Today

- Appearance of the Sky
  - Orientation
  - Motion of sky
  - Seasons
  - Precession (?)

The Principle of Doubt

- Hypotheses can be *rejected* but never completely *confirmed.*

- At best, a theory can be *adequate* for describing a specific set of phenomena.

- Do not trust - verify through experiment.

- Simple theories are preferable to complicated theories (Occam's Razor)

  – Any theory can be made complicated enough to explain anything

  – Elegance and Understanding trump Age and Authority

  – If a theory has its predictions come true, we are obliged to acknowledge its efficacy, even if it means rejecting something we formerly believed.

Measurement Uncertainty

- No experiment is perfect
- Experimental uncertainty is often the difference between rejecting a hypothesis and an ambiguous result
- It is important to quantify both measurements AND their accuracy

e.g., Newton's constant:

$$G = (6.67428 \pm 0.00067) \times 10^{-11} \ \mathrm{m^3 \ kg^{-1} \ s^{-2}}. \quad (0.01\%)$$
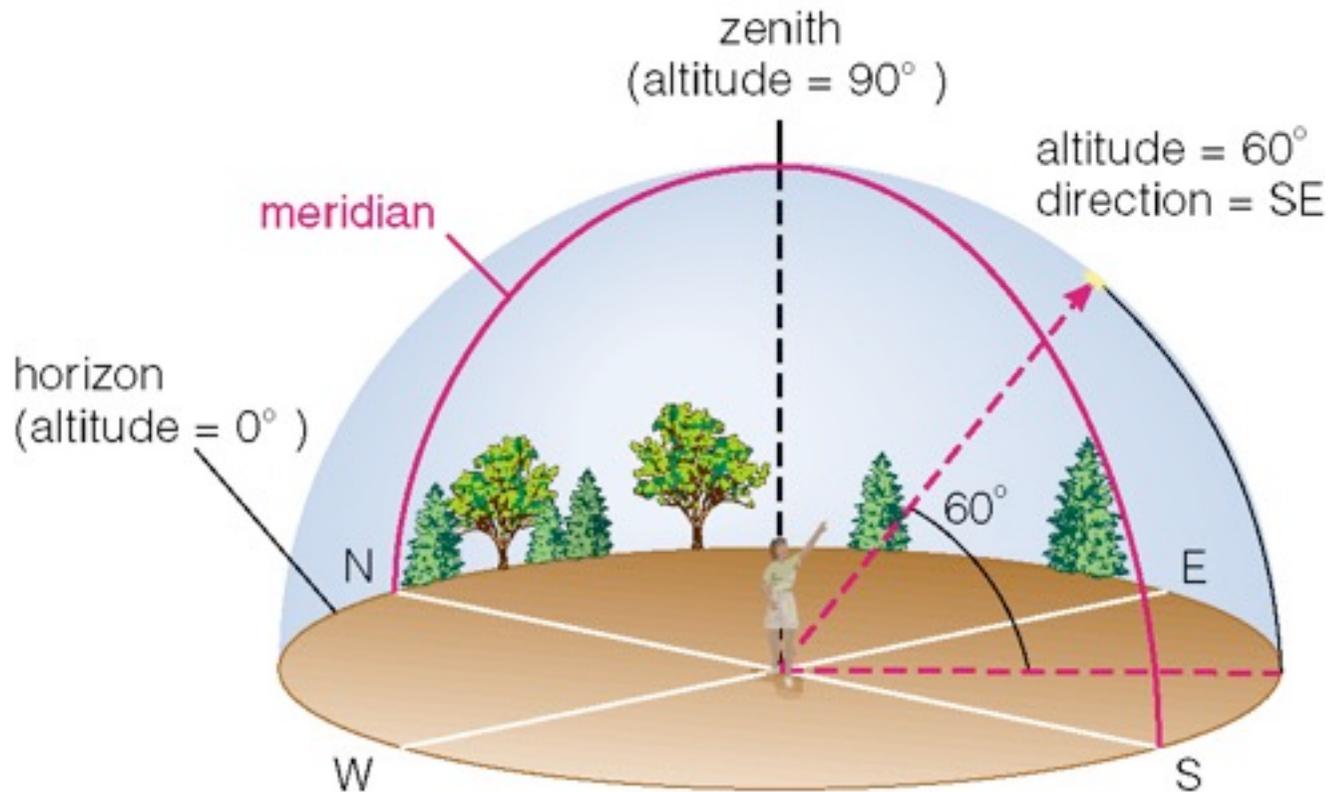
the distance to the center of the Milky Way

$$R_0 = 26,000 \pm 2,000 \ \mathrm{light \ years} \qquad (8\%)$$

The Appearance of the Sky

The Local Sky

An object's **altitude** (above horizon) and **direction** (along horizon) specify its location in your local sky.

zenith
(altitude = 90°)

altitude = 60°
direction = SE

meridian

horizon
(altitude = 0°)

60°

N
W
E
S

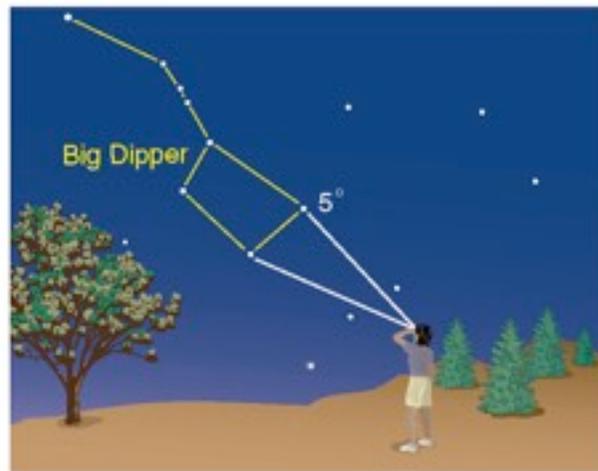*Everything is measured in angles!*
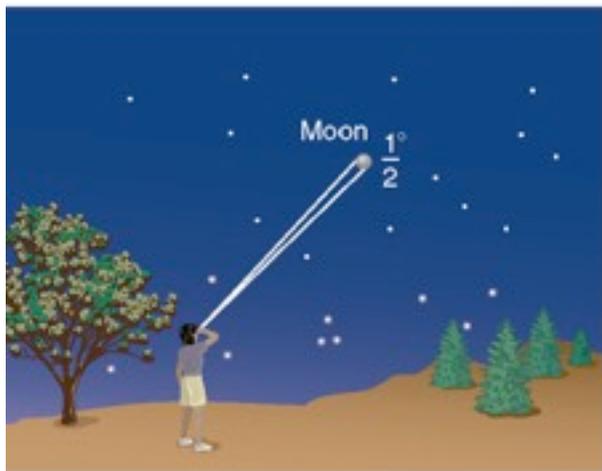
The Local Sky

Zenith: The point directly overhead

Horizon: All points 90° away from zenith

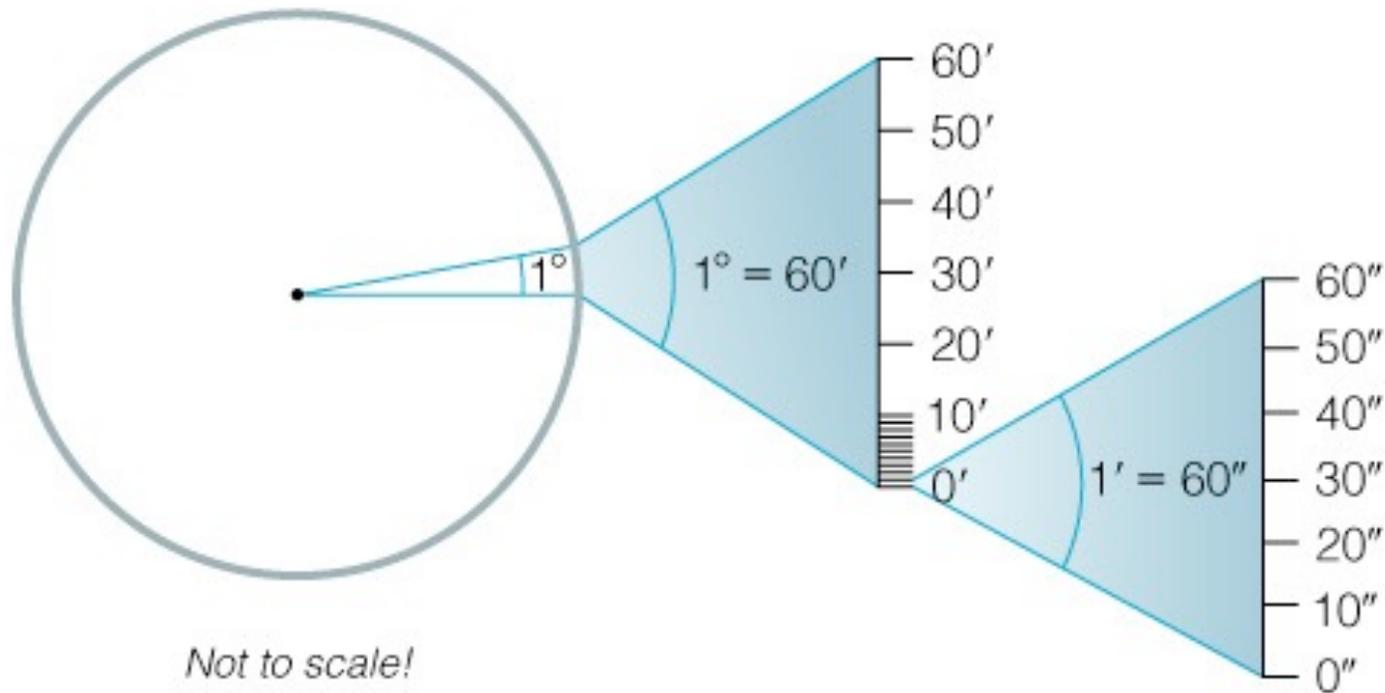**Meridian:** Line passing through zenith and connecting N and S points on the horizon
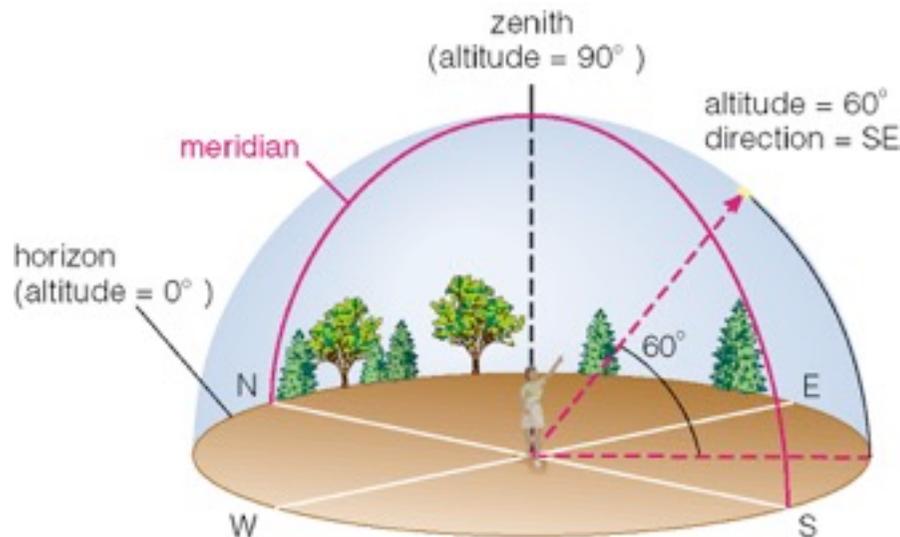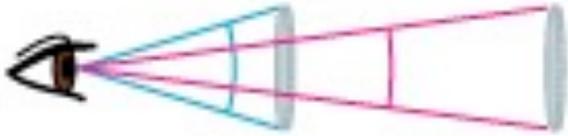
We measure the sky using *angles*

Angular Measurements

- Full circle $=360^{\circ}$
- $1^{\circ} = 60'$ (arcminutes)
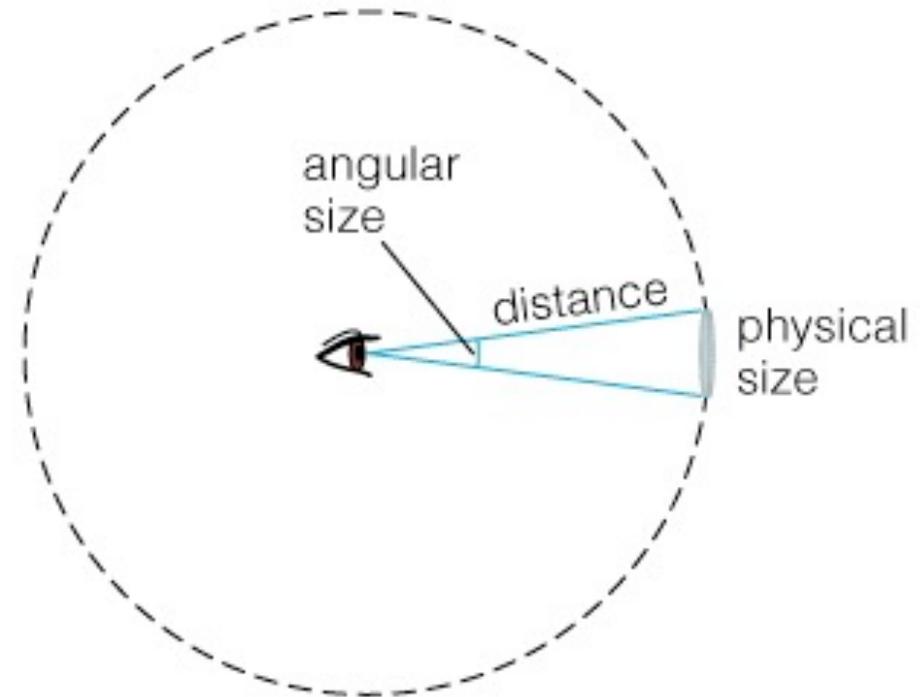- $1' = 60''$ (arcseconds)

Not to scale!

Angular Size

$$\text{angular size} = \text{physical size} \times \frac{360 \text{ degrees}}{2\pi \times \text{ distance}}$$
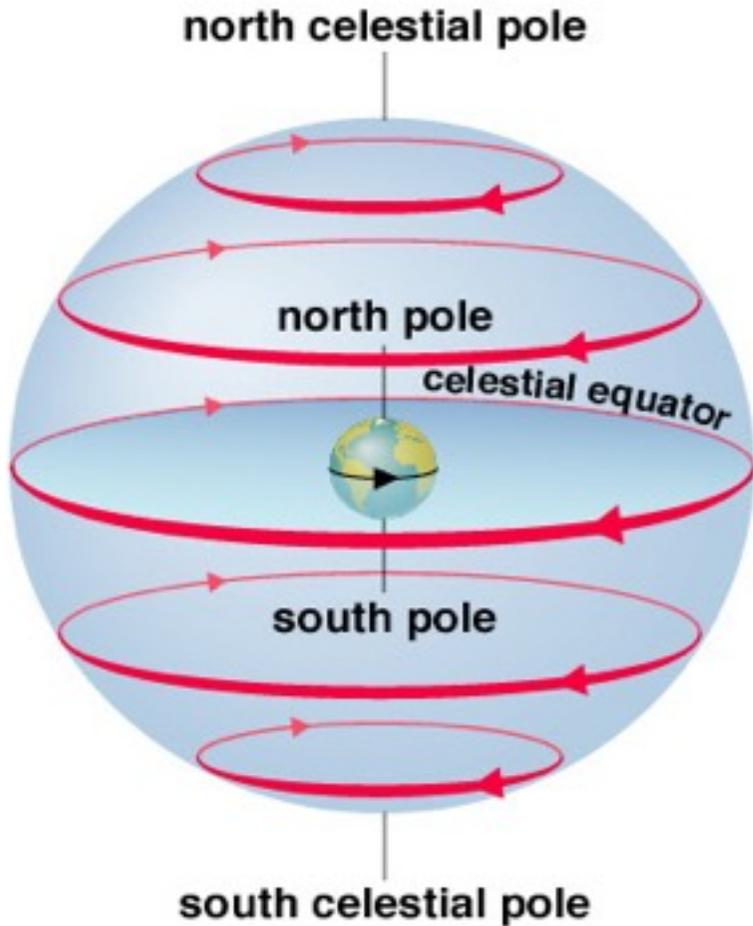
An object's angular size appears smaller if it is farther away.

$$\theta = \frac{L}{D}$$

$$\text{angular size (in radians)} = \frac{\text{physical size}}{\text{distance}}$$

Why do stars rise and set?

Earth rotates west to east, so stars appear to circle from east to west.

PLAY *Stellarium*

Our view from Earth:

- 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.

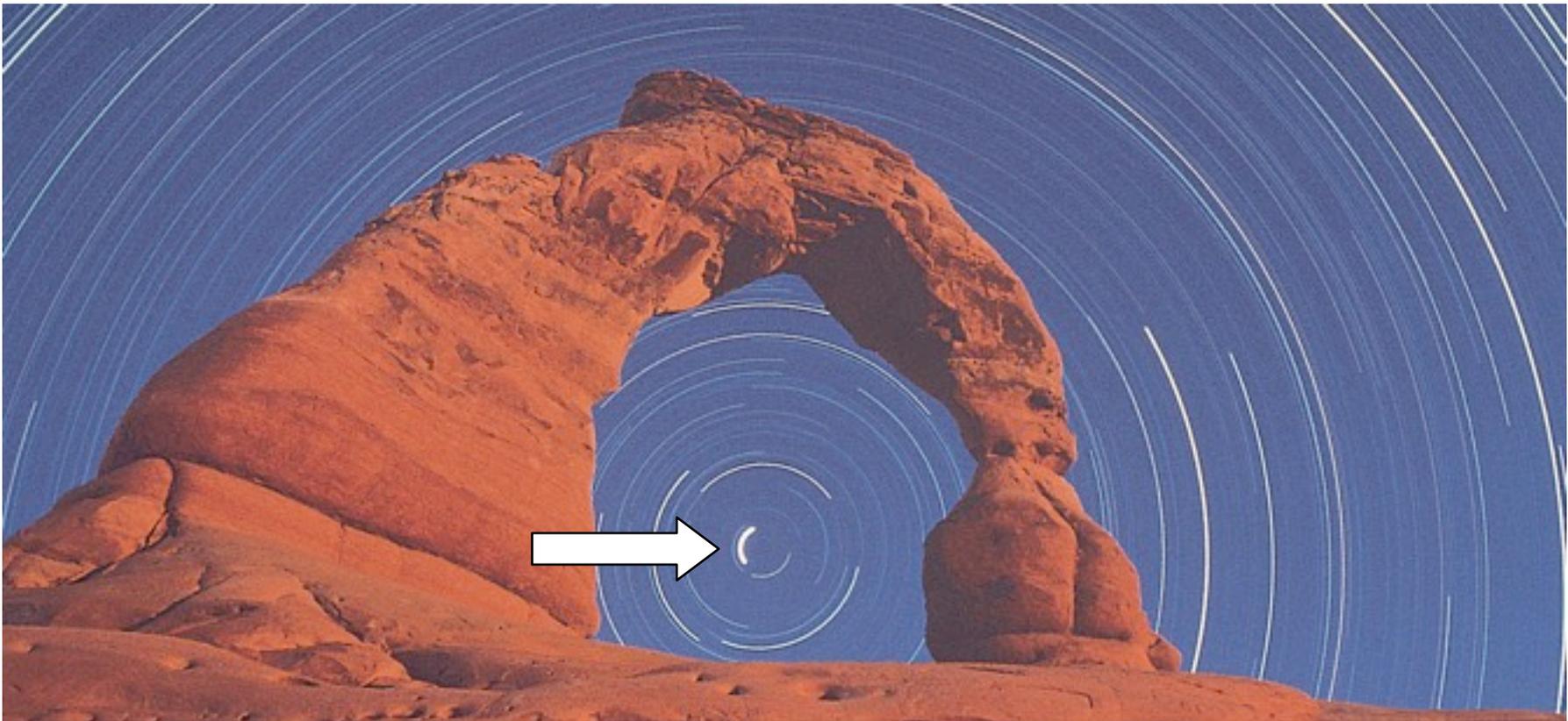A circumpolar star never sets

This star never rises

north celestial pole

zenith

Celestial equator

celestial equator

Your horizon

south celestial pole
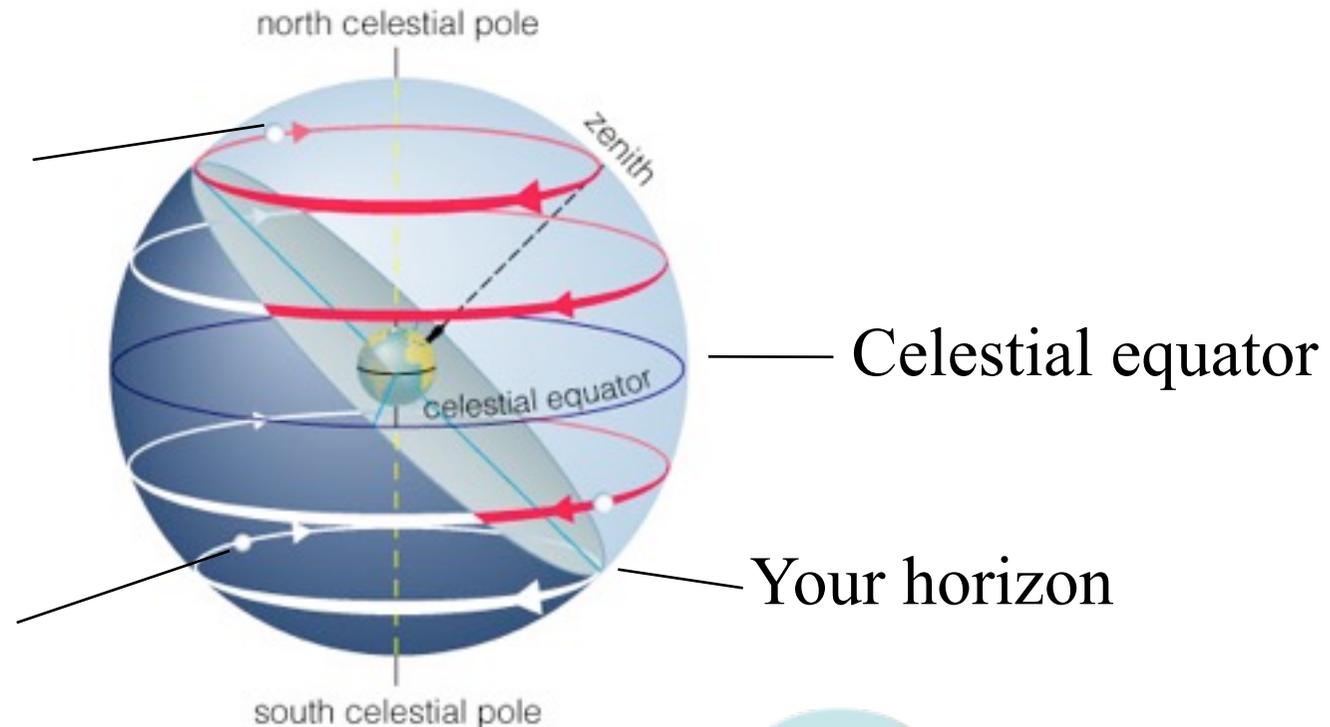
PLAY   02_01

Thought Question

What is the arrow pointing to?

The North Star

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

- They depend on latitude because your position on Earth determines which constellations remain below the horizon.

- They depend on time of year because Earth's orbit changes the apparent location of the Sun among the stars.

Review: Coordinates on the Earth

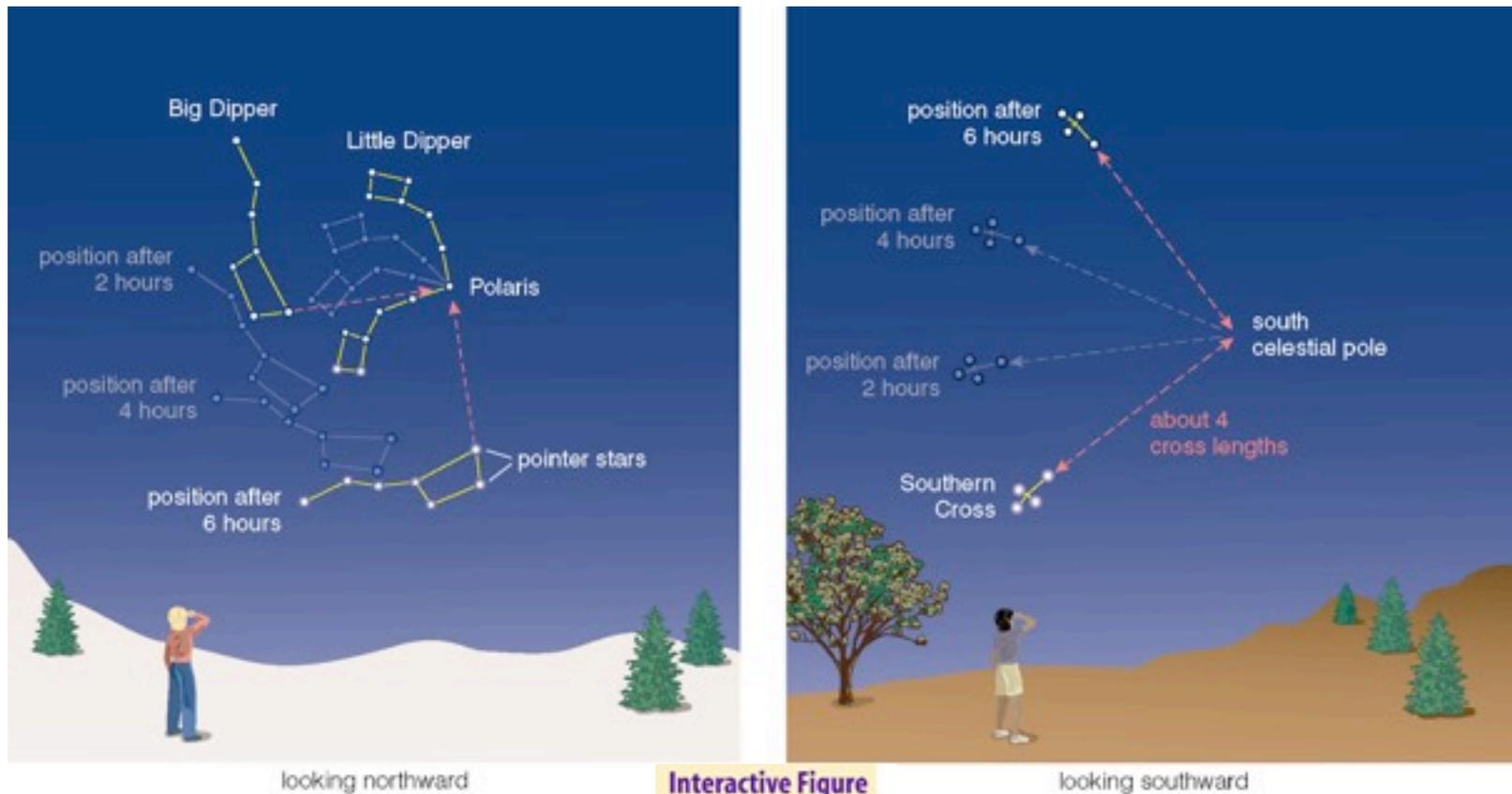- Latitude: position north or south of equator
- Longitude: position east or west of prime meridian (runs through Greenwich, England)

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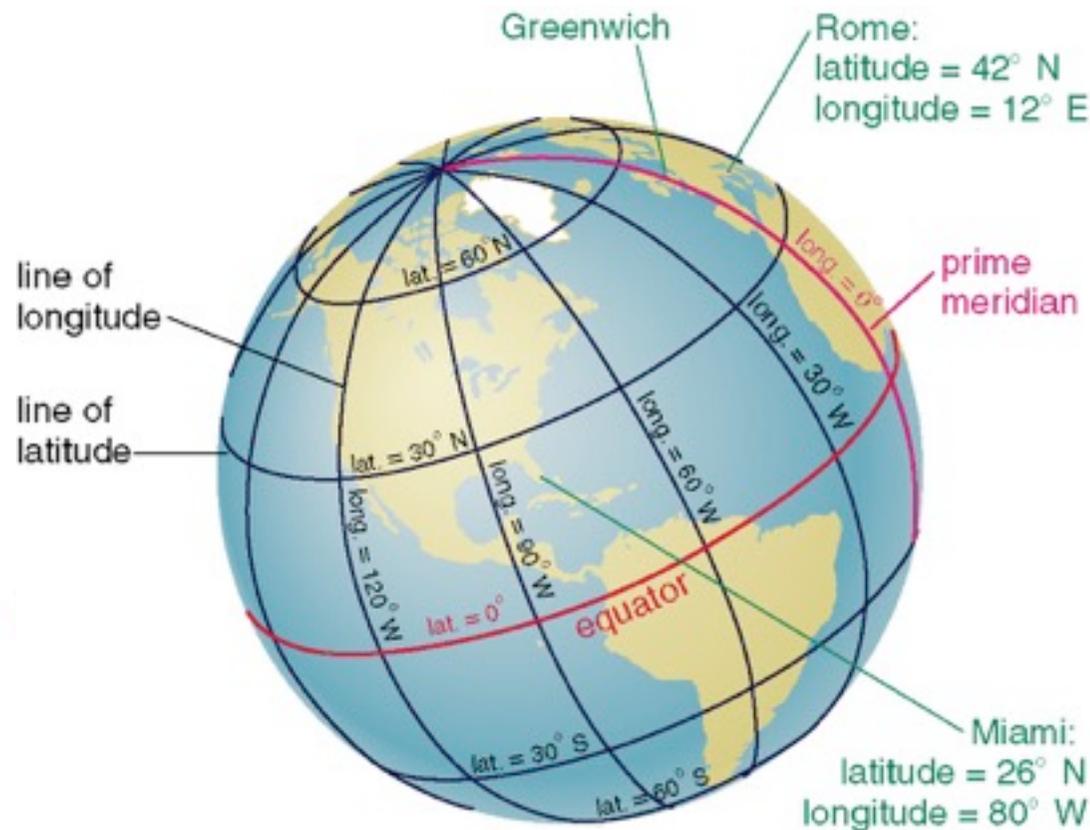
The sky varies with latitude but not longitude.
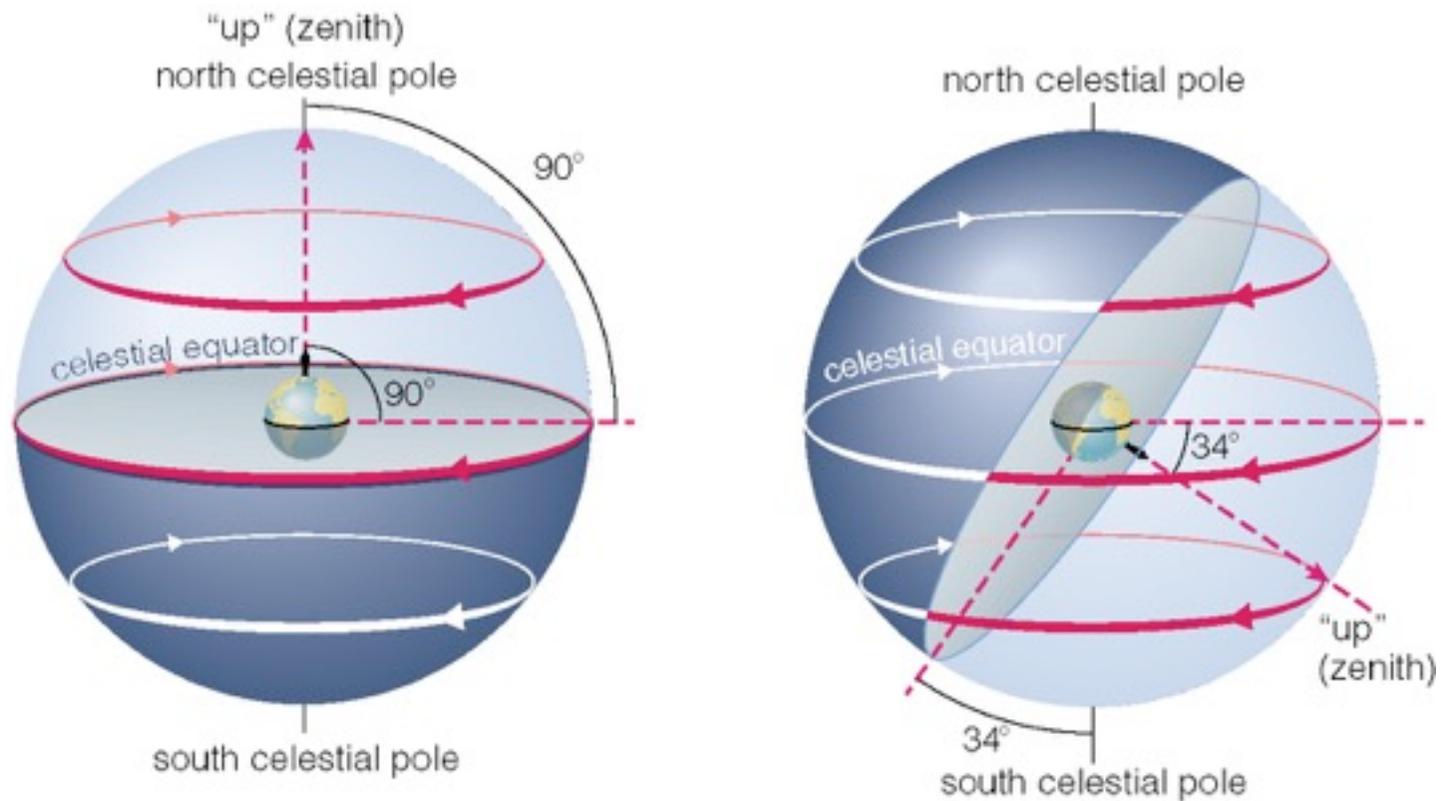
Altitude of the celestial pole = your latitude

looking northward

Interactive Figure

looking southward

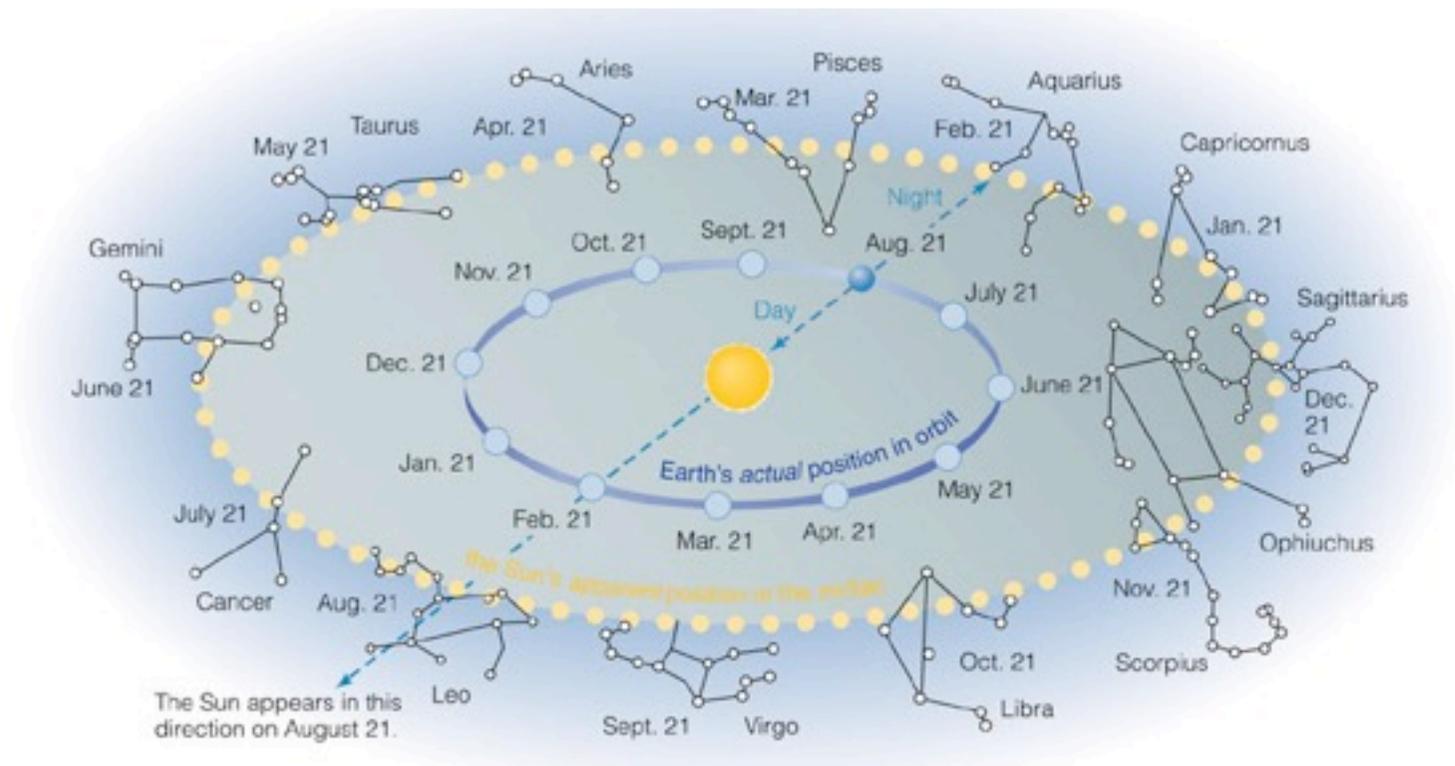PLAY   02_02

The sky varies as Earth orbits the Sun

- As the Earth orbits the Sun, the Sun appears to move eastward along the ecliptic.

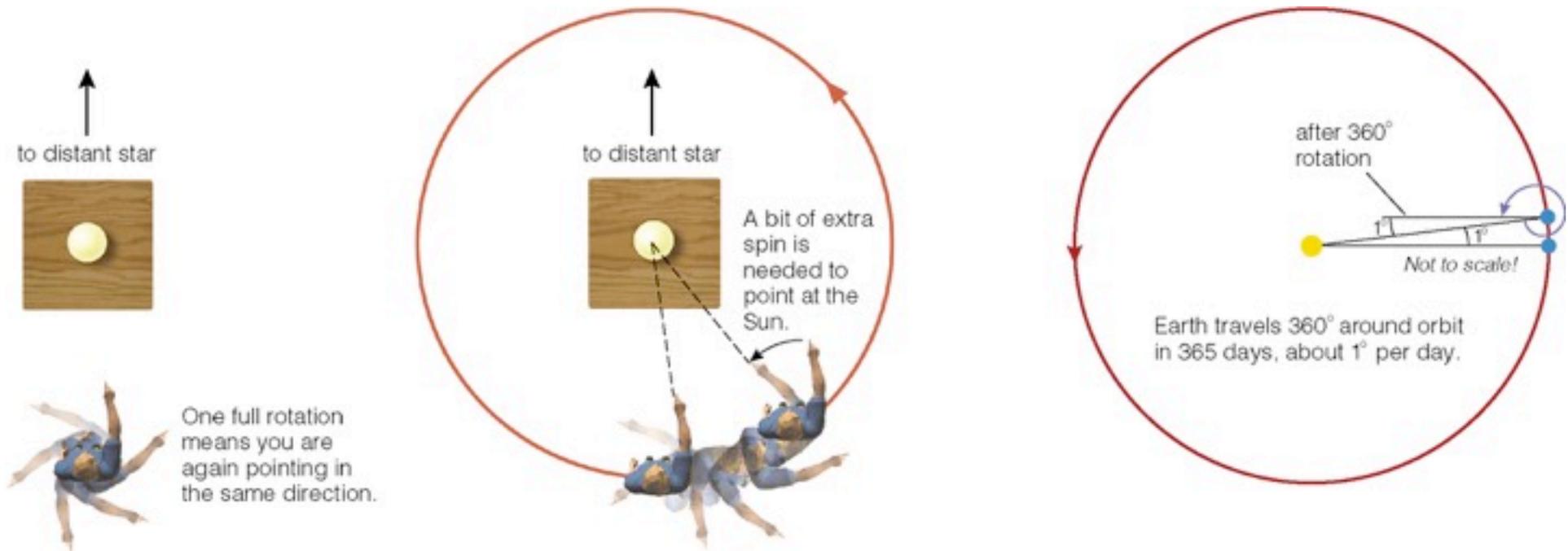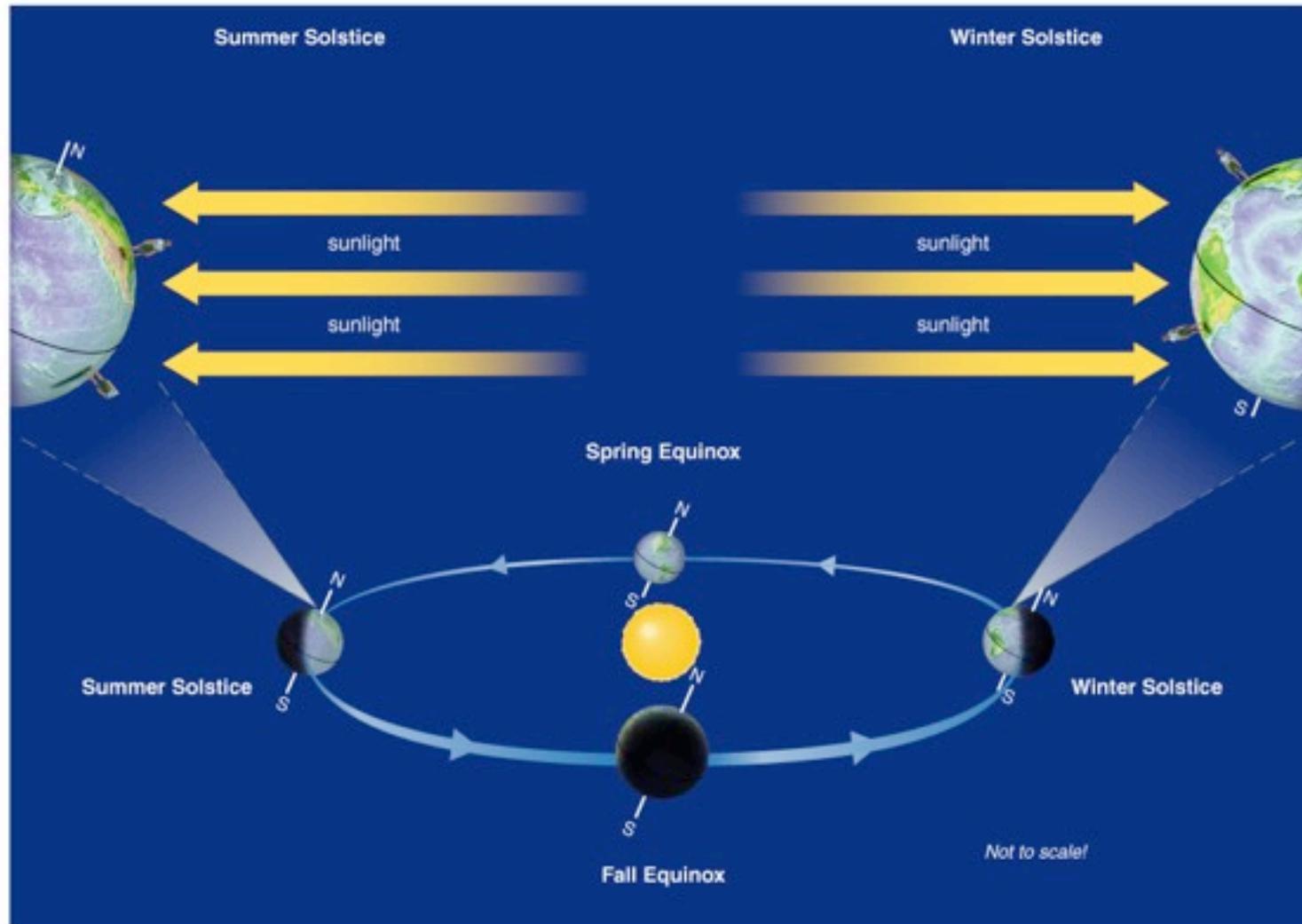- At midnight, the stars on our meridian are opposite the Sun in the sky.

PLAY 02_03 Sun's Apparent Path through the Zodiac

Solar & Sidereal Day

- **Solar** day = 24:00 hours (noon to noon)
  - combination of Earth's spin
  - plus Earth's orbital motion
- **Sidereal** day (Earth's spin period) = 23:56
  - time between meridian crossings of one star

to distant star

One full rotation means you are again pointing in the same direction.

to distant star

A bit of extra spin is needed to point at the Sun.

after 360° rotation

Not to scale!

Earth travels 360° around orbit in 365 days, about 1° per day.
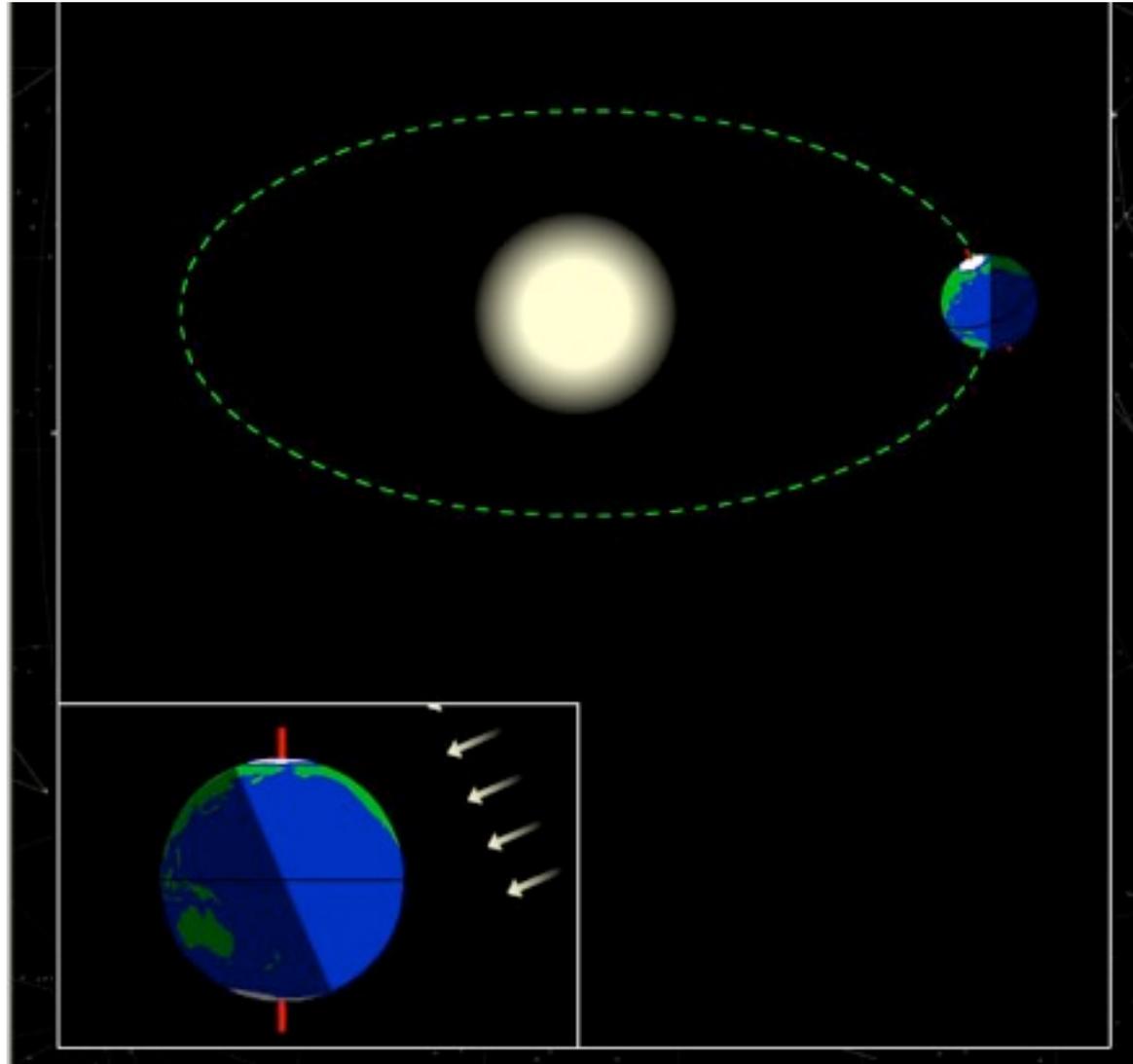
What causes the seasons?

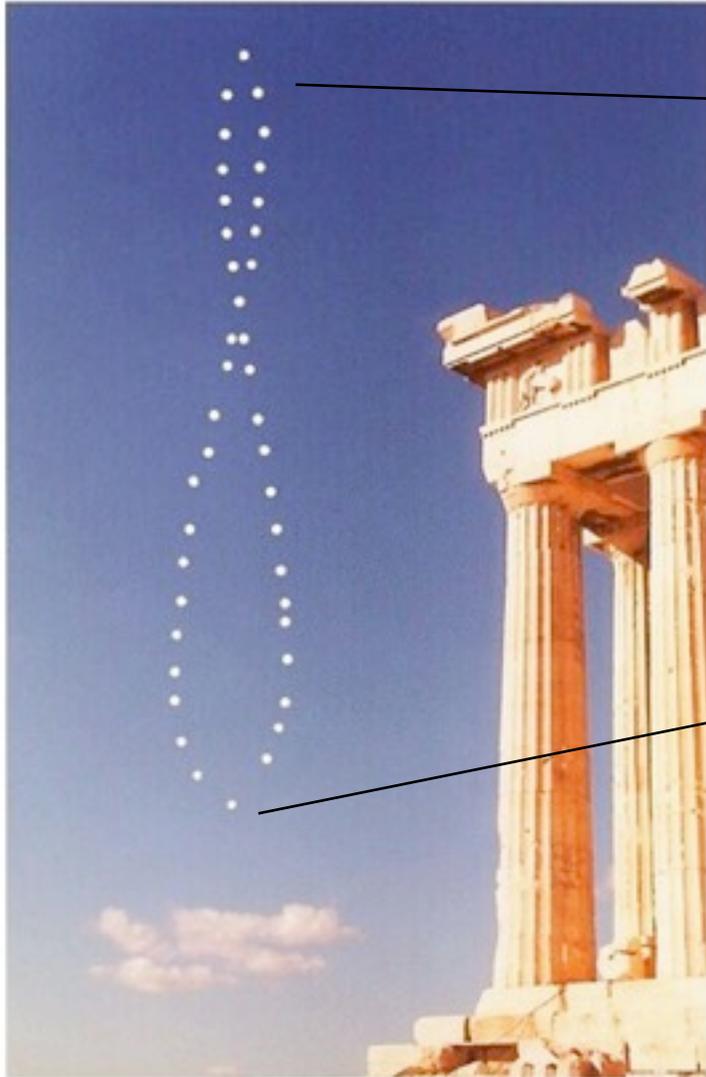Seasons depend on how Earth's axis affects the directness of sunlight.

Axis tilt changes directness of sunlight during the year.

Sun's altitude also changes with seasons

Sun's position at noon in summer: higher altitude means more direct sunlight.

Sun's position at noon in winter: lower altitude means less direct sunlight.

Summary: The Reason for Seasons

- Earth's axis points in the same direction (to Polaris) all year round, so its orientation *relative to the Sun* changes as Earth orbits the Sun.

- Summer occurs in your hemisphere when sunlight hits it more directly; winter occurs when the sunlight is less direct.

- **AXIS TILT** is the key to the seasons; without it, we would not have seasons on Earth.

- DISTANCE from the sun matters relatively little because the Earth's orbit is *nearly* circular. The variation of the Earth-Sun distance is only about 3%.

Distance variation could matter (e.g., for comets);
it just isn't an important factor for the Earth.

Hypothesis check: how would seasons in the northern and southern hemisphere relate if distance from the sun cause the seasons?