FIELD ASTRONOMY

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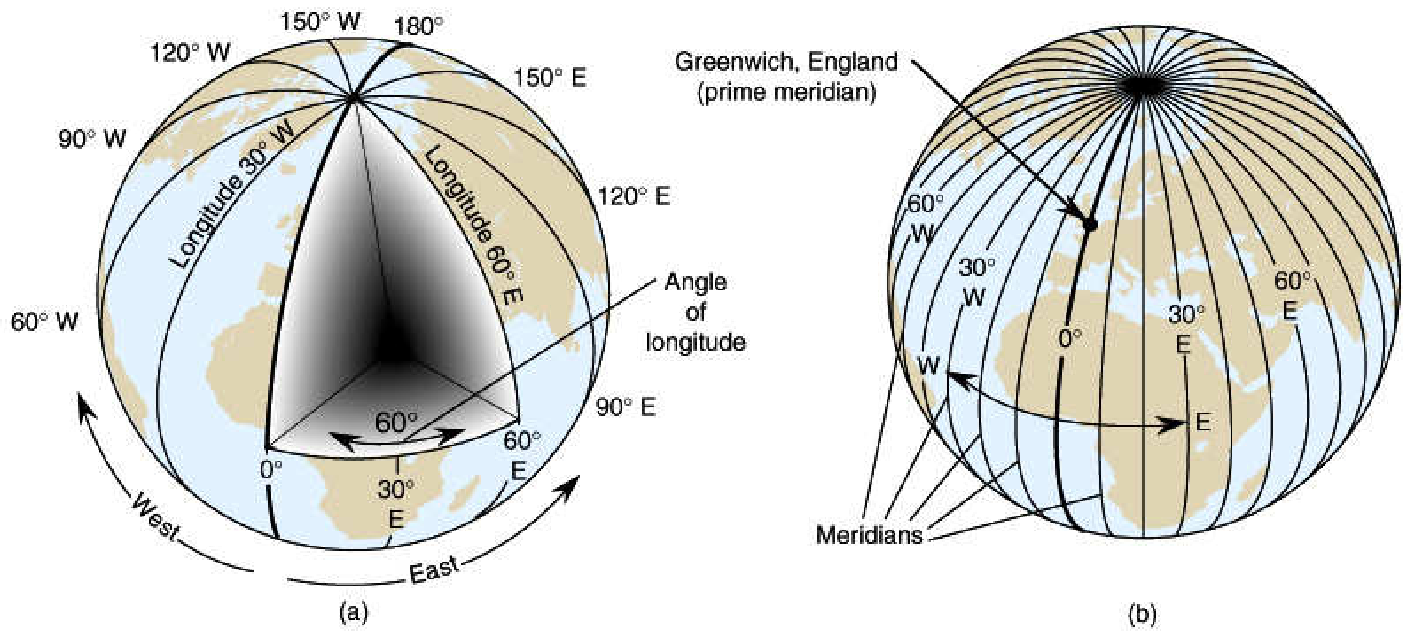
Longitude



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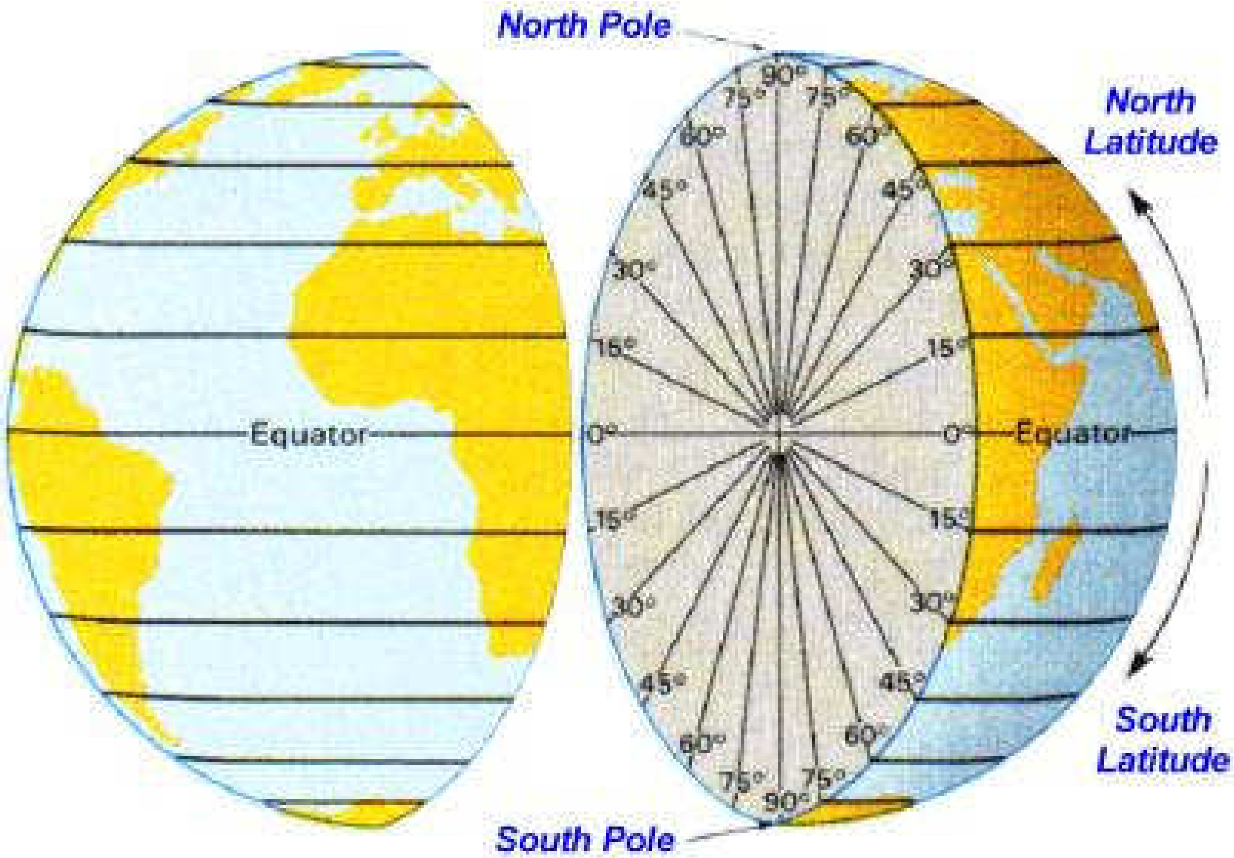
Latitude



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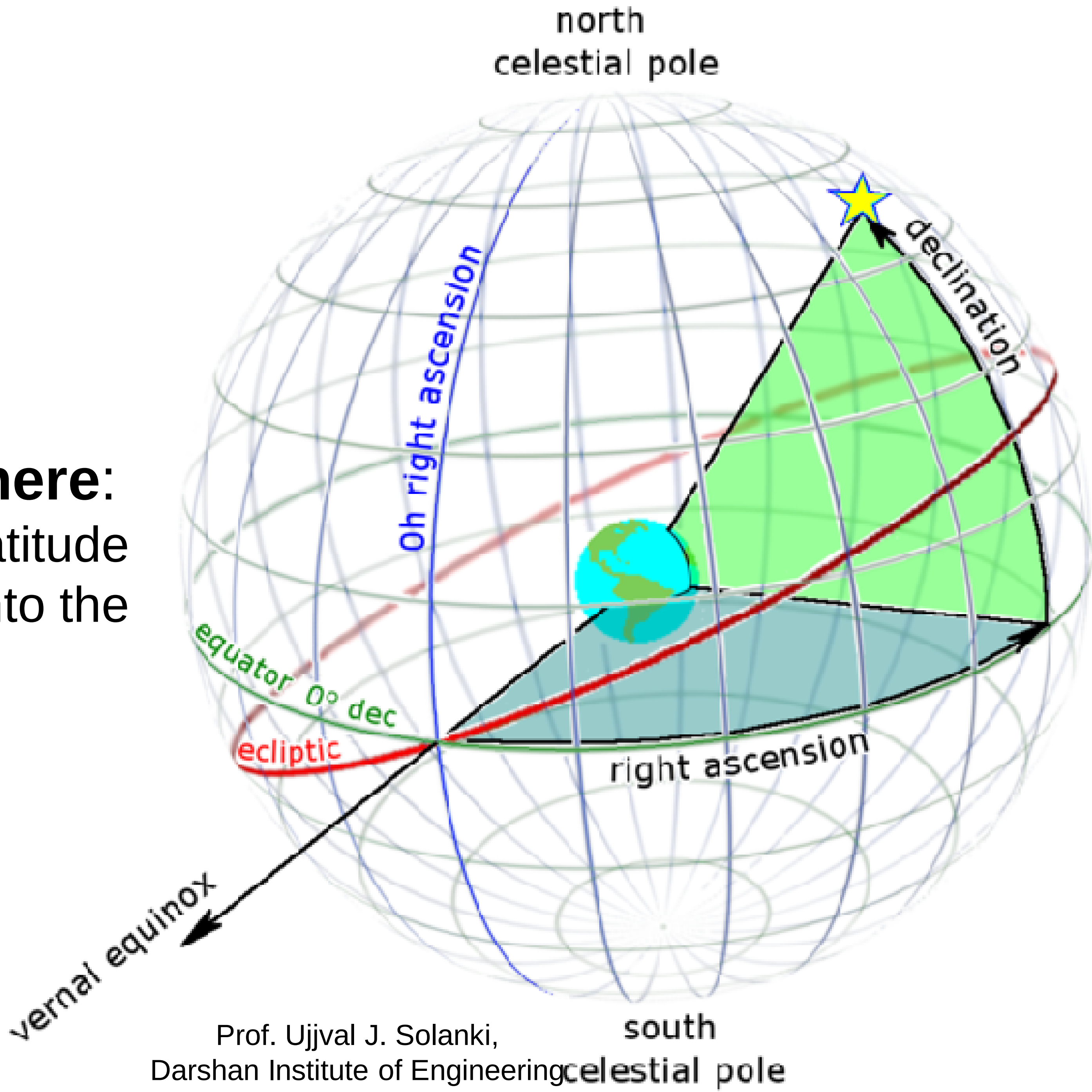
Celestial Sphere:

A projection of latitude and longitude onto the sky.



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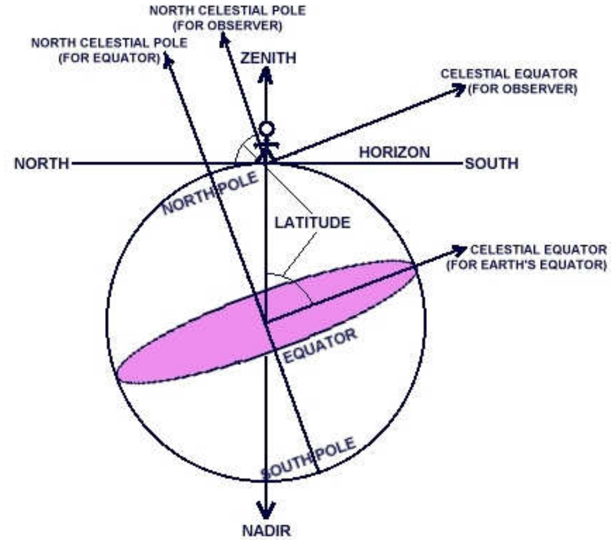
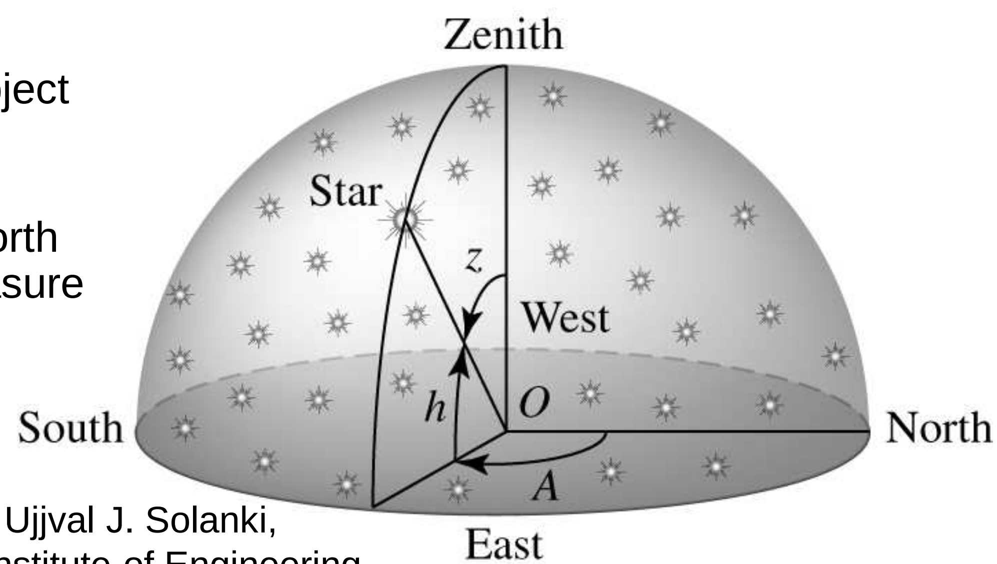
Positions on the Celestial Sphere

The Altitude-Azimuth Coordinate System



- Coordinate system based on observers local horizon
- Zenith - point directly above the observer
- North - direction to north celestial pole NCP projected onto the plane tangent to the earth at the observer's location
- h: altitude - angle measured from the horizon to the object along a great circle that passes the object and the zenith
- z: zenith distance - is the angle measured from the zenith to the object z+h=90°
- A: azimuth - is the angle measured along the horizon eastward from north to the great circle used for the measure of the altitude



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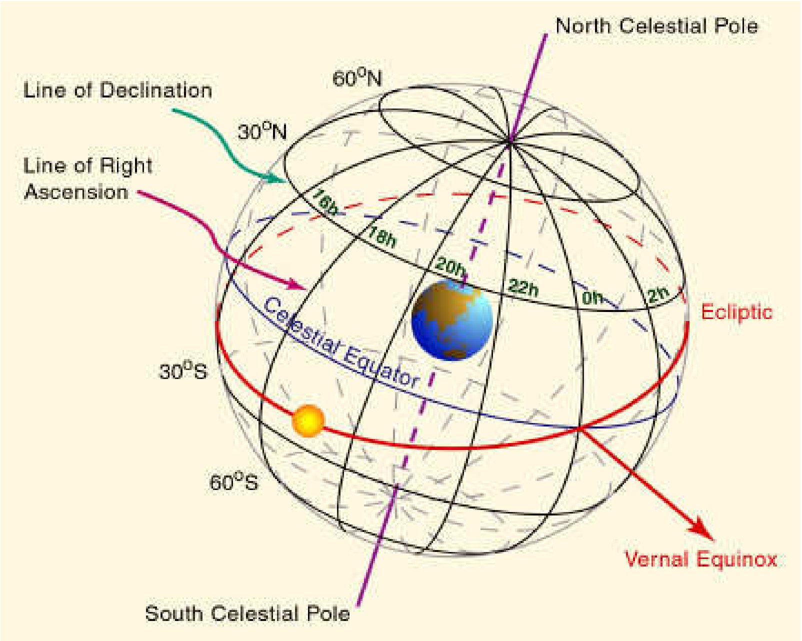
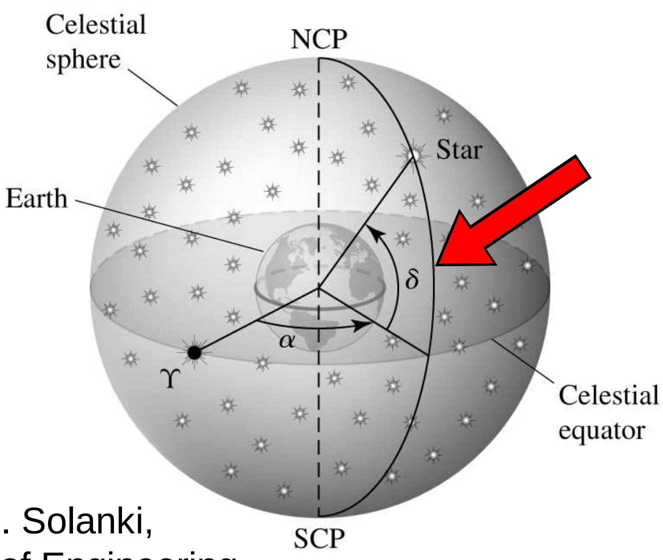
Equatorial Coordinate System

- Coordinate system that results in nearly constant values for the positions of distant celestial objects.
- Based on latitude-longitude coordinate system for the Earth.
- **Declination** - coordinate on celestial sphere analogous to latitude and is measured in degrees north or south of the celestial equator
- **Right Ascension** - coordinate on celestial sphere analogous to longitude and is measured eastward along the celestial equator from the vernal equinox γ to its intersection with the objects hour circle





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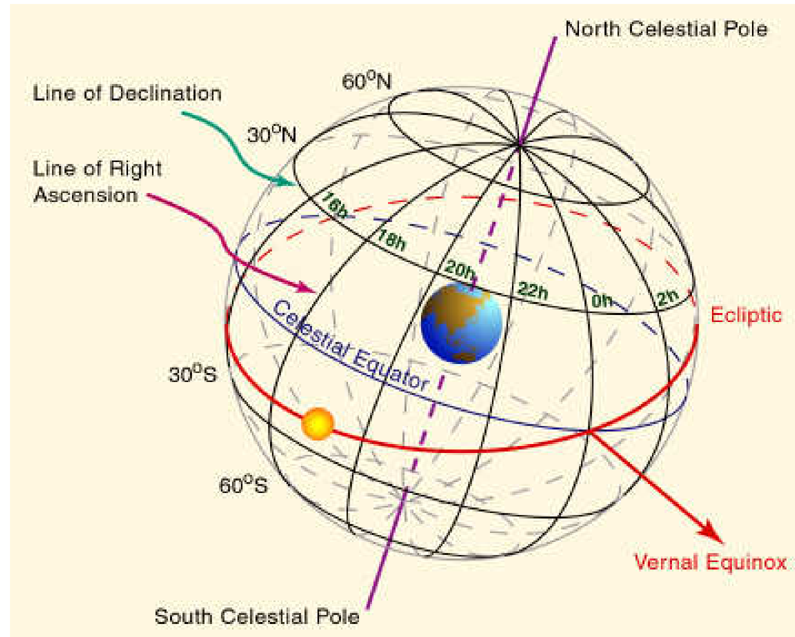
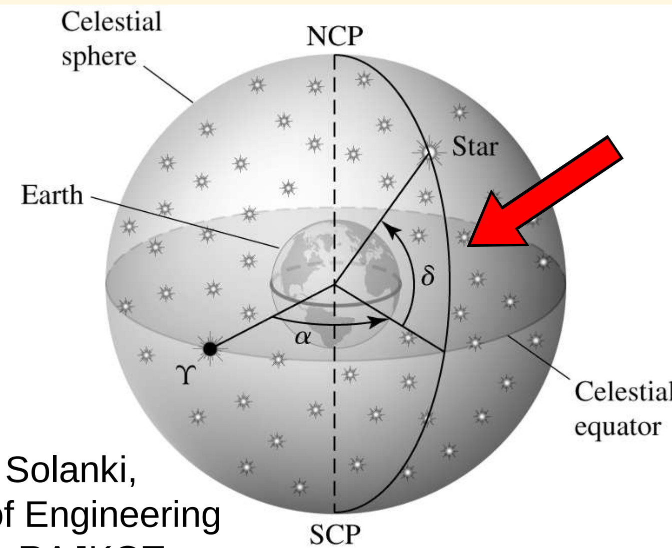
Positions on the Celestial Sphere
The Equatorial Coordinate System

- **Hour Angle** - The angle between a celestial object's hour circle and the observer's meridian, measured in the direction of the object's motion around the celestial sphere.
- **Local Sidereal Time(LST)** - the amount of time that has elapsed since the vernal equinox has last traversed the meridian.
- Right Ascension is typically measured in units of hours, minutes and seconds. 24 hours of RA would be equivalent to 360°.
- Can tell your LST by using the known RA of an object on observer's meridian





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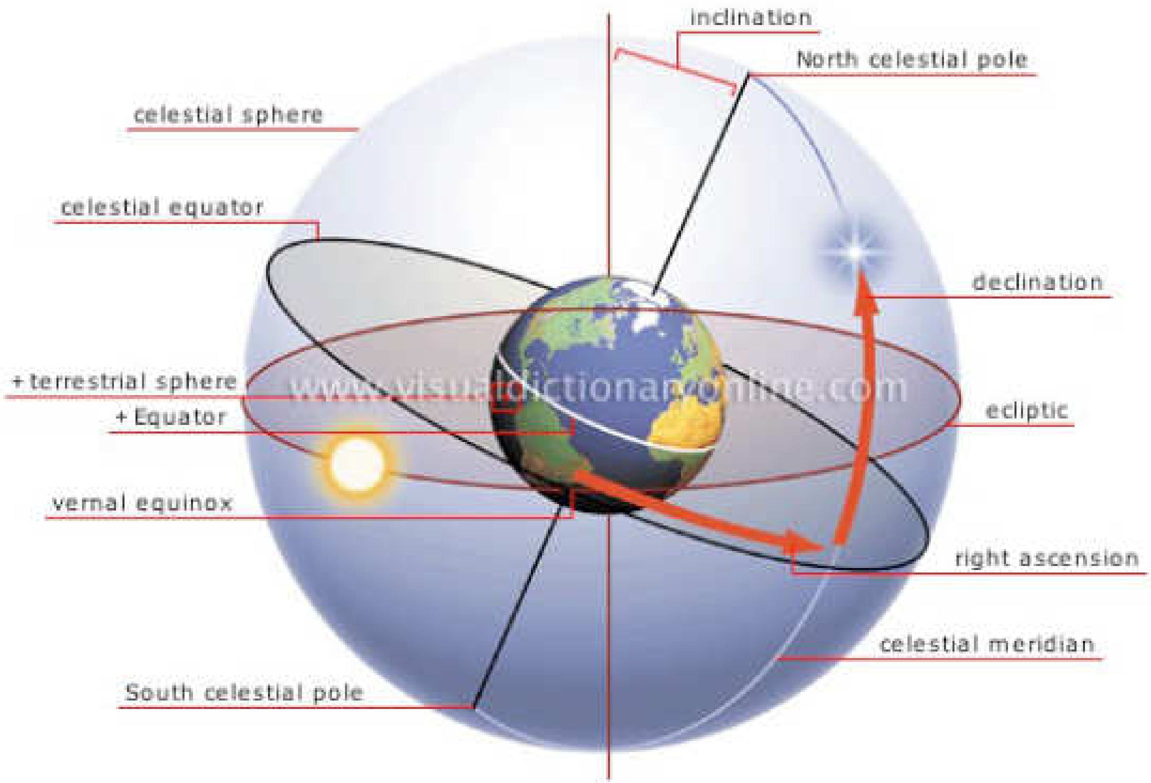
Celestial Coordinates



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Sky Coordinates

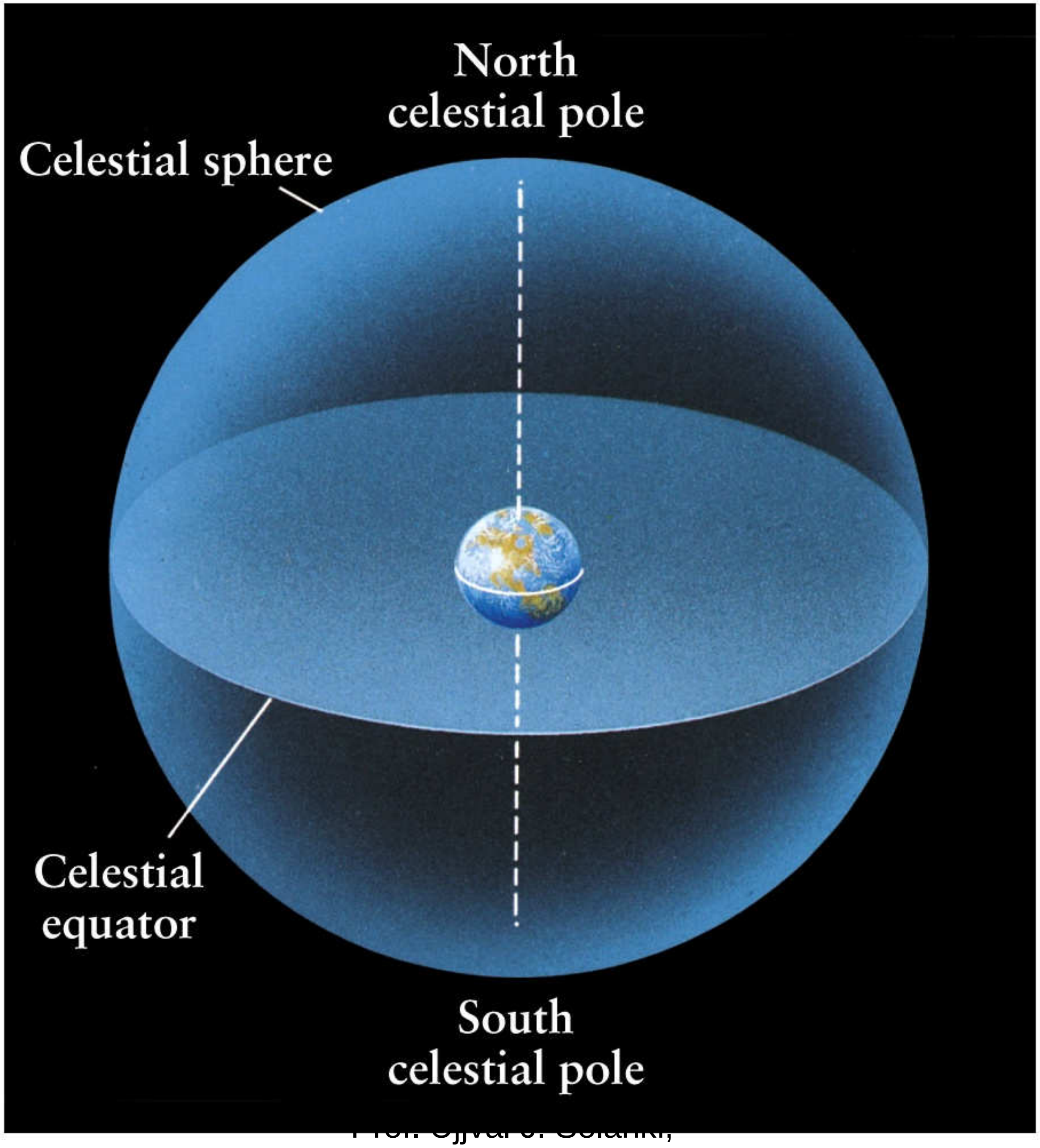
Horizon Coordinates:

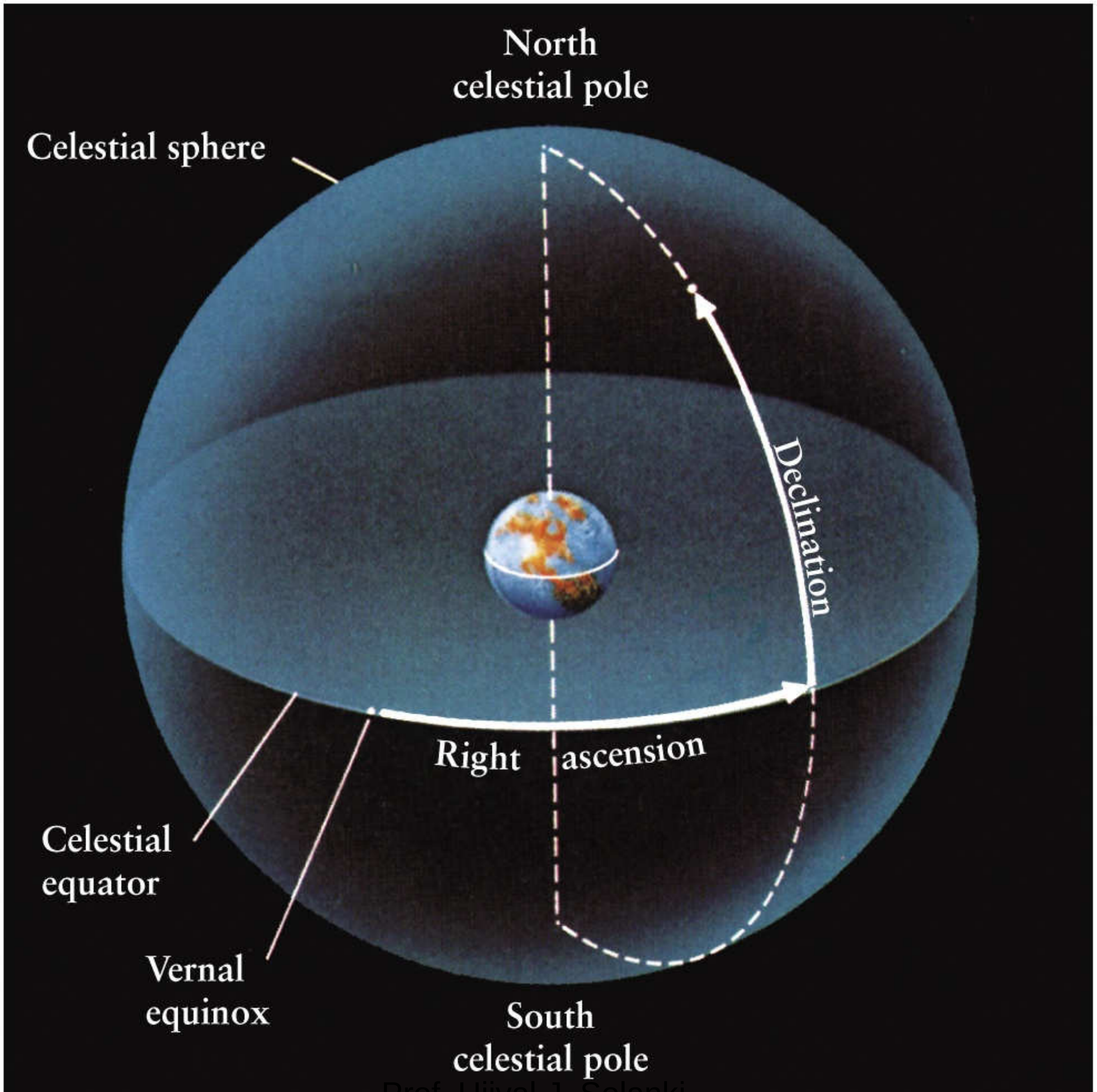
- **Horizon** - the "sky line", i.e. where the sky apparently meets the earth.
- **Azimuth (Az)** - Angular coordinate measure around the horizon, starting from the North point and moving Eastward.
- **Altitude (Alt)** - angular measure above the horizon along a great circle passing through the zenith
- **North Point** - the point that is on the horizon and directly North
- **Zenith** - The point in the sky directly overhead.
- **Nadir** - The point directly beneath one’s feet.
- **Meridian** - the great circle that passes from the North point through the zenith to the South Point

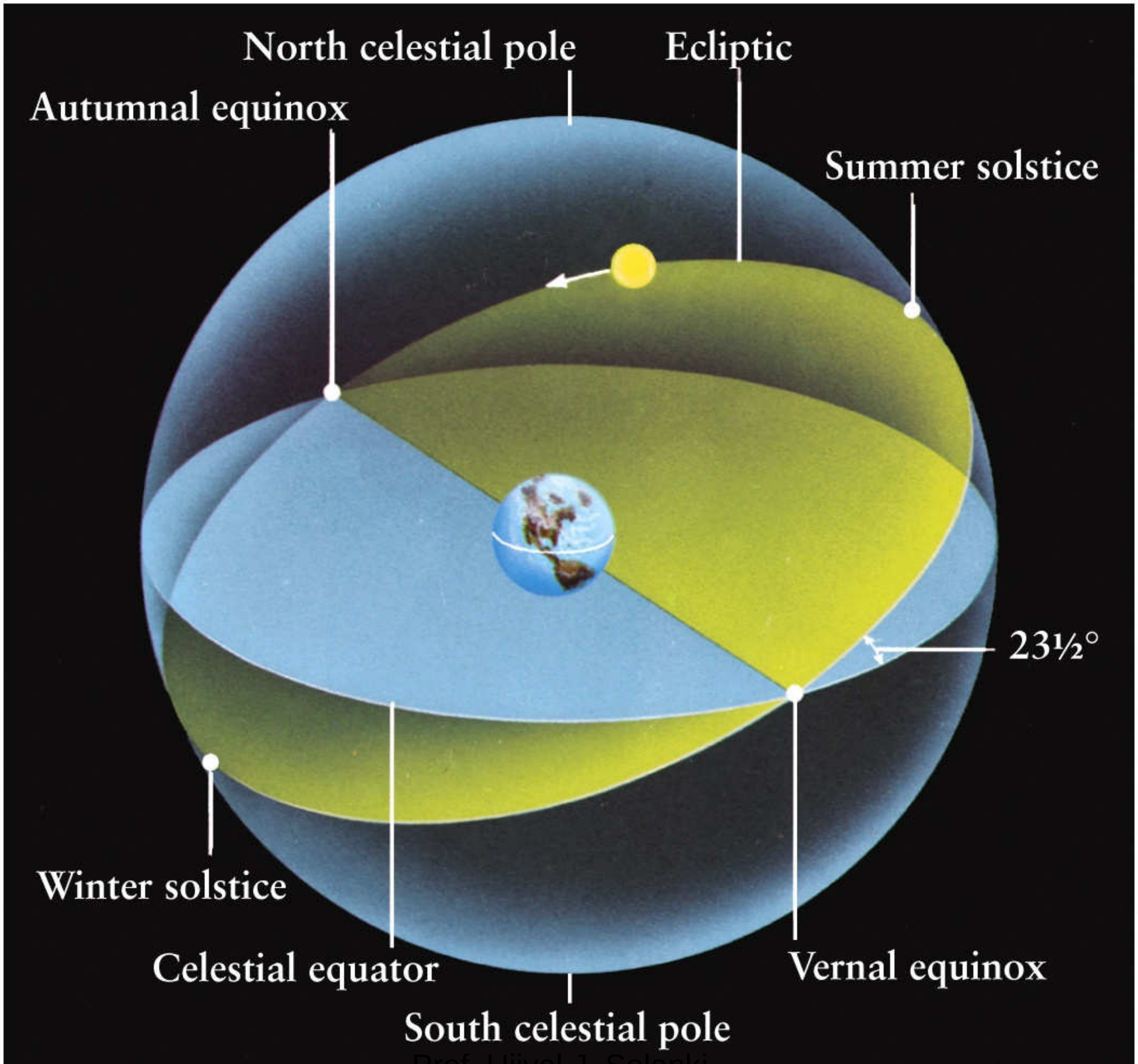
Sky Coordinates

Celestial Coordinates:

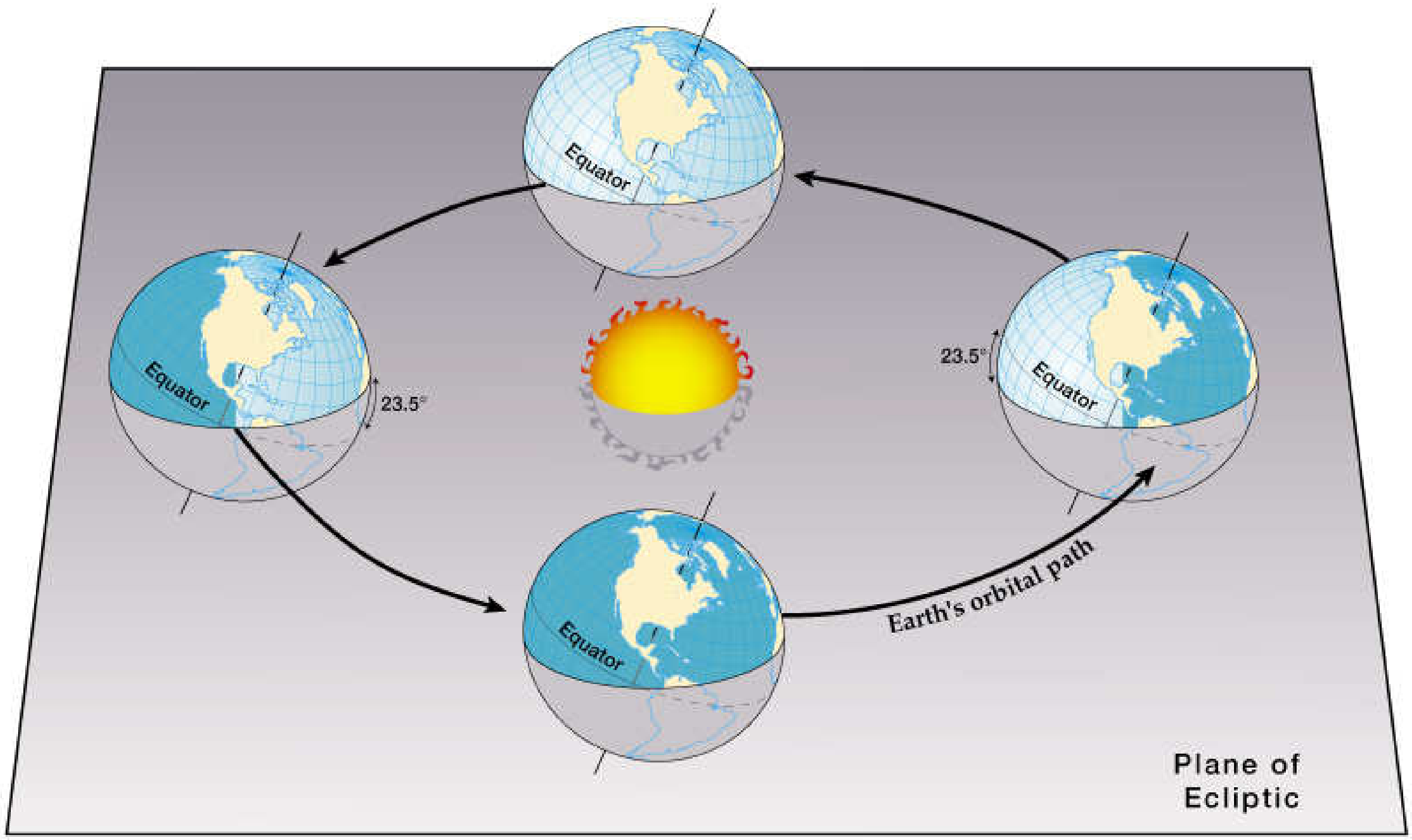
- **Right Ascension (RA)** - similar to Earth longitude but for the sky; RA is measured Eastward starting from the Vernal Equinox
- **Declination (Dec)** - similar to Earth latitude but for the sky; Dec is positive in the North Celestial Sphere and negative in the South
- **Celestial Poles** - projection of North and South Poles onto the sky
- **Celestial Sphere -** The imaginary sphere centred on the observer upon which the stars appear to be projected.
- **Celestial Equator (CE)** - projection of equator onto the sky
- **Ecliptic** - apparent path of the Sun over the course of one year
- **Solstice** - Time of greatest or smallest declination for the Sun.
- **Equinox** - Time when the Sun crosses the celestial equator. (Vernal = spring)


North
celestial pole
Celestial sphere
Celestial
equator
South
celestial pole


North
celestial pole
Celestial sphere
Declination
Right ascension
Celestial
equator
Vernal
equinox
South
celestial pole


North celestial pole
Ecliptic
Autumnal equinox
Summer solstice
23½°
Winter solstice
Celestial equator
Vernal equinox
South celestial pole

Perspective: The ecliptic is Earth's orbital plane around the Sun.



Seasons and the Sky

- *Vernal Equinox* - first day of spring; the Sun lies exactly over the equator and is passing into the N. hemisphere
- *Autumnal Equinox* - first day of autumn; the Sun lies exactly over the equator and is passing into the S. hemisphere
- *Summer Solstice* - first day of summer; the Sun is highest in the sky for N. observers (lowest for S. observers)
- *Winter Solstice* - first day of winter; the Sun is lowest in the sky for N. observers (highest for S. observers)

Summary

Earth Globe	**Celestial Sphere**
North Pole	North Celestial Pole
South Pole	South Celestial Pole
Equator	Celestial Equator
Prime Meridian	Vernal Equinox
Latitude	Declination
Longitude	Right Ascension

Sky Coordinates

- **Vertical Circle** - A secondary great circle in the horizon system. Such a circle passes through the zenith and nadir and is vertical since it is perpendicular to the horizon.
- **Hour Circle** - A secondary great circle in the equatorial system. Such a circle therefore passes through the celestial poles and is perpendicular to the celestial equator.
- **Hour Angle (HA)** - Another longitude-like coordinate in the equatorial system. It is measured in units of time *westward* along the celestial equator *from the celestial meridian* to the hour circle of a point. (Unlike the right ascension it does depend both upon the observer's position and also upon the time. A star's hour angle can be thought of both as an angle and also as the elapsed time since that star crossed the celestial meridian.)
- **Celestial Meridian** - A great circle passing through the zenith, nadir, north and south celestial poles, and north and south points of the horizon. It is both a vertical circle and an hour circle and is therefore perpendicular to both the celestial equator and horizon. The celestial meridian bisects the sky into eastern and western halves.
- **Local Sidereal Time (LST)** - The hour angle of the vernal equinox or, equivalently, the right ascension of points on the celestial meridian. LST is dependent upon the observer's position and is constantly changing with time.

Coordinate systems

- In order to find something one needs a system of coordinates. For determining the positions of the stars and planets where the distance to the object often is unknown it usually suffices to use *two coordinates.*
- Different types of coordinate systems are:
  - The Horizon System
  - Equatorial Coordinate System .
  - Ecliptic Coordinate System.
  - Galactic Coordinate System.

Horizon Coordinate System

Note that

(0) The celestial sphere is shown. The observer's position is at the center of the sphere with his/her head toward the zenith.

(1) $-90° \leq$ ***altitude*** $\leq 90°$.

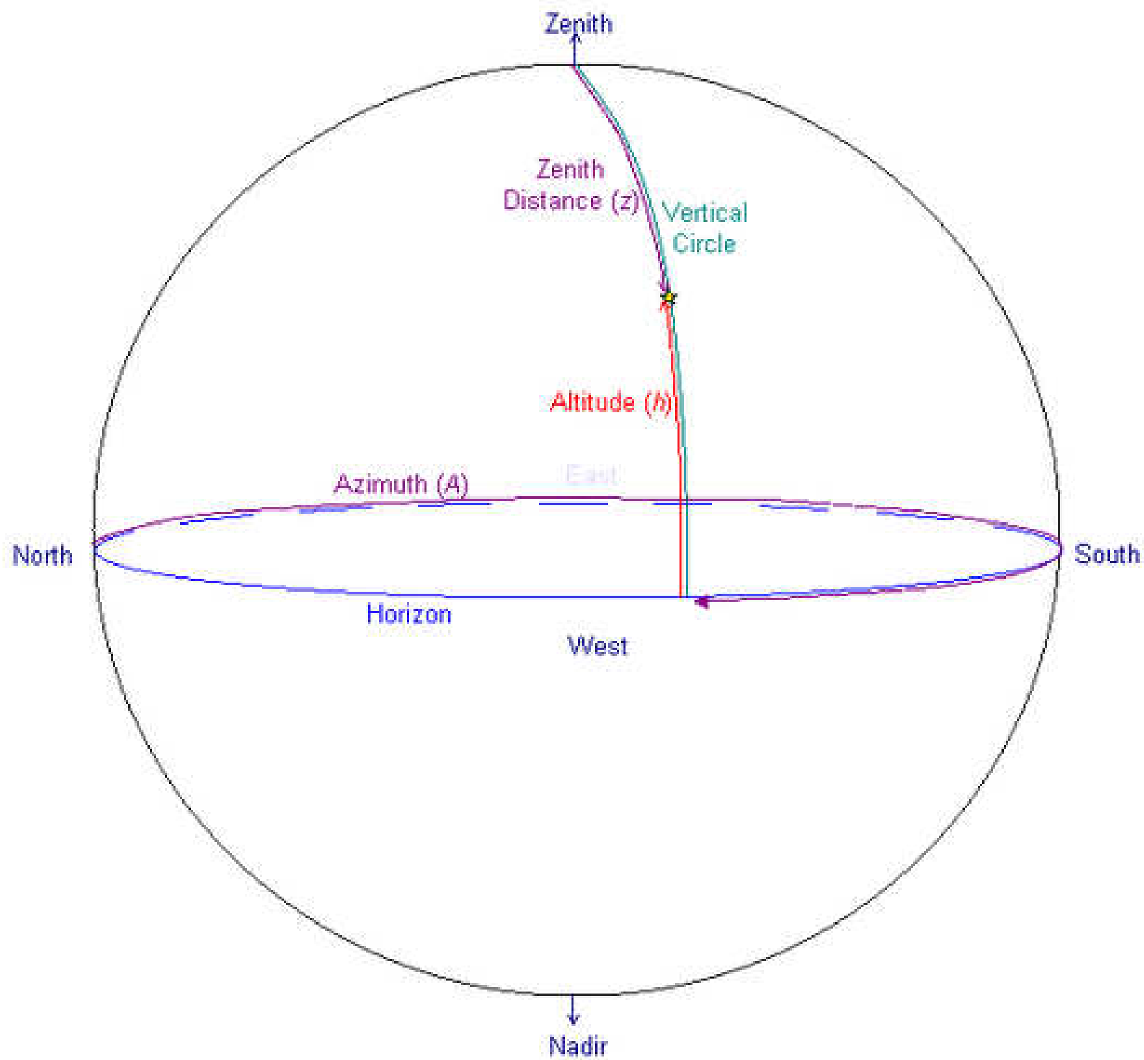
(2) Points above the horizon have positive altitudes and points below the horizon have negative altitudes.

(3) $0° \leq$ ***azimuth*** $\leq 360°$.

(4) ***Azimuth*** is measured eastward from the north point on the horizon.

(5) ***Azimuth*** is undefined at the zenith and the nadir.

(6) $z = 90° - h$, *i.e.*, the zenith distance, z, is the complement of the altitude, h.



Equatorial Coordinate System

Note that

(1) $-90° \le \delta \le 90°$.

(2) δ is positive for points north of the celestial equator and negative for points south of the celestial equator.

(3) $0^{hr} \le \alpha \le 24^{hr}$.

(4) $0^{hr} \le HA \le 24^{hr}$.

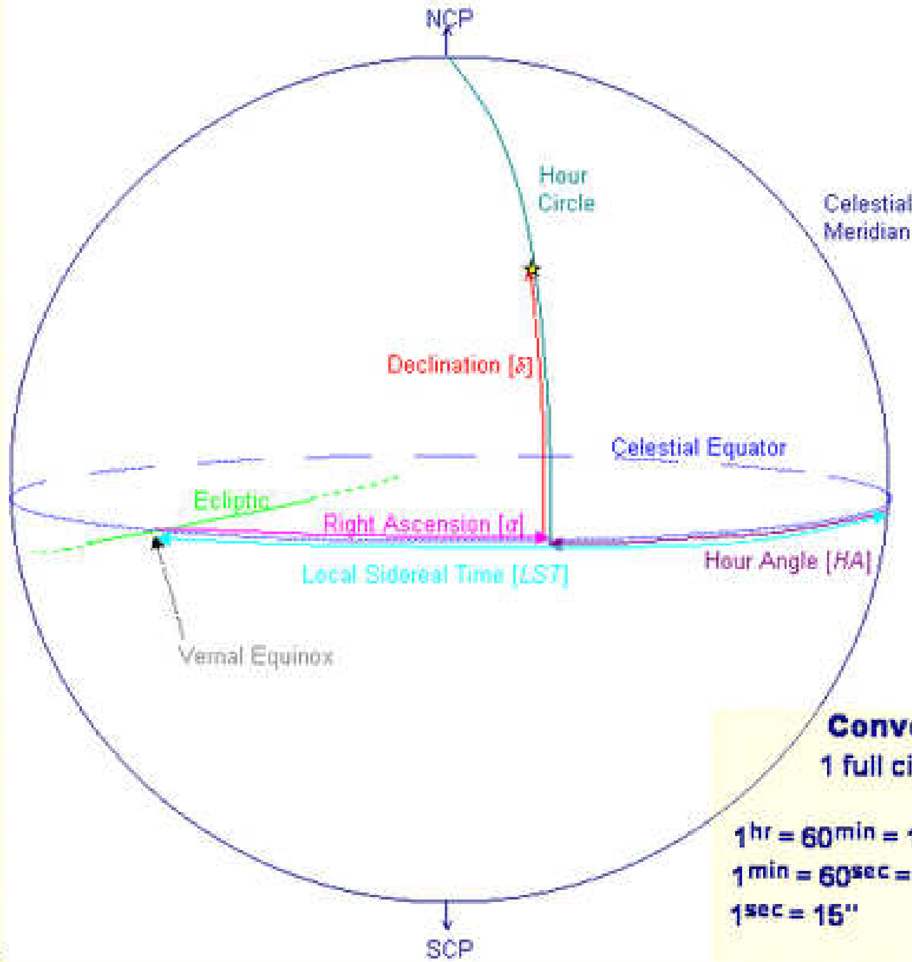
(5) $LST = HA + \alpha$.

(6) $LST = HA$ (vernal equinox) = α (celestial meridian).

(7) Right ascension, α, is measured eastward from the vernal equinox.

(8) Hour angle, HA, is measured westward from the celestial meridian.

(9) Both α and HA are undefined at the NCP and the SCP. The celestial meridian is undefined for observers at the earth's north and south poles.



Conversion Factors

1 full circle = $360° = 24^{hr}$

$1^{hr} = 60^{min} = 15°$ | $1° = 60' = 4^{min}$

$1^{min} = 60^{sec} = 15'$ | $1' = 60'' = 4^{sec}$

$1^{sec} = 15''$ | $1'' = (1/15)^{sec}$

(10) α equals the elapsed sidereal time between when the vernal equinox crosses the celestial meridian and the subsequent crossing of the meridian by the object of right ascension α.

Cancel

Ecliptic System
Note that

(1) $-90° \leq \beta \leq 90°$.

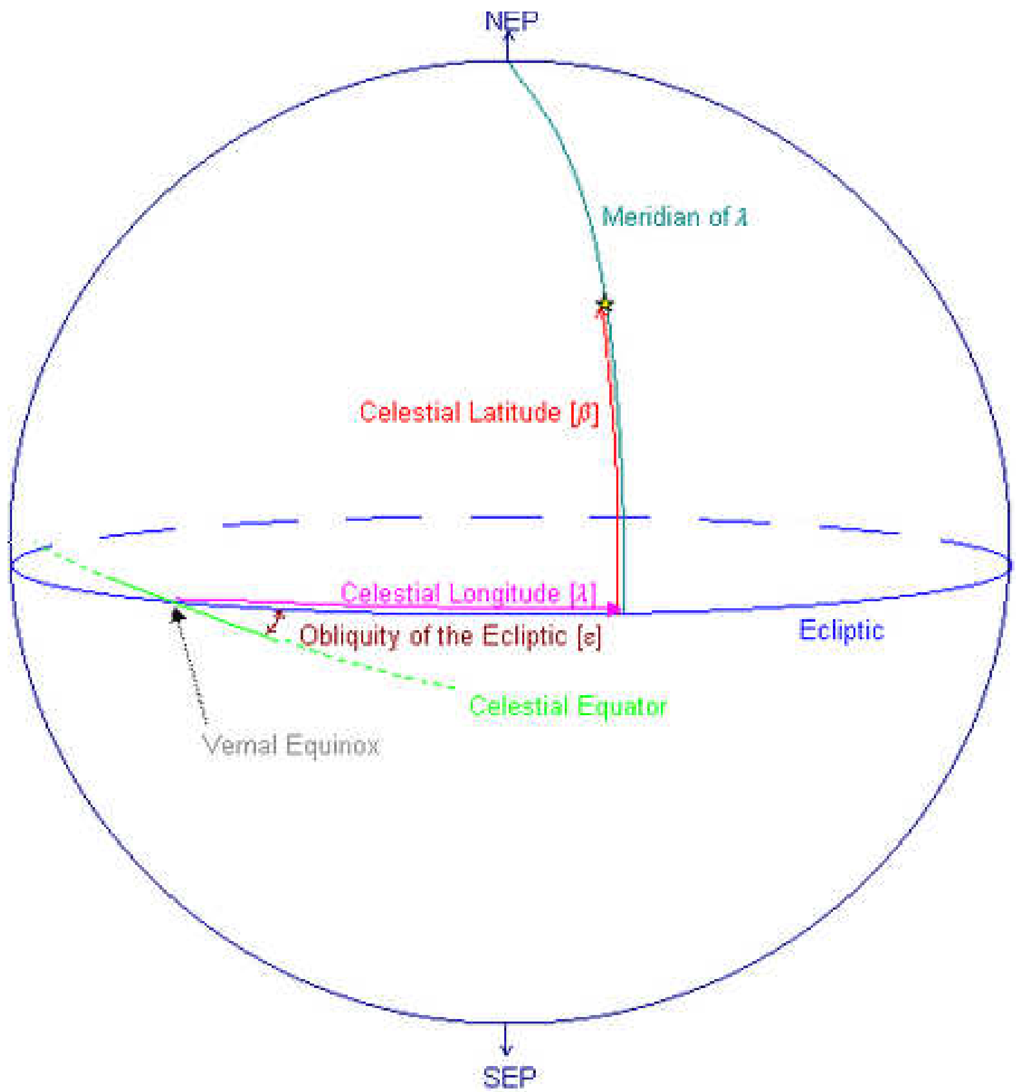
(2) $0° \leq \lambda \leq 360°$.

(3) $\varepsilon \sim 23½°$

(4) Celestial longitude is measured eastward from the vernal equinox.

(5) The ecliptic system is particularly useful for studies of solar system structure.

(6) λ is undefined at the NEP and SEP.



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Galactic System
Note that

(0) The system is centered on the observer (effectively the sun because of the large size of the Galaxy).

(1) The Galactic equator is the roughly the mean plane of the Milky Way.

(2) The NGP is chosen to be the galactic pole which lies in the northern hemisphere of the equatorial coordinate. Thus, viewed from either the NGP or NCP, galactic rotation would be clockwise, whereas, from the same perspectives, the rotations of the earth and the solar system would be counterclockwise.

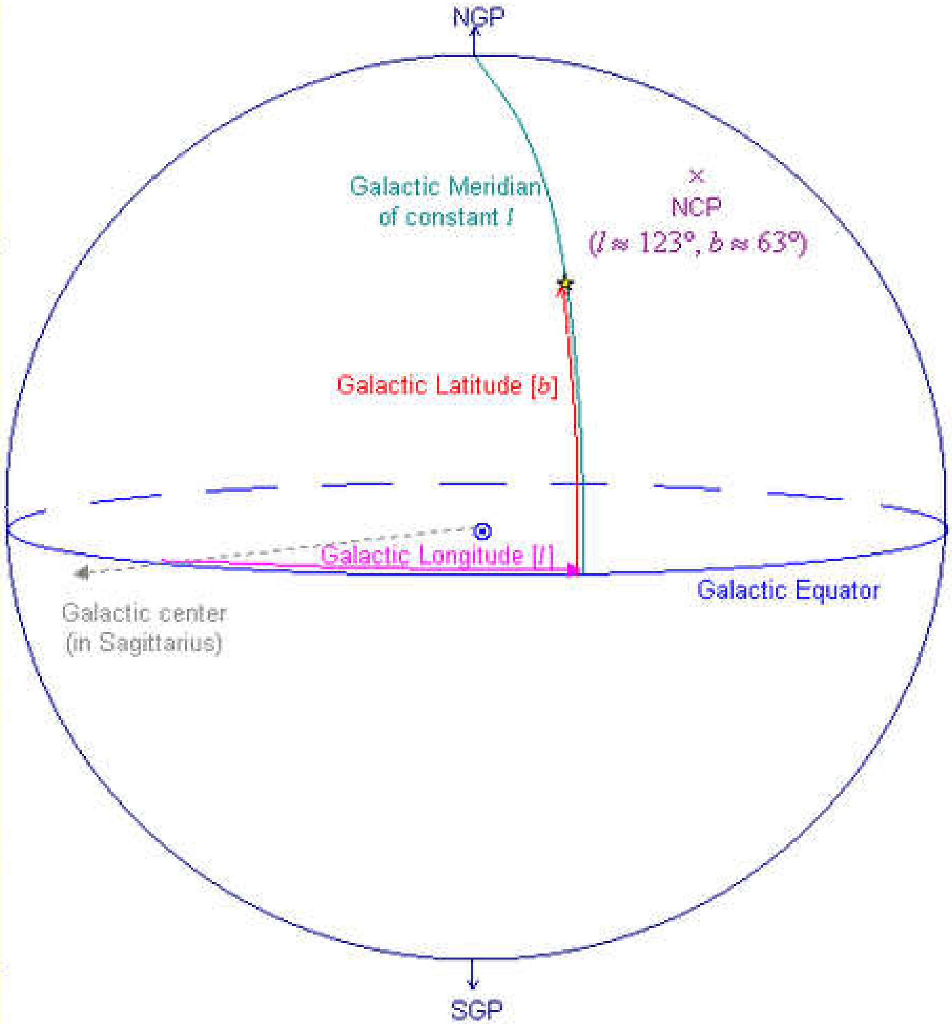
(3) $-90° \leq b \leq 90°$.

(4) $0° \leq l \leq 360°$.

(5) Galactic longitude is measured eastward from the galactic center.

(6) The galactic system is particularly useful for studies of galactic structure.

(7) l is undefined at the NGP and SGP.)



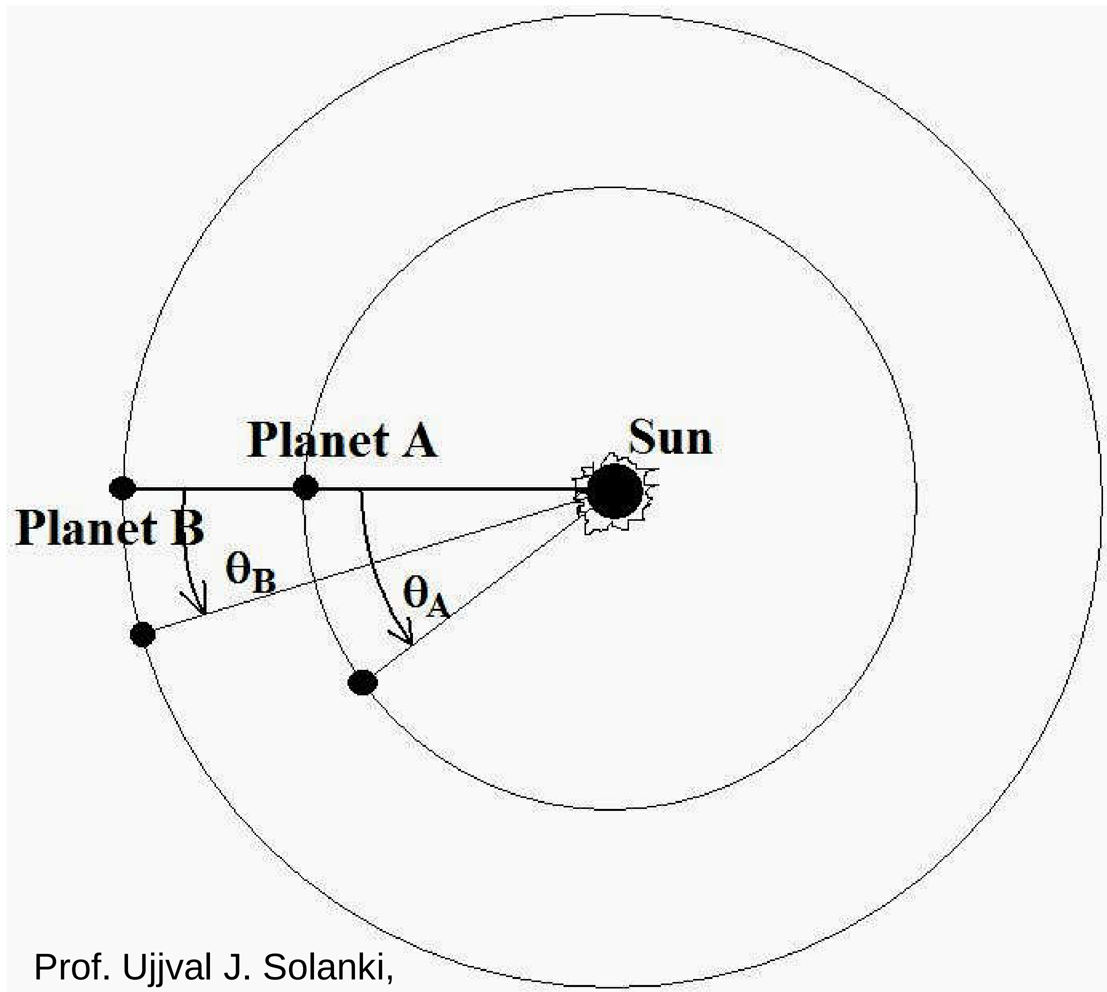
(8) A hypothetical star coincident with the sun, but in a perfectly circular orbit about the galactic center, would be moving towards $l = 90°$, $b = 0°$. Such is the motion of the so-called "dynamical local standard of rest." In this frame the average motion of stars in the the solar neighborhood is very nearly zero. The sun's motion with respect to this frame, the sun's peculiar motion, is called the "solar motion."

Over the course of one day, planet A advances through the angle

$$\theta_A = \frac{360^\circ}{P_A}$$

Planet B advances through the angle

$$\theta_B = \frac{360^\circ}{P_B}$$



The difference in the angles is the amount by which planet A has gained on planet B, which is related to its synodic period, *i.e.*:

$$\theta_{AB} = \theta_A - \theta_B = \frac{360^\circ}{S_{AB}}$$

In other words,

$$\frac{360^\circ}{S_{AB}} = \frac{360^\circ}{P_A} - \frac{360^\circ}{P_B}$$

Or:

$$\frac{1}{S_{AB}} = \frac{1}{P_A} - \frac{1}{P_B}$$

If A is Earth, and B a *superior planet* (orbits outside Earth's orbit), then:

$$\frac{1}{S} = \frac{1}{P_\oplus} - \frac{1}{P_{sid}}$$

For Earth $P_\oplus$ = 365.256363 days (a little more than 365¼ days), *i.e.*:

$$\frac{1}{S} = \frac{1}{365^{d}.256363} - \frac{1}{P_{sid}}$$

Given two values, the third can be found !

Local and Projected coordinates for earth resources mapping

- **Local Geographic coordinate systems**

- ✓ Geographic coordinate systems use a ***3-D spherical surface*** to represent the earth and define locations on it, which are referenced by longitude and latitude values.

- ✓ Because the earth is not completely round, it isn't possible to base a coordinate system on a perfect sphere. Therefore ***a variety of "spheroids" are used*** instead, each of which is more accurate in a particular part of the world. In North America, the most popular spheroid is known as GRS 1980. Another spheroid which is used is WGS 1984.

- ✓ Going even further, ***spheroids can have datums associated with them, which incorporate local variations in elevation***, since the earth is not really smooth. In North America, the most popular datums are NAD 1983 (North American Datum; based on the GRS 1980 spheroid) and WGS 1984 (World Geodetic System; based on the WGS 1984 spheroid).

❑ Projected coordinate systems

Projection refers to the process of representing the earth's round surface as a flat surface (a piece of paper, or your computer screen). Projected coordinate systems, or projections, are always based on a geographic coordinate system.
There are many different types of projections, and each one of necessity distorts the representation of the earth in some way. When selecting a projection for your data, it is important to be aware of what distortions are in place - certain types of distortion are more acceptable for some purposes than for others.

Here is a description of the features of the projections currently used:

- ***Lambert Conformal Conic***

Type:	**Conic**
Properties:	Conformal - all angles at any point are preserved. Maintains shapes for small areas (i.e. large scale maps), but distorts the size of large areas.
Common uses:	mapping Canada and the US; mapping equatorial/mid-latitute areas; mapping at large and medium scales.

- ***Transverse Mercator***

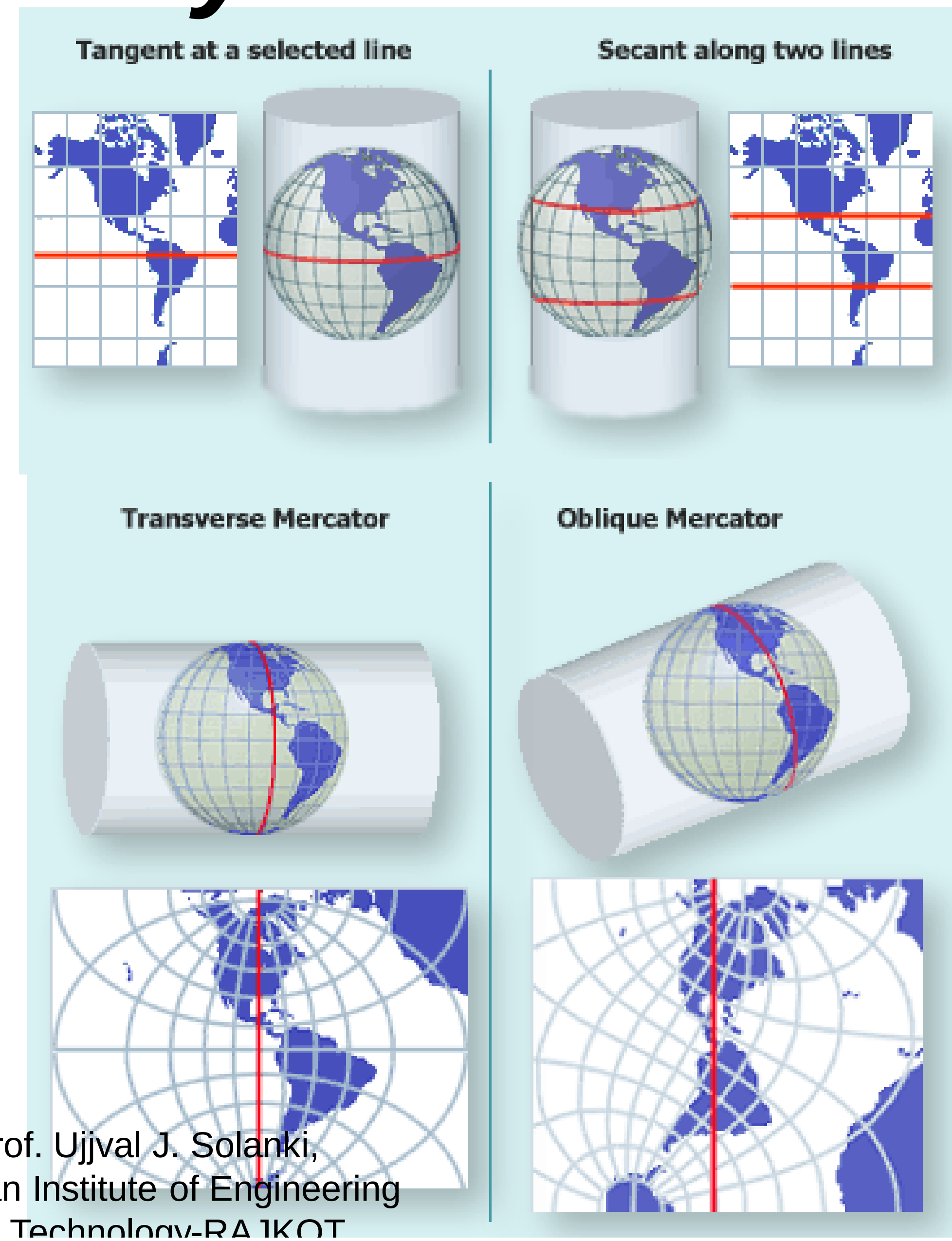
Type:	**Cylindrical**
Properties:	Conformal - all angles at any point are preserved. Maintains shape for small areas-specifically, in zones only a few degrees wide in east-west extent.
Common uses:	large scale topographic map series, NTS and USGS maps.

- **Planar Projection**

A planar projection projects information to a plane. The plane may be either tangent or secant.

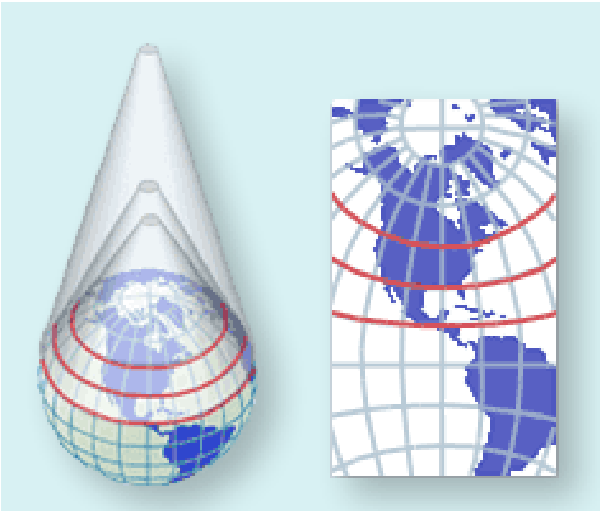
Mercantor Cylinderical

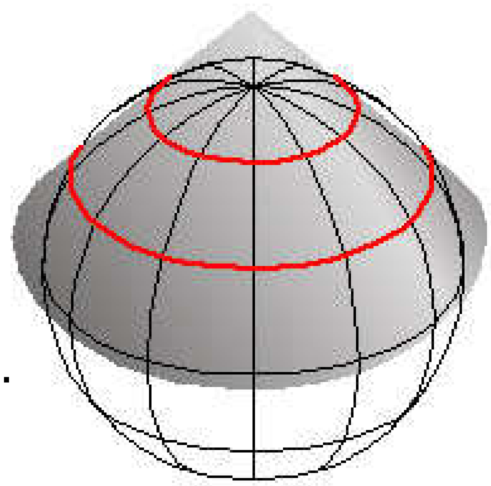
- A Mercator projection is created using a cylinder tangent at the equator. A Transverse Mercator projection is created using a cylinder that is tangent at a selected meridian. An Oblique Mercator projection is created using a cylinder that is tangent along a great circle other than the equator or a meridian.

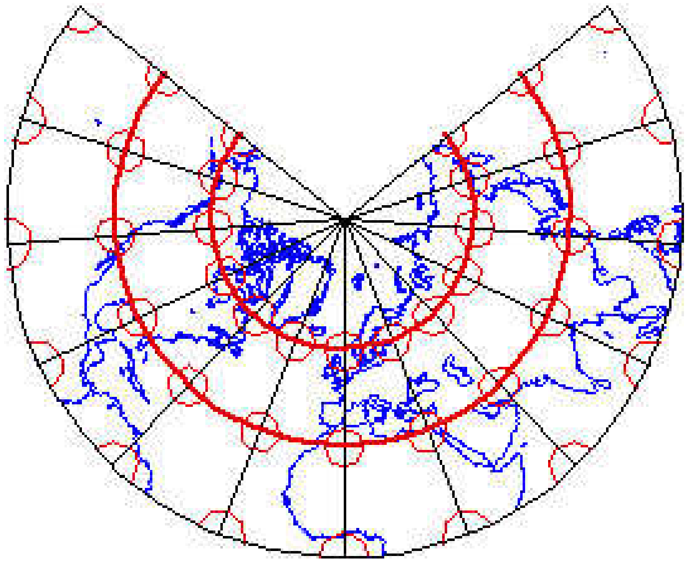


Lambert Conformal Conic

- A conic projection projects information from the spherical Earth to a cone that is either tangent to the Earth at a single parallel, or that is secant at two standard parallels. Once the projection is complete, the cone is unwrapped to form a flat surface. The lines where the cone is tangent or secant are the places with the least distortion. A polyconic projection uses a series of cones to reduce distortion.

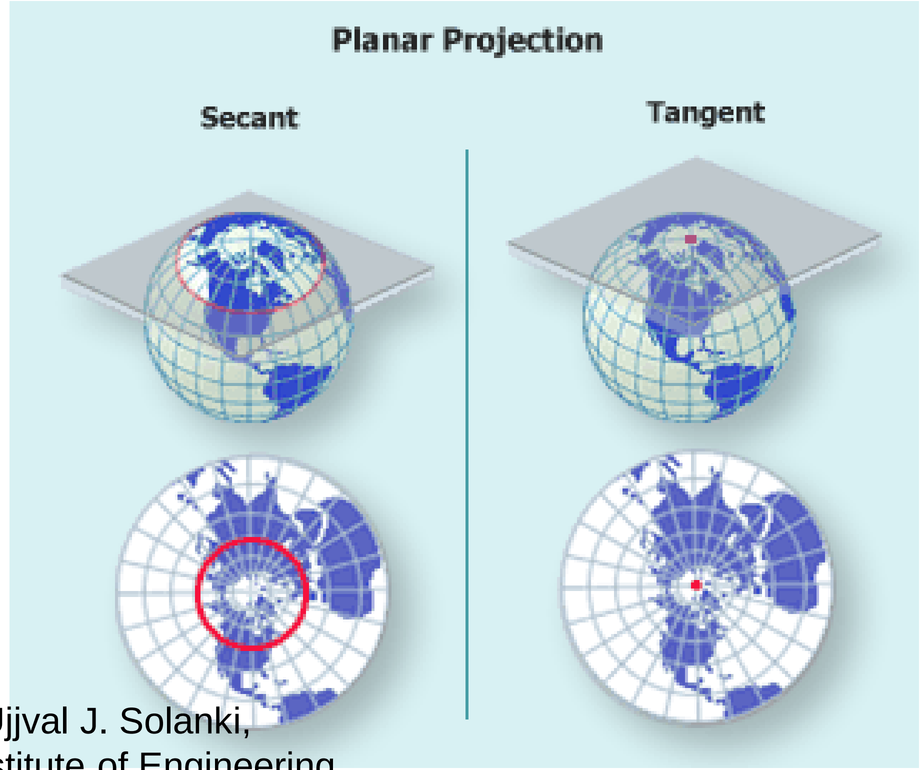






Planar Projection

A map projection resulting from the conceptual projection of the Earth onto a tangent or secant plane. Usually, a planar projection is the same as an azimuthal projection.



Determination of Latitude

A LATITUDE is also defined as the angle between the zenith & the celestial equator.

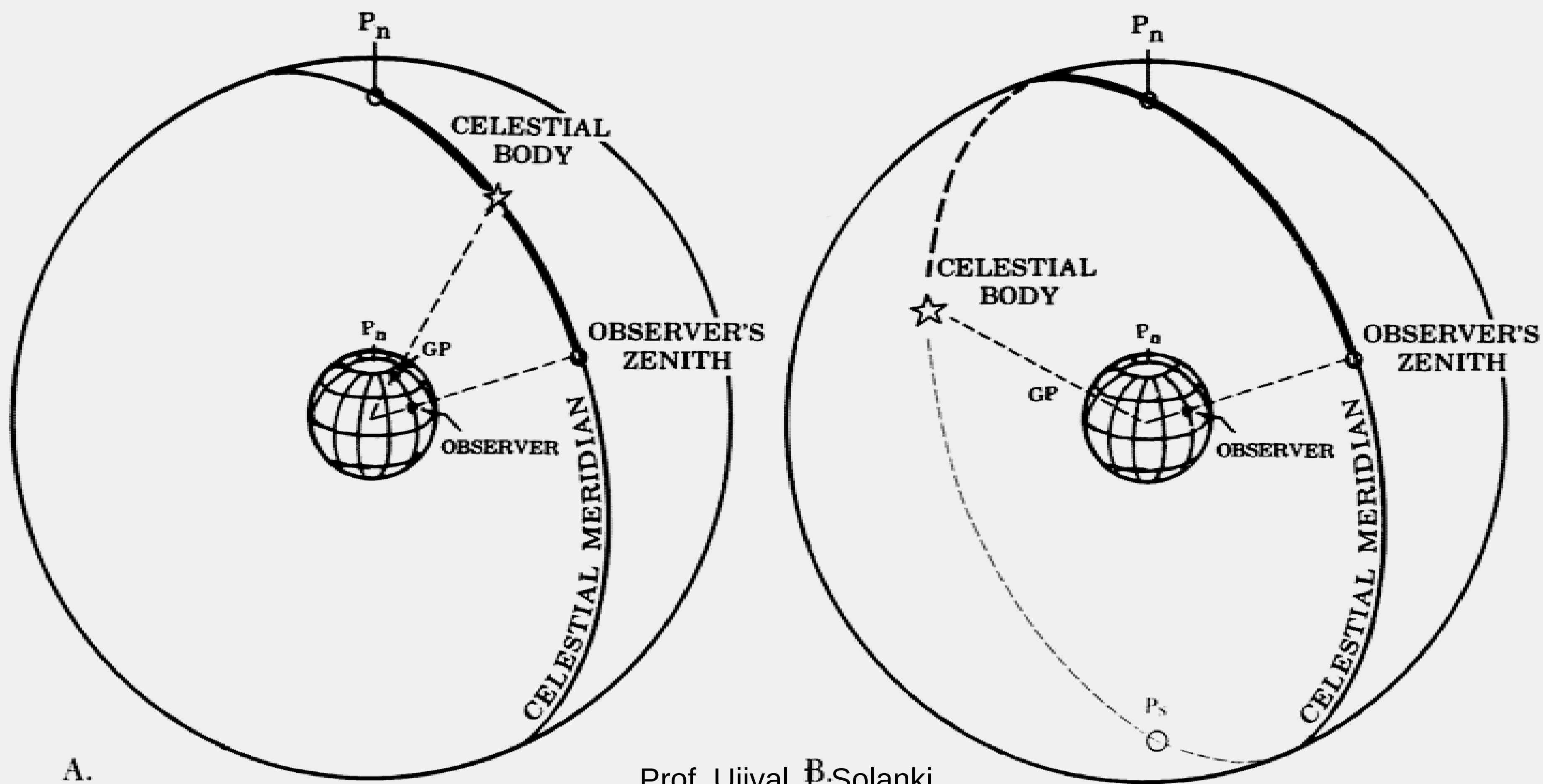
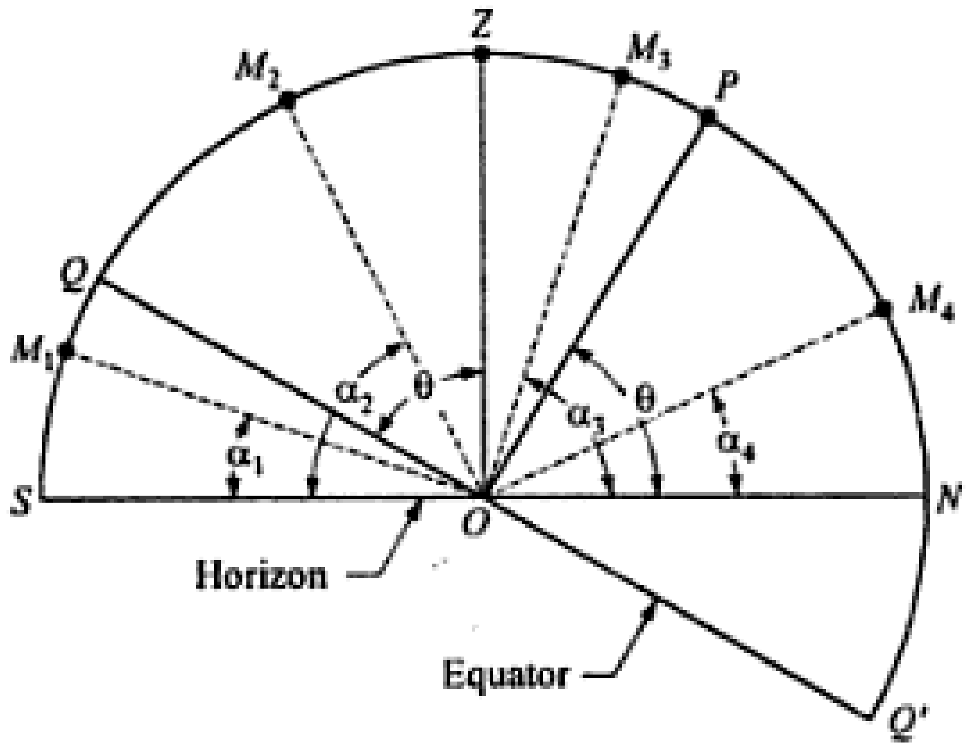


Figure 25–1. *Celestial triangle of a body at (A) upper meridian transit, (B) lower*

CASE 1: By meridian altitude of sun or star



Four Positions of Star *M1, M2, M3, M4*

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Explained in the class