A205 - 2019 Course Details

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Textbook: Ryden, Peterson: Foundations Astrophysics

Normal Classes: Monday, Wednesday
Problem Solving Sessions: Friday: No credit but these are the types of questions that will be on exam

Assignments (expect ~5) Given Friday due following Monday (25%), 2 Midterms Feb 8, March 8 (total 25%), Final as scheduled (45%), participation 5%.

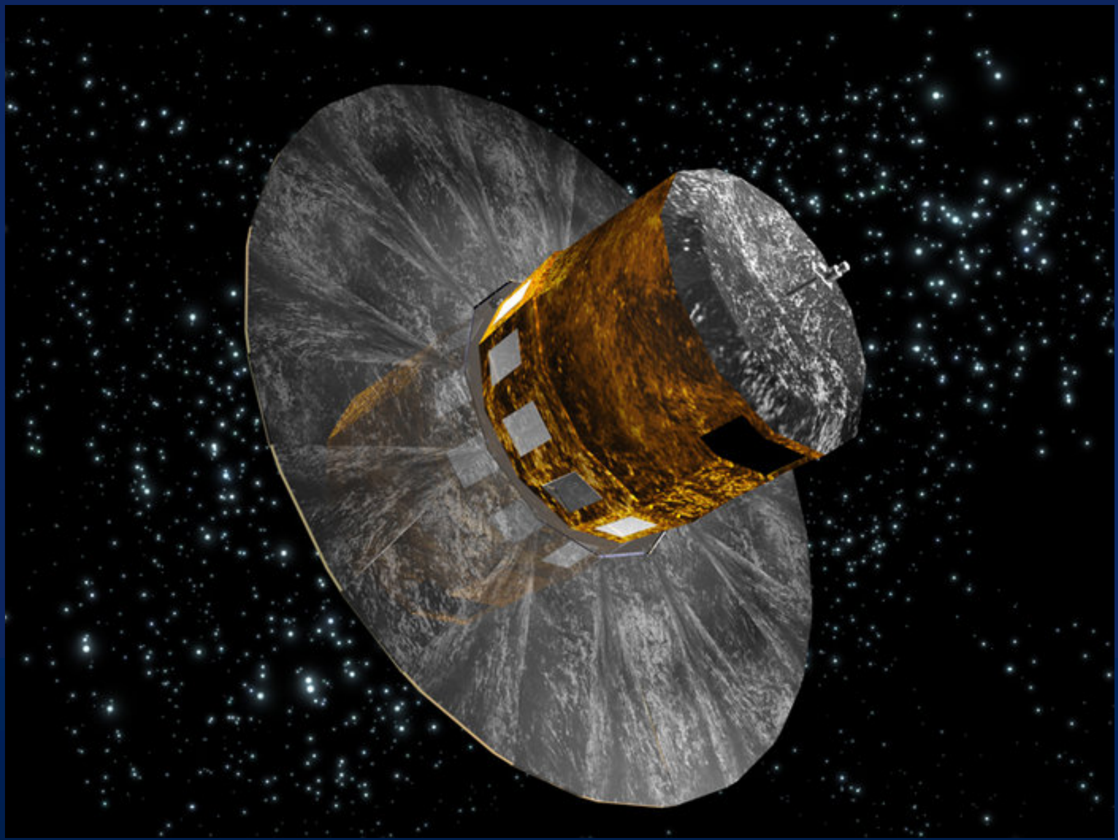
Some Research I Am Doing

Visual Image Core 47 Tucanae

UV Image Core 47 Tucanae

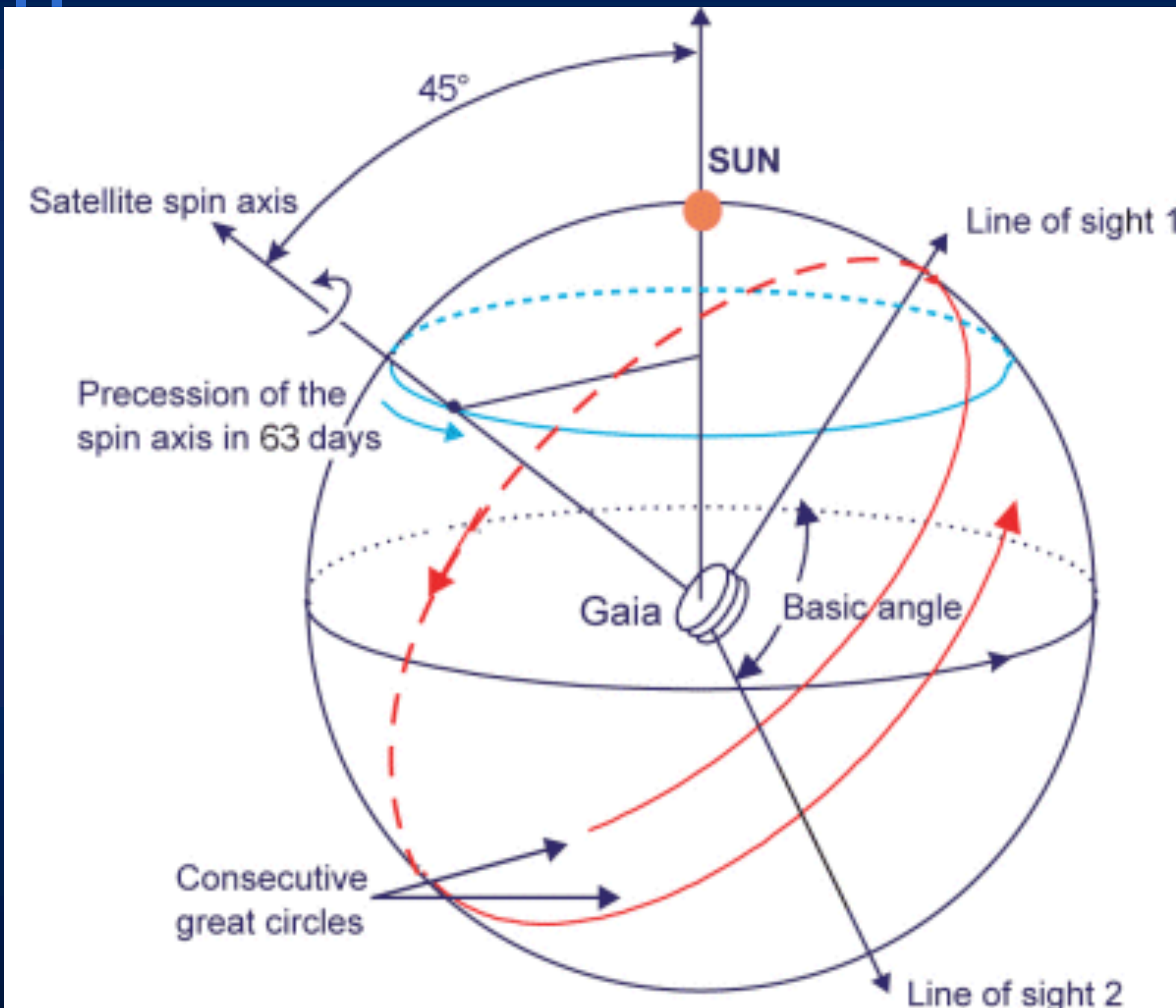
Gaia – Astrometric Satellite

Parallaxes, Proper Motions, Positions



ESA

How Gaia Works



Gaia at L2

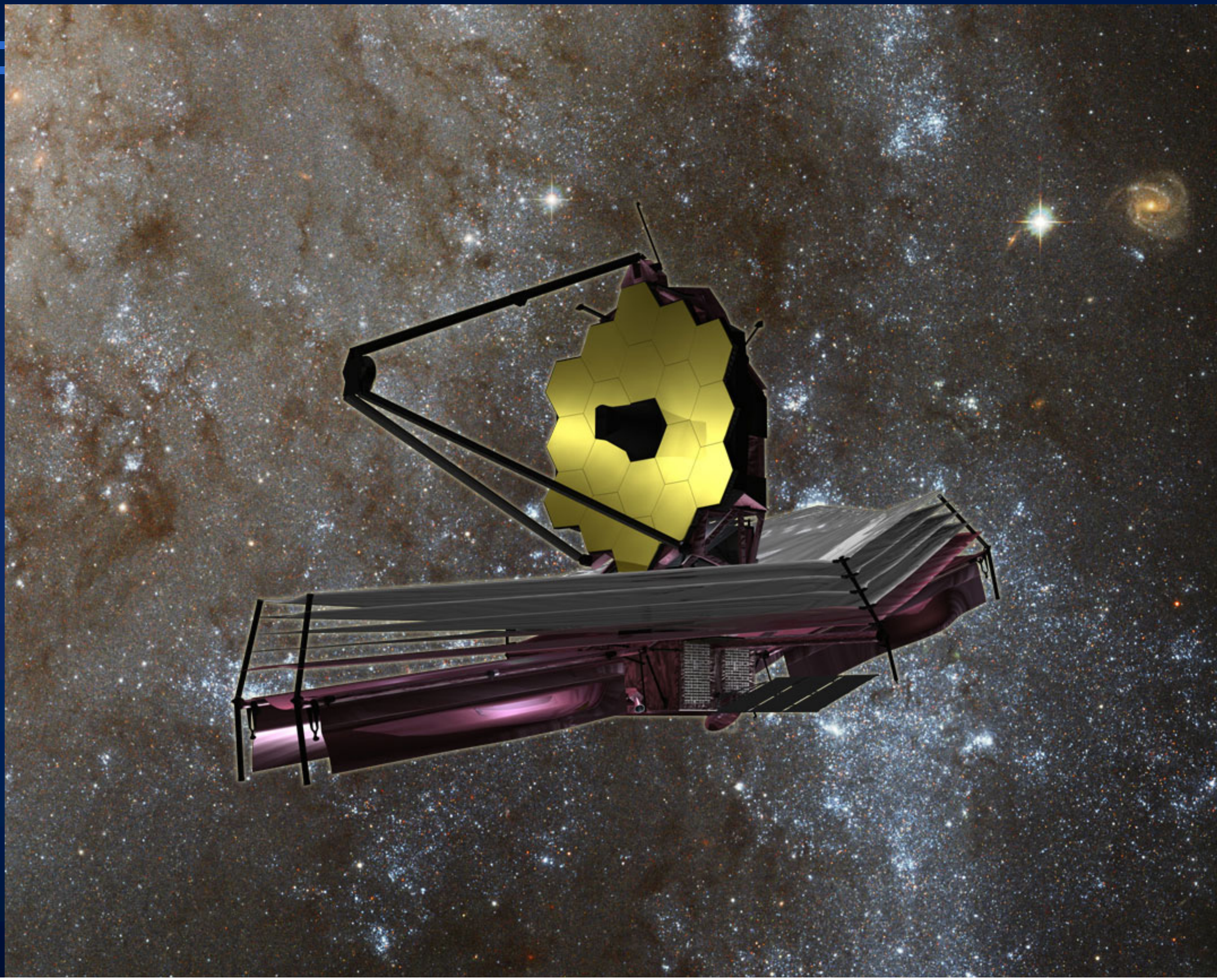
1) Spins around its axis every 6 hours

2) Axis precesses around Sun period 63 days

3) Each point in sky sampled ~70 times

ESA

The Future – JWST – Launch March 30 2021



Readings Week #1

Chapter 1: Background, coordinate systems
Cursory reading

Chapter 13: Begin detailed reading

Stellar Astrophysics

At least 5000 years old – from time Bronze Age person looked up at the sky and saw mostly stars.

Signs of the zodiac – first attempts at classifying and arranging

Today: Epoch reionization ~600 Myrs after Big Bang Universe went from mostly neutral to mostly ionized, caused by first stars

When massive stars explode (SN or gamma-ray burst) they can outshine entire galaxy – most distant GRB z~9.4 – record for most distant object known - until 2014 – now galaxy z=11.1)

Properties stars so well known – can reconstruct spectrum entire galaxy

Now realized most stars have their own planetary systems – currently 3575 known – radial velocity, transits, microlensing

Stellar Astrophysics

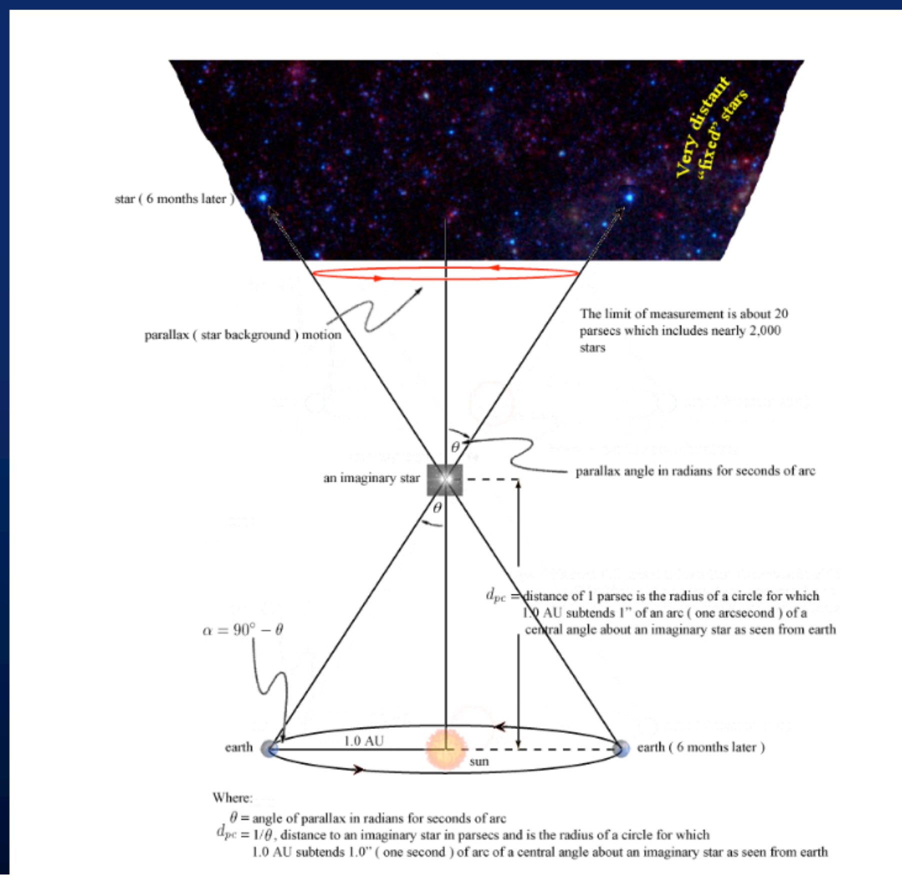
Useful Astronomical Units

Distances:

Radius Earth's orbit around Sun: == 1 AU = 1.5×10^{11} m

Distance at which 1 AU subtends angle 1 sec arc

$(1.5 \times 10^{11} \times 360 \times 60 \times 60) / 2\pi = 3.1 \times 10^{16}$ m = 1 parsec



Stellar Astrophysics

pc, kpc, Mpc most commonly used distances in astronomy

eg 1.3 pc = distance from Sun to closest star (Proxima Centauri)

8.5 kpc = distance from Sun to Galactic Centre

1 Mpc = size Local group Galaxies

20 Mpc = distance Virgo Cluster Galaxies – closest large cluster

4300 Mpc = Hubble radius (universe) = c/H_0 (H_0= 70 km/s/Mpc)

Stellar Astrophysics

Masses

1 solar mass = 2 x 10^{30} kgm

Stellar mass Milky Way = 10^{11} M_{sun}

Luminosities and Magnitudes

Brightnesses measured on log scale $F1/F2 = 10^{0.4(m2-m1)}$

F are fluxes, m the magnitudes (note the scale is backwards)

Note: $\Delta m = +0.75 \rightarrow F1/F2 = 2$

$\Delta m = +1 \rightarrow F1/F2 = 2.5$

$\Delta m = +2.5 \rightarrow F1/F2 = 10$

$\Delta m = +5 \rightarrow F1/F2 = 100$

Absolute magnitude M is magnitude object has if placed at distance 10 pc called distance modulus

$m – M = 2.5 \log(d/10)^2 = 5 \log(d/10) = 5 \log d – 5$ (d in pc)

Definition of a Star

A star is a body that satisfies two conditions:

(1) Bound by self gravity (spherical)
Is this strictly true?

(2) Radiates energy largely supplied by an internal source

Source of radiation is usually nuclear energy released by FUSION reactions in stellar interior but could be gravitational potential energy released in contraction

Consequences of Definition of a Star

Stars must evolve (as they release energy) - changes in structure and/or chemical composition

Death of a star can occur in 2 ways

(a) Violation of first condition - self gravity (breakup of star scattering material into space)

(b) Violation second condition - internally supplied radiation (exhaustion nuclear fuel)

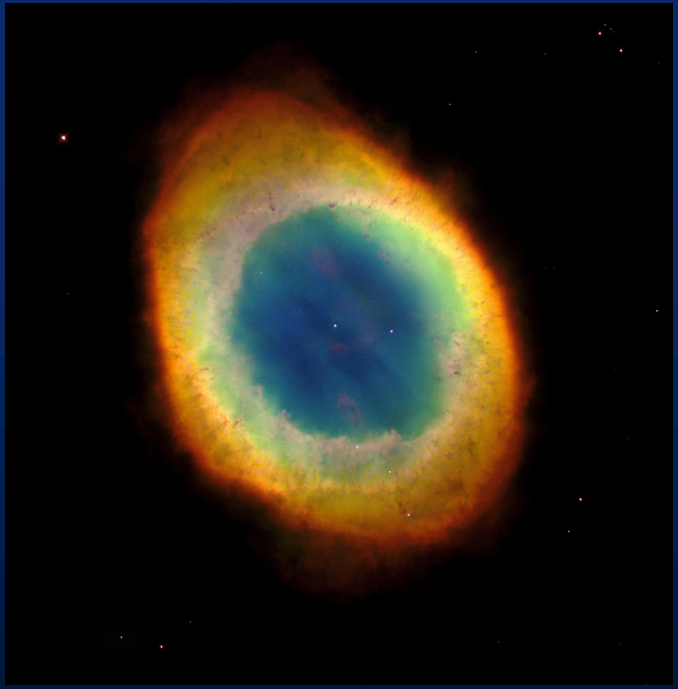
Birth of Stars

Starts when cold molecular gas pushed out of equilibrium – eg passing shock wave – cloud collapses under its own gravity – temperature and density increase as collapses – eventually high enough values (~10^7 K) that nuclear fusion begins – heat provides pressure to stop further collapse.

Death of Stars

H → He in interior of star, He → C and O in low mass stars and in massive stars this can continue up to Fe. When star has Fe core it can no longer supply pressure to counteract pull gravity and star ends its life in a supernova explosion →

In less massive stars events are less energetic and stars end their lives as planetary nebulae. →



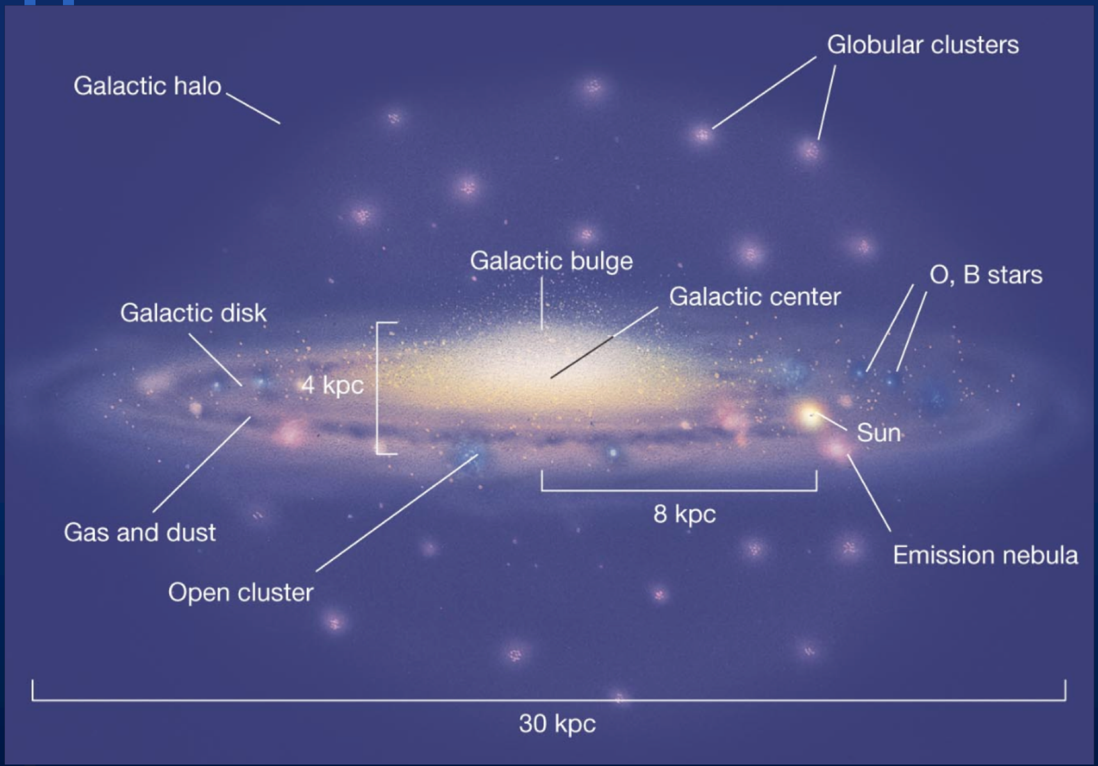
Galactic Chemical Evolution

Whether stars end their lives as SN or PN elements synthesized in their interiors are returned to the interstellar medium where it will be available for subsequent generations of star formation.

All elements in the periodic table were manufactured in interior of stars – including those critical for life (exceptions H, some He, Li). H = X = 0.74, He = Y = 0.25, everything else = Z = 0.01. Hence all previous star formation in Milky Way has had the effect of enriching gas in interstellar medium by only 1% over age universe.

Stellar Populations

Stars in our Galaxy have distinct populations often with different kinematics, ages metallicities and locations.



Disk: most stellar mass ~ $4 \times 10^{10}\ M_{sun}$ rotationally supported - at Sun V_{rot} = 200 km/s, current SFR 1 M_{sun}/yr

Bulge: ~ $2 \times 10^{10}\ M_{sun}$, mix stars, some old some young and SMBH with mass ~ $4 \times 10^{6}\ M_{sun}$

Halo: Oldest stars, globular clusters, most metal-poor stars known

Astrophysics (physics of stars)

- Is not an experimental science - we cannot devise and conduct experiments in order to test theories

- Theory is validated by observations

- Evidence often derived from past events

- Information we can gather is very restricted - apparent brightness (depends on distance), luminosity, temperature, chemical composition, mass, radius

Why should I care about stellar astrophysics?

We live next to a star.

It controls most of what happens on Earth

Tests many aspects physics

Stars drive evolution galaxies

Provide most visible mass in Universe

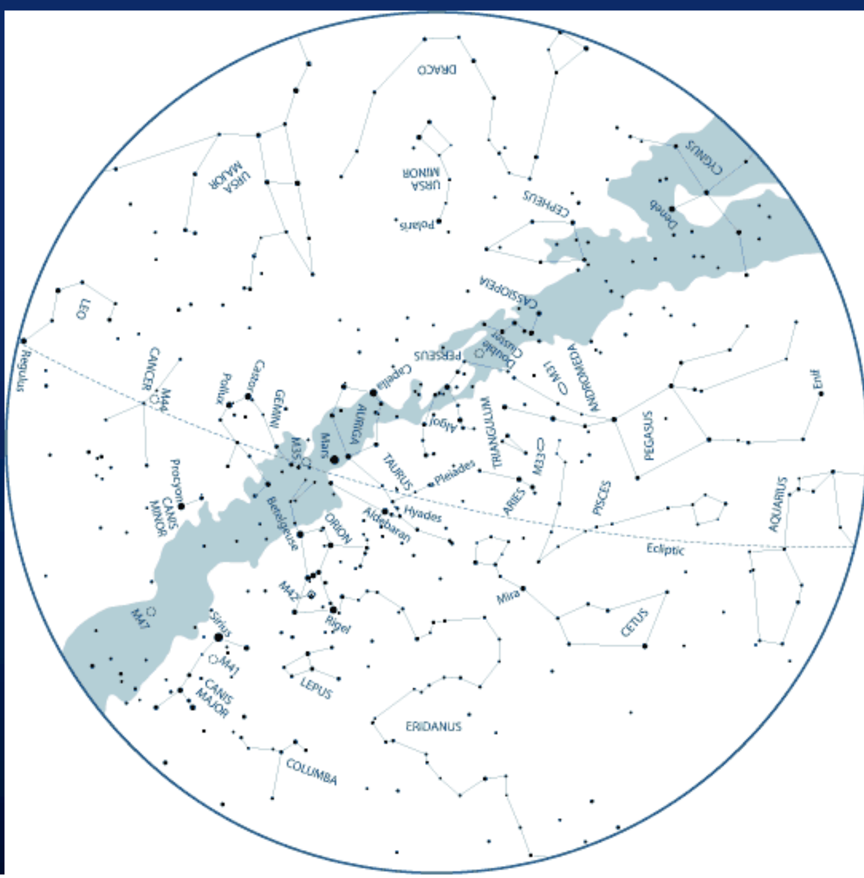
Trace chemical evolution Universe (life)

Some stellar statistics

A few 1000 visible to the naked eye

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

Sirius is brightest



SOME STELLAR STATISTICS

A few billion stars can be seen with best telescopes (not counting distant galaxies where individual stars generally unresolved but light is still detected).

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

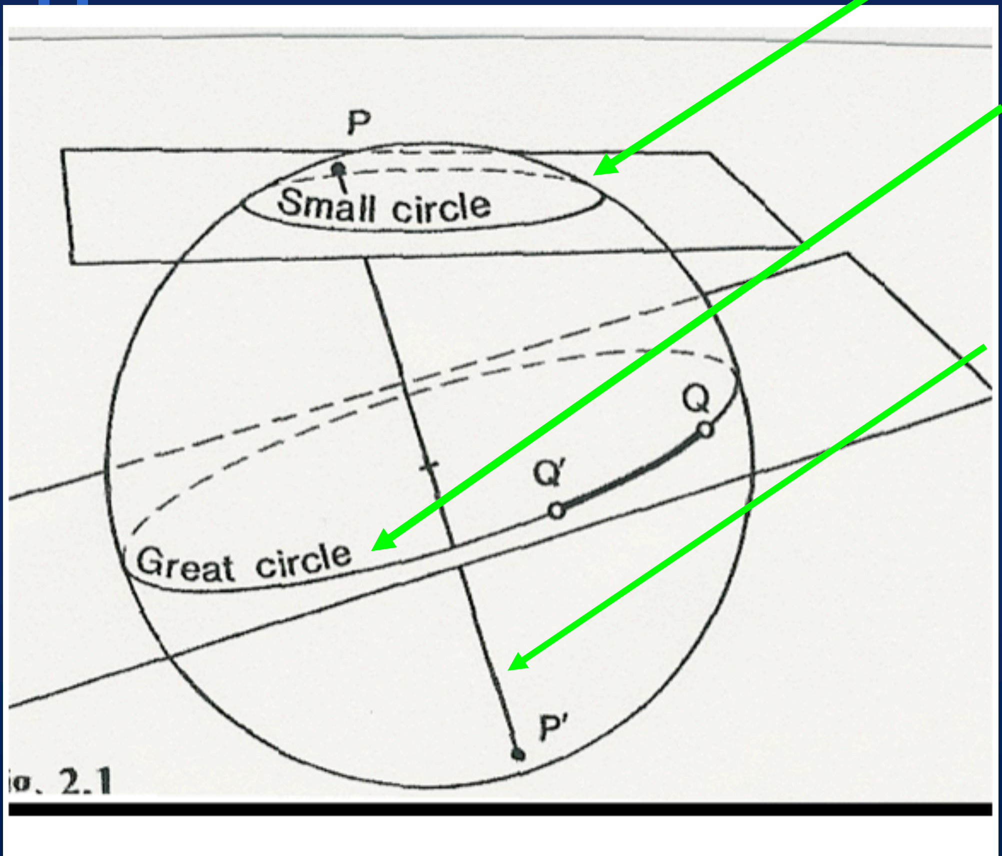
Nearest star (Proxima Centauri) is 300,000 times more distant than Sun.
(by comparison, Neptune is 30 times farther than Sun).

Basic Properties of Stars

Celestial Sphere

(not really a stellar property)

Small and Great Circles



Small Circle: Curve on sphere produced by plane NOT containing the centre.

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 Sphere

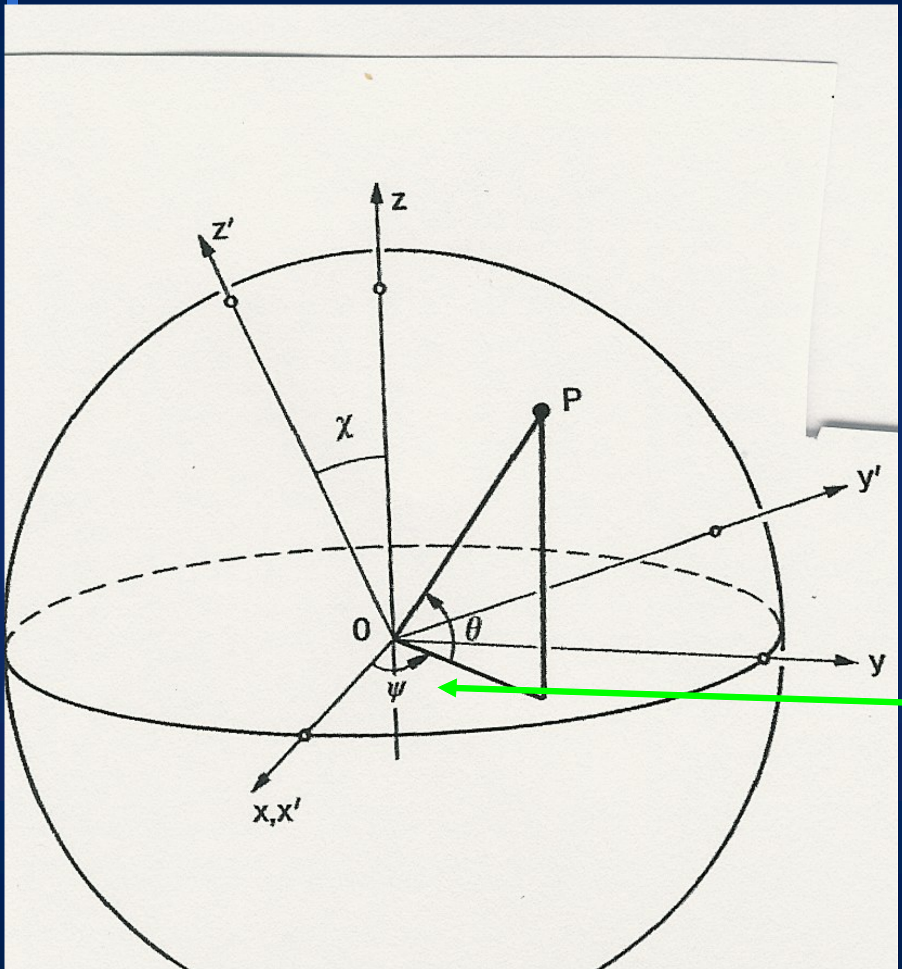


Fig. 2.4

Either XYZ coordinates or 2 angles, ψ and θ, can be used to locate a point, P, on the surface of a unit sphere.

Note that for angle, ψ, a reference point along the equator is required.

Latitude, Longitude on Earth

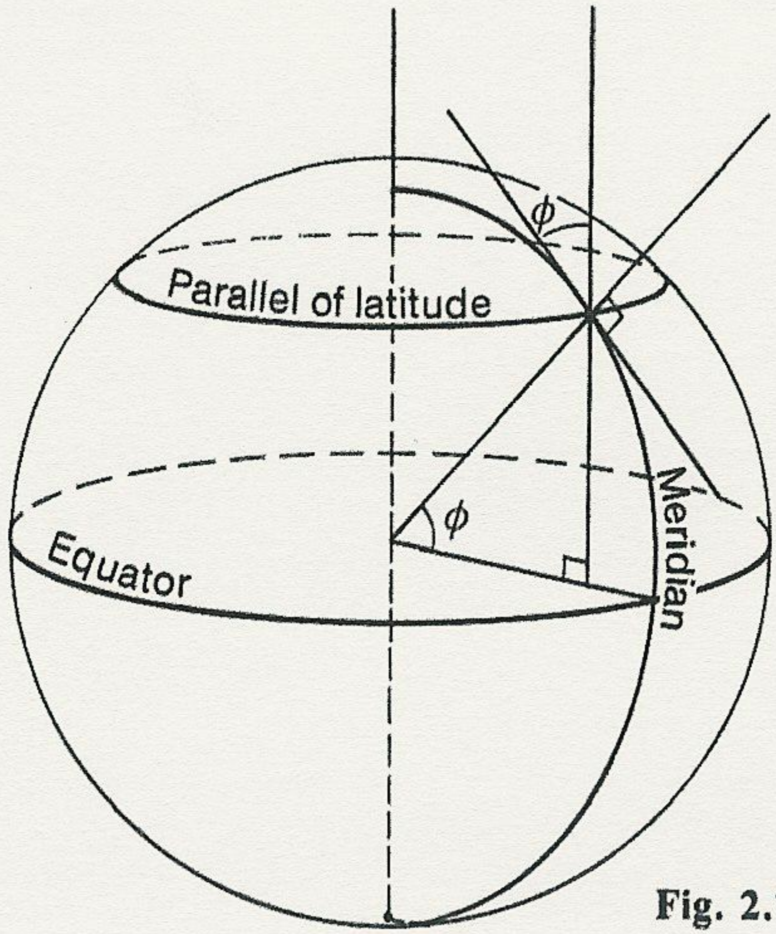


Fig. 2.7

Reference plane is equator.

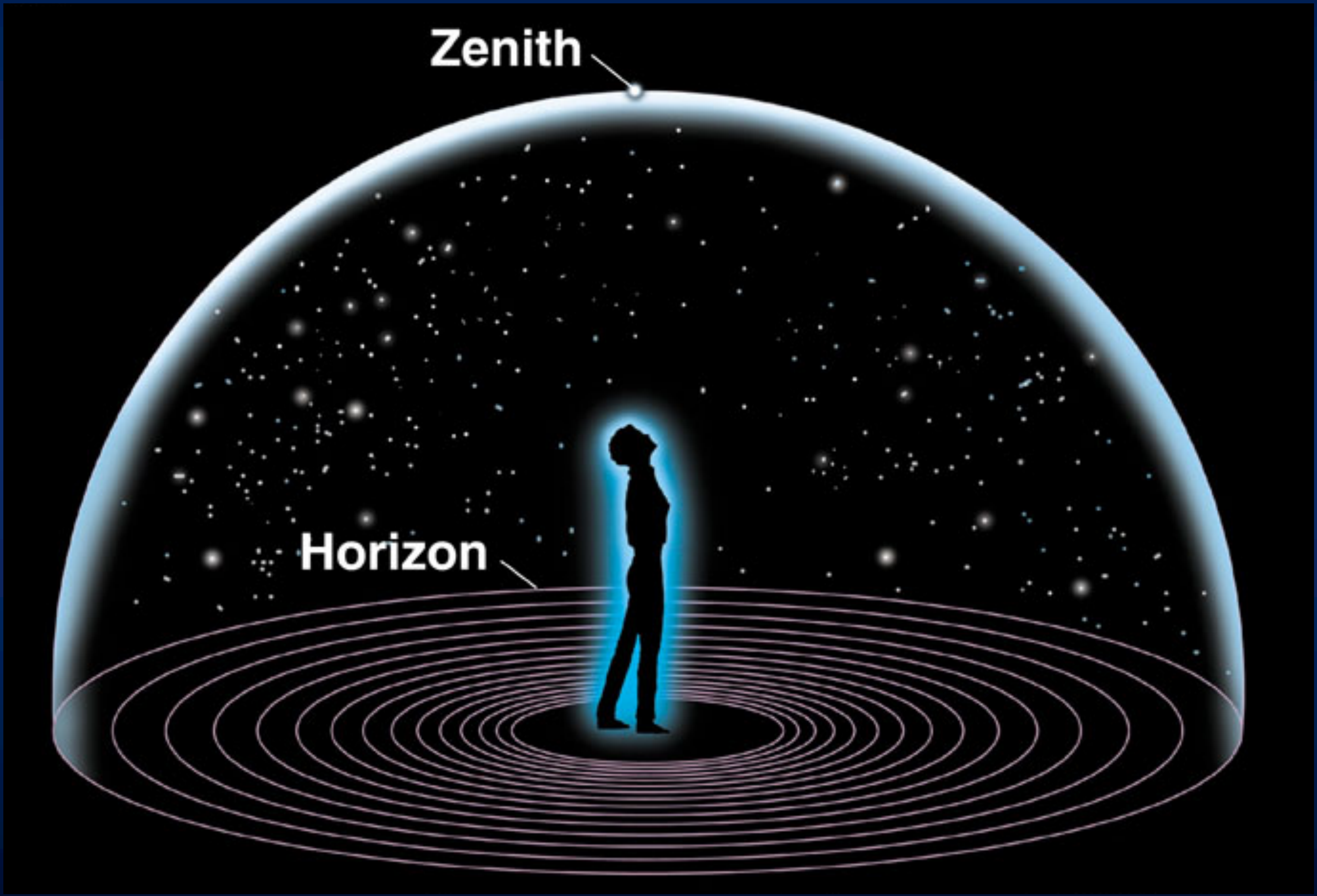
Small circles parallel to equator are parallels of latitude. + north, - south.

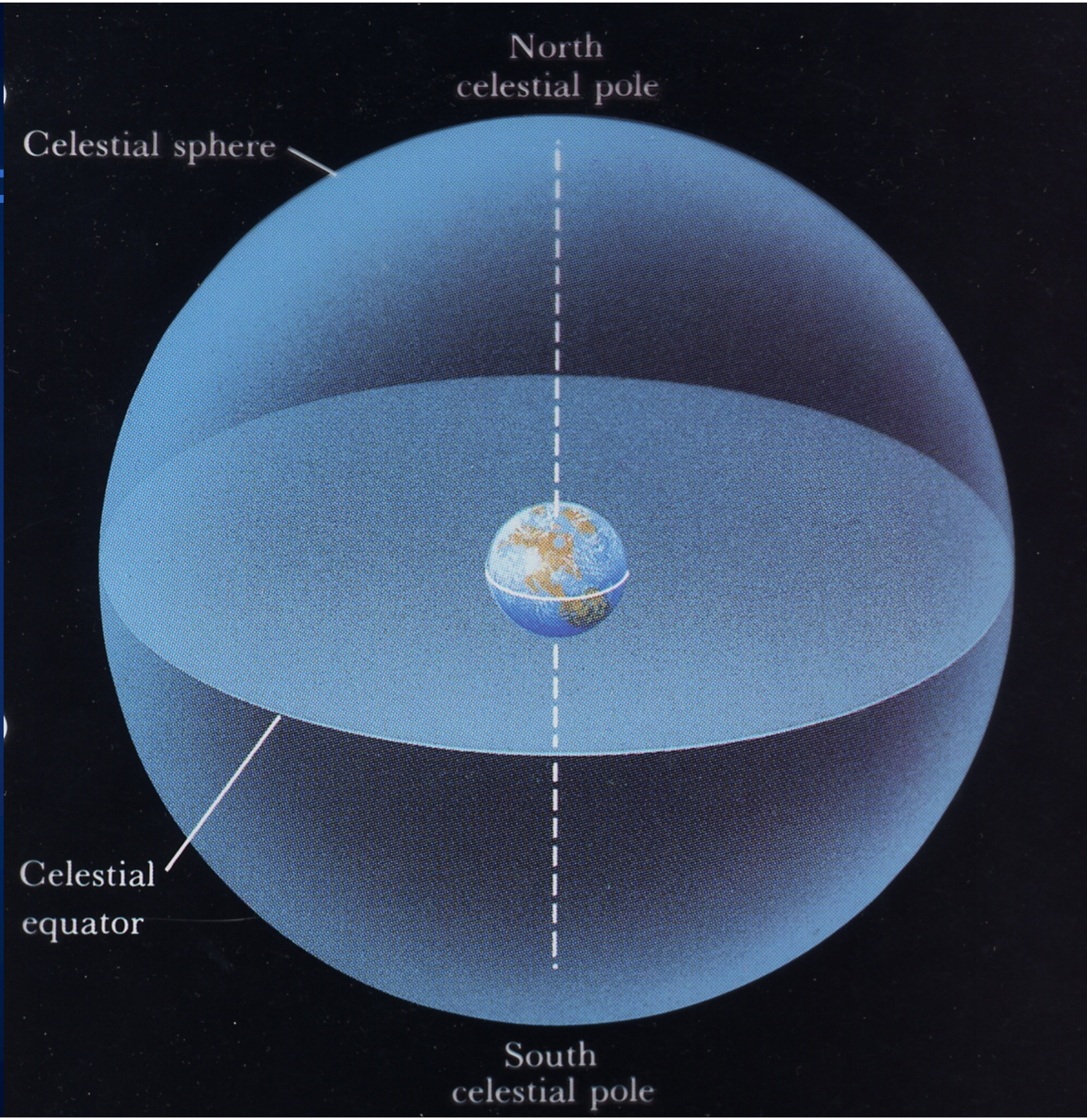
Altitude of celestial pole is your latitude. (Vancouver 49 D)

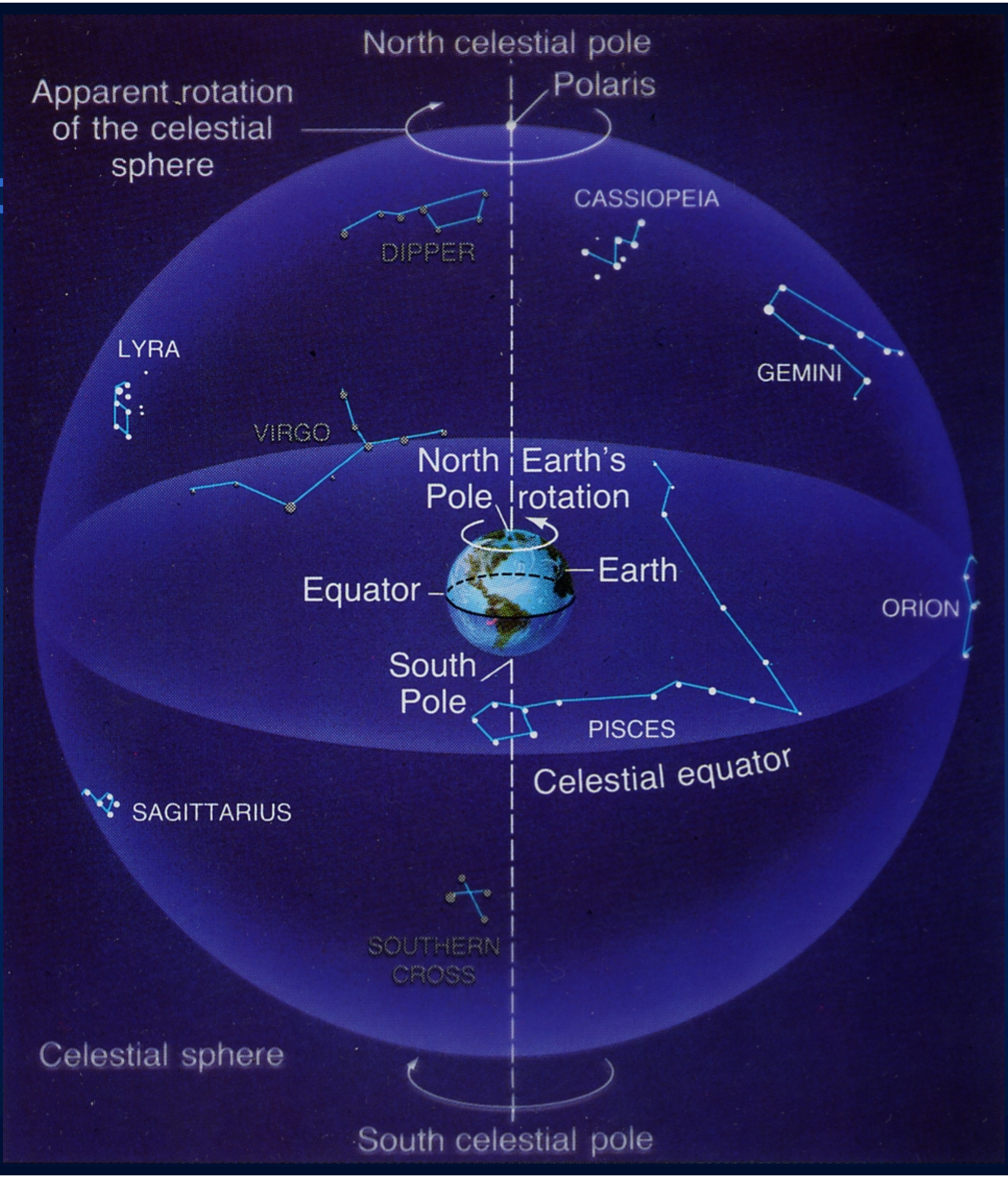
Semicircles from pole to pole are meridians.

Longitude is angle between meridian and zero meridian (Greenwich). + west, - east. (Vancouver 123 D)

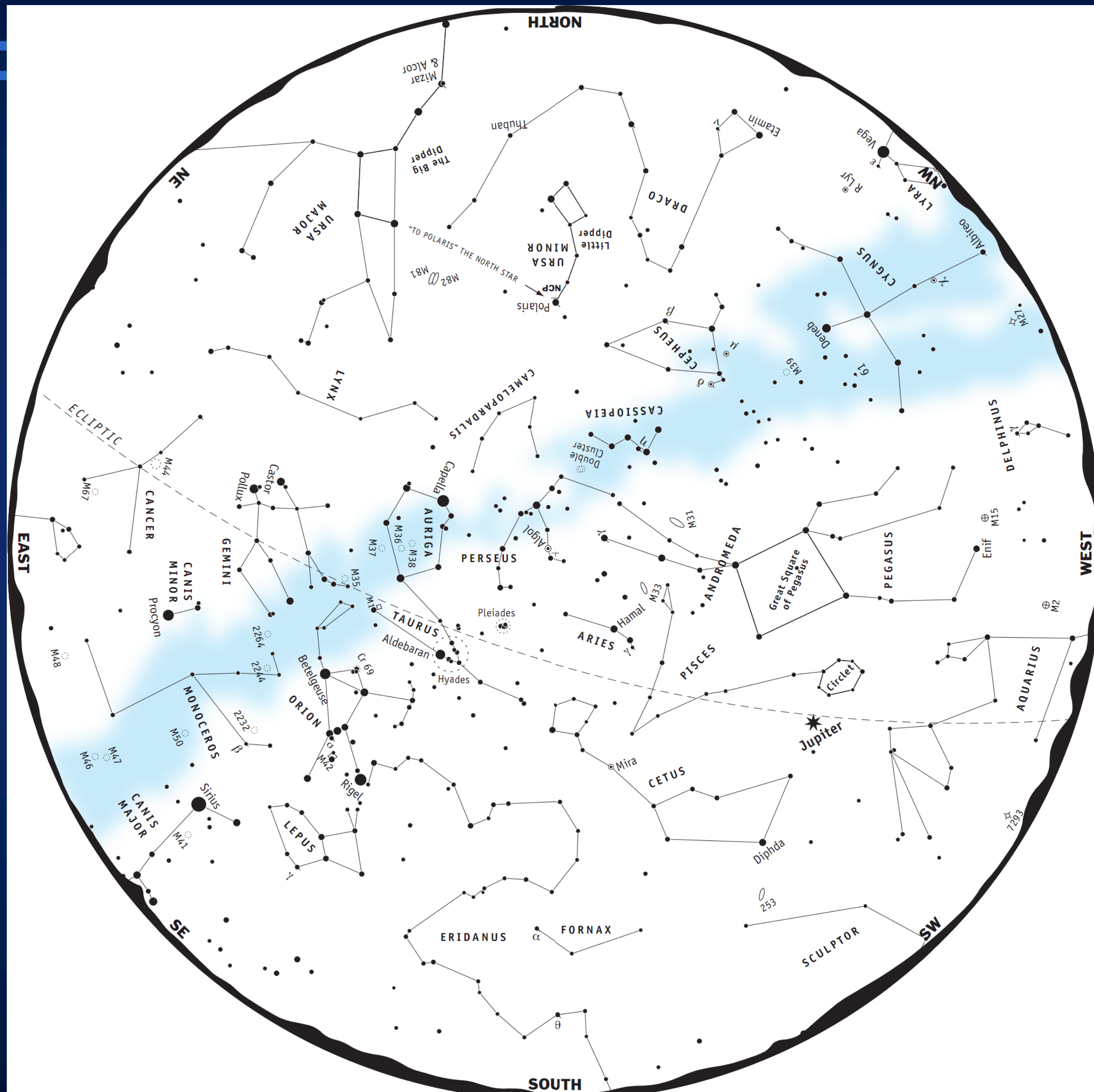
CELESTIAL SPHERE




North
celestial pole
Celestial sphere
Celestial
equator
South
celestial pole

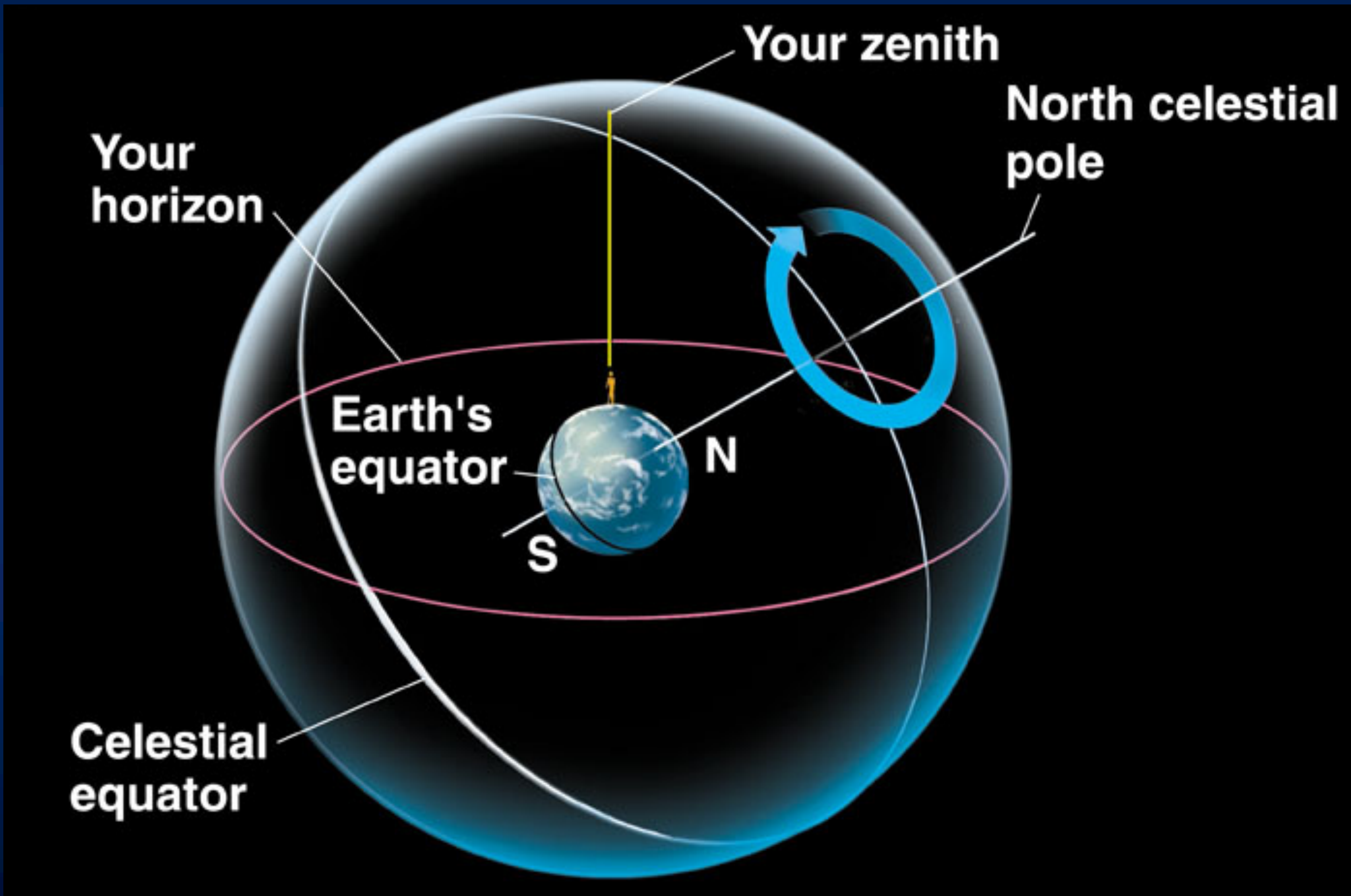

North celestial pole
Apparent rotation of the celestial sphere
Polaris
CASSIOPEIA
DIPPER
GEMINI
LYRA
VIRGO
North Pole
Earth's rotation
Earth
Equator
ORION
South Pole
PISCES
Celestial equator
SAGITTARIUS
SOUTHERN CROSS
Celestial sphere
South celestial pole

Celestial Sphere

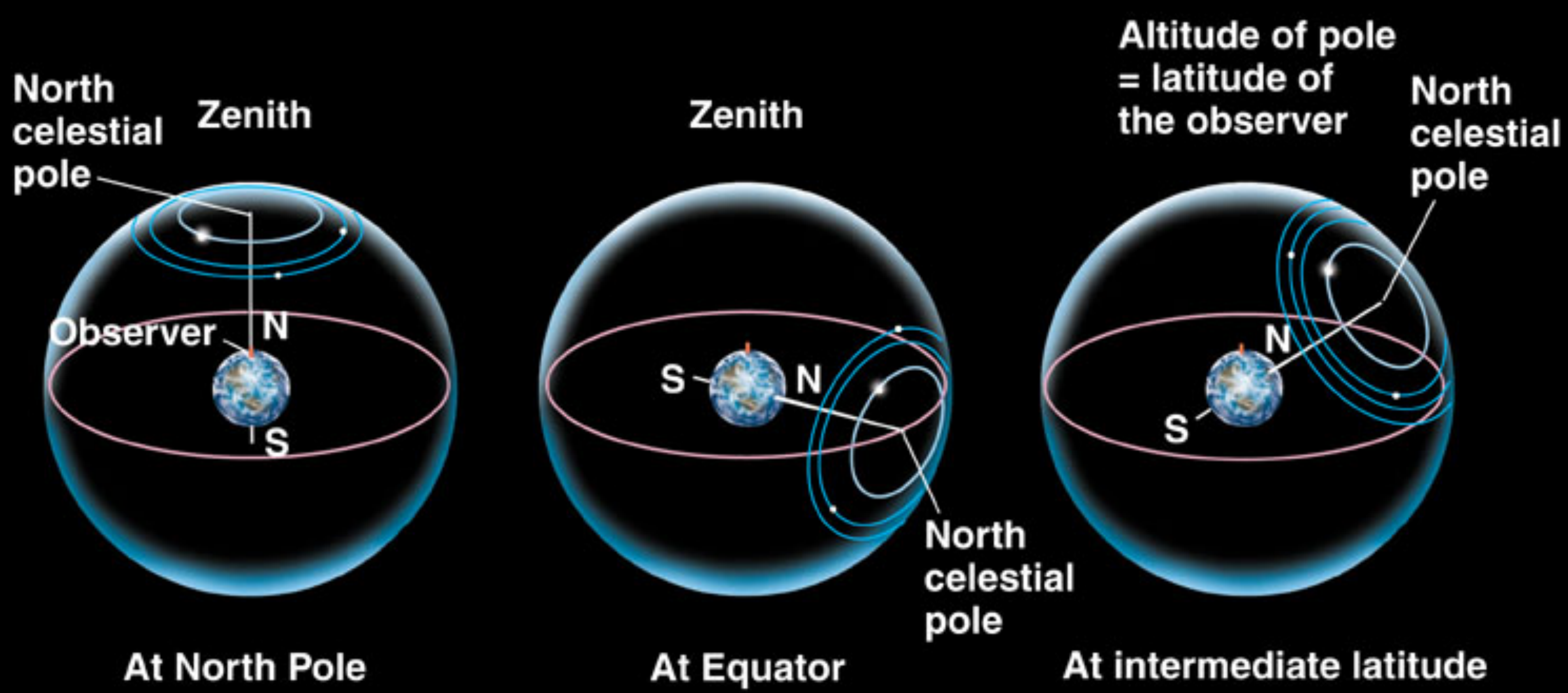


January
Sky Map

APPARENT SKY ROTATION



STAR CIRCLES



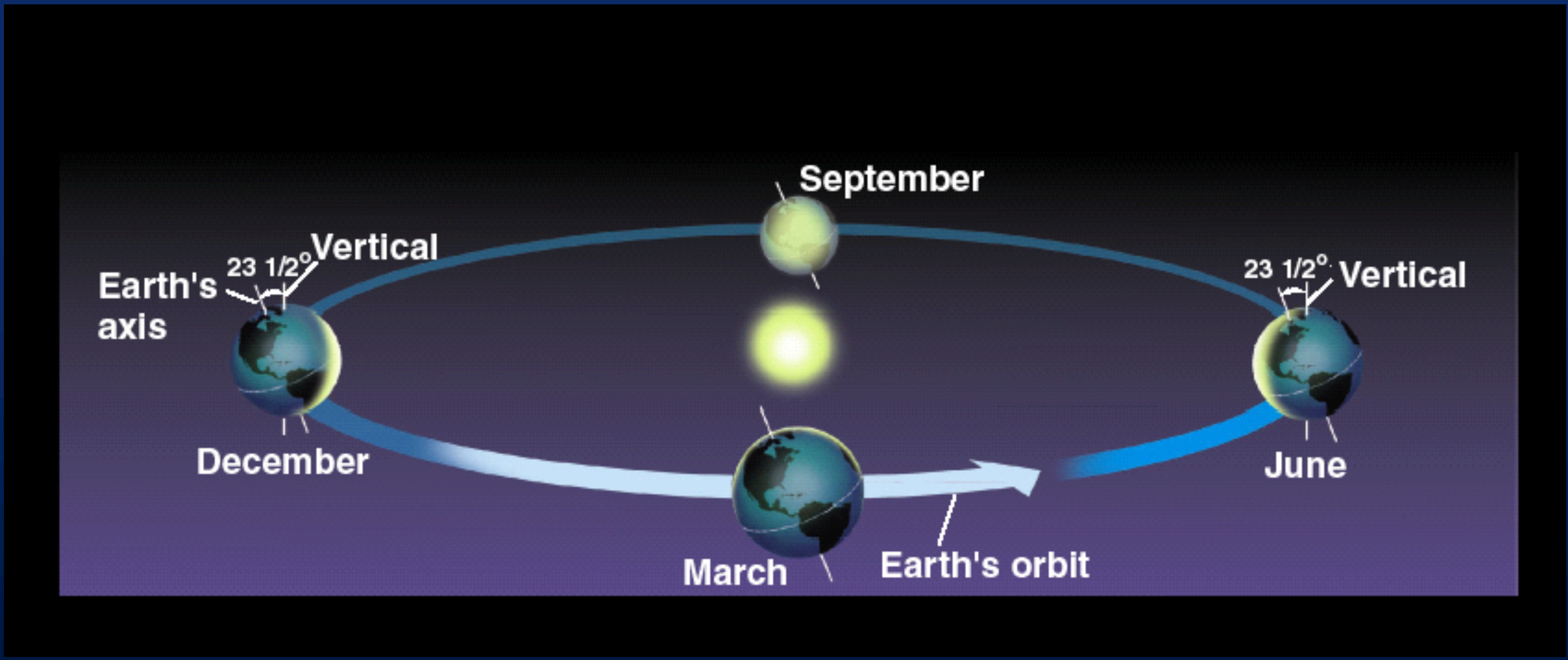
STAR TRAILS NEAR THE POLE

EQUATORIAL STAR TRAILS

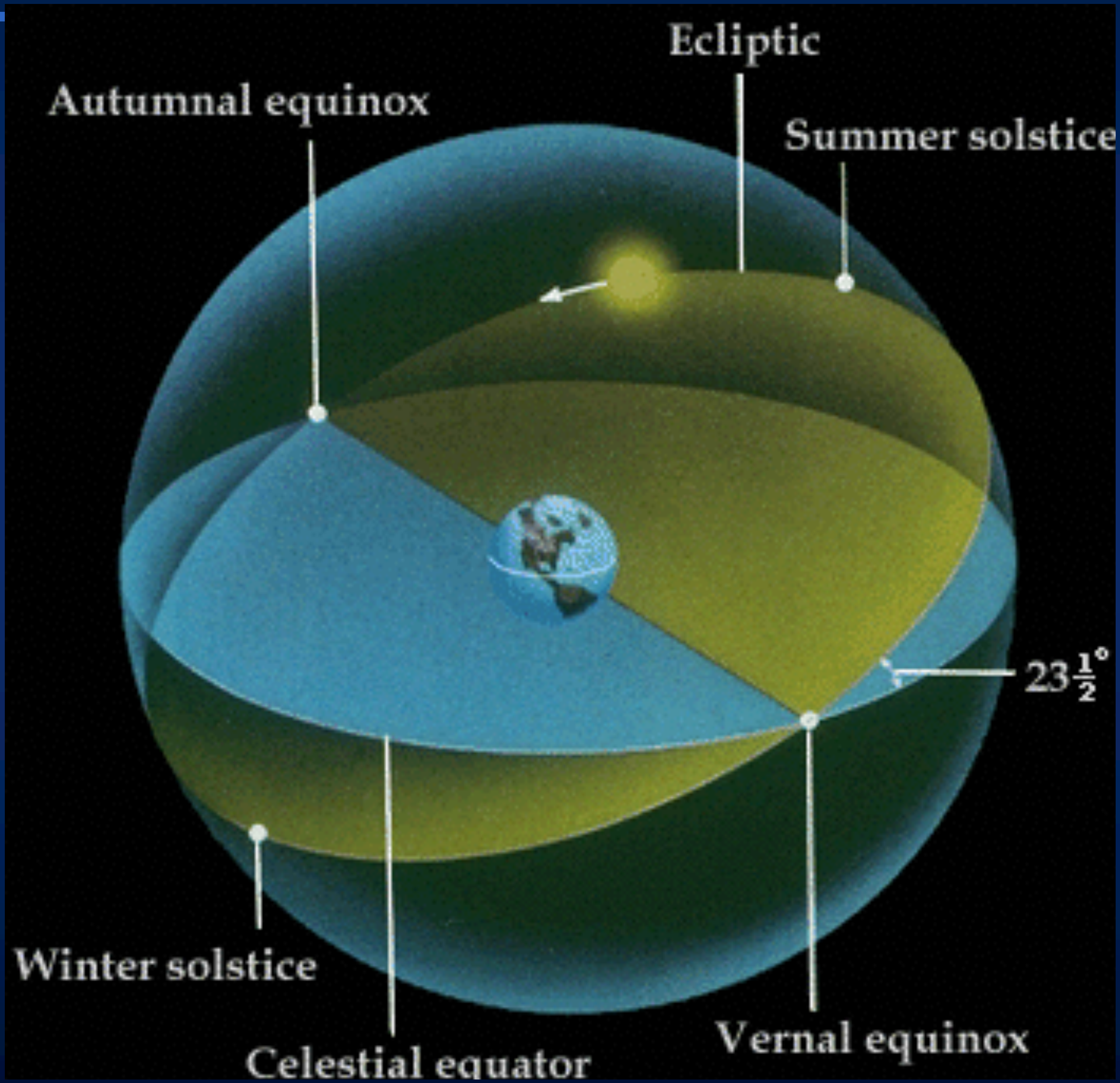
INTERMEDIATE LATITUDE STAR TRAILS

Earth's Inclined Axis

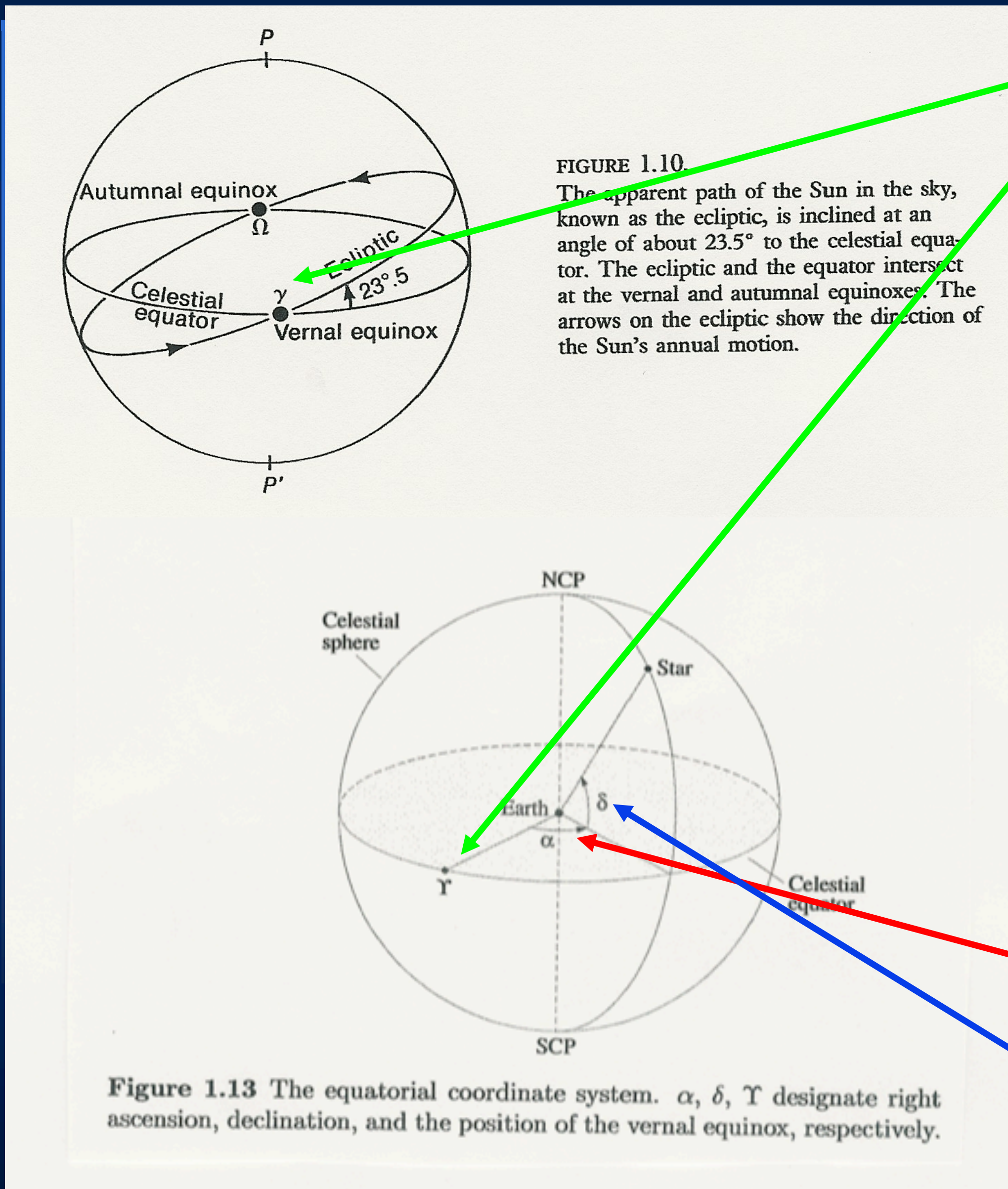
Earth's axis inclined 23.5 degrees to plane of its orbit



SEASONS on EARTH



Right Ascension and Declination

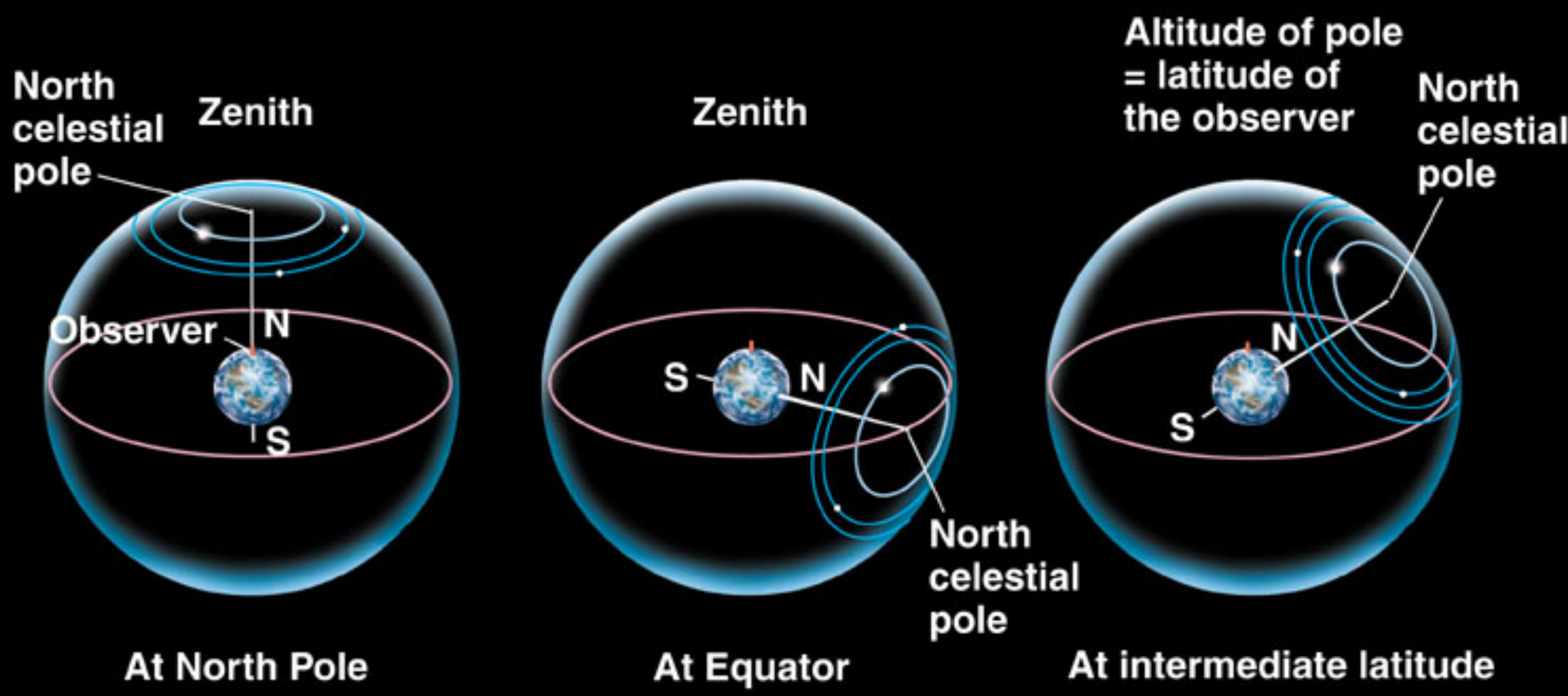


γ is position of crossing of celestial equator and equatorial plane of Earth - position of vernal equinox. This is a fixed point from which to measure angles.

α is Right Ascension

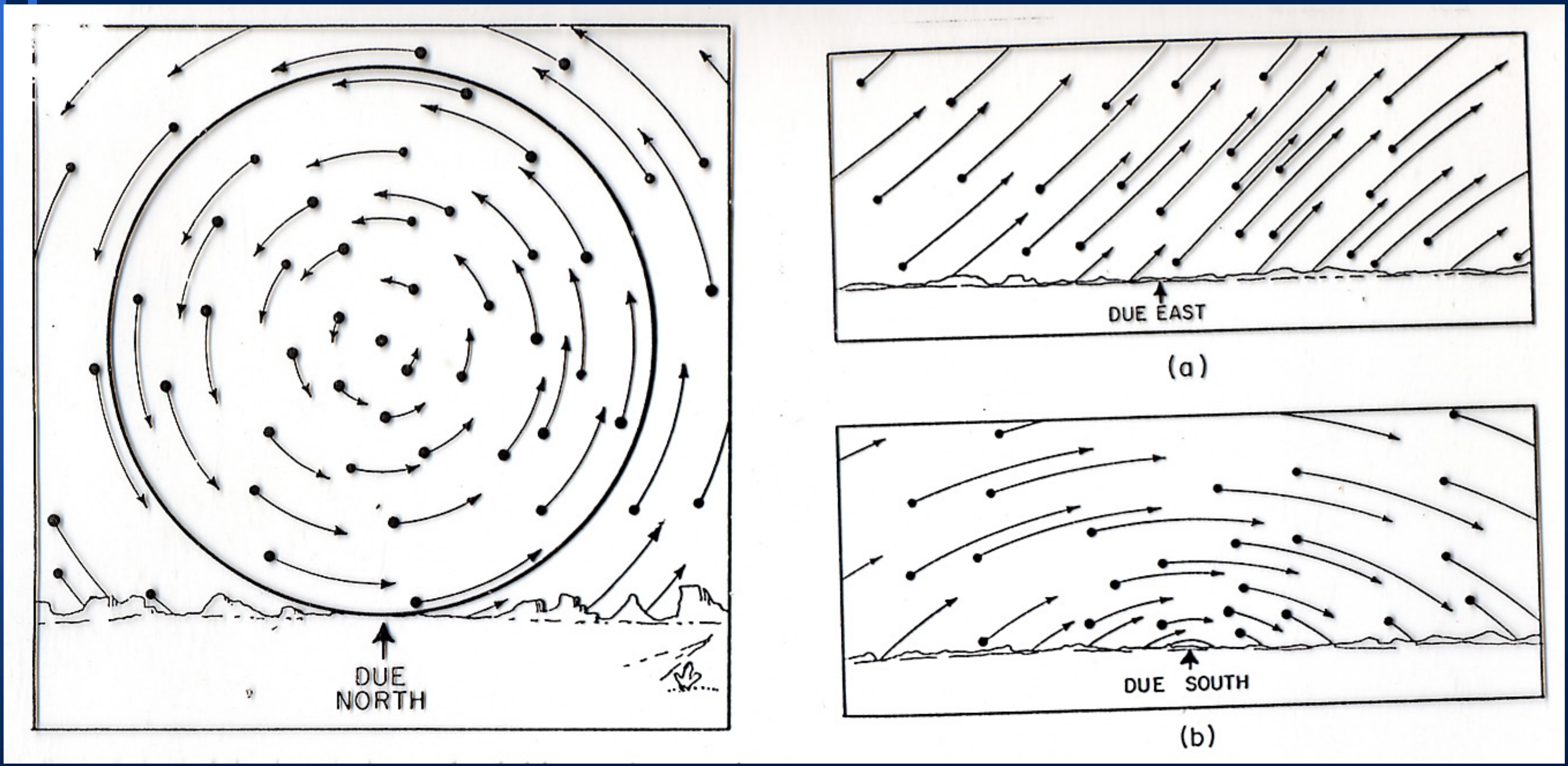
δ is Declination

CIRCUMPOLAR STARS - STARS THAT NEVER SET BELOW YOUR HORIZON



Are there circumpolar stars at any of these latitudes?

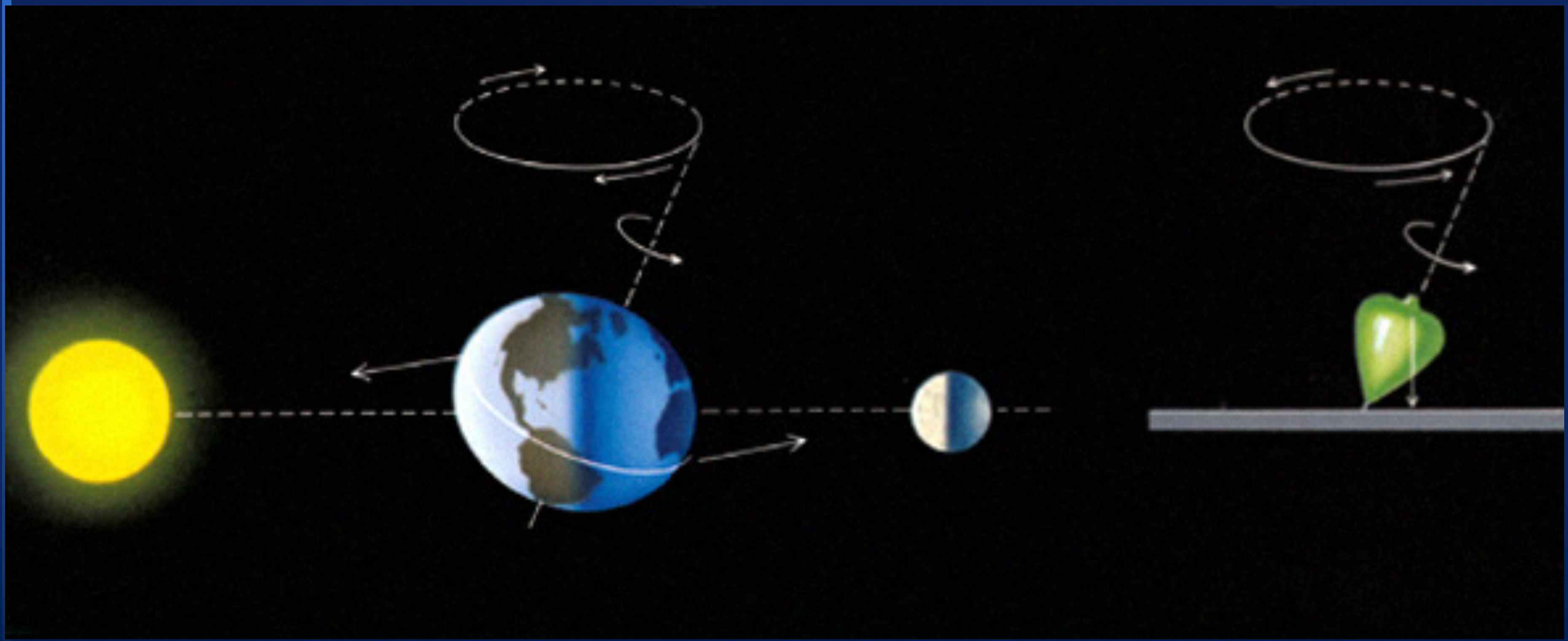
STAR TRAILS



Circumpolar stars are those that never set – inside circle

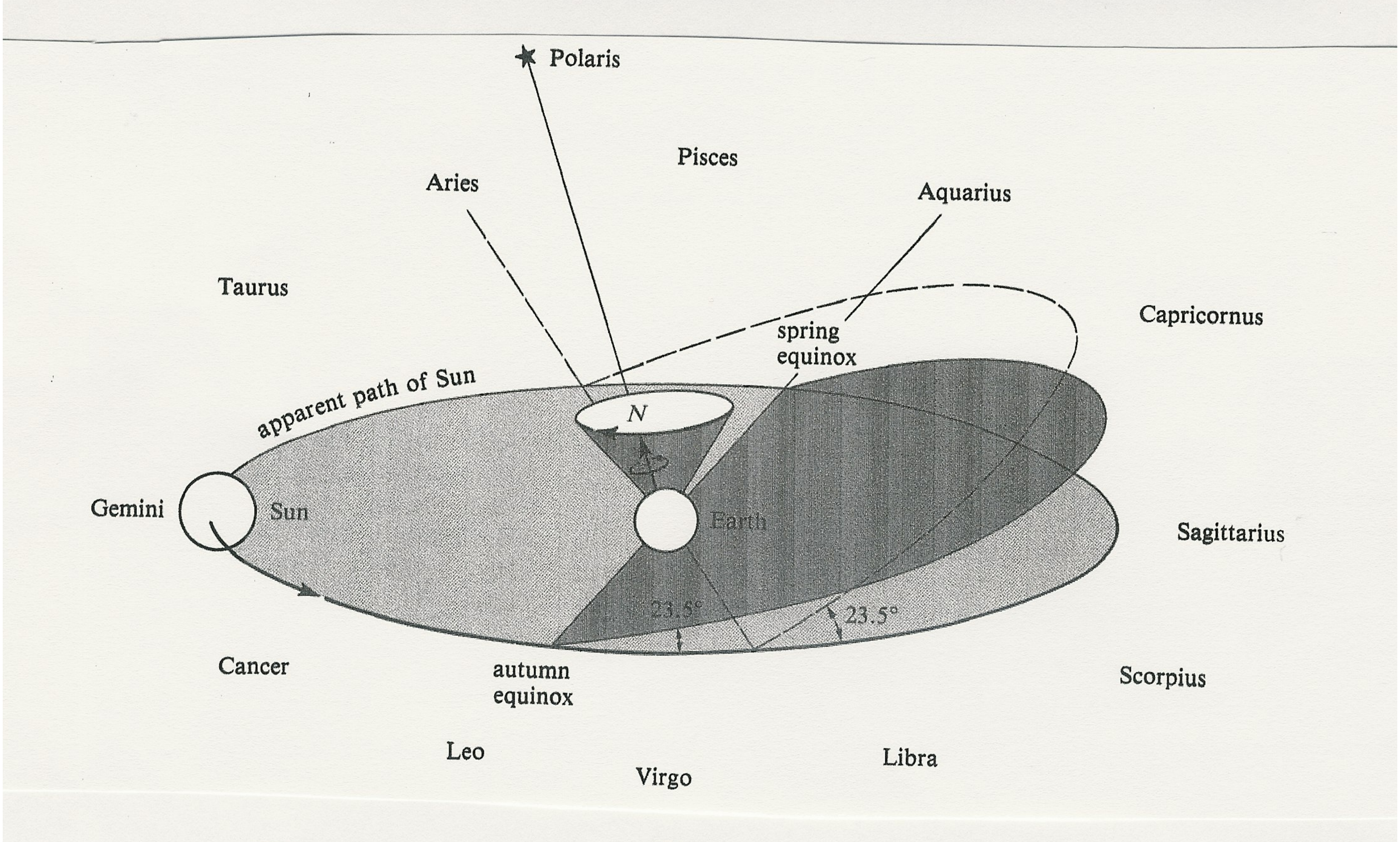
EARTH' S PRECESSION

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).

EARTH' S PRECESSION



Deneb
CYGNUS
AD 8000
CASSIOPEIA
CEPHEUS
LYRA
Vega
Polaris
AD 15,000
DRACO
Path of north
celestial pole
URSA
MINOR
AD 1
Thuban
5000 BC
CORONA
BOREALIS
URSA MAJOR

Some precession details

Polaris is currently within 1 degree of pole. Where will it be in 13,000 years?

Same effect causes 50.3”/year westward motion of vernal equinox - use tropical year for calendar.

J2000 is reference (Jan 1, 2000 noon at Greenwich)

$\Delta\alpha = [\ m + n \sin\alpha \tan\delta\ ]\ N$

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

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

A Problem

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

In these units G is 6.673×10^{-11} m^3 kg^{-1} s^{-2}

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