X
TIME (1)

Kepler's First Law

A planet travels around the Sun in an elliptical orbit as shown, where the Sun is at one of the foci.

The planet will be at its closest point known as '**perihelion**' and is at a point furthest from the Sun known as '**aphelion**'. Perihelion occurs in early January (approx 4th). Aphelion occurs in early July (approx 3rd).

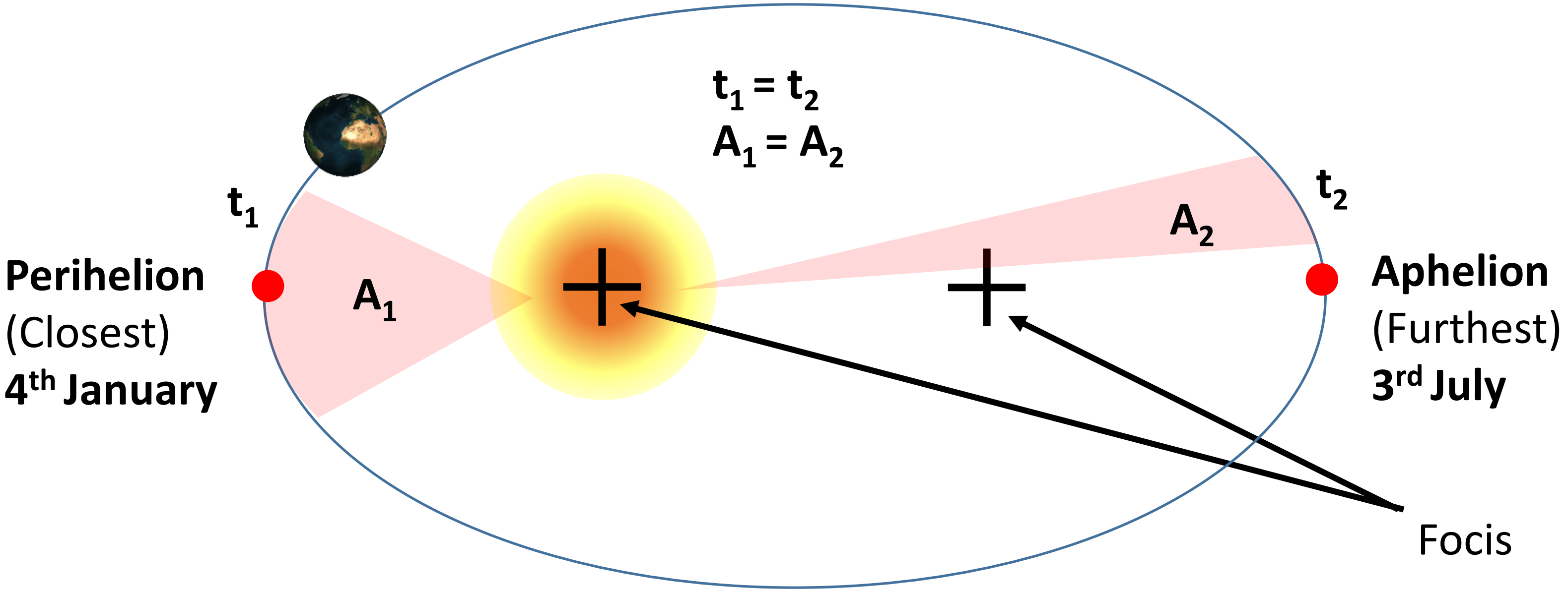
Kepler's Second Law

The radius Earth-Sun sweeps equal areas (**A**) at equal time (**t**). The Earth travels faster near the perihelion and slower near the aphelion.

Kepler's Third Law

The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.

Johannes Kepler (1571-1630) German astronomer, mathematician, and astrologer



MEASUREMENT OF DAYS AND YEARS

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, (the Sun or a star). Measurements against a star are called ‘sidereal’ and against the Sun are called ‘solar’.

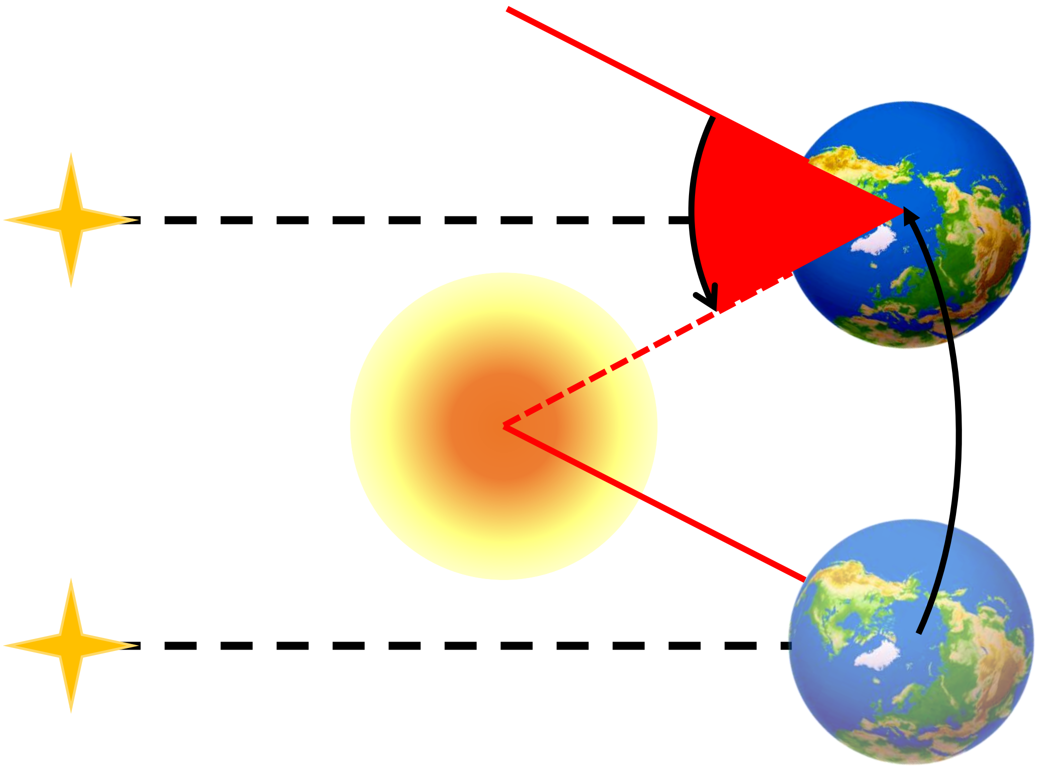
Sidereal Day

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 (the one that ‘appears’ to you).

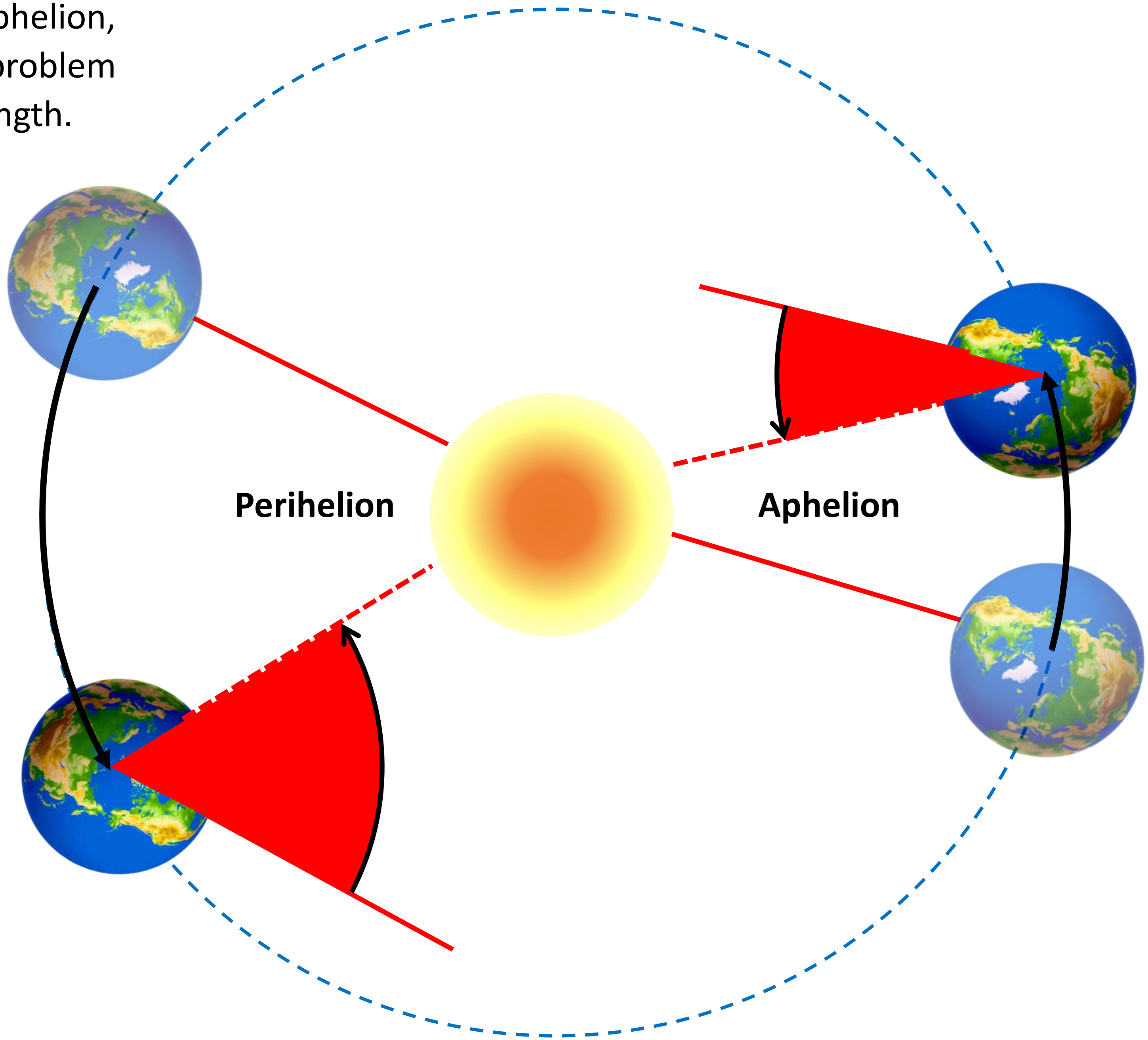
Compared to a distant star, the Earth will have After 360° rotation, the same orientation to that start. However, compared to the apparent Sun, the Earth will need to make an additional rotation to obtain the same orientation to the apparent Sun. This means that, **an apparent Solar Day is longer than a Sidereal Day**.



Remember, the Earth orbits at different speed, it will faster near the Perihelion and slower near the Aphelion, so using the apparent (real) Sun introduces the problem of the Apparent Solar Day not being a constant length. For that, we need to make an average.

Mean Solar Day

The 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. **we consider the mean (average) Sun circling the earth every 24 hours**.



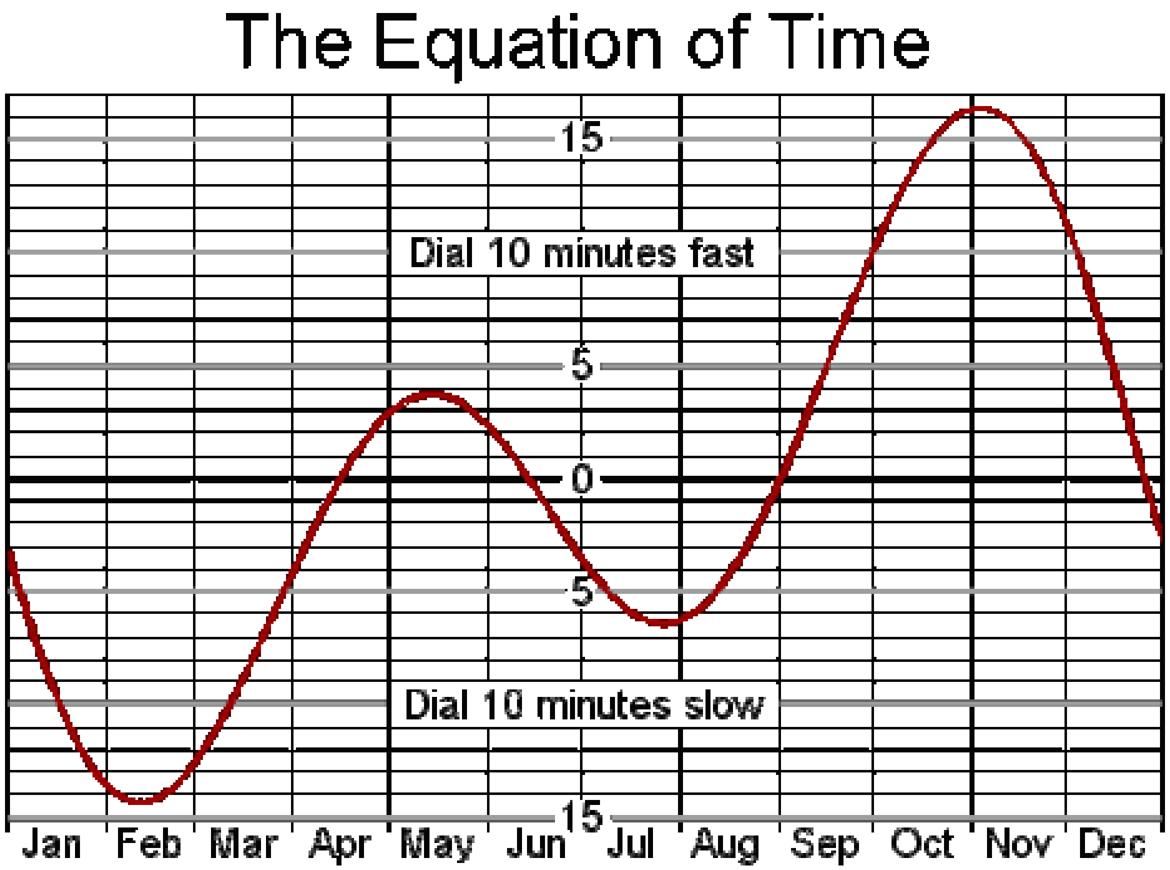
'Civil' Day

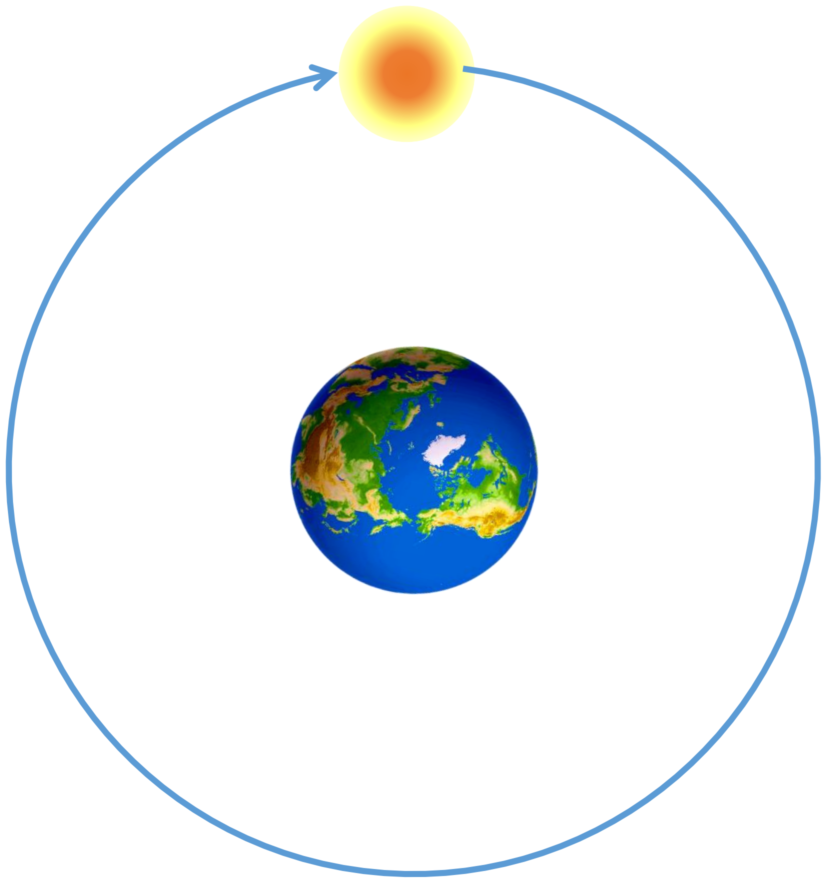
A 'civil' day should be:

- Related to periods of light and darkness so that 1200 hrs is always about halfway between sunrise and sunset. The civil day should therefore be based on the Sun.
- Of a constant length.

It is sometimes helpful to think of the Sun traveling westwards around the Earth rather than the earth spinning eastwards. We consider the mean (average) Sun circling the earth every 24 hours. This is the basis of Local Mean Time (LMT).

The maximum difference between Mean Time and apparent (real) sun time is about 16 minutes and occurs in mid-November. A second maximum occurs in mid-February at about 14 minutes difference. In between these maxima, the difference reduces. The difference is known as the Equation of Time.





Angle Hours – Local Mean Time (LMT)

The Earth rotation angular speed is:

360°/24 h

15°/ h *or 15°/60 min*

1°/ 4 min *or 60'/4 min*

15'/ min *or 15'/60 sec*

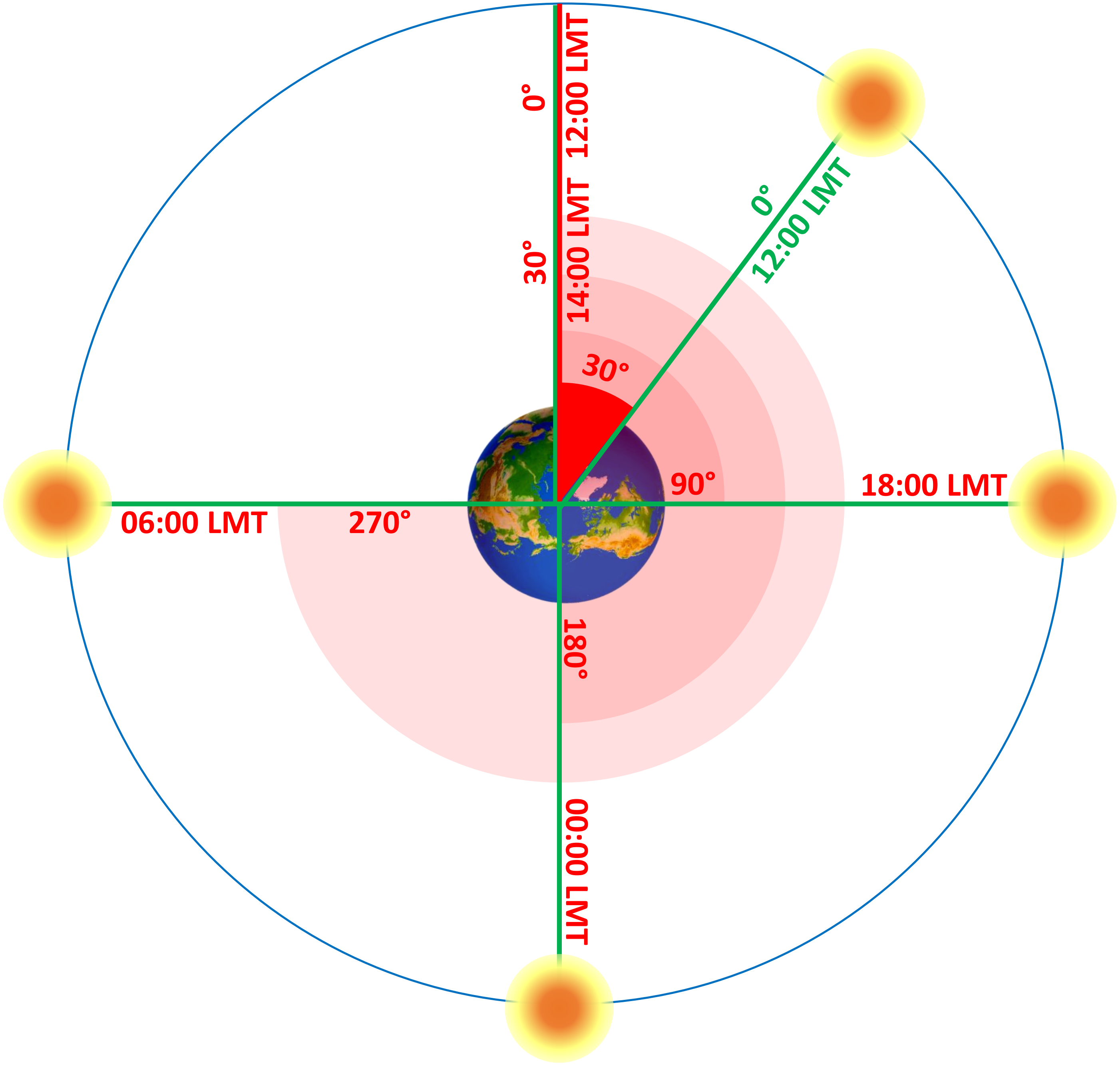
1'/ 4 sec *or 60"/4 sec*

15"/ sec

When the Mean Sun is in transit with a **meridian**, it will reach the zenith (highest point in the sky). The angle between the **meridian** and **the radius Mean Sun-Earth** is **0°**, where the **LMT is 12:00** (12pm)

The angle between the **meridian** and the **radius Mean Sun-Earth** is measured clockwise for the current meridian. If it is **30°**, 30/15=2, it is **LMT is 14:00** (2pm)

However, it is **12:00 LMT** at the **meridian** where the Sun is in transit (**0°**)



Sidereal Year

It’s the time taken by the Earth to complete an orbit of the Sun measured against a distant star. Its length is 365 days 6 hrs.

A Tropical Year (an apparent solar year)

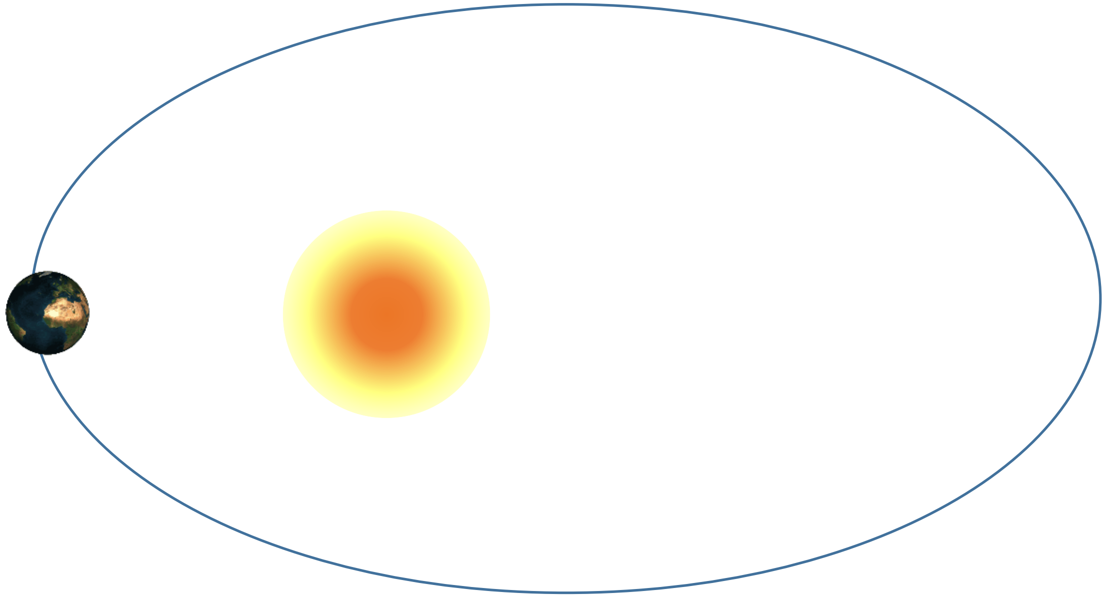
It’s the length of one cycle of the seasons. Its length is 365 days, 5 hrs 48 min 45 sec

Calendar Year

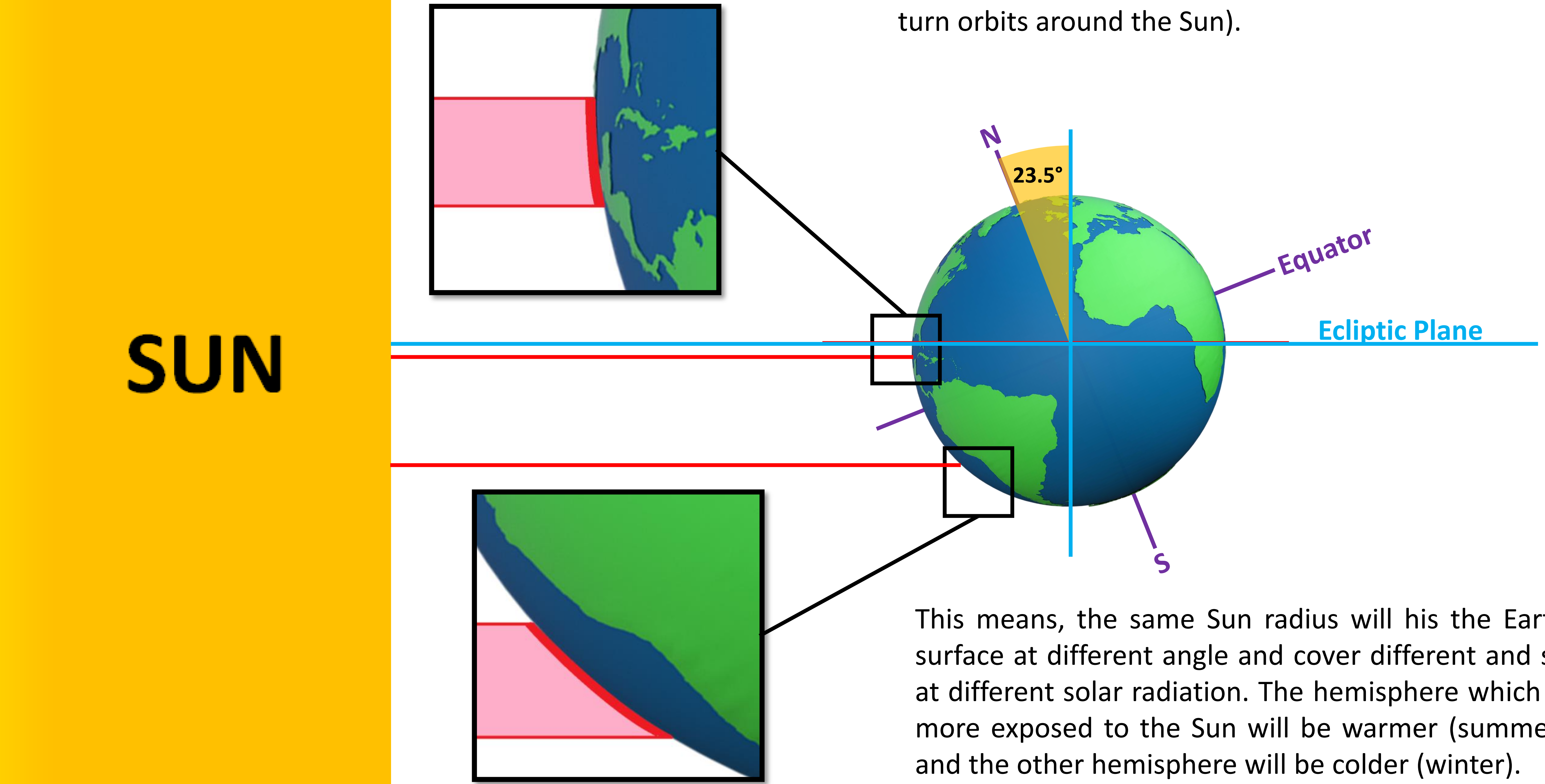
It’s normally 365 days. It is kept in step with the tropical year by adding a day every 4th year, a ‘leap’ year. A fine adjustment is made on 3 occasions every 400 years.

365 days, 5 hrs 48 min 45 sec	After 4 years, we gain	After 8 years, we gain	After 16 years, we gain	After 128 years, we gain
365 days, 6 hrs 00 min 00 sec	***4x 0 hrs 11 min 15 sec***	***8x 0 hrs 11 min 15 sec***	***16x 0 hrs 11 min 15 sec***	***128x 0 hrs 11 min 15 sec***
→ 0 day, 0 hrs 11 min 15 sec	***= 0 hrs 45 min 00 sec***	***= 1 hrs 30 min 00 sec***	***= 3 hrs 00 min 00 sec***	***= 24 hrs 00 min 00 sec***

(At a centennial, when the first 2 numbers of the century are not divisible by 4, the leap year is omitted.)

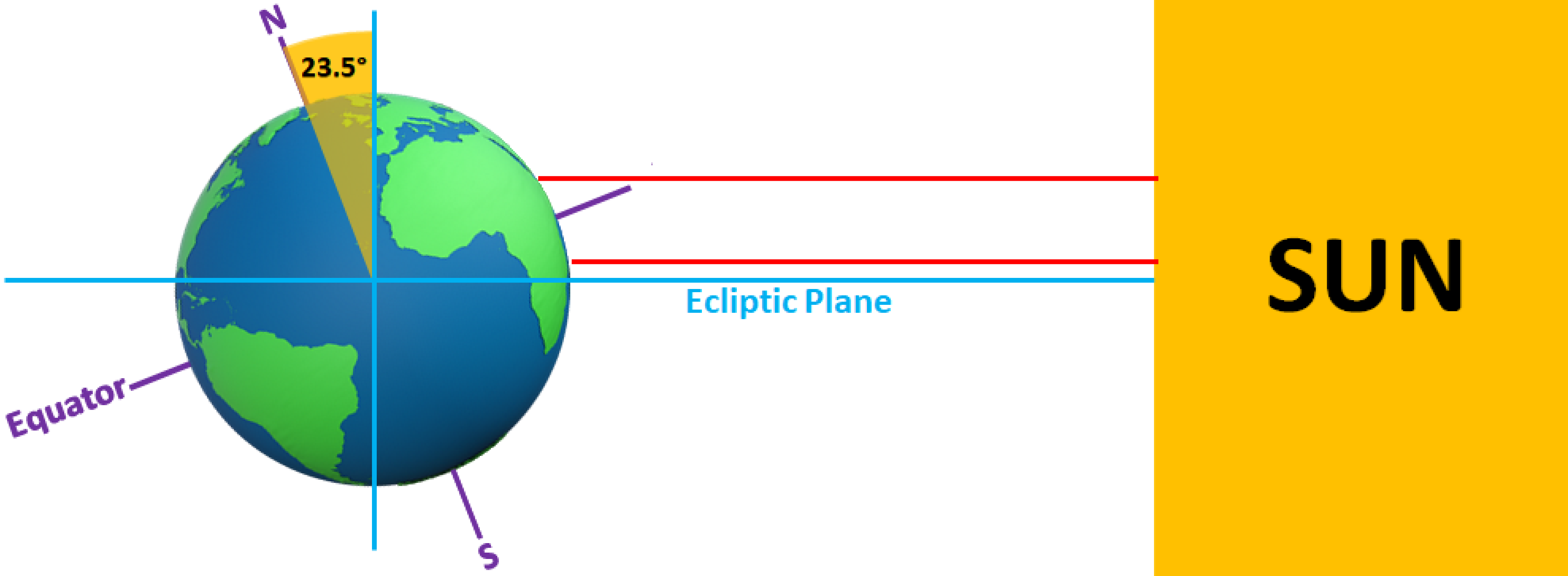


The Earth polar axis is tilted about 23.5° from the plan perpendicular to the **ecliptic plan** (plan on which the turn orbits around the Sun).



This means, the same Sun radius will his the Earth surface at different angle and cover different and so at different solar radiation. The hemisphere which is more exposed to the Sun will be warmer (summer) and the other hemisphere will be colder (winter).

The opposite phenomena will happen 6 months later, this what explains the seasons on Earth and opposite seasons in the two hemispheres

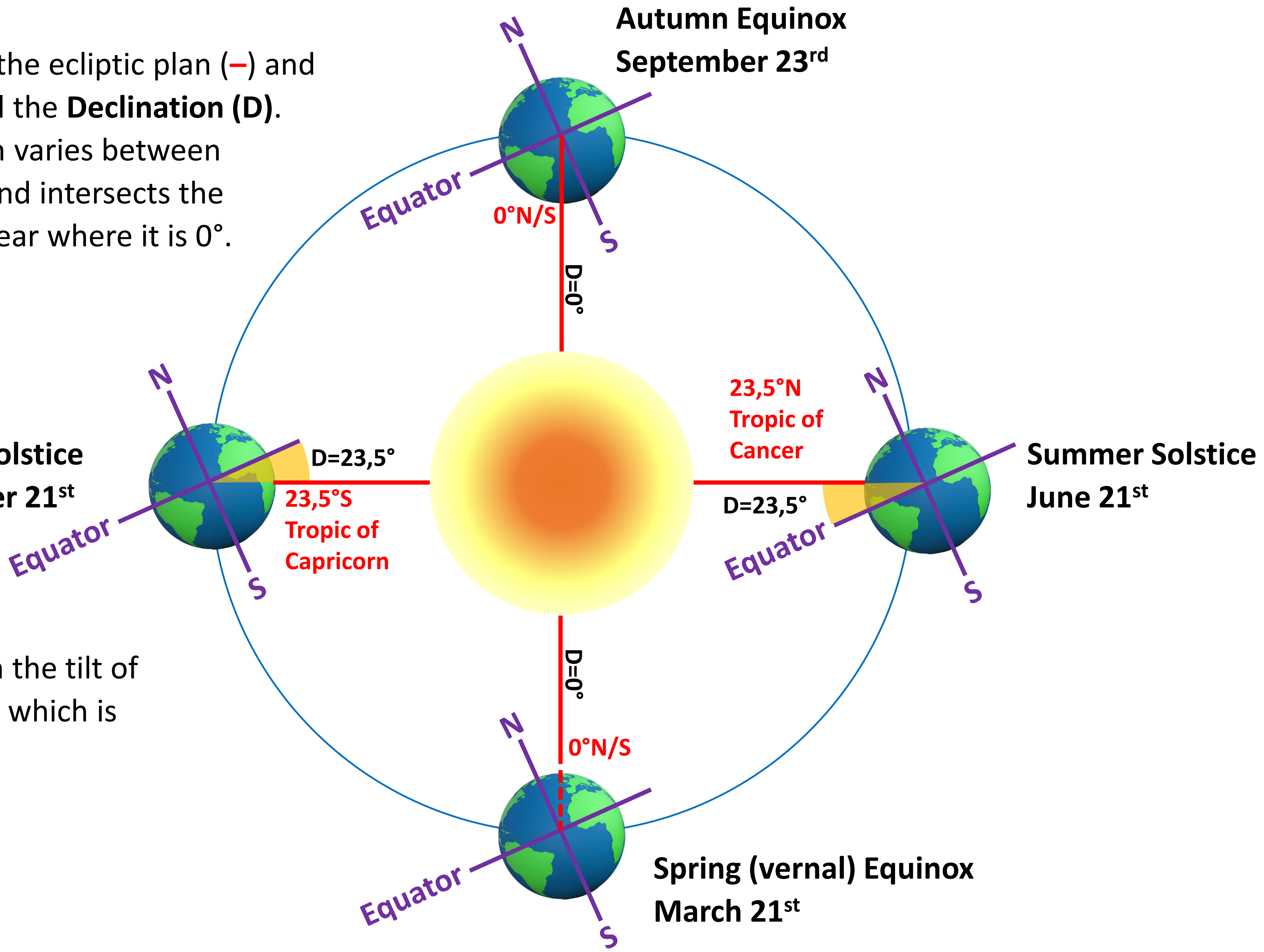


The seasons are caused by the tilt of the Earth's polar axis and its orbit around the Sun

Sun Declination

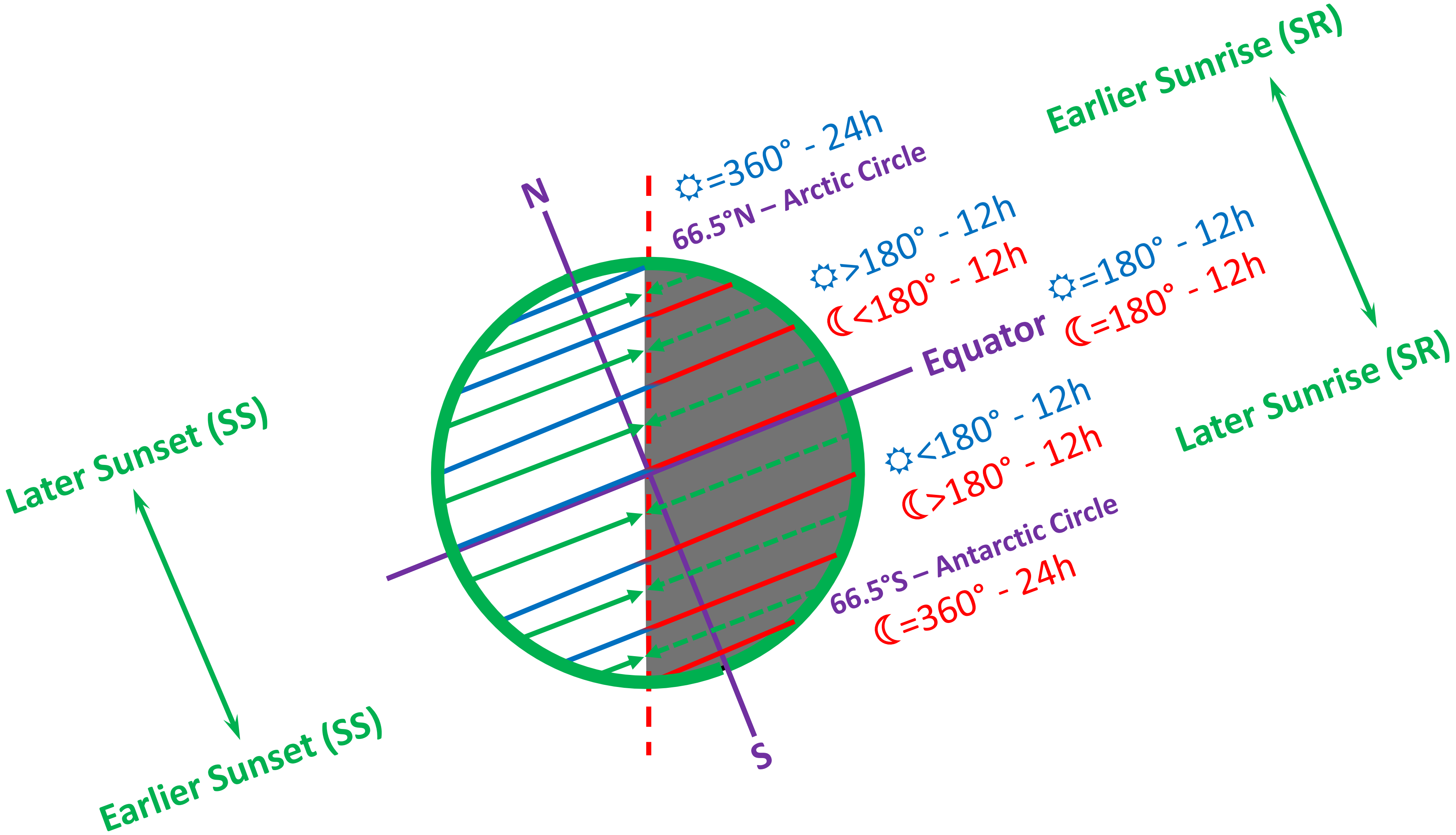
The angle between the ecliptic plan (–) and the Equator is called the **Declination (D)**.

The Sun Declination varies between 23.5°N and 23.5°S and intersects the Equator twice in a year where it is 0°.

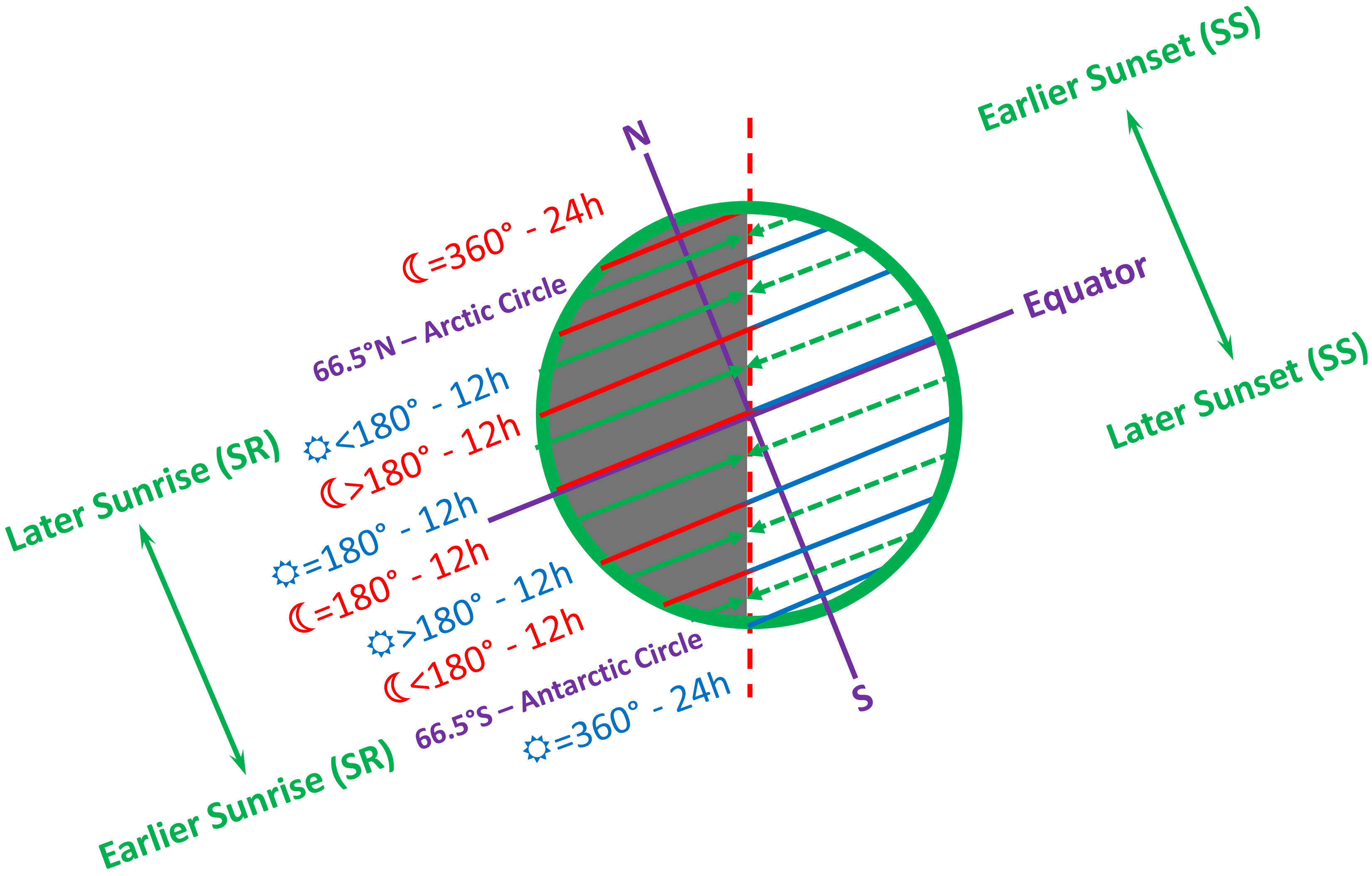


Do not confuse with the tilt of the Earth' polar axis which is always 23.5°.

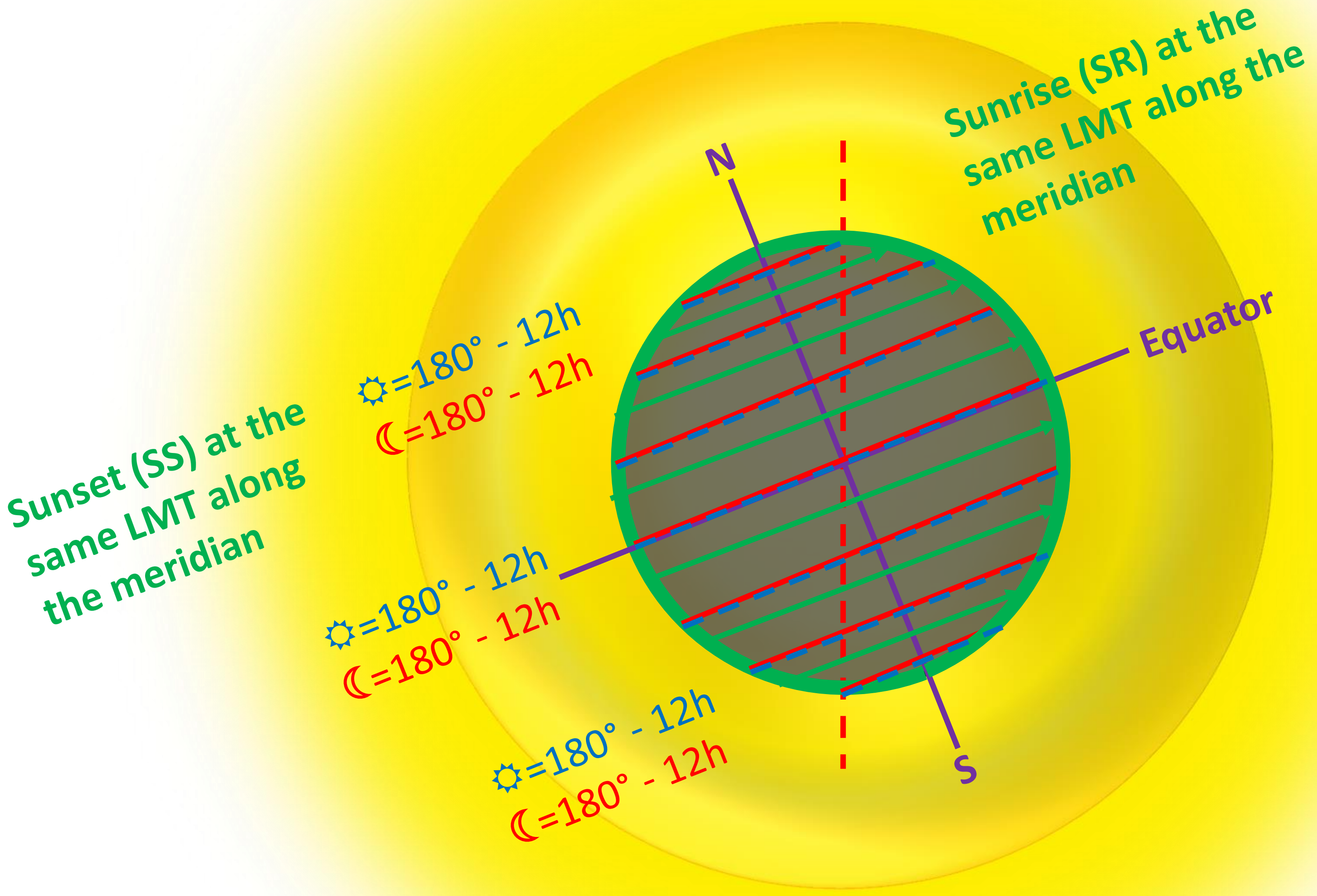
Summer Solstice - June 21st
Declination 23.5°N (Tropic of Cancer)



Winter Solstice - December 21st
Declination 23.5°S (Tropic of Capricorn)

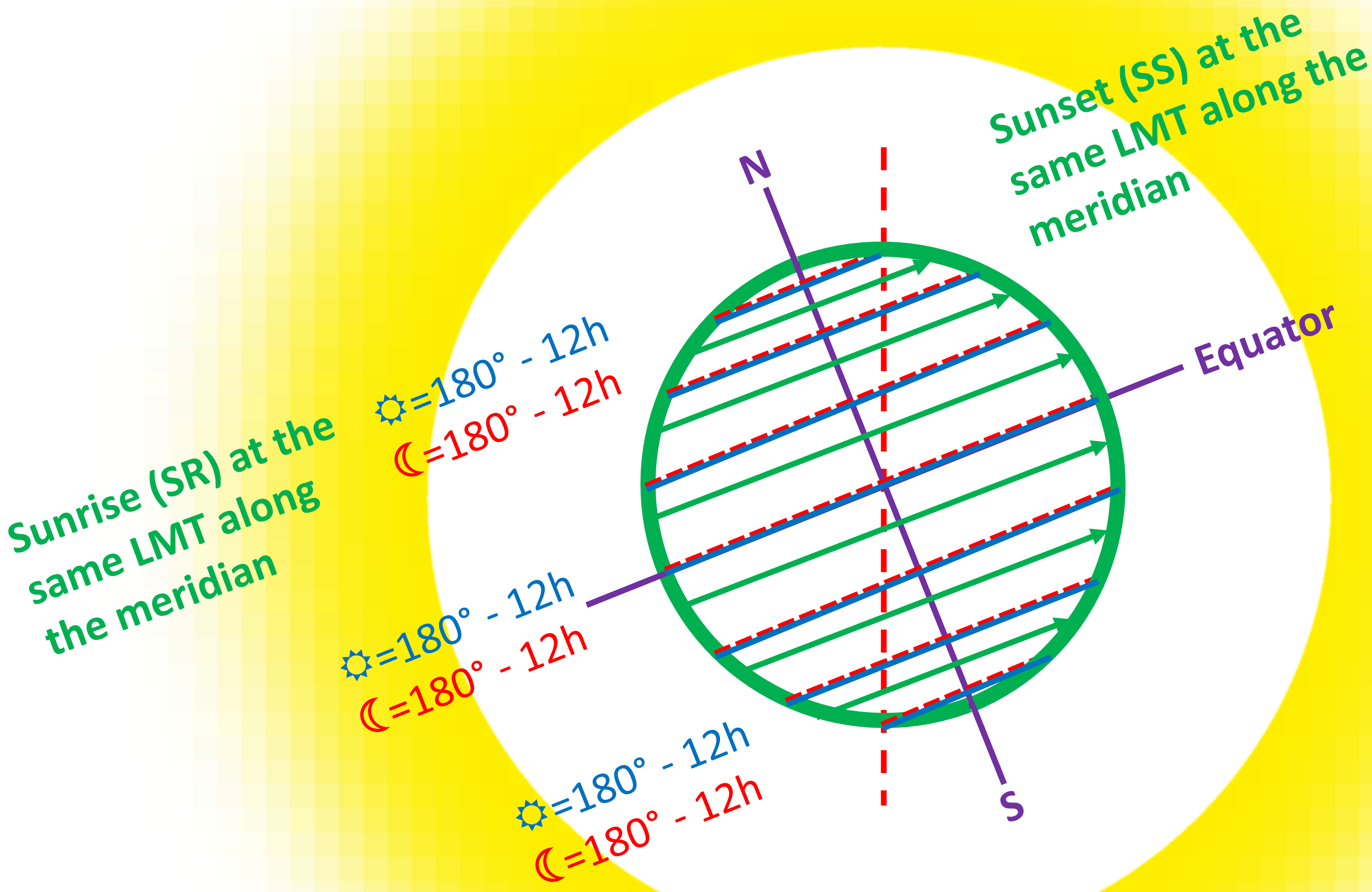


Spring (vernal) Equinox - March 21st
Declination 0°N/S (Equator)

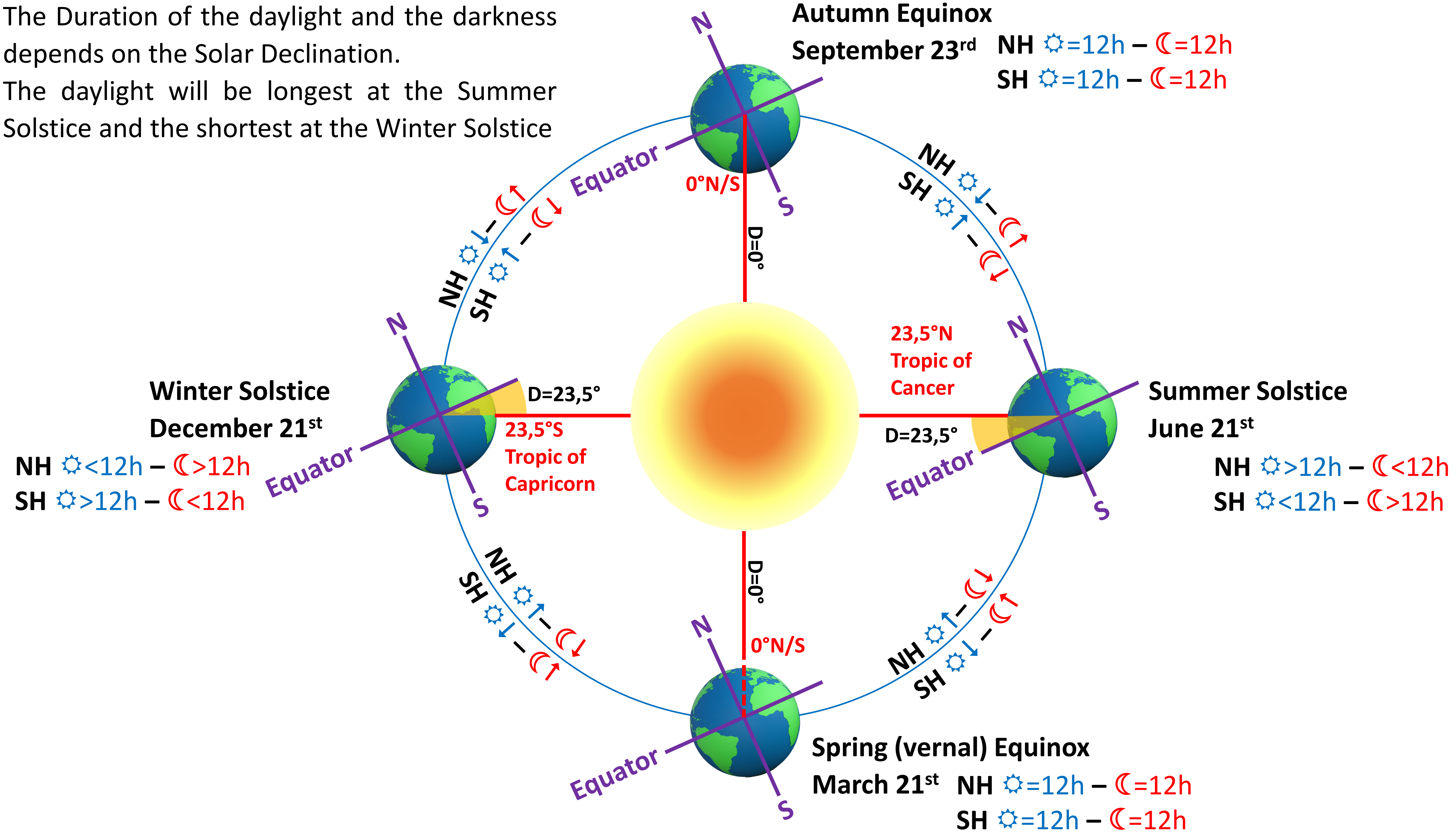


Autumn Equinox - September 23rd

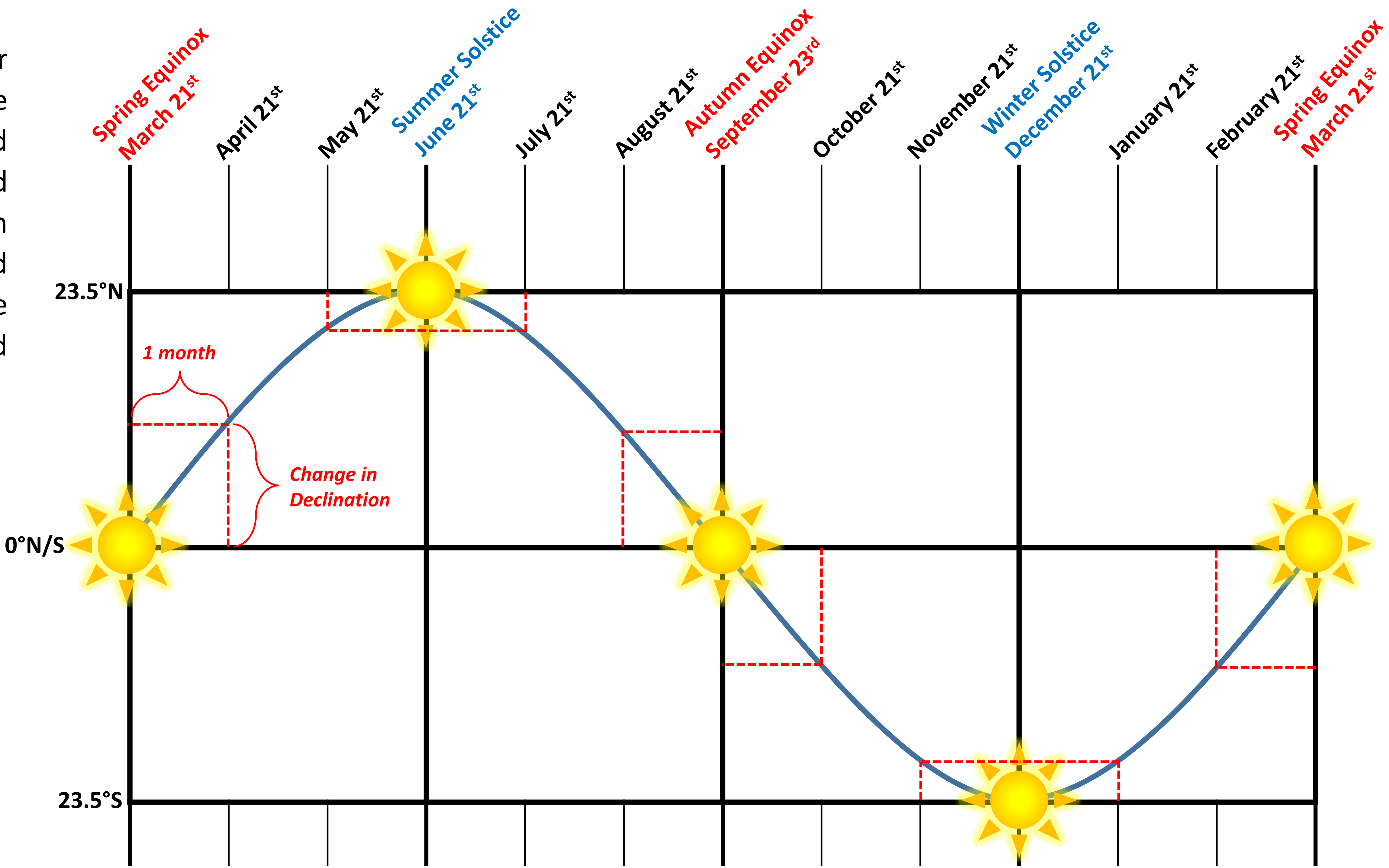
Declination 0°N/S (Equator)



The Duration of the daylight and the darkness depends on the Solar Declination.
The daylight will be longest at the Summer Solstice and the shortest at the Winter Solstice



The variation over the year of the Sunrise (SR) and Sunset (SS) is caused by the declination between the Sun and the Earth and the Earth's orbit around the Sun.



The biggest variations of the SR and the SS will occur near the equinoxes

However, the biggest difference between SRs and SSs over one meridian, will occur near the solstices

XI
TIME (2)

The Universal Time Coordinated (UTC), is time set according to Mean Solar Time of the **Greenwich meridian**, and it is measured with an atomic clock. This time is used to coordinate events that occur at different locations on Earth.

In aviation, UTC is the time standard used, e.g. for flight plans and air traffic control. Weather forecasts and maps all use UTC to avoid confusion about time zones and daylight saving time.

In some countries, the term Greenwich Mean Time (GMT) is used, however this is confusion because GMT is a time zone which is subject to Daylight Saving Time, and UTC is fixed time without any variation.

In theory, it exist 24 time zones separated at the marginal meridians (7°30'W, 7°30'E, 22°30'E, 37°30'E etc). The time zone around Greenwich meridian is UTC+0.

UTC is also called ZULU (Z) for UTC+0 (zero)

Example:

10:00 UTC Can also be written **10:00Z**

The first time zone east of UTC will deviate by 1 hour faster from UTC (UTC+1), the second by 2 hours faster (UTC+2), etc
The first time zone west of UTC will deviate by 1 hour slower from UTC (UTC-1), the second by 2 hours slower (UTC-2), etc

20ème siècle

The Standard Time (ST) is the time deviation from UTC set by local authority. Each authority is free to align on the needed time zone for geopolitical, economical or entities purpose, and they are free to adjust their time zone if necessary. Some local authorities find it more suitable to be one day ahead by using UTC+13 or UTC+14 instead of UTC-11 or UTC-12.

Example:
The Lithuania ST is aligned on the **Eastern European Time (EET)**, where **EET = UTC+2**
Which means, if it is 15:00UTC or 15:00Z, the time in Lithuania is 17:00 ST.

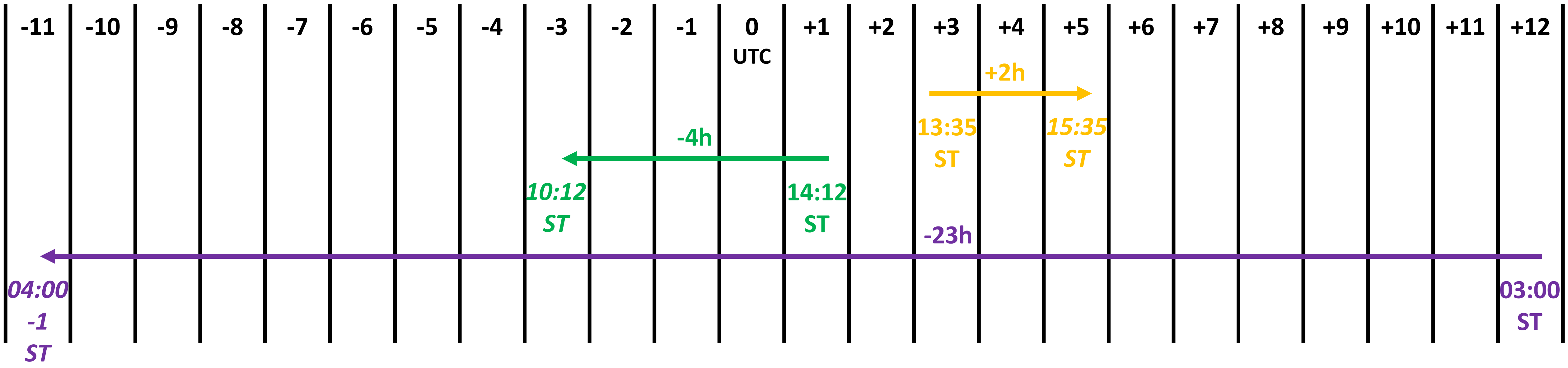
Daylight Saving Time
It is a yearly adjustment that consist of setting the ST **one hour faster**. Not all the authorities are applying it, where some of them used to, some of them are still applying it, and some even decided to remain on this adjustment.

Example:
The **Eastern European Time (EET)**, which is **EET = UTC+2**,
become the **Eastern European Summer Time (EEST)**, which is **EEST = UTC+3** (UTC+2 +1).

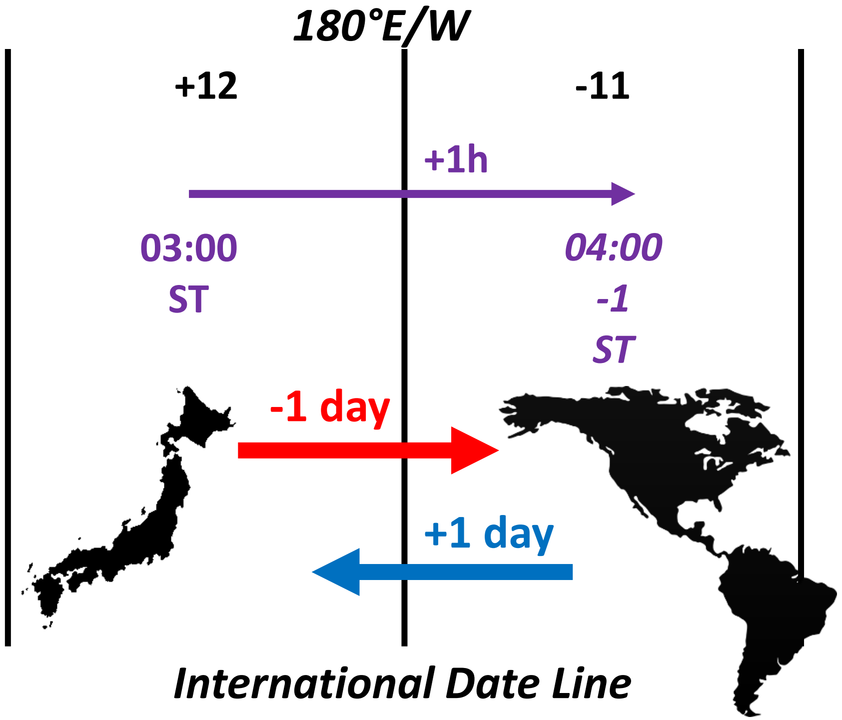
or
The **Greenwich Mean Time (GMT)**, which is **GMT = UTC**,
become the **Greenwich Mean Summer Time (GMST)**, which is **GMST = UTC+1**
This is why we use UTC and not GMT, become GMT is subject to the daylight saving time while the UTC is not

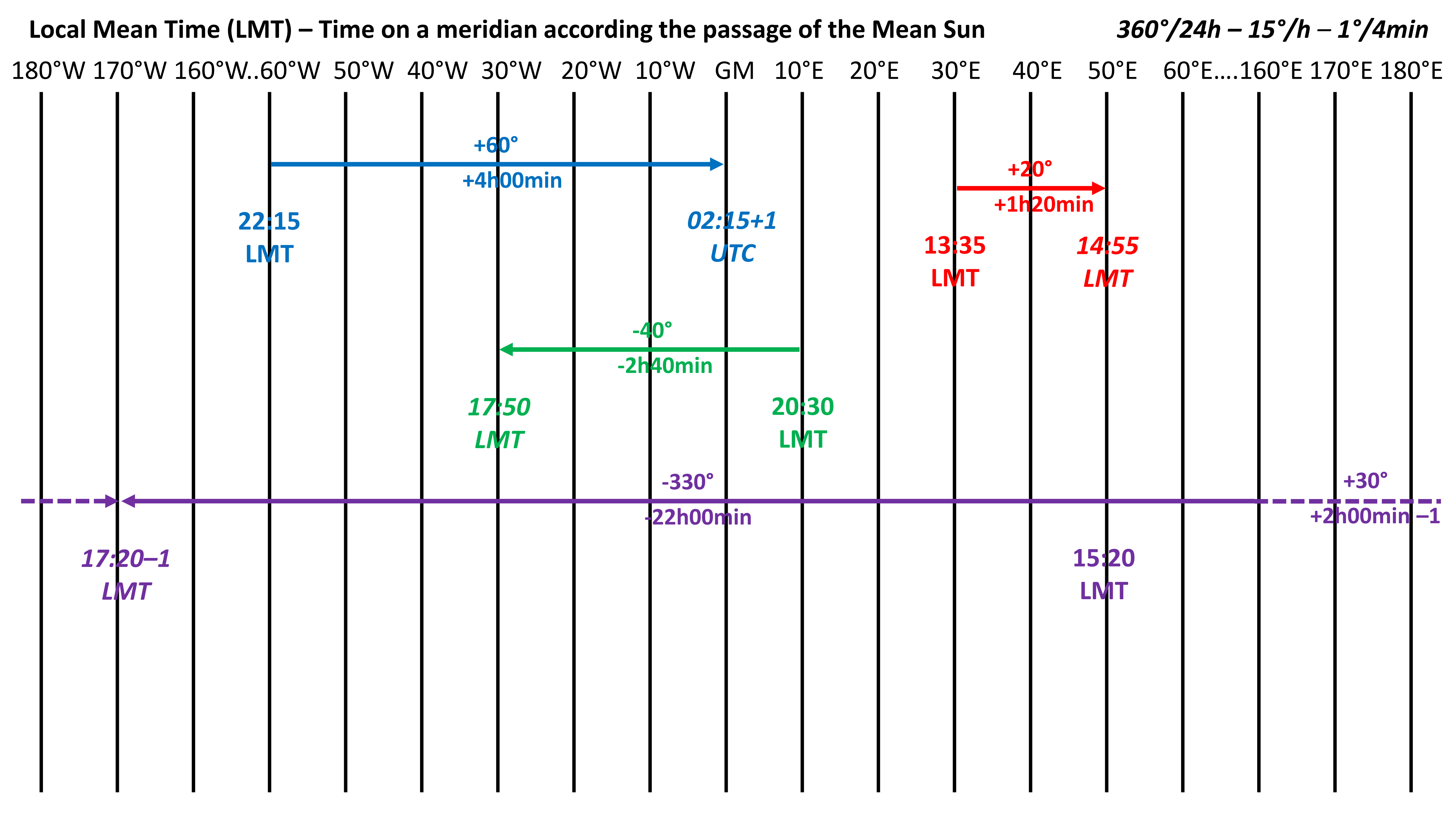
For the countries applying the Daylight Saving Time, it is applied:
- From the last Sunday of March *(First Sunday of April in the question bank)* at 2:00AM (one minute after 1:59AM, it is 3:00AM)
- Until the last Sunday of October at 2:00AM (one minute after 1:59AM, it is 1:00AM)

The list of the time zones used for each country and whether they apply the Daylight Saving Time or not, can be found in the **Air Almanac**.



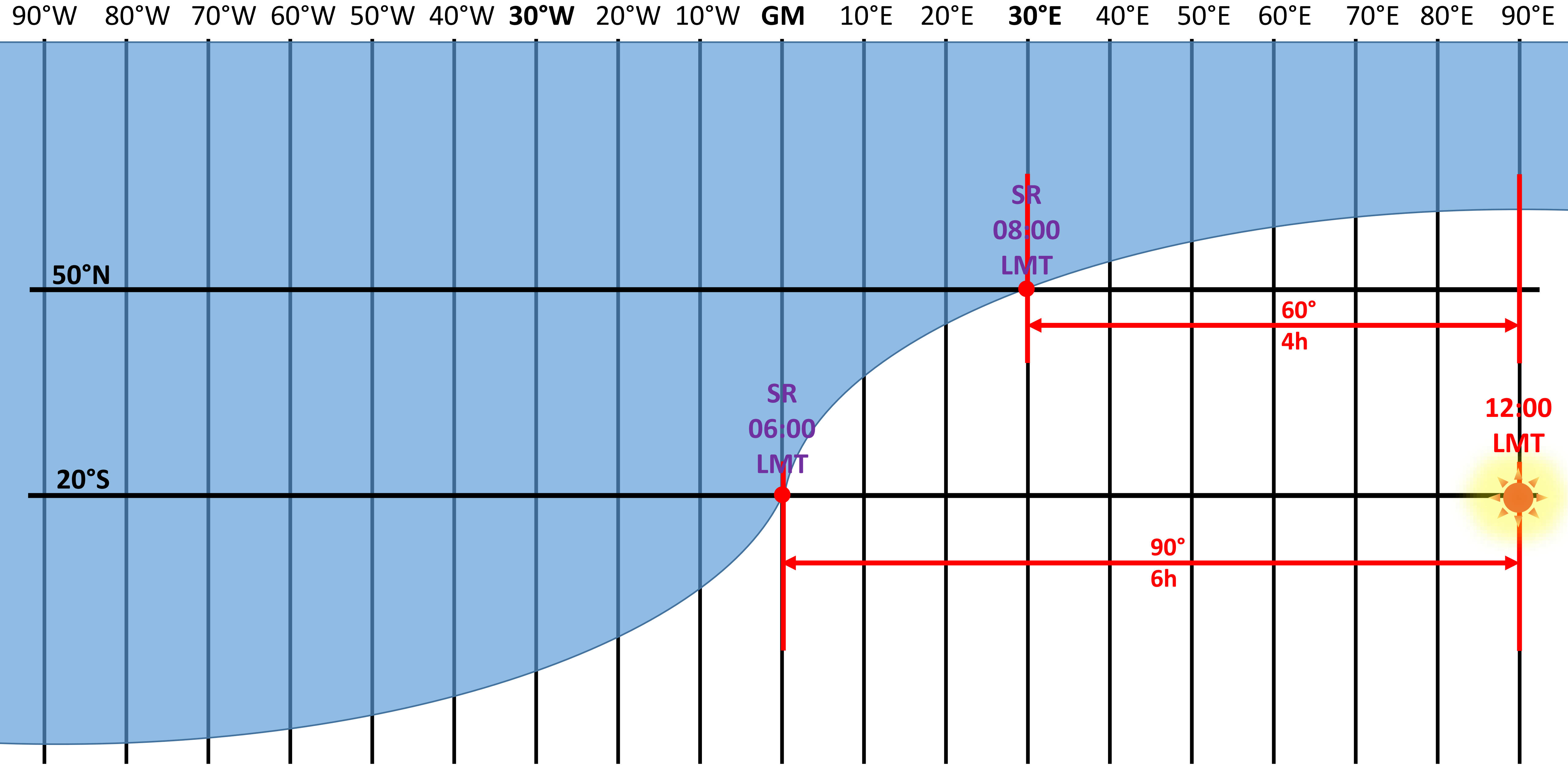
When the International Date Line is crossed **easterly**, we **remove a day**, and when cross **westerly**, we **add a day**.



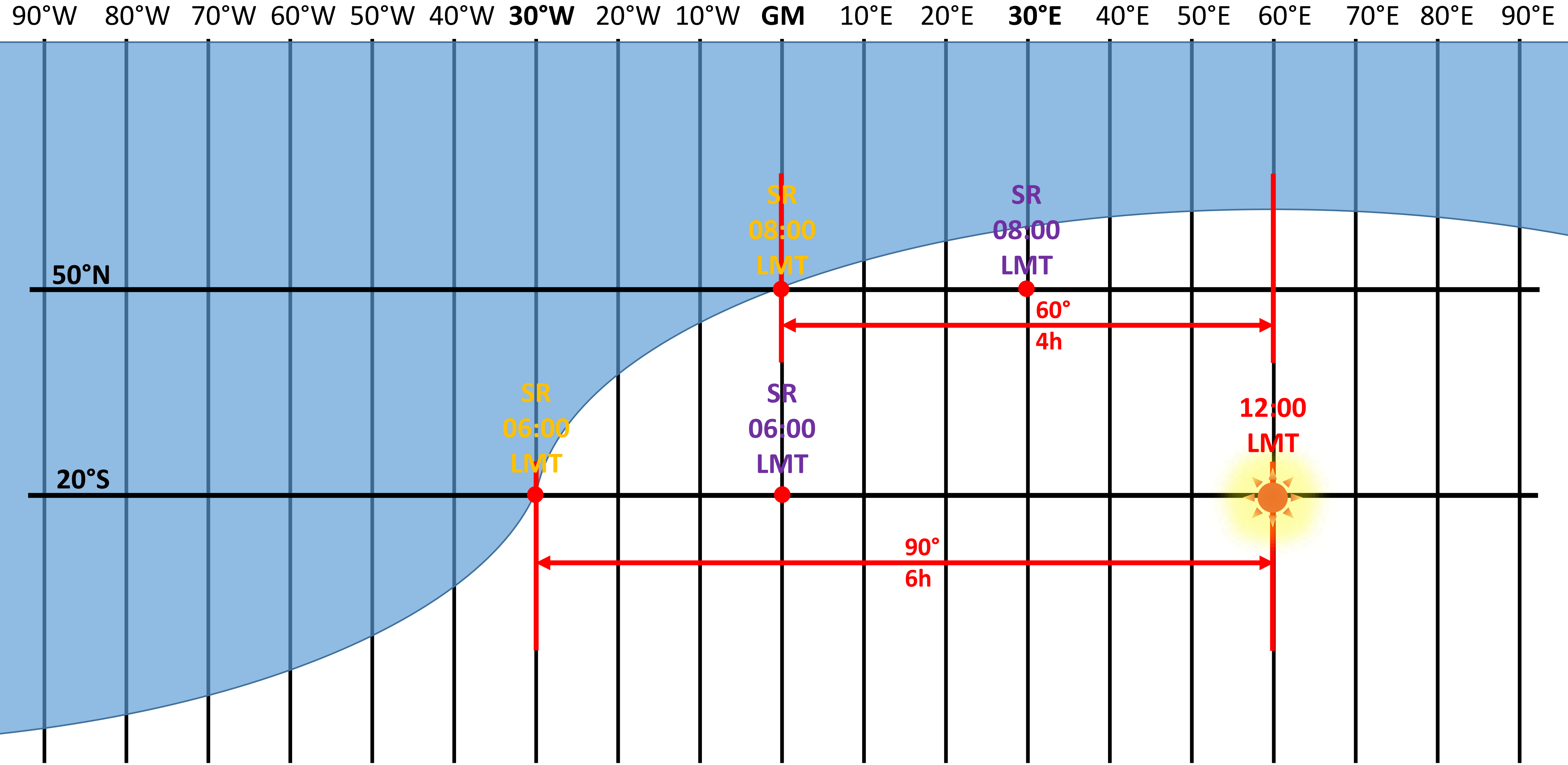

Local Mean Time (LMT) – Time on a meridian according the passage of the Mean Sun
360°/24h – 15°/h – 1°/4min
180°W 170°W 160°W..60°W 50°W 40°W 30°W 20°W 10°W GM 10°E 20°E 30°E 40°E 50°E 60°E....160°E 170°E 180°E
+60°
+4h00min
22:15
LMT
02:15+1
UTC
+20°
+1h20min
13:35
LMT
14:55
LMT
-40°
-2h40min
17:50
LMT
20:30
LMT
-330°
-22h00min
+30°
+2h00min –1
17:20–1
LMT
15:20
LMT

A solar event on a meridian in LMT (SR, SS, transit, etc) can be calculated if we know a solar event on another meridian in LMT

Eg. If we know that the Mean Sun is transiting 90°E (12:00 LMT), so we can calculate the SR at 50°N 30°E and at 20°S 0°E/W.



Since all the meridians will experience the same event (SR, SS, etc) in LMT, in the Air Almanac only the GM events are calculated and published for different latitudes and these data can be used for all other meridians.



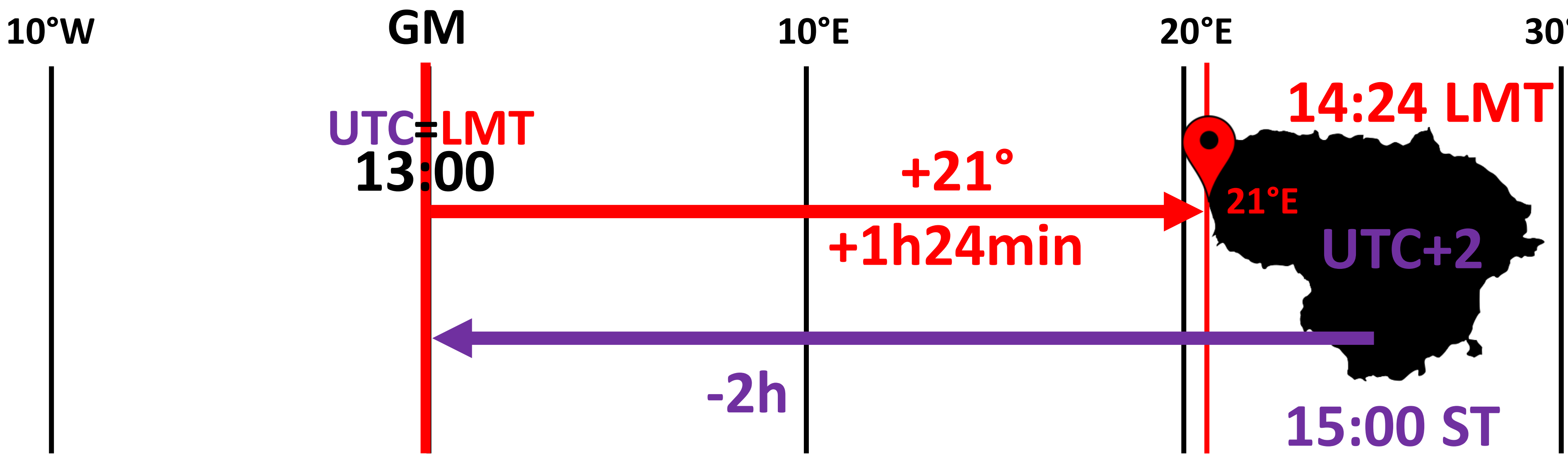
To calculate a ST in Time Zone from another known ST in another Time Zone, we count the number of Time Zones in between.

To calculate a LMT over one meridian from another known LMT over another meridian, we count the longitudes in between.

However to calculate a LMT over one meridian from a known ST in a Time Zone and vice-versa, requires a “conversion” since the LMT is only for one meridian, and the ST is for a Time Zone covering many meridians, and we don’t know according which meridian the this ST is set.

Eg. If it is 15:00 ST in Kleipeda, Lithuania (EET=UTC+2), what is the LMT in Kleipeda (on meridian approx. 21°E)?

The **ST in Kleipeda** is the same as in the entire Lithuanian territory, which is **EET=UTC+2**, and this Time Zone is applied over many meridians. However if we know the **UTC**, it means that we know the **LMT over Greenwich meridian**.
So the conversion consist of switching the **ST** to **UTC** **which is** the **LMT over Greenwich Meridian**, then we count the longitudes between **Greenwich meridian** and **Kleipeda meridian** to obtain the **LMT in Kleipeda**.

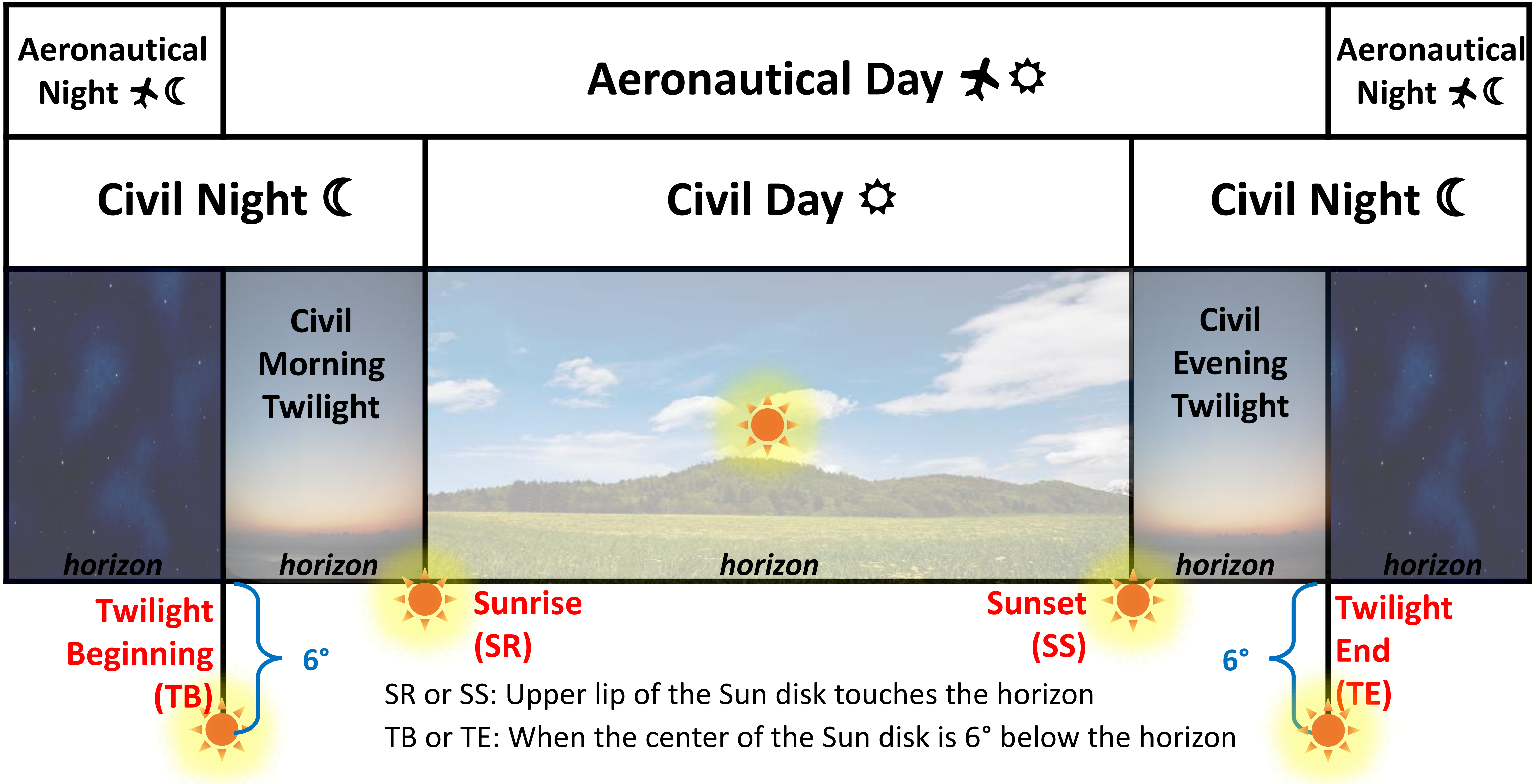


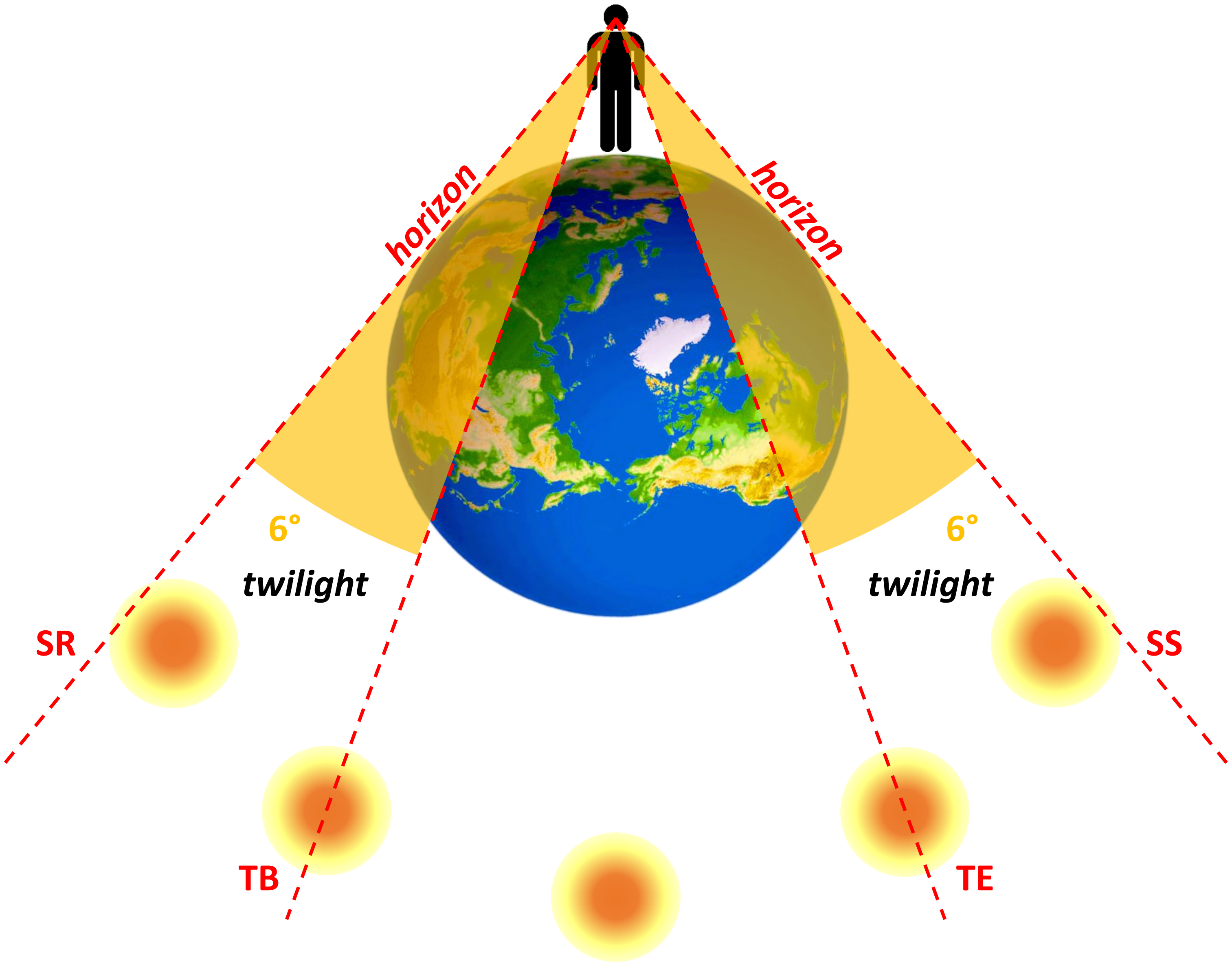
*The **difference** between the **ST** and the **LMT** in Kleipeda is:*
0 day 0 h 36 min

Note: *In some locations, the **difference** between the **ST** and the **LMT** can even be more than a day, this is very common in the territories using UTC+13 or UTC+14.*

XI
TIME (3)

Aeronautical Night: the period between the end of evening civil twilight and the beginning of morning civil twilight, or such other period between sunset and sunrise as may be prescribed by the appropriate authority




horizon
horizon
6°
6°
twilight
twilight
SR
SS
TB
TE

Twilight duration

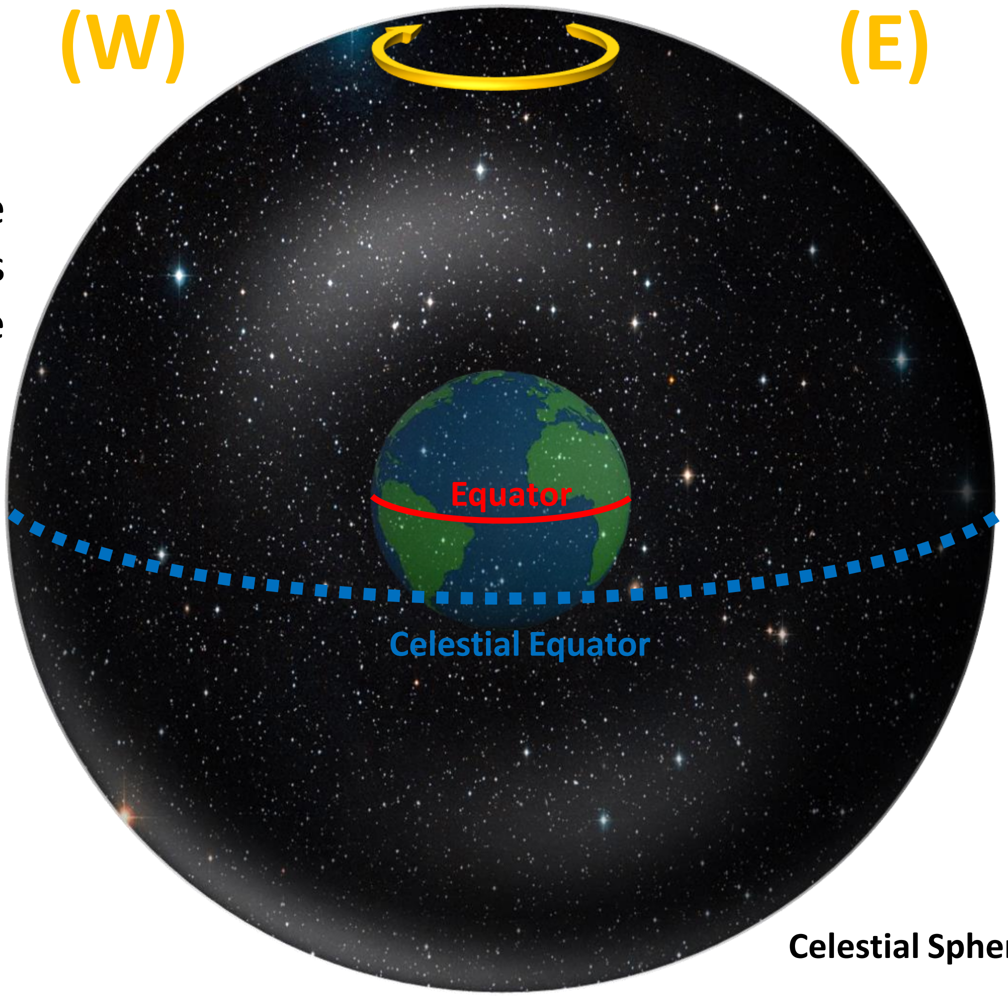
The duration of the twilight, varies along the year and according to the latitude.

To understand this, let's visualize the motion of the celestial body how they appear to be in the sky at different latitudes:

- Poles
- Mid-Latitudes
- Equator

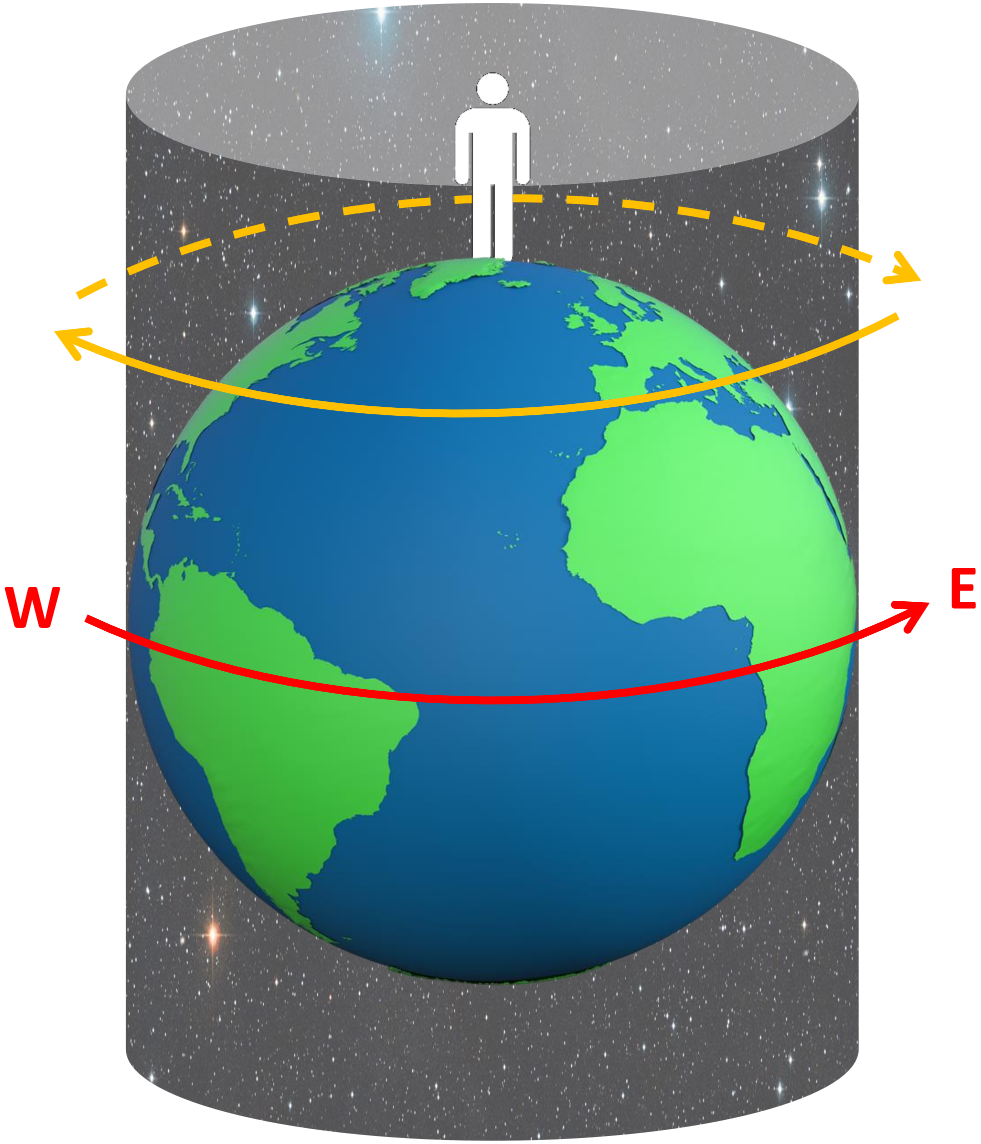
For that we will make extension of the Earth's sphere, where celestial bodies are projected on it. This Earth's extension sphere is called the **Celestial Sphere**, where the **Celestial Equator** is the projection of the **Geographic Equator**.

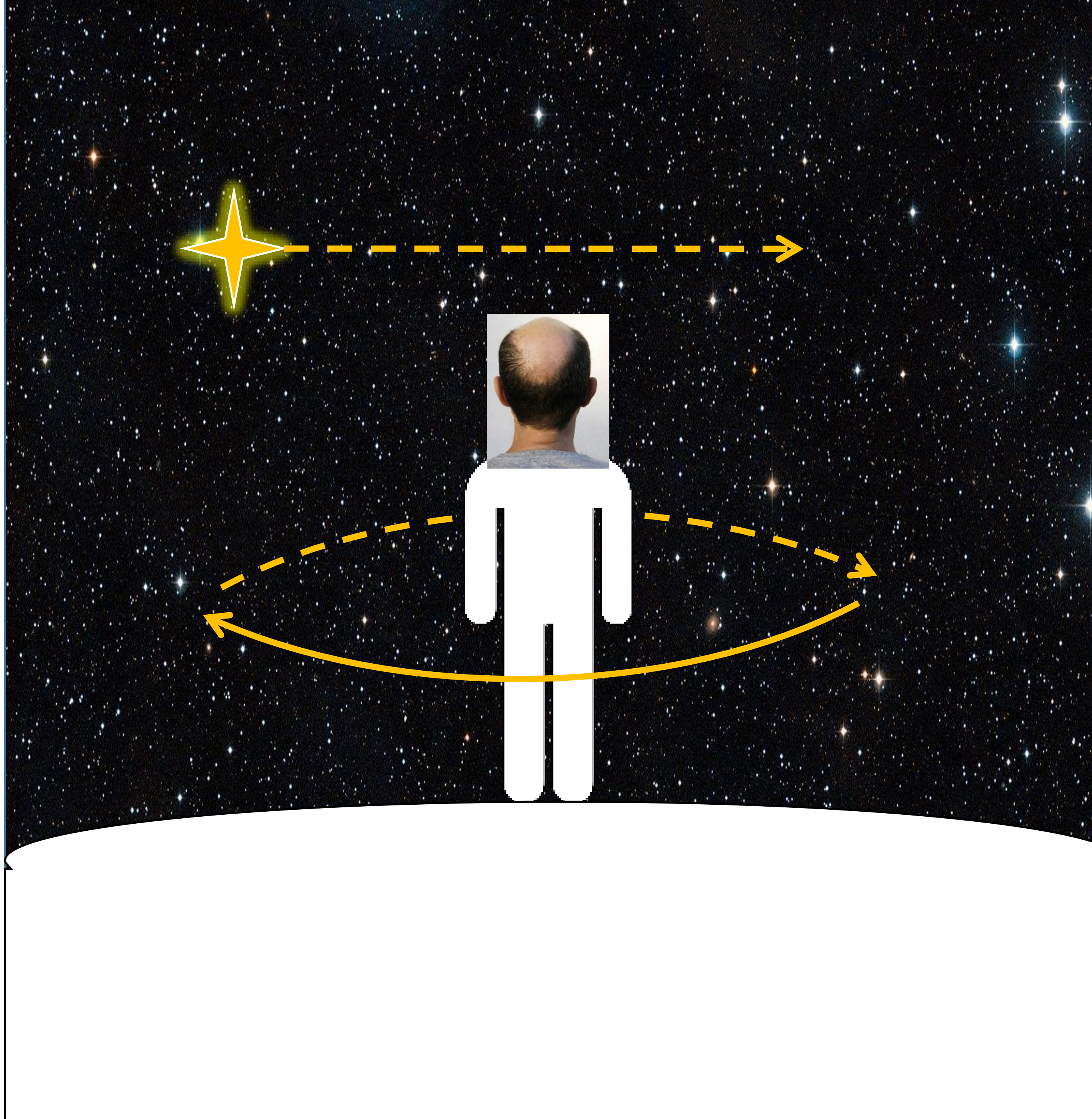
We will assume, for an observer, that the Earth is fixed and that the celestial sphere is turning around the Earth for East (E) to West (W)



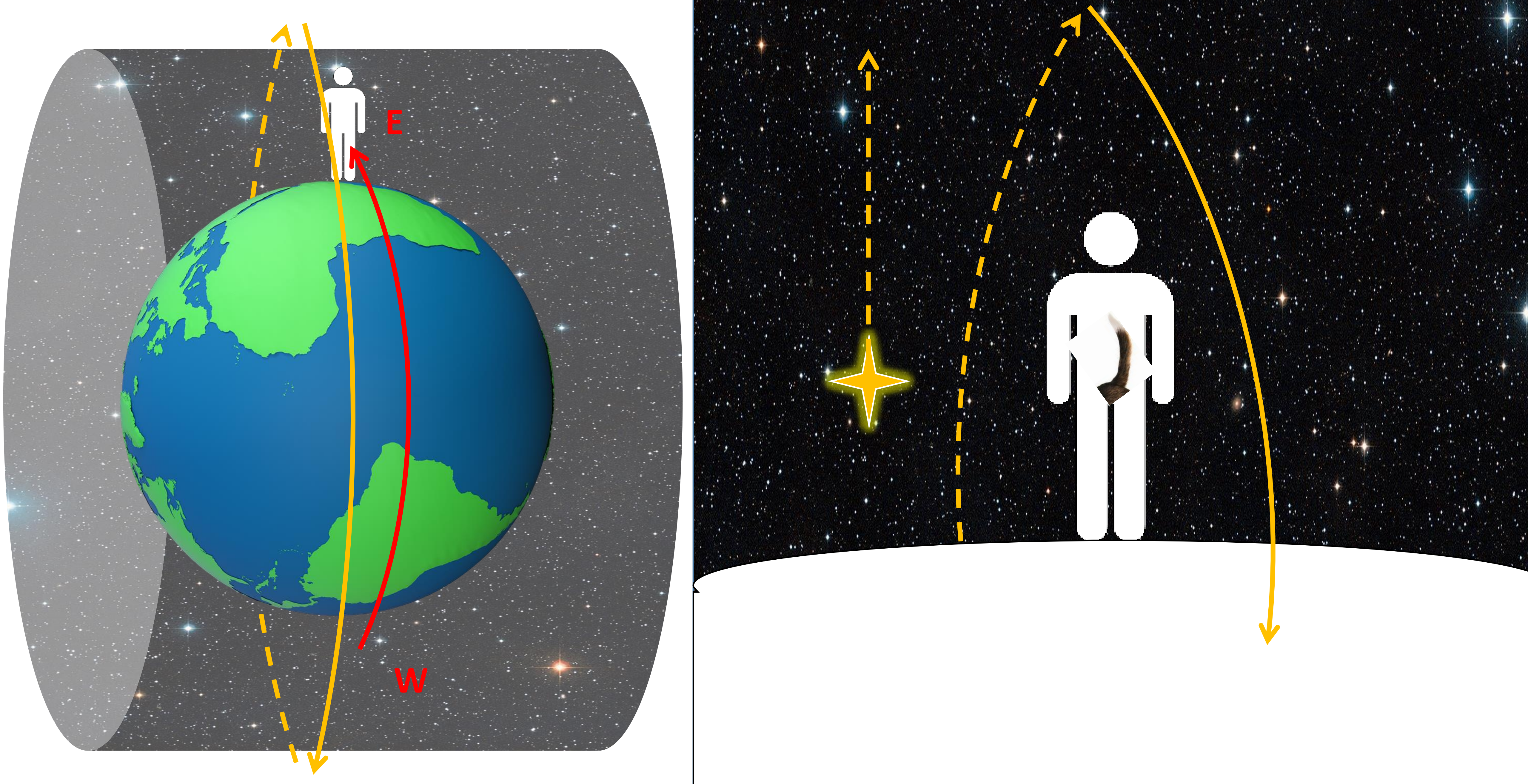
Celestial Sphere

Polar latitudes (eg 90°N)

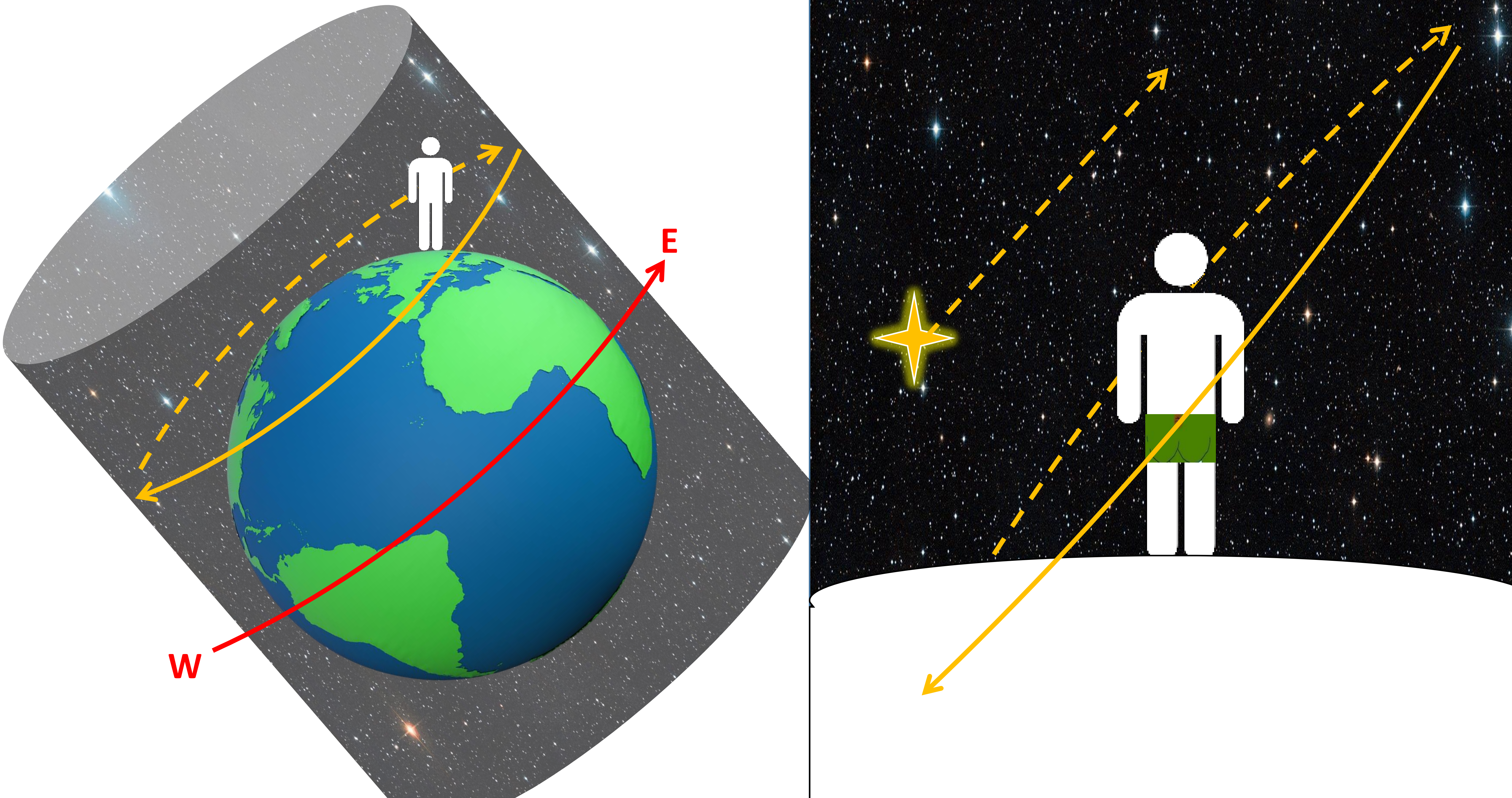




Equatorial latitudes (eg 0°N/S)

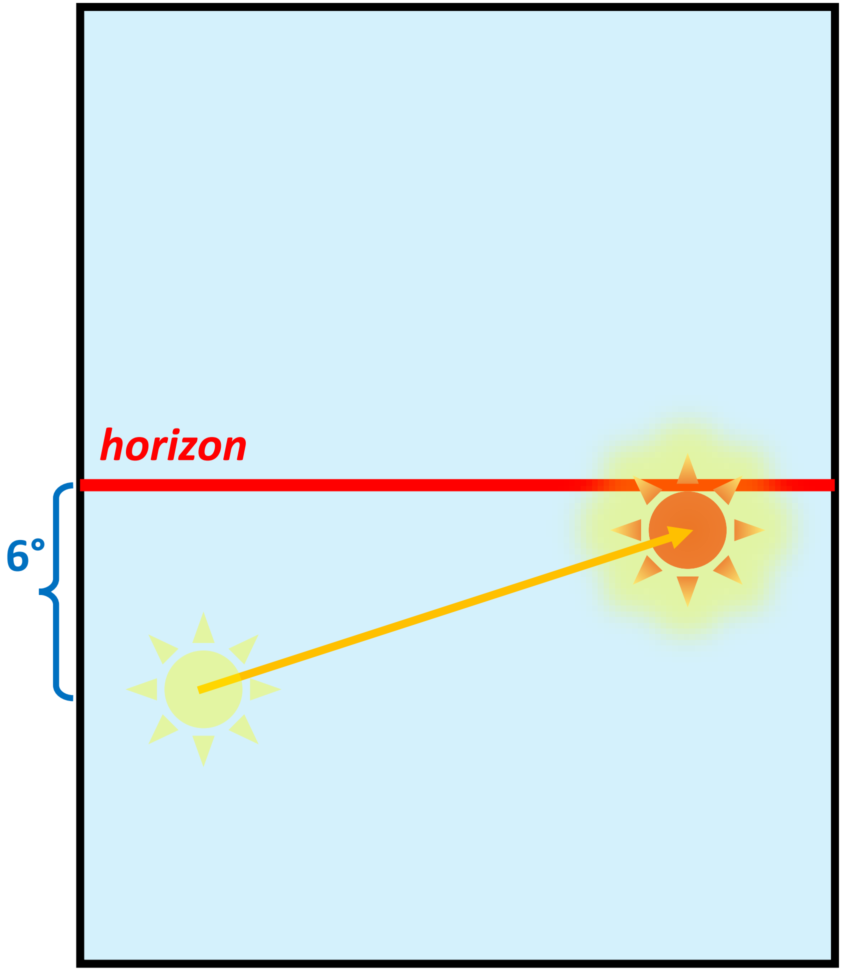


Mid-Latitudes (eg 45°N)



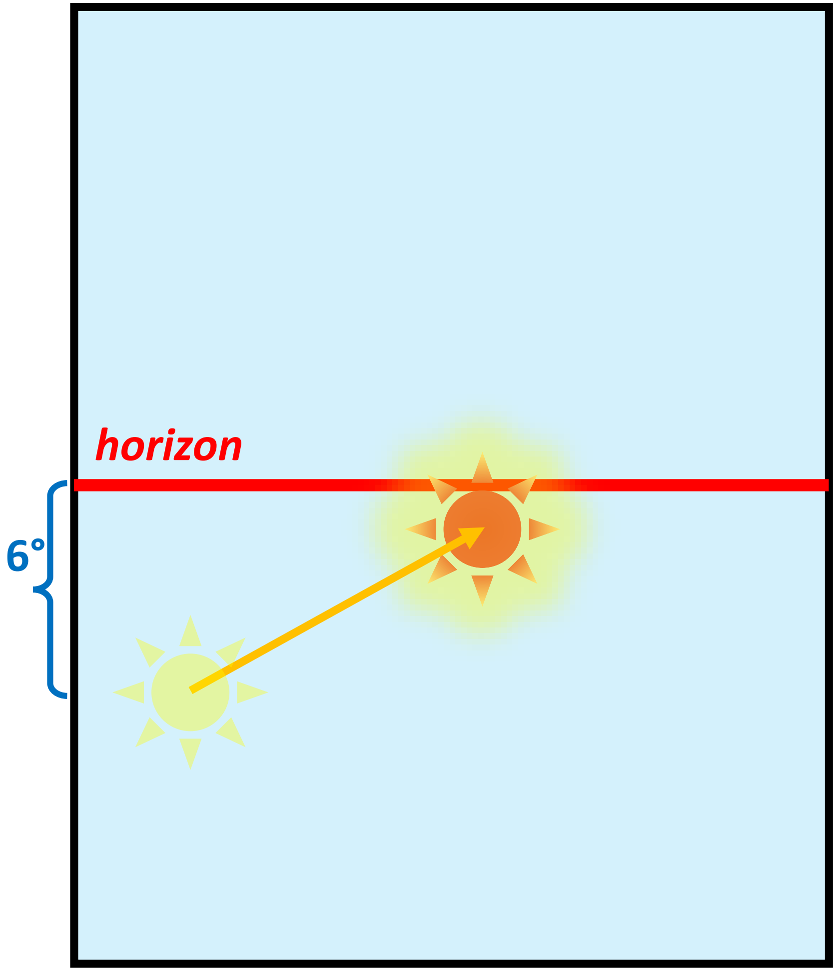
Now let's reproduce the same trajectories to the Sun, from TB to SR, but not exactly at the latitudes in the demonstrations. We can see that from the TB to the SR, the Sun has to travel longer distance at higher latitudes, so the twilight is longer at higher latitudes. This is the same for the twilight between the SS and TE.

Polar latitudes



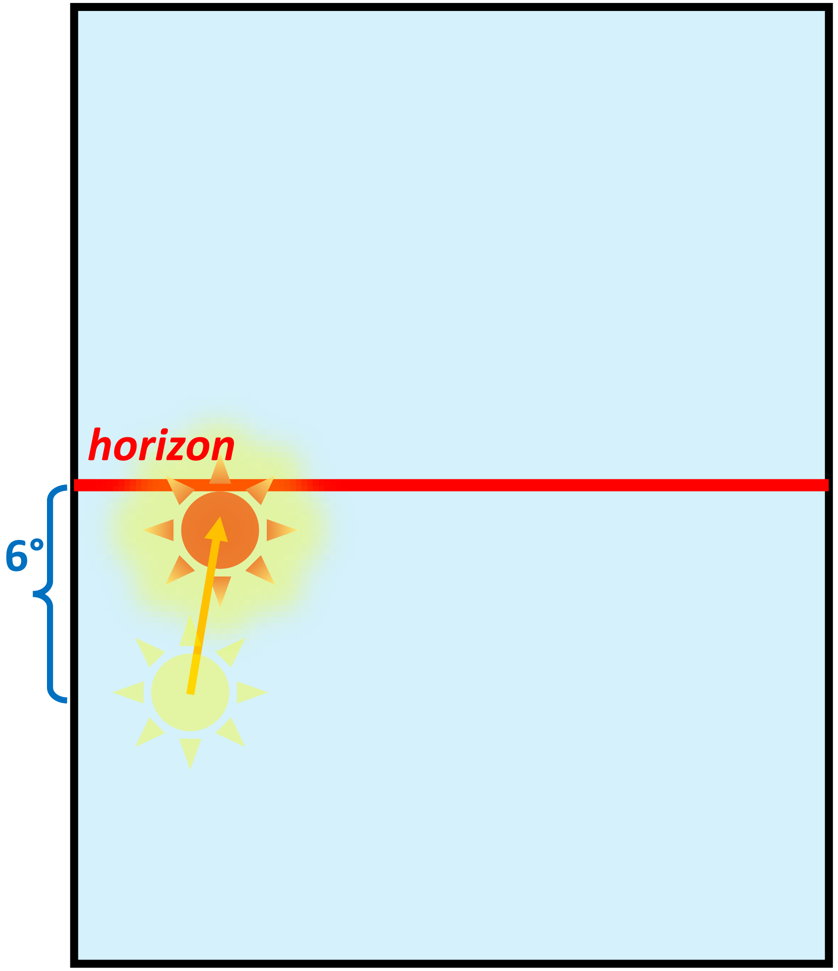
Twilight duration: ≈ 1 hour

Mid-Latitudes



Twilight duration: ≈ 30 min

Equatorial latitudes



Twilight duration: ≈ 10-15 min