The Science of Astronomy

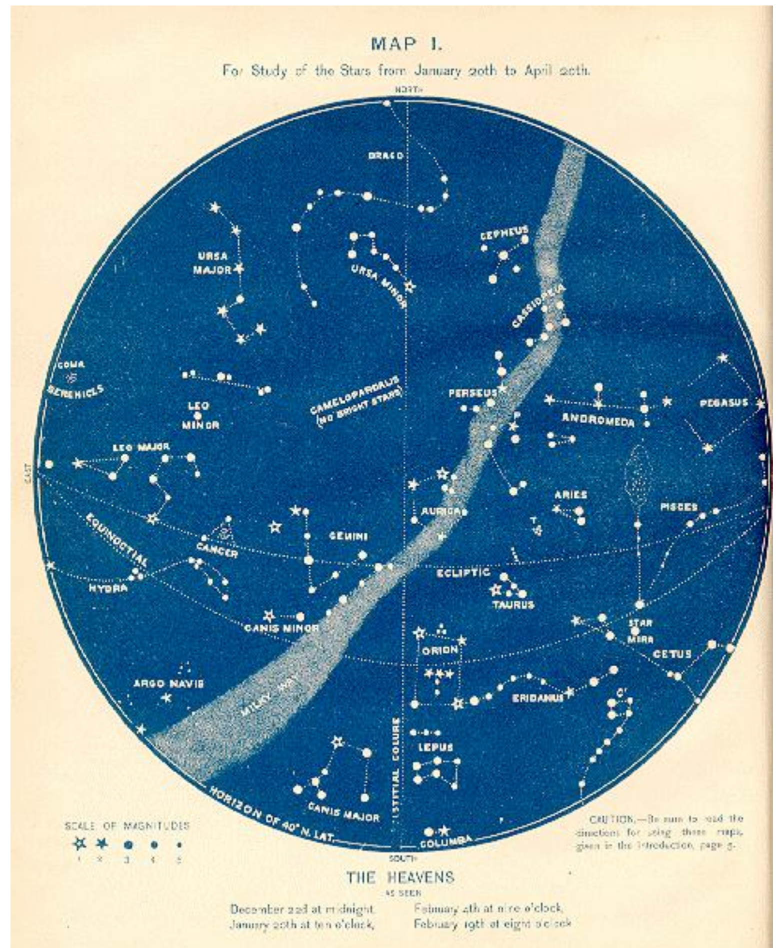
- Astronomy – understanding what happens in the sky
- Astrophysics – understanding what happens in space

The Lovely Sky

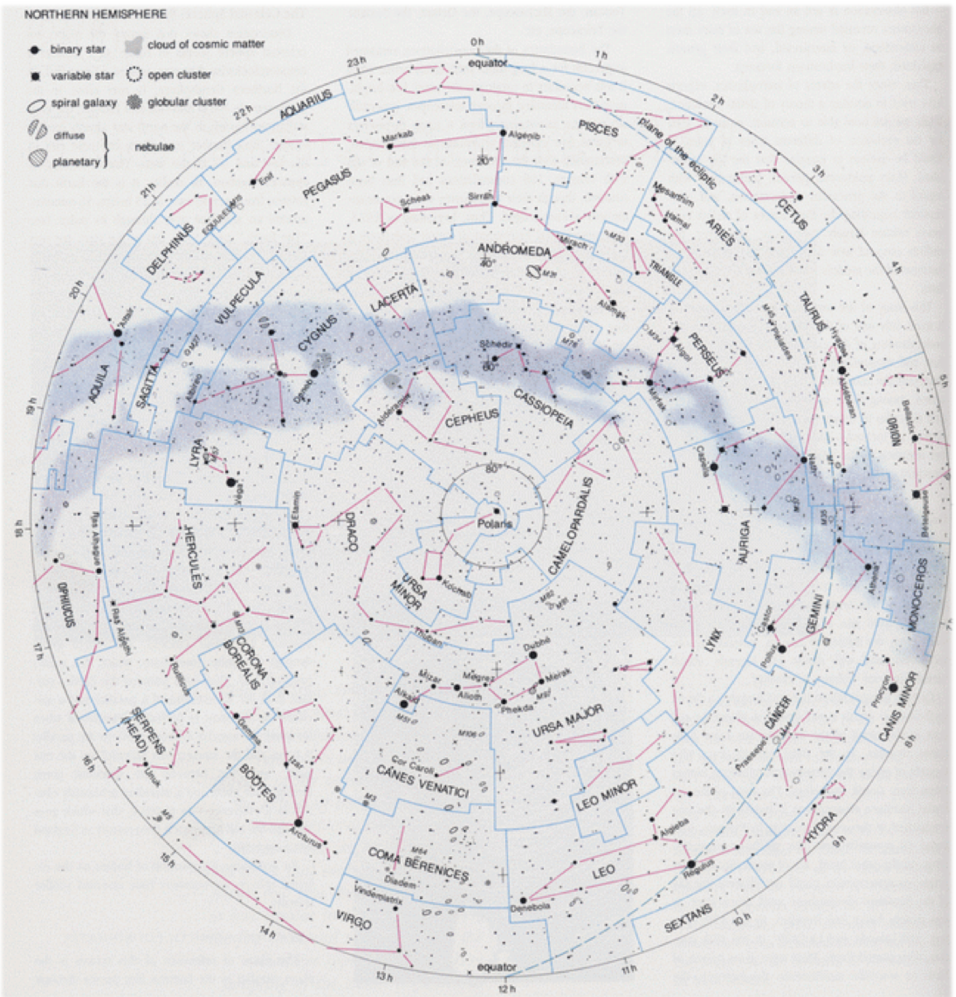
The Southern View

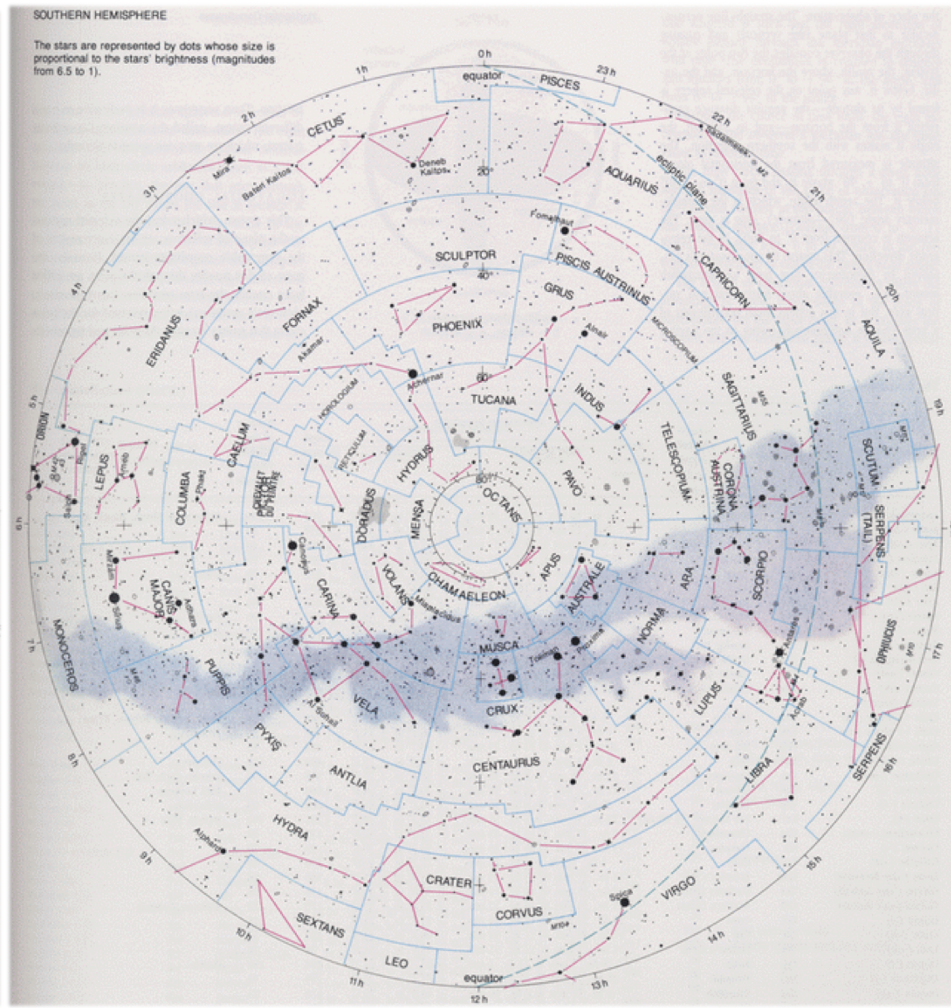
Orion

Sky Maps: Finding Your Way

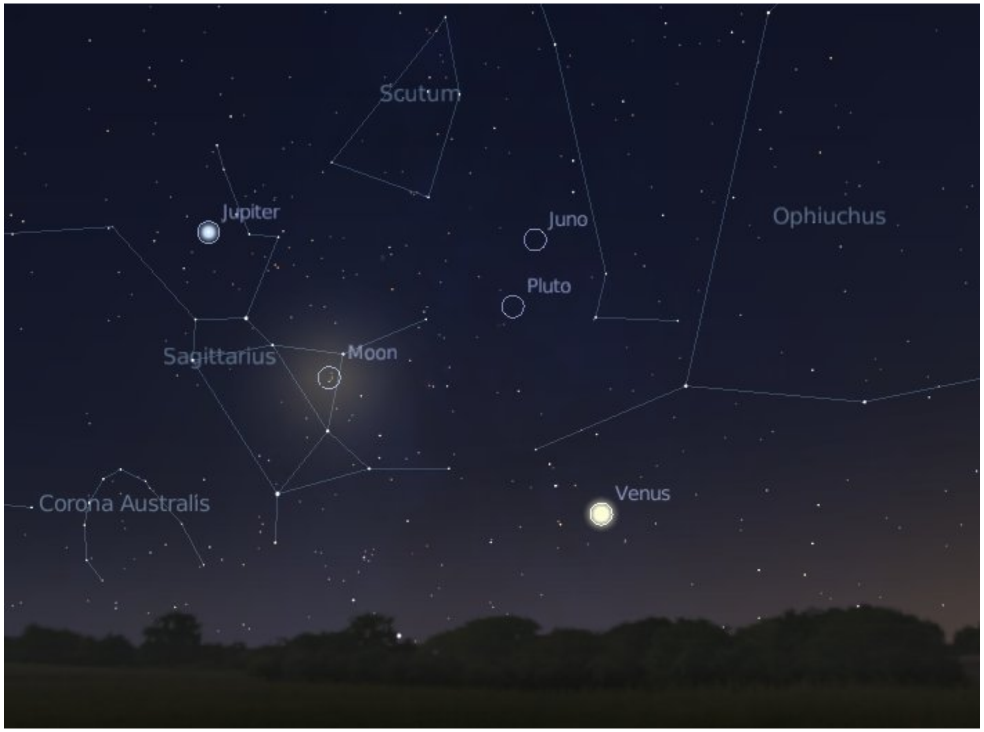


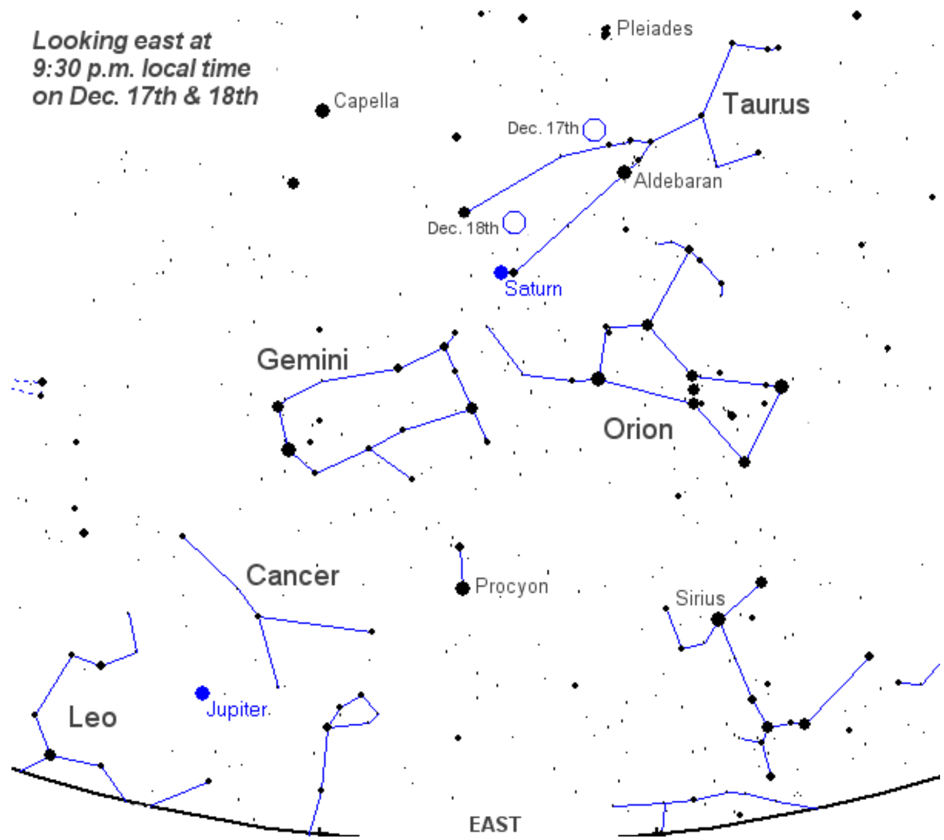
Constellations - Neighborhoods of the Sky



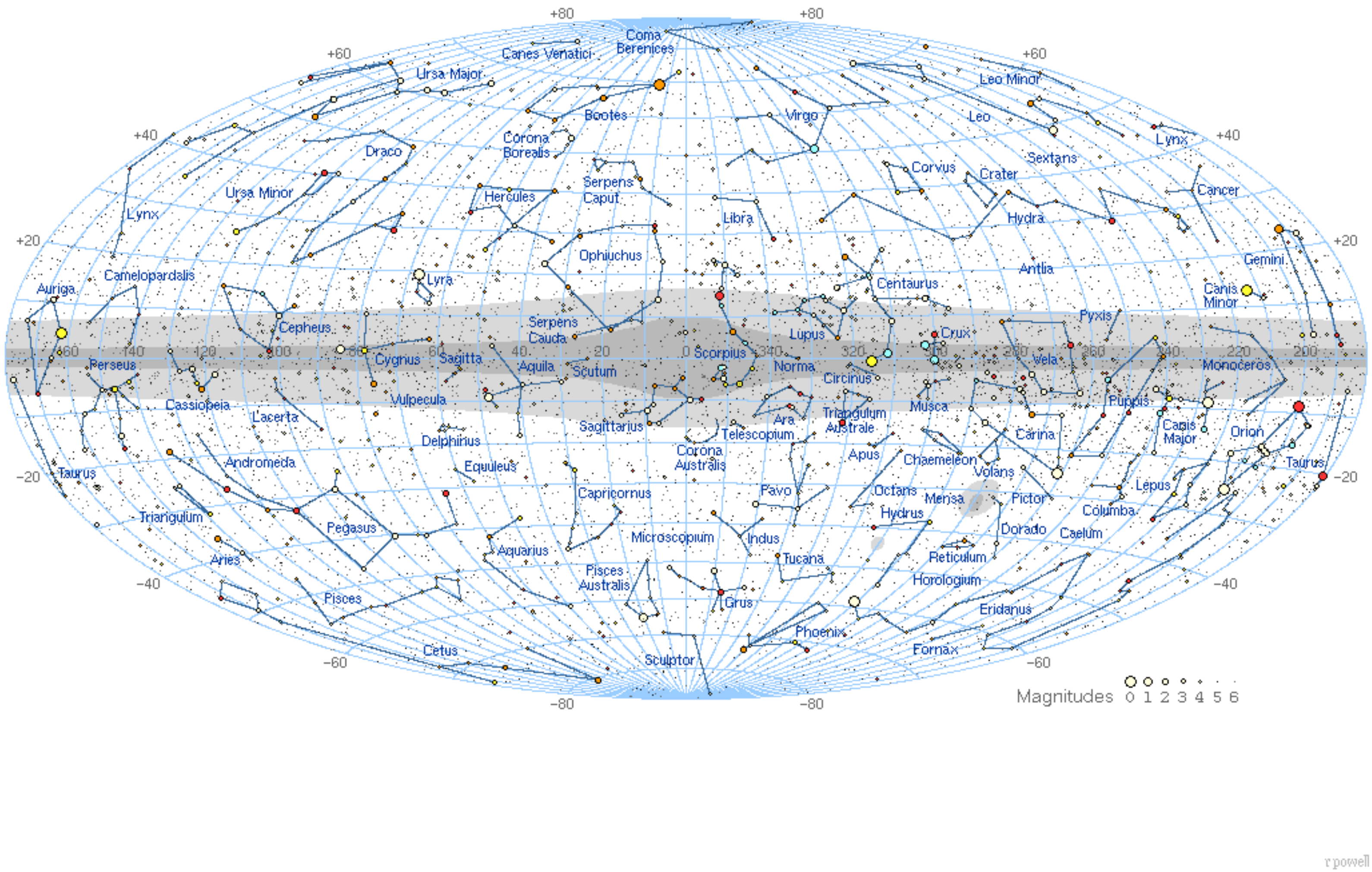


Using Sky Maps



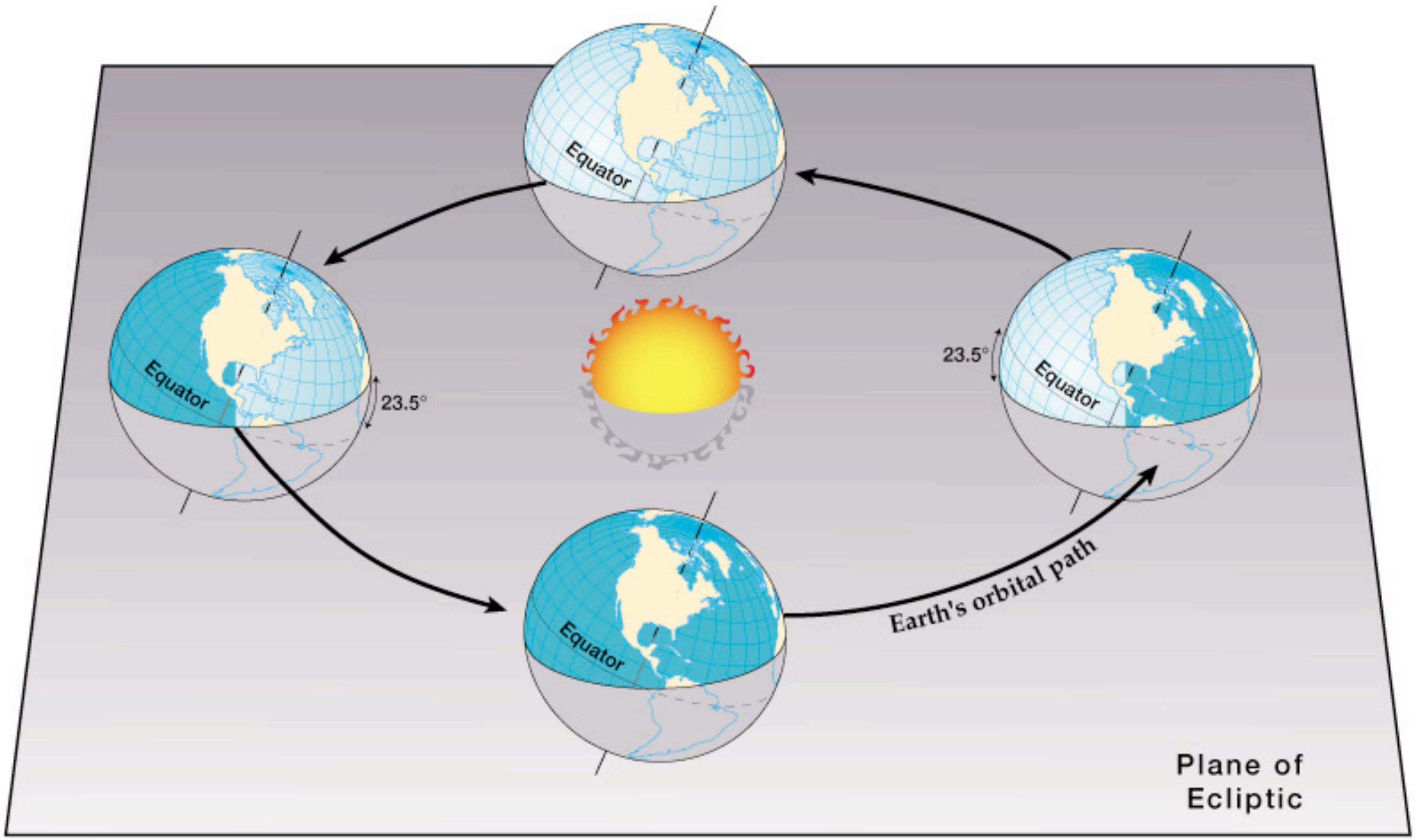


Milky Way: A Different Reference



View of the MW

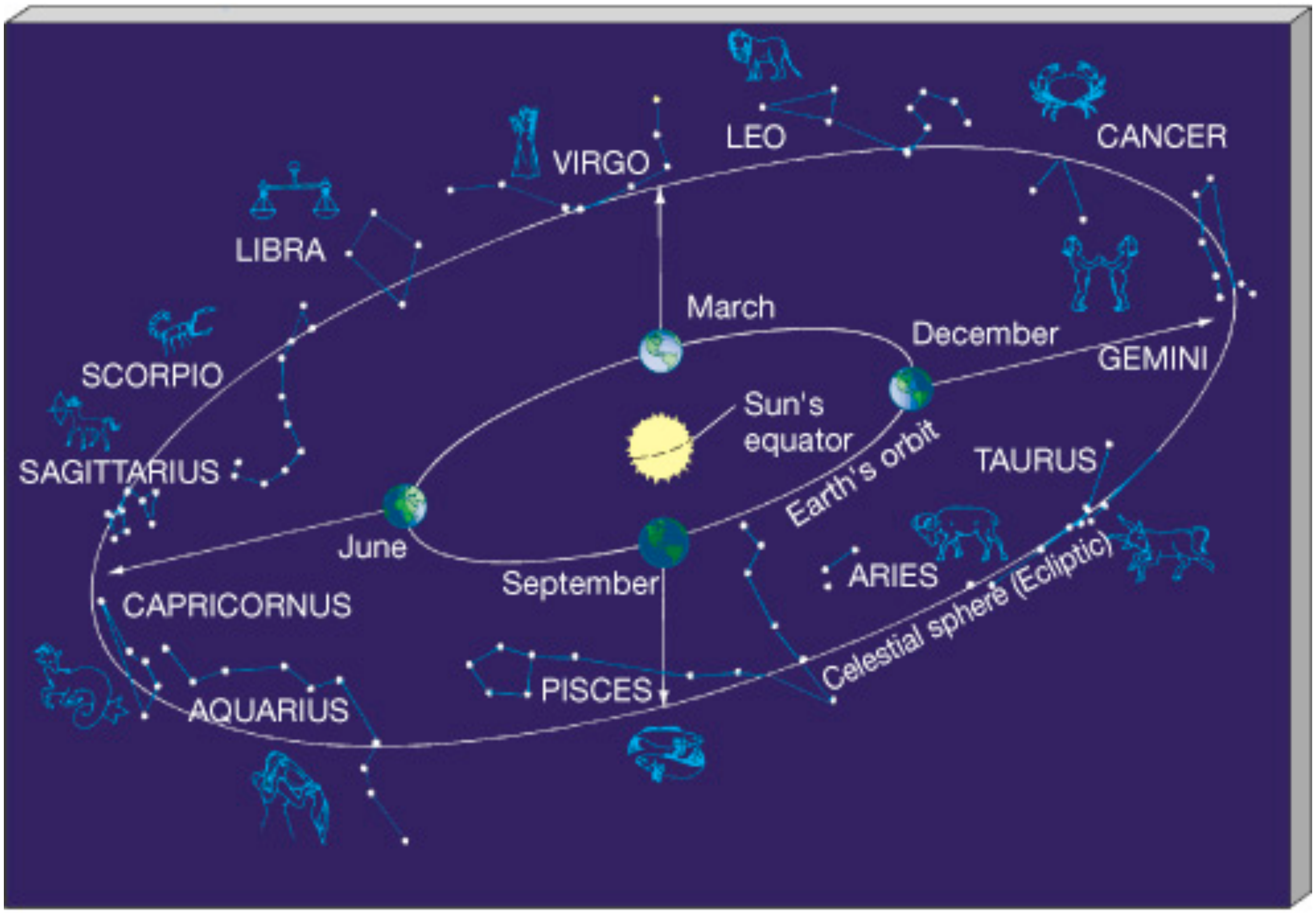
The Ecliptic



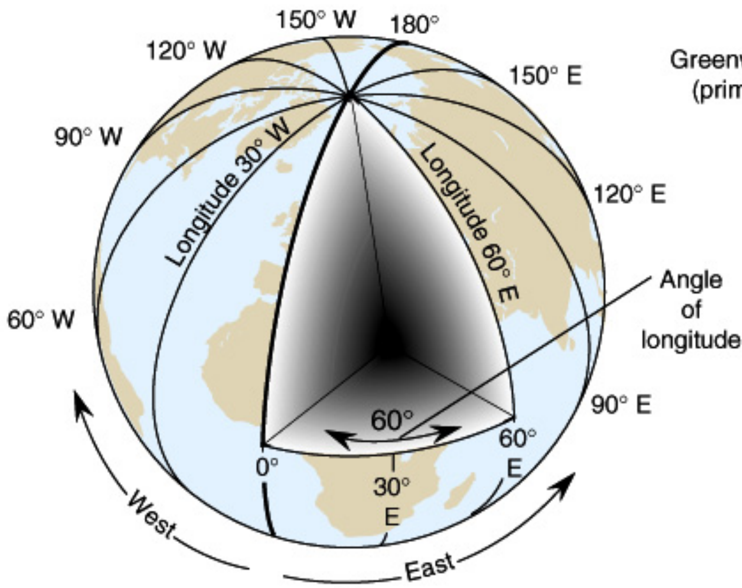
Anatomy of the Sky

- Ecliptic
- Zodiac
- Coordinate systems
- Horizon, zenith, nadir
- The Celestial Sphere
- A handy rule: altitude for latitude
- Diurnal vs annual
- The seasons

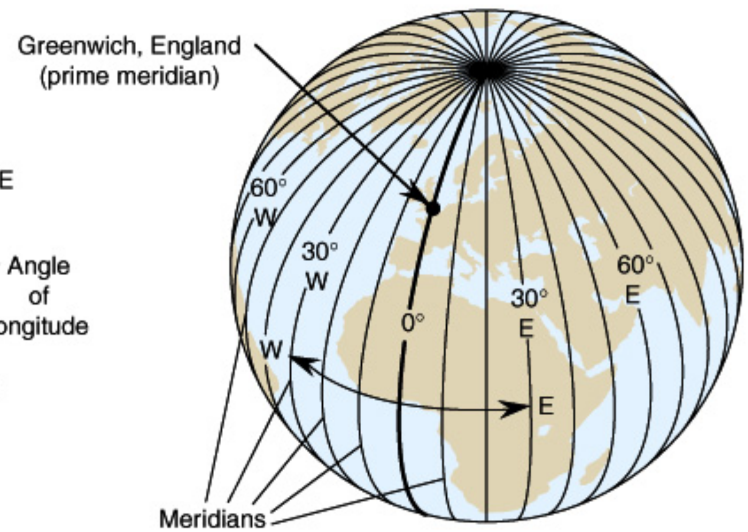
The Zodiac


LEO
CANCER
VIRGO
LIBRA
March
December
GEMINI
SCORPIO
Sun's
equator
Earth's orbit
SAGITTARIUS
TAURUS
June
September
ARIES
CAPRICORNUS
Celestial sphere (Ecliptic)
PISCES
AQUARIUS

Coorindate Refresher: Longitude

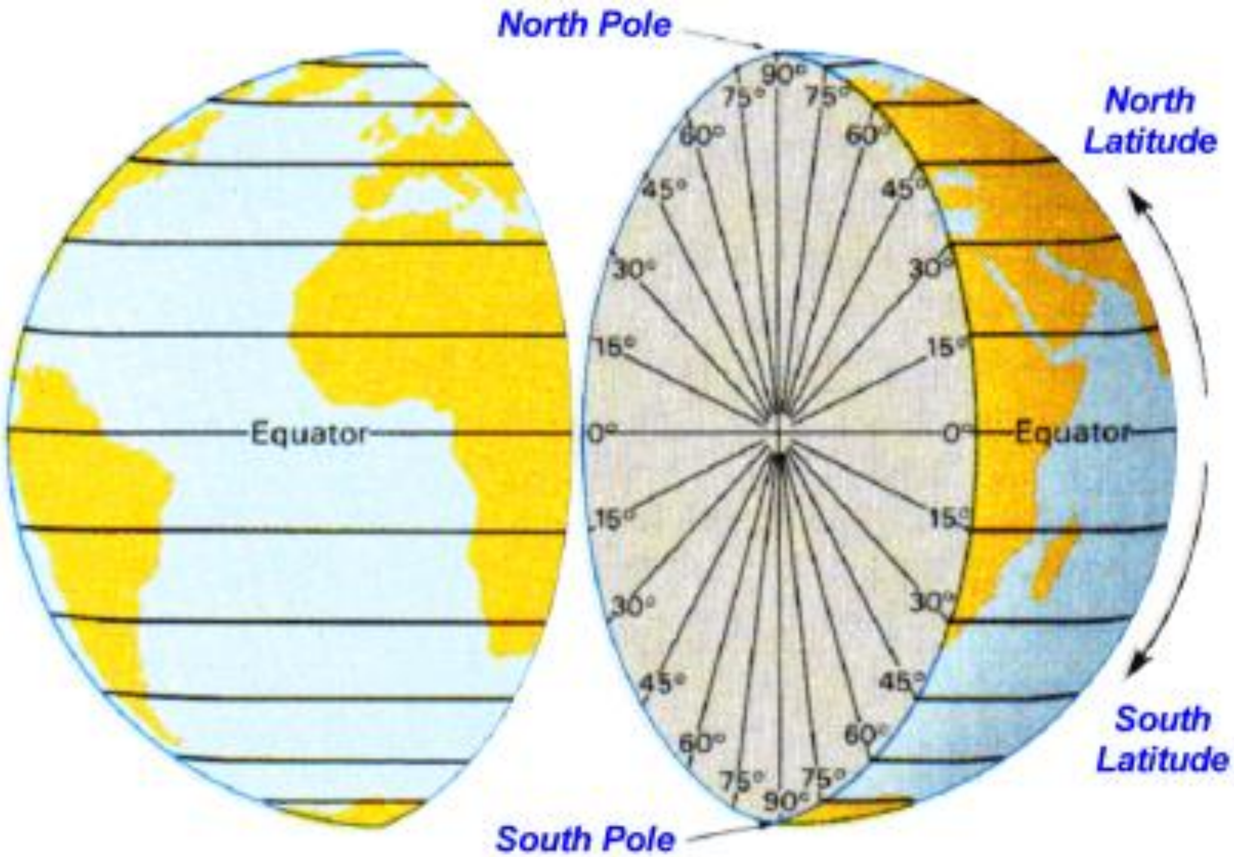


(a)



(b)

Coordinate Refresher: Latitude



Sky Coordinates: Two Systems

Horizon Coordinates:

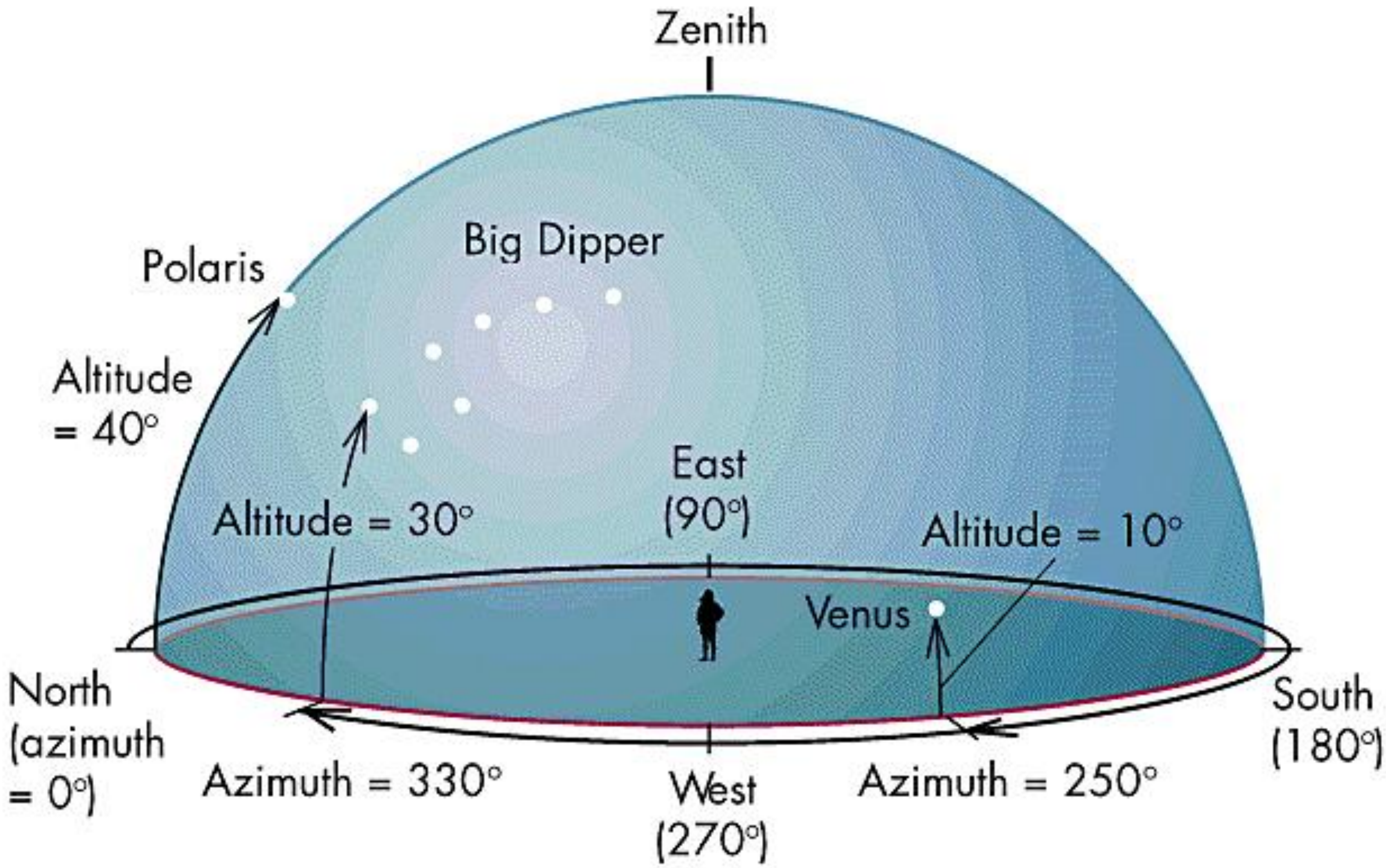
- Horizon - the "sky line", i.e. where the sky apparently meets the land
- Azimuth (Az) - angular coordinate measure around the horizon, starting from the North point and moving Eastward
- Altitude (Alt) - angular measure above the horizon along a great circle passing through the zenith
- North Point - the point that is on the horizon and directly North
- Zenith - the point directly above
- Nadir - the point directly below
- Meridian - the great circle that passes from the North point through the zenith to the South Point

Celestial Coordinates:

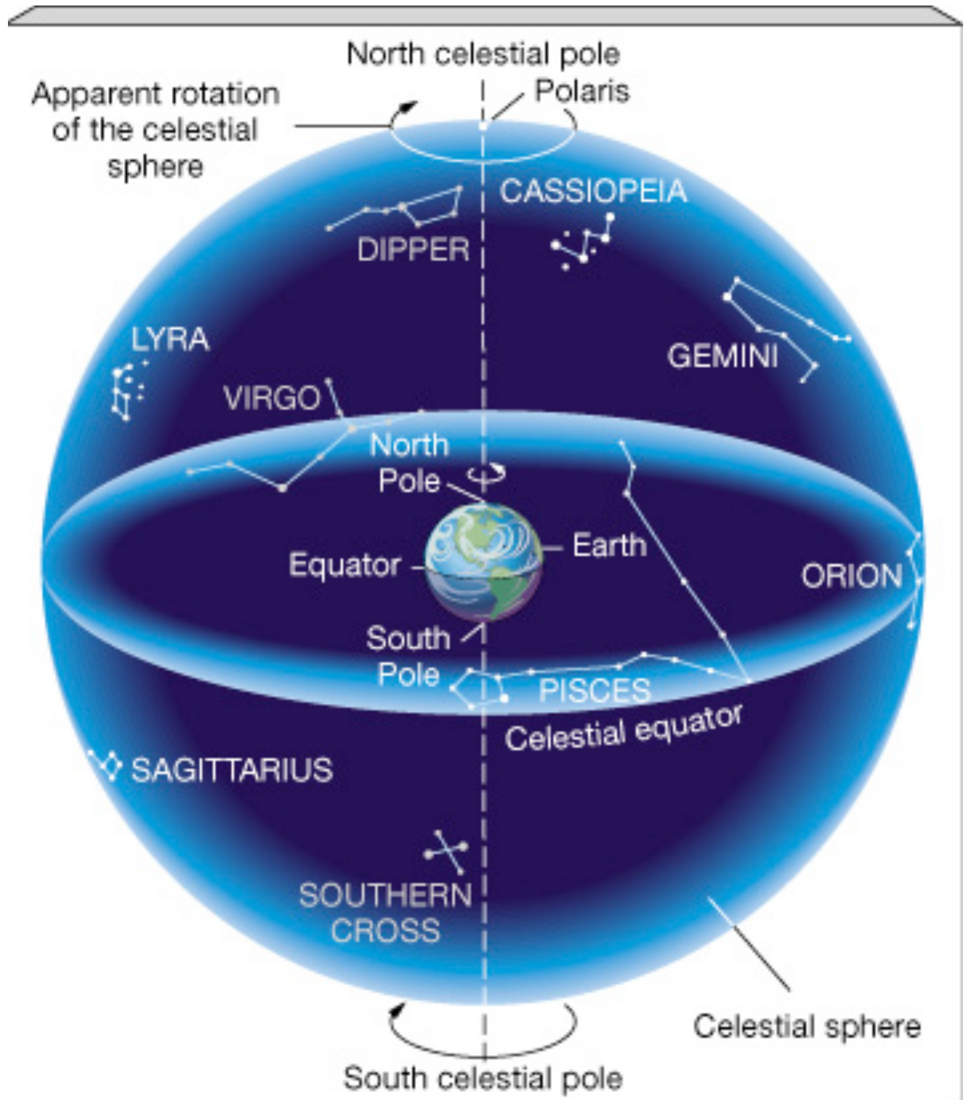
- Right Ascension (RA) - similar to Earth longitude but for the sky; RA is measured Eastward starting from the Vernal Equinox
- Declination (Dec) - similar to Earth latitude but for the sky; Dec is positive in the North Celestial Sphere and negative in the South
- Celestial Poles - projection of North and South Poles onto the sky
- Celestial Equator (CE) - projection of equator onto the sky
- Ecliptic - apparent path of the Sun over the course of one year

The Horizon System

Azimuth - Altitude



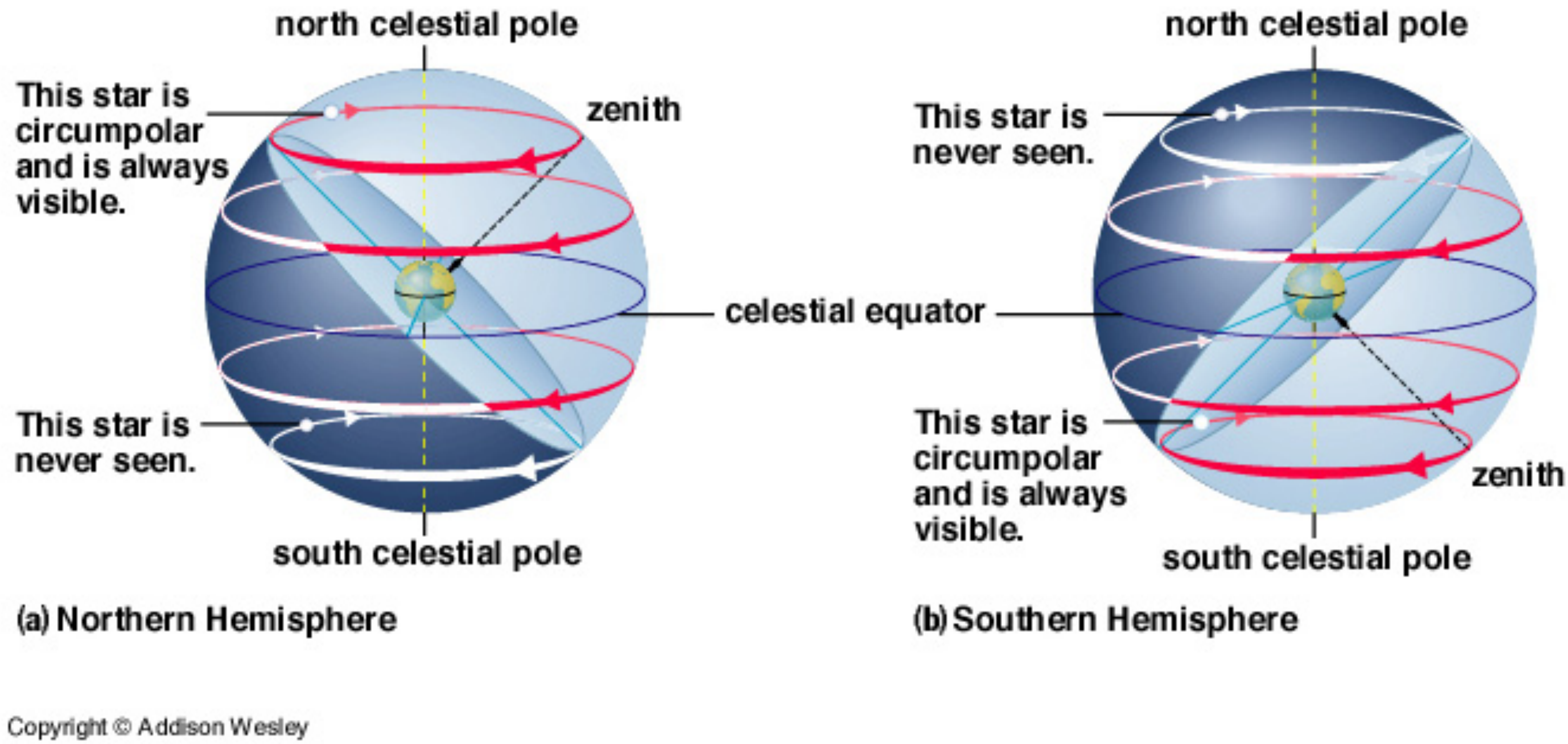
The Celestial Sphere



Star Trails

More Trails

Diurnal Motion

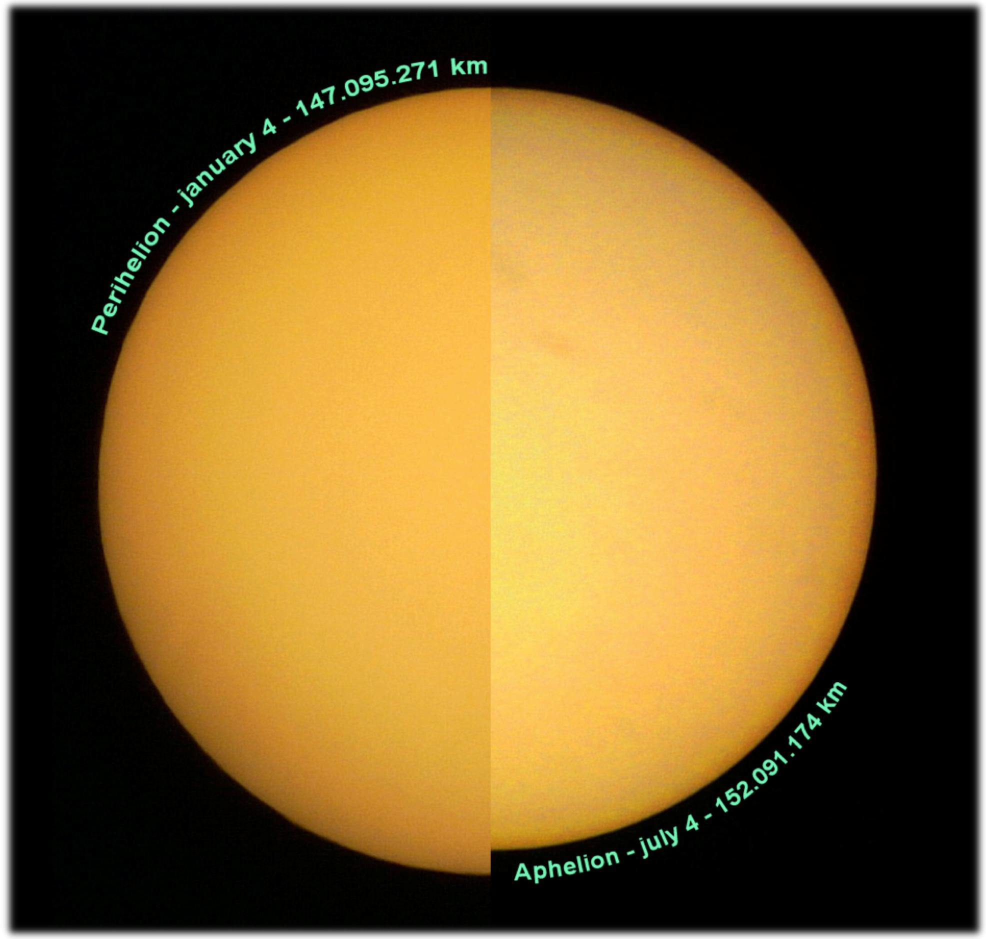


Seasons and the Sky

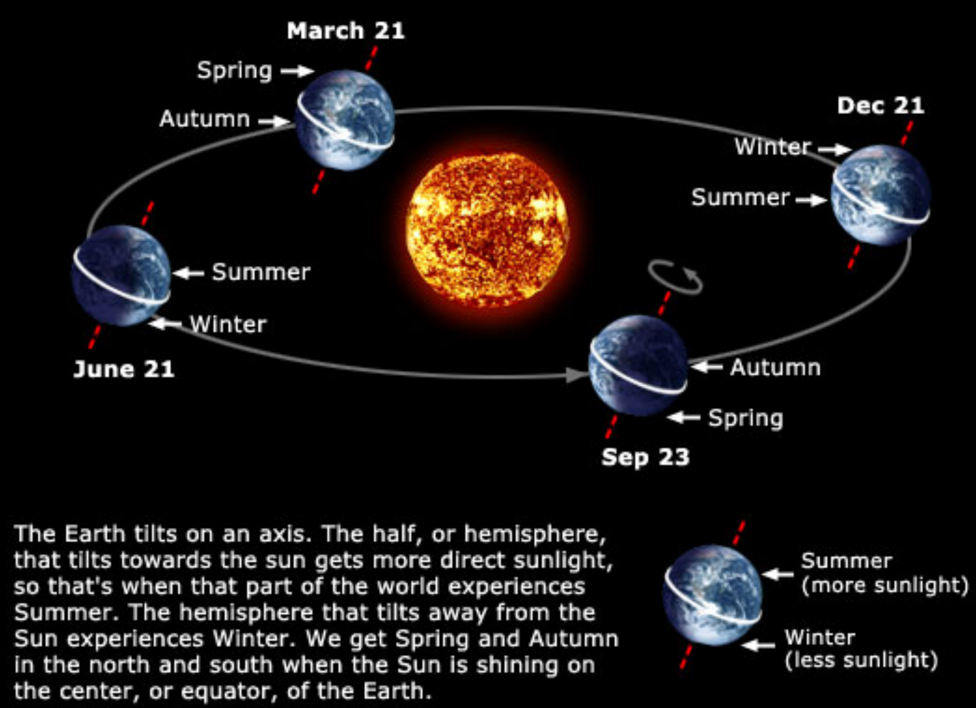
- *Vernal Equinox* - first day of spring; the Sun lies exactly over the equator and is passing into the N. hemisphere
- *Autumnal Equinox* - first day of autumn; the Sun lies exactly over the equator and is passing into the S. hemisphere
- *Summer Solstice* - first day of summer; the Sun is highest in the sky for N. observers (lowest for S. observers)
- *Winter Solstice* - first day of winter; the Sun is lowest in the sky for N. observers (highest for S. observers)

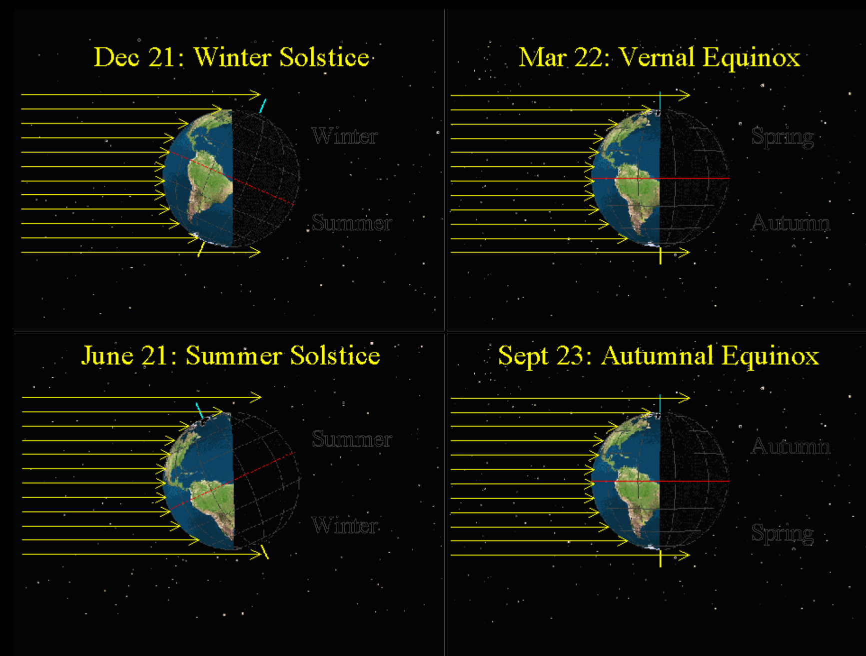
Earth's Orbit is NOT a Circle

- The orbit of the Earth around the Sun is slightly elliptical and not perfectly circular.
  - Perihelion – closest approach
  - Aphelion – furthest distance
- However, the change in distance can NOT account for our seasons!



Earth's Tilt



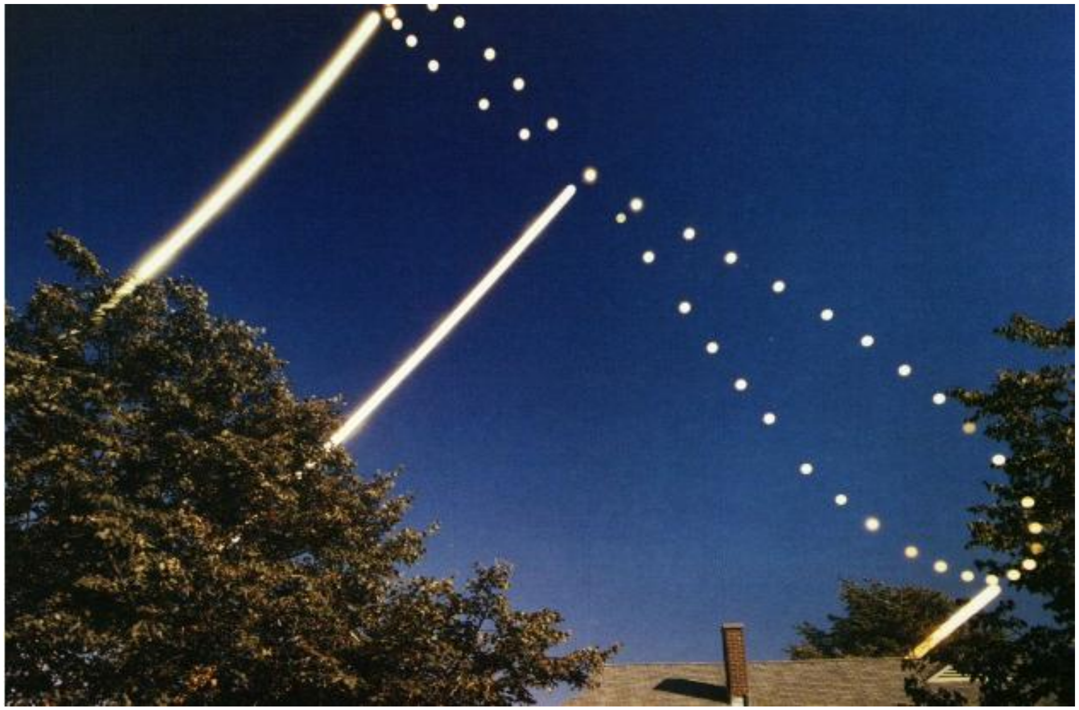


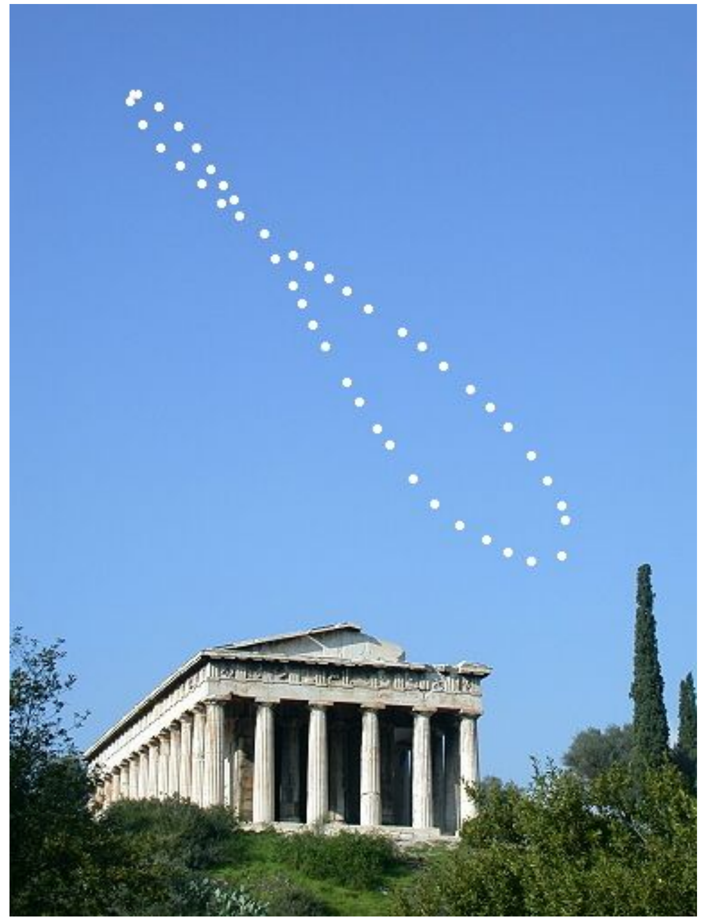
The Earth's equator and the ecliptic are not in the same plane. The tilt of the Earth's axis (or the inclination between these two planes) is about 23.5 degrees. It is this tilt that causes us to have seasons.

The Cause of Seasons

- The climate on Earth depends on latitude. This is because the Earth is round.
- By contrast if the Earth were flat, all places would have the same climate.
- Sunlight is absorbed by the curved Earth
- A bundle of light strikes falls across much land at the poles; the same amount of light (and energy) is concentrated into less land at the equator.
- Whether Earth is tilted toward or away from the Sun changes how a bundle of light is concentrated on land at a given latitude over the course of a year.

The Analemma





Ancient Astronomy

- Mesopotamia – (~6000 yrs ago) first to keep long term astronomical records; introduced zodiac and 360 degrees in a circle
- Babylonia – (~500 BC) determined synodic periods of planets
- Egypt – little known (influence on Greeks?)
- China – long timeline of records (eclipses, other events)
- Mesoamerica – complex calendars (e.g., Aztecs and Mayans)
- Greeks - *Moved astronomy from the level of prediction to one explanation (or made attempts to do so)*

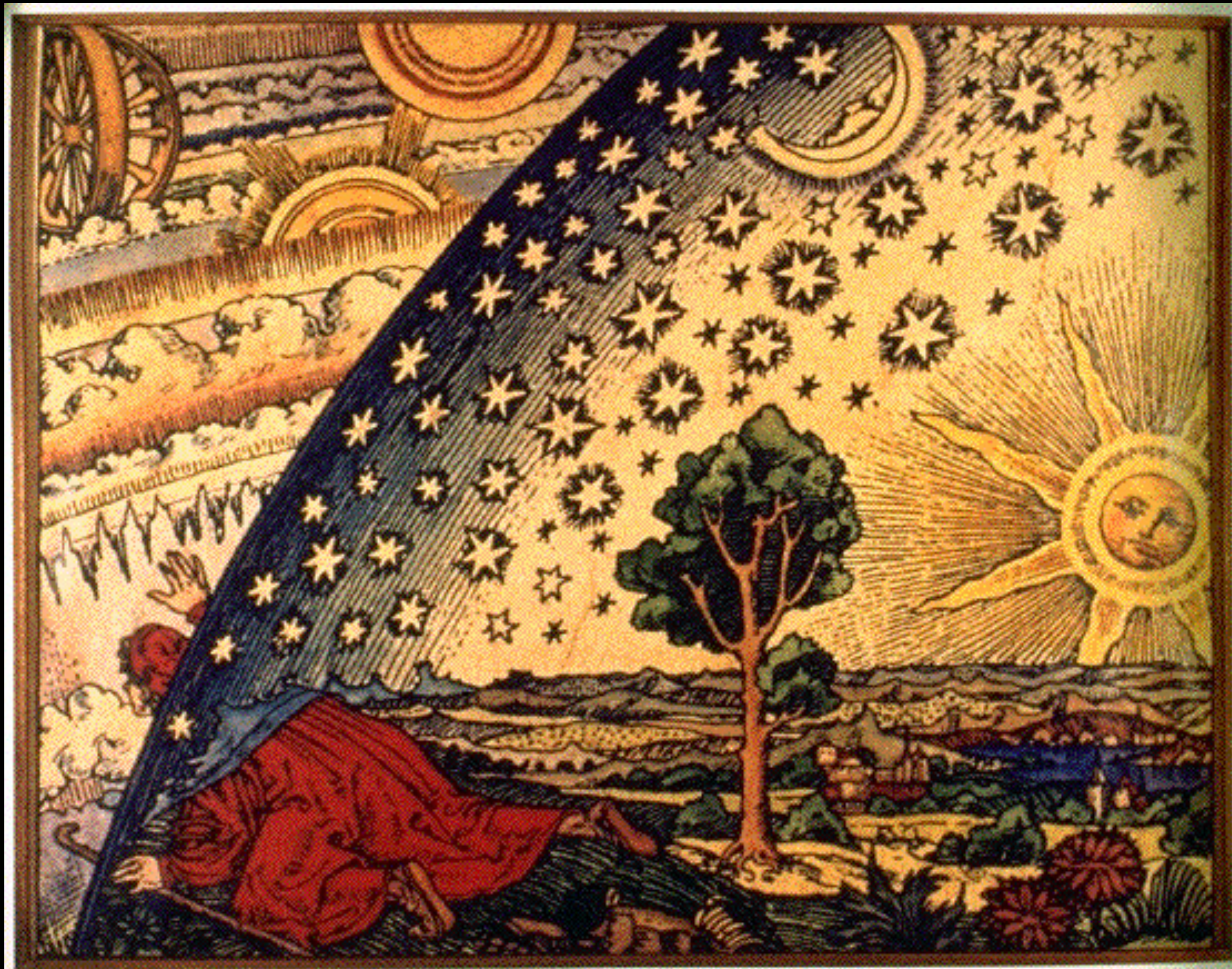
Ancient Astronomical Tools

Aztec

Chinese

Mayan

Stonehenge



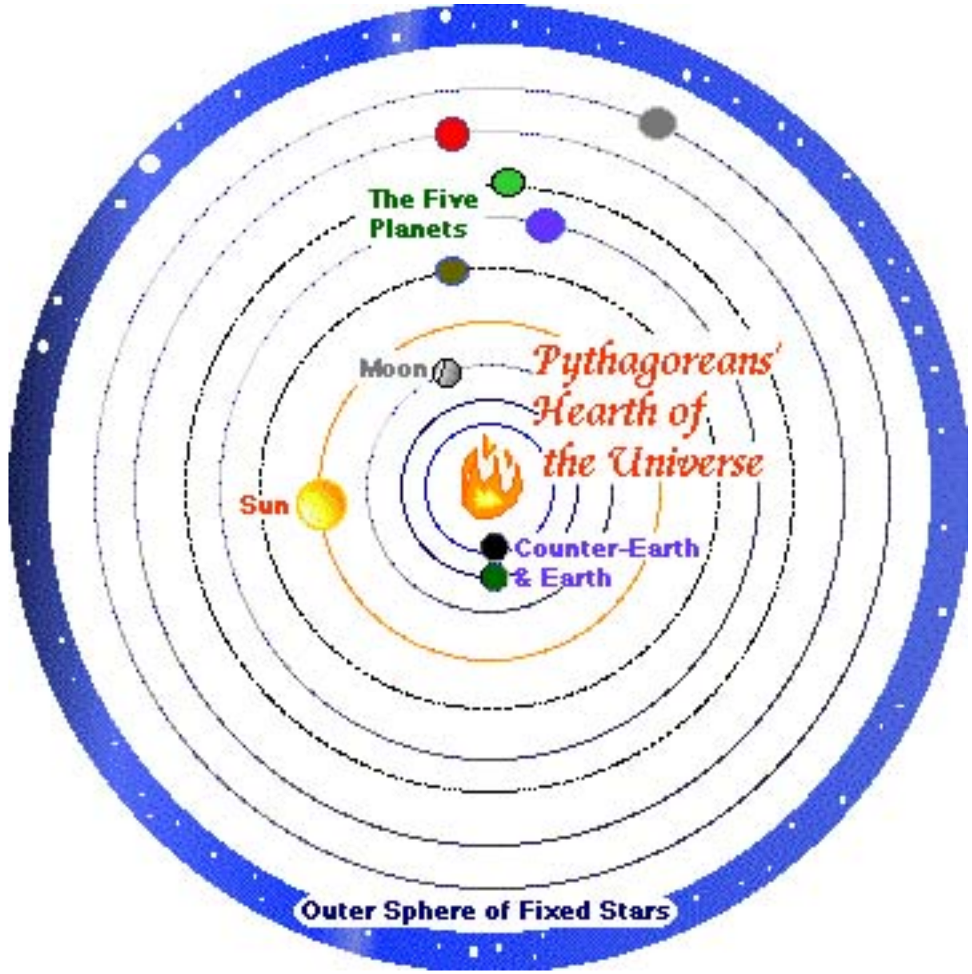
Early Approaches to Science and Astronomy

- Pythagoras – circles
- Aristotle – rationales
- Eratosthenes – measuring the Earth
- Aristarchus – applications of geometry
- Ptolemy – the Earth-centered view

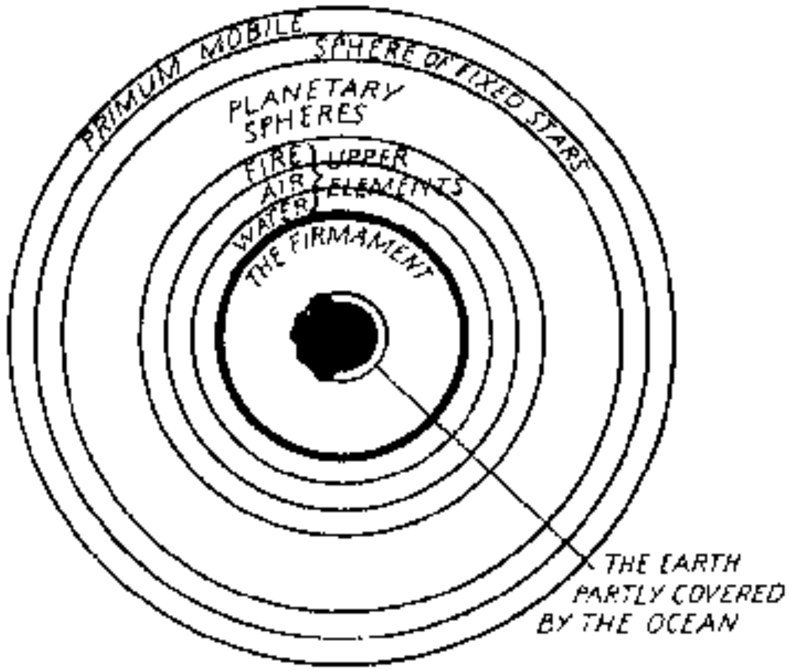
The Cosmos of Pythagoras

(~540 BC)

quasi-scientific models for the Solar System; bodies are spheres and move on circular paths (including the Earth!)



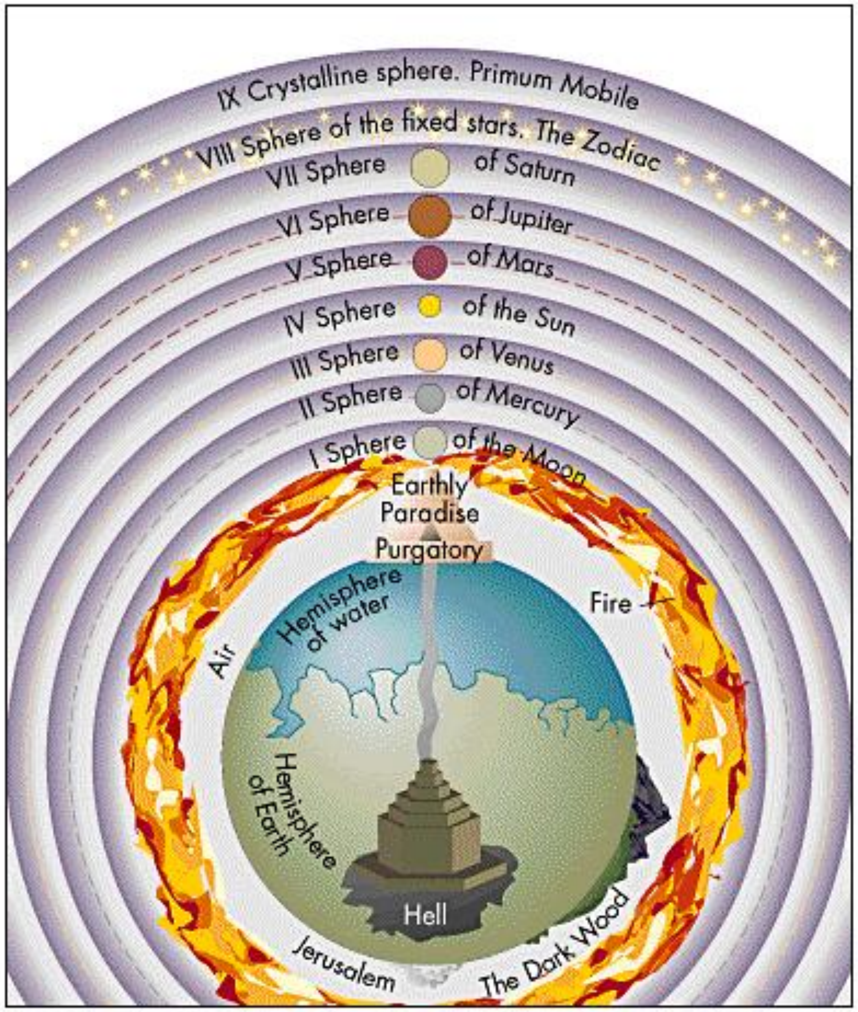
The Universe of Aristotle



The Universe of Aristotle as Conceived by a Medieval Writer

From Runes' Pictoral History, p. 89.

Cosmology of Dante

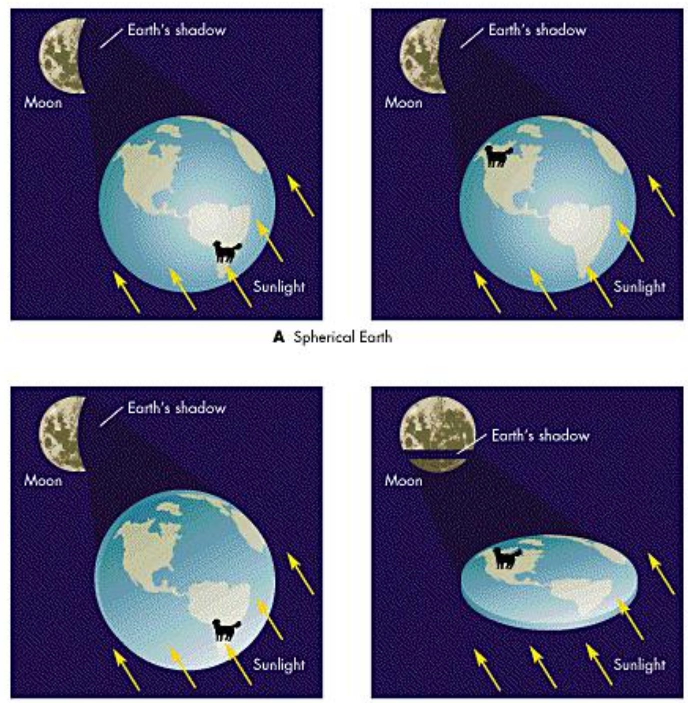


Aristotle and the Shape of the Moon

(~350 BC)

Used "proofs" to support the idea that Earth is a sphere:

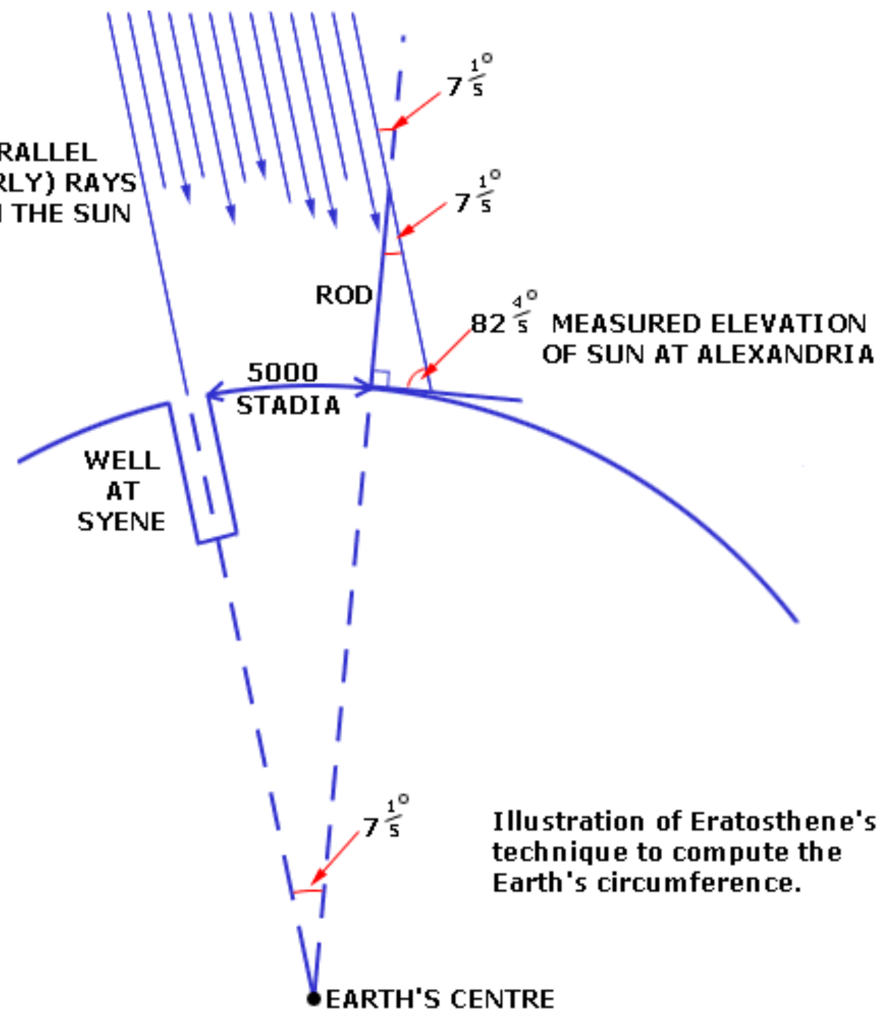
- Falling objects move toward Earth's center
- Shadow of Earth against Moon is always circular
- Some stars can be seen in certain places, but not in others



A Spherical Earth

B Flat Earth

Eratothenes and the Earth's Circumference



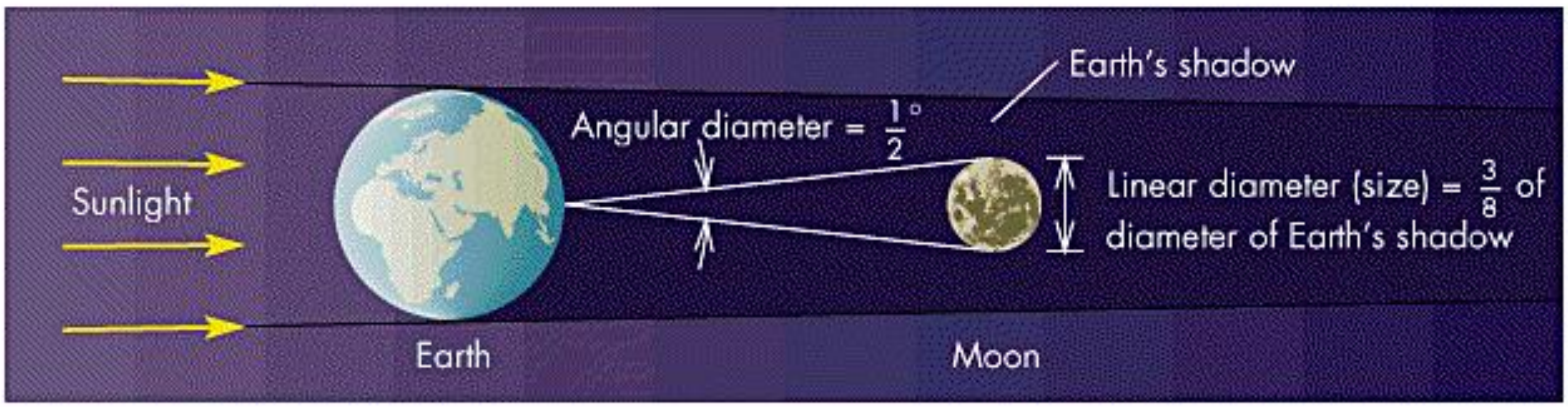
Aristarchus

(~270 BC)

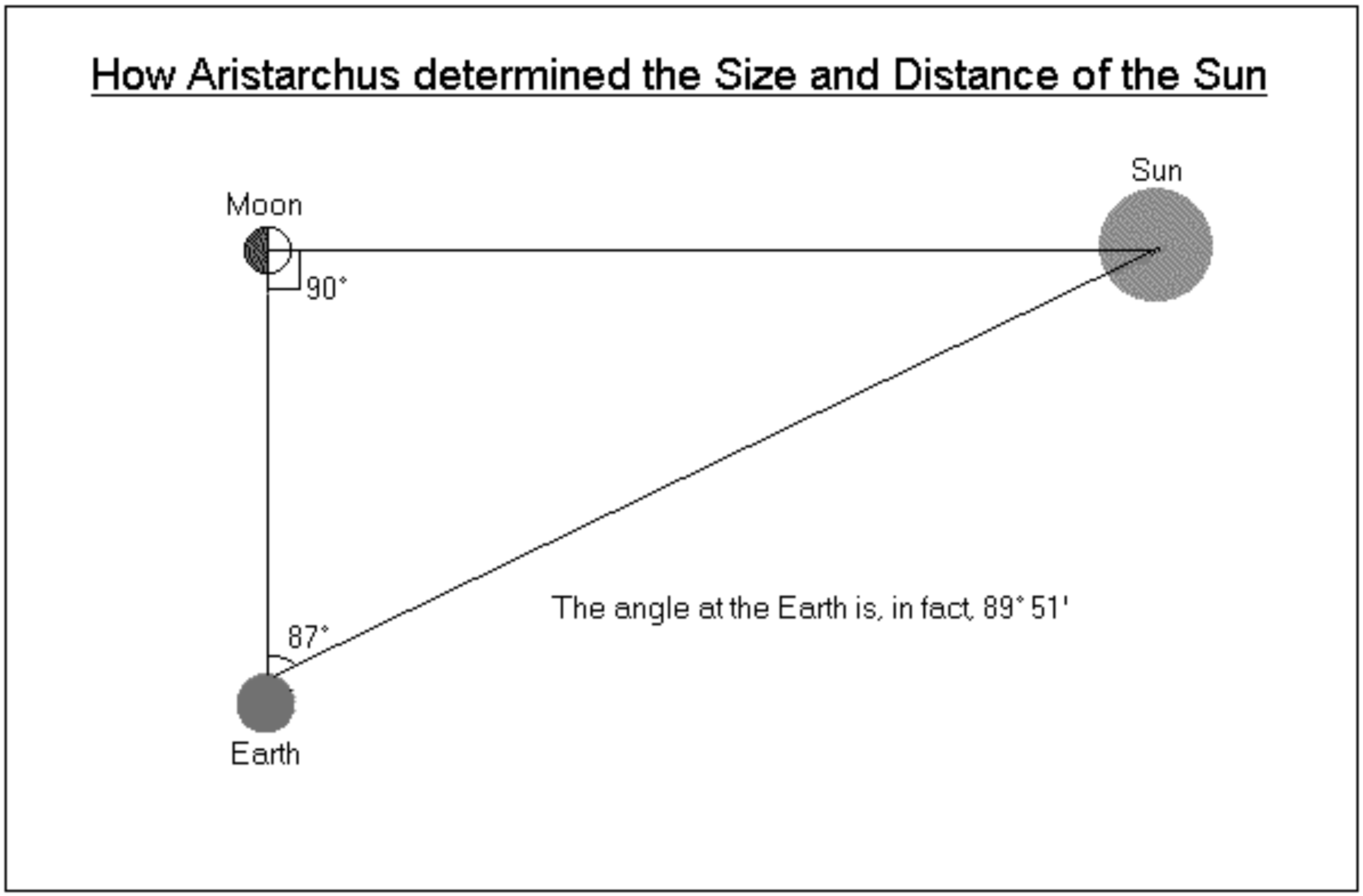
Applied geometry to astronomical considerations:

1. Size of Moon relative to Earth
2. Distance of Moon
3. Distance of Sun relative to Moon
4. Size of Sun
5. Earth rotates about an axis
6. Earth revolves about the Sun

Aristarchus and the Size of the Moon



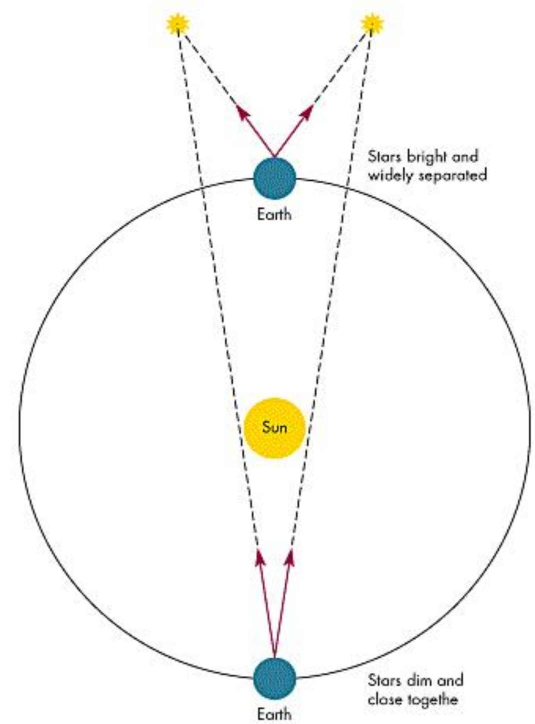
Aristarchus and the Distance to the Sun



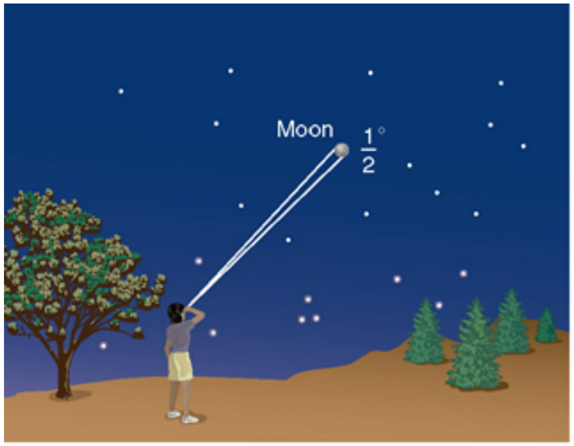
Objections to Aristarchus

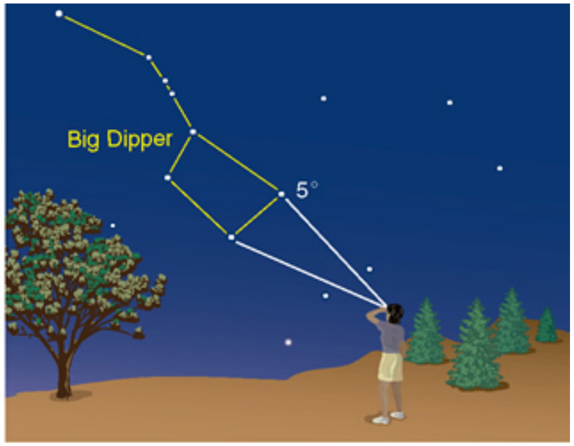
Greeks disregarded ideas of Earth rotation and revolution as "unreasonable":

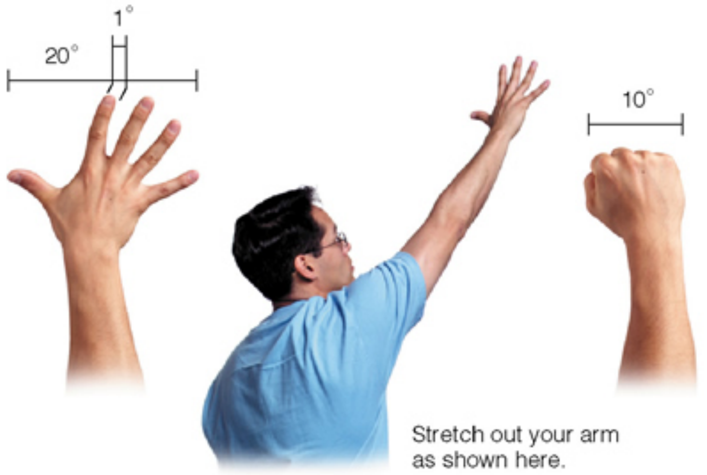
- no "rushing" winds
- stones fall straight down
- there is no parallax or change in brightness of the stars over a year



Angular Measure







Arc Length, and the All Important Rule of Angular Size

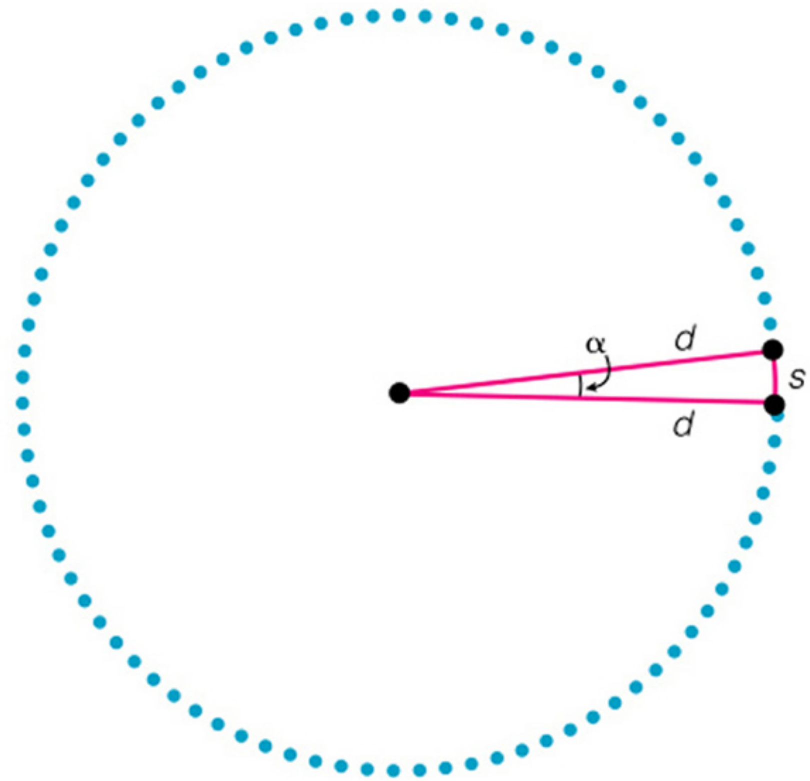
Physical Size = Angular Size X Distance

$$s = d\alpha$$

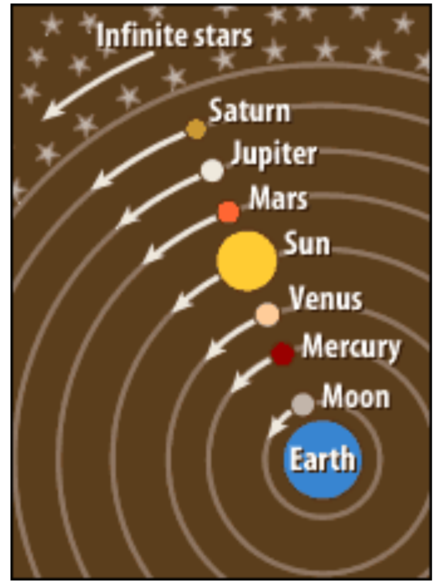
Special Case: circumference of a circle is

$$C = 2\pi r$$

Radians!

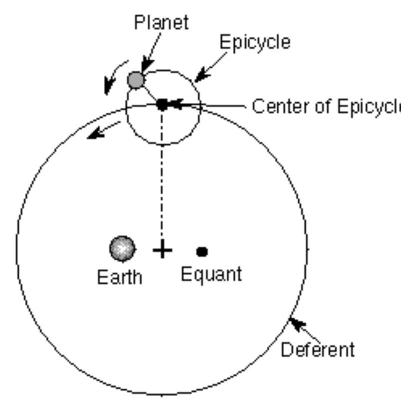


Ptolemy's Geocentric Model

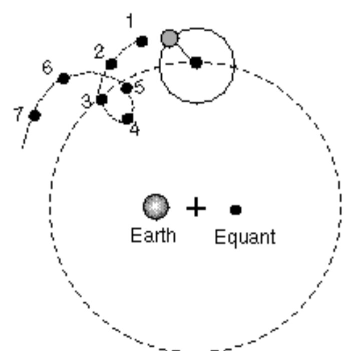


(~140 AD)

Summarized and extended a detailed geocentric model for the motions of celestial objects (description published in the *Almagest*)



Center of epicycle moves counter-clockwise on deferent and epicycle moves counterclockwise. Epicycle speed is uniform with respect to equant. The combined motion is shown at right.



Deferent motion is in direction of point 1 to 7 but planet's epicycle carries it on cycloid path (points 1 through 7) so that from points 3 through 5 the planet moves backward (retrograde).