

# A Problem

The Earth's mean distance from the Sun is  $1.496 \times 10^{11}$  m,  
and its orbital period is  $3.156 \times 10^7$  sec.

In these units  $G$  is  $6.673 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$

Use this to derive the mass of the Sun in kg.

# Some fundamental stellar properties

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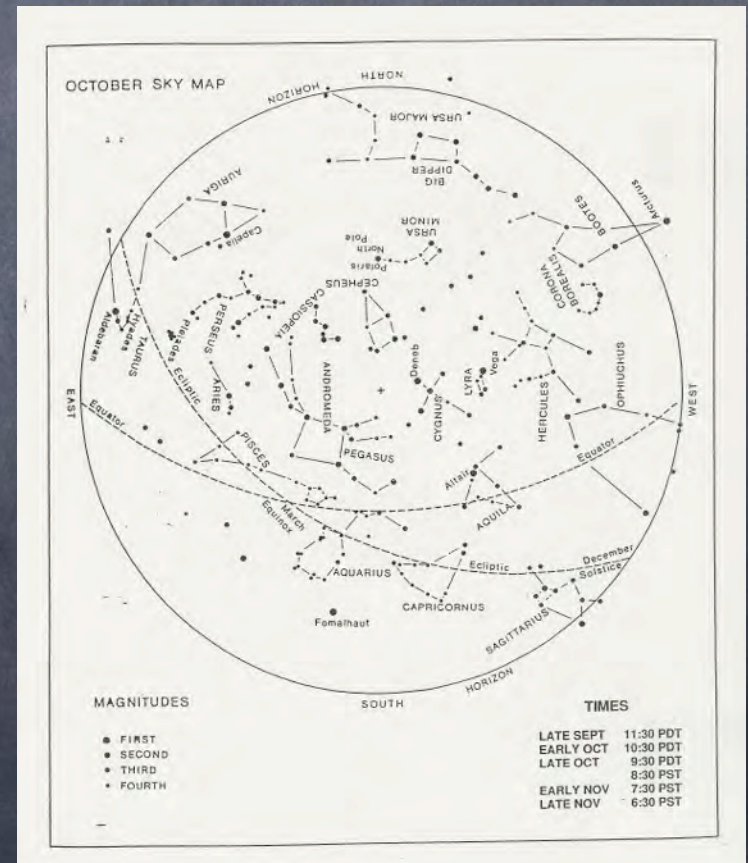
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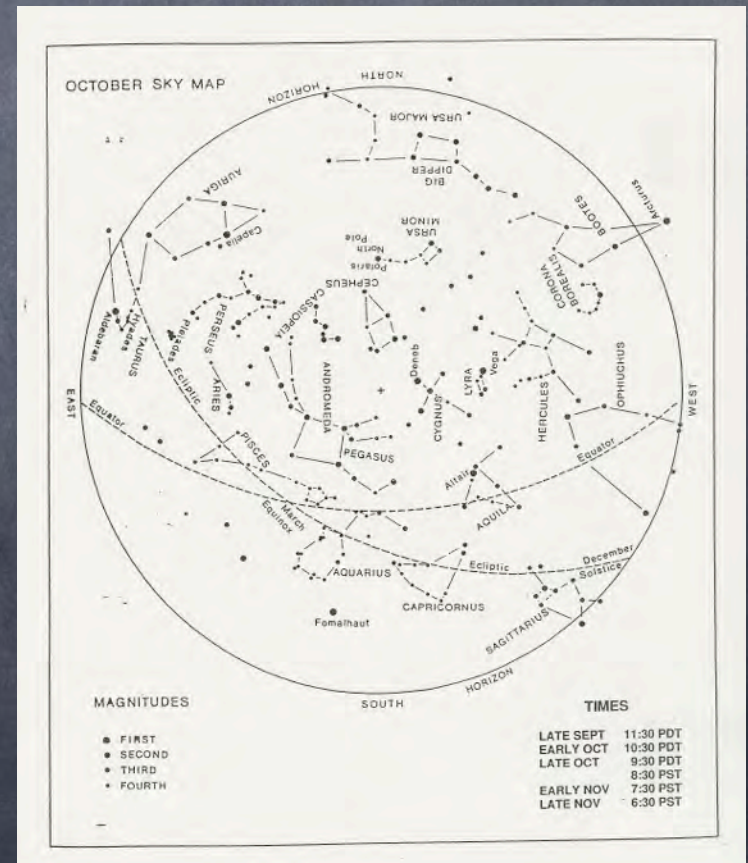
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- *(e) Masses and radii of stars from binary systems,*

# Some stellar statistics



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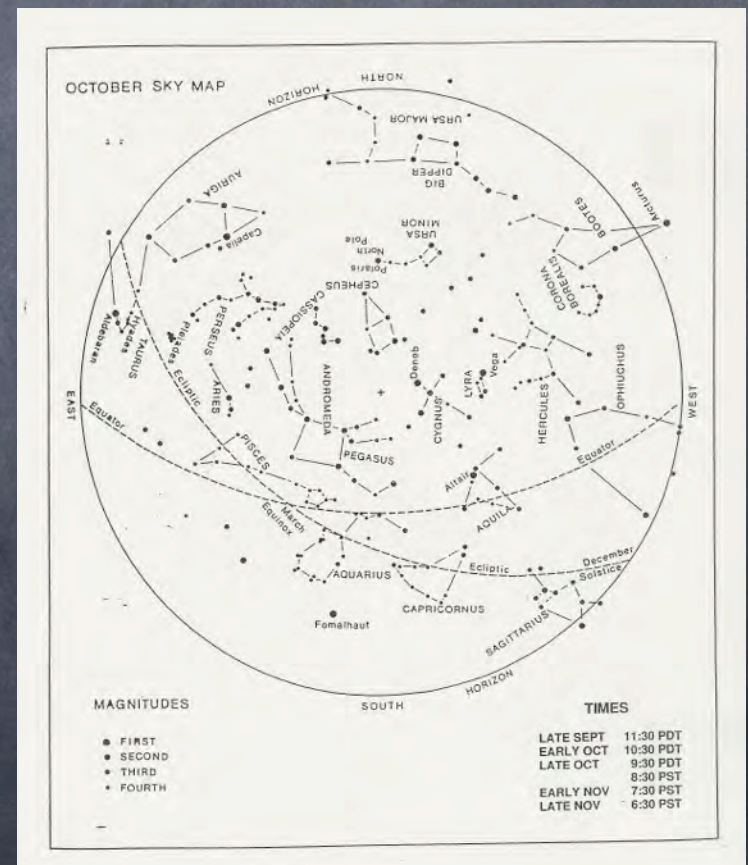
A few 1000 visible to the naked eye



# Some stellar statistics

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Polaris (North Star) not brightest (only 50th)

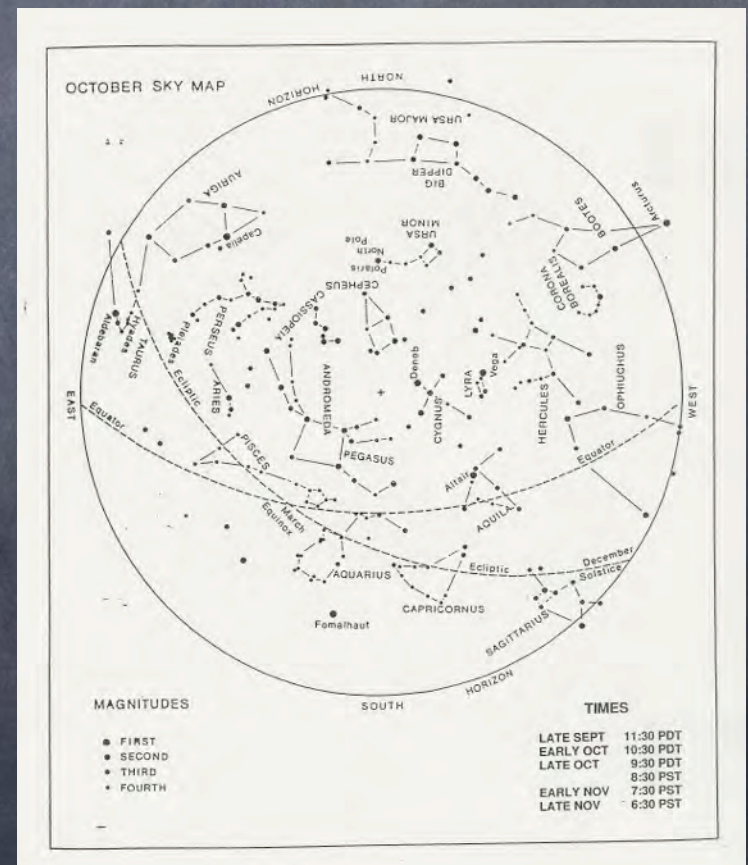


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Sirius is brightest



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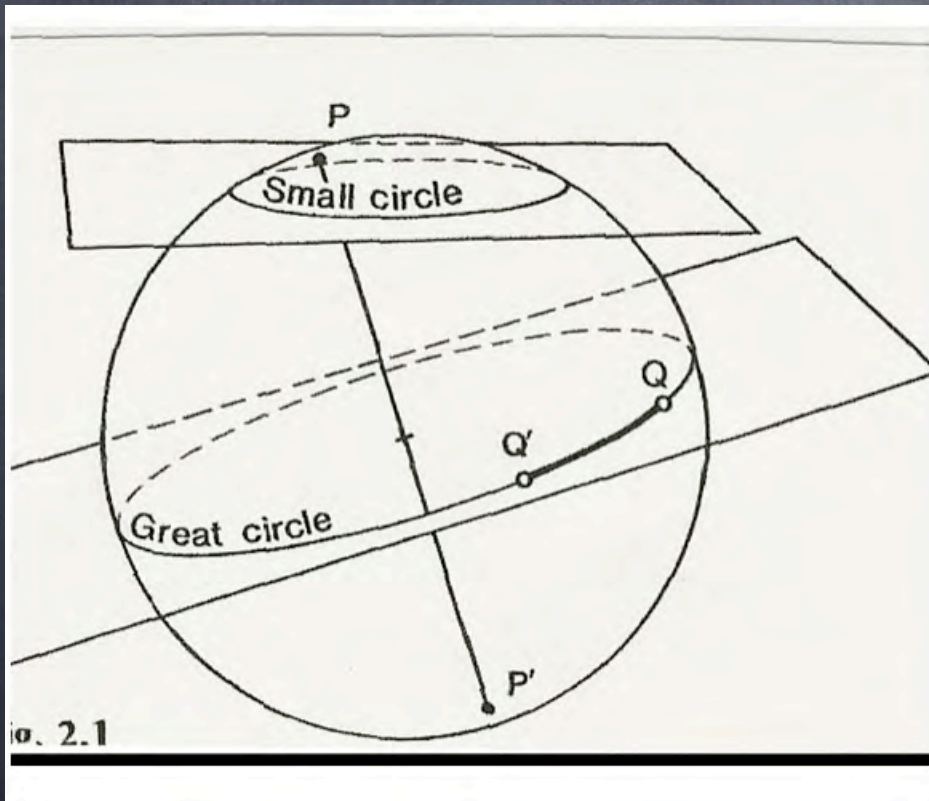
Estimate # of stars in observable Universe  $\sim 10^{23}$

Nearest star (Proxima Centauri) is 300,000 times more distant than Sun. (by comparison, Neptune is 30 times farther than Sun).

# Basic Properties of Stars

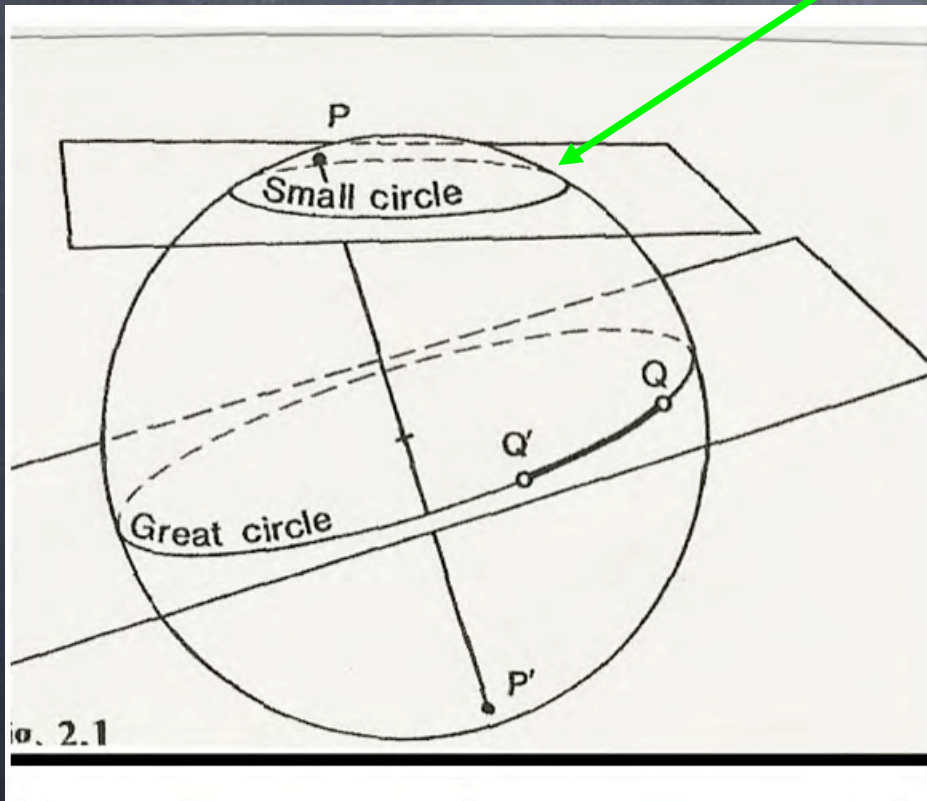
Celestial Sphere  
(not really a stellar property)

# Small and Great Circles



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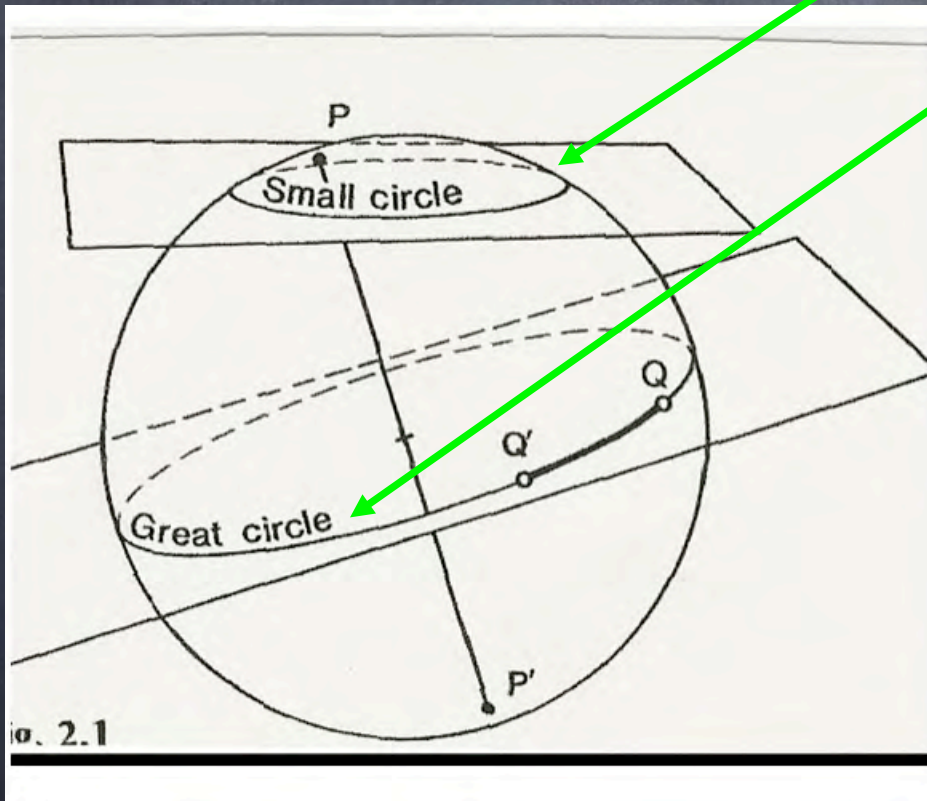
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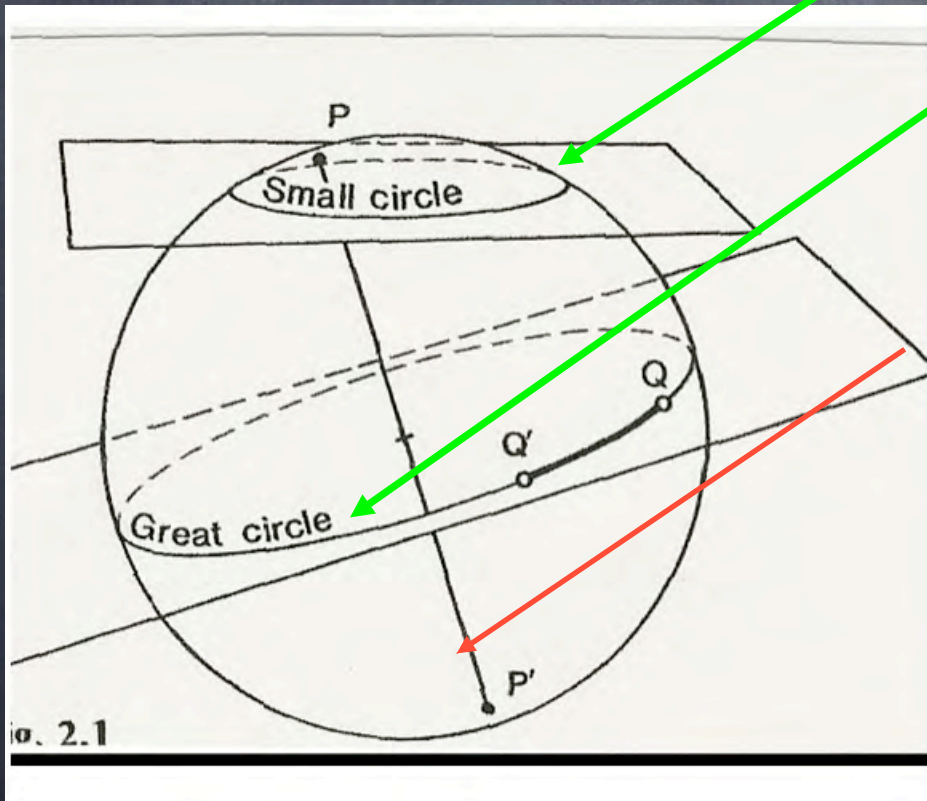
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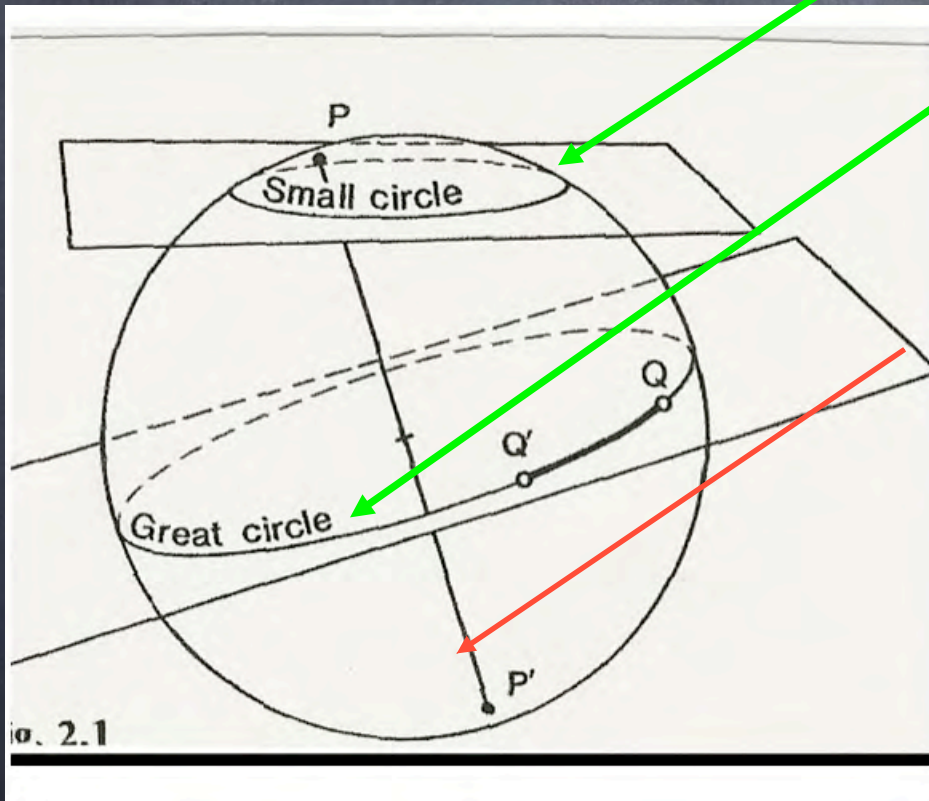


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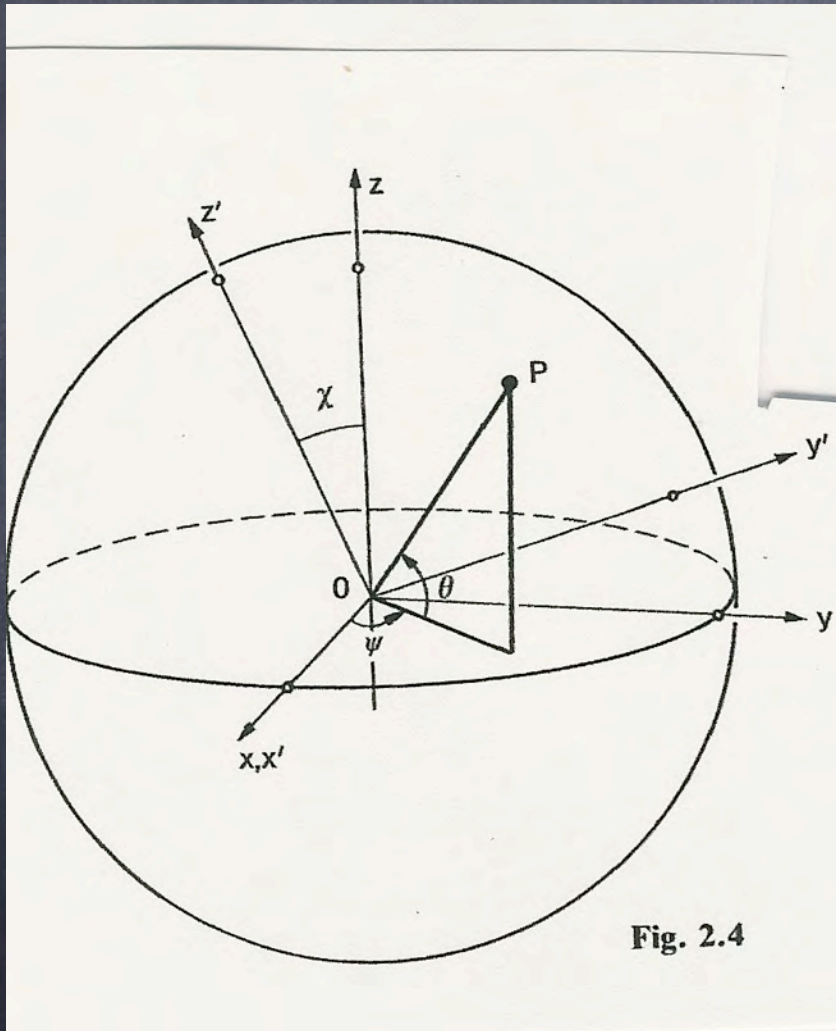
Great Circle: Curve on sphere when plane contains centre.  
The line perpendicular to plane that passes through the centre intersects sphere at poles  $P, P'$ .

Only 1 great circle passes through any 2 given points on sphere,  $Q, Q'$ . Arc  $QQ'$  is shortest distance between these points.



# Location of a Point on a

Either XYZ coordinates or 2 angles,  $\psi$  and  $\theta$ , can be used to locate a point, P, on the surface of a unit sphere.



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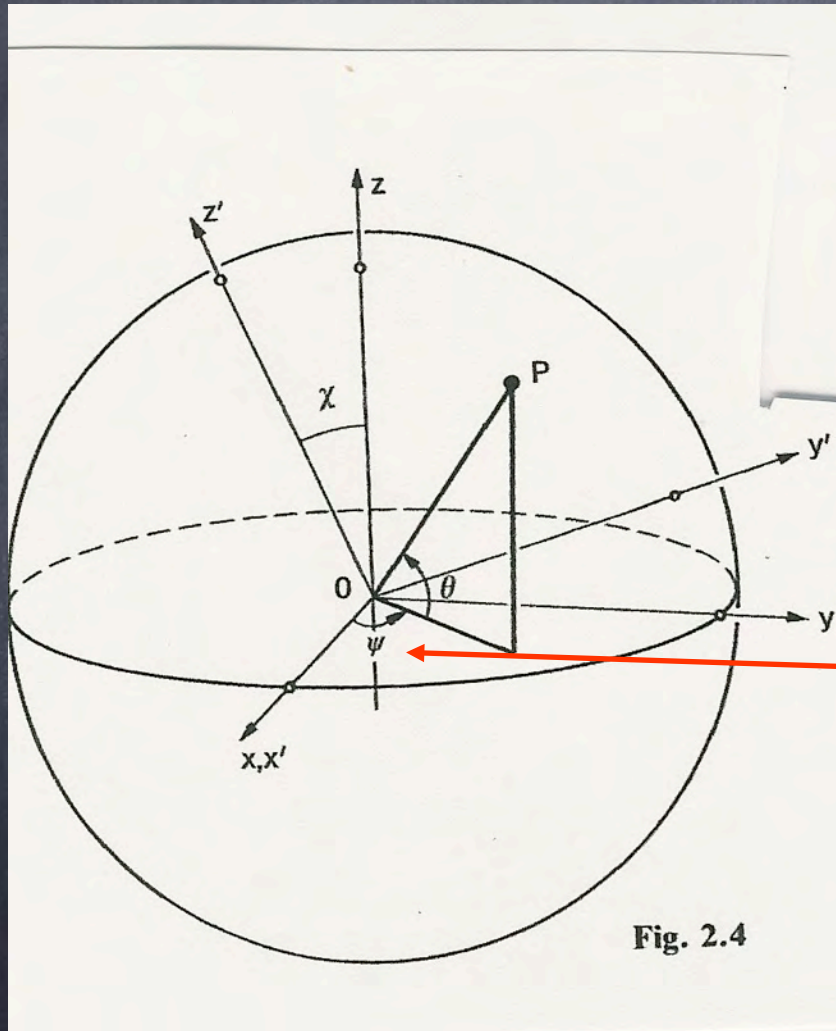


Fig. 2.4

Note that for angle,  $\psi$ , a reference point along the equator is required.

# Latitude, Longitude on Earth

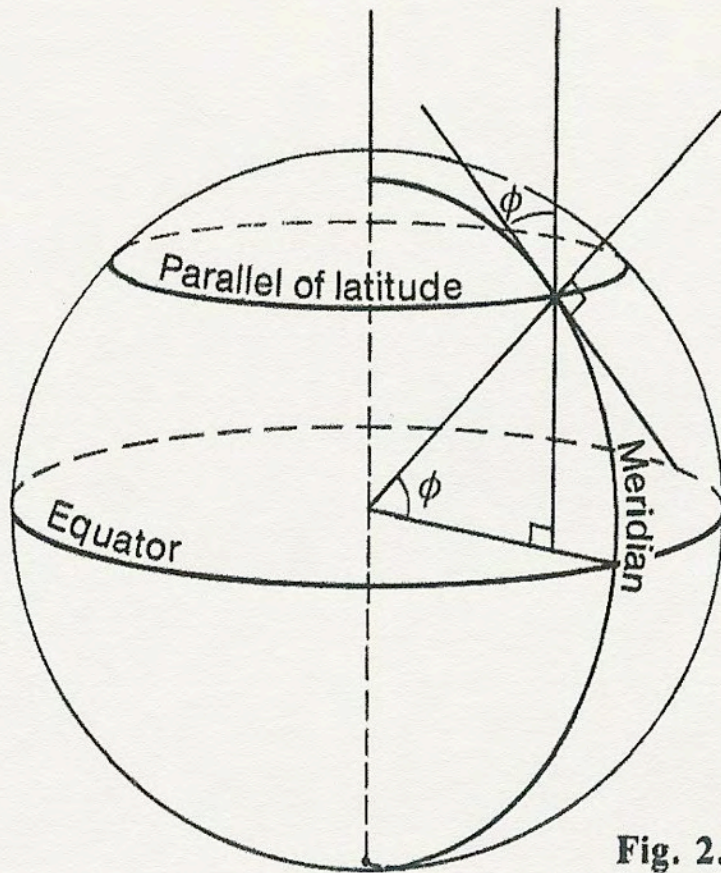


Fig. 2.7

# Latitude, Longitude on Earth

Reference plane is **equator**.

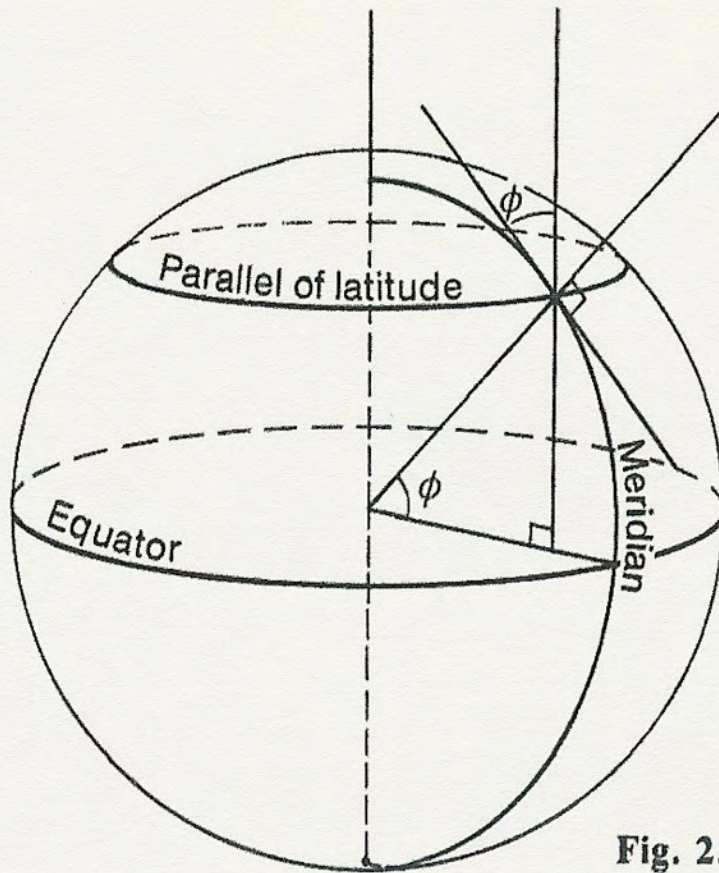


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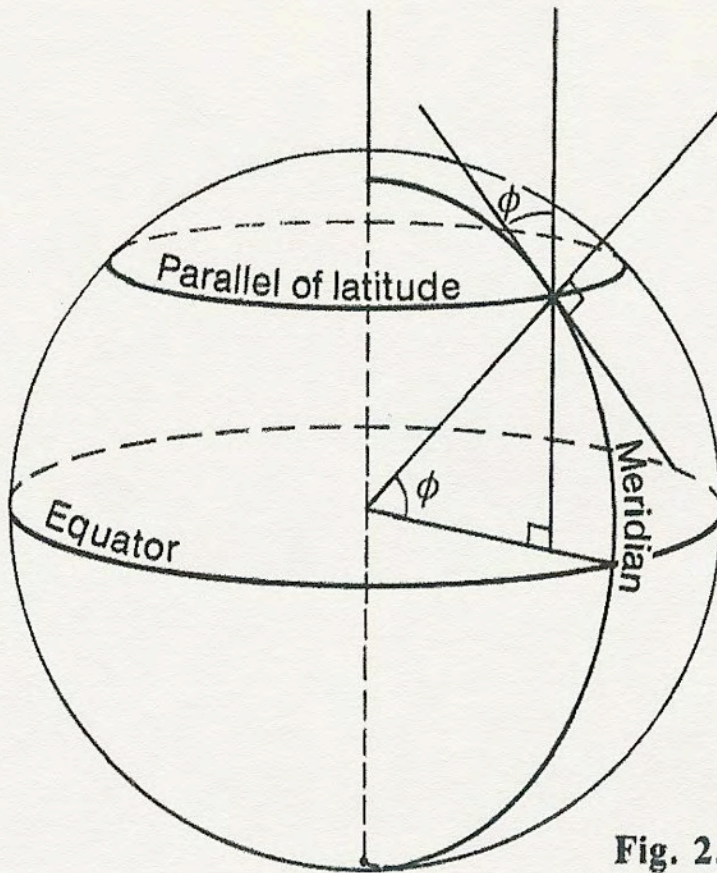


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Altitude of celestial pole is your **latitude**. (Vancouver?)

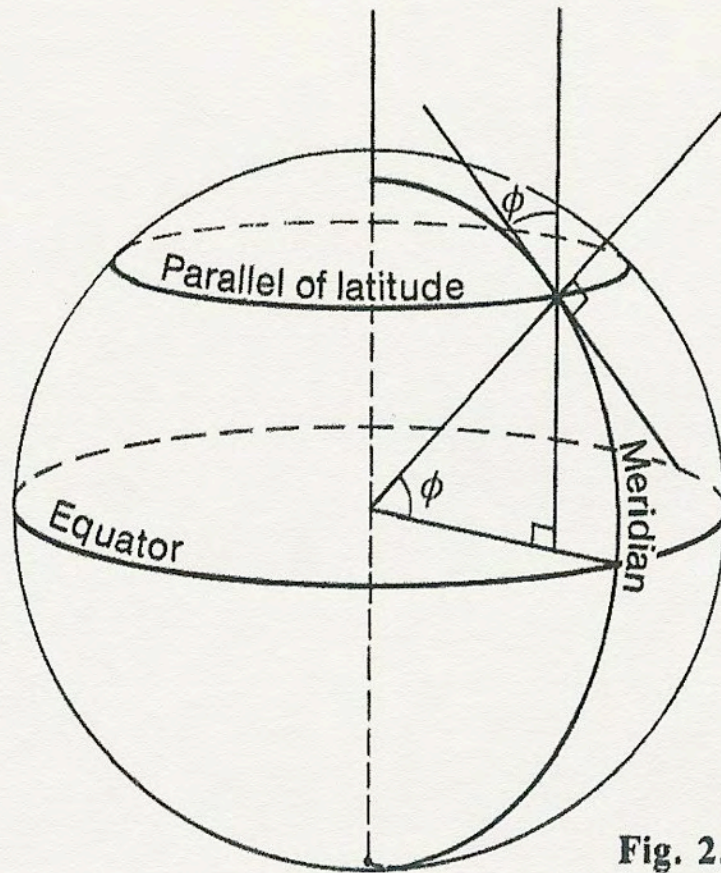
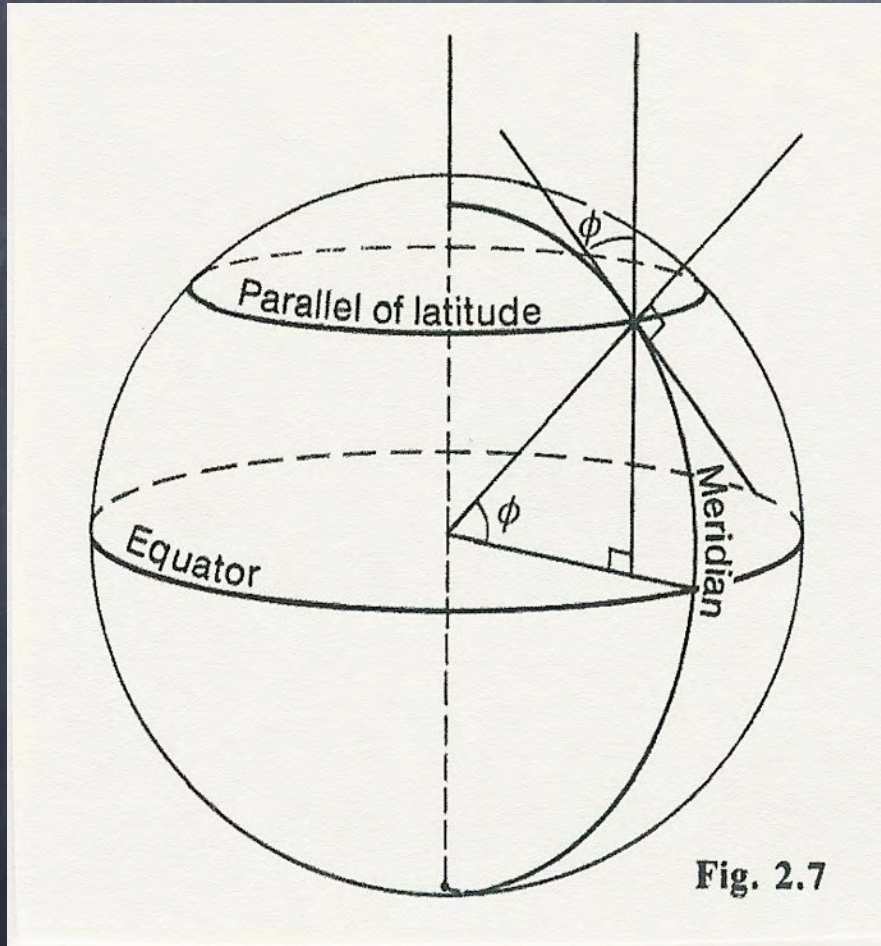


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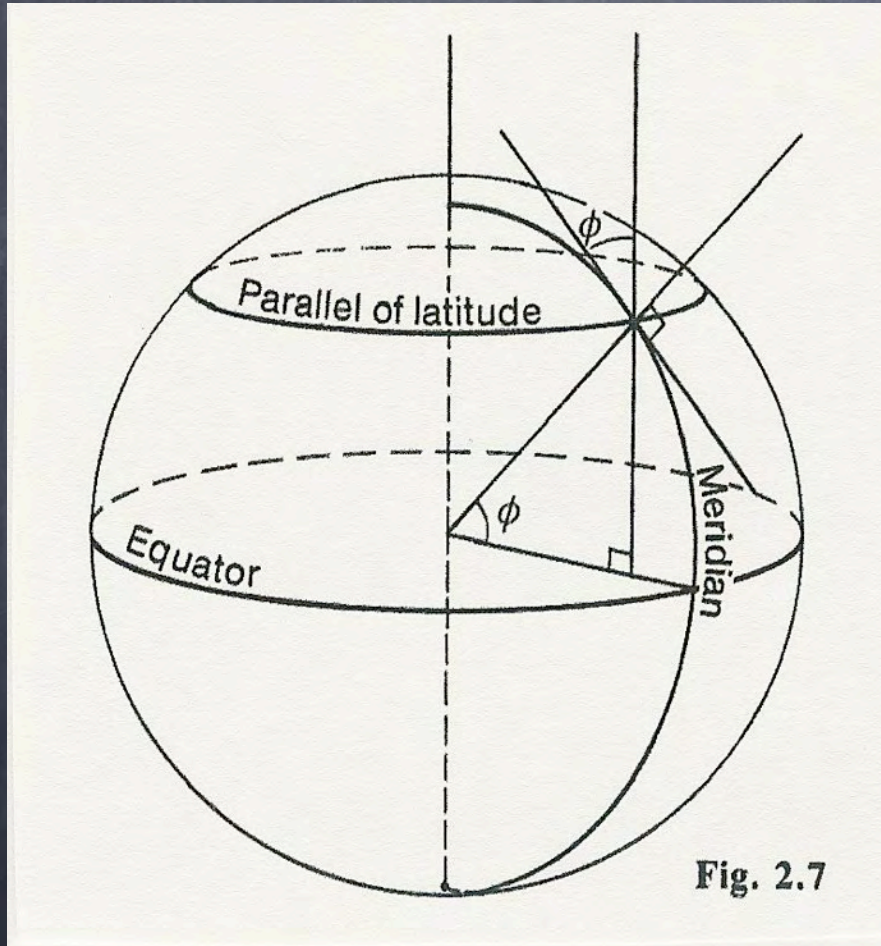
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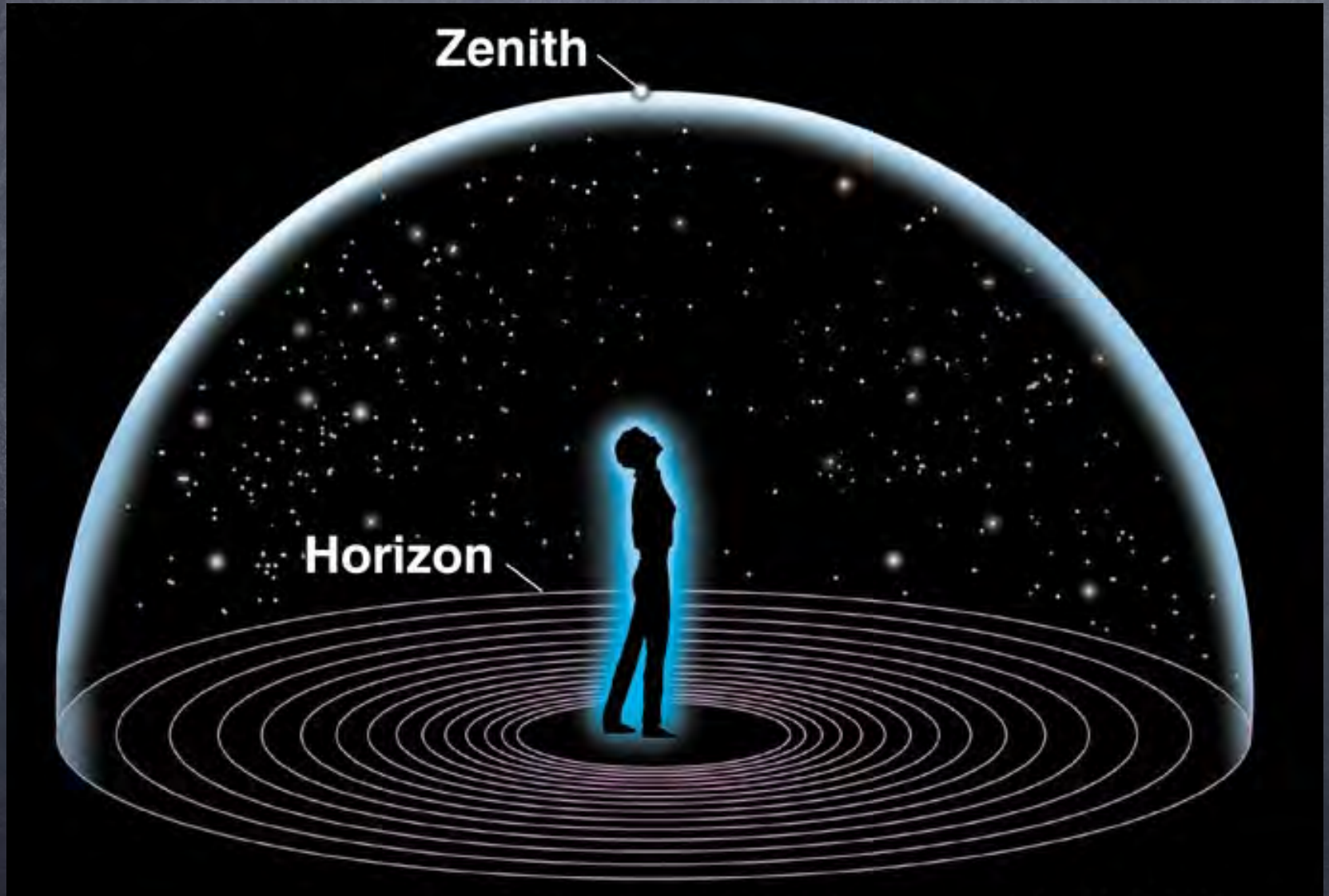
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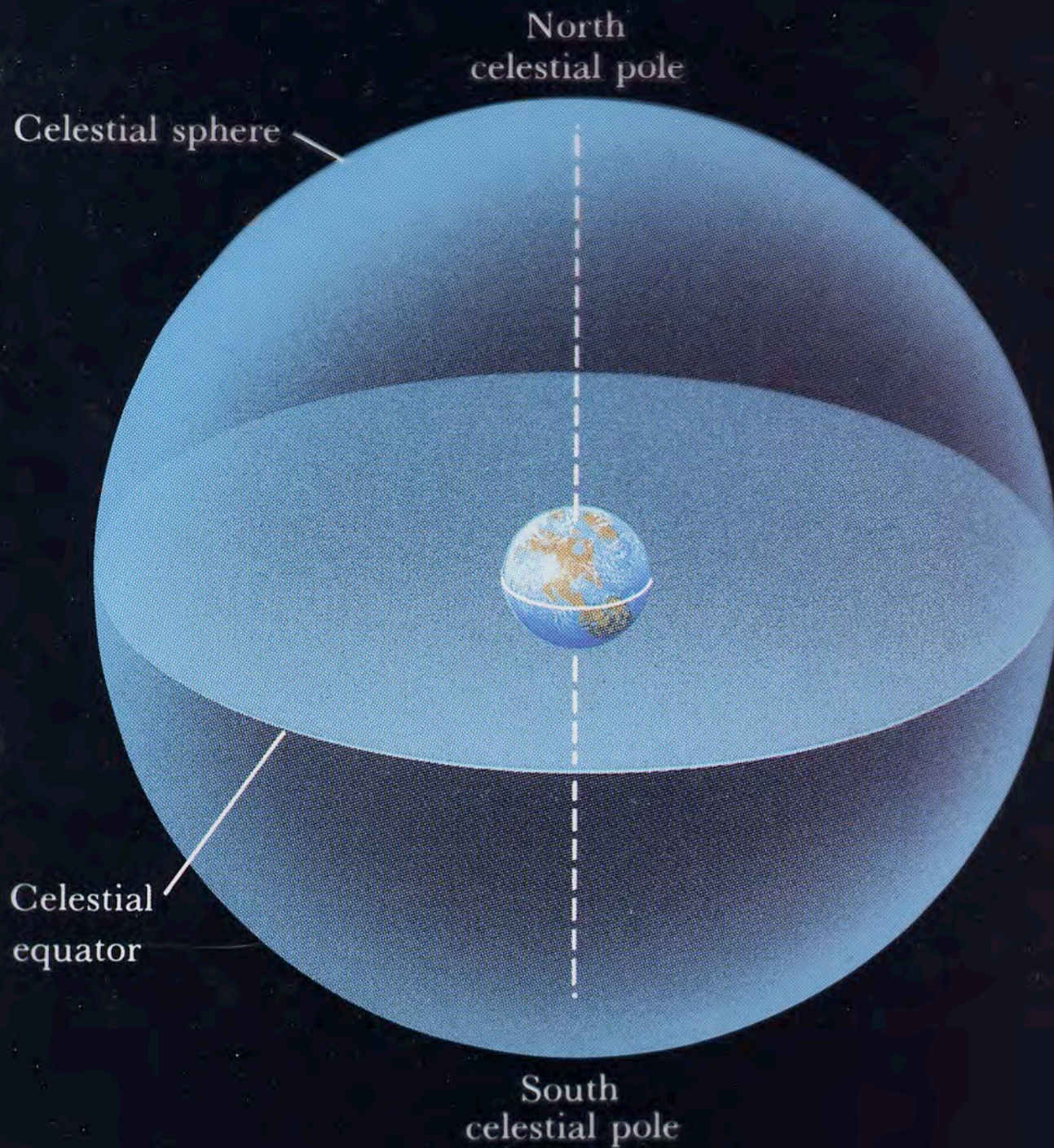
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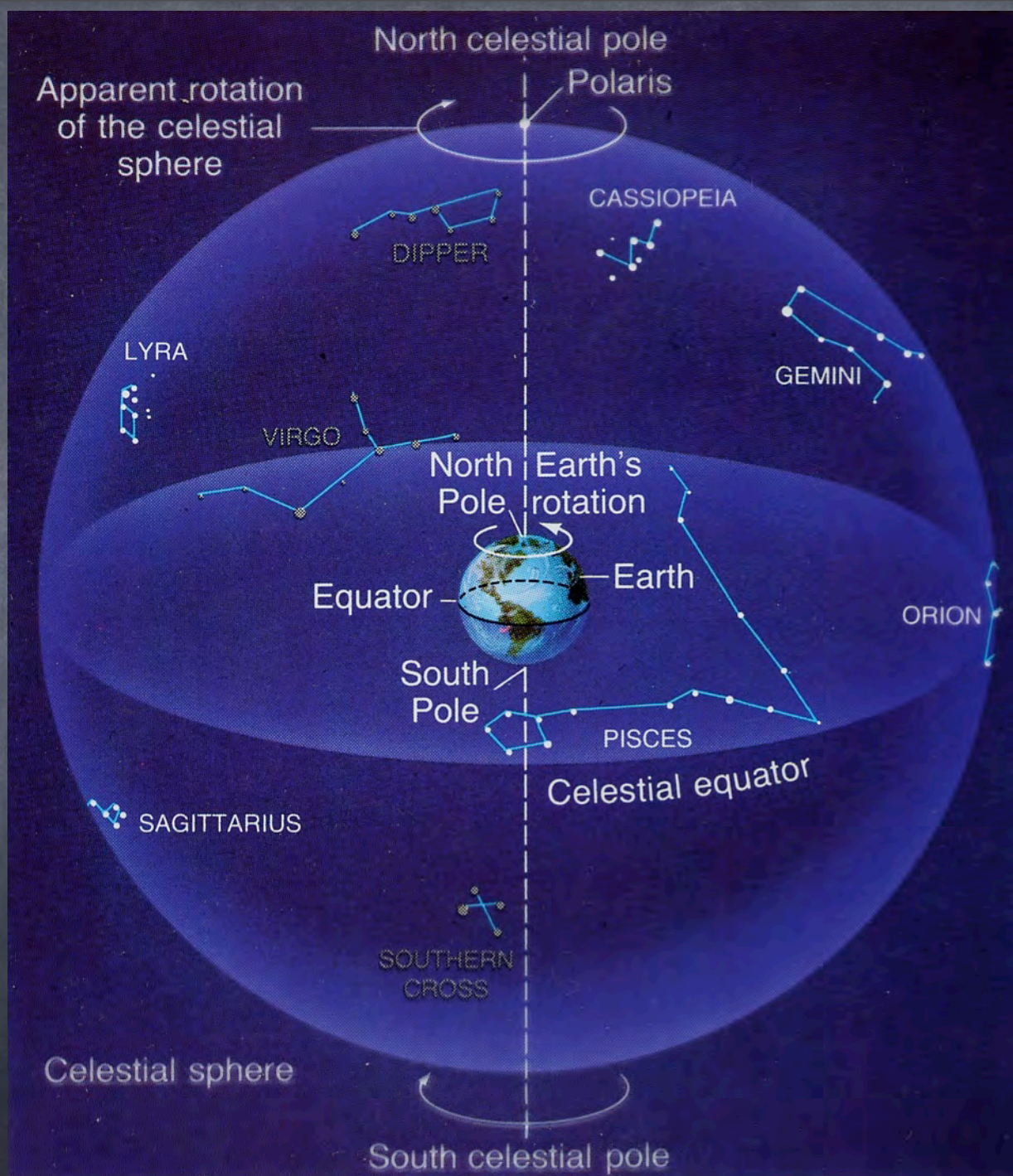
Semicircles from pole to pole are **meridians**.

**Longitude** is angle between meridian and zero meridian (Greenwich). + west, - east.

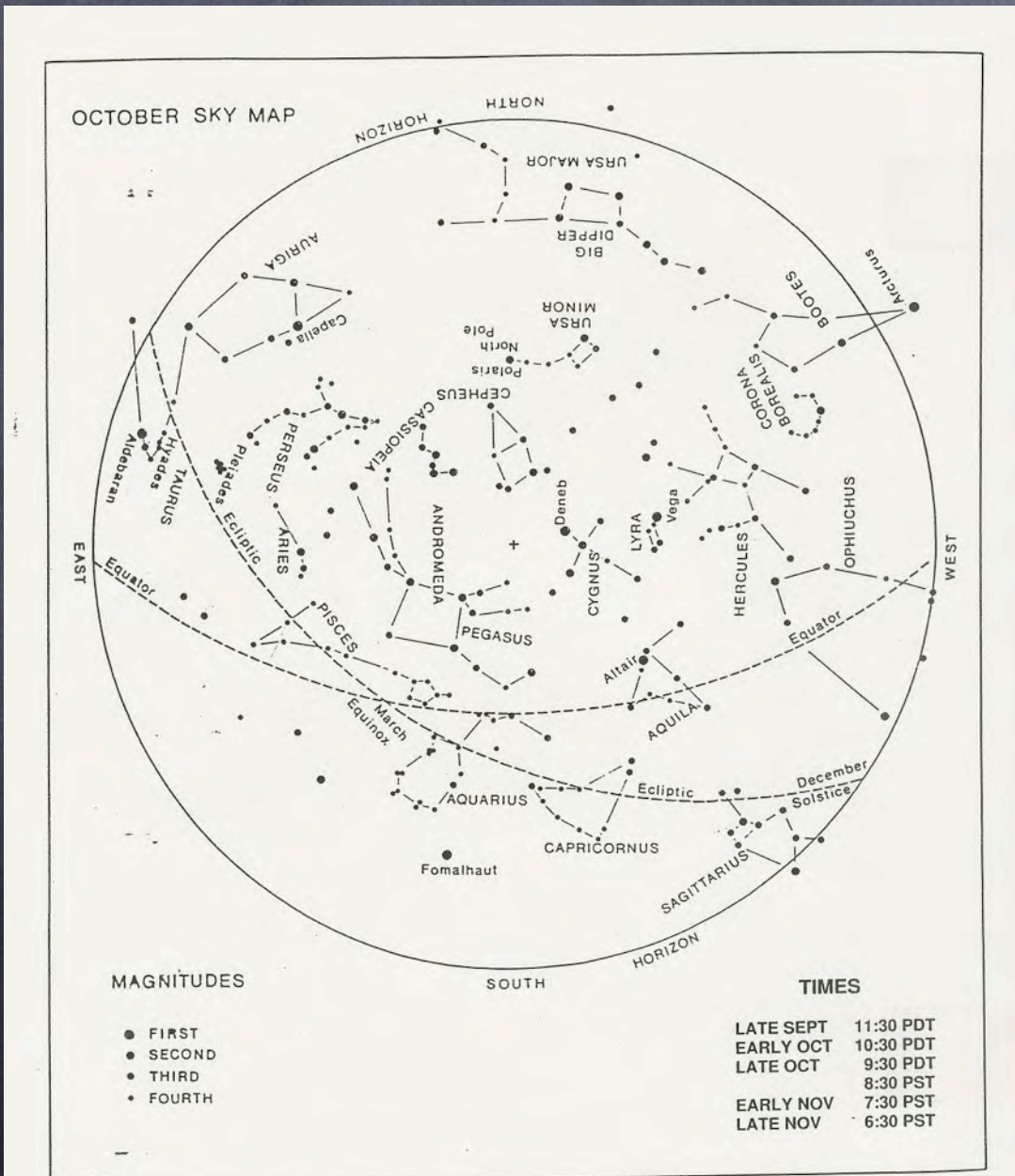
# CELESTIAL SPHERE §1.3



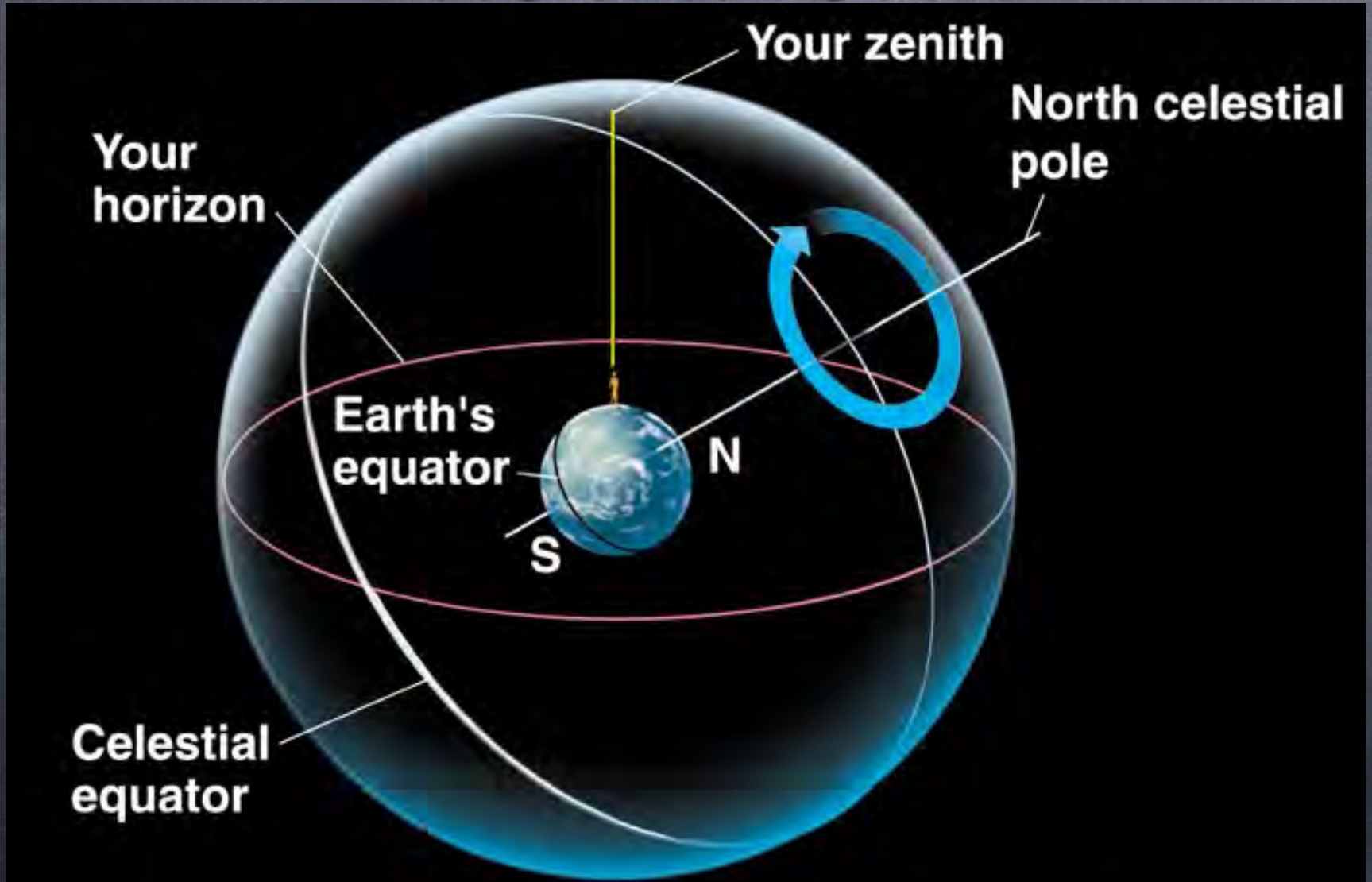




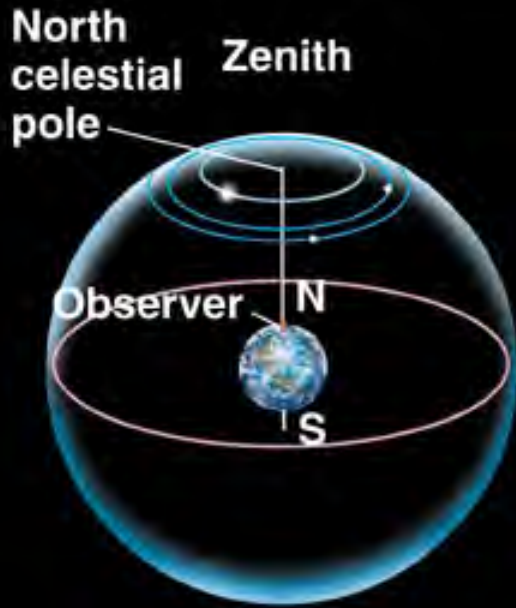
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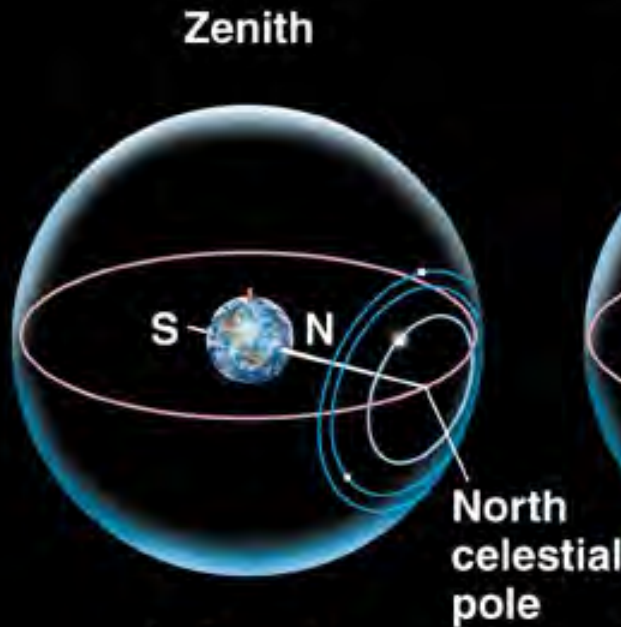
# APPARENT SKY ROTATION



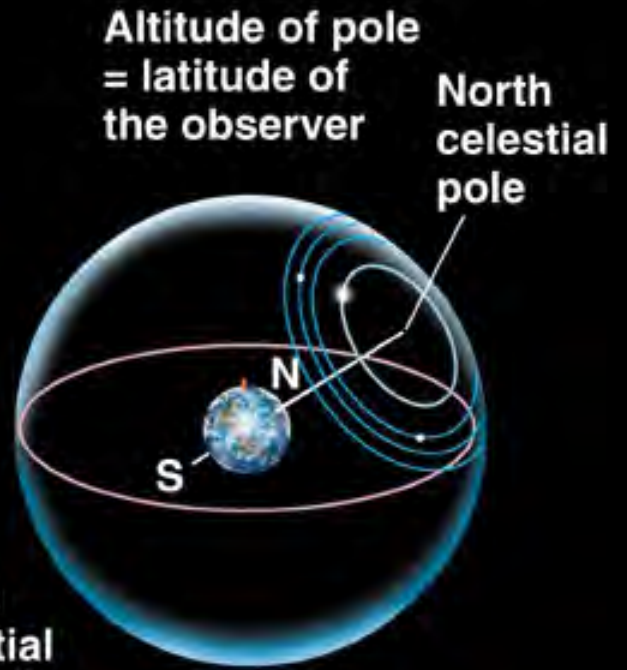
# STAR CIRCLES



At North Pole



At Equator



At intermediate latitude

# STAR TRAILS NEAR THE



Thursday, 13 September, 12

# EQUATORIAL STAR TRAILS



Thursday, 13 September, 12

# INTERMEDIATE LATITUDE



Thursday, 13 September, 12

# EARTH SPINS on its AXIS



Stars seem to revolve  
around the celestial  
pole.

# FOR ABOUT HOW LONG WAS THE CAMERA OPEN IN THIS PICTURE?

A) 30 seconds

B) 5 minutes

C) 2 hours

D) 5 hours

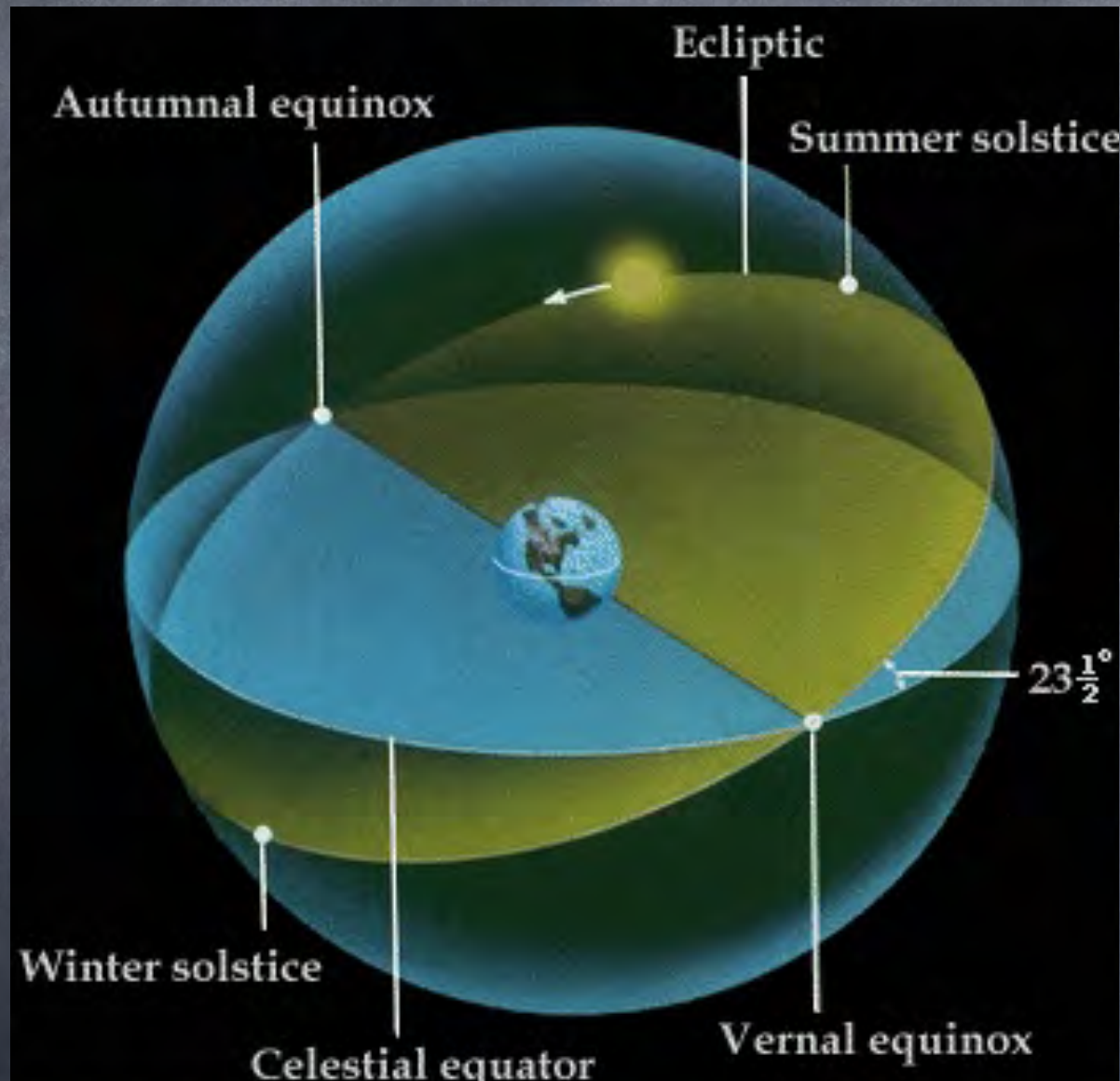


# Earth's Inclined Axis

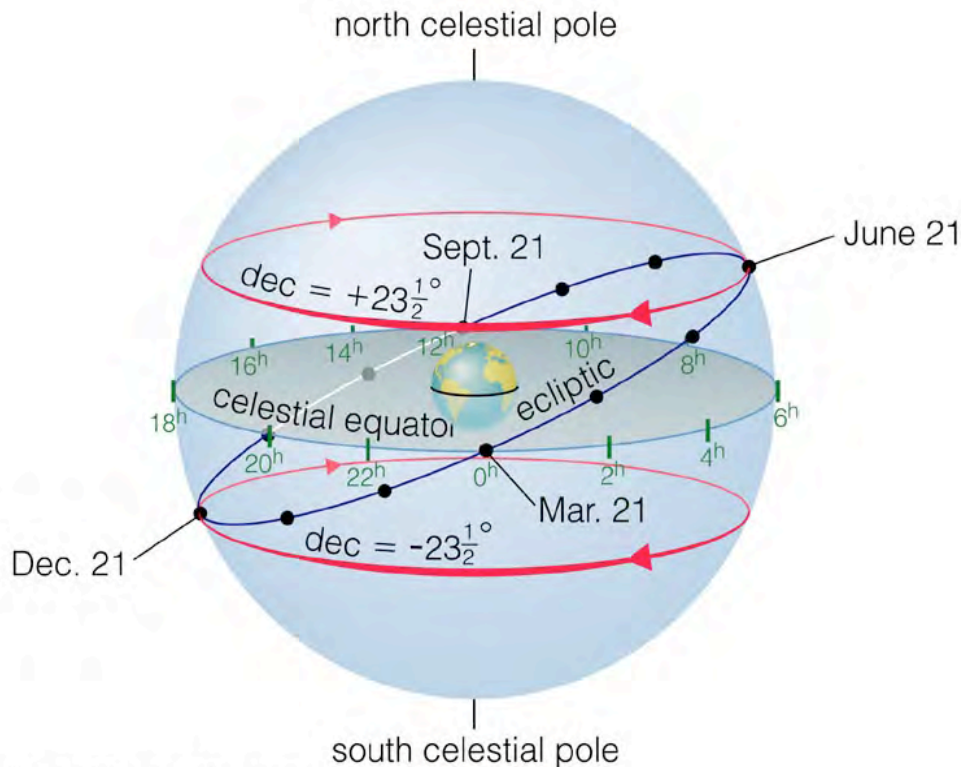
*Earth's axis inclined 23.5 degrees to plane of its orbit*



# SEASONS on EARTH



# The Sun follows a well-defined path



**Table S1.1 The Sun's Approximate Celestial Coordinates at 1-Month Intervals**

Approximate Date	RA	Dec
Mar. 21 (Spring equinox)	0hr	$0^\circ$
Apr. 21	2 hr	$+12^\circ$
May 21	4 hr	$+20^\circ$
June 21 (Summer solstice)	6 hr	$+23\frac{1}{2}^\circ$
July 21	8 hr	$+20^\circ$
Aug. 21	10 hr	$+12^\circ$
Sept. 21 (Fall equinox)	12 hr	$0^\circ$
Oct. 21	14 hr	$-12^\circ$
Nov. 21	16 hr	$-20^\circ$
Dec. 21 (Winter solstice)	18 hr	$-23\frac{1}{2}^\circ$
Jan. 21	20 hr	$-20^\circ$
Feb. 21	22 hr	$-12^\circ$

**Origin of time-keeping.**

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# Right Ascension and

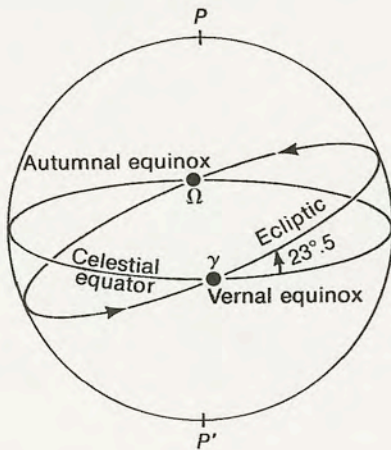


FIGURE 1.10.

The apparent path of the Sun in the sky, known as the ecliptic, is inclined at an angle of about  $23.5^\circ$  to the celestial equator. The ecliptic and the equator intersect at the vernal and autumnal equinoxes. The arrows on the ecliptic show the direction of the Sun's annual motion.

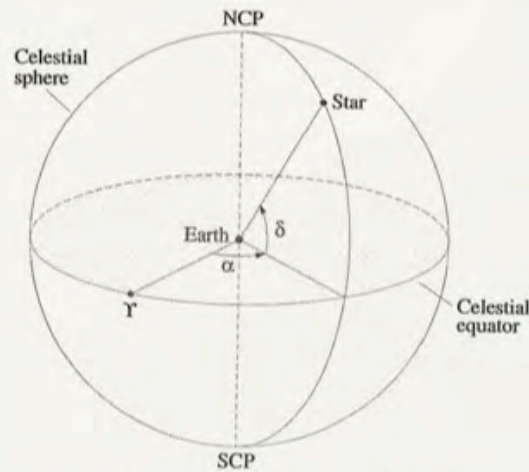


Figure 1.13 The equatorial coordinate system.  $\alpha$ ,  $\delta$ ,  $\Upsilon$  designate right ascension, declination, and the position of the vernal equinox, respectively.

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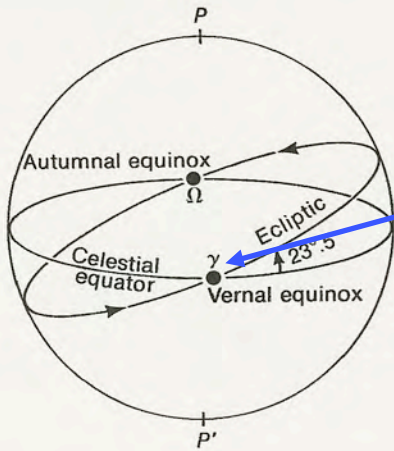


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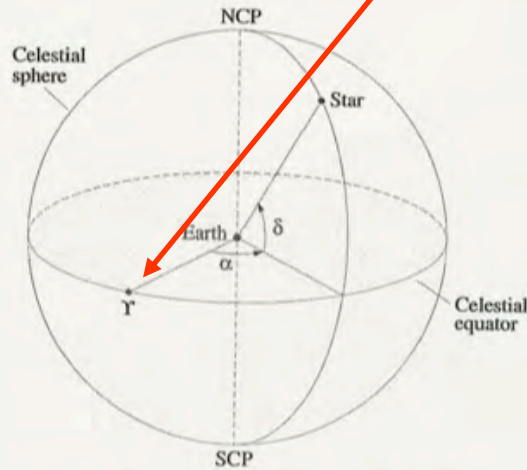


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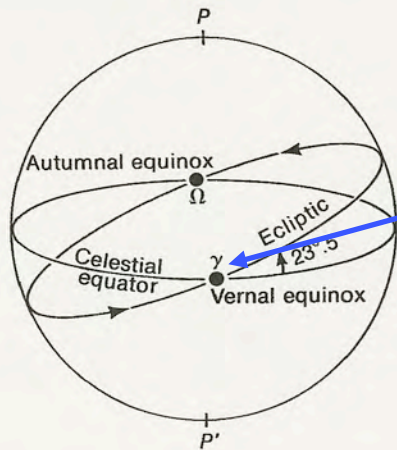


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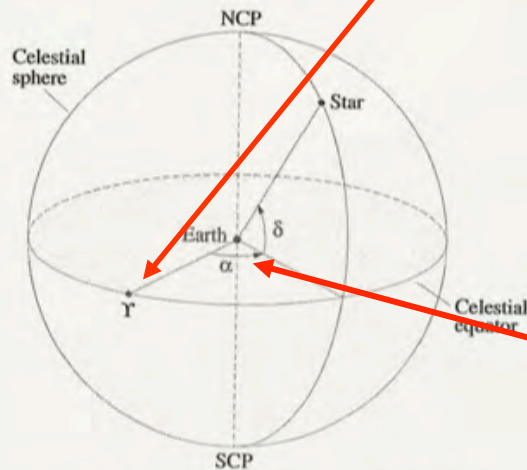


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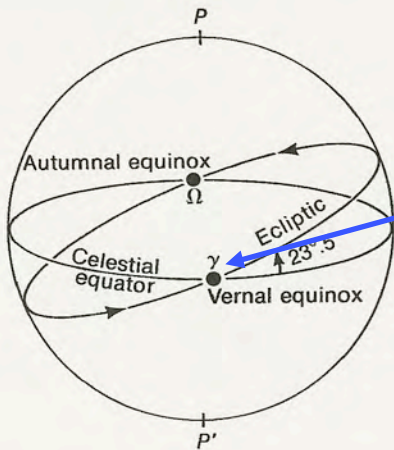


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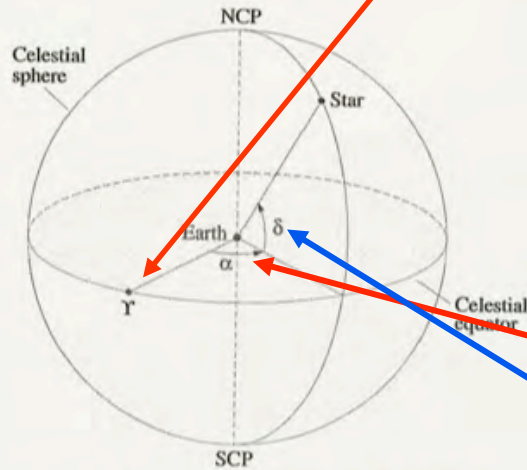


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$\alpha$  is Right Ascension

$\delta$  is Declination

# EARTH'S PRECESSION

Most members of Solar System are near ecliptic, and tend to pull equatorial bulge of Earth towards it. Mostly due to Moon and Sun.



Because Earth rotating, this torque cannot change inclination of equator to ecliptic, but causes rotation axis to turn in a direction perpendicular to axis and torque, describing a cone ( $P = 26,000$  yr).

# How Precession Works

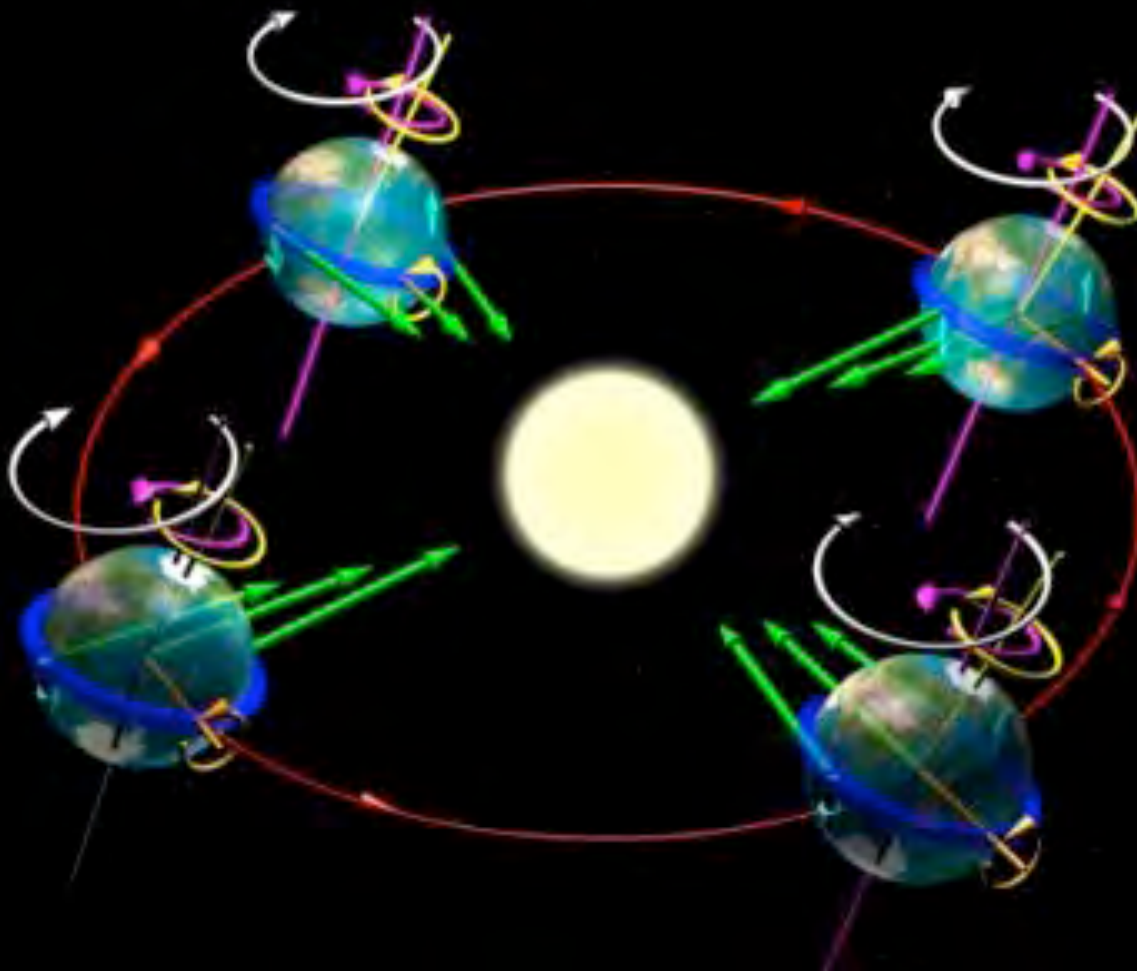
Green - gravitational force different positions

This creates torque (orange)

Add this to rotation (magenta)

Produces shift to  
new

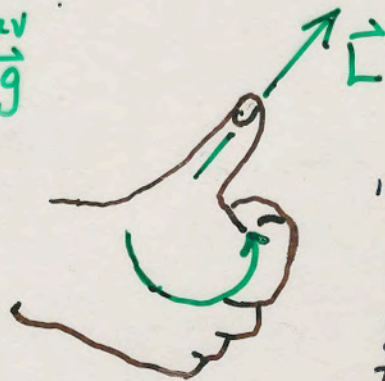
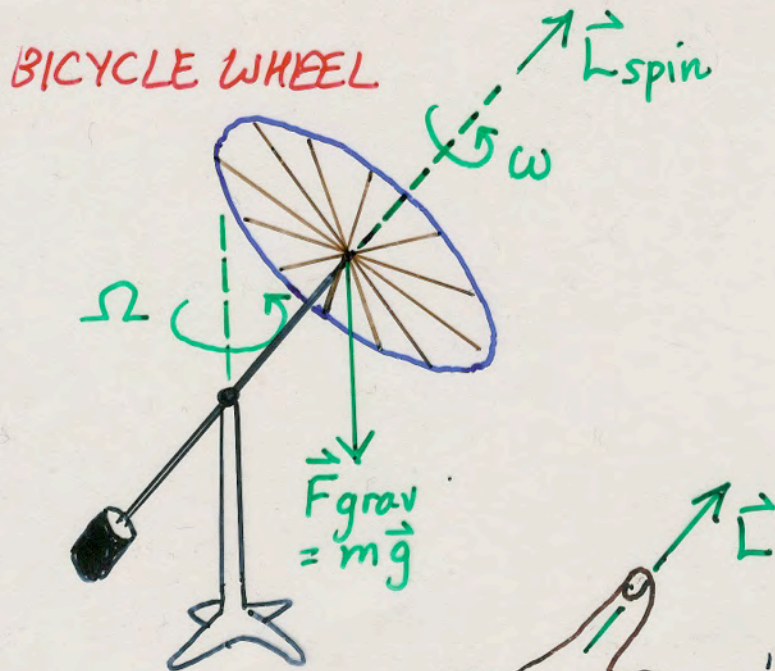
Position (yellow)



Over time causes  
precession along  
white circle

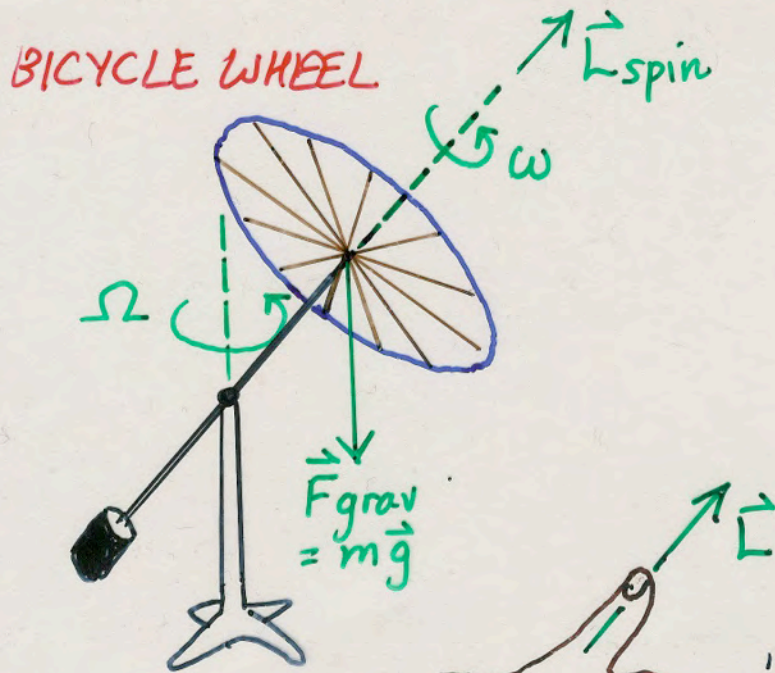
Torque is approx  
perpendicular to  
spin axis of Earth

# PRECESSION p.12 - 14



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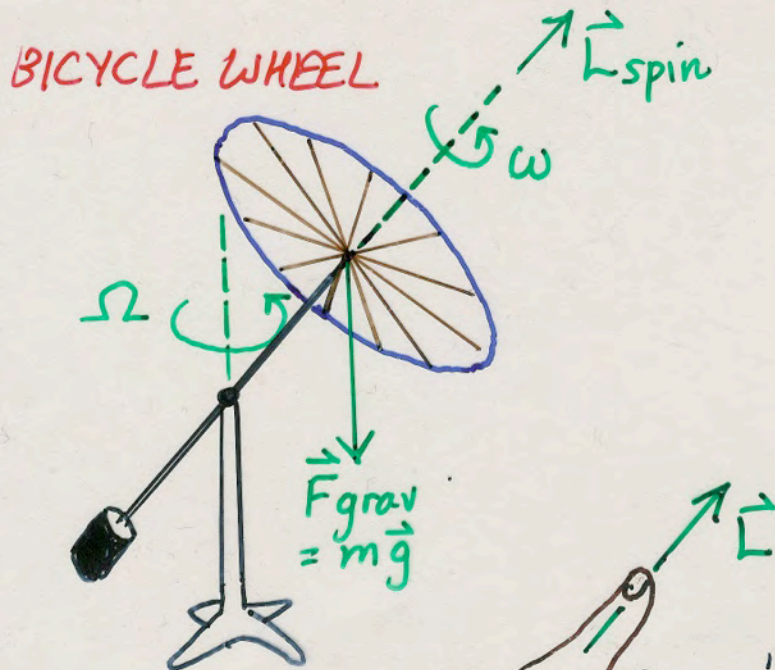
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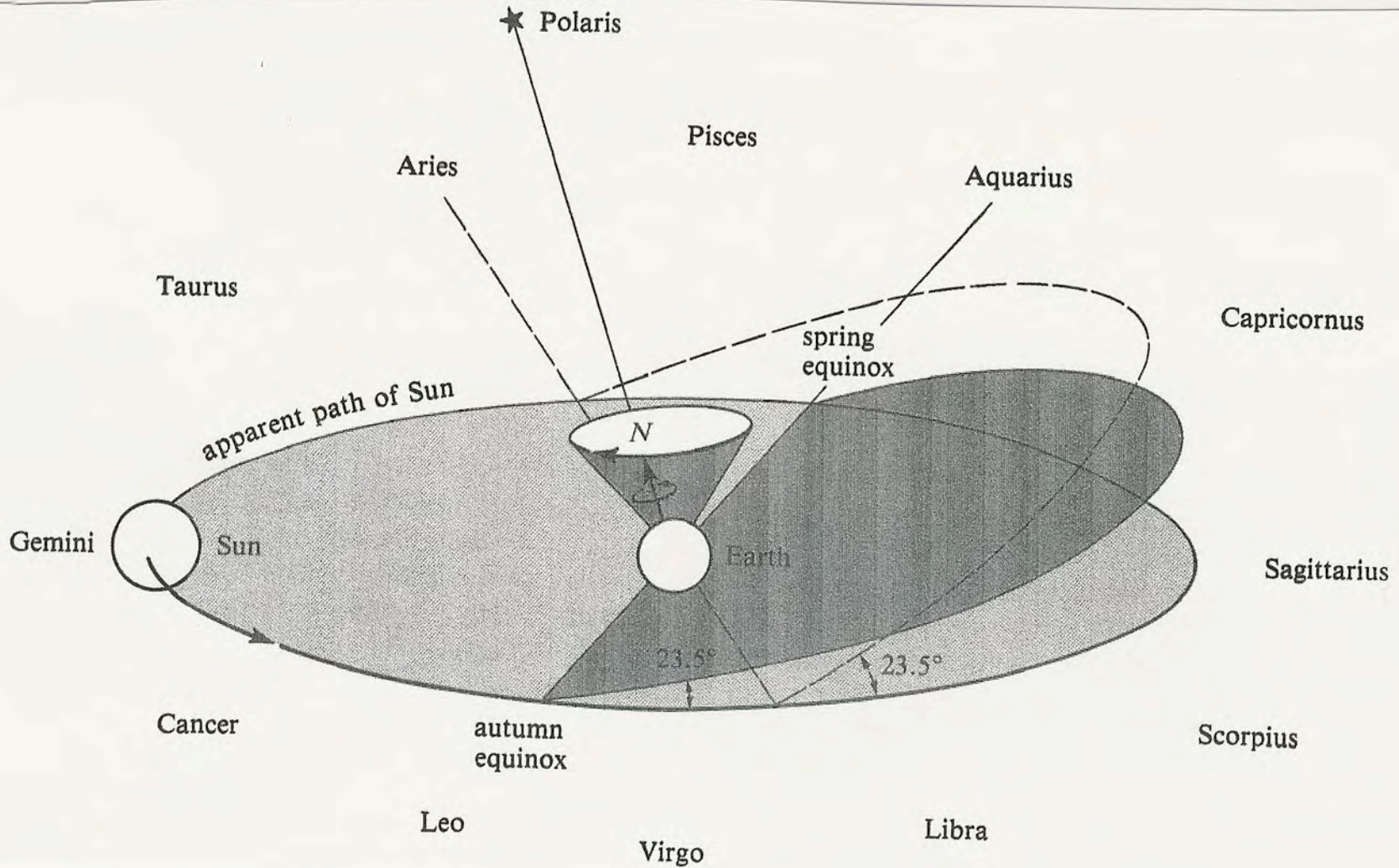


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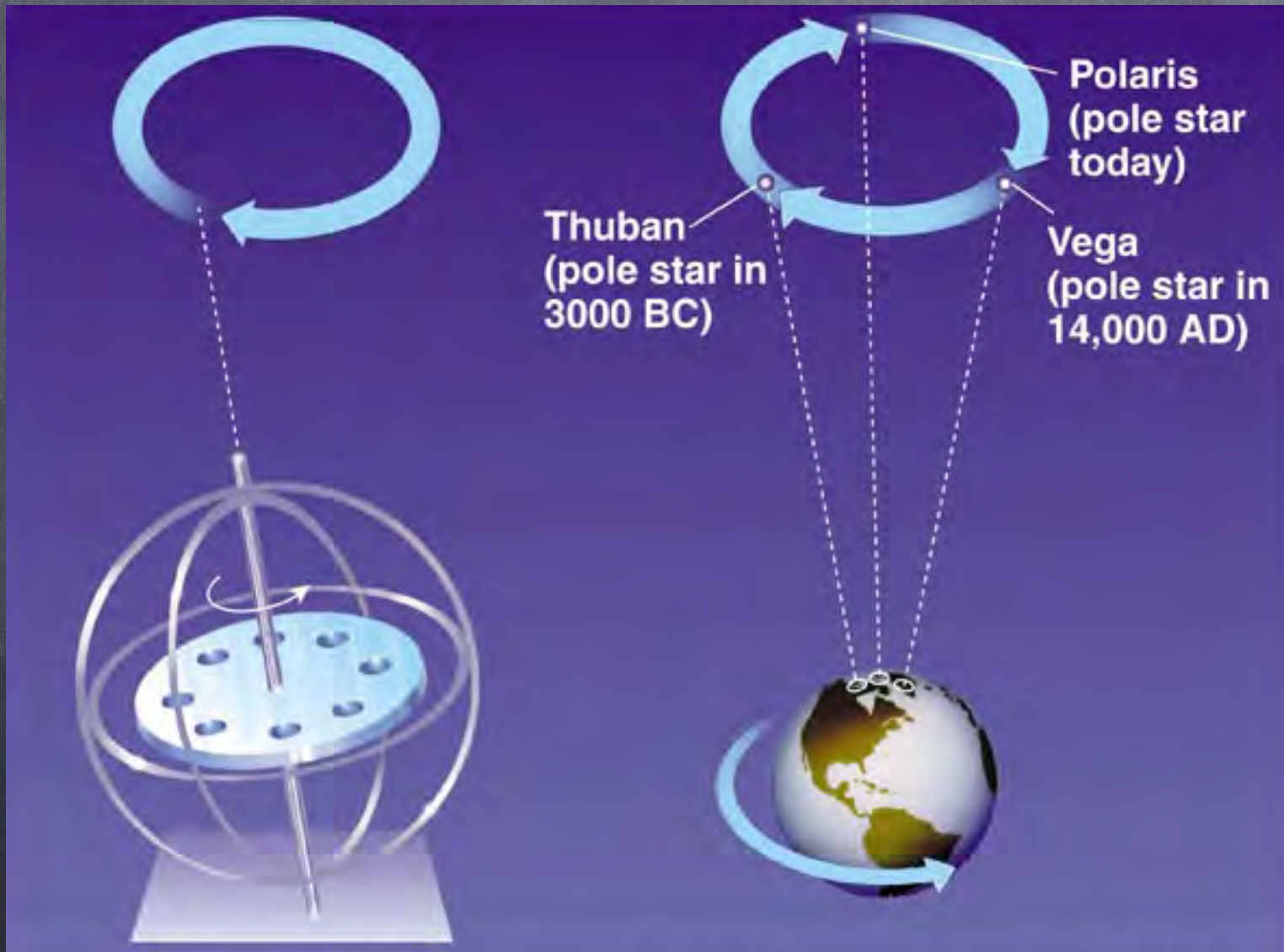
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Precession  
changes position  
of NCP and  $\gamma$ , so  
we must define  
when  $\alpha$  and  $\delta$  are  
measured.

# EARTH'S PRECESSION



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$$\Delta\delta = [n \cos \alpha] N$$

**N = # years between desired time and reference epoch (can be negative), and  $m = 3.07419\text{s/yr}$ ,  $n = 20.0383\text{"/yr}$  for reference epoch = 2000. Eg 13,000 years from now, where will Polaris be?**

