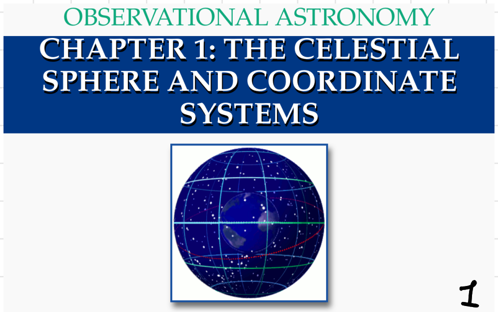
Ch1 Lecture Notes



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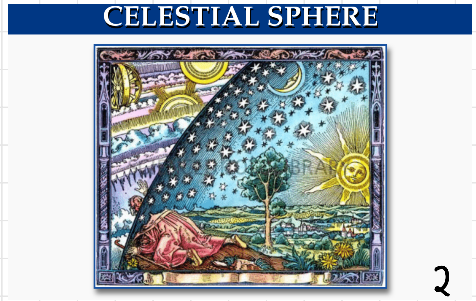

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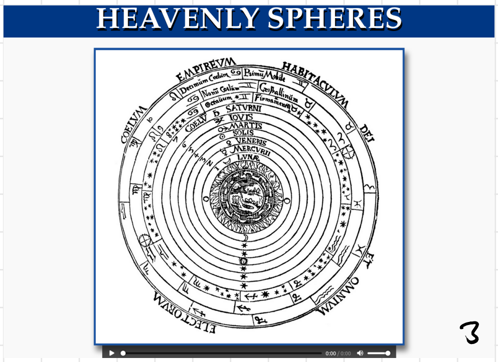
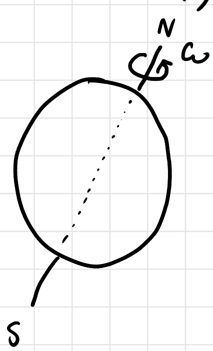


3

Societies use to think the celestial spheres was the true arrangement of the heavens.

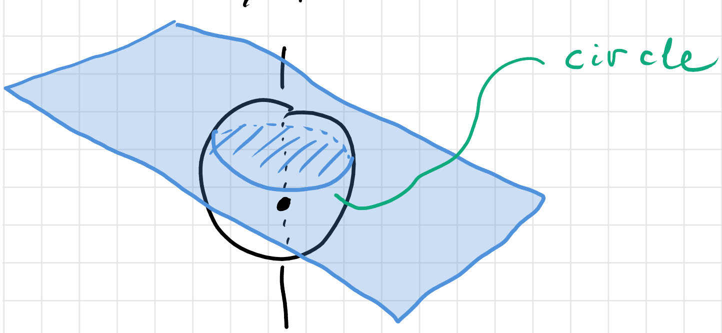
Multiple observations & ideas force astronomy to abandon this model, but the celestial sphere is still a useful tool.

Assume a rotating sphere. The axis of rotation defines the N & S poles

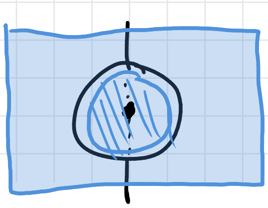


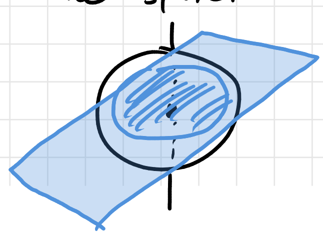
- N pole defined s.t from "birds eye view" sphere rotates CCW

An arbitrary plane can slice through the sphere & trace out a circle

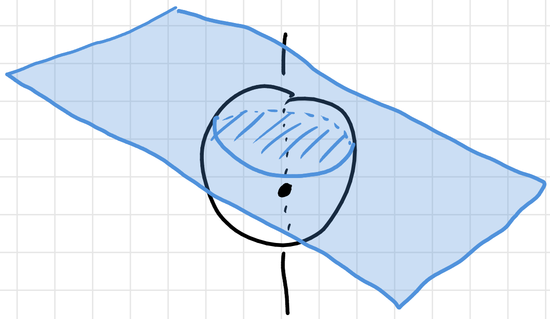


A great circle is created when an intersecting plane encompasses the center of the sphere

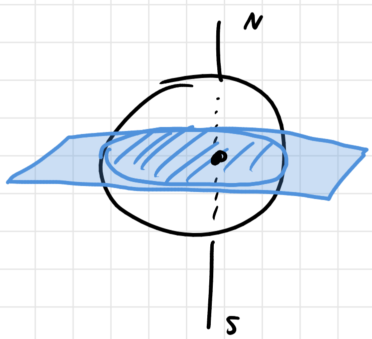




A small circle is created when an intersecting plane does not encompass center of the sphere

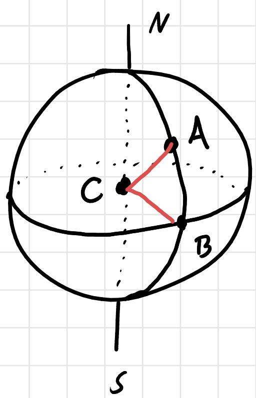


The fundamental plane is the great circle that is perpendicular to the rotation axis



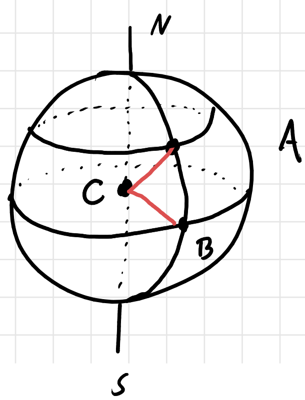
- on Earth we call this the equator
- what we call the fundamental plane will change depending on the coordinate system an astronomer is working with.

Now consider a point A on the sphere by making a great circle that includes the poles



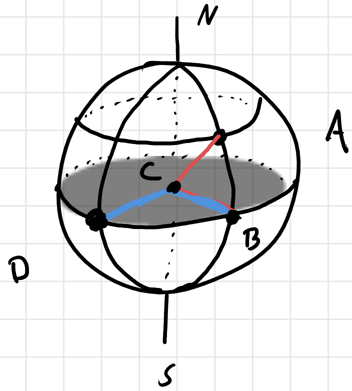
$\angle BCA$ = latitude (on Earth)

Make a small circle // to the fundamental plane & intersects A



- all points on this small circle have the latitude

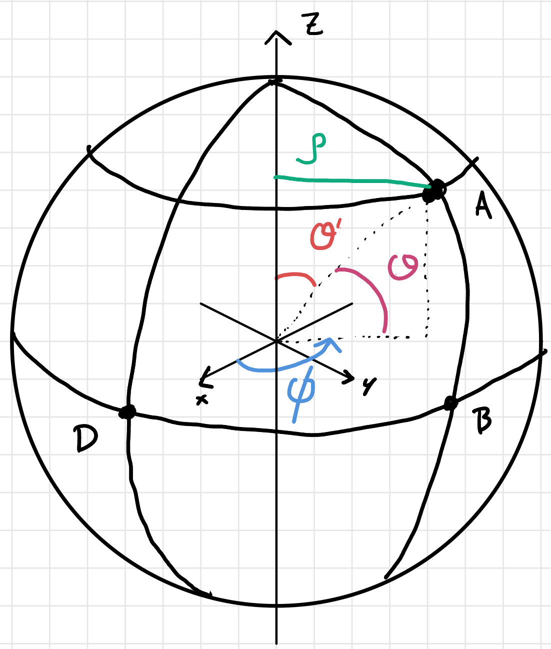
We need one more great circle to get the longitude of A.



$\angle DCB$ = longitude of A

The NDS meridian is the prime meridian. (where $\phi = 0$)

On Earth this is Greenwhich England



ϕ = azimuthal angle

θ = polar angle

note that ϕ & θ labels are opposite by mathematics convention

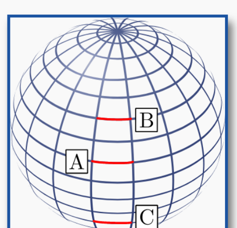
$0 \leq \phi \leq 2\pi$

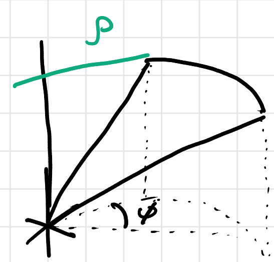
$0 \leq \theta' \leq \pi$ or $-\frac{\pi}{2} \leq \theta \leq \frac{\pi}{2}$

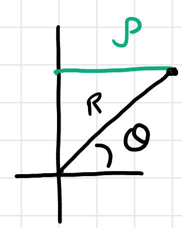
PQ: LONGITUDINAL DISTANCES

The radius of Earth is $R_E = 6378.1$km. What is the physical distance between two meridians separated by 1° at the following latitudes?

A. At the equator $\theta = 0^\circ$.
B. At Norfolk VA $\theta = 36.88^\circ$.
C. Near Outpost 31 in the Antarctic $\theta = -70.7^\circ$.







S = arclength $= \rho\phi$

$\rho = R\cos\theta$

$S = R\cos\theta \cdot \phi$

A) $S = (6378.1\text{km})\left(1^\circ \frac{\pi \text{ rad}}{180^\circ}\right)\cos(0) = 111.3\text{km}$

B) $S = (6378.1\text{km})\left(1^\circ \frac{\pi \text{ rad}}{180^\circ}\right)\cos(36.88^\circ) = 89.04\text{km}$

C) $S = (6378.1\text{km})\left(1^\circ \frac{\pi \text{ rad}}{180^\circ}\right)\cos(-70.7^\circ) = 36.79\text{km}$

Astronomers use several spherical coordinate systems depending on there needs.

For example: we all know the sun is the center of the solar system, but it is perfectly valid to work in a reference frame where Earth is the center.

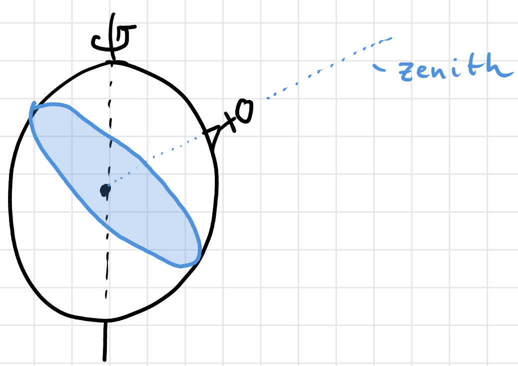
- run Orbital_Transformation.py script from Nick Lucid (Science Asylum)

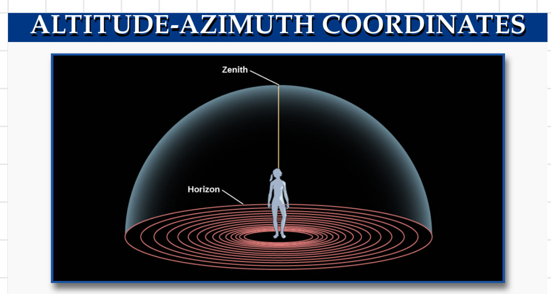
We will discuss 4 coordinate systems in this chapter. Key differences are what is that coordinates fundamental plane.

- Altitude - azimuth
- Equatorial
- Ecliptic
- Galactic equator

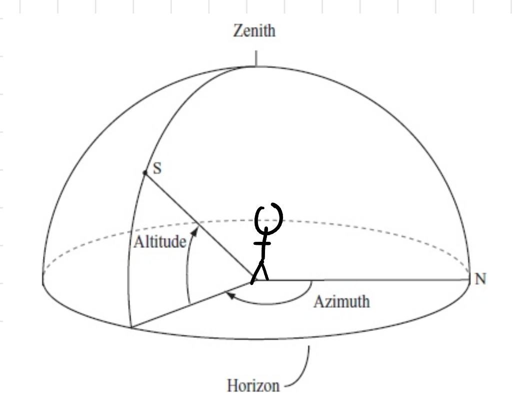
<u>Altitude - azimuth</u> (aka horizon system, alt-az system)

The fundamental plane is the observers horizon





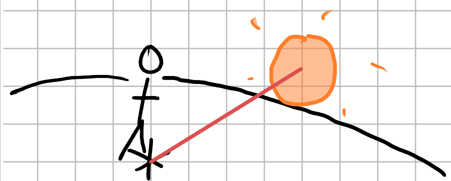
Coordinates: Altitude & Azimuth

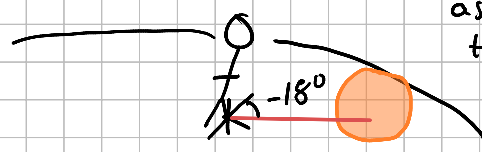


go to stellarium & show view at different locations on Earth

Note cancel Tuesday Jan 17 class (Isaac appointment)

Altitude varies from 0 - 90°. An object beneath the horizon has negative altitude.

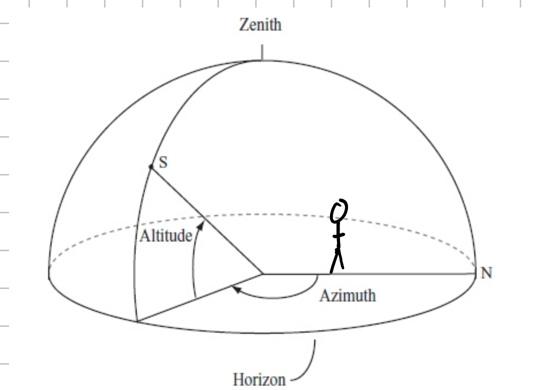


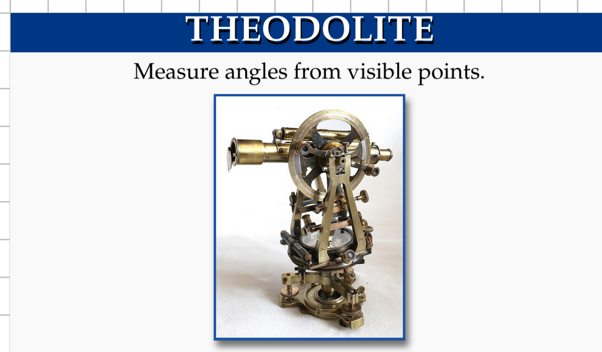


astronomical twilight

sun has altitude of -18°

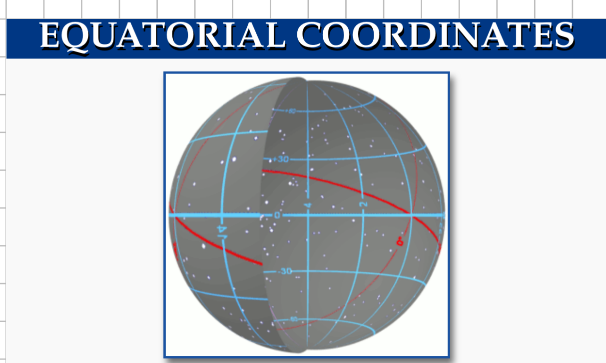
- Our 2nd coordinate, the azimuth is taken to be zero degrees due North.
- Azimuth increases due East!



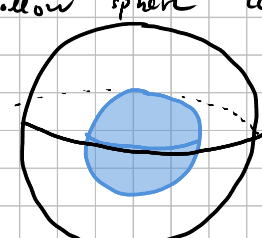


- Can use tools like a theodolite to measure altitude & azimuth
- This is a rotating reference frame since Earth rotates towards the East
  - ↳ causes objects to "move" East to West
- Useful for telling where to find objects at the persons geographic location
  - ↳ not good for permanent description of stellar object positions

Equatorial Coordinates

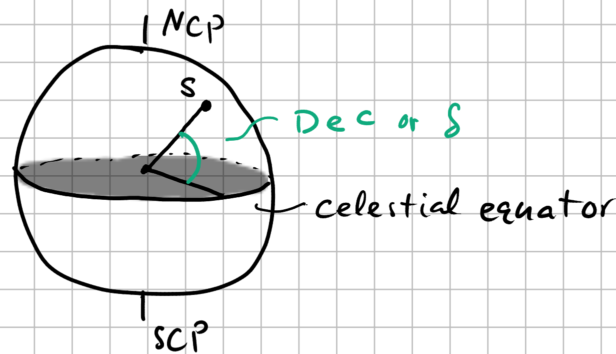


Imagine Earth inside a hollow sphere w/ the equator of Earth and this hollow sphere co-planar



coordinates: declination & right ascension
(Dec) (RA)

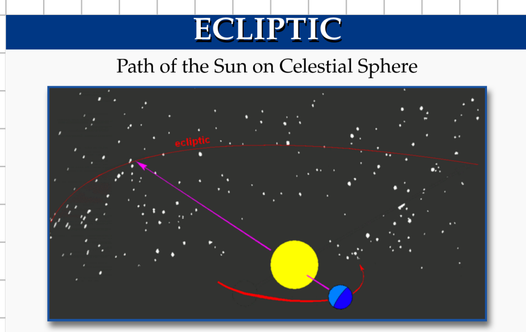
- Earth's axis of rotation defines the N & S celestial poles (NCP & SCP)
  - polaris nearest star
- Declenation measures angle N or S of celestial equator

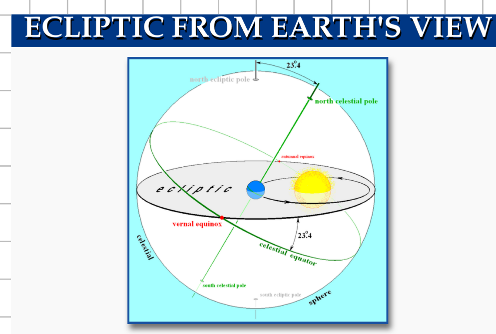


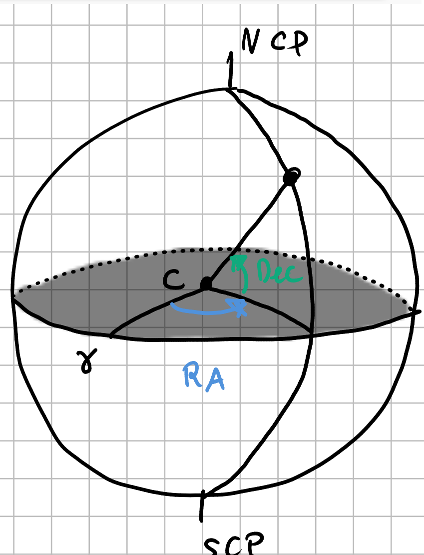
+ for objects in N hemisphere
− for objects in S hemisphere

denoted as Dec or δ
- measured in degrees
  $-90° \le \delta \le 90°$

- Right ascension measures CCW angle in fundamental plane
  - RA = 0° at March equinox (♈ or ♈) (vernal equinox in N-hemisphere)
    when Sun's path crosses celestial equator from S → N
    - ecliptic ~ March 20







• denoted as RA or α
- measured in units of time

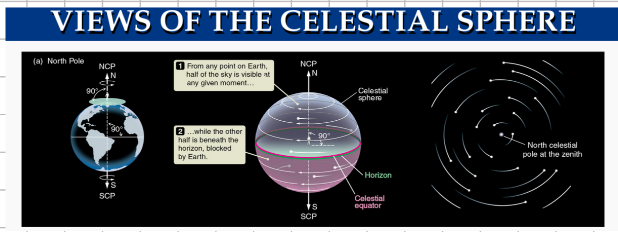
$0 \le \alpha \le 24\,hr$

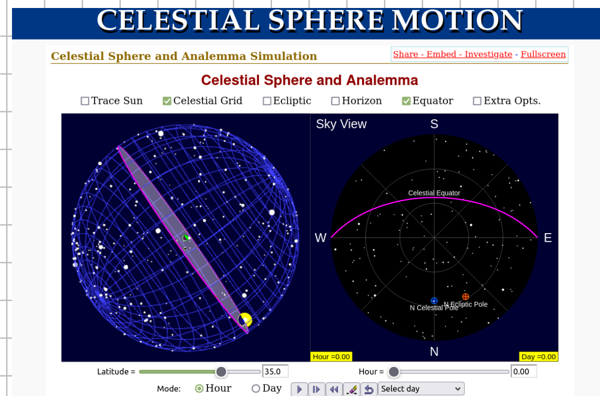
$360° = 24\,hr$
or
$15° = 1\,hr$

Side Note: Because Earth is a spinning top, its axis of rotation precesses.
Around year 3,100 Gamma Cephei will be the North star

Demo: Gyroscope

How much of the celestial sphere you see depends on your location on Earth.



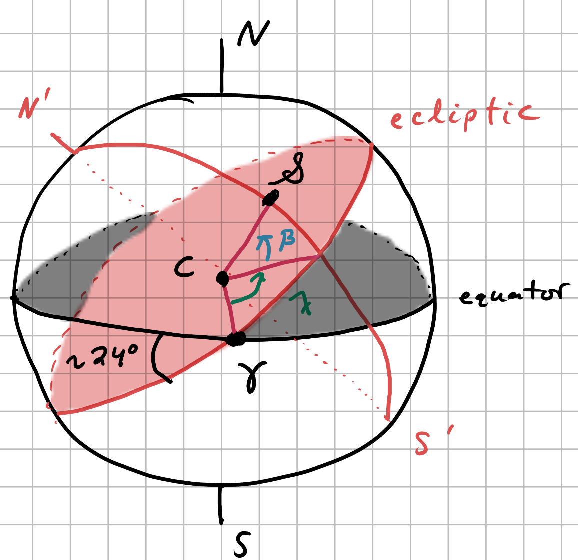


Q: Where is the best place to build ground base telescopes

Ecliptic Coordinates

fundamental plane is the ecliptic (apparent path of Sun)

coordinates: ecliptic latitude (β), ecliptic longitude (λ)
∟ vernal equinox is where $\lambda = 0°$



ecliptic system superimposed onto the equatorial system

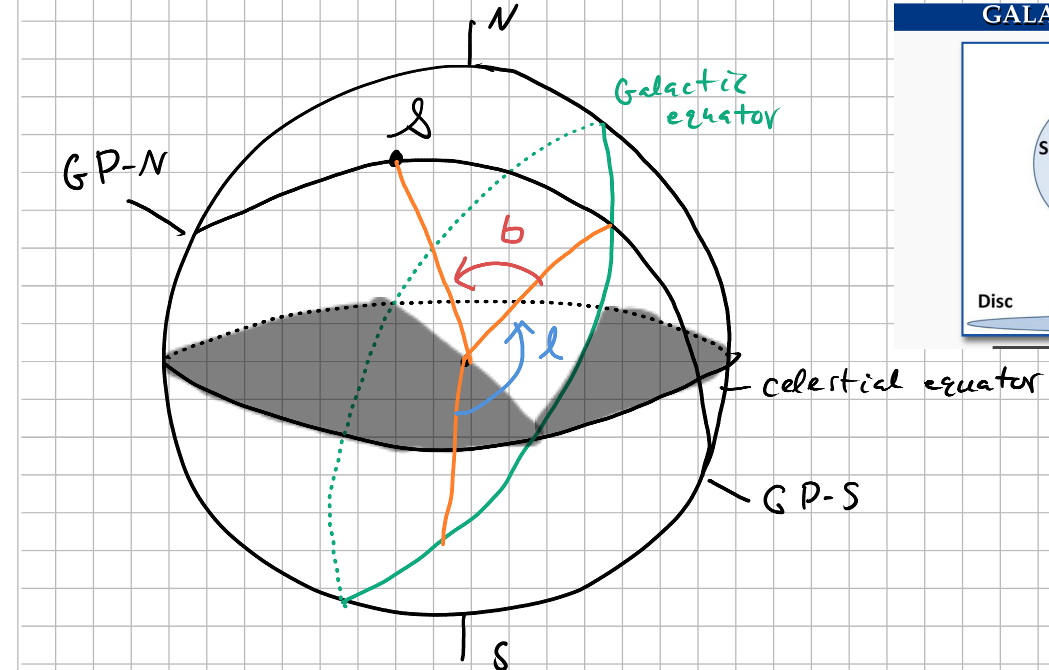
• useful for people studying the motion of the planets

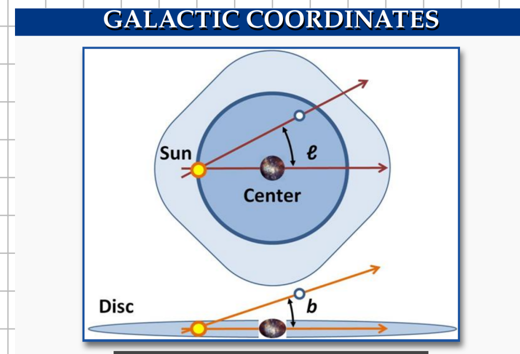
Galactic Coordinates

fundamental plane is the galactic equator
a great circle on the center line of the Milky Way on sky

coordinates: galactic latitude (b), galactic longitude (ℓ)

$\ell = 0$ towards center of Milkyway (in Sagittarius constellation)

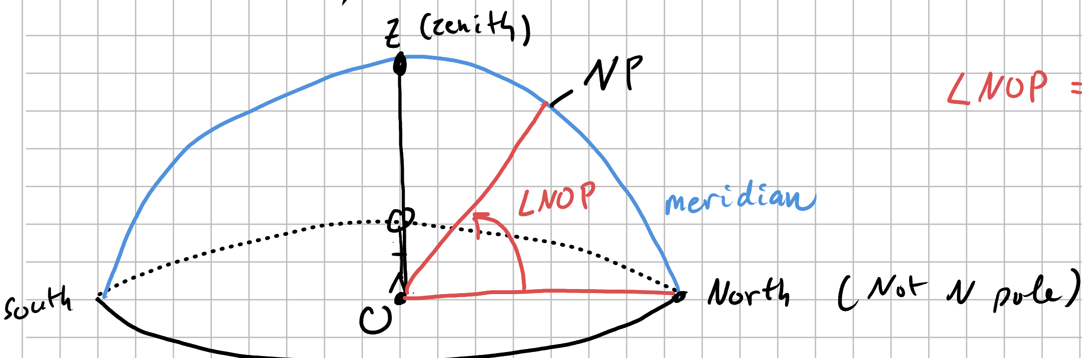




the galactic coordinates cannot be directly measured and must be calculated (Ch4)

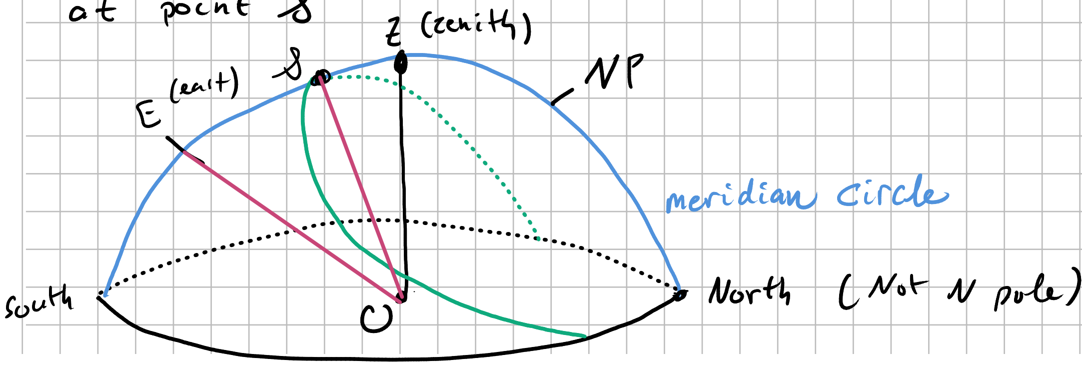
Measuring Stellar Coordinates

Take an arbitrary observer and draw their view of the celestial sphere



∠NOP = latitude of observer

Now draw the small circle representing the path of a star.
This star rises in the East, sets in the West & crosses the meridian at point δ



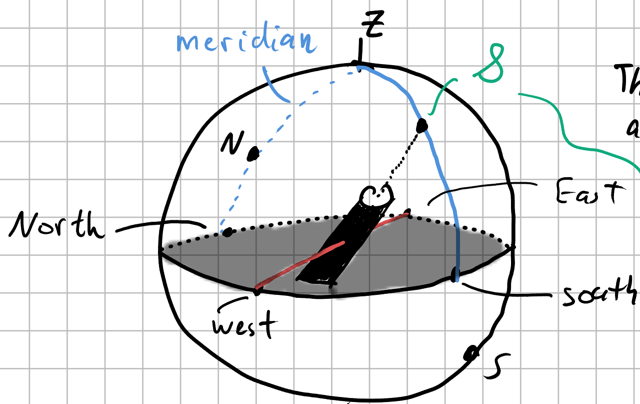
$\angle \delta OE$ = declination

we need precise way to measure this angle!

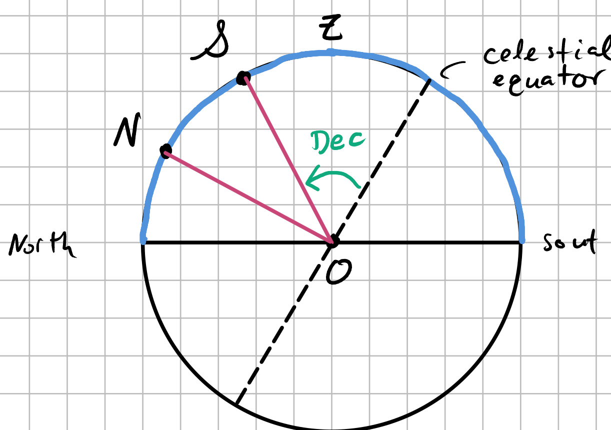
- Have a telescope "mounted" to the E-W axis

aka transit telescope

This meridian telescope can move only along the meridian

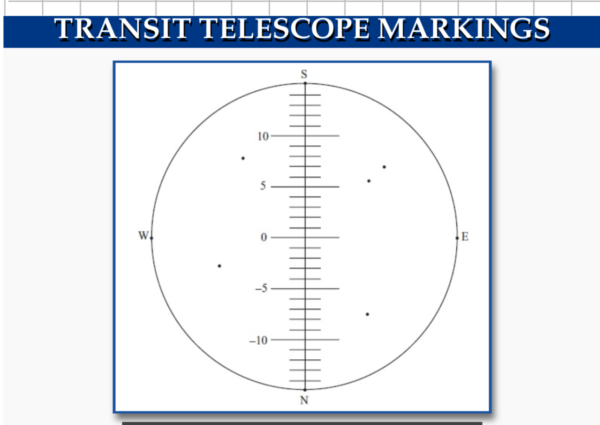


View from West to East



$\angle NO\delta$ we measure w/ Meridian telescope

$$\boxed{Dec = 90^\circ - \angle NO\delta}$$



Use marks on transit telescope to set $\angle NO\delta$

If one has a sidereal clock then you can measure the right ascension

- sidereal time is time for distant stars to be in same position in the sky

Demo: Draw dots on board (representing background stars) then rotate with a laserpointer

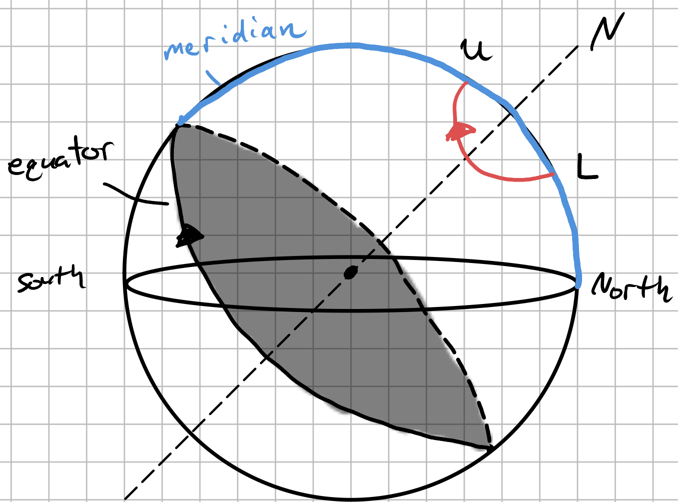
a sidereal day $\neq$ solar day

- sidereal clock set to zero when the vernal equinox crosses observers meridian
- time on clock $\longleftrightarrow$ right ascension of star

Finding the Celestial Pole

Consider a star in your field of view that is circumpolar.

└ over 24 sidereal hour star will cross <u>meridian</u> twice



U = upper transit
or
upper culmination } when star reaches its highest altitude

L = lower transit
or
lower culmination

- If we measure altitude of star at U & L we can find altitude of the pole

$$\text{altitude of pole} = \text{your latitude} = \frac{U+L}{2}$$