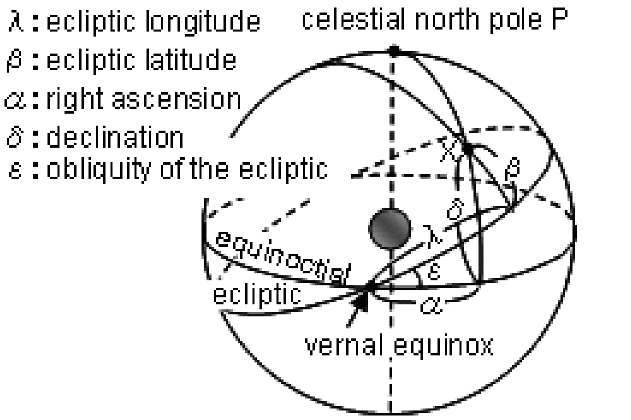
equinox. The angle between equator plane and ecliptic plane is 23.5°, which is known as the obliquity of the ecliptic (ε).

نظام الإحداثيات الكسوفي او البروجي هو نظام إحداثيات سماوية شائعة الاستخدام لتمثيل مواقع ومدارات اجسام النظام الشمسي. نظرًا لأن معظم الكواكب (باستثناء عطارد) لها مدارات ذات ميلان صغيرة عن الدائرة البروجيه، فمن المريح استخدامها كمستوي أساسي (المستوى الأساسي هي مستوى مدار الأرض، وتسمى المستوي البروجي او الكسوفي). يمكن أن يكون أصل النظام إما مركز الشمس أو مركز الأرض، واتجاهه الأساسي هو نحو الاعتدال الربيعي. الزاوية بين مستوى خط الاستواء والمستوى البروجي هي 23.5°، والتي تُعرف باسم ميل المحوري البروجي (ε).



ecliptic and equatorial coordinate system

Ecliptic longitude or celestial longitude (symbols: λ) measures the angular distance of an object along the ecliptic (counterclockwise) from the primary direction (vernal equinox) (0° ecliptic longitude) (0°-360°).

Ecliptic latitude or celestial latitude (symbols: β), measures the angular distance of an object from the ecliptic towards the north (positive) or south (negative) ecliptic pole. For example, the north ecliptic pole has a celestial latitude of +90° (+90°,-90°).

زاوية الطول البروجي أو الطول السماوي تقيس المسافة الزاوية للجسم على طول البروج (عكس اتجاه عقارب الساعة) من الاتجاه الأساسي (الاعتدال الربيعي حيث زاوية الطول البروجي 0 °) (0°-360°).

زاوية العرض البروجي أو العرض السماوي تقيس المسافة الزاوية للجسم من دائرة البروج نحو القطب البروجي الشمال (الإيجابي) أو الجنوبي (السلبي). على سبيل المثال، يحتوي القطب البروجي الشمالي على خط عرض سماوي +90 درجة

2. Converting Coordinates:

Conversions between the various coordinate systems are given. Notes on conversion:

- λ_o – observer's longitude.
- φ_o – observer's latitude.
- ε – obliquity of the ecliptic 23.5°
- Angles in the hours (^{h}), minutes (^{m}), and seconds (^{s}) of time measure must be converted to decimal degrees or radians before calculations are performed.
  $1^h = 15°$ $1^m = 15'$ $1^s = 15''$
- Angles greater than 360° (2π) or less than 0° may need to be reduced to the range 0° - 360° (0 - 2π) depending upon the particular calculating machine or program.
- An object on the meridian to the south of the observer has $A = h = 0°$ with this usage.

- **Equatorial ←→ horizontal**

Note that Azimuth (A) is measured from the South point, turning positive to the West. Zenith distance, the angular distance along the great circle from the zenith to a celestial object, is simply the complementary angle of the altitude: 90° − *E*.

$$\tan A = \frac{\sin h}{\cos h \sin \phi_o - \tan \delta \cos \phi_o} \quad \text{.........(3)}$$

$$\sin E = \sin \phi_o \sin \delta + \cos \phi_o \cos \delta \cos h \quad \text{...........(4)}$$

$$\tan h = \frac{\sin A}{\cos A \sin \phi_o + \tan E \cos \phi_o} \quad \text{..........(5)}$$

$$\sin \delta = \sin \phi_o \sin E - \cos \phi_o \cos E \cos A \quad \text{..........(6)}$$

The altitude of an object is greatest when it is on the south meridian (the great circle arc between the celestial poles containing the zenith). At that moment (called upper **culmination**, or **transit**) its hour angle is 0 h. At the lower culmination the hour angle is h = 12 h. When h = 0 h, from the equation (4)

$$\sin E = \cos \delta \cos \phi + \sin \delta \sin \phi$$
$$= \cos(\phi - \delta) = \sin(90^\circ - \phi + \delta) \,.$$

Thus, the altitude at the upper culmination is

$$E_{max} = 90^\circ - \emptyset + \delta \quad \text{.........(7)}$$

The altitude is positive for objects with $\delta > \varphi - 90^\circ$. Objects with declinations less than $\varphi - 90^\circ$ can never be seen at the latitude φ. On the other hand, when h = 12 h we have

$$\sin E = -\cos \delta \cos \phi + \sin \delta \sin \phi$$
$$= -\cos(\delta + \phi) = \sin(\delta + \phi - 90^\circ) \,,$$

and the altitude at the lower culmination is

$$E_{min} = \delta + \phi - 90^\circ \,. \quad \text{..........(8)}$$

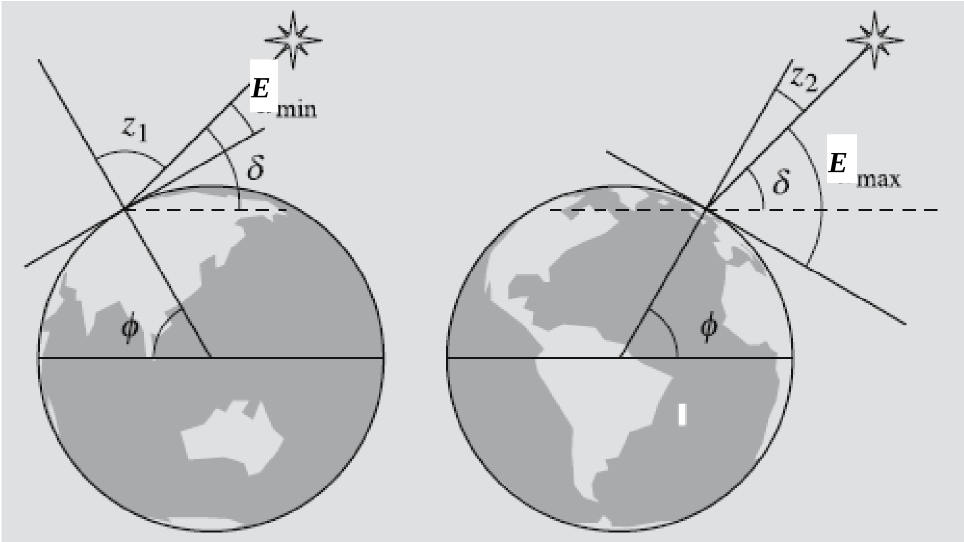
Stars with $\delta > 90^\circ - \varphi$ will never set. For example, in Helsinki ($\varphi \approx 60^\circ$), all stars with a declination higher than 30° are such circumpolar stars. And stars with a declination less than 30° can never be observed there.

Suppose we observe a circumpolar star at its upper and lower culmination. At the upper transit, its altitude is $E_{max} = 90^\circ - \varphi + \delta$ and at the lower transit, $E_{min} = \delta + \varphi - 90^\circ$.

Eliminating the latitude, we get

$$\delta = \frac{1}{2}(E_{min} + E_{max}) \quad \text{.........(9)}$$

Thus, we get the same value for the declination, independent of the observer's location.



The altitude of a circumpolar star at upper and lower culmination

- **Rising and Setting Times**

From the eq. (4), we find the hour angle *h* of an object at the moment its altitude is *E*:

$$\cos h = -\tan\delta\tan\phi + \frac{\sin E}{\cos\delta\cos\phi}\ . \qquad \text{........(10)}$$

This equation can be used for computing rising and setting times. Then *E* = 0 and the hour angles corresponding to rising and setting times are obtained from

$\cos h = -\tan\delta\tan\varphi$ …………………(11)

If higher accuracy is needed, we have to correct for the refraction of light caused by the atmosphere of the Earth. In that case, we must use a small negative value for *E* in (10). This value, the horizontal refraction, is about **−34′.**

- **Equatorial ←→ ecliptic**

The classical equations, derived from spherical trigonometry,

$$\tan\lambda = \frac{\sin\alpha\cos\varepsilon + \tan\delta\sin\varepsilon}{\cos\alpha}; \qquad \text{.......(12)}$$

$$\sin\beta = \sin\delta\cos\varepsilon - \cos\delta\sin\varepsilon\sin\alpha \text{..........(13)}$$

$$\tan\alpha = \frac{\sin\lambda\cos\varepsilon - \tan\beta\sin\varepsilon}{\cos\lambda}; \qquad \text{..........(14)}$$

$$\sin\delta = \sin\beta\cos\varepsilon + \cos\beta\sin\varepsilon\sin\lambda \quad \text{...............(15)}$$

Example 1 : Find the altitude and azimuth of the Moon in Helsinki at midnight at the beginning of 1996. The right ascension is $\alpha = 2^h\ 55^m\ 7^s = 2.9186$ h and declination $\delta = 14^\circ\ 42' = 14.70^\circ$, the sidereal time is $\Theta = 6^h\ 19^m\ 26^s = 6.3239^h$ and latitude $\varphi = 60.16^\circ$.

Example 2 : The coordinates of Arcturus are $\alpha = 14^h\ 15.7^m$, $\delta = 19^\circ\ 11'$. Find the sidereal time at the moment Arcturus rises or sets in Boston ($\varphi = 42^\circ\ 19'$). neglecting refraction.

Example 3 : The right ascension of the Sun on June 1, 1983, was $4^h\ 35^m$ and declination $22^\circ\ 00'$. Find the ecliptic longitude and latitude of the Sun and the Earth.

Example 4 : A star of azimuth (A)=221.22^o from the south and altitude (E)= 22.076^o is observed when its sidereal time is $8^h16^m42^s$ .If the observer's latitude (ϕ) is 60^o N, calculate the star's ecliptic longitude (λ) and ecliptic latitude (β) at the time of observation.

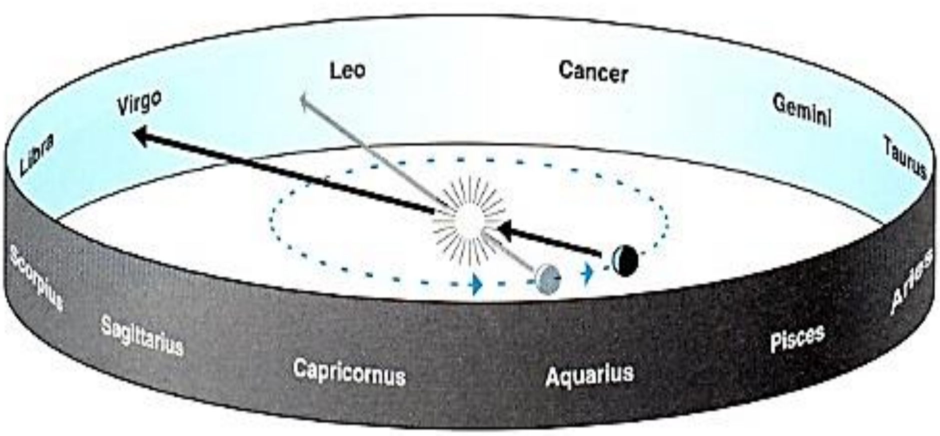
Ecliptic and Zodiac

The ecliptic is an imaginary line on the sky that marks the annual path of the sun. It is the projection of Earth's orbit onto the celestial sphere, and is the basis for the ecliptic coordinate system.

Zodiac: an imaginary band, centered on the ecliptic, across the celestial sphere and about 16°-18° wide, in which the Sun, Moon and the planets Mercury, Venus, Jupiter and Saturn are always located. The band is divided into 12 intervals of 30°, each named (the Signs of the Zodiac) after the constellation of stars which it contains.

الخط البروجي هو خط وهمي على السماء الذي يمثل المسار السنوي للشمس. إنه إسقاط مدار الأرض على الكرة السماوية، وهو أساس لنظام الإحداثيات البروجي.

دائرة البروج: حزام وهمي، مركزه الخط البروجي، عبر الكرة السماوية وعرضها حوالي 16 درجة إلى 18 درجة، حيث توجد دائمًا الشمس والقمر والكواكب عطارد والزهرة والكوكب المشتري والزحل. ينقسم الحزام إلى 12 مسافة ب 30 درجة، كل واحده اسمها (علامات البروج) حيث الكوكبة النجمية التي تحتوي عليها.



The zodiac signs come from the constellations which lie along the ecliptic (red line).