FUNDAMENTALS OF SATELLITE TECHNOLOGY

Prepared
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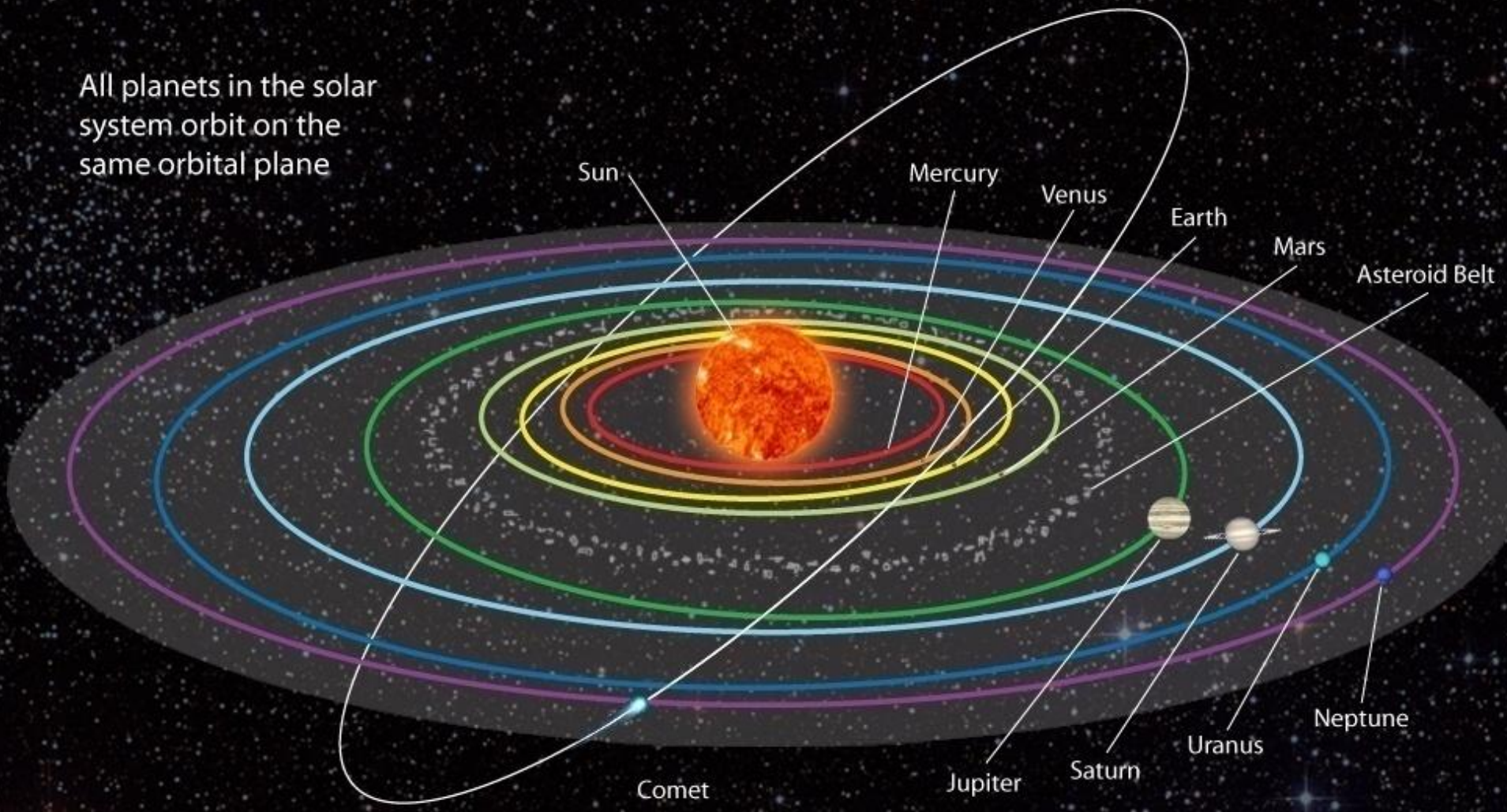
Orbital Plane

All planets in the solar system orbit on the same orbital plane



* Many comets exist outside the orbital plane

- Orbital Plane

  All of the planets, comets, and asteroids in the solar system are in orbit around the Sun. All of those orbits line up with each other making a kind of flat disk called the orbital plane.

- Inner Planets

  The inner planets are closer to the Sun and are smaller and rockier. (mercury, Venus, Earth and Mars)

- Outer planets

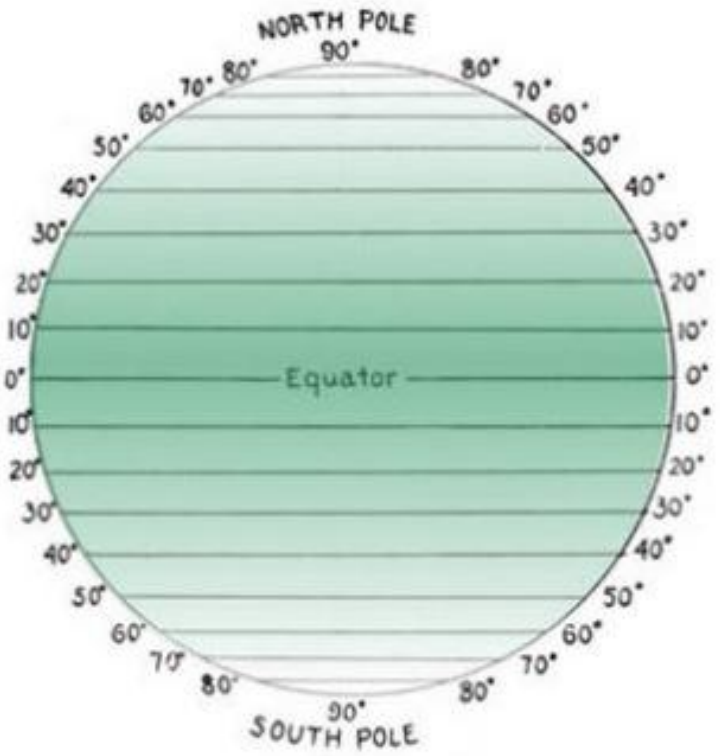
  The outer planets are further away, larger and made up mostly of gas.(Jupiter, Saturn, Uranus, Neptune and Pluto)

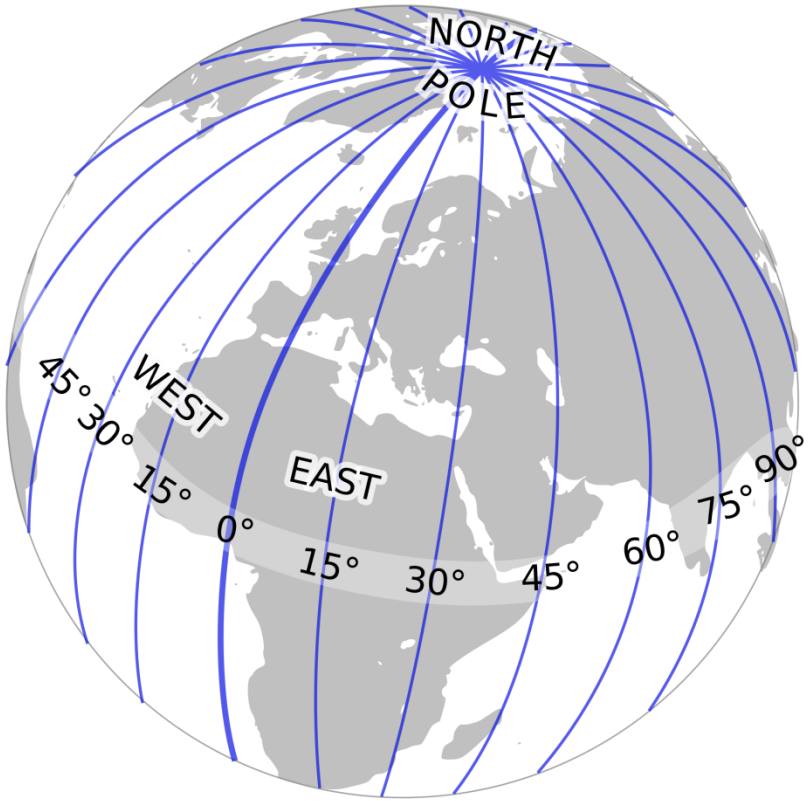
- Latitude (φ) is a geographic coordinate that specifies the north–south position of a point on the Earth's surface.

(or)

- Latitude is defined as the measurement of distance in degrees with respect north or south.

- The word Latitude is derived from Latin word ‘Latus’ meaning ‘wide’.




NORTH
POLE
45°
30°
WEST
15°
0°
EAST
15°
30°
45°
60°
75°
90°

- Longitude (φ) is a geographic coordinate that specifies the east-west position of a point on the Earth's surface.

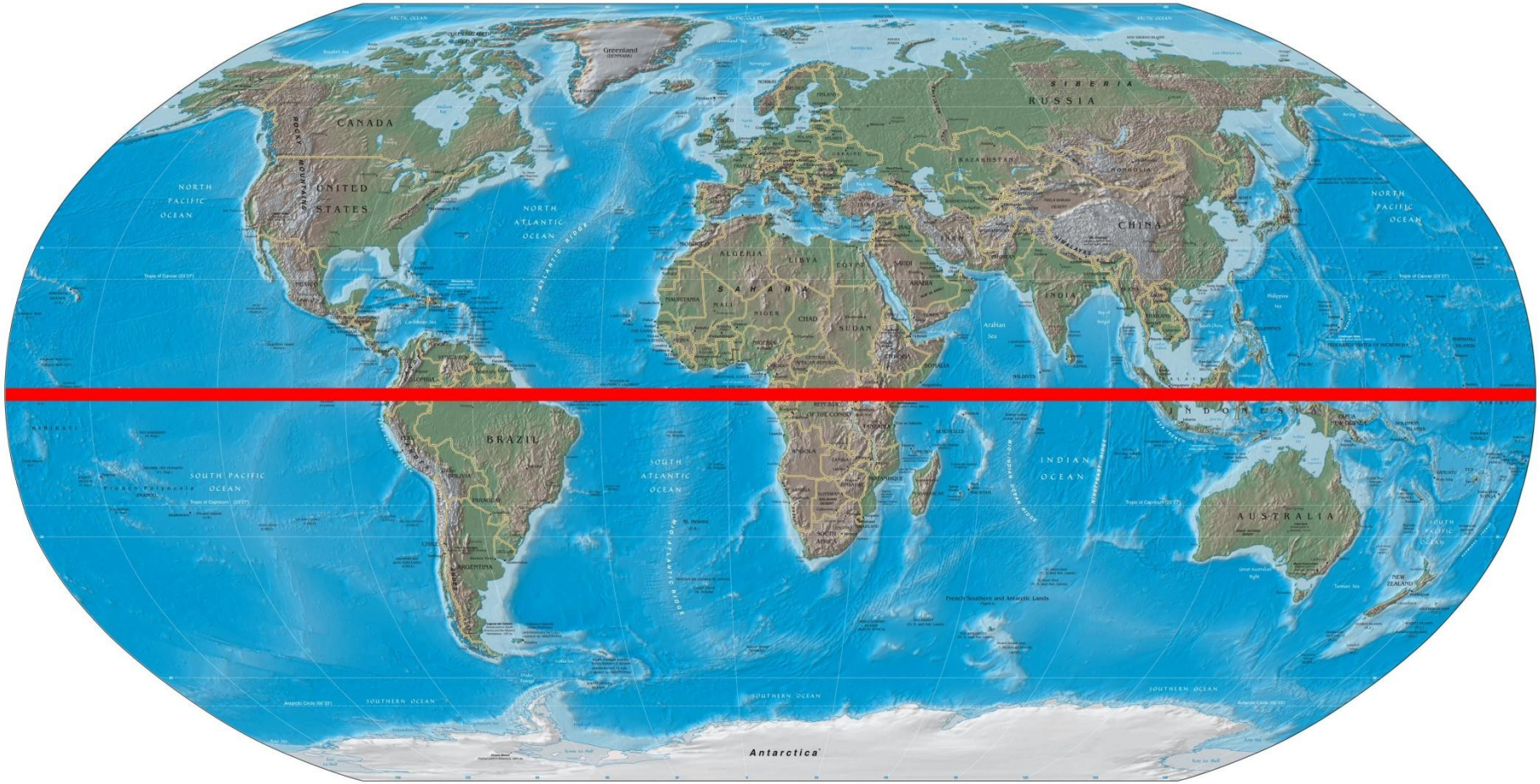
(or)

- Longitude is defined as the measurement of distance in degrees east or west of the prime meridian.
- The word Latitude is derived from Latin word ‘Longus’ meaning ‘Length’.

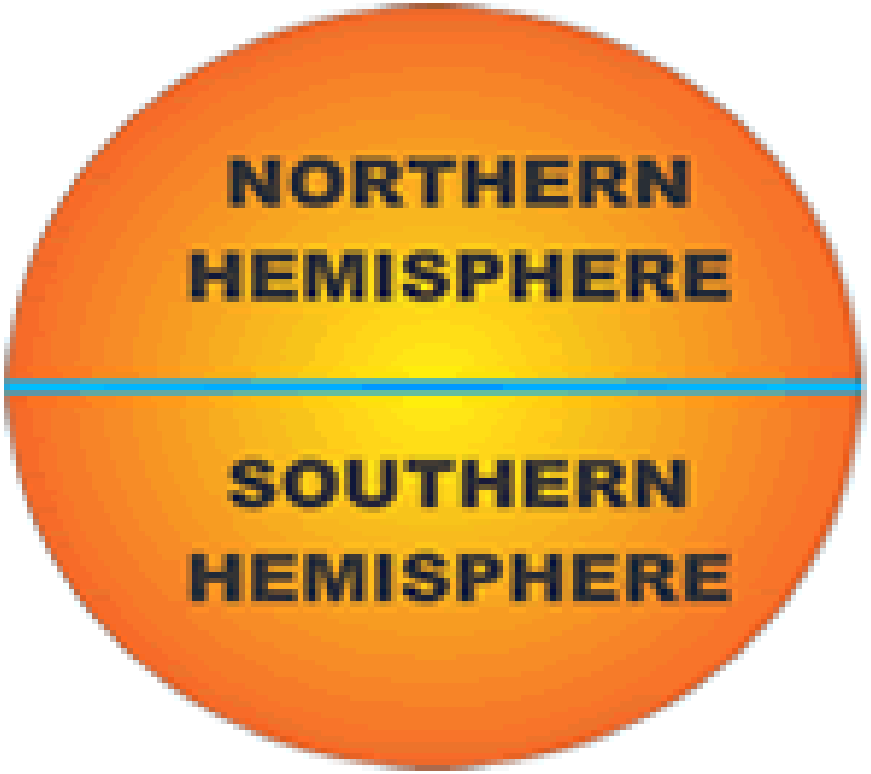
PRIME MERIDIAN

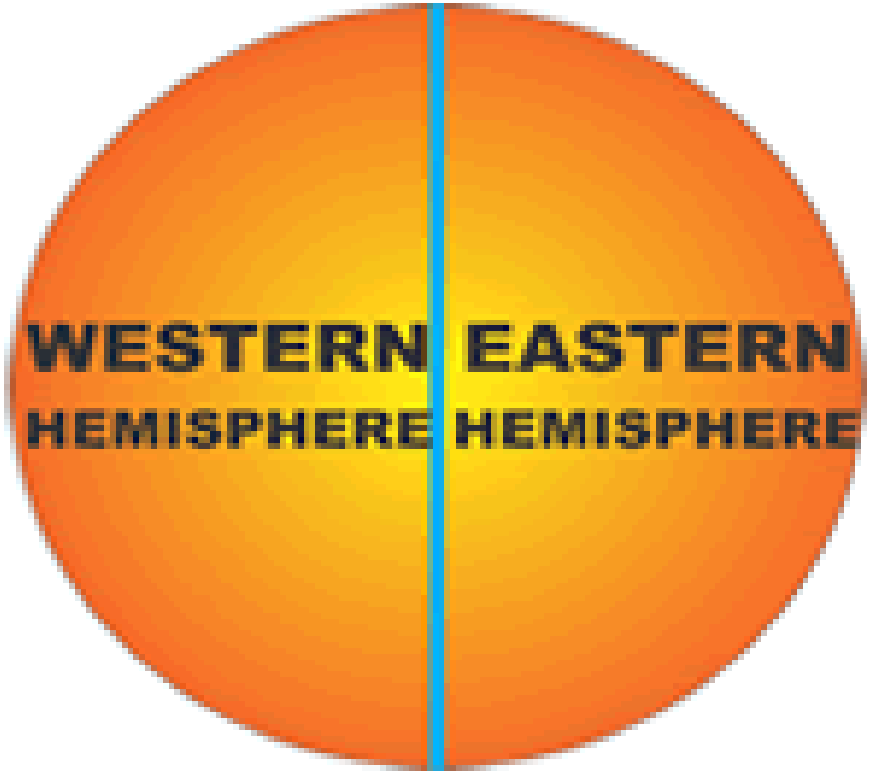
- An imaginary line starts from north pole to south pole divides the earth into two half's which passes through Greenwich, England.
- Like the prime meridian as do, all other lines are pass through north and south pole makes the earth look likes a peeled orange.

EQUATOR


Greenland
CANADA
ROCKY MOUNTAINS
UNITED STATES
NORTH PACIFIC OCEAN
NORTH ATLANTIC OCEAN
MID-ATLANTIC RIDGE
SIBERIA
RUSSIA
KAZAKHSTAN
MONGOLIA
CHINA
INDIA
ALGERIA
LIBYA
EGYPT
SAUDI ARABIA
SAHARA
MAURITANIA
MALI
NIGER
CHAD
SUDAN
ETHIOPIA
SOMALIA
Arabian Sea
BRAZIL
SOUTH PACIFIC OCEAN
SOUTH ATLANTIC OCEAN
INDIAN OCEAN
AUSTRALIA
INDONESIA
NEW ZEALAND
SOUTHERN OCEAN
Antarctica

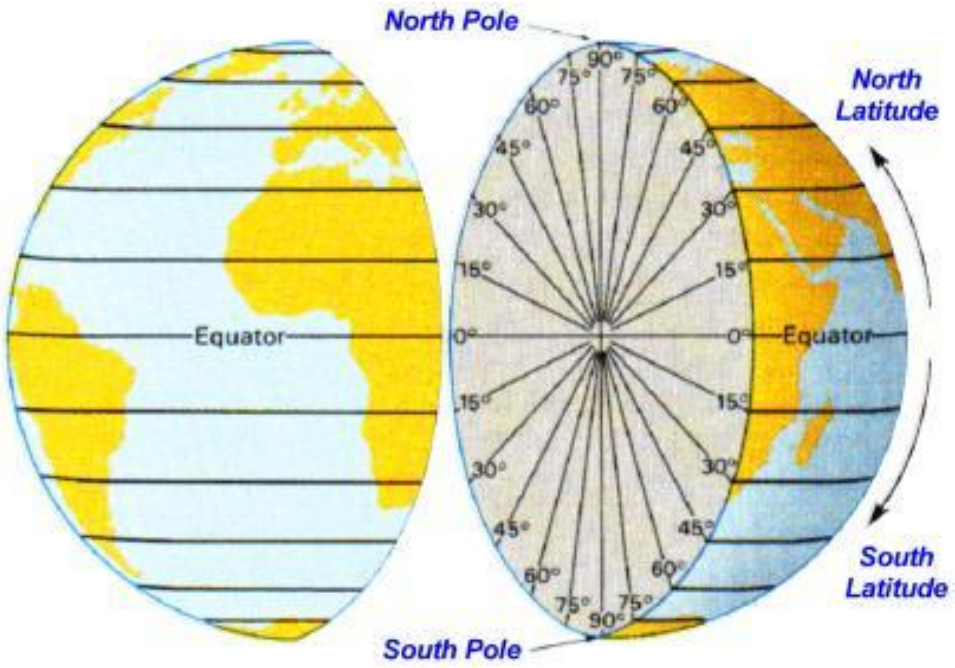
- The Equator is the longest of all lines of latitude.
- It divides the earth into two half and is measured as zero degree at equator.


NORTHERN
HEMISPHERE
SOUTHERN
HEMISPHERE


WESTERN
HEMISPHERE
EASTERN
HEMISPHERE

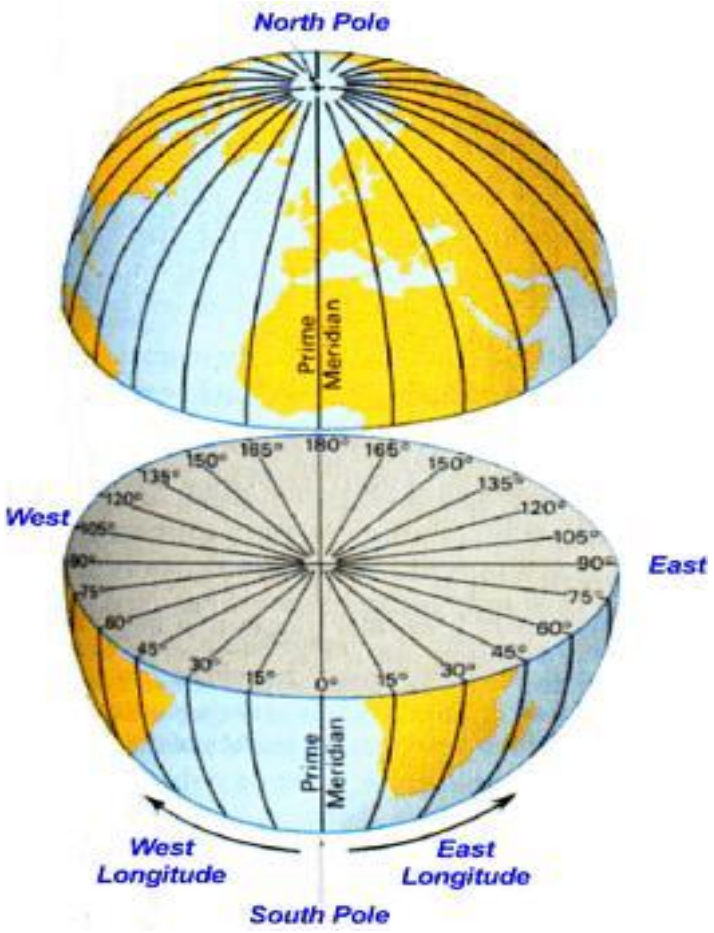
NORTH AND SOUTH LATITUDES

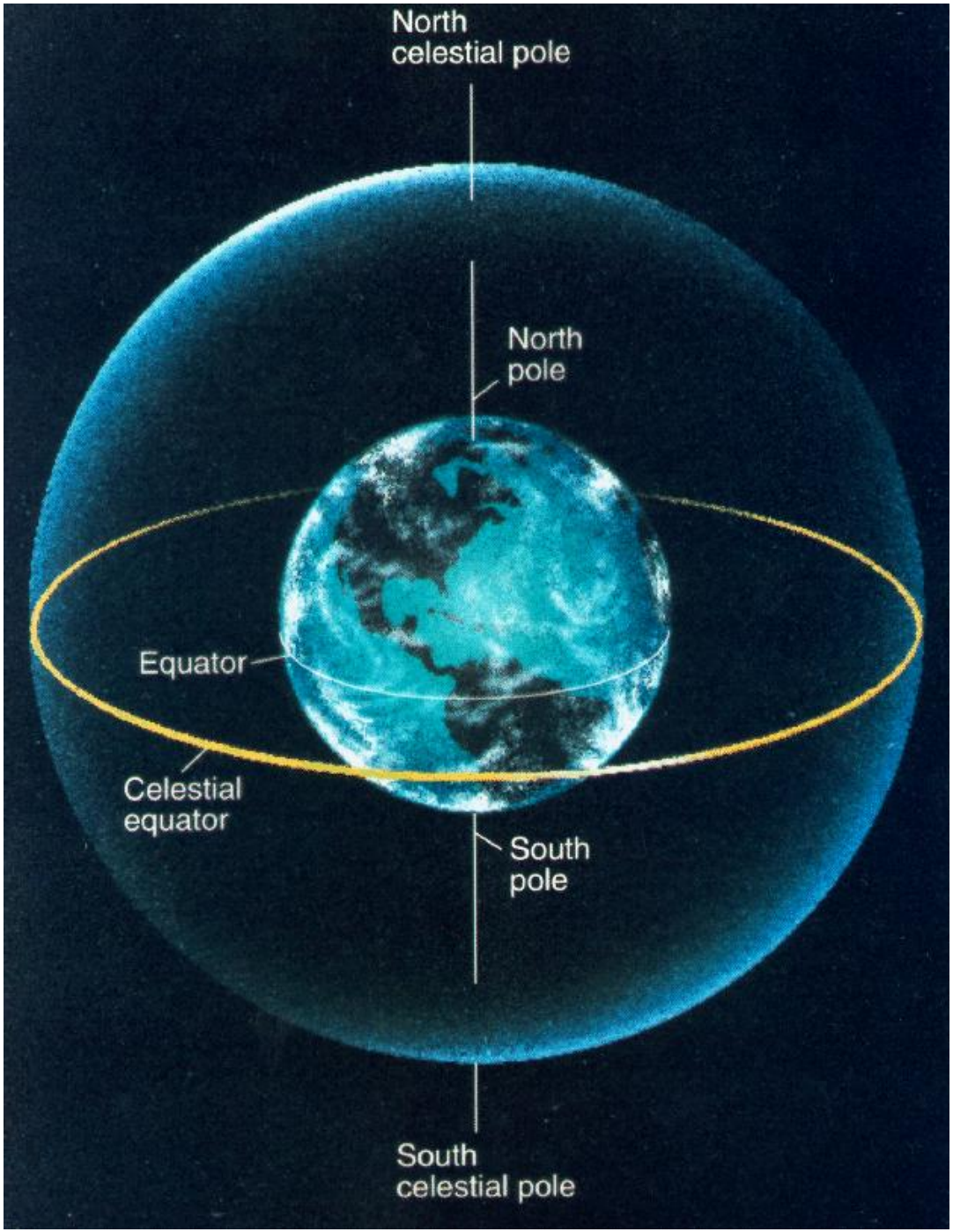
- Position on latitude lines above the equators are called North and are in the northern hemisphere.
- Position on latitude lines below the equators are called south and are in the southern hemisphere.



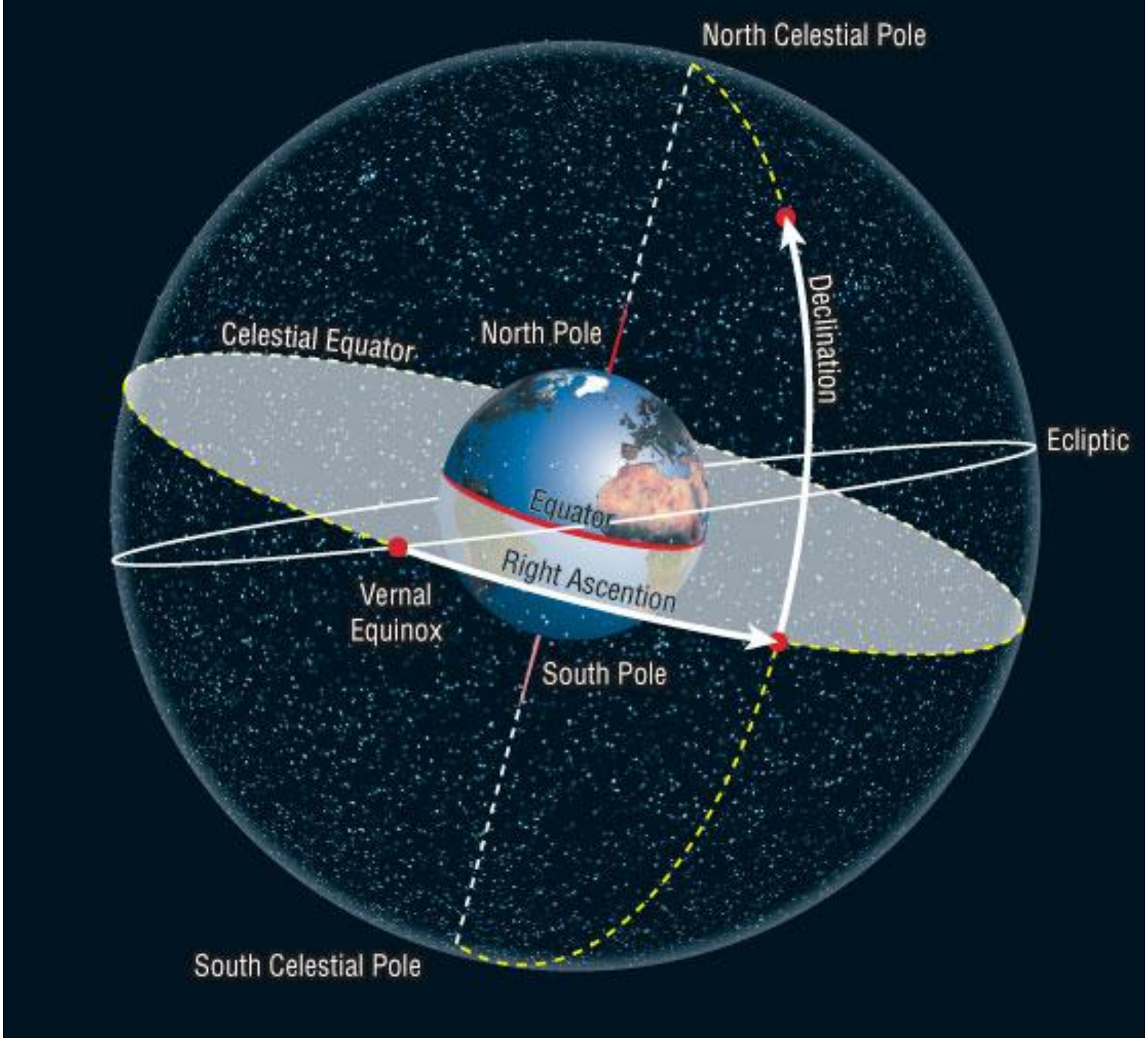
EASTERN AND WESTERN LONGITUDES

- Longitude lines left of the prime meridian gives location west in the western hemisphere.
- Longitude lines right of the prime meridian gives location east in the eastern hemisphere.




North
celestial pole
North
pole
Equator
Celestial
equator
South
pole
South
celestial pole

The Earth rotates from West to East


North Celestial Pole
Declination
Celestial Equator
North Pole
Ecliptic
Equator
Right Ascention
Vernal
Equinox
South Pole
South Celestial Pole

Equinox & Direction of Vernal Equinox

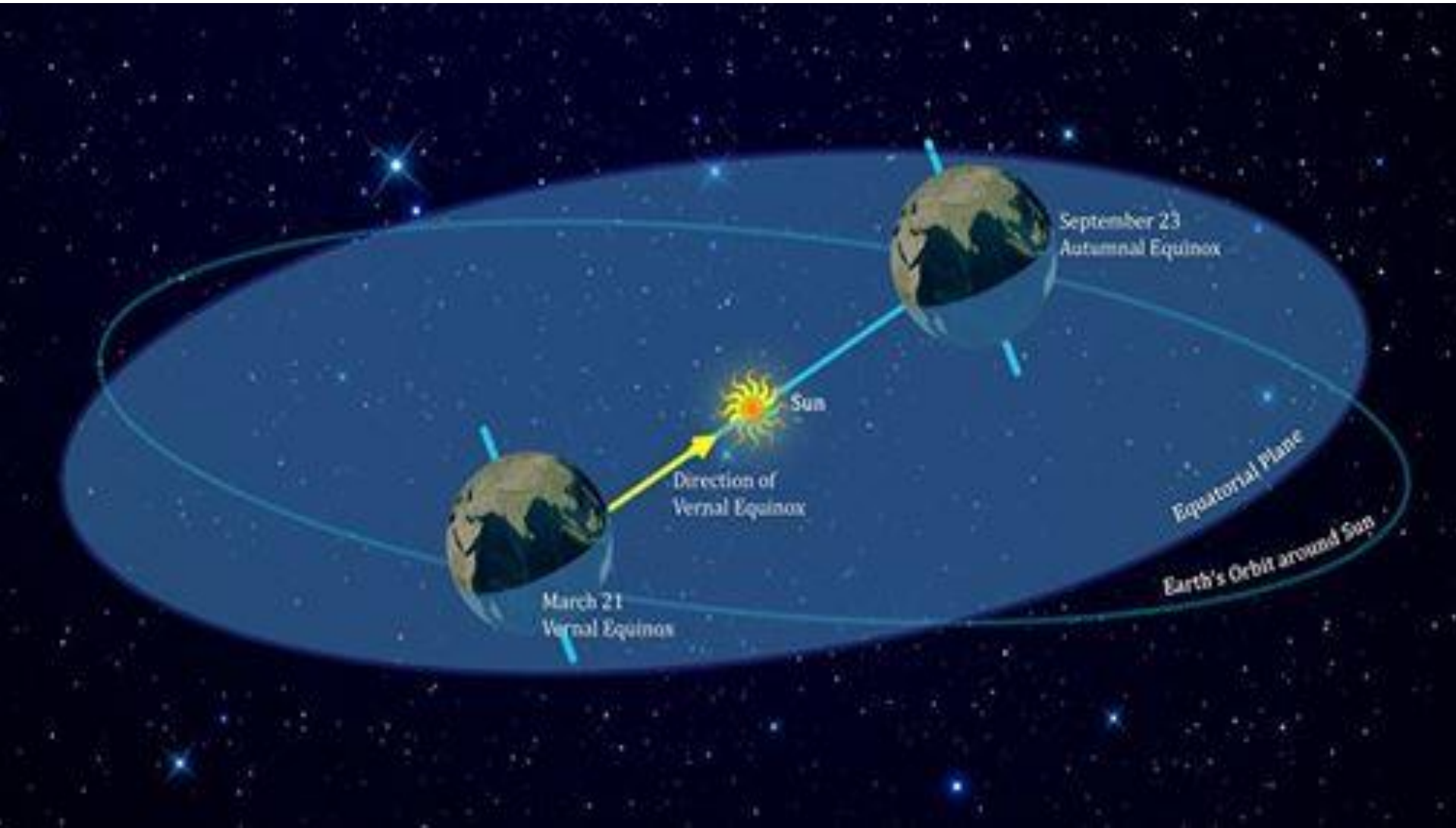
- There are two epochs in a year around which the day and night are of almost equal length, these are referred to as ‘Equinox’.

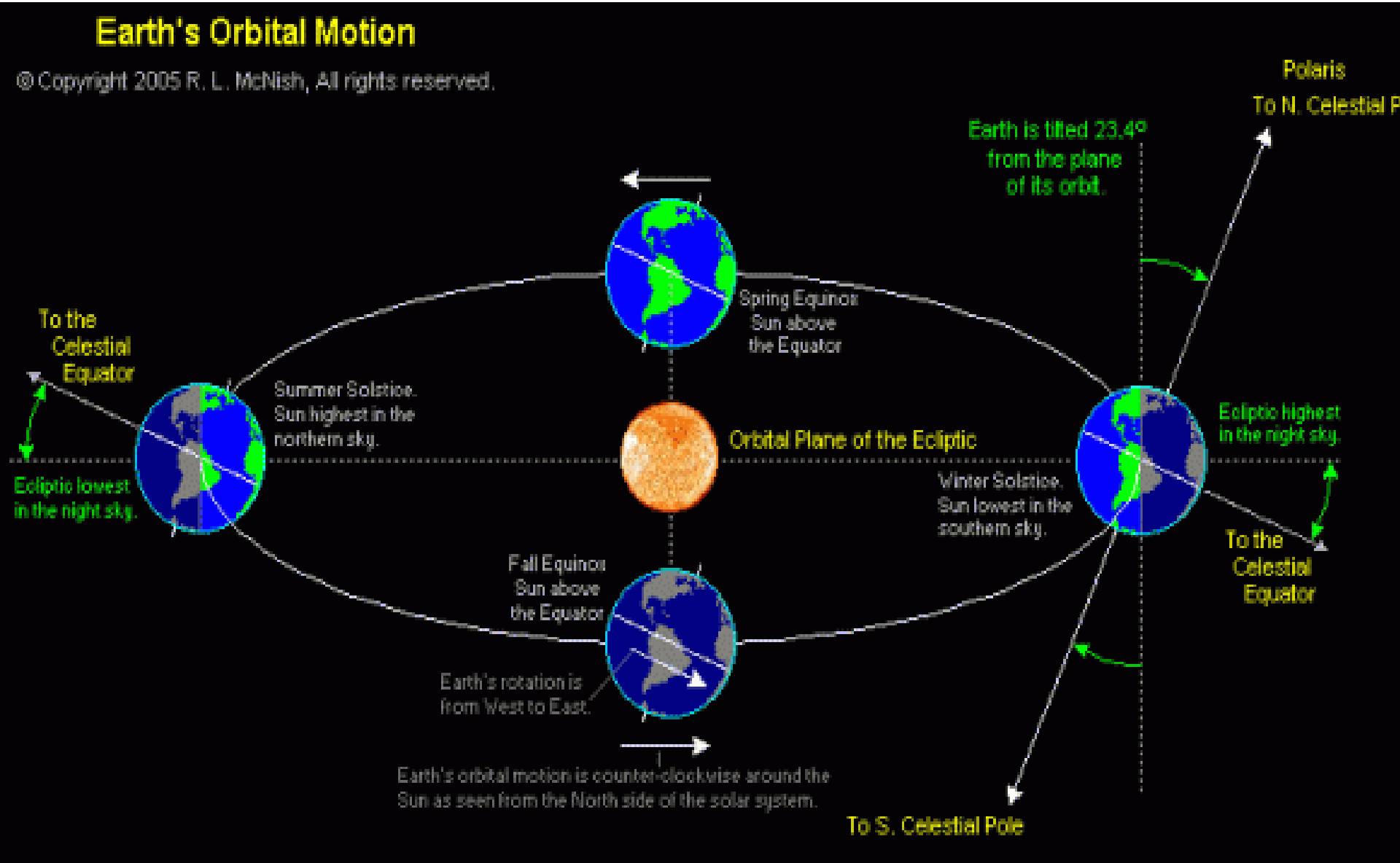
- This happens because at these epochs, the Earth’s equatorial plane passes through the centre of the Sun.

- The Equinox that occurs around 21st March is called ‘Vernal Equinox’ and the one that occurs around 23rd September is called ‘Autumnal Equinox’.

- The Direction of Sun, as seen from Earth, at Vernal Equinox is called ‘Direction of Vernal Equinox’. This direction stays relatively fixed over time and hence is used as a reference direction for navigation in deep space.

Vernal Equinox




Earth's Orbital Motion
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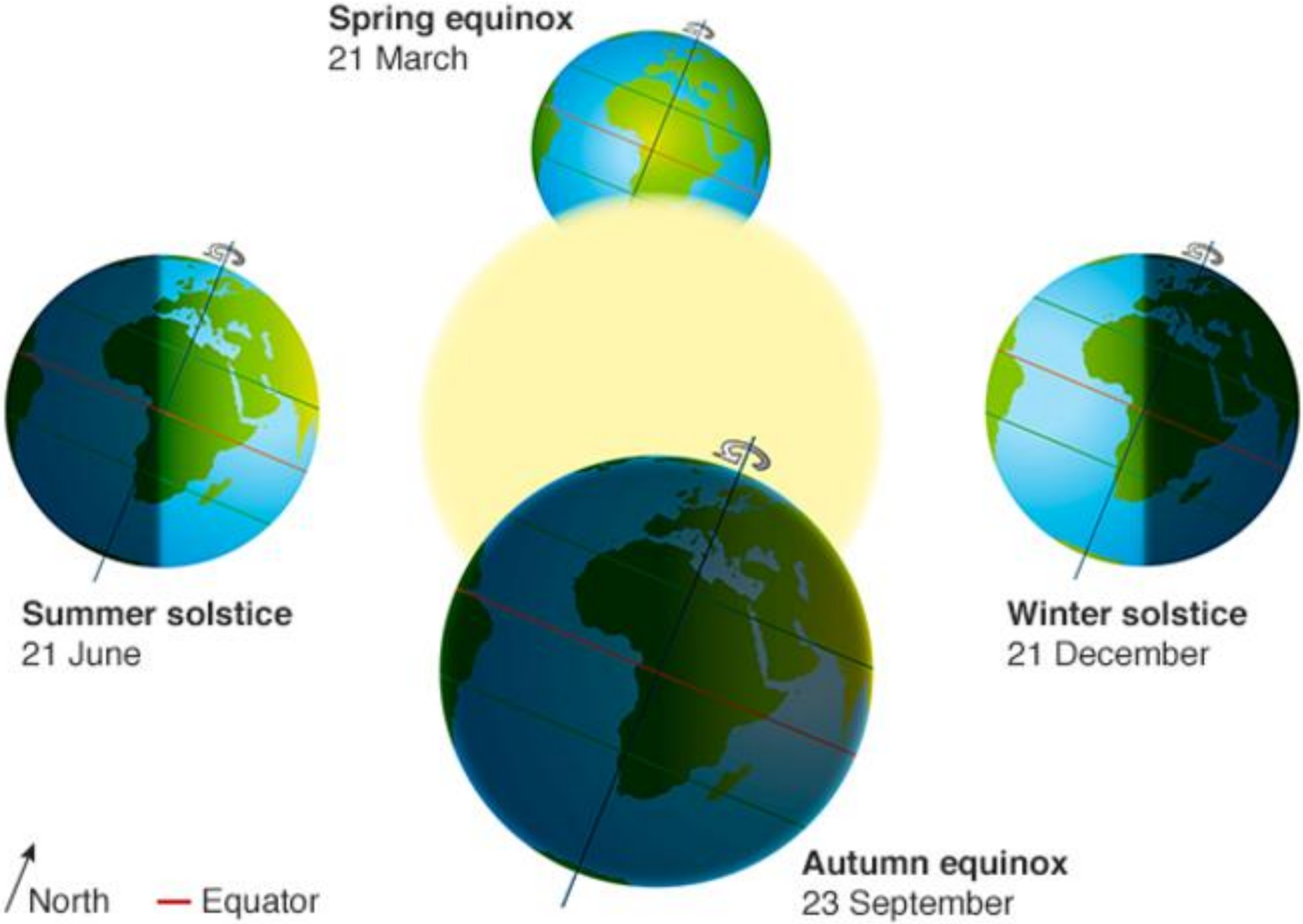
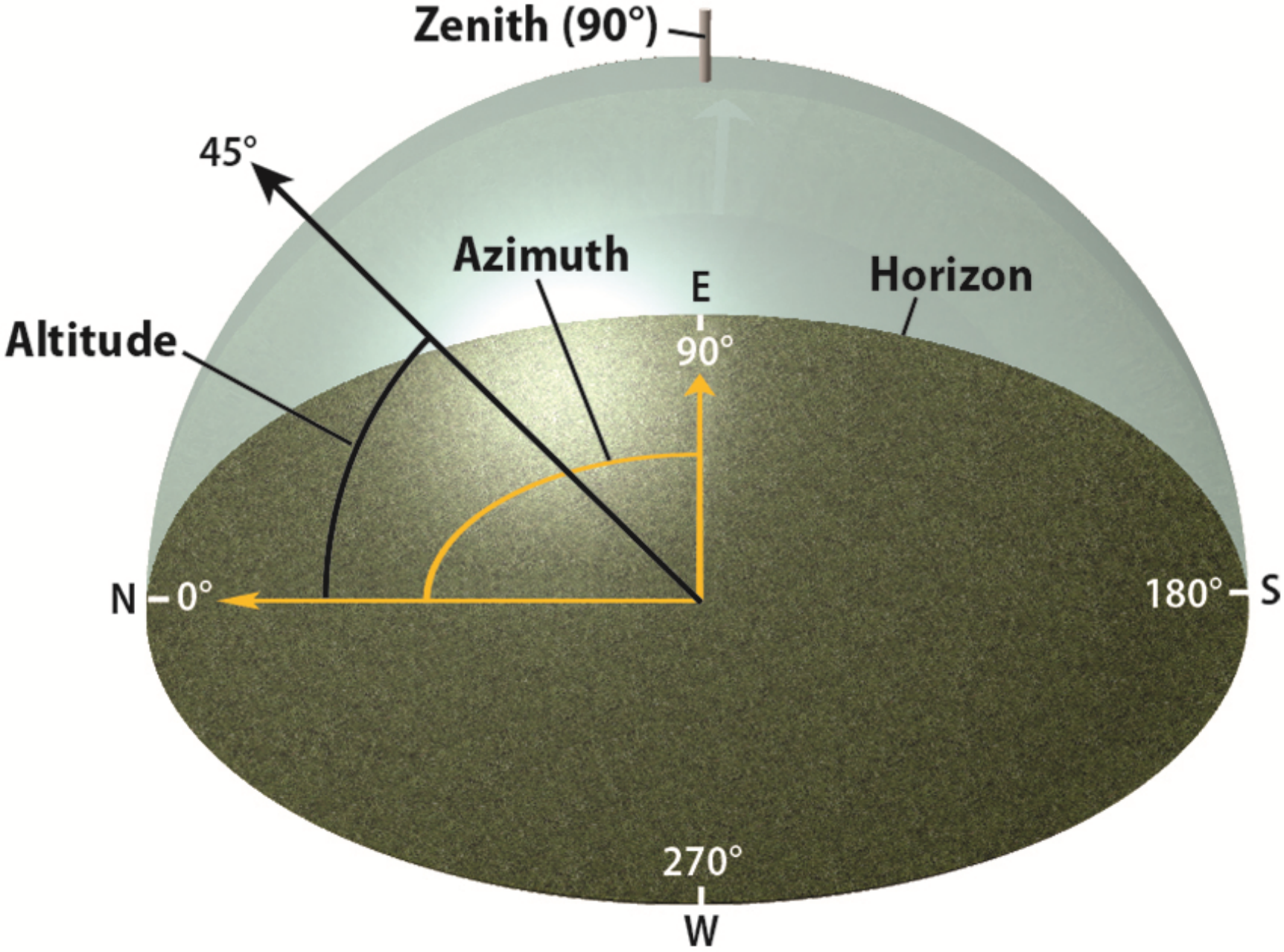
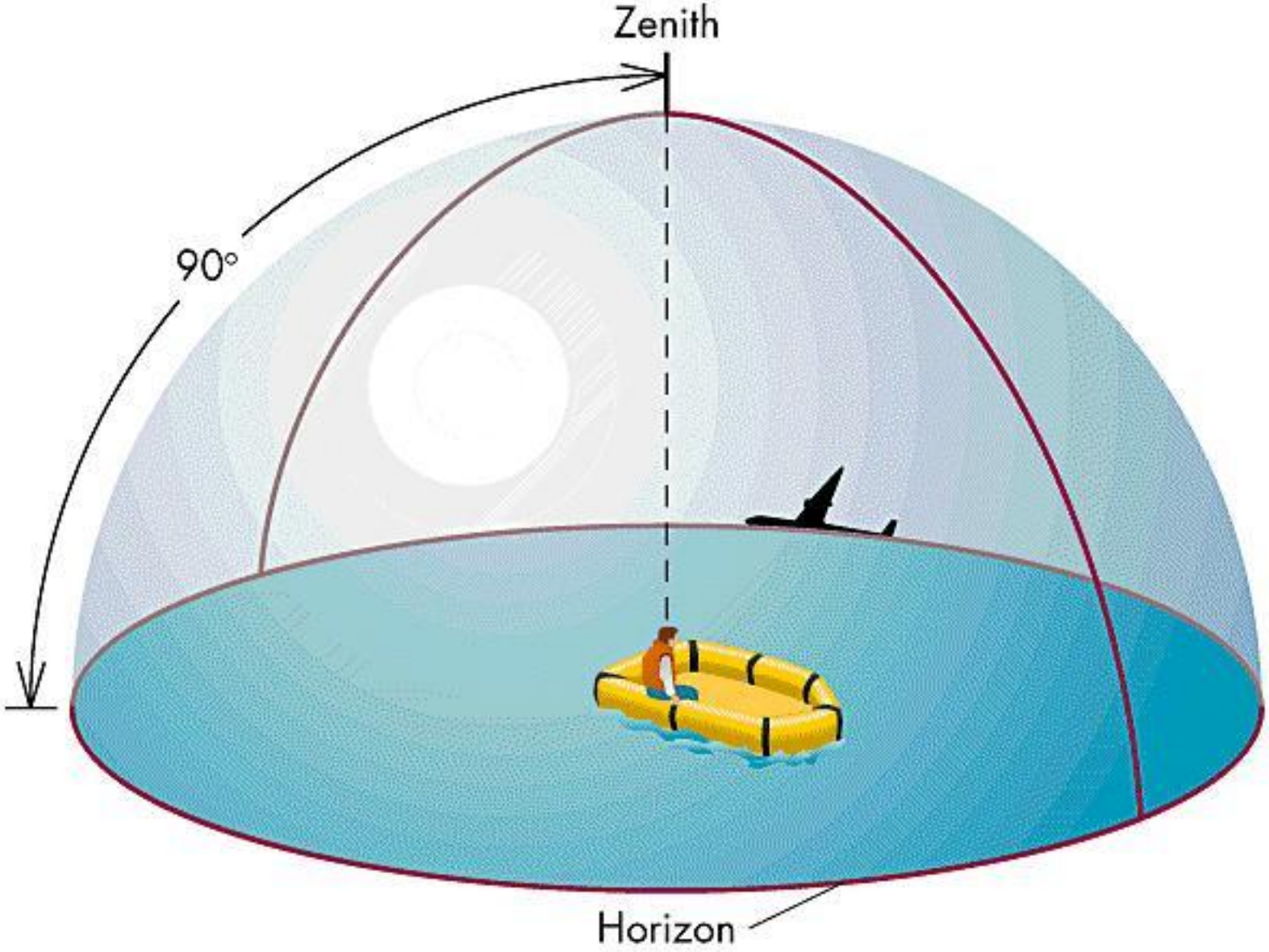
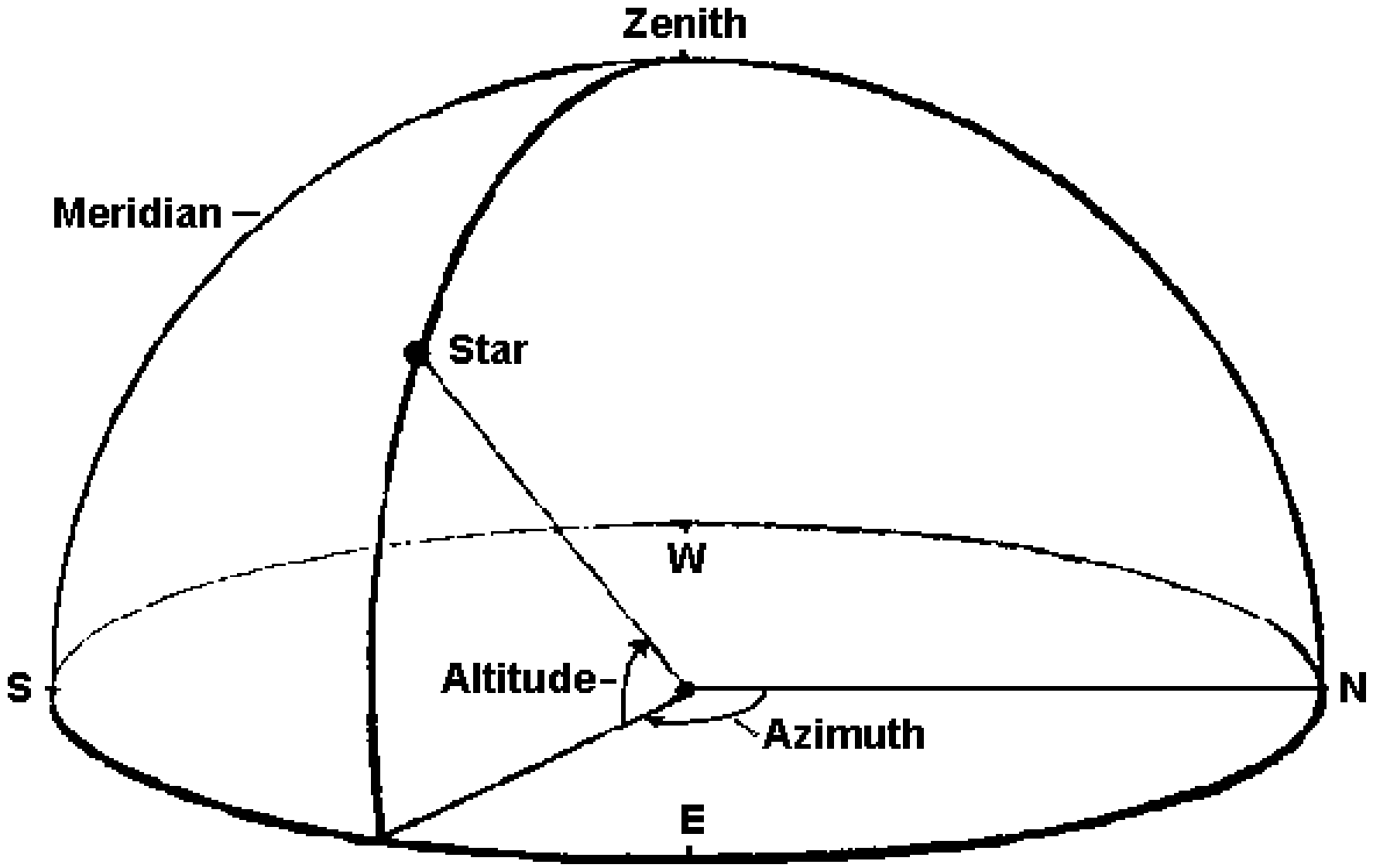
Polaris
To N. Celestial P
Earth is tilted 23.4°
from the plane
of its orbit.
Spring Equinox
Sun above
the Equator
To the
Celestial
Equator
Summer Solstice.
Sun highest in the
northern sky.
Orbital Plane of the Ecliptic
Ecliptic highest
in the night sky.
Ecliptic lowest
in the night sky.
Winter Solstice.
Sun lowest in the
southern sky.
To the
Celestial
Equator
Fall Equinox
Sun above
the Equator
Earth's rotation is
from West to East.
Earth's orbital motion is counter-clockwise around the
Sun as seen from the North side of the solar system.
To S. Celestial Pole

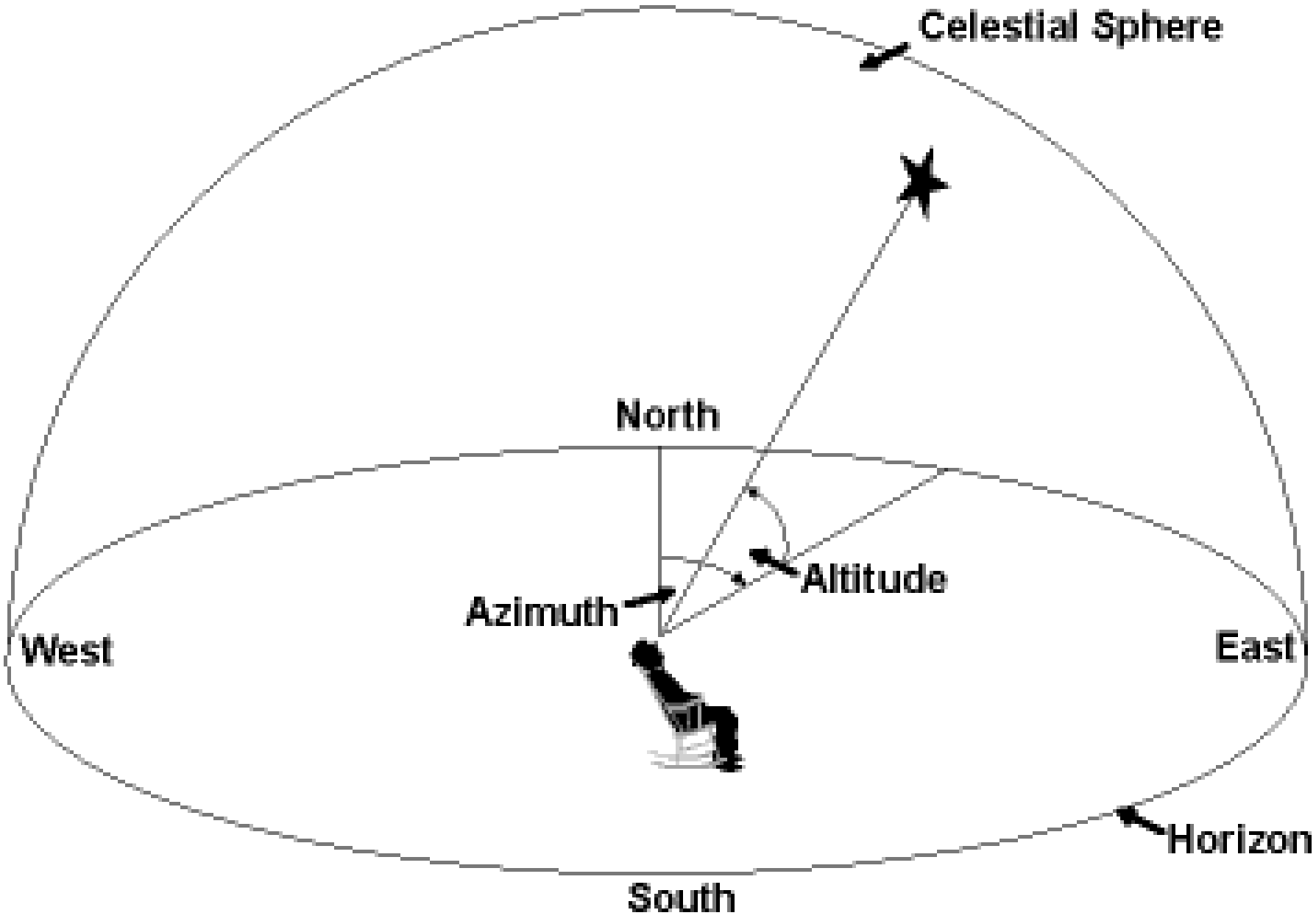


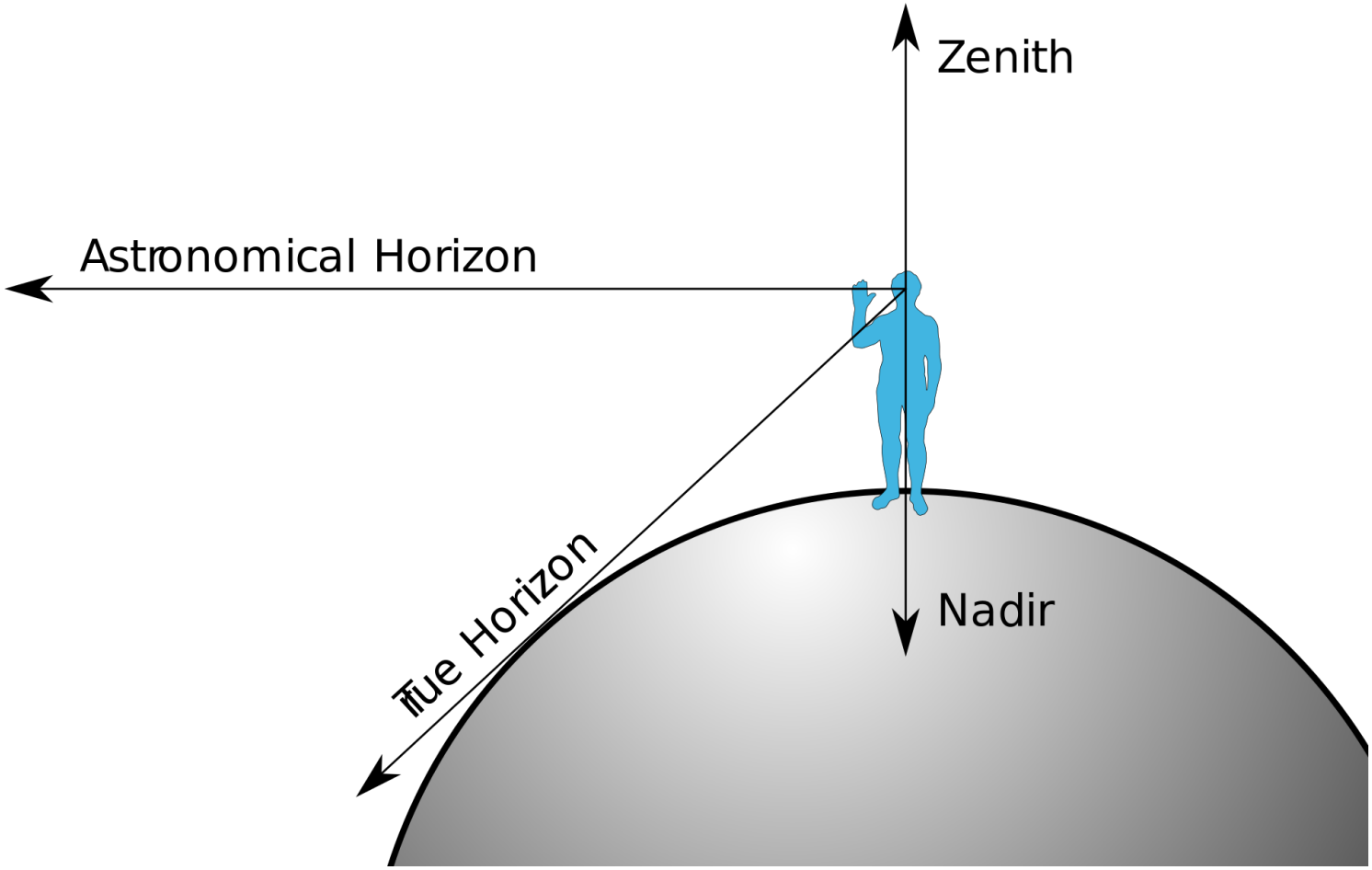
Source: Alamy


Zenith (90°)
45°
Azimuth
Horizon
E
Altitude
90°
N
0°
180°
S
270°
W


Zenith
90°
Horizon


Zenith
Meridian
Star
W
S
Altitude
N
Azimuth
E


Celestial Sphere
North
Azimuth
Altitude
West
East
Horizon
South


Zenith
Astronomical Horizon
True Horizon
Nadir

MEASUREMENT OF DAY

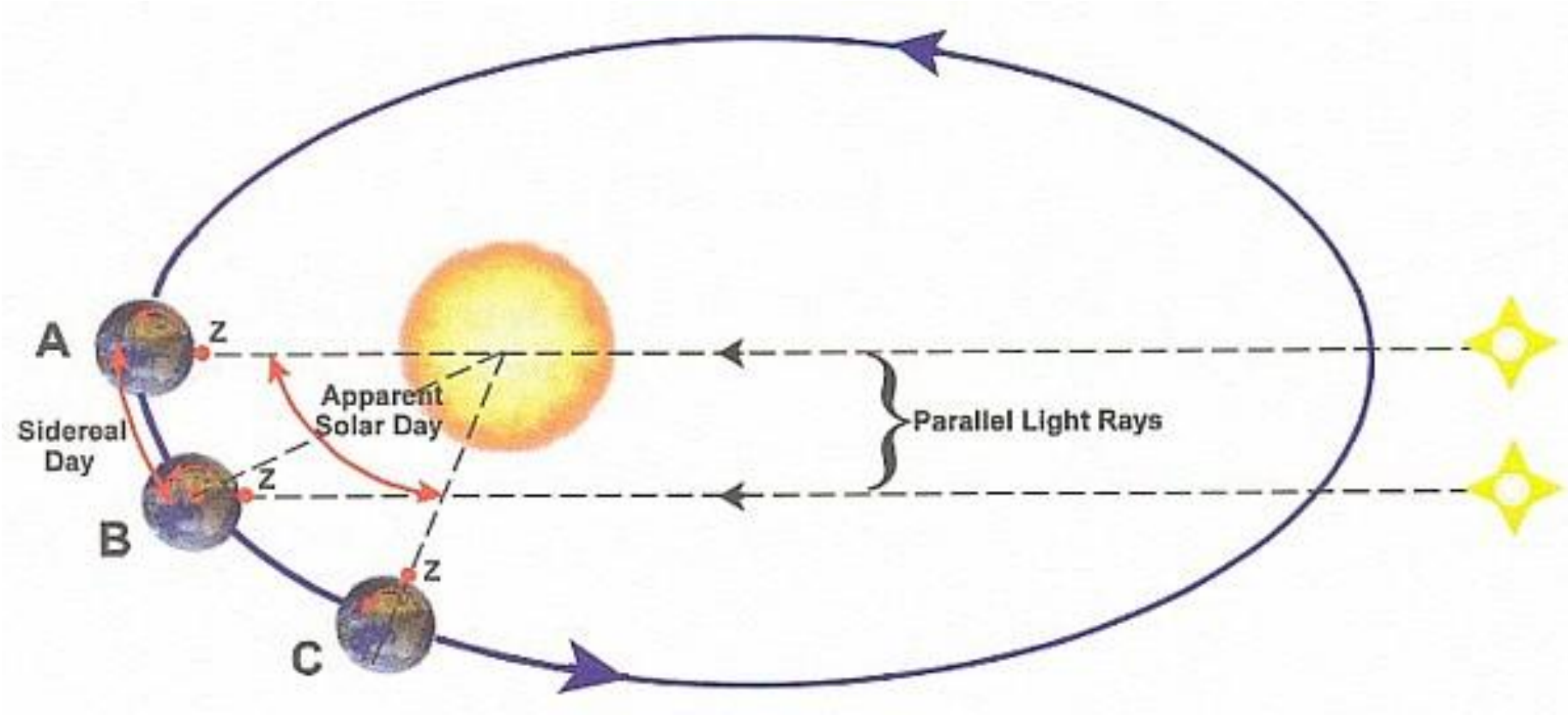
- A "day" may be defined as the length of time taken for the Earth to rotate once about its axis measured against a celestial body, e.g., the Sun or a star.
- Measurements against a star are called 'sidereal'.
- Measurements against the sun are called 'solar'.

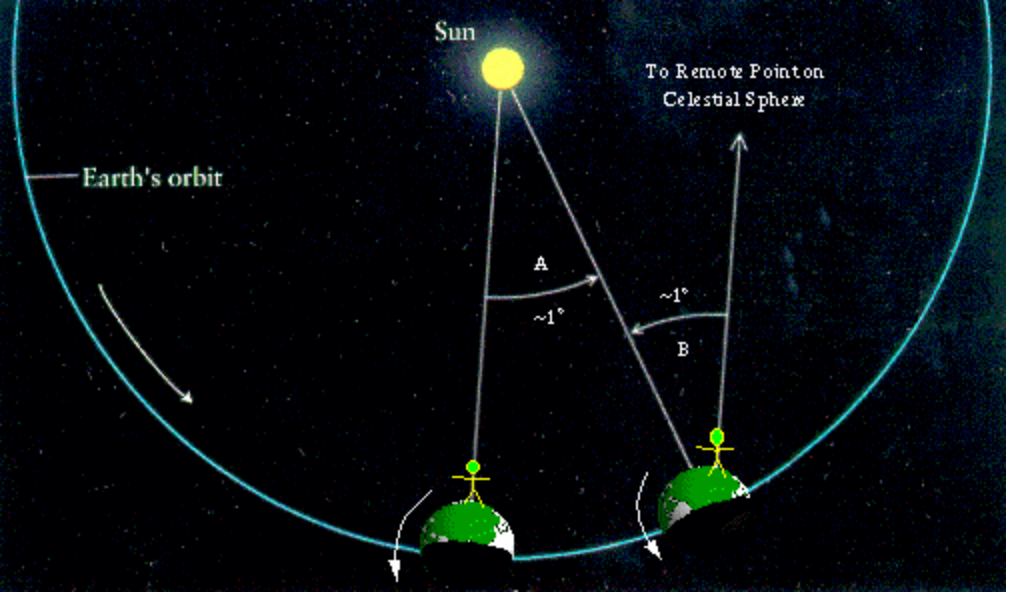
SIDEREAL DAY

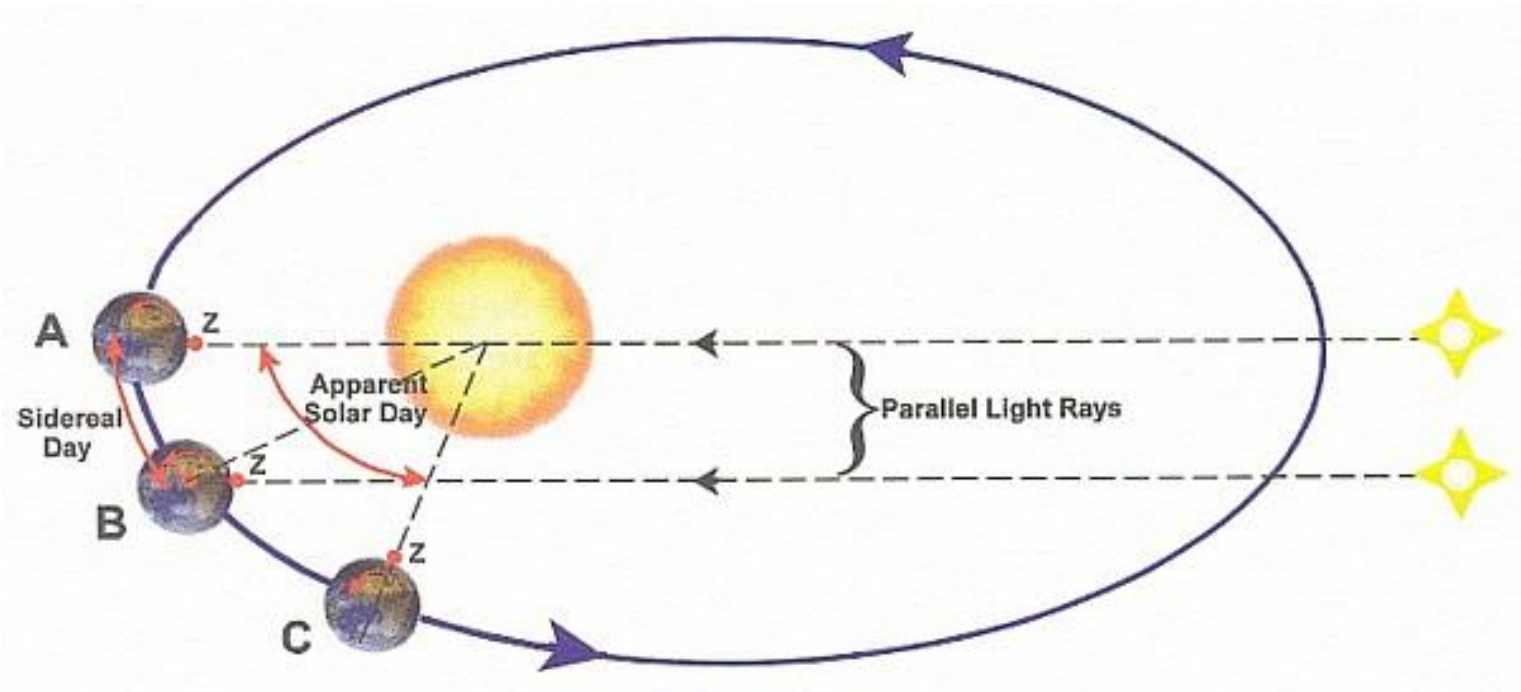
- A Sidereal day is measured against a distant star and is of nearly constant length.
- However, it is not related to light and dark and is not suitable as a civil day.

Apparent Solar Day

- An apparent Solar day is measured against the real or apparent Sun.
- However the Apparent Solar Day is not of a constant length.


A
Z
Sidereal Day
Apparent Solar Day
Parallel Light Rays
Z
B
Z
C

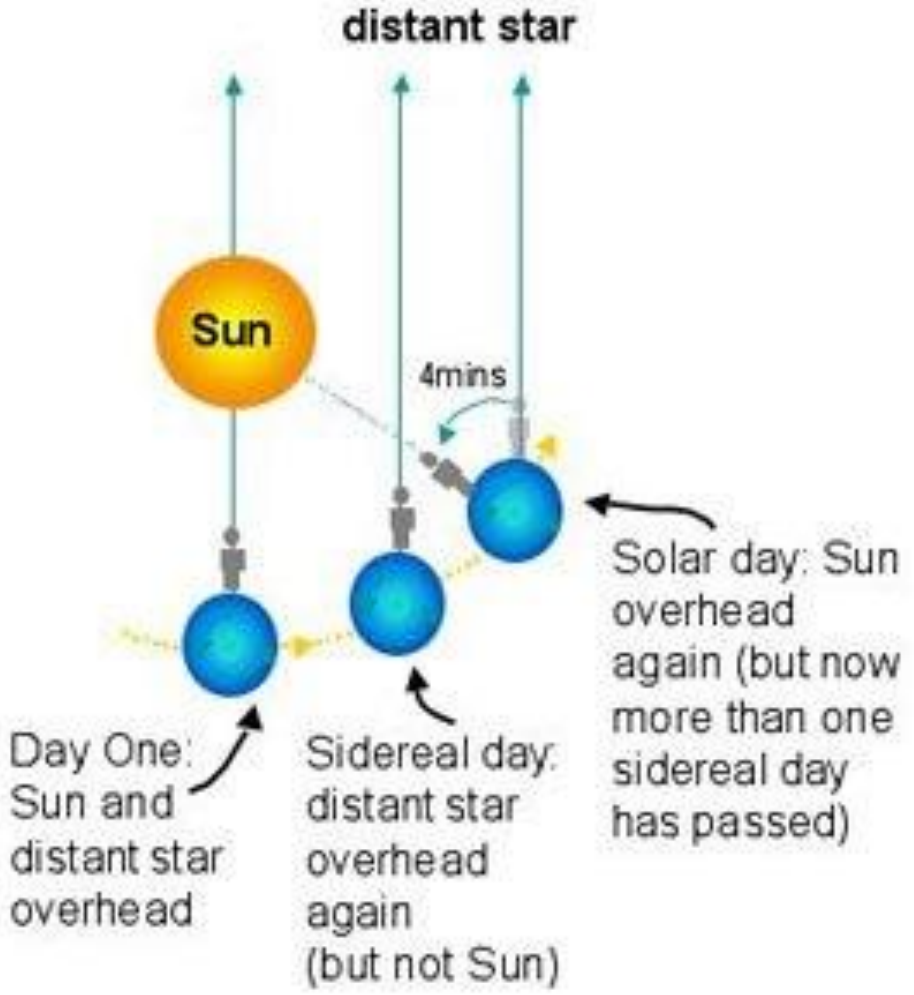

Sun
To Remote Point on
Celestial Sphere
Earth's orbit
A
~1°
~1°
B

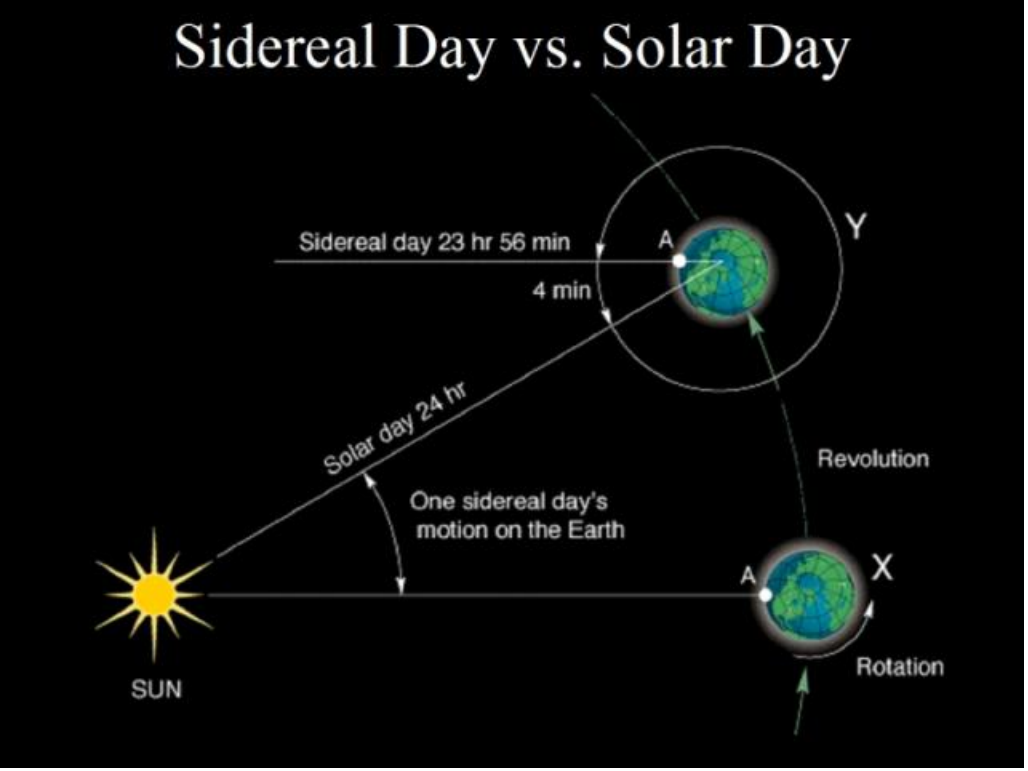

A
Z
Apparent
Solar Day
Sidereal
Day
Parallel Light Rays
B
Z
Z
C

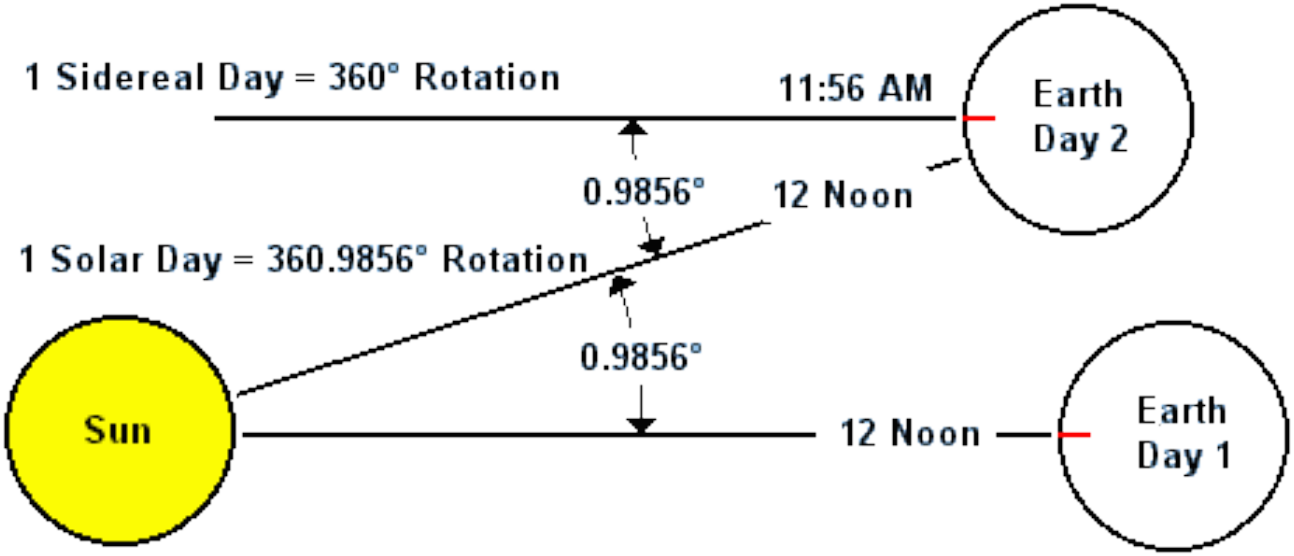
- Consider the Earth at position A but assuming it is stationary.
- An observer at position Z would have the Sun and a distant star directly over his meridian.
- After one complete anti-clockwise rotation of the Earth, the Sun and the star would be over the observer's meridian again.
- The apparent solar day and the sidereal day (based on the star) would be equal.
- However this is is not true because earth is not stationary. While rotating, the Earth travels around its elliptical orbit to position B.

- After a 360° revolution, the distant star is again over the observers meridian (a sidereal day) but an additional rotation and further orbit to position C is needed put the Sun again over the observer's meridian. Therefore an apparent solar day is longer than a sidereal day.

- Since the Earth's orbital speed changes throughout the year, an Apparent Solar Day cannot be of constant length.


distant star
Sun
4mins
Solar day: Sun overhead again (but now more than one sidereal day has passed)
Day One: Sun and distant star overhead
Sidereal day: distant star overhead again (but not Sun)


Sidereal Day vs. Solar Day
Sidereal day 23 hr 56 min
4 min
A
Y
Solar day 24 hr
Revolution
One sidereal day's
motion on the Earth
A
X
Rotation
SUN

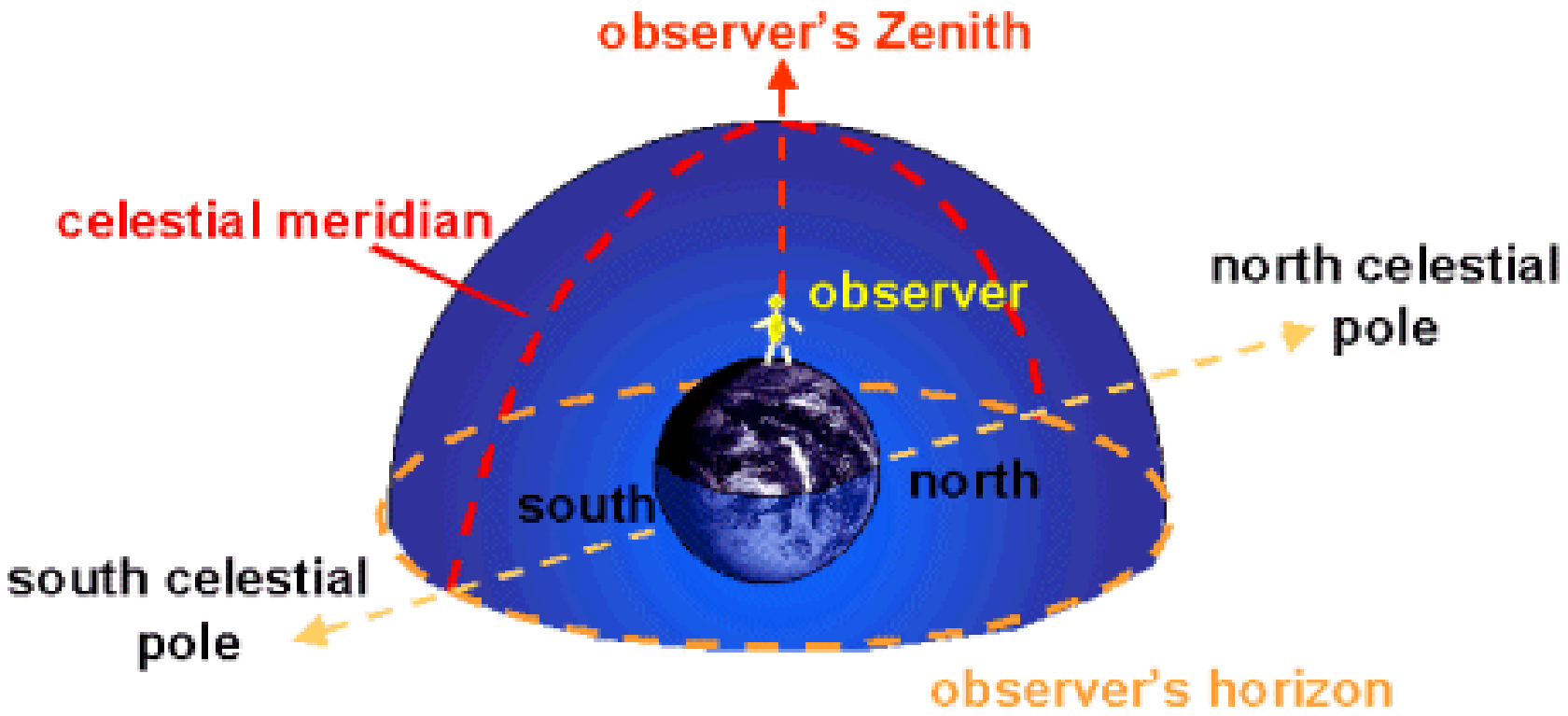

1 Sidereal Day = 360° Rotation
11:56 AM
Earth
Day 2
0.9856°
12 Noon
1 Solar Day = 360.9856° Rotation
0.9856°
Sun
12 Noon
Earth
Day 1

MEAN SOLAR DAY

- Mean Solar Day is the average length of an apparent solar day (averaged over the year).
- It is of constant length and related to light and darkness .
- It is used as the 'civil' day and is divided into hours, minutes and seconds of "mean" time.
- In the case of mean time, we consider the mean (average) Sun circling the earth every 24 hours (sun movement is just an assumption to visualize).

ZENITH

- Zenith is an imaginary point directly above a particular location, on the Imaginary celestial sphere.
- Above means vertical direction opposite to the apparent gravitational force at the particular location.
- The zenith angle is always perpendicular to the local horizon.
- Zenith depends upon observer location.
- It has an altitude of +90o in the horizontal coordinate system.


observer's Zenith
celestial meridian
observer
north celestial
pole
south
north
south celestial
pole
observer's horizon

ALTITUDE OR ELEVATION

- The angular height of a point or celestial object above the horizon 0° (on the horizon) to 90° (at the zenith).

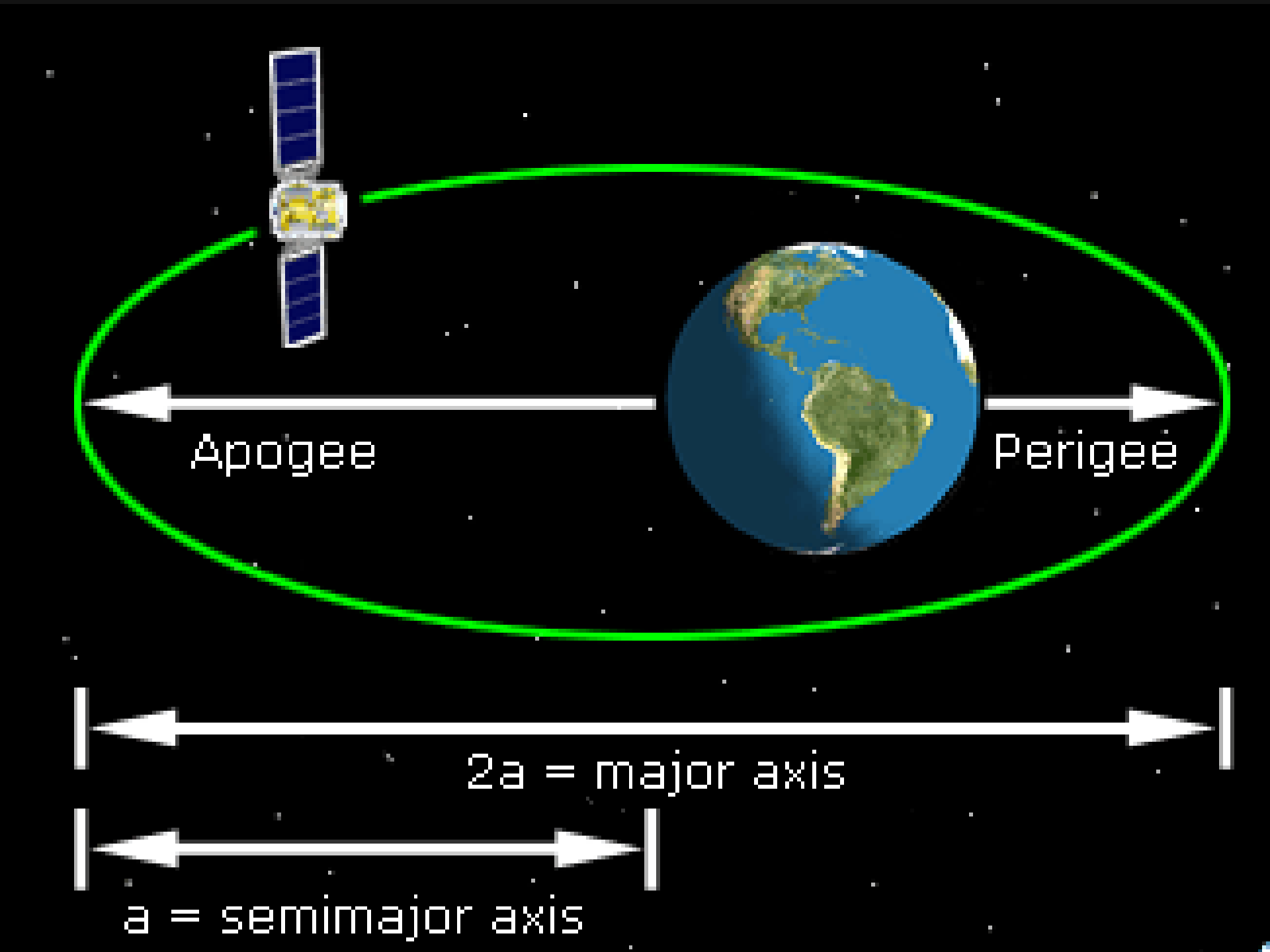
Shadows of trees when the sun is directly overhead (at the zenith). This happens at the solar noon if the tree's latitude equals the sun's declination at that moment.

Six Keplerian Elements

SEMI-MAJOR AXIS

- Semi-major axis of an orbit represents the size of the orbit.
- Semi-major axis is the distance measured from the centre of the ellipse to either the Periapsis or the Apoapsis.
- The nearest and farthest points in the orbital plane of any satellite around a celestial body, from the centre of the celestial body, are defined as Periapsis and Apoapsis respectively.

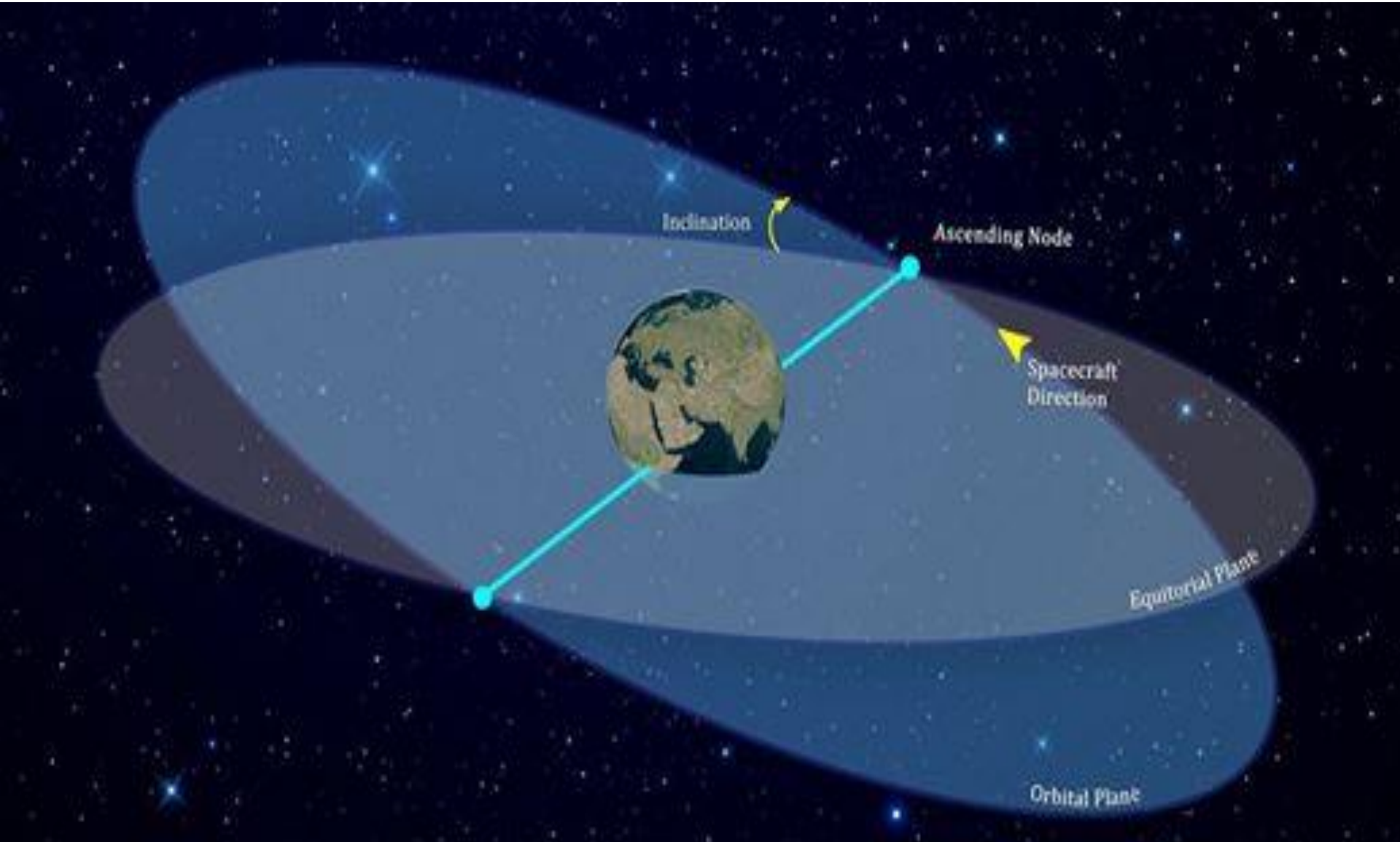
Semi-major Axis, Apogee and Perigee


Apogee
Perigee
2a = major axis
a = semimajor axis

ECCENTRICITY

- Eccentricity of an orbit is a numerical representation of the shape of the orbit.
- Eccentricity is an indication of the extent of deviation of an orbit with respect to a perfect geometric circle.
- A value of 0 is a circular orbit, values between 0 and 1 form an elliptical orbit, 1 is a parabolic escape orbit, and greater than 1 is a hyperbola.

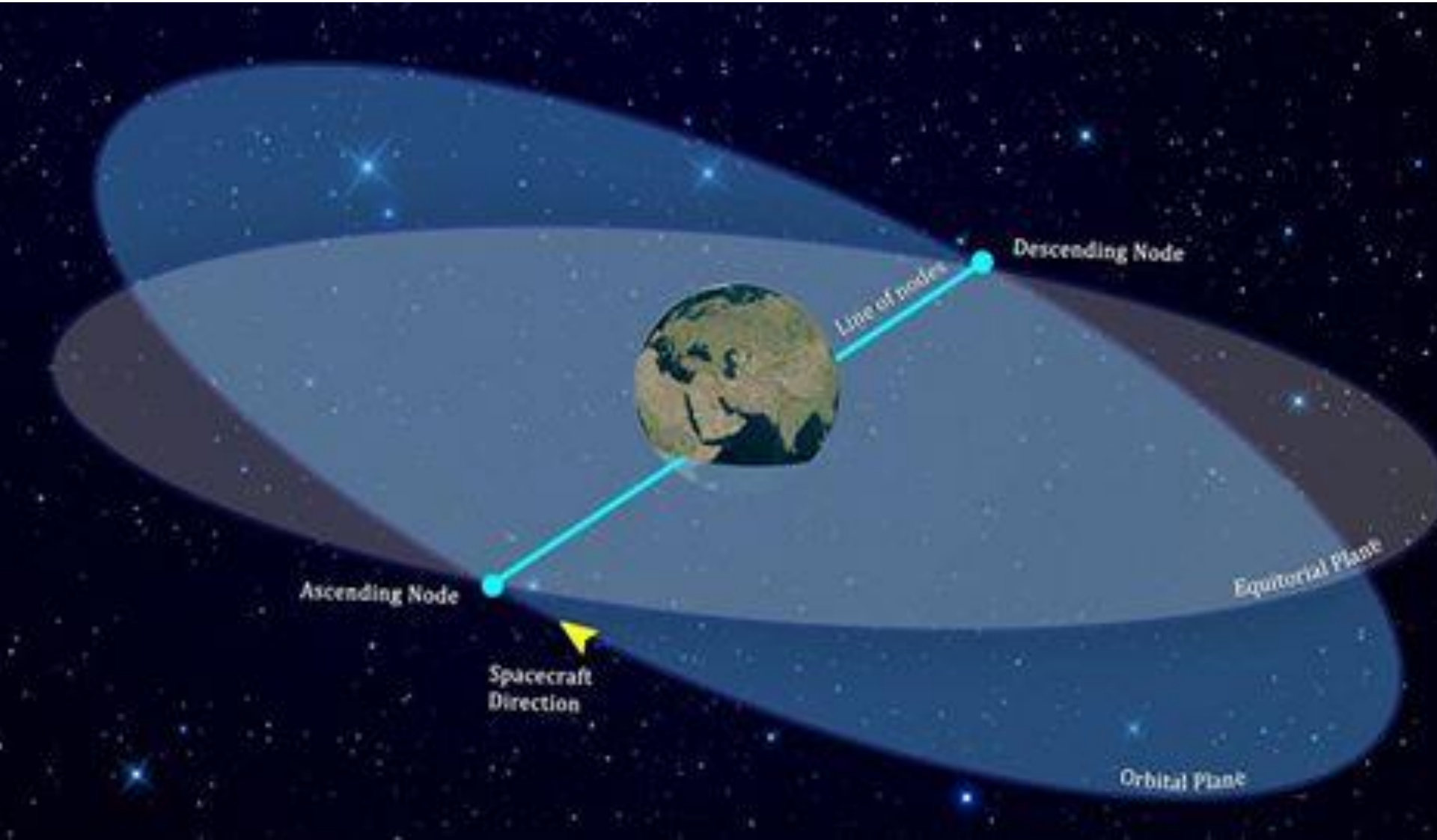
ORBITAL INCLINATION



INCLINATION

- Inclination for an orbit around earth is the angle between orbital plane and equatorial plane.

Ascending and Descending Node



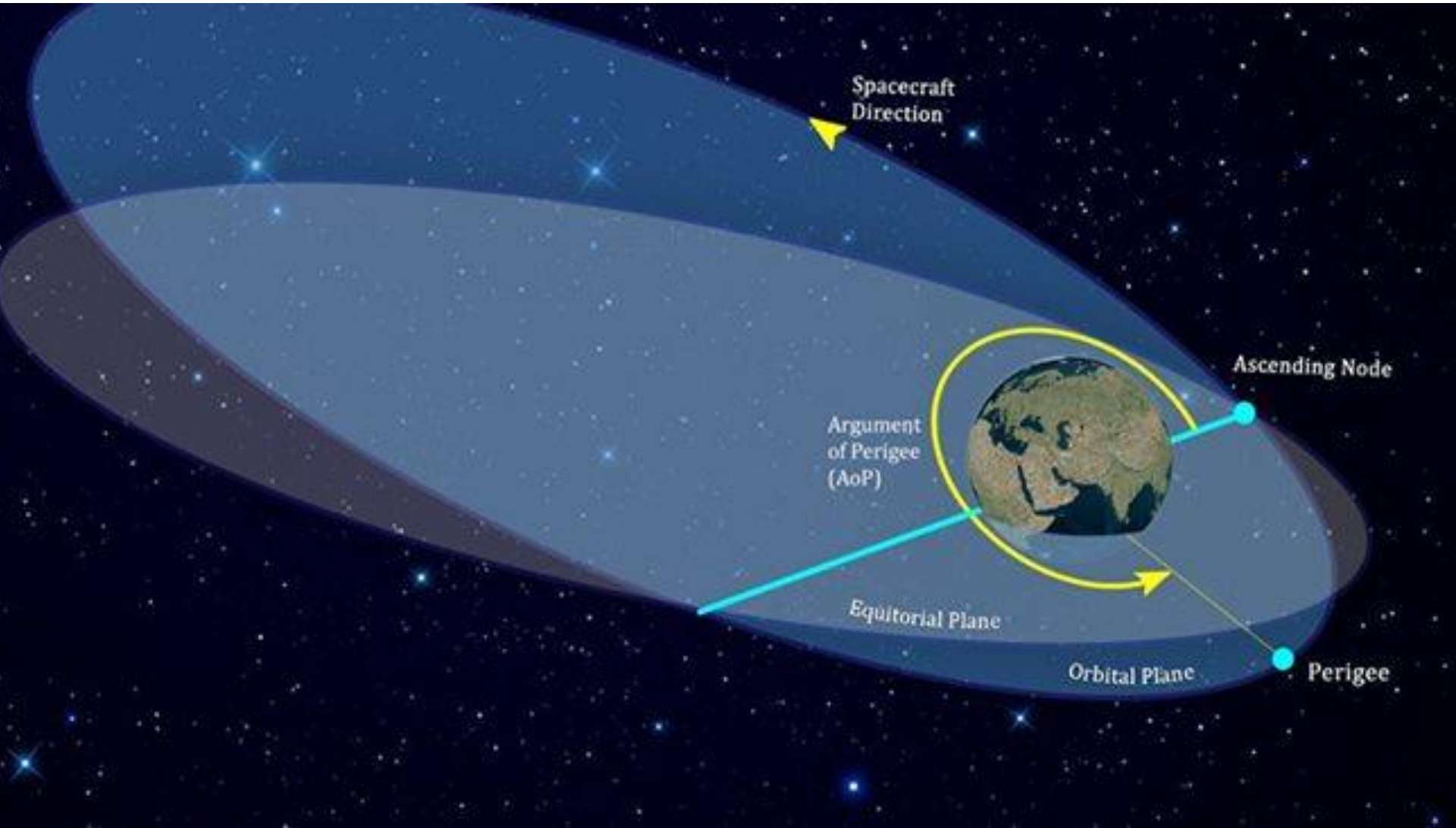
ASCENDING NODE AND DESCENDING NODE

- Orbital nodes for an orbit around Earth are the two points where the orbit intersects the equatorial plane.
- The node from which the satellite ascends northwards in the orbital plane is called the 'ascending node' whereas the node from which the satellite descends southwards is called the 'descending node'.
- The line joining the ascending and descending nodes is called 'Line of nodes'.

Right Ascension of Ascending Node (RAAN)

- Right Ascension of Ascending Node (RAAN) is an angle, measured at the center of the earth, from the 'direction of vernal equinox' to the ascending node.

Argument of Perigee (AoP)



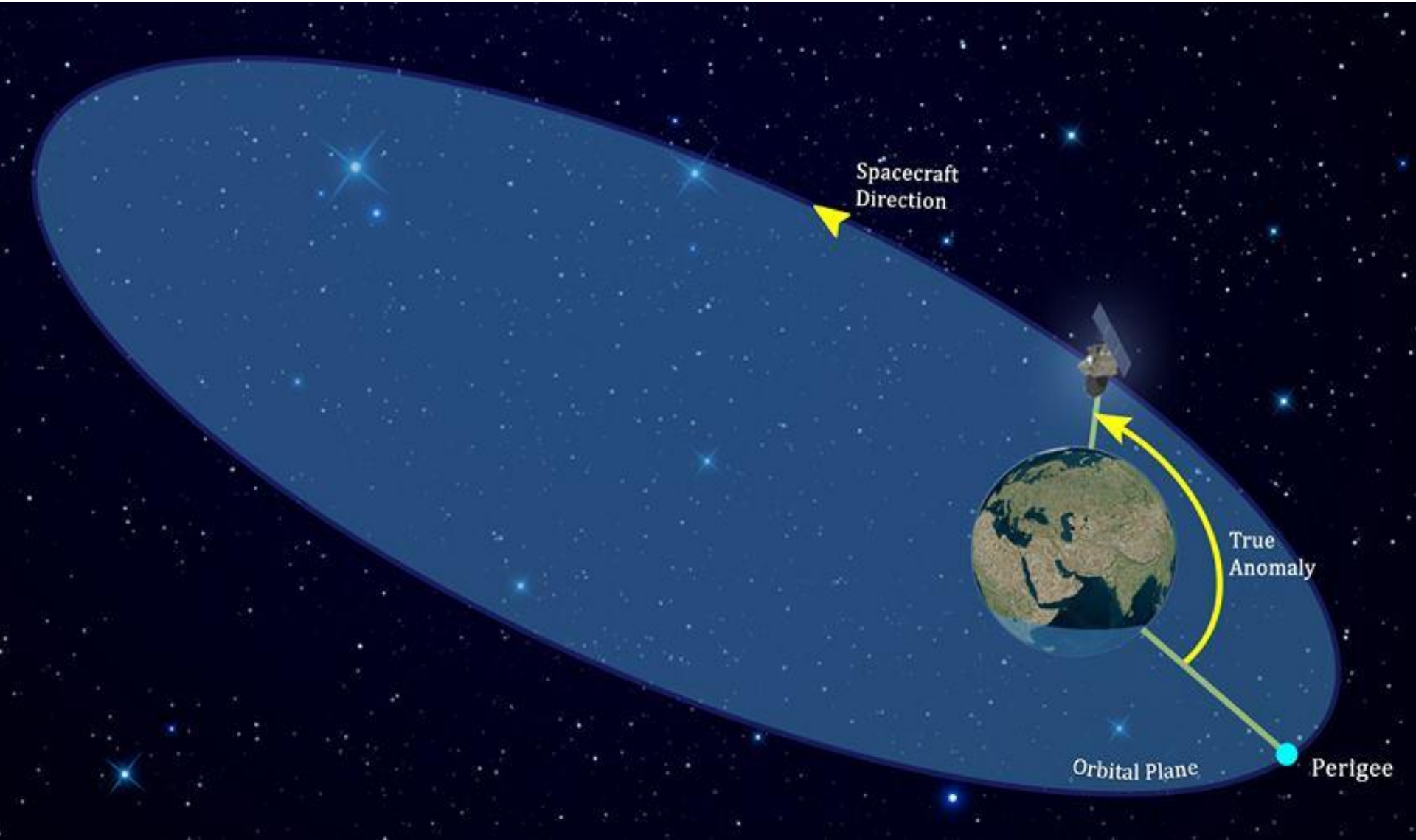
ARGUMENT OF PERIGEE (AOP)

- Argument of Perigee is an angle, measured at the centre of the earth, between the orbit's perigee and the 'ascending node'.

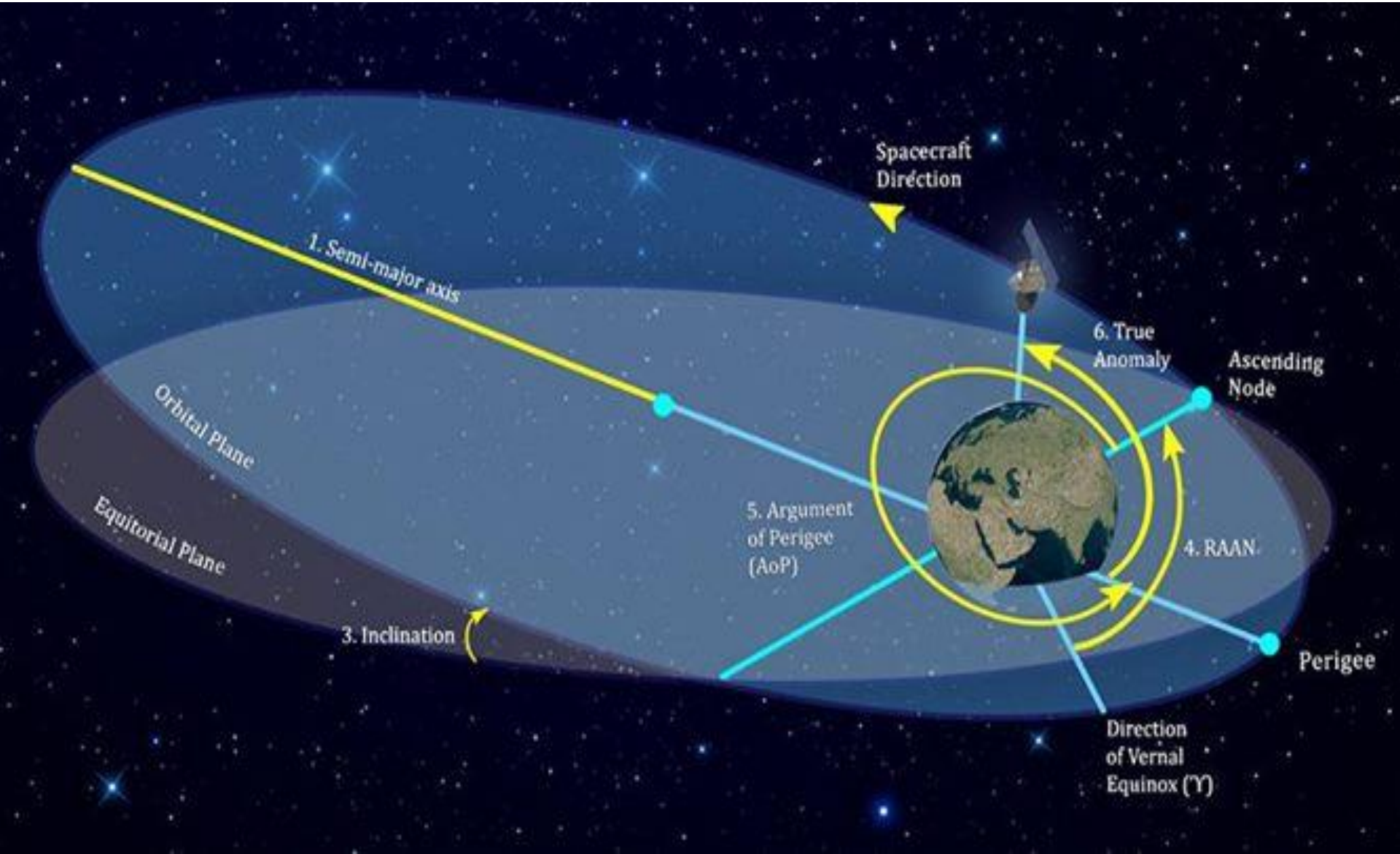
TRUE ANOMALY

- True Anomaly is the angle measured at the centre of earth, between the direction of perigee and the position of the body at a given time.

TRUE ANOMALY



THE SIX KEPLERIAN ELEMENTS



Vernal Axis and Equinox

- Vernal Axis is the axis from the Earth's centre pointing to the First Point of Aries in the sky.
- There are two equinoxes in a year, one in the spring and one in the fall. On these days the Earth is located at the intersection line of the equatorial and ecliptic planes.
- The axis of rotation of the earth is in a plane perpendicular to the sun's rays; as a result the length of the day and night is the same where on the earth.
- The vernal equinox vector is the vector from the center of mass of the earth to the center of mass of the sun on the spring (northern hemisphere) which occurs around march 21.