

Astronomy of the Solar System – Module 2: Observing The Sky – Birth of Astronomy Part 1

GEORGIA STATE UNIVERSITY
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Long exposure photo showing star trails around the South Celestial Pole as Earth rotates. (Credit: OpenStax, ESO/Iztok Bončina)



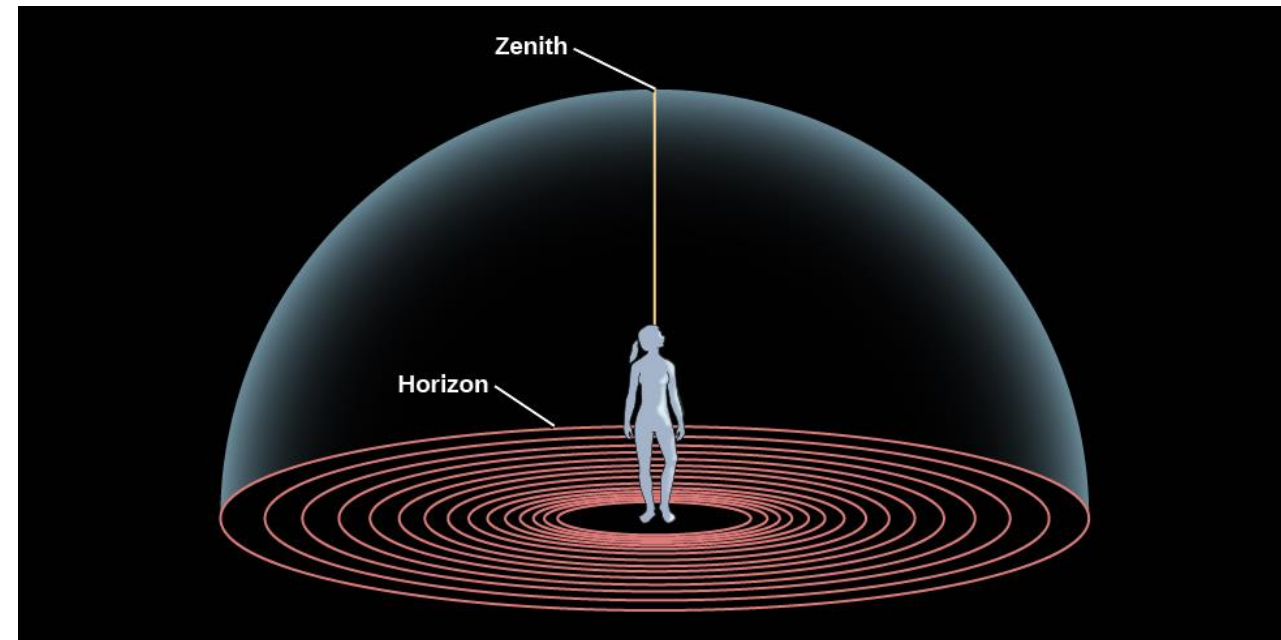
What do we see in the sky when you look up?

OpenStax Astronomy: 2.1

- **Depends on surrounding light sources**
 - More light sources, more light pollution
 - Can't see fainter objects in sky
 - Worst in urban and metro-areas
- **Most human history: No light pollution**
 - Celestial objects, their patterns, their motion firmly embedded in human cultures
 - Started with individual sensory perspective: Everything revolves around me! *Earth-centered* = “geocentric”
- ***Dome of the sky in which celestial objects move* = “Celestial Sphere”**
 - Simplest model of visible celestial objects
 - Practical use as dynamic map of sky
 - Still works: solar system is stable, all other stars are so far away they appear fixed



The constellation of Orion without (left) and with urban light pollution (right) (Credit: Jeremy Stanley, Sbarnes under Creative Commons Attribution 2.0 Generic), https://upload.wikimedia.org/wikipedia/commons/thumb/2/2c/Light_pollution_It%27s_not_pretty.jpg/800px-Light_pollution_It%27s_not_pretty.jpg

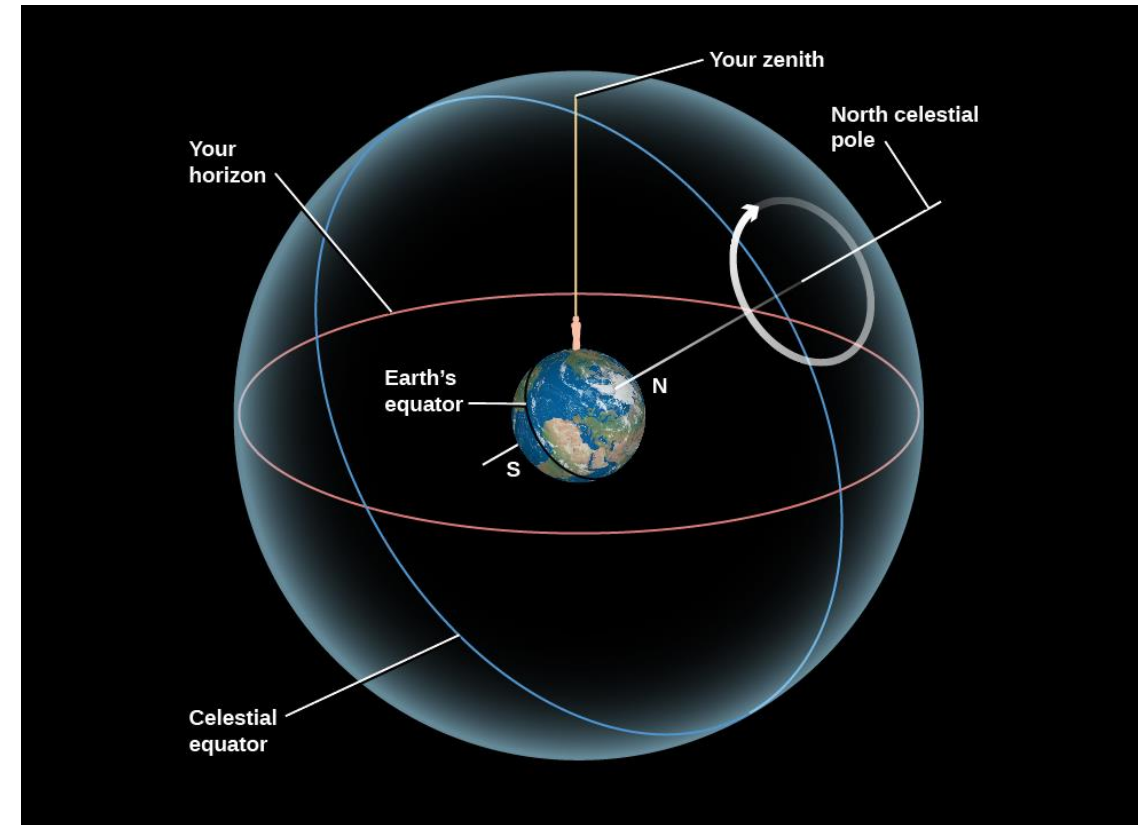


The horizon is where the sky meets the ground; an observer's zenith is the point directly overhead. (Credit: OpenStax)

What do we see when we observe regularly?

OpenStax Astronomy: 2.1

- **All objects appear to revolve during 24 hrs – Reality: Earth spins on its axis**
 - Stars form certain patterns that move together, most rise & set at different times during year
 - Sun is in different star patterns during year
 - Moon is in different locations compared to Sun, shows different lit parts during month
 - Planets move separate from Sun through different star patterns during year
- **“Celestial Sphere”** = imaginary sphere around Earth with fixed stars and other objects moving
 - **Reality:** Sun, Moon, planets, stars at vastly different distances from Earth
- **“Celestial Equator”** = line in the sphere above Earth’s equator
- **“North/South Celestial Pole”** = points in the sphere above Earth’s North/South Poles

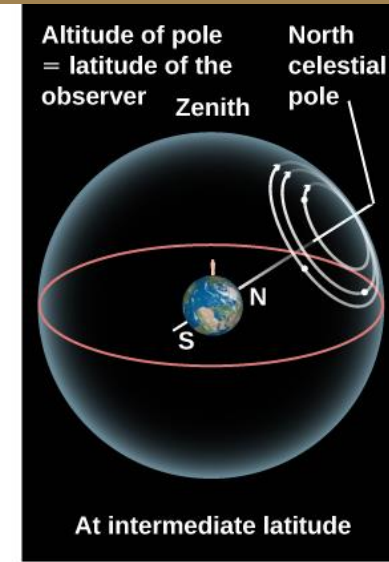
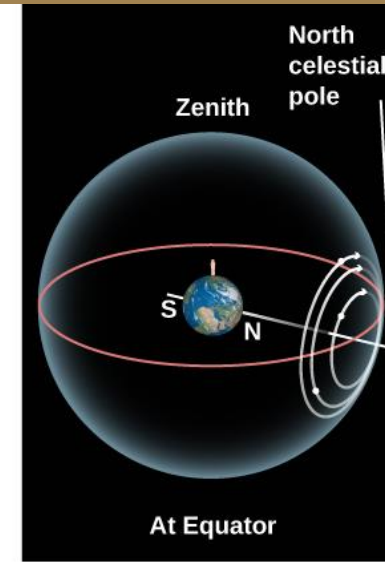
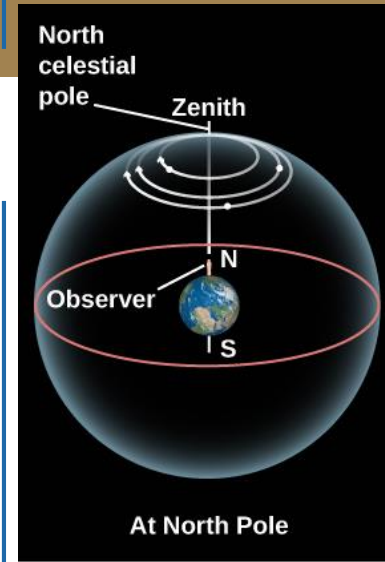


Model of *Celestial Sphere*: fixed celestial objects rotate around Earth. Reality: Earth’s rotation causes illusion of revolving sky. Earth is tilted with your location at the top. The circular arrow shows the apparent motion of celestial sphere around the pole. (Credit: OpenStax)

What do people in different places on Earth see the sky?

OpenStax Astronomy: 2.1

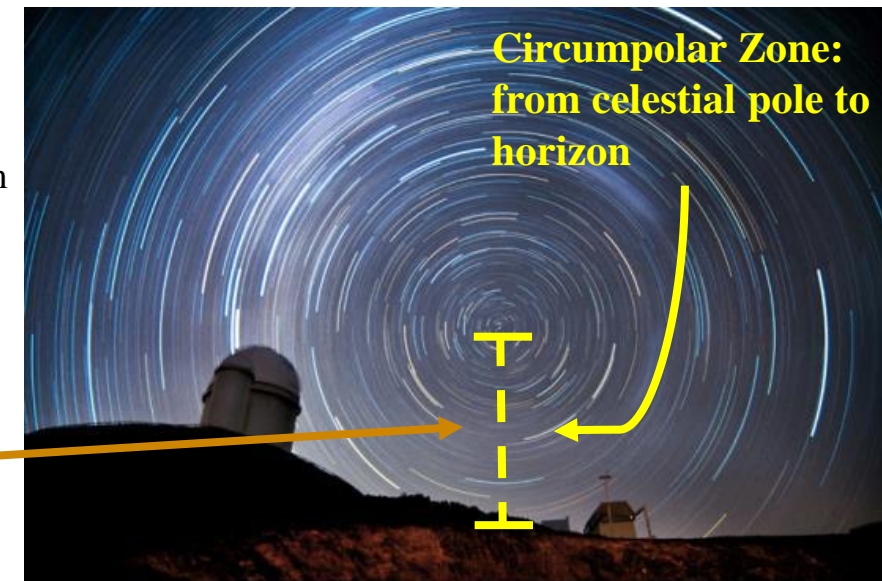
- **Celestial poles** = *where Earth's axis points in sky*
 - Do not turn, but everything turns around them
 - Height in sky depends on observer's latitude (North – South)
- **a) From North/South pole ($\pm 90^\circ$ latitude)**
 - North/South celestial pole at zenith
 - Celestial equator at horizon
 - All stars circle celestial pole, none rise & set = **“circumpolar”**
- **b) From equator (0° latitude)**
 - North/South celestial pole on equator
 - Celestial equator passes through zenith
 - All stars rise & set, none are circumpolar
- **c) Observer at latitudes in between**
 - Celestial pole same angle above horizon as your latitude; celestial equator 90° further up
 - Stars between pole & equator = **circumpolar**, stars beyond = non-circumpolar



Star circles (a) observed from different latitudes (b) (Credit: OpenStax)

(c)

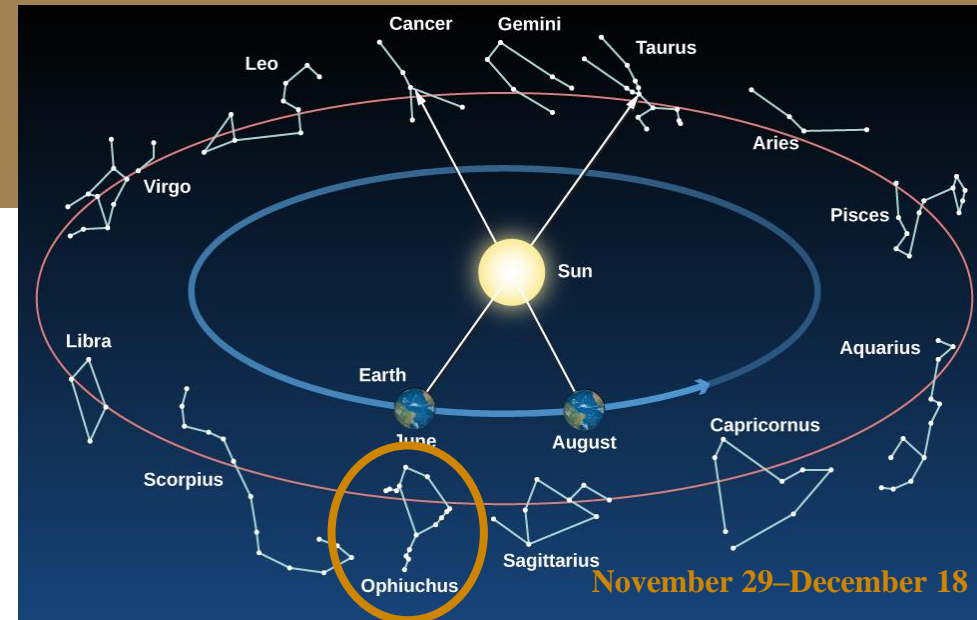
Long exposure photo: star trails around the South Celestial Pole as Earth rotates. Taken from European Southern Observatory, $-24^\circ 37'$ min (Credit: OpenStax, ESO/Iztok Bončina)



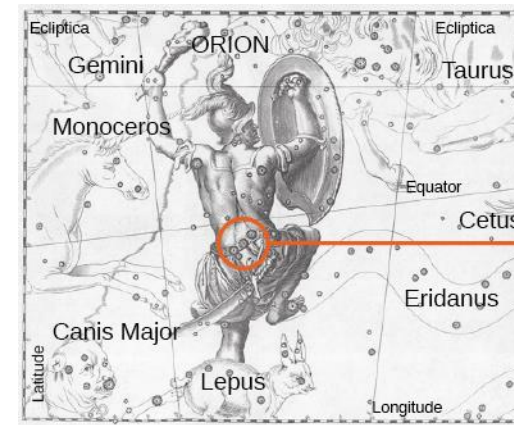
How does the Sun move in the Celestial Sphere?

OpenStax Astronomy: 2.1

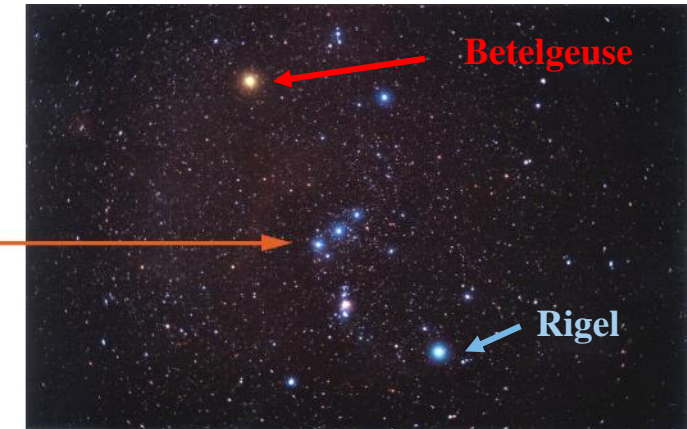
- **As Earth orbits: see Sun in front of different background stars**
 - Moves 1° East & rises 4 minutes later each day relative to stars (Earth spins 1° more than 1 full rotation)
 - 1 year = 365 days for complete orbit (back in front of same stars)
- **“Constellation”** = distinct pattern of brightest stars, differently grouped by ancient cultures; *modern Astronomy: whole sector around these stars* with official boundaries
 - Sphere divided into 88 sectors, map of sky
 - *Analogy: US composed of 50 states*
- **“Ecliptic”** = annual path of Sun through sphere
- **“Zodiac”** = group of constellations on ecliptic
 - 12 when Astrology arose ~ 1000 years ago
 - Now 13 with *Ophiuchus* – Snake Charmer
 - All constellation date ranges have shifted!



Constellations on the Ecliptic. Note: We can't see the constellation the Sun is in because of its glare during the day. We see the constellations opposite to the Sun at night. (Credit: OpenStax)



(a)



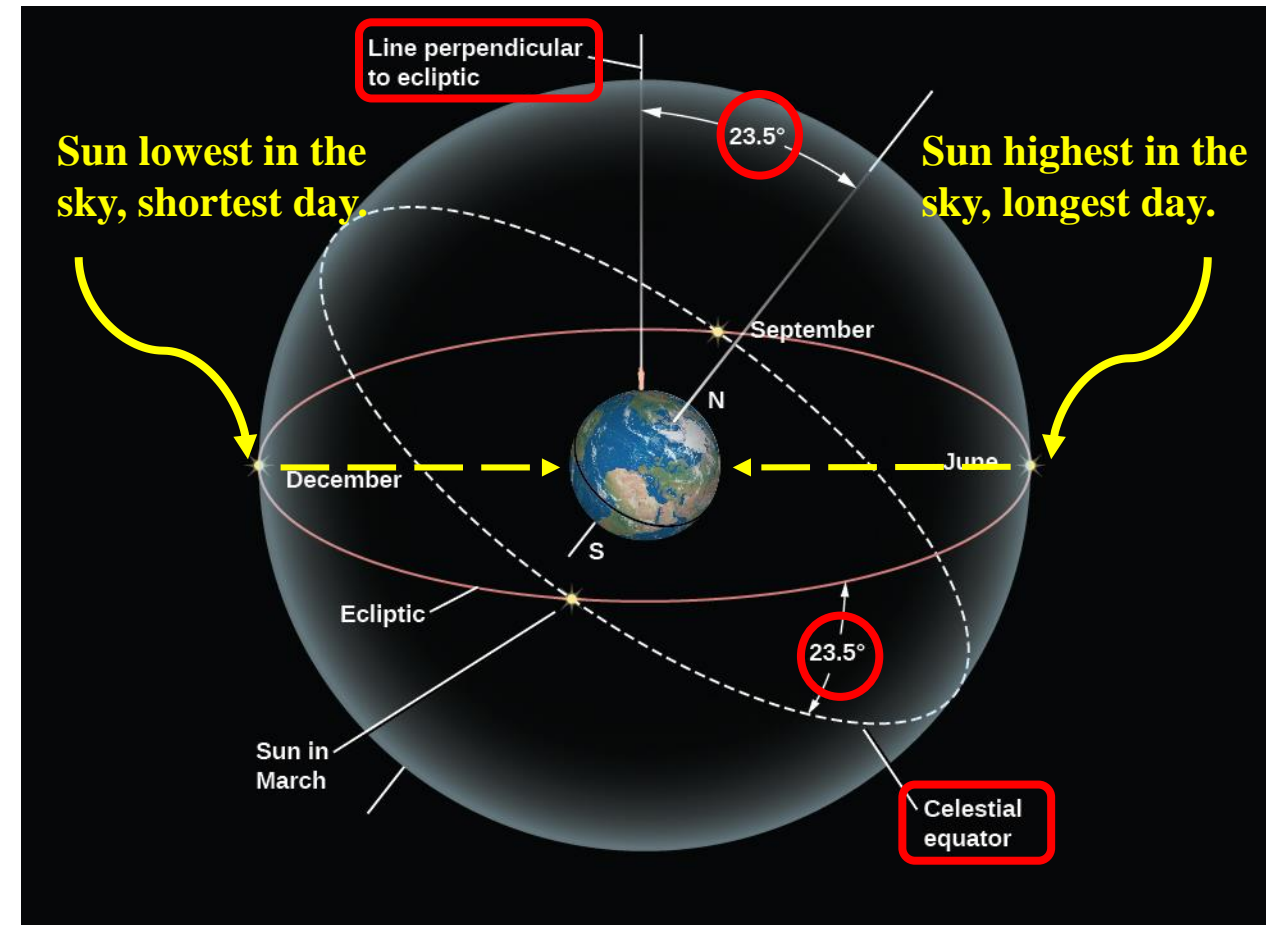
(b)

(a) Constellation of Orion, the hunter, among neighbor constellations in 17th century atlas. (b) Photograph of the Orion region in the sky. (credit: OpenStax, modification of work by a) Johannes Hevelius, b) Matthew Spinelli)

Why is the path of the Sun tilted relative to celestial equator?

OpenStax Astronomy: 2.1

- Earth's axis tilted **23.5 ° from vertical**
- Earth's & celestial equators tilted **23.5 ° to ecliptic**
 - Sun 6 months north of CE (Northern Spring, Summer), *highest in June (longest days)*
 - Sun 6 months south of CE (Northern Fall, Winter), *lowest in December (shortest days)*
 - Sun crosses ecliptic south to north first day of Northern Spring
 - Sun crosses ecliptic north to south on first day of Northern Fall
 - Southern hemisphere: reversed heights of Sun in sky, lengths of days & seasons



The ecliptic is tilted by 23.5° to the celestial equator (CE). (Credit: OpenStax)

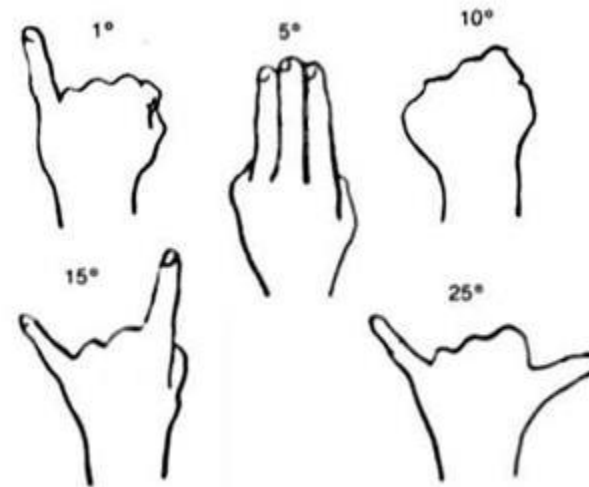
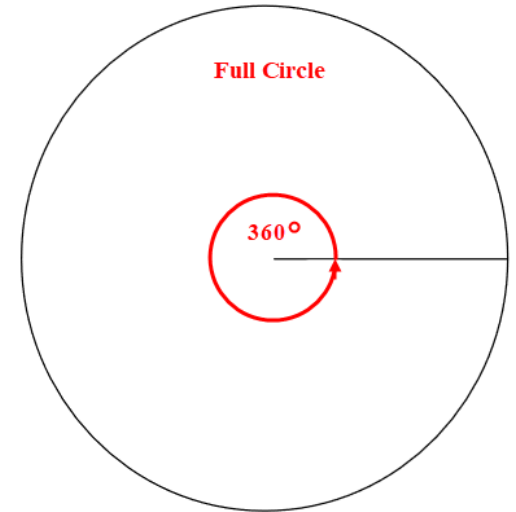
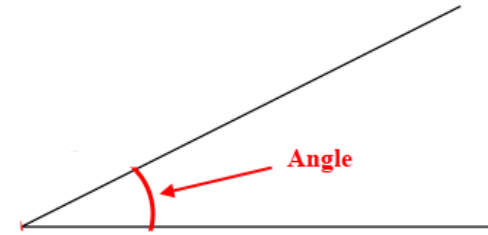
How do we measure distances and sizes in the sky?

OpenStax Astronomy: 2.1

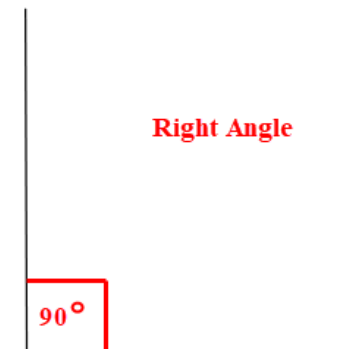
Review of Angles

figures of angles by Bill & Ulrike Lahaise

- “**Angle**” = exact measure of opening between two connecting straight lines
- Most practical for distances and sizes on sphere
- Units: degrees = $^{\circ}$, arc minutes = $'$, arc seconds = $''$
 - $1^{\circ} = 60'$, $1' = 60''$, so $1^{\circ} = 60' (60''/1') = 3600''$
 - Full circle = 360° , right angle = 90°
- Different **hand positions at arms length subtend certain angles** – can *estimate distances and sizes* in angular dimensions *in celestial sphere*
 - 1° ~ width of little finger
 - 5° ~ combined width of middle three fingers
 - 10° ~ width of fist
 - 15° ~ spread of pointer & little finger
 - 25° ~ spread of thumb & little finger
 - Fingers in natural position & Arm all stretched
 - Hands & arms proportional to height of person



Hand positions at arm's length to measure angles in the sky (unknown source, used by University of Iowa & other public educational institutions)



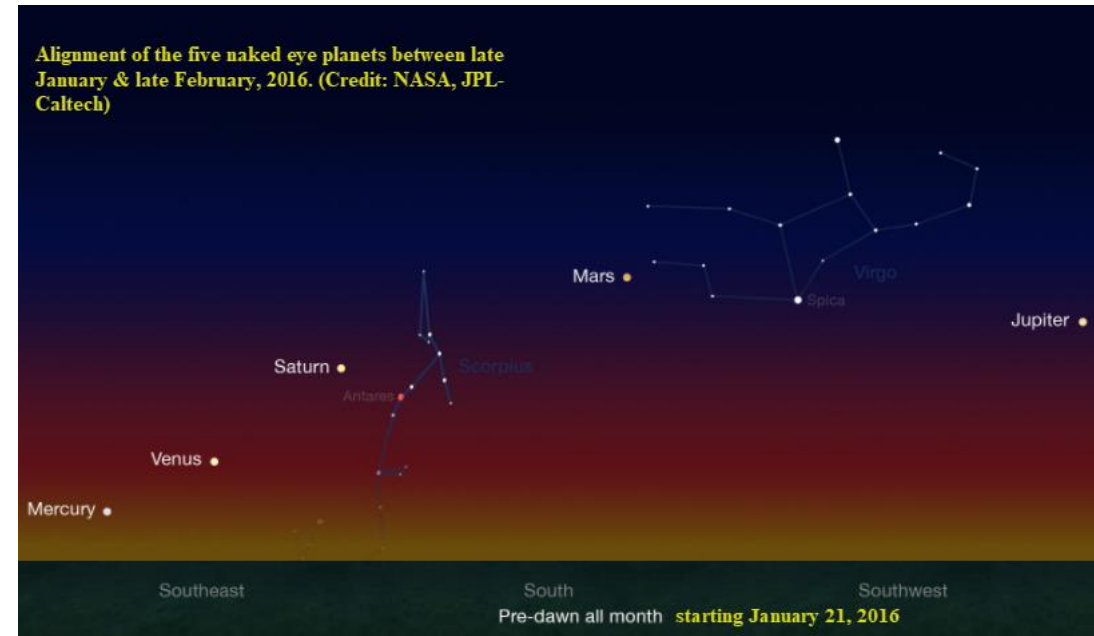
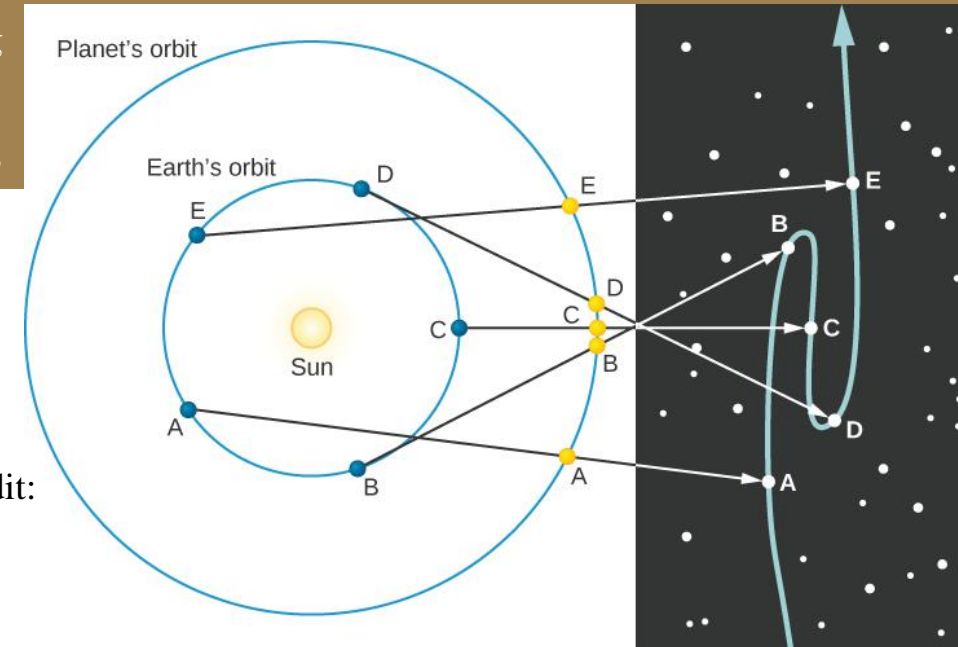
How can we tell planets apart from stars?

OpenStax Astronomy: 2.1

- **“Planets”** = other celestial objects moving among fixed stars
 - “Planetes” = “Wanderers” in Greek
 - Move among the fixed stars
- Greeks included Sun and Moon
 - Moon moves $\sim 12^\circ$ in celestial sphere & rises ~ 1 hr later each day
 - Moon takes ~ 1 month for one cycle, close to ecliptic
 - Moon is fastest because it is closest to Earth relative to other objects
- Today, **Sun & Moon are NOT “Planets”**
 - *5 planets visible to naked eye: Mercury, Venus, Mars, Jupiter, Saturn*
 - Move close to ecliptic (within 18° in longer cycles the farther from Earth)

Mars moves among fixed stars as seen from Earth. Letters for Earth's & Mars' positions on left

correspond to the locations we see Mars against background stars while both planets orbit the Sun. (Credit: OpenStax)



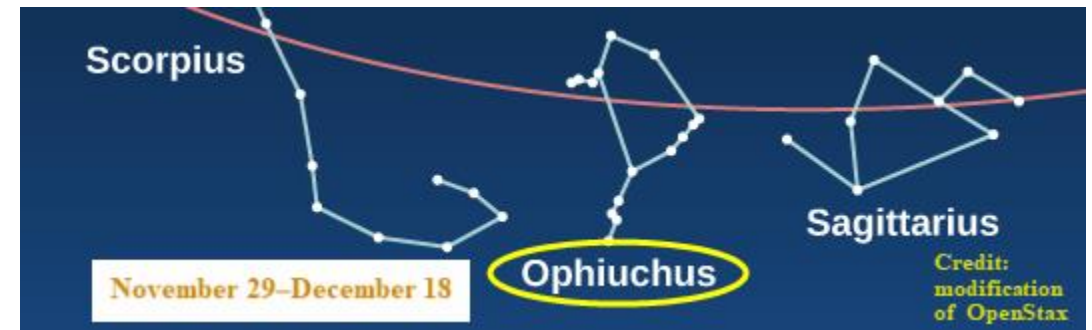
Are our lives determined by the Sun, Moon & planets among the stars?

OpenStax Astronomy: 2.3

- **Ancient cultures: knowledge of sky and spirituality were unified**
 - Planets & stars symbolized gods & supernatural forces believed to affect lives
- **Ancient Greeks: 5 naked eye planets have same powers as their name sake gods**
 - **2000 years ago: “natal astrology”** = configuration of Sun, Moon, & planets (*astrology*) at birth (*natal*) determines your personality & fortune
 - Greek astronomer Ptolemy wrote astrological rule book still used today by followers
- **“Horoscope”** = configuration chart of 7 moving objects in Zodiac at birth
 - Zodiac = 30 sectors of 12° (“**signs**”) – same name as constellation in it, **still used today!**
 - Your sign = where Sun was at your birth

Is Astrology scientifically accurate?

- Direction of Earth’s axis in celestial sphere slowly shifts over centuries = “**Precession**” (*see Part 2 for more*)
 - Ecliptic shifts too: Zodiac has 13 signs today (+ Ophiuchus) – date ranges also shifted!
 - **Modern sign might not be astrological sign!**



- Only physical effect due to planets: force of gravity
 - But: **gravity by people in room > gravity of planets!**
- Thousands of people born same date/time all over world: **do NOT have same personalities & fortunes!**
- Astrological predictions scientifically testable, example:
 - better presidential birth signs? Marriage pairings?
 - **Fails all scientific tests!**