GEOMATICS ENGINEERING DEPARTMENT

SECOND YEAR GEOMATICS

GEODESY 2 (GED209)

LECTURE NO: 12

GEODETIC ASTRONOMY – PART I

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Overview Of Previous Lecture

- Gravity Dependent Observations
- Adjustment Computations In Geodesy
- Two-Dimensional Geodetic Computations
- Three-Dimensional Geodetic Computations
- Summary

Overview Of Today's Lecture

- Why to Study Geodetic Astronomy
- The Solar System and The Celestial Sphere
- Reference Circles on the Surface of the Earth and Celestial Sphere
- Observation Circles Linking The Terrestrial And The Celestial Spheres

Expected Learning Outcomes

- Gain insights into how geodetic astronomy contributes to mapping, navigation, surveying, and satellite positioning systems.
- Understand the positions, motions, and characteristics of celestial objects such as the Sun, Moon, planets, stars, and constellations.
- Become acquainted with reference circles on the celestial sphere, including the celestial equator and celestial meridians.
- Grasp the geometry and calculations involved in solving spherical triangles in field astronomy.

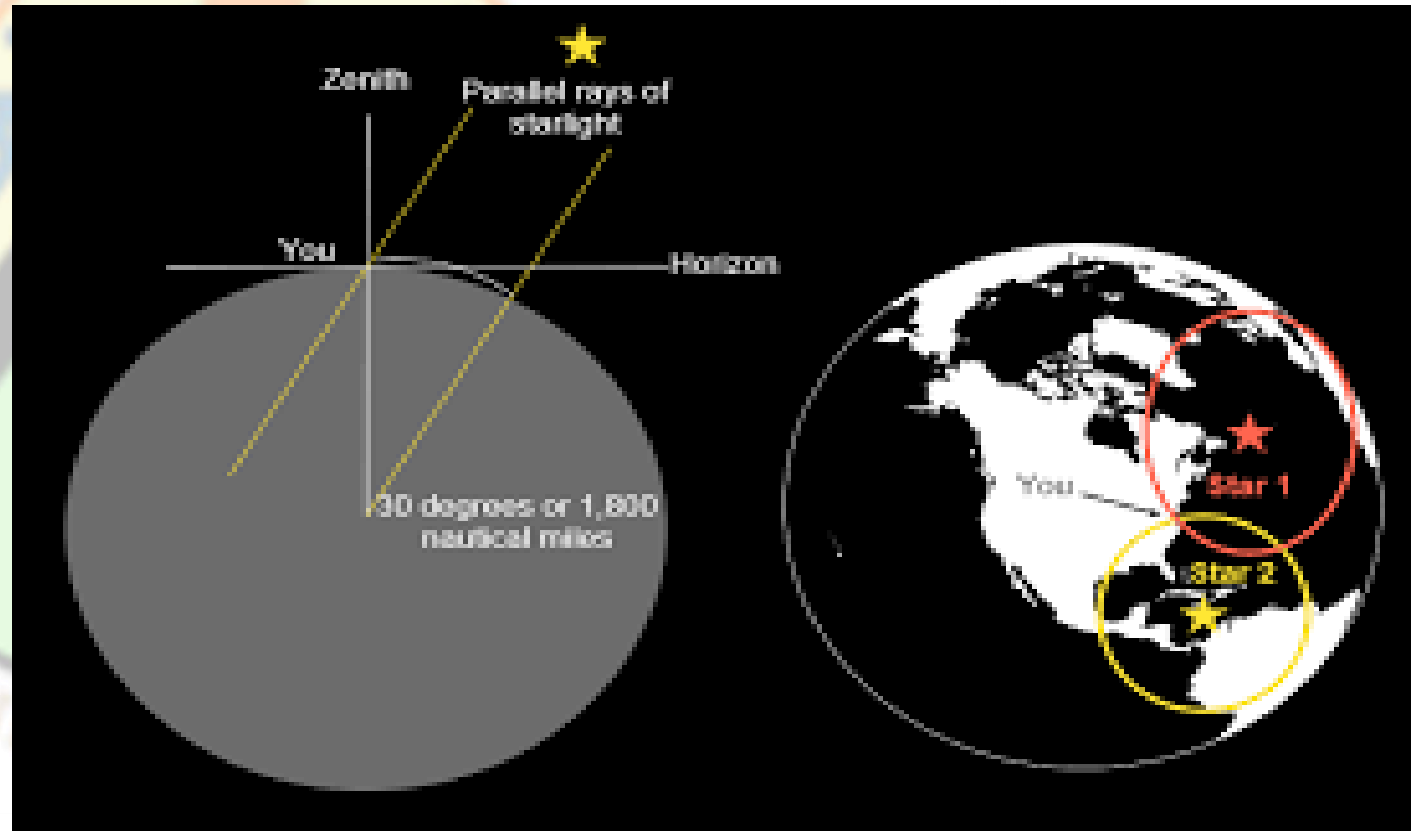
What is Astronomy?

What is Astronomy?

- Astronomy is the scientific study of the universe beyond the earth, especially the observation, calculation, and theoretical interpretation of the positions, dimensions, distribution, motion, composition, and evolution of celestial bodies and phenomena".
- Astronomy is the oldest of the natural sciences dating back to ancient Chinese and Babylonian civilizations. Prior to 1609, when the telescope was invented, the naked eye was used for measurements.

WHAT IS *GEODETIC* ASTRONOMY?

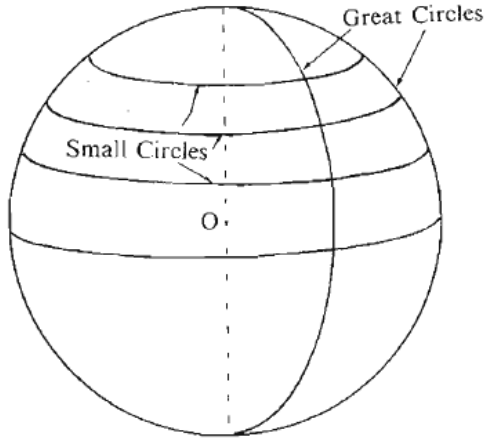
- Geodetic astronomy, on the other hand, is the art and science for determining, by astronomical observations, the positions of points on the earth and the azimuths of the geodetic lines connecting such points.



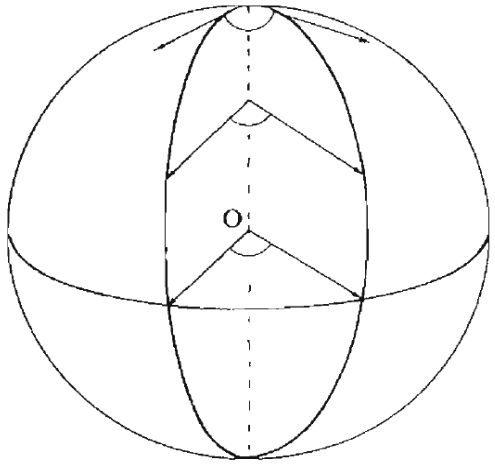
Reference Circles on the Surface of the Earth

Reference Circles on the Surface of the Earth

- Any plane, intersecting a sphere and containing its center, cuts its surface along a circle of radius equal to that of the sphere. Such a circle is a ***Great Circle***.
- *The relationships of spherical Trigonometry apply only to Great Circles.*



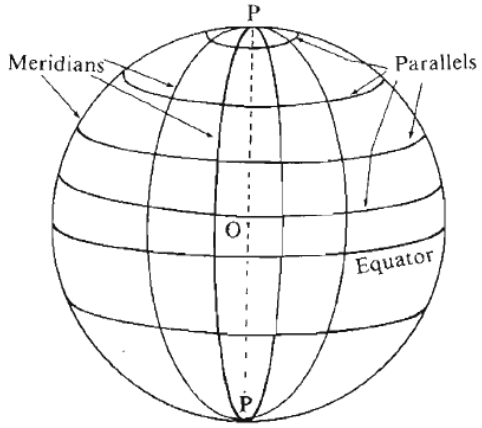
Small and great circles



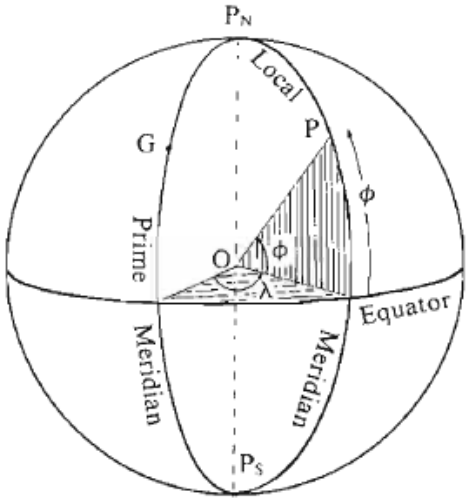
Dihedral angle

Reference Circles on the Surface of the Earth

- Any plane, which intersects the earth and has its rotational axis as a normal, cuts the earth's surface in a circle called a ***Parallel of Latitude***.
- One of parallels is a great circle known as the Equator, which is the prime parallel of latitude. The others are all small circles.
- Any plane, which contains the earth's rotational axis, cuts its surface along a great circle called a ***Meridian***.
- All meridians pass through the two terrestrial poles and the angle at each pole between any two meridians is equal to the dihedral angle (longitude λ) between them.
- The position of a place on the earth can be defined by specifying the meridian and the parallel, on which it lies.



Meridians and Parallels



Latitude and Longitude

Reference Circles On The Celestial Sphere

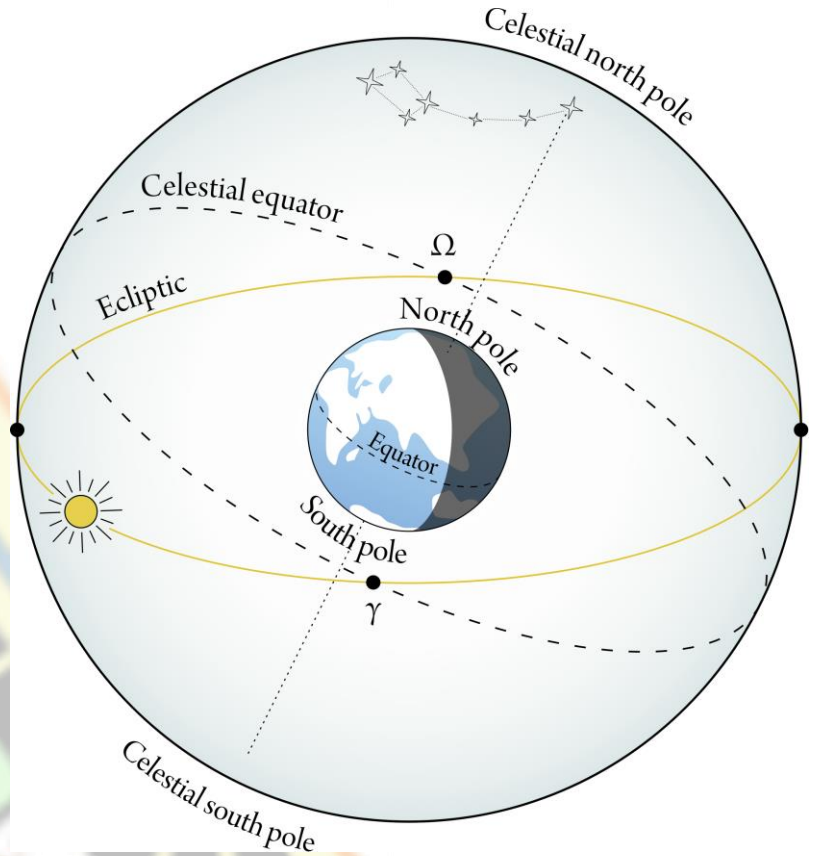
- The earth rotates about its own axis. If this terrestrial axis is produced outwards in both directions into the sky, it will intersect the celestial sphere at two points known respectively as the North Celestial Pole and the South Celestial Pole.
- The stars appear to rotate about these poles.
- There is a bright star (*Ursae Minoris* α) of magnitude *2.1* called Polaris, because it lies very close to the north celestial pole. It shows continuously where north is and, for an observer at a particular station, it maintains its altitude practically unaltered unlike other stars.

Reference Circles On The Celestial Sphere

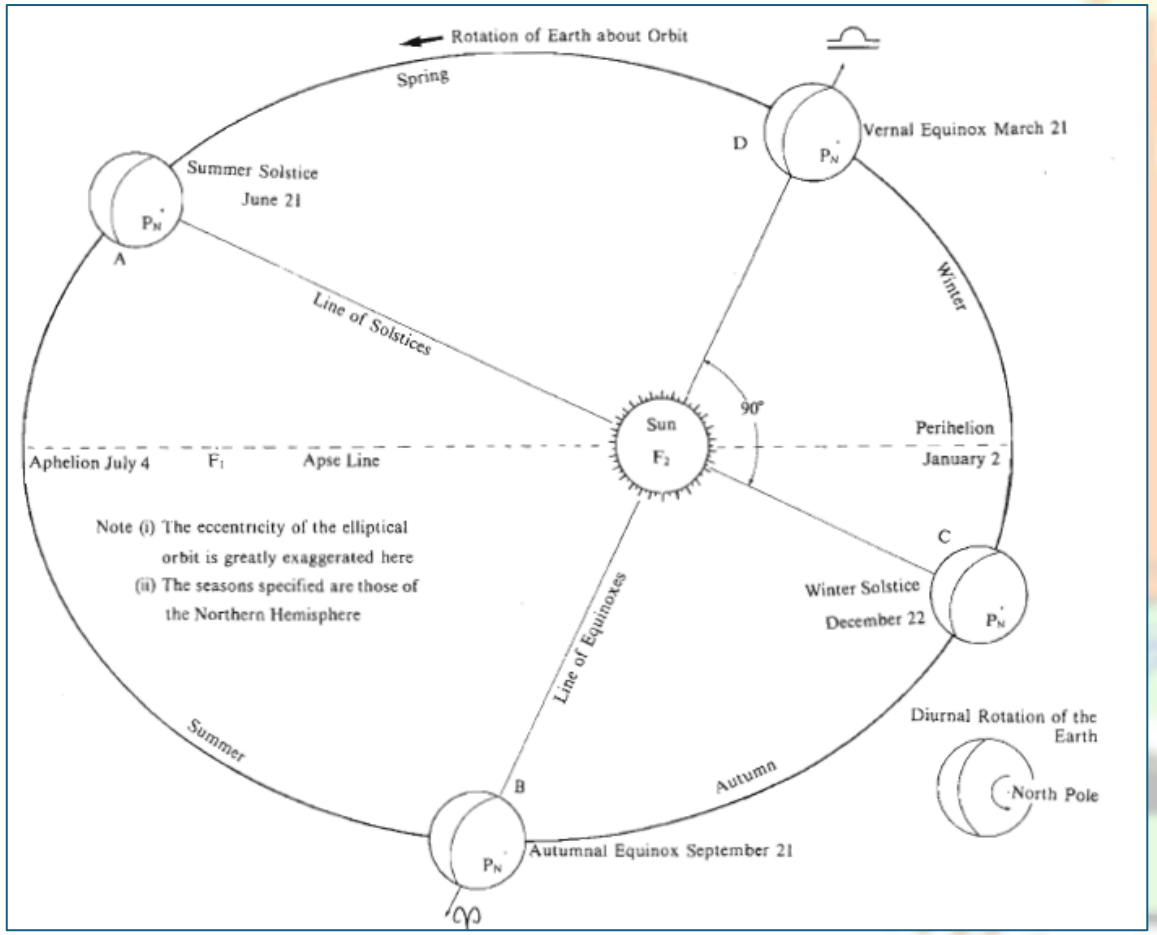
- In the southern hemisphere, where there is a dearth of visible stars in the vicinity of the south celestial pole. However, there is a faint star, *Octantis* σ, of magnitude 5.5, within one degree of the south pole. It cannot, like the northern Pole Star, be seen easily by the naked eye but requires a telescope, with which it may be viewed at night.
- The earth's axis of rotation very nearly maintains its direction in space except for minor periodic effects. In other words, the two pole stars (i.e, *Polaris*, and *Octantis*) will remain close to the celestial pole for many years to come.

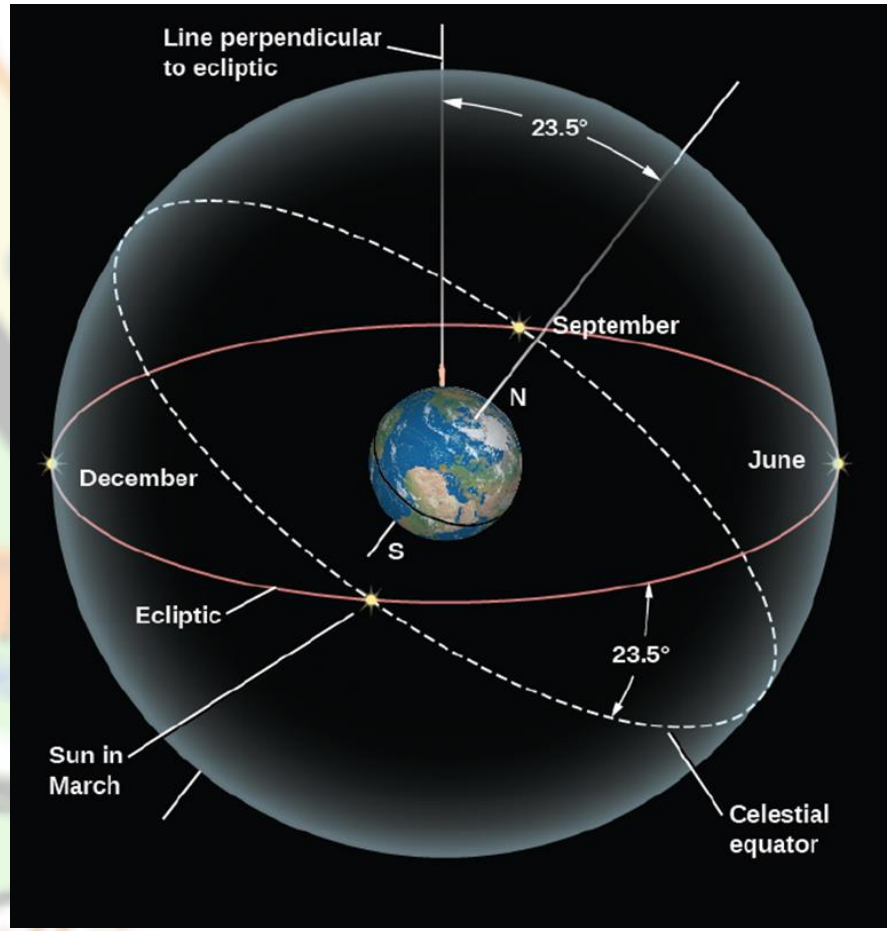
CELESTIAL SPHERE

- The distance from the earth to the nearest star is more than 109 earth radii, thus the dimensions of the earth can be considered as negligible compared to the distances to the stars.
- An imaginary sphere surrounding the Earth on which celestial objects appear to be located; thought to really exist in antiquity, today used as tool to identify locations in the sky.
- ***Special places:*** Celestial Equator, North and South Celestial Poles, the Ecliptic; Solstices and equinoxes.
- The relationship between the earth and stars can be closely approximated by considering the stars all to be equidistant from the earth and lying on the surface of a celestial sphere
- At any location on Earth, the altitude of the Celestial Pole is the same as the latitude of that location.



Reference Circles On The Celestial Sphere





Plan view of earth's orbit according to an observer looking down on to the north pole P" of the earth

* Images from Internet

Reference Circles On The Celestial Sphere

- If the earth's Equatorial Plane is extended out to cut the celestial sphere, it will intersect this along a great circle called the ***celestial Equator***, which lies mid-way between the Celestial Poles.
- All planes parallel to the equatorial one will cut the celestial sphere in small circles, called ***Parallels of Declination***. The celestial equator is, of these, the only one which is a great circle, and it therefore is taken as the prime declination circle, to which the others are referred.

Position of a Celestial Body

Coordinate Systems!

Reference Circles On The Celestial Sphere

- The position of any point on the surface the sphere may be fixed by angular measurements from two planes of reference at right angles to each other passing through the center of the sphere; these measurements are called the spherical coordinates of the point.

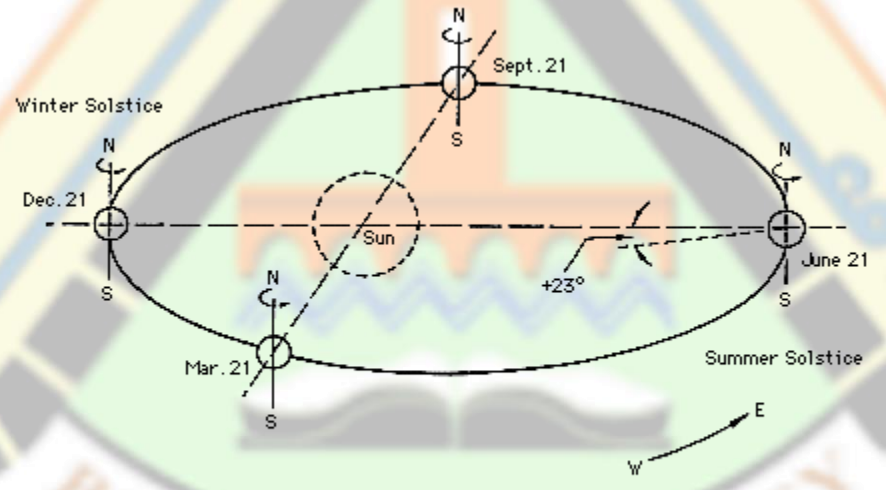


Figure 2. Relative positions of the earth and sun during a year.

(1) Horizon System

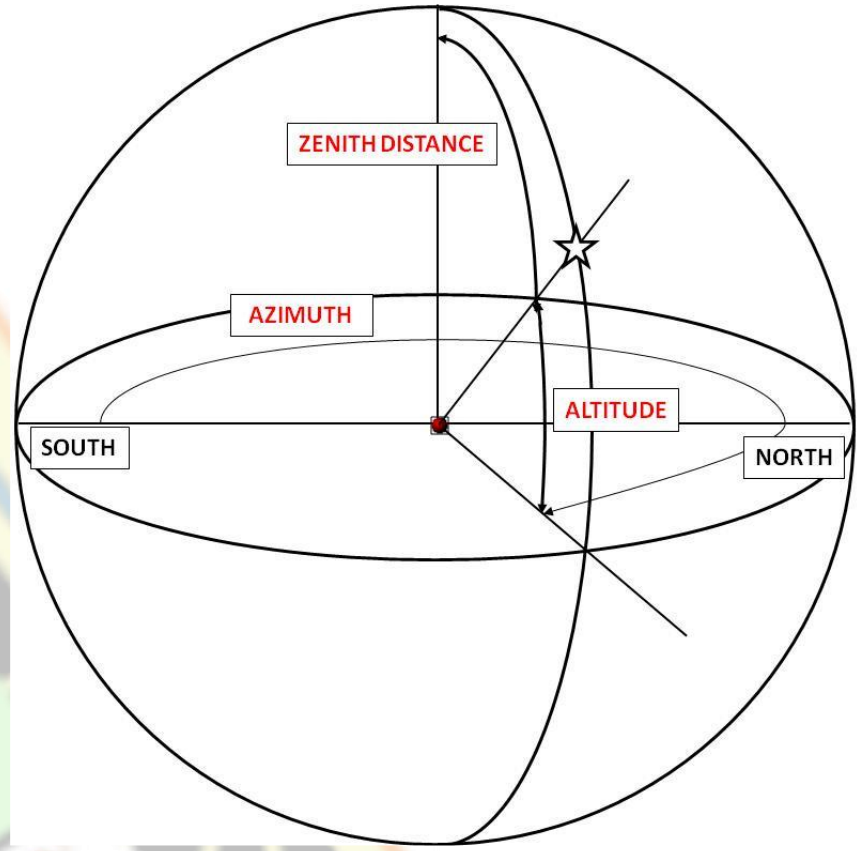
- In the horizon system of coordinates, the position of a star is uniquely specified by its azimuth and either its altitude or its zenith distance.

1. AZIMUTH (A) - the angular distance measured along the horizon from the observer's meridian to the vertical circle through the body.

2. ALTITUDE (h) – the angular distance measured along the vertical circle from the horizon to the celestial body.

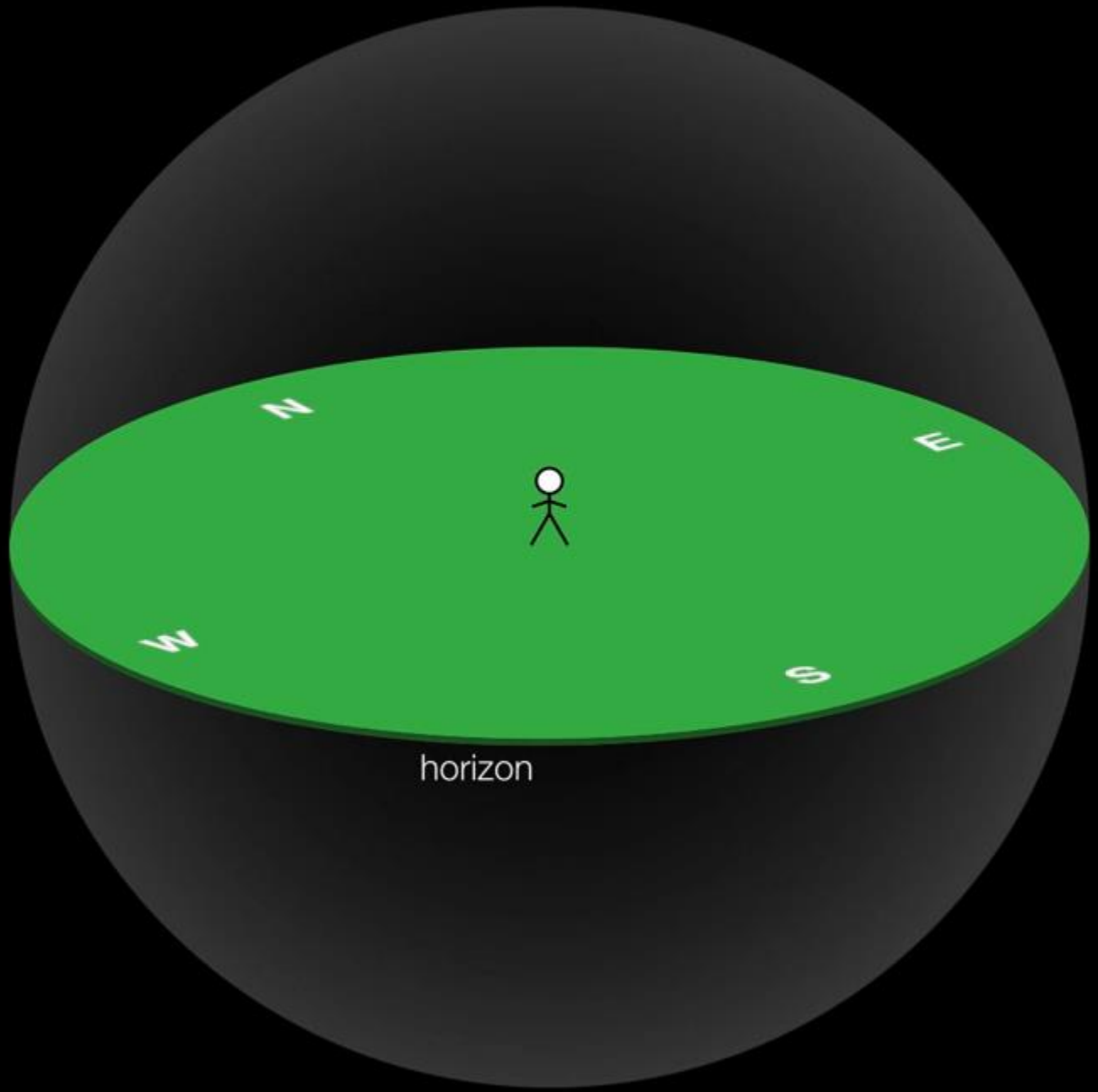
3. ZENITH DISTANCE (z) – the complement of the altitude. It is the angular distance measured from the zenith to the star along the vertical circle passing through the celestial body.

$$h + z = 90$$



- The Horizon System is also called the ***Altazimuth System***.

* Images from Internet


N
E
W
S
horizon

(2) Right Ascension System

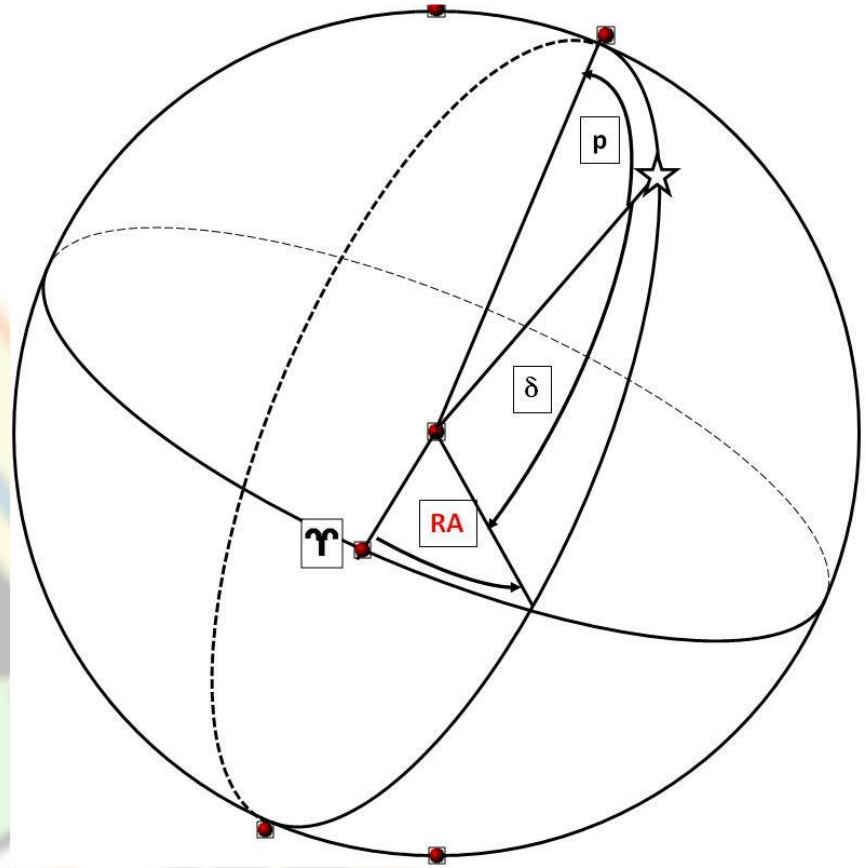
- In the Right Ascension System of coordinates, the position of a star is uniquely specified by its right ascension (RA) and either its declination (δ) or its polar distance (p).

1. RIGHT ASCENSION (RA) - The angle taken counter-clockwise along the celestial equator from the First Point of Aries (Vernal Equinox) to the hour circle of the star.

2. DECLINATION (δ) – the angular distance measured along the hour circle from the celestial equator to the celestial body.

3. POLAR DISTANCE (p) – the complement of the declination. It is the angular distance measured from the celestial pole to the star along the hour circle passing through the celestial body.

$$\delta + p = 90$$



* Images from Internet

(3) Hour Angle System

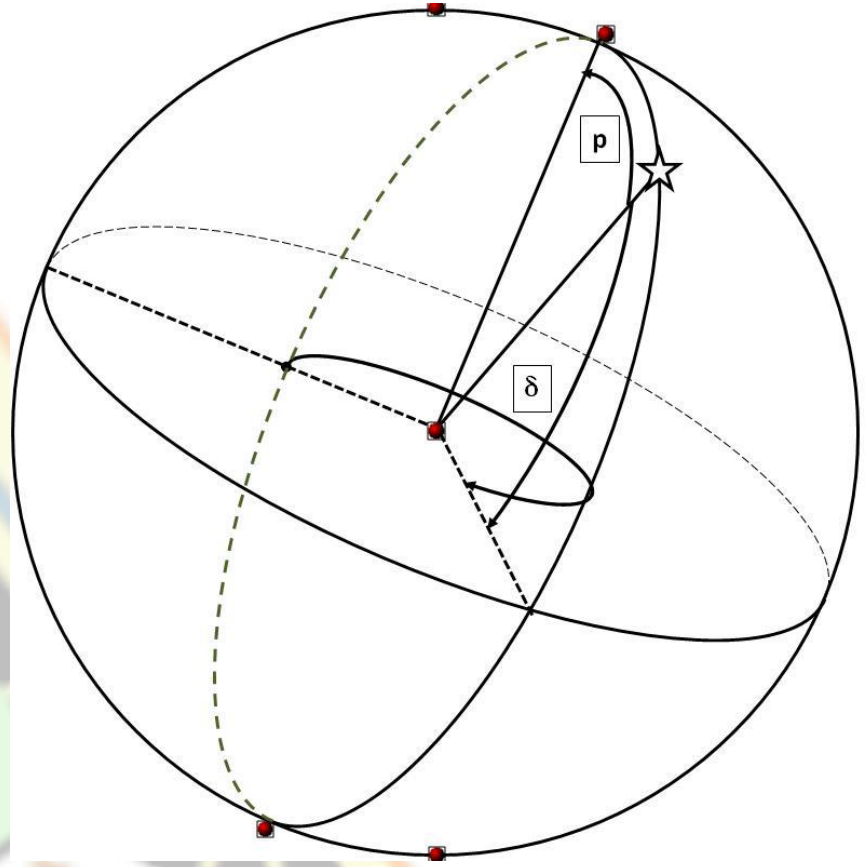
- In the hour angle system, the position of the celestial body is based on the location of the observer. The position of the star is defined by the local hour angle of the star and its declination or polar distance.

1. LOCAL HOUR ANGLE (LHA) – The angle measured clockwise from the upper branch of the meridian of observation to the meridian of the celestial body.

2. DECLINATION (δ) – the angular distance measured along the hour circle from the celestial equator to the celestial body.

3. POLAR DISTANCE (p) – the complement of the declination. It is the angular distance measured from the celestial pole to the star along the hour circle passing through the celestial body.

$$\delta + p = 90$$



* Images from Internet

(3) Hour Angle System

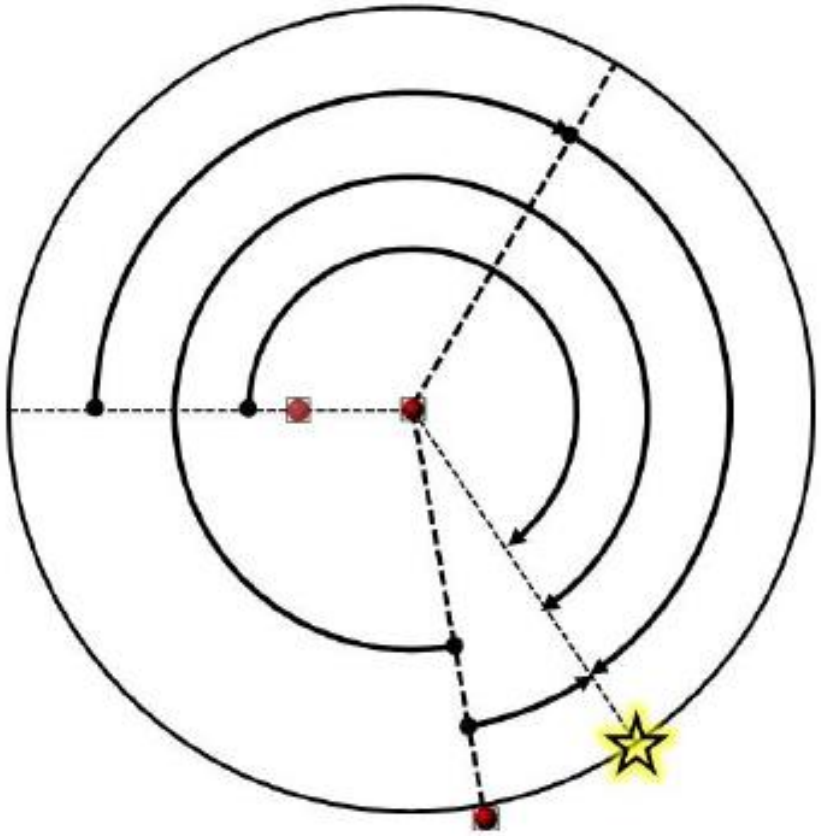
- The relationship between the Local Hour Angle (LHA), Greenwich Hour Angle (GHA), Sidereal Hour Angle, and the Right Ascension.

1. GREENWICH HOUR ANGLE (GHA) – The angle measured clockwise from the Greenwich Meridian to the Hour Angle of the star.

2. SIDEREAL HOUR ANGLE (SHA) - The angle measured clockwise from the Vernal Equinox to the Hour Angle of the star.

3. LONGITUDE (λ) – The longitude of the place of observation.

Since the earth rotates around its axis from west to east, all celestial bodies appear to rotate east to west. Therefore, when one faces north, the stars revolve around the North Celestial Pole in a counter-clockwise direction. A star which revolves around the North Celestial Pole and never goes below the observer's horizon is called *a circumpolar star*.



* Images from Internet

Relations Among Latitude (Φ), Altitude (H), And Declination (Δ)

- **LATITUDE (φ)** – the angular distance measured from the equator along the meridian of longitude to the vertical line through the observer's station.
- **DECLINATION (δ)** – the angular distance measured from the equator along the *hour circle* to the celestial body.
- **ALTITUDE (h)** – the angular distance measured from the horizon along the hour circle to the celestial body
- **POLAR DISTANCE (P)** – the angular distance measured from the polar axis along the hour circle to the celestial body
- **ZENITH DISTANCE (z)** – the angular distance measured from the vertical axis along the hour circle to the celestial body

WHY SHOULD GEOMATICS ENGINEER STUDY GEODETIC (*FIELD*) ASTRONOMY?

Uses of Field Astronomy

1. Knowledge of celestial coordinate systems, transformations amongst them, and variations in each of them.
2. Celestial coordinate systems define the *link* between satellite and terrestrial coordinate systems.
3. The concepts of time for geodetic purposes are developed.
4. Tidal studies require a knowledge of geodetic astronomy.
5. Astronomic coordinates of terrain points are essential when studying 3D terrestrial networks.

Uses of Field Astronomy

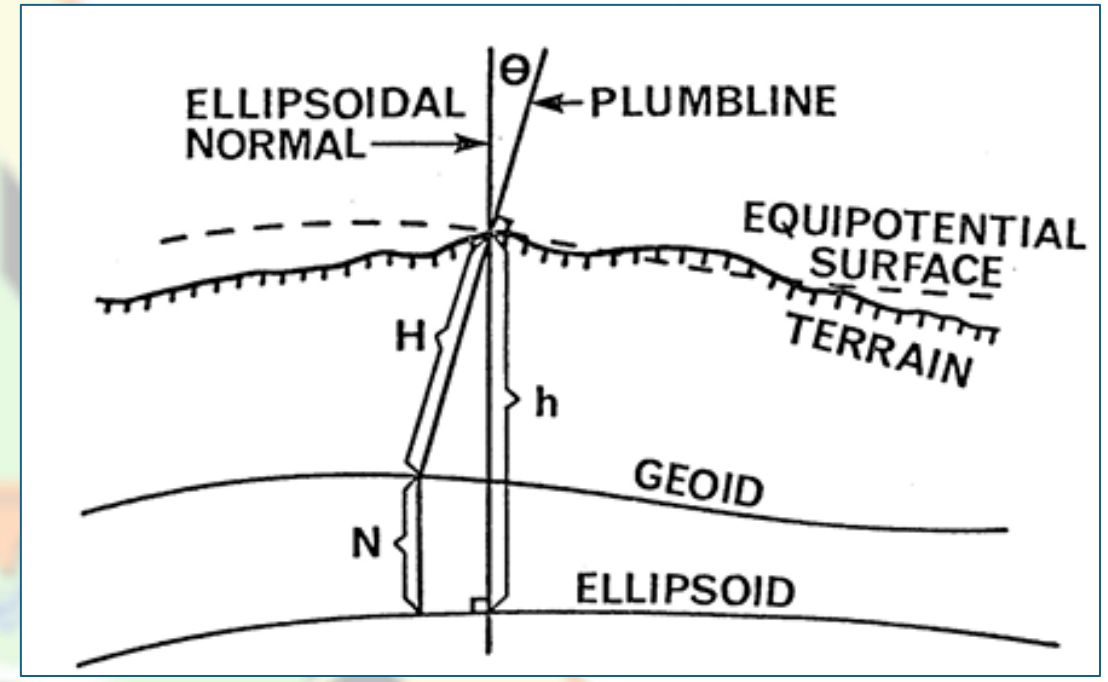
6. Astronomically determined azimuths provide orientation for terrestrial networks.
7. The determination of astrogeodetic deflections of the vertical are useful for geoid determination, which in turn may be required for the rigorous treatment of terrestrial observations such as distances, directions, and angles.
8. Geodetic astronomy is useful for the determination of the origin and orientation of independent surveys in remote regions.
9. Geodetic astronomy is essential for the demarcation of astronomically defined boundaries.

Uses of Field Astronomy

10. Determination of the astronomic longitudes and latitudes at some station of known geodetic coordinates are necessary for: -

a. Geoid determination

b. Rigorous reduction of terrestrial observations to the reference ellipsoid.



End Of Presentation

Thank You For Attention!