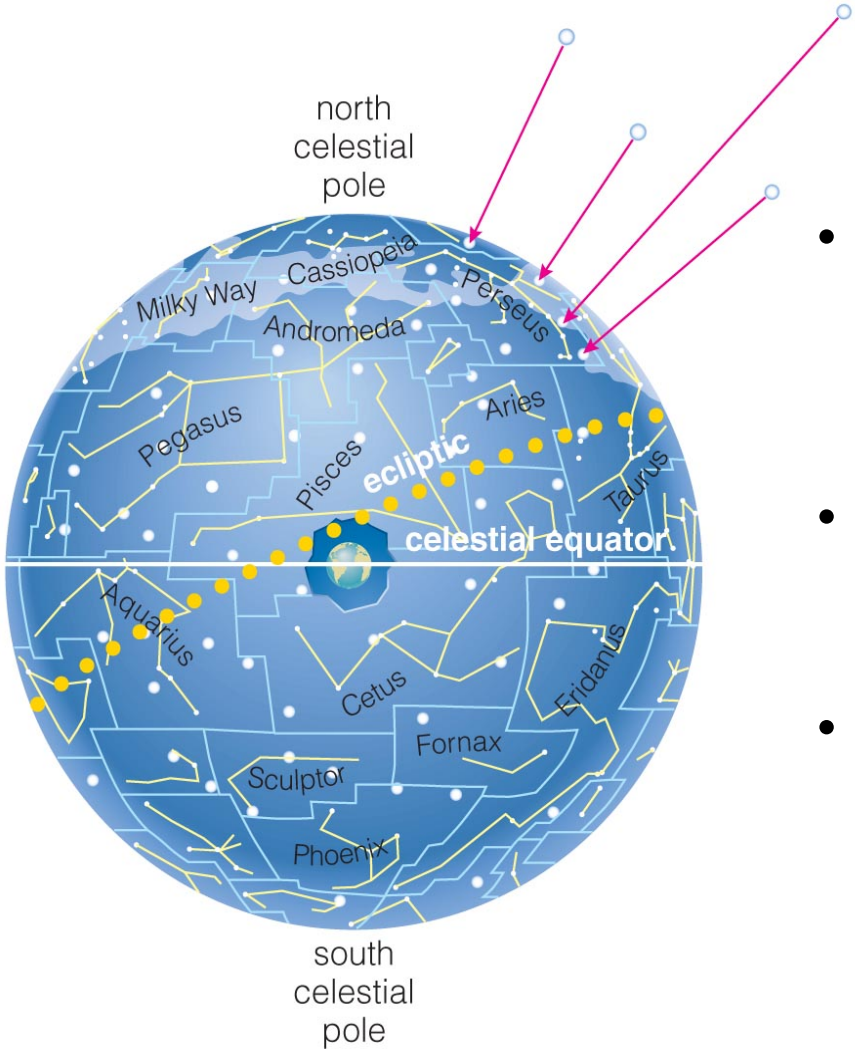


- **Zenith:** The point directly overhead
- **Horizon:** All points 90° away from zenith
- **Meridian:** Line passing through zenith and connecting N and S points on the horizon

An object's **altitude** (above horizon) and **azimuth** (direction around horizon) can also specify its location in the sky at a specific time:

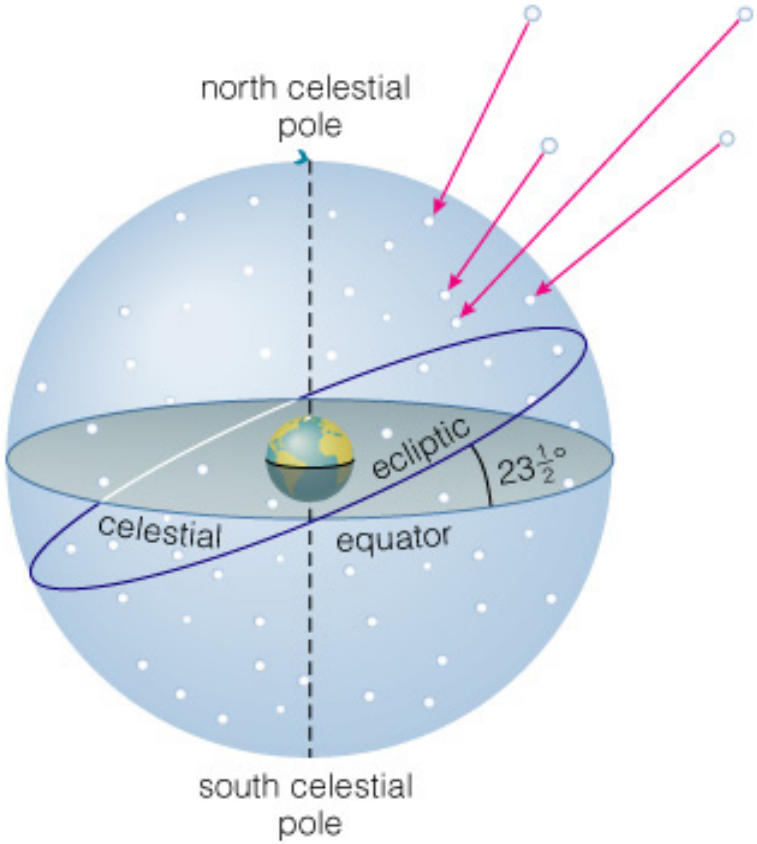
North – 0, East – 90, South – 180, West – 270

The Celestial Sphere



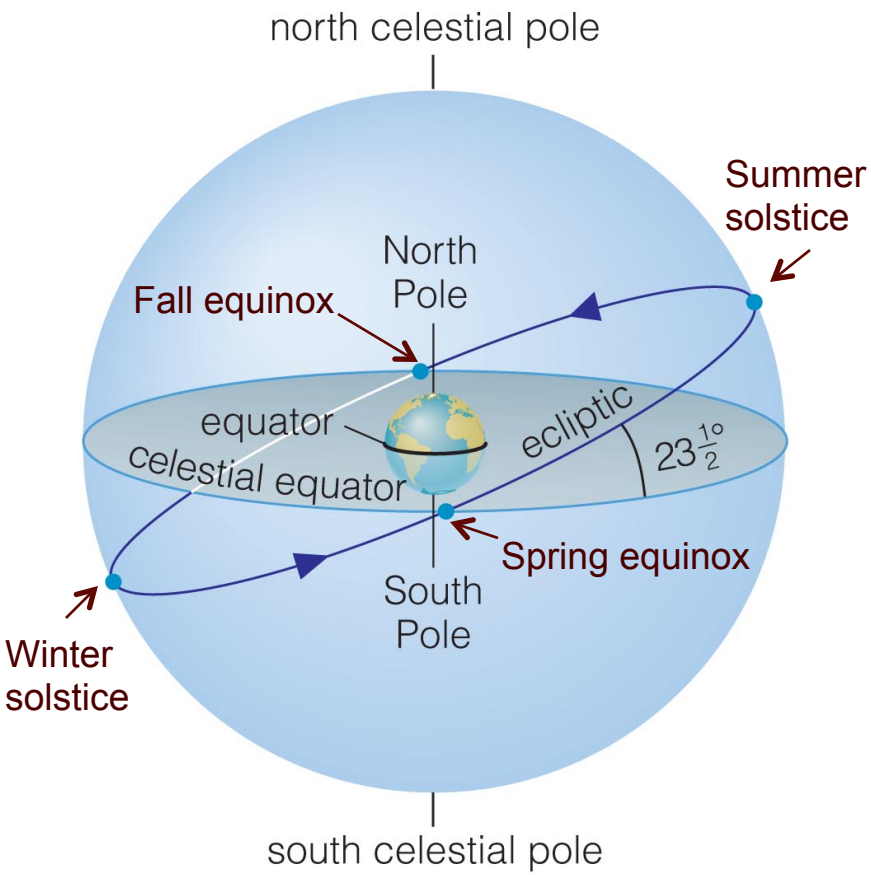
- Stars at different distances *appear* to lie on the **celestial sphere**, an imaginary sphere we look up at from inside.
- A **constellation** is a *region* of the sky surrounding an ancient historical figure.
- In the 20th century, astronomers divided the sky into 88 official constellations in the entire sky.

The Celestial Sphere



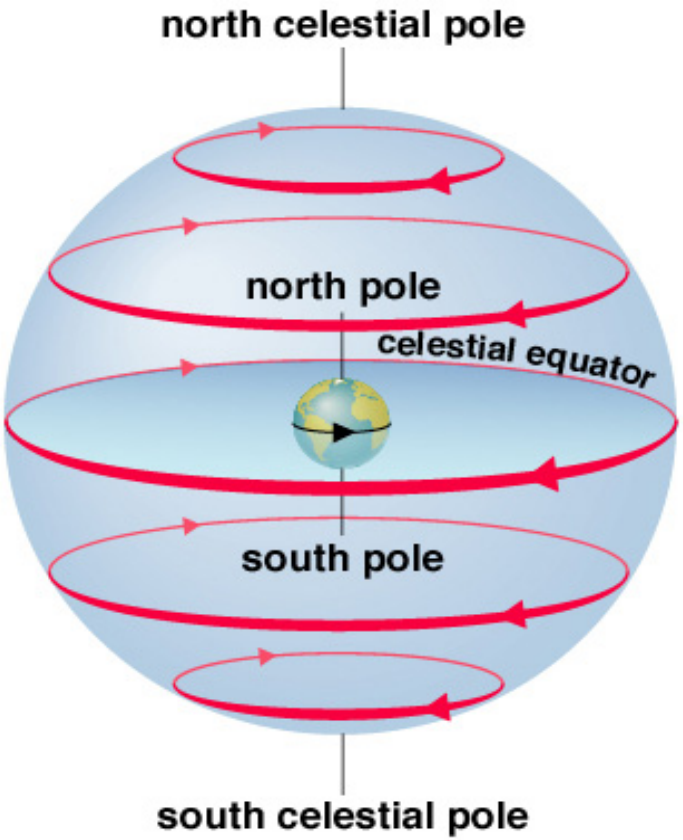
- **North & South Celestial Pole** – extensions of Earth's poles
- **Celestial Equator** – extension of Earth's equator.
- **Ecliptic** –
  - the Sun's apparent path around the celestial sphere.
  - It is also the path of the Earth around the Sun

Equinoxes and Solstices



- **Equinoxes** occur when the Sun's path on ecliptic crosses the celestial equator
- **Solstices** occur when Sun is at highest and lowest points above & below celestial equator

Why do stars rise and set?

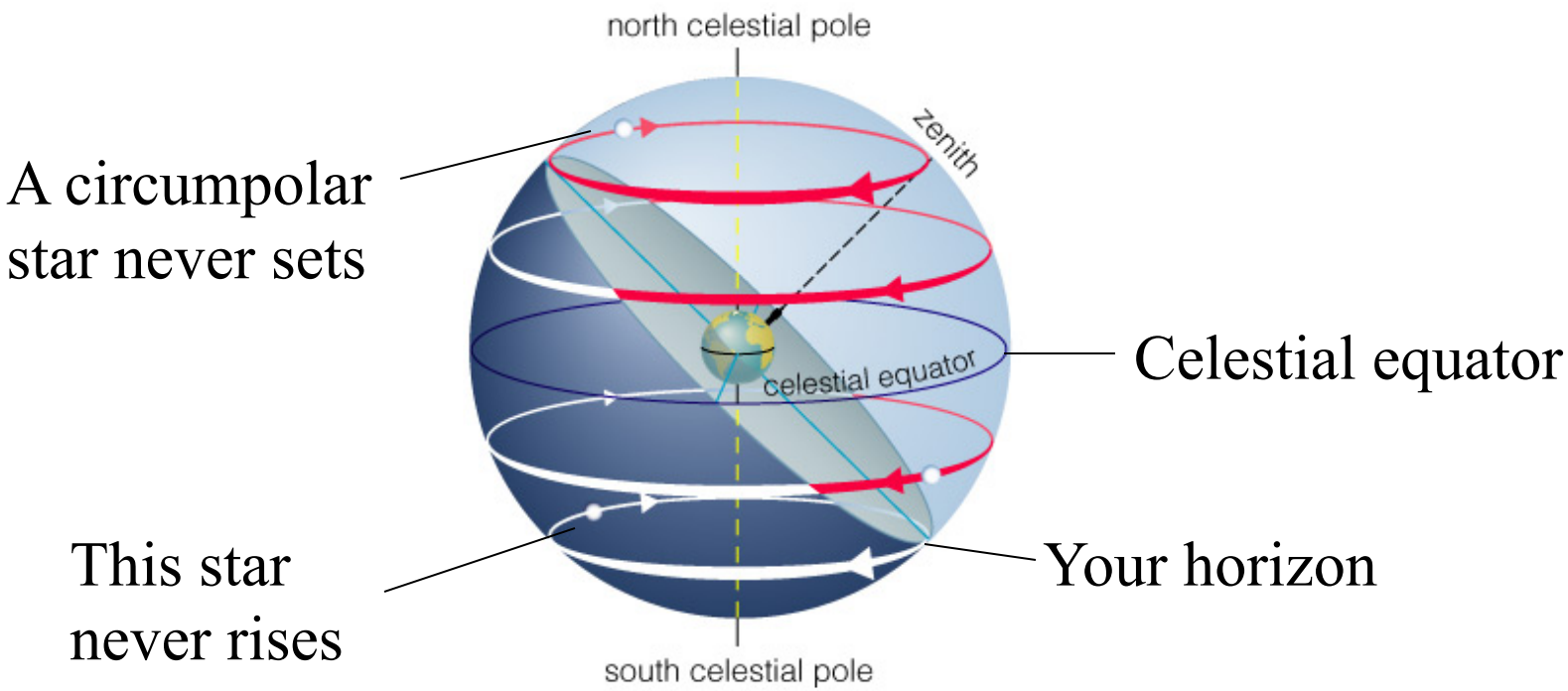


Earth rotates from west to east so stars *appear* to circle from east to west around the celestial poles – **diurnal motion.**

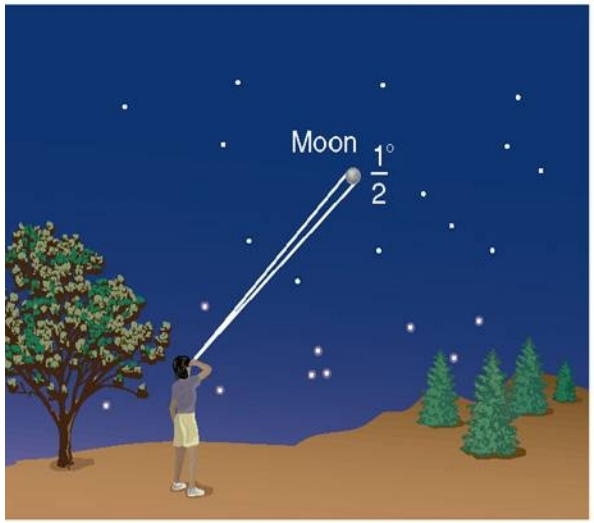
A time-lapse view towards the NCP

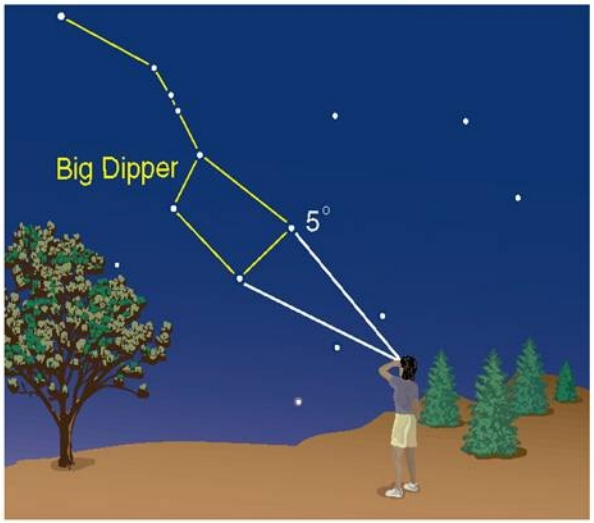
Our view from Northern Hemisphere

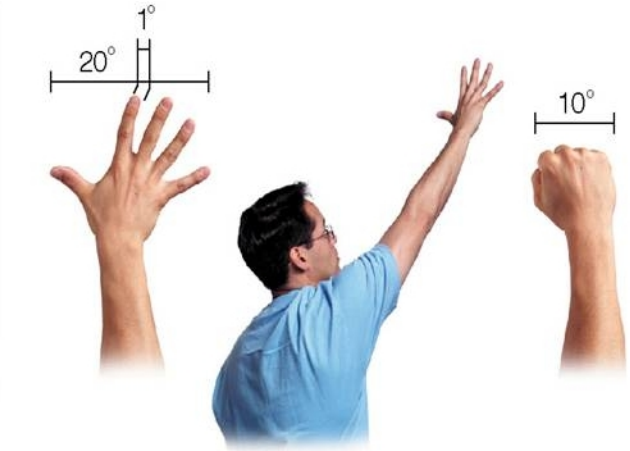
- Stars near the north celestial pole are **circumpolar** and never set.
- We cannot see stars near the south celestial pole.
- All other stars (and Sun, Moon, planets) rise in east and set in west.



Distances in sky are measured using *angles*



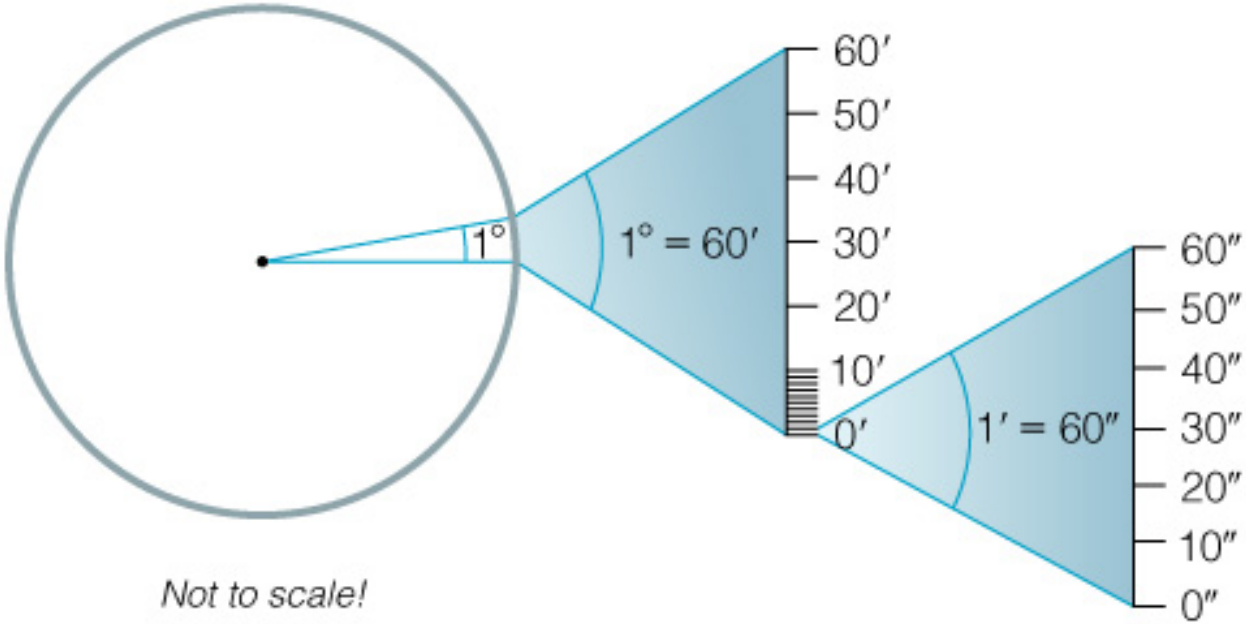




Stretch out your arm as shown here.

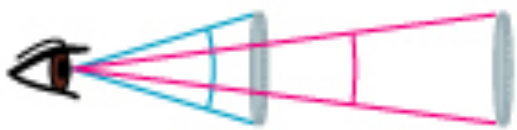
Angular Measurements

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

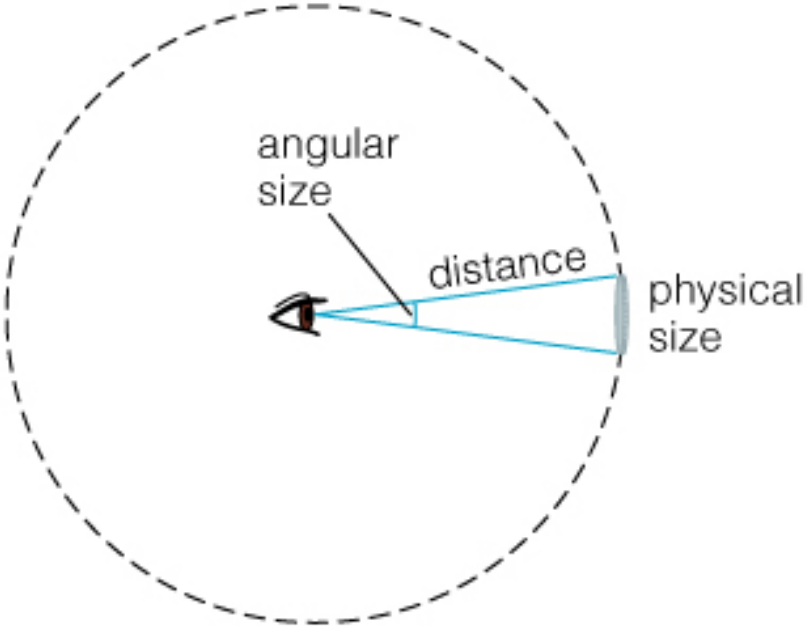


Angular Size

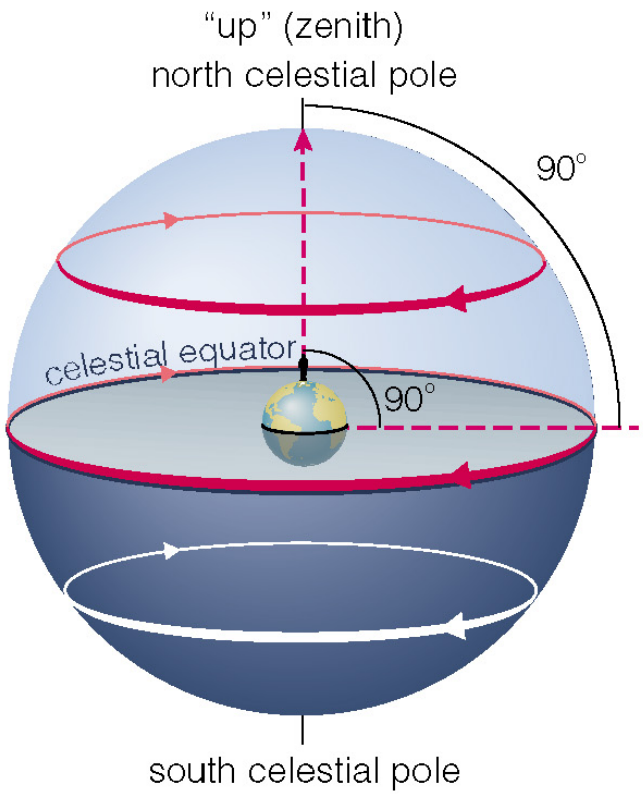
$$\text{angular size} = \text{physical size} \times \frac{360 \text{ degrees}}{2\pi \times \text{ distance}}$$



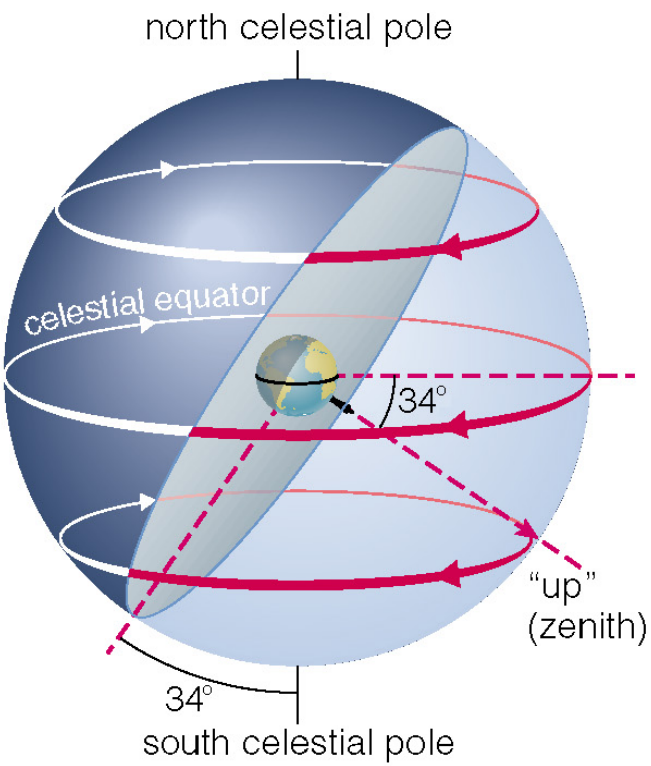
An object's *angular* size appears smaller if it is farther away.



The appearance of the sky varies with your latitude but not longitude.

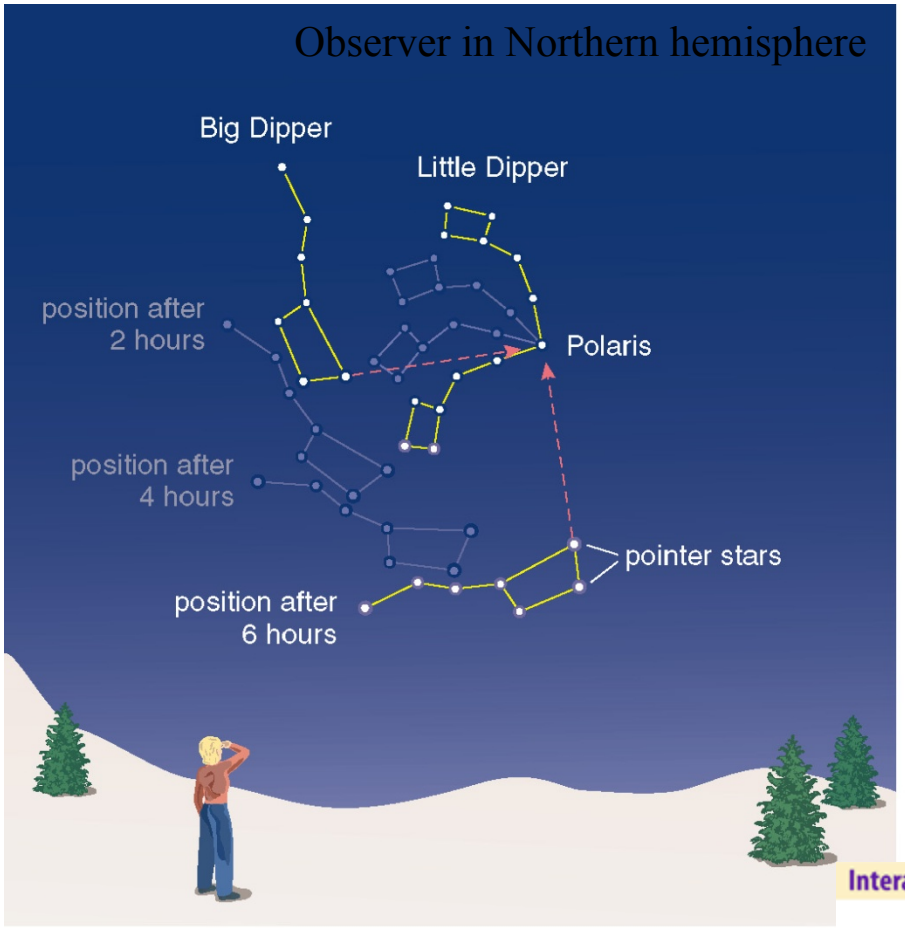


Observer in Northern hemisphere

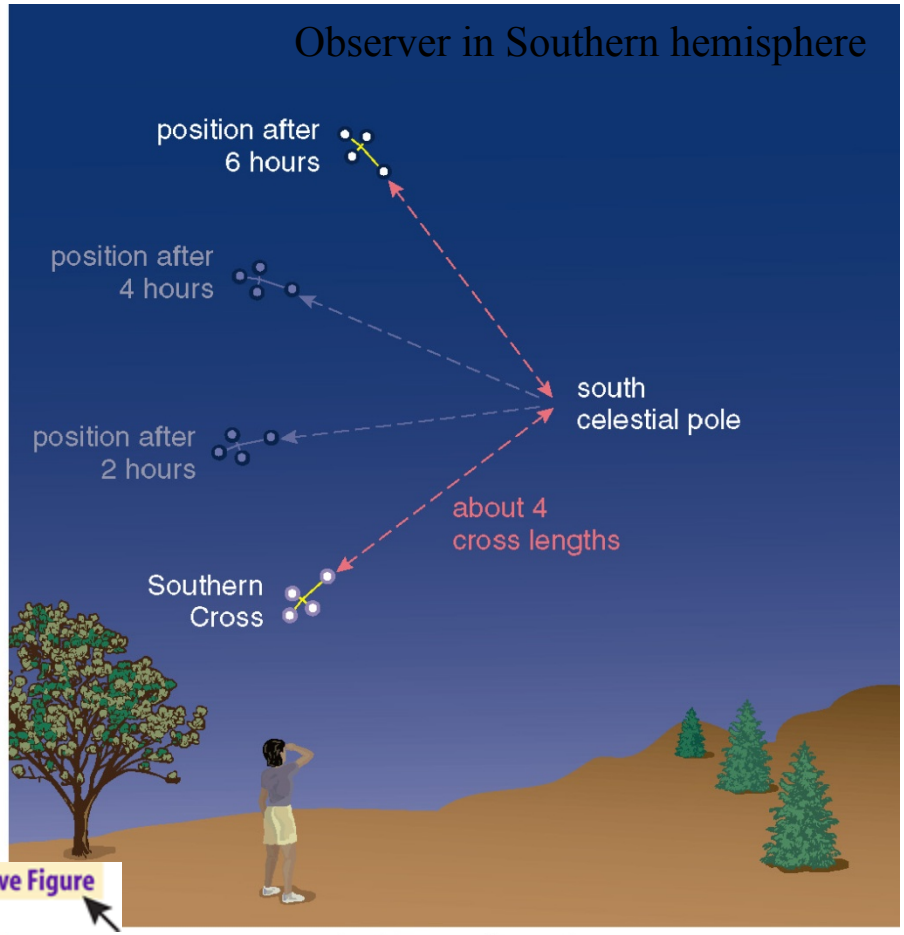


Observer in Southern hemisphere

* Altitude of the celestial pole = your latitude *



looking northward



Interactive Figure

looking southward

The north star (Polaris) can be found using the Big Dipper's pointer stars

Think/Pair/Share

The North Star (Polaris) is 50° above your horizon, due north. Where are you?

A. You are on the equator.
B. You are at the North Pole.
C. You are at latitude 50°N.
D. You are at longitude 50°E.
E. You are at latitude 50°S.

Think/Pair/Share

The North Star (Polaris) is 50° above your horizon, due north. Where are you?

A. You are on the equator.
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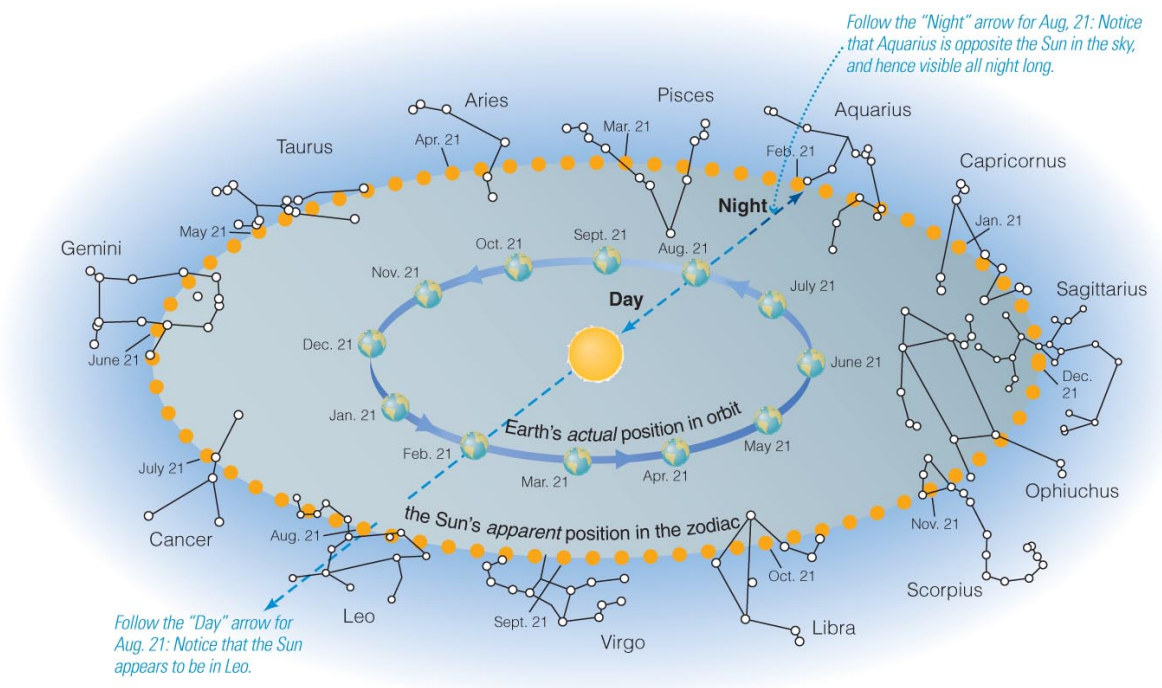
D. You are at longitude 50°E.
E. You are at latitude 50°S.

Why do the constellations we see depend on time of year?

- As the Earth orbits the Sun, the Sun *appears* to move along ecliptic
- At midnight, the stars on our meridian are opposite the Sun in sky.



What have we learned?

Begin 3 minute review

What have we learned?

- What does the sky look like from Earth?

  We see over 2,000 stars and the Milky Way with naked eye; each star is part of a **constellation**.

  An imaginary celestial sphere includes the **celestial poles, celestial equator** and the **ecliptic**; **equinoxes** and **solstices** mark the Sun's motion.

- Why do stars rise and set?

  Earth's **diurnal rotation** makes the sky appear to move east to west.

- Why do the constellations we see depend on latitude and time of year?

  Your **latitude** determines which constellations are hidden by Earth.

  Time of year determines the location of the Sun in the sky.

Thought Question

TRUE OR FALSE?

Earth is closer to the Sun in summer and farther from the Sun in winter.

Thought Question

TRUE OR **FALSE**

Earth is NOT closer to the Sun in summer and farther from the Sun in winter.

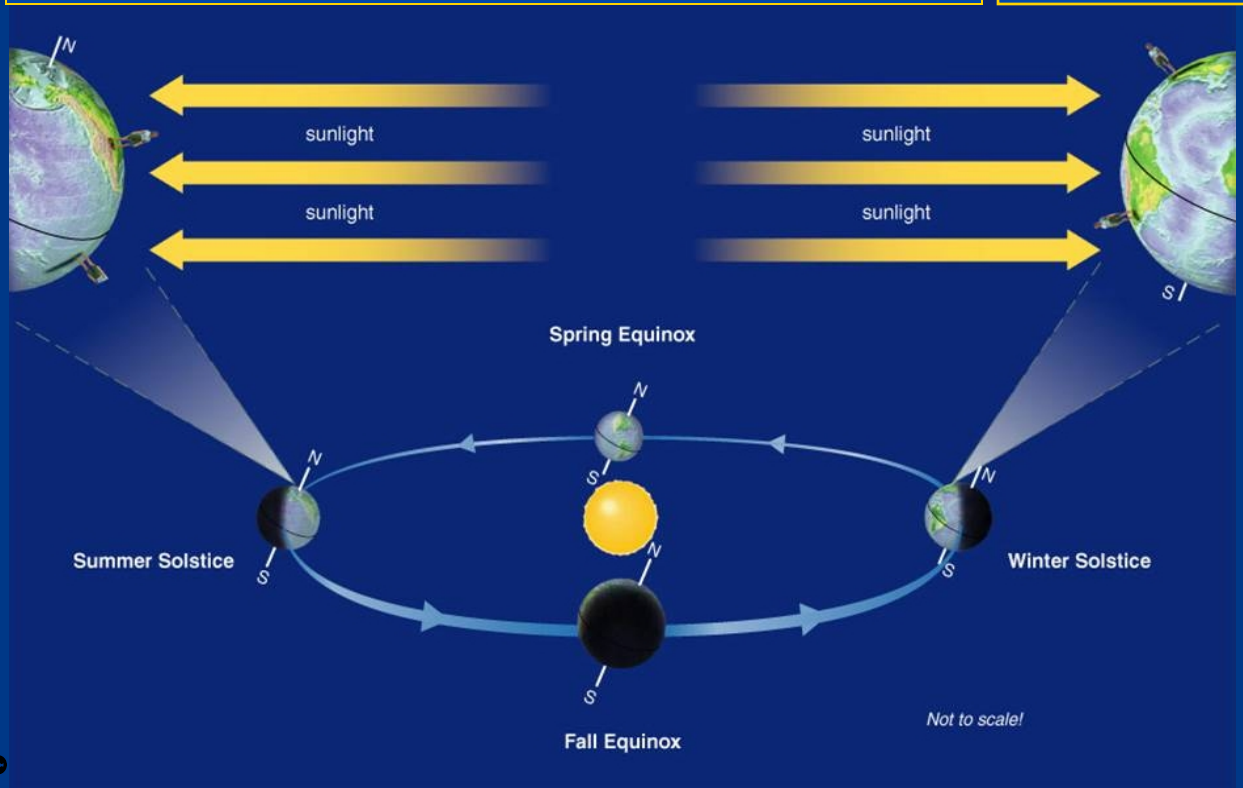
- Seasons are opposite in the North and South hemispheres, so distance cannot be the reason.
- *The real reason for seasons involves* ***Earth's axis tilt***.
- Variation of Earth–Sun distance is small—about 3%; this is overwhelmed by the effects of axis tilt.

What causes the seasons?

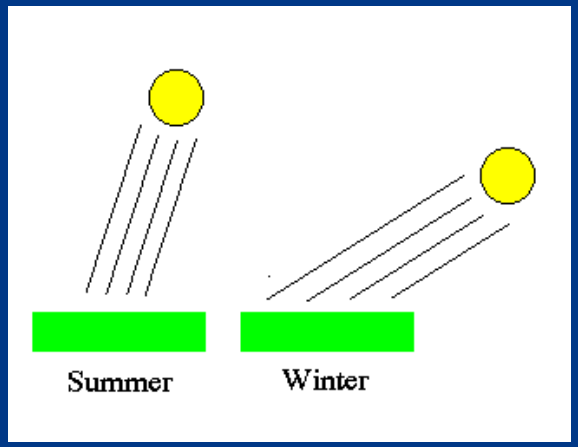
- Seasons depend on ***tilt of Earth's axis*** affecting **directness** & **strength** of sunlight, NOT distance from the Sun.
- Direct sunlight is stronger, causing summer; indirect sunlight is weaker, causing winter.
- Length of the day also plays a role – longer in summer, shorter in winter, etc.

We define four seasonal points:

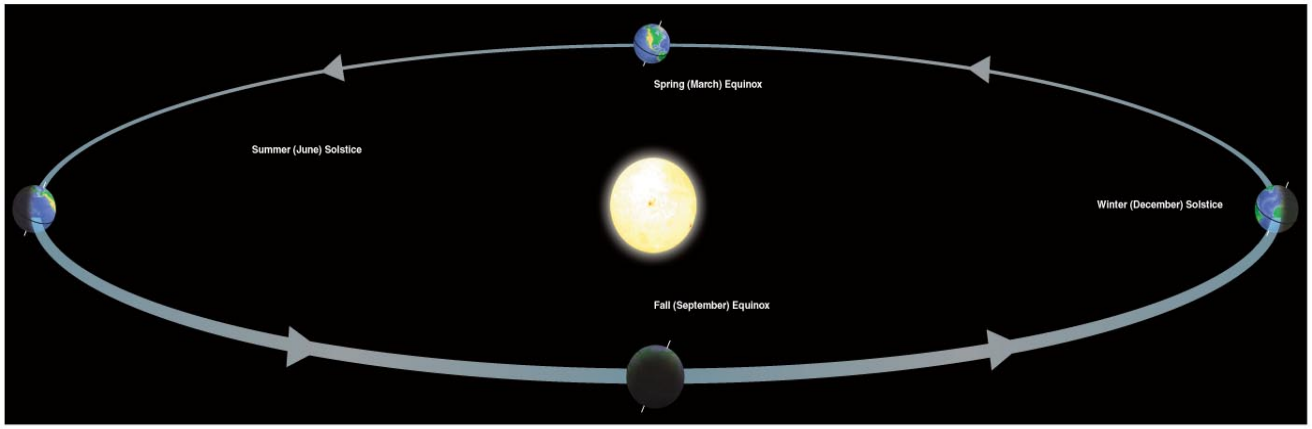
- ✓ Summer **solstice** (June)
- ✓ Winter **solstice** (December)
- ✓ Spring (vernal) **equinox** (March)
- ✓ Fall (autumnal) **equinox** (September)



Sunlight is more concentrated and stronger when the sun is higher in summer; but less concentrated and weaker in winter



Earth's axis tilt causes the seasons!

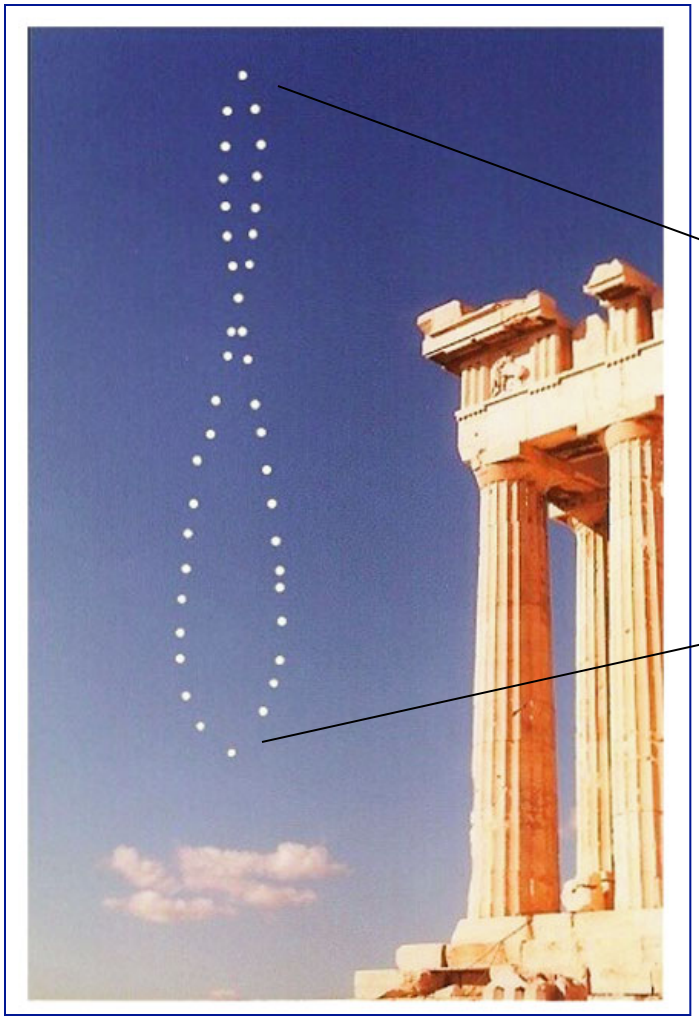


Interactive Figure

- Earth's axis always points towards North Celestial Pole so its orientation *relative to the Sun* changes as Earth orbits the Sun.
- Summer occurs in your hemisphere when sunlight hits more directly; winter occurs when sunlight is less direct.
- **The TILT of Earth's AXIS** is the key to the seasons; without it, no seasons.
- Variation of Earth–Sun distance is small (about 3%)

Sun’s altitude changes with seasons

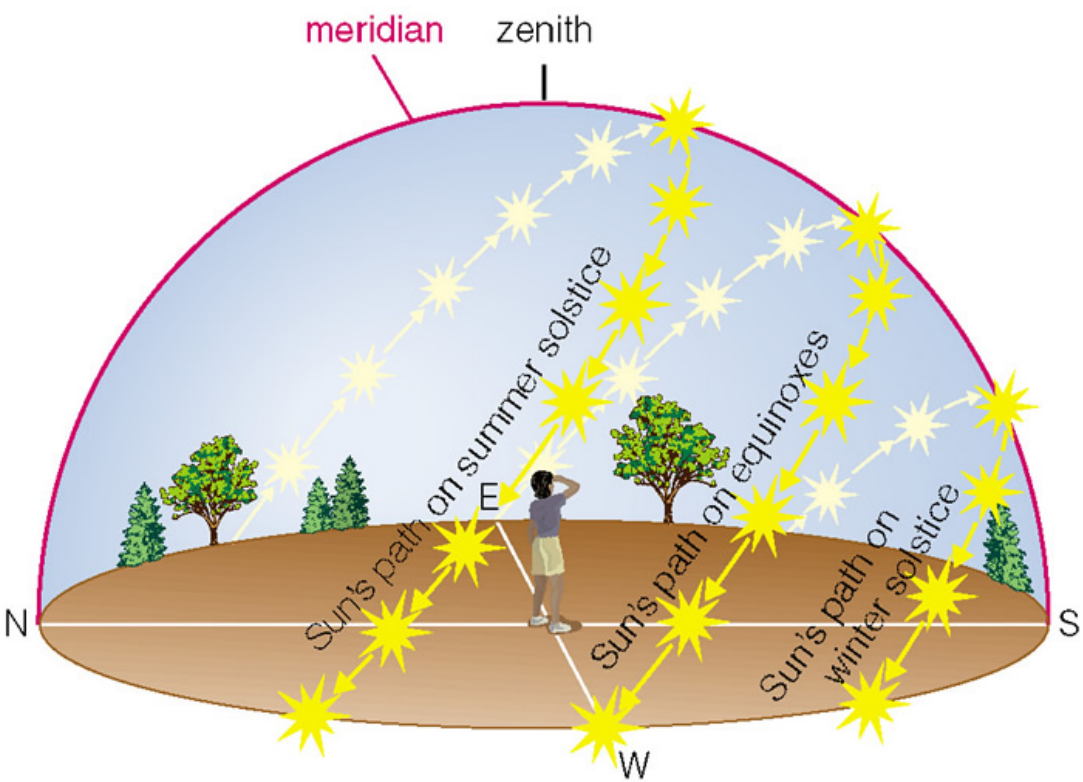
These images of the Sun were taken at *the same time of the day over the course of a year*. They show it is higher or lower in the sky at the same time of the day throughout the year.



Sun’s position at noon at **summer solstice**: higher altitude means more direct, stronger sunlight.

Sun’s position at noon at **winter solstice**: lower altitude means less direct, weaker sunlight.

Solstices and equinoxes are marked by the Sun's path across the sky.



Summer solstice:

Highest and longest path of Sun; rises and sets most northerly (Jun 21)

Winter solstice:

Lowest and shortest path of Sun; rises and sets most southerly (Dec 21)

Equinoxes:

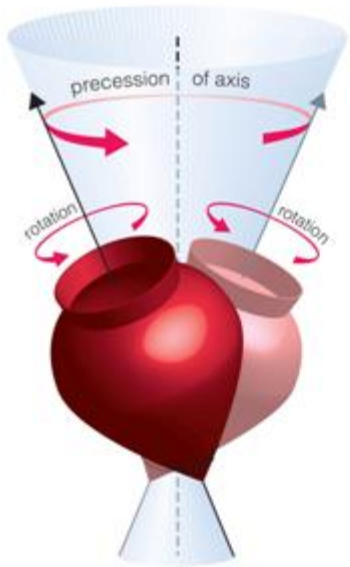
Sun rises exactly due east and sets precisely due west. (Mar & Sep)

What is the longest day of sunlight? The shortest? What days are equal in light and darkness?

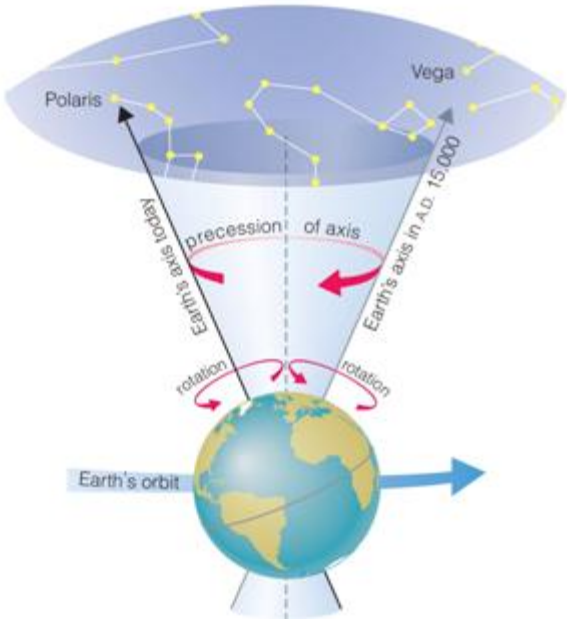
How does the orientation of Earth's axis change with time?

Although it seems fixed on human time scales, it actually "precesses" (changes direction) over 26,000 years.

— Polaris won't always be (and wasn't) the North Star.
— Positions of equinoxes also shift around orbit.
— Tilt changes slightly over very long periods.



Earth's axis precesses like the axis of a spinning top



What have we learned?

Begin 3 minute review

What have we learned?

- What causes the seasons?

The tilt of the Earth's axis causes sunlight to hit Earth more directly during summer and less directly during winter.

- How do we mark the progression of the seasons?

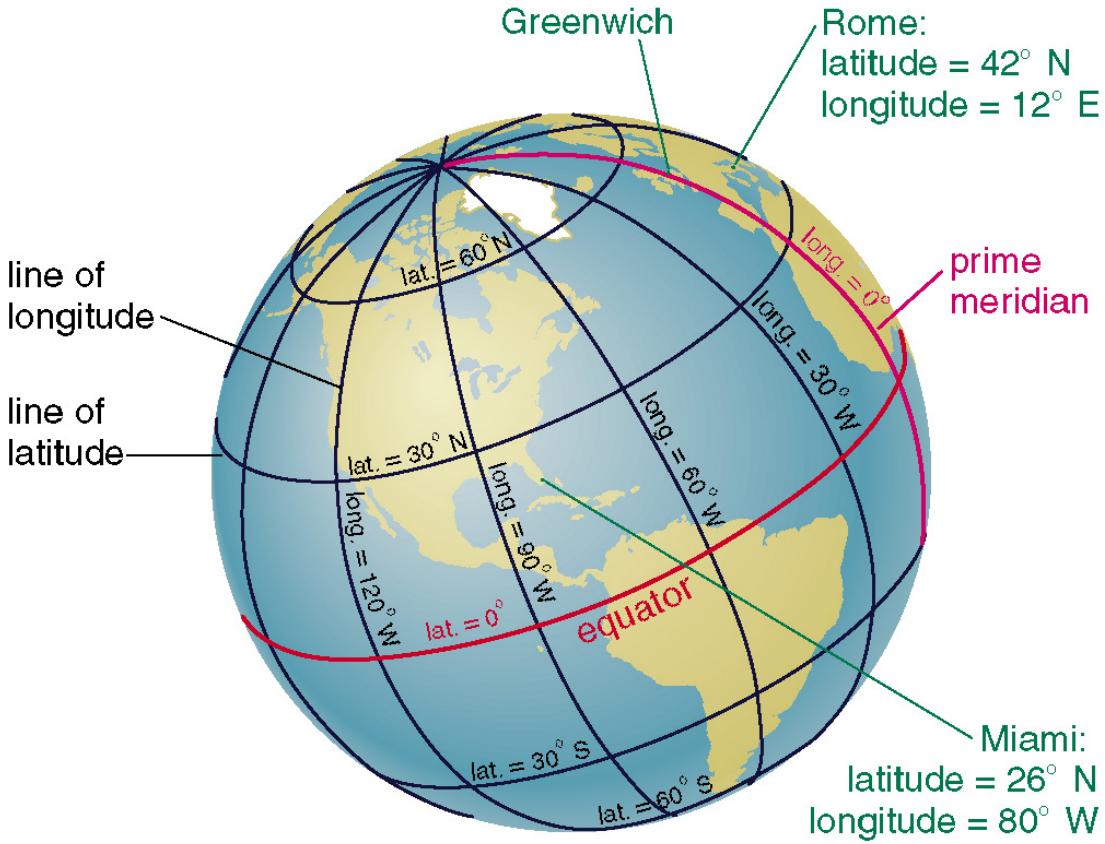
The **summer and winter solstices** are when the Northern Hemisphere gets its most and least direct sunlight, respectively. The **spring and fall equinoxes** are when both hemispheres get equally direct sunlight.

- How does orientation of Earth's axis change with time?

The *tilt* remains about 23.5 degrees relative to ecliptic, but slowly changes *direction* over a 26,000 year precession cycle.

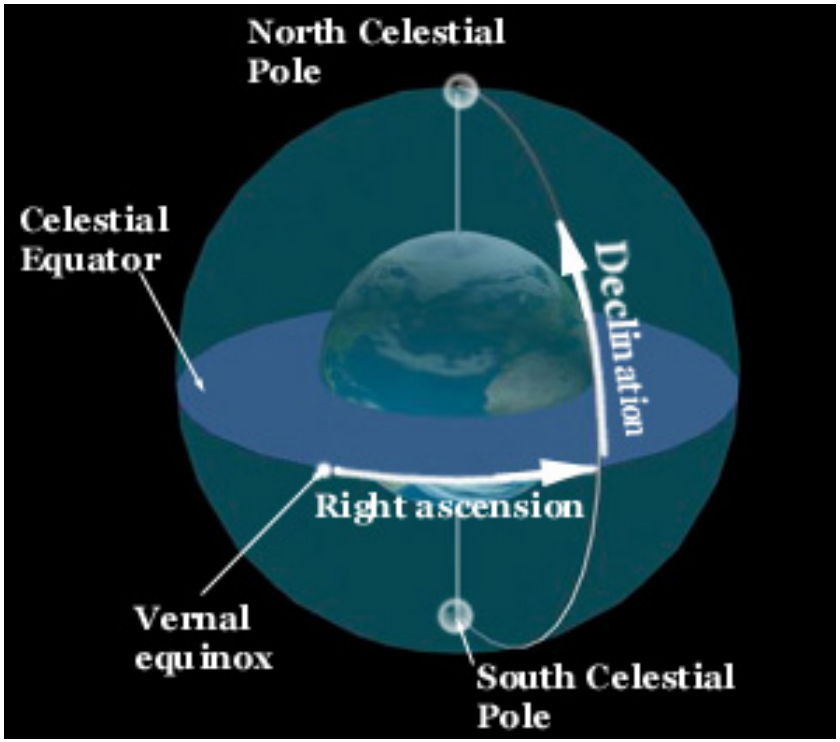
Review: Coordinates on the Earth

- **Latitude**: position *north or south* of equator
- **Longitude:** position *east or west* of prime meridian (Greenwich, England)



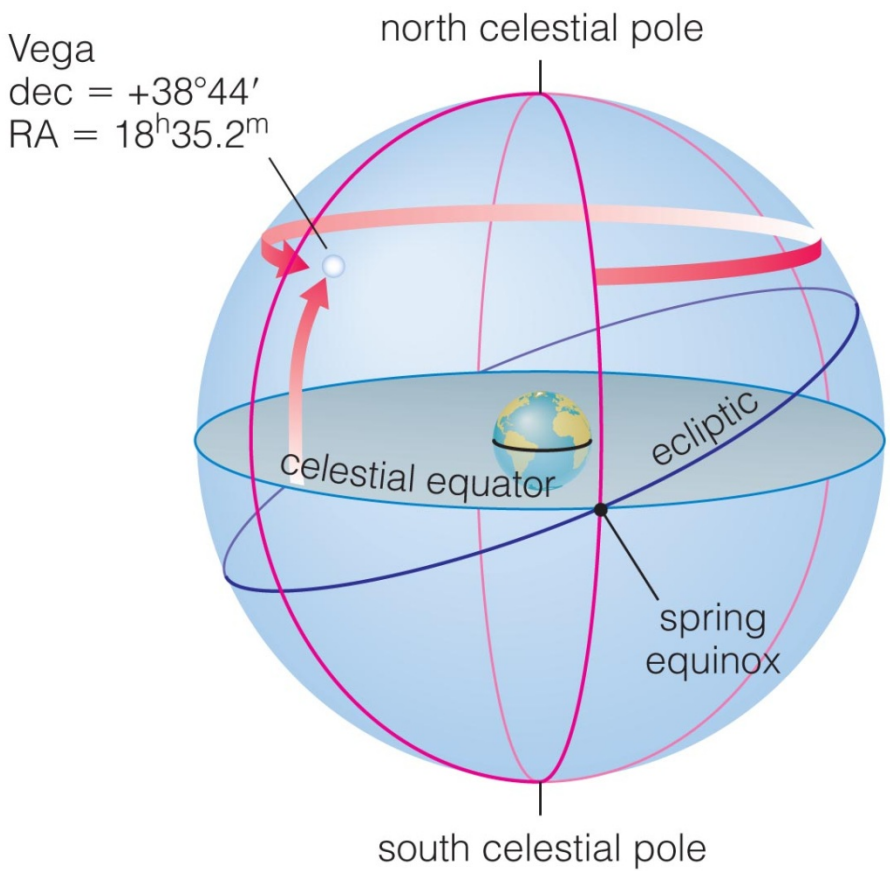
How do we locate objects on the celestial sphere?

- Location of objects on the celestial sphere is similar to latitude and longitude but are called *declination* and *right ascension.*
- To locate an object in the sky you need its right ascension and its declination - like finding a city with latitude and longitude.



- **Declination:** angular distance in degrees, arcminutes, arcseconds north or south of the celestial equator.
- **Right ascension:** distance in hours, minutes, seconds *eastward* with respect to spring equinox.

Celestial Coordinates of Vega



- **Right ascension:**
  - Vega's RA of 18^h35^m (out of 24^h) places it most of the way around celestial sphere from spring equinox.
- **Declination:**
  - Vega's dec of +38°44' puts it almost 39° north of celestial equator.

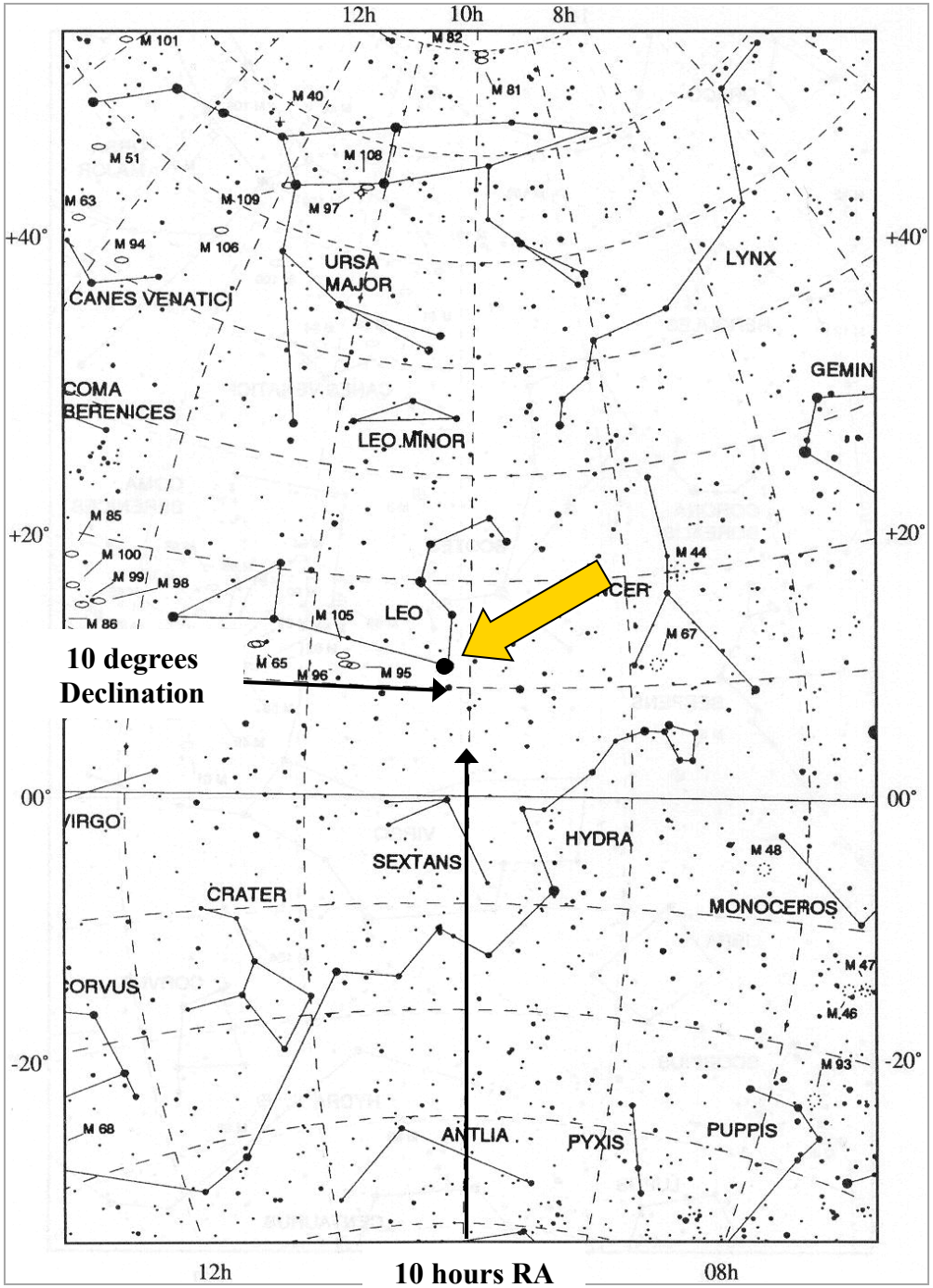
Coordinates in the Sky

Right Ascension and Declination

This chart shows part of the celestial sphere. **Note the lines of right ascension and declination**; these coordinates allow us to specify the location of any object.

Example:

What is the right ascension and declination of the star Regulus in Leo?



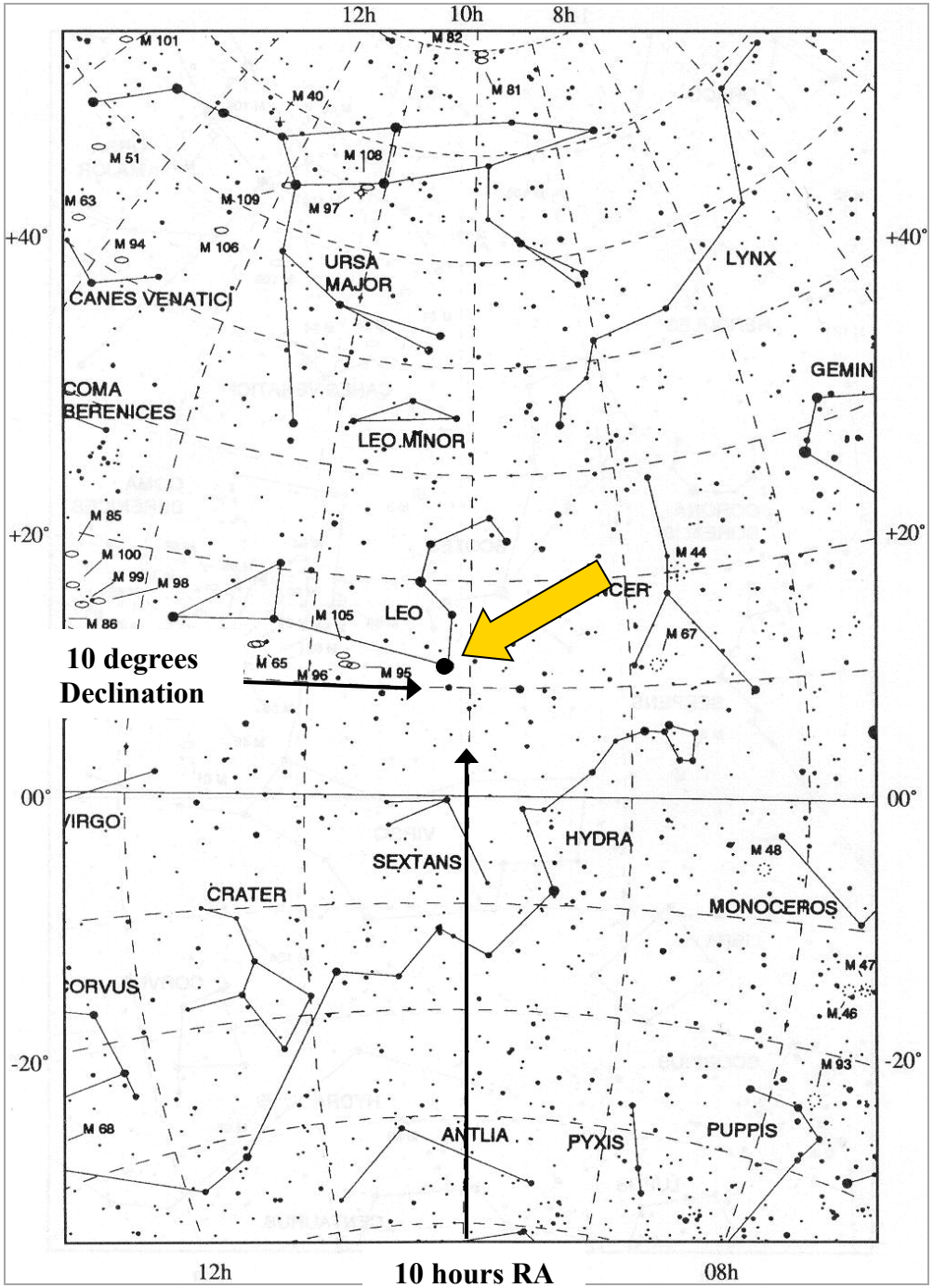
Coordinates in the Sky

Right Ascension and Declination

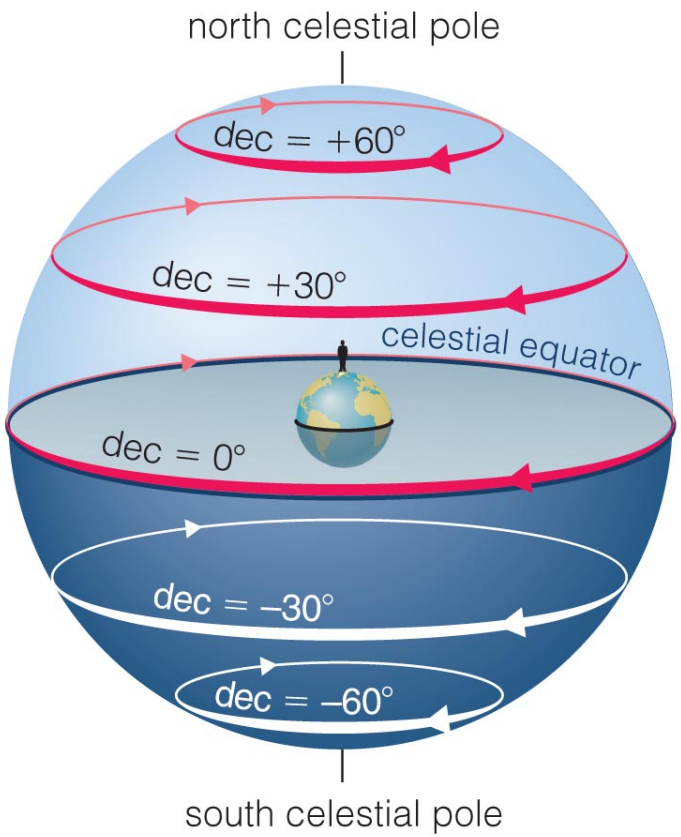
This chart shows part of the celestial sphere. **Note the lines of right ascension and declination**; these coordinates allow us to specify the location of any object.

Example:

The star Regulus in Leo (marked by arrow is near **10 hours, 10 min right ascension** and **declination 12 degrees north** of the celestial equator.

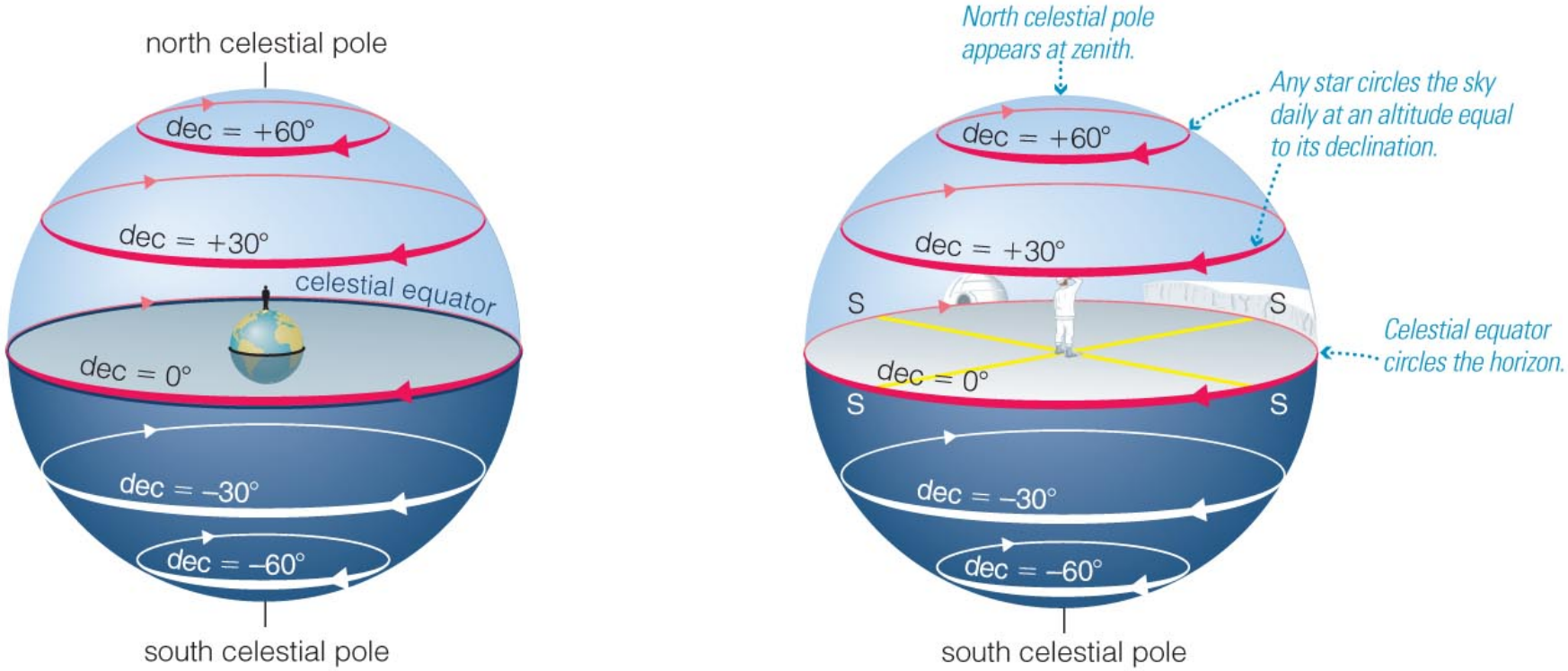


How do stars move through the sky?



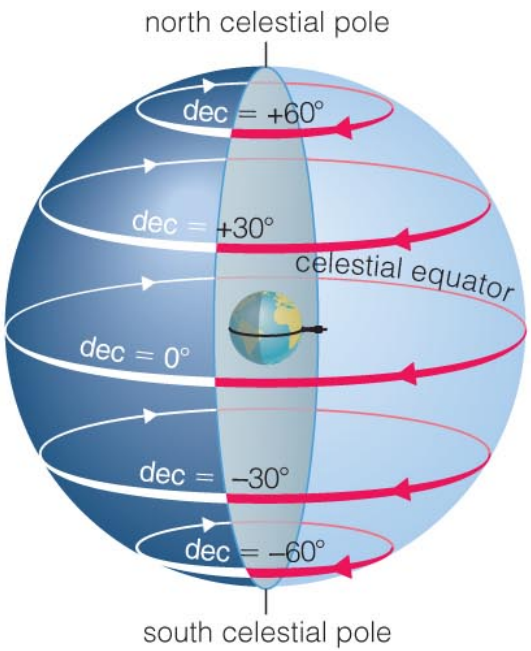
- A star's path depends on your latitude and the star's declination.
- But a star's RA & Dec coordinates do *not* change (in the short term).

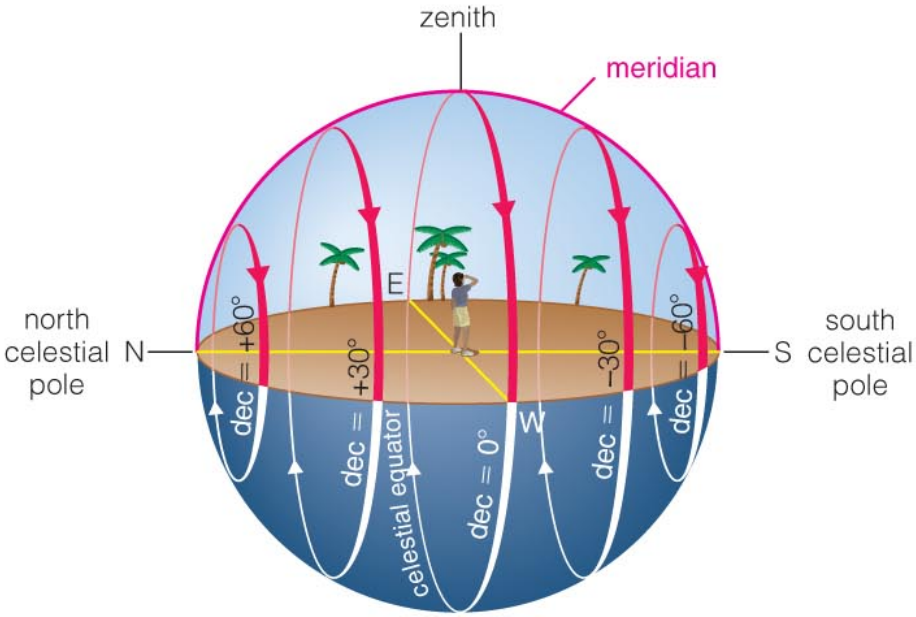
Star Paths at North Pole



- Stars move parallel to horizon (same altitude) as Earth rotates.
- Star's altitude above horizon equals its declination.
- Stars remain above (or below) horizon all year.

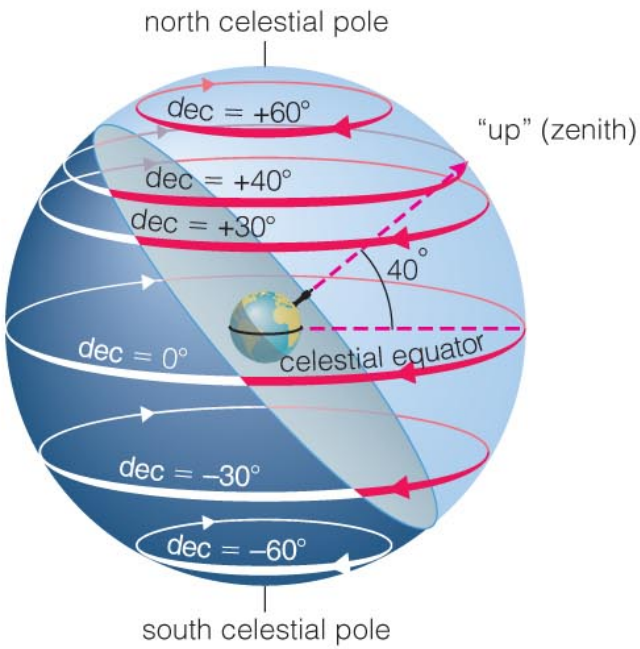
Star Paths at Equator

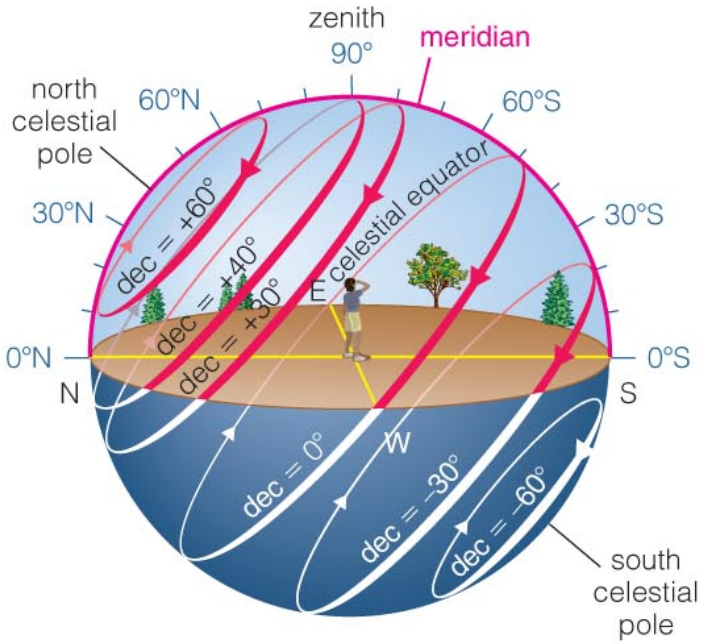




- Stars rise/set perpendicular to horizon.
- Celestial equator passes overhead.
- Stars remain above horizon for exactly 12 hours each day.

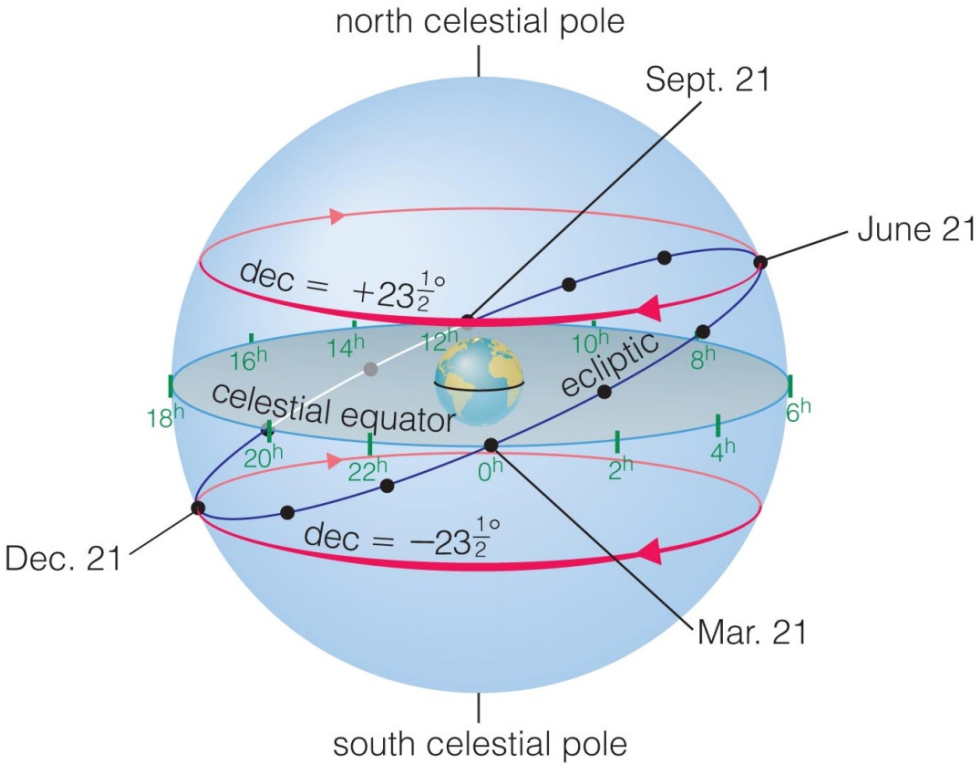
Star Paths in Northern Hemisphere





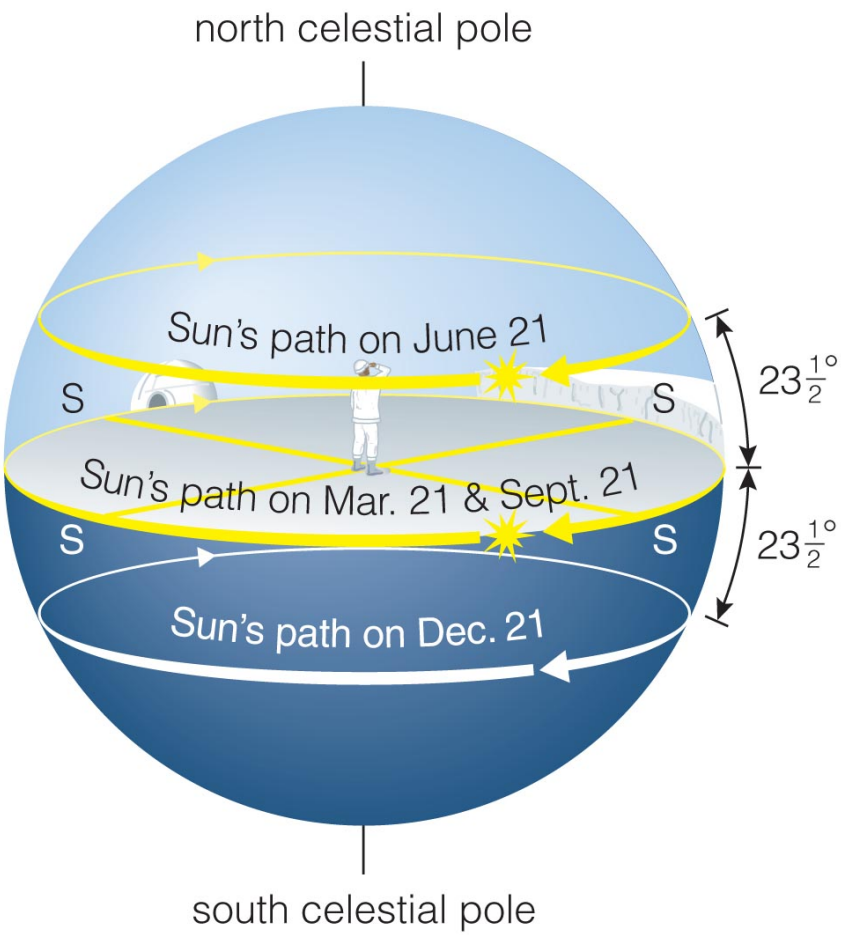
- In northern hemisphere, some stars are circumpolar.
- Celestial equator is in southern part of sky.

How does Sun move thru sky?



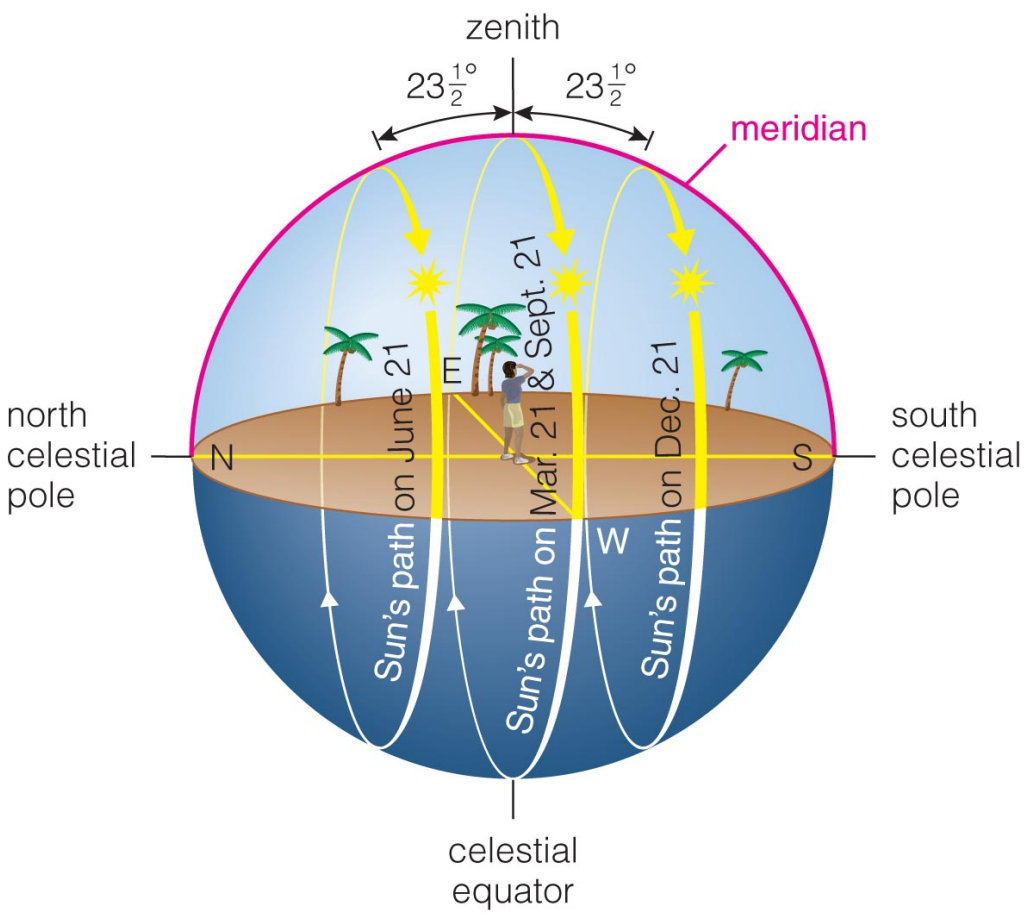
- The Sun's RA and Dec *change* as it travels along the ecliptic during the year.
- Sun's declination is negative in fall and winter and positive in spring and summer.

Sun's Path at North Pole



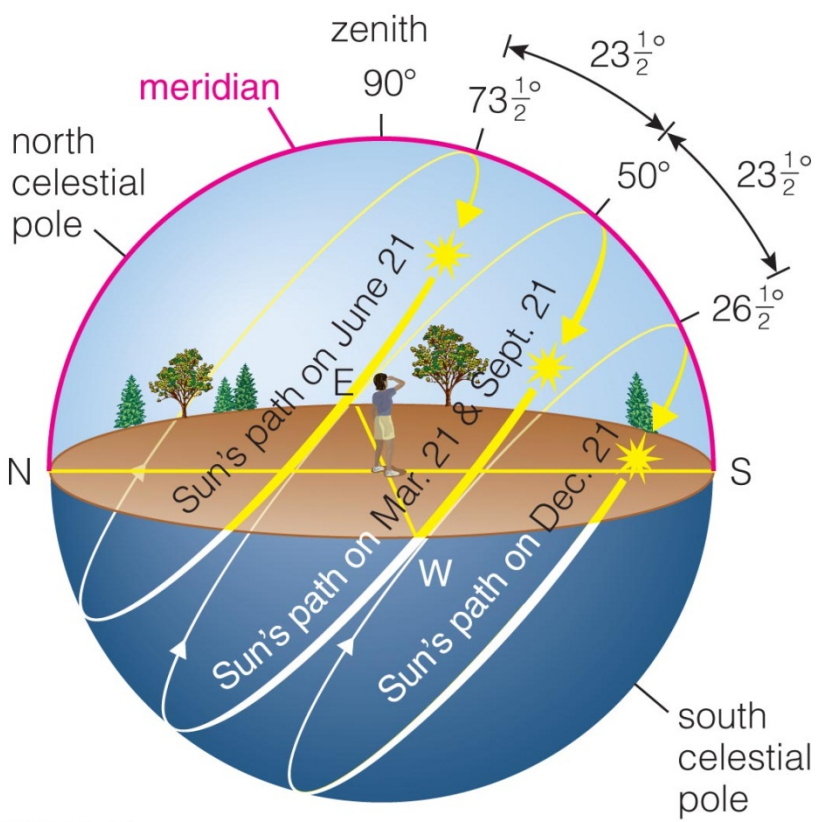
- Sun above (and moves parallel to) horizon from spring equinox to fall equinox.
- Sun below horizon from fall equinox to spring equinox
- Altitude barely changes during a day.

Sun's Path at Equator



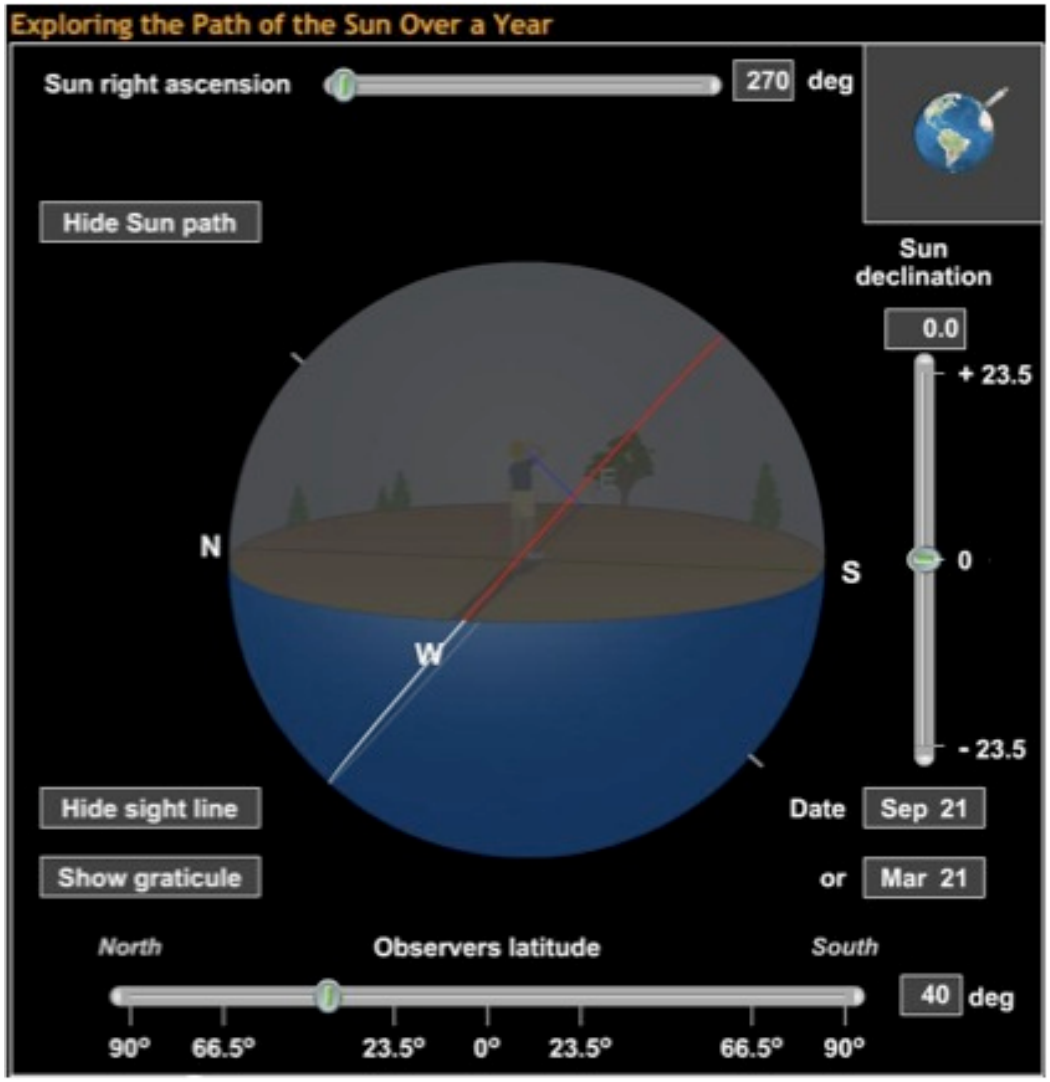
- Sun rises and sets perpendicular to horizon.
- North of celestial equator during spring and summer
- South of celestial equator during winter and fall

Sun's path in Northern Hemisphere



- Sun rises and sets at an angle to horizon depending on latitude
- Sun rises/sets farther north during spring & summer
- Sun rises/sets farther south during fall/winter

Sun’s Path in the Sky



What have we learned?

Begin 3 minute review

What have we learned?

- How do we locate objects on the celestial sphere?

Each point on the celestial sphere has a particular **right ascension** (like longitude) and **declination** (like latitude).

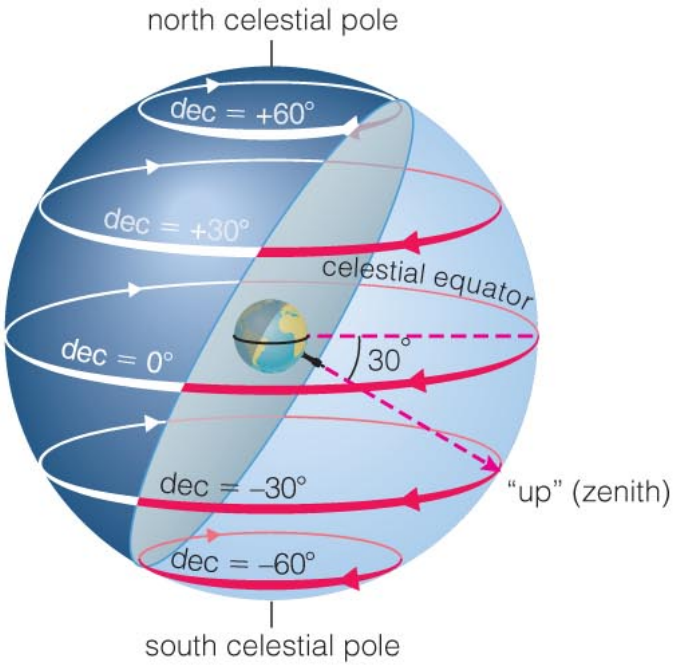
- How do **stars** move through the local sky?

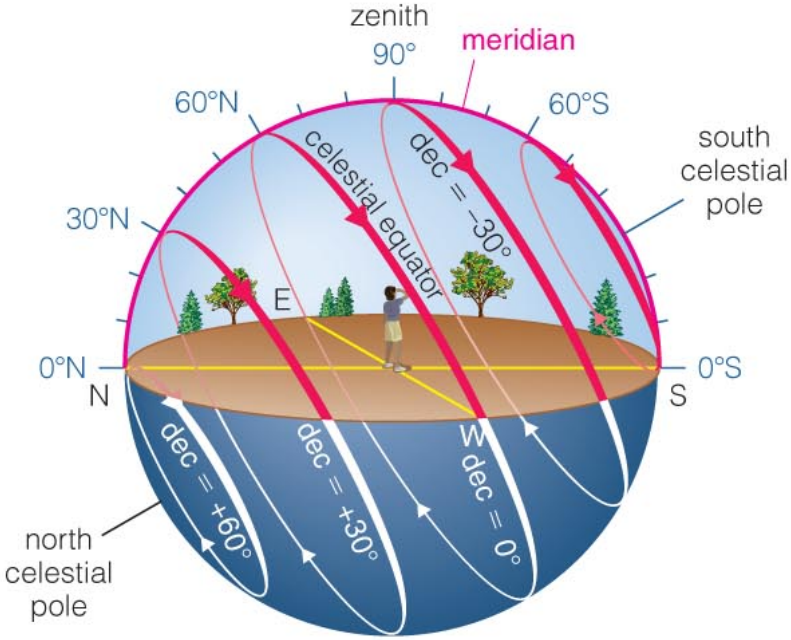
Their paths depend on your latitude and the star's declination.

- How does the **Sun** move through the local sky?

Sun moves like the stars except its declination depends on your latitude and the time of year.

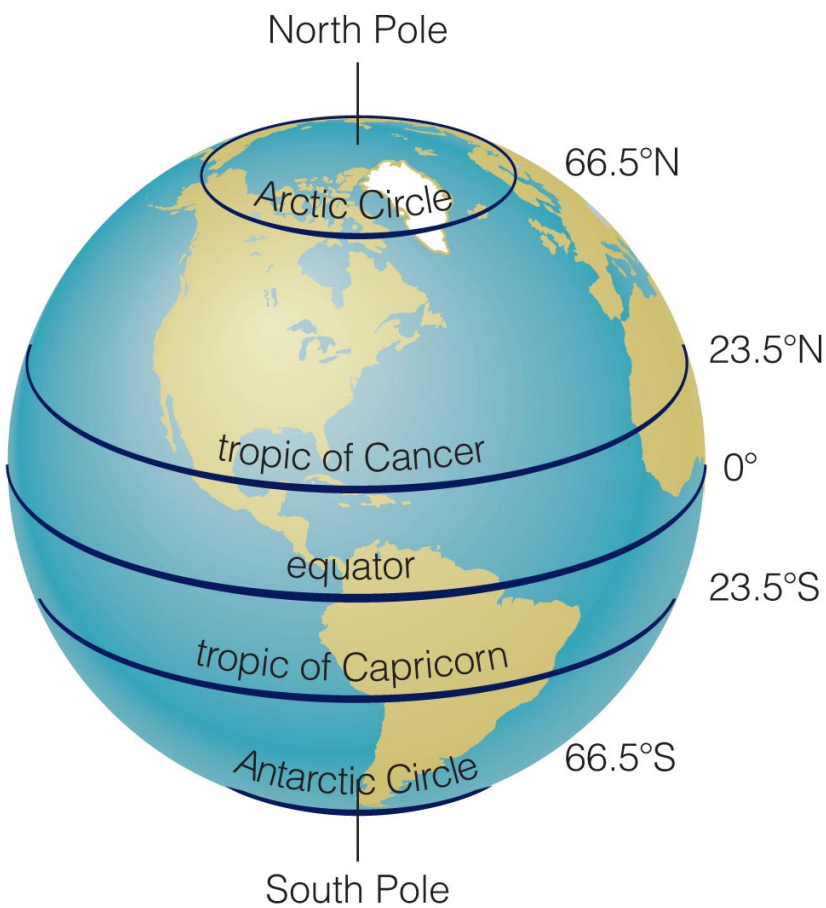
Star Paths in Southern Hemisphere





- In southern hemisphere, stars with dec < (your latitude – 90°) are circumpolar.
- Celestial equator is in north part of sky.

Special Latitudes



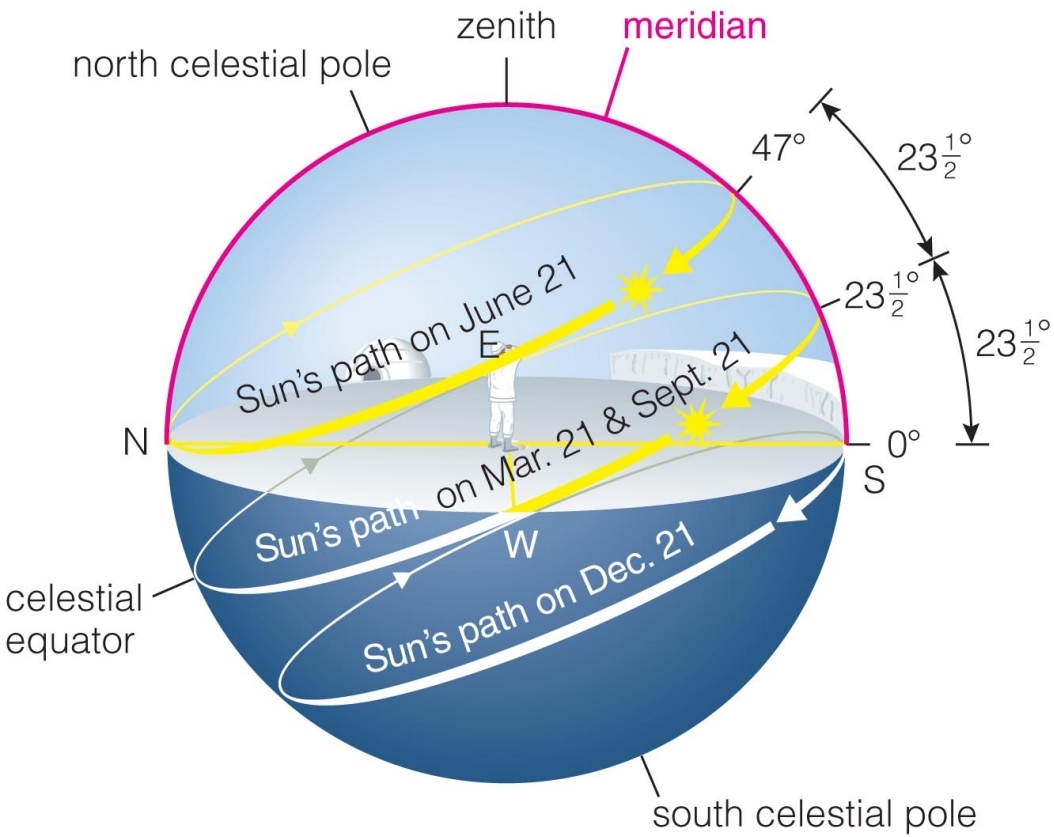
Northern hemisphere:

- North Pole
- Arctic Circle (66.5°N)
- Tropic of Cancer (23.5°N)

Southern hemisphere

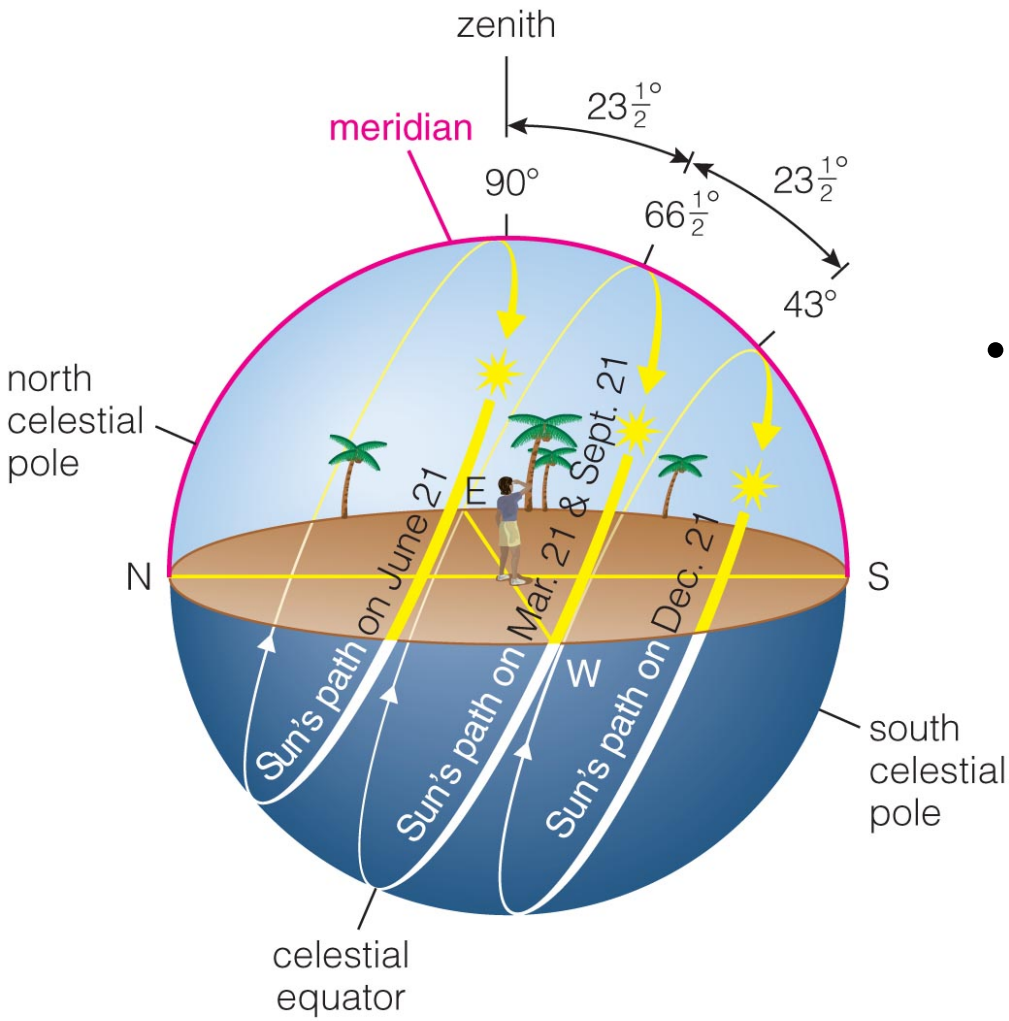
- South Pole
- Antarctic Circle (66.5°S)
- Tropic of Capricorn (23.5°S)

Sun's Path at 66.5 N (Arctic Circle)



- Sun grazes horizon at midnight on summer solstice.

Sun's Path at 23.5 N



- Sun passes through zenith at noon on summer solstice.