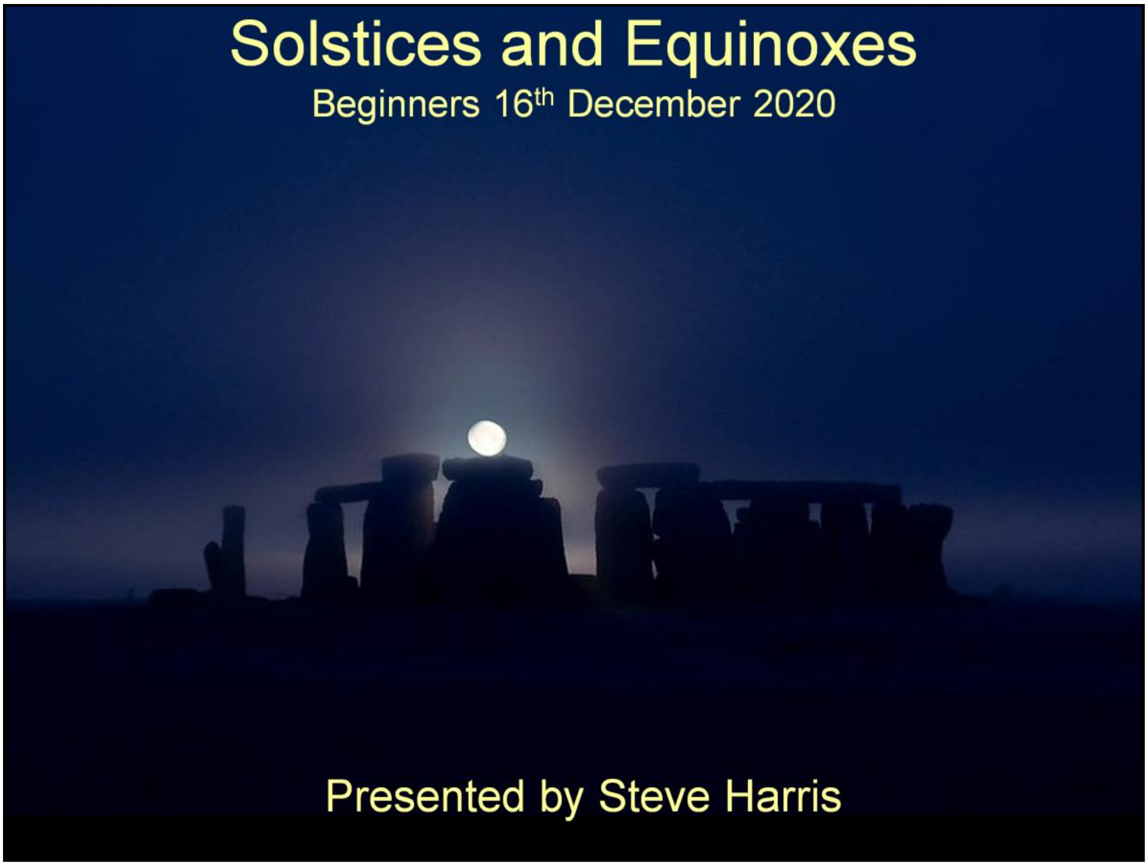
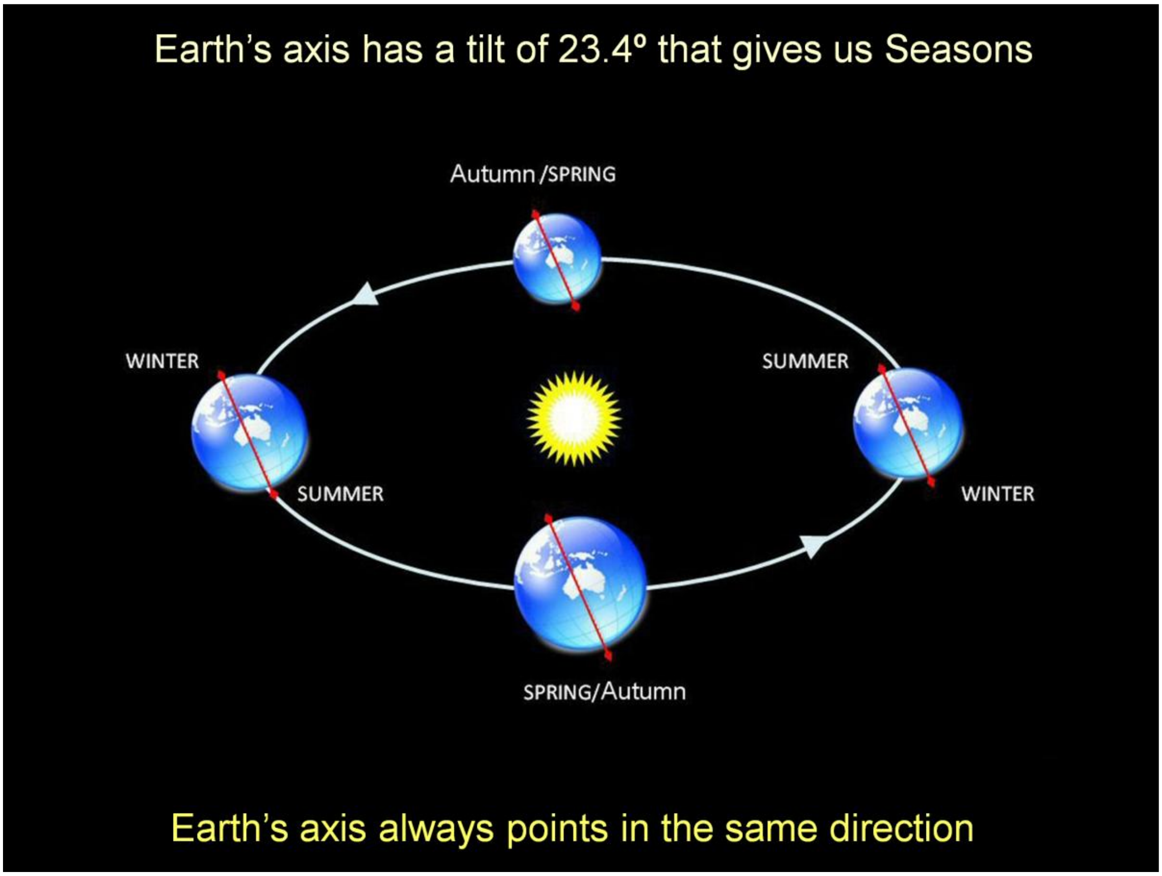
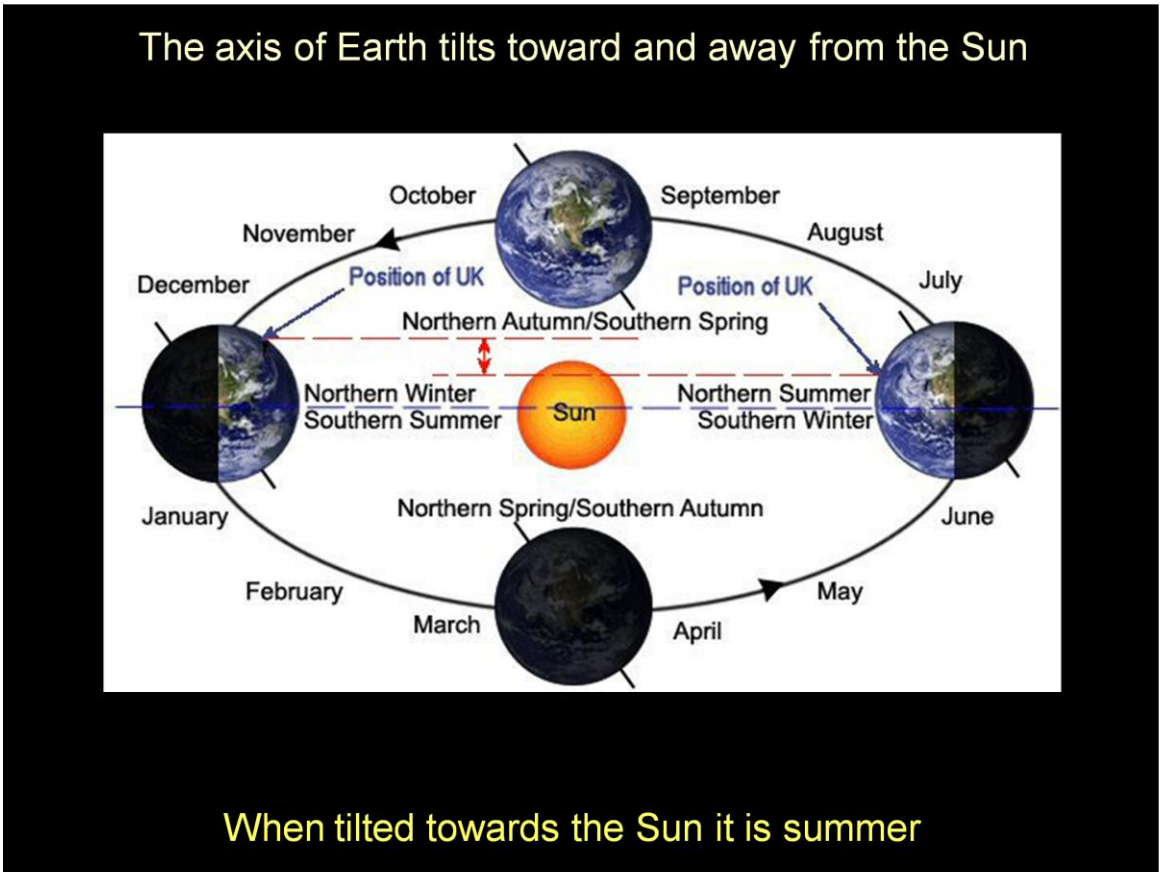


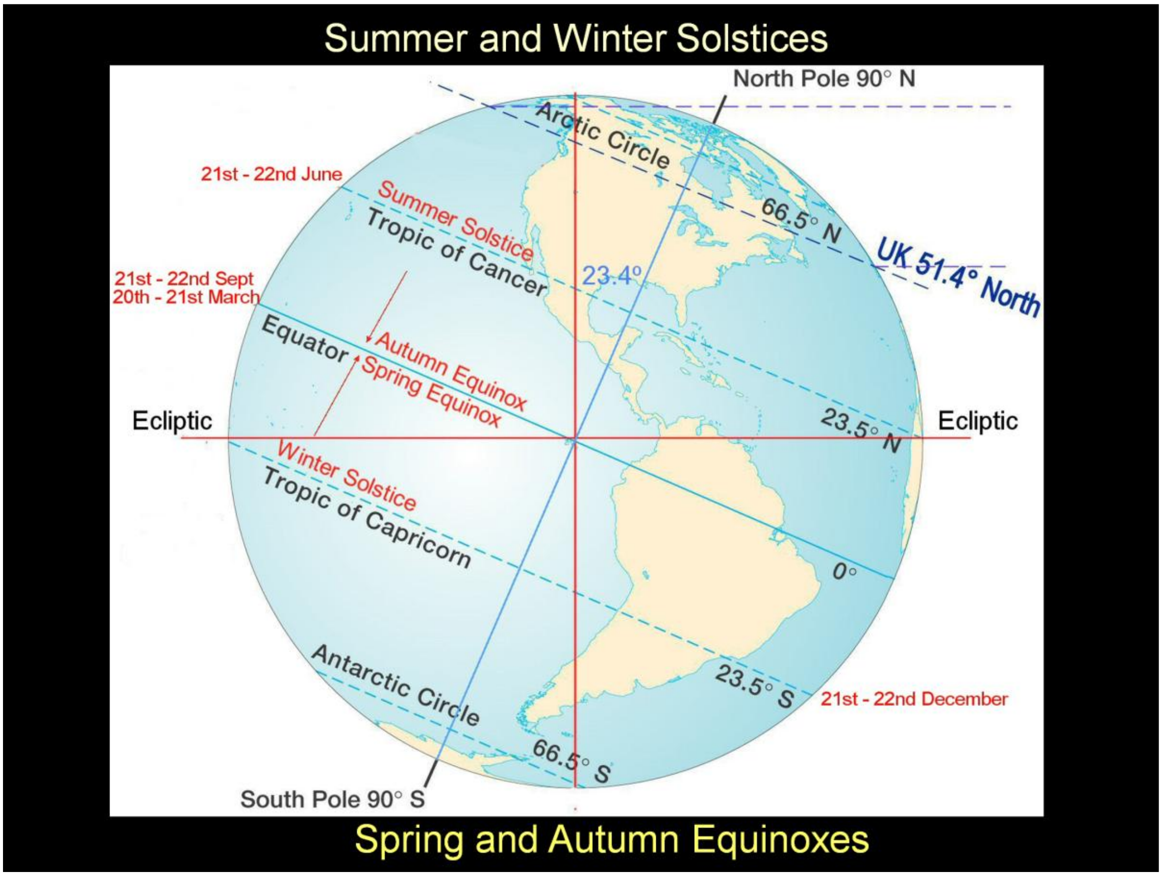
We hear a lot about Stonehenge and the Summer Solstice but the Winter Solstice was probably more important to the ancient people who built Stonehenge. So what is a Solstice?



Another name for a Solstice is Midsummer and Midwinter so it is to do with the seasons. The tilt of the axis of Earth's rotation always points in the same direction as Earth moves around its orbit. Consequently a location on Earth (for instance the UK) effectively tilts toward and away from the Sun during the year creating Summer and Winter seasons.

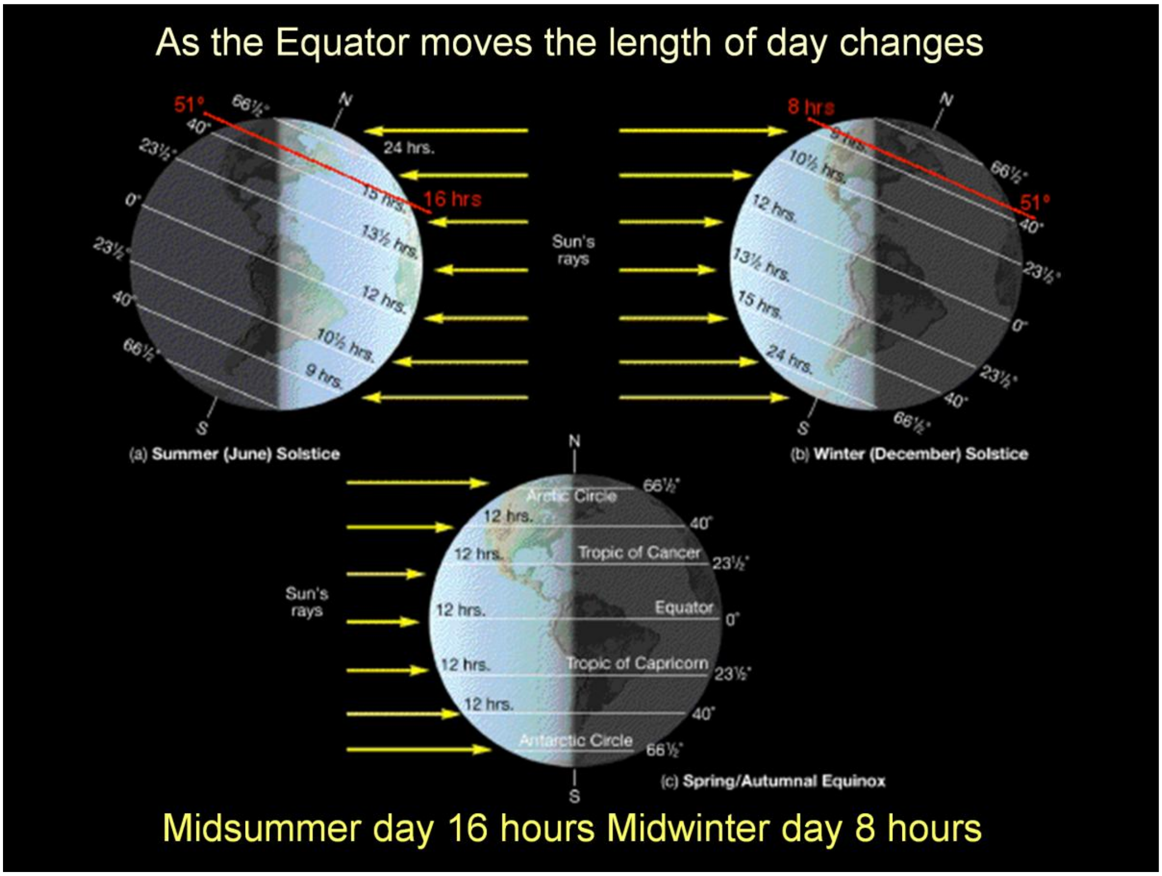


A location on Earth's surface (for instance the UK), effectively moves closer to Earth's Equator or to the North Pole during the year creating Summer and Winter seasons.

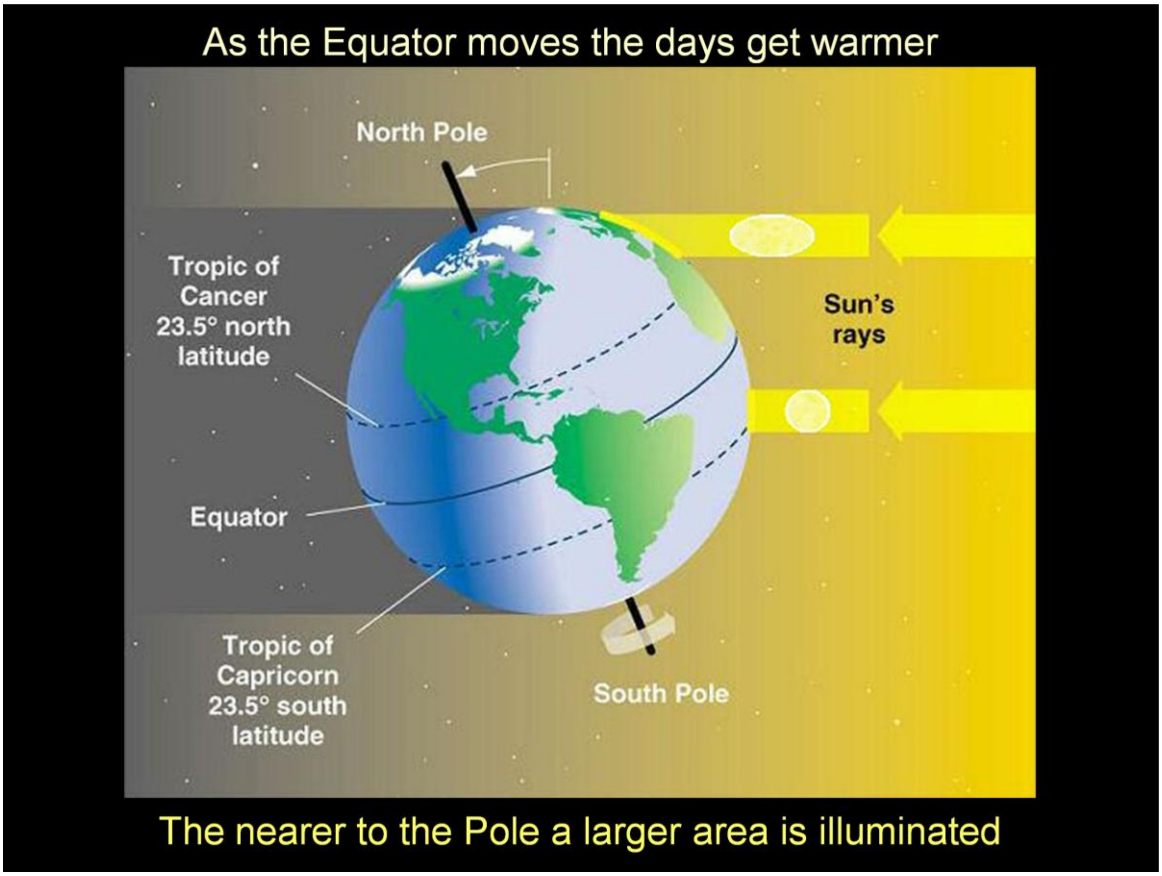


The diagram above shows the two equators that produce our tilted view of the sky. The 'Ecliptic' marked in red on the diagram is the equatorial plane of the Sun and Solar System. It is the equator of the Sun projected out as a flat plane on which the planets, including Earth, orbit the Sun. The Celestial Equator is the Equator of Earth and is the plane through the point on Earth half way between the North and South pole. The Celestial Equator (Earth's Equator) is tilted at 23.4^{o} from the Ecliptic due to the Earths tilt.

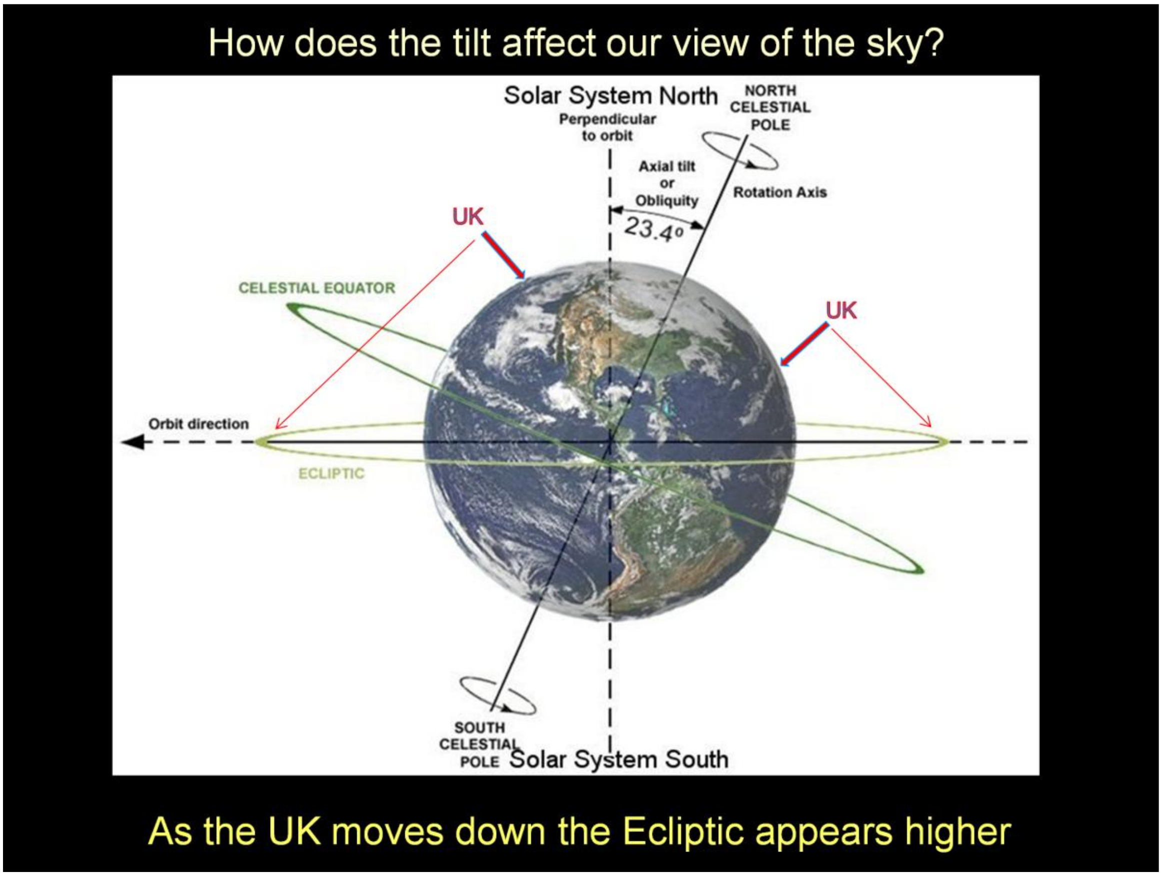
As Earth moves around the Sun in one year the Sun appears to move up and down in the sky up 23.4^{o} and down 23.4^{o}. So the Sun will appear directly overhead 23.4^{o} North of Earth's Equator on about 21st June every year. This furthest point to the North is called the Tropic of Cancer and the furthest point to the South is called the Tropic of Capricorn and this occurs around 21st December. Half way between the Tropics the Sun appears directly overhead on the Equator on or about 20th March. This is called the Vernal Equinox or Spring Equinox when the Sun is moving North. The Autumn Equinox occurs on or about 21st September when the Sun is moving South and appears directly overhead on Earth's Equator. The Solstices and Equinoxes occur a quarter of a day later every year up to the next Leap Year when a day is added to the calendar.



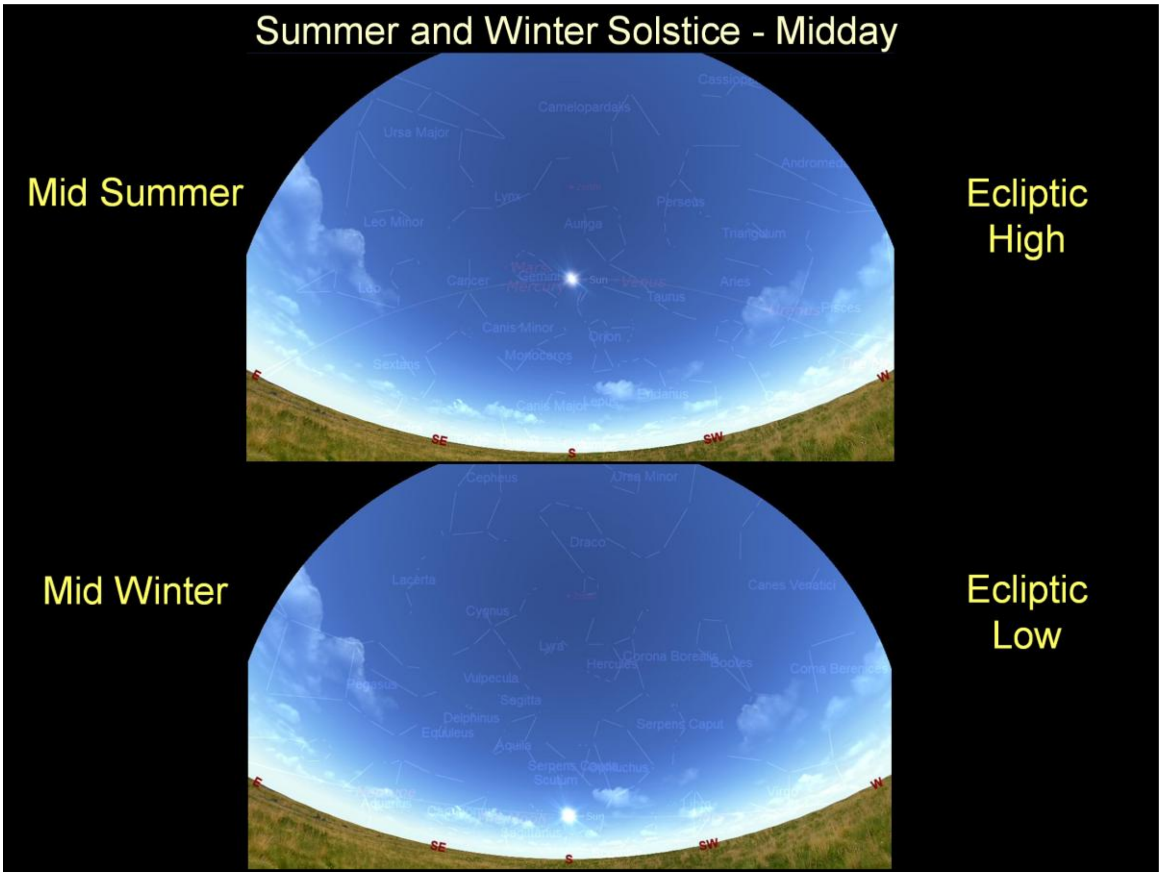
The tilt of the axis of Earth's rotation always points in the same direction as Earth moves around its orbit. Consequently a location on Earth (for instance the UK) effectively tilts toward and away from the Sun during the year creating Summer and Winter seasons. The Sun always illuminates exactly half of Earth (daytime) and the other half is in Earth's shadow and it is night. When the North Pole is tilted towards the Sun a point on the planet such as the UK will pass through less of Earth's shadow so the night will be shorter. Night will just 8 hours long on midsummer day (the Summer Solstice) and the day will be 16 hours long.



As the tilt of the axis of Earth's rotation begins to point away from the Sun the area of the Sun's illumination moves further up the curve of the surface of Earth. Consequently a location on Earth (for instance the UK) effectively moves further up the curved surface and the available light is distributed over a larger area. Consequently the heating effect is reduced and the surface becomes colder and we have winter.



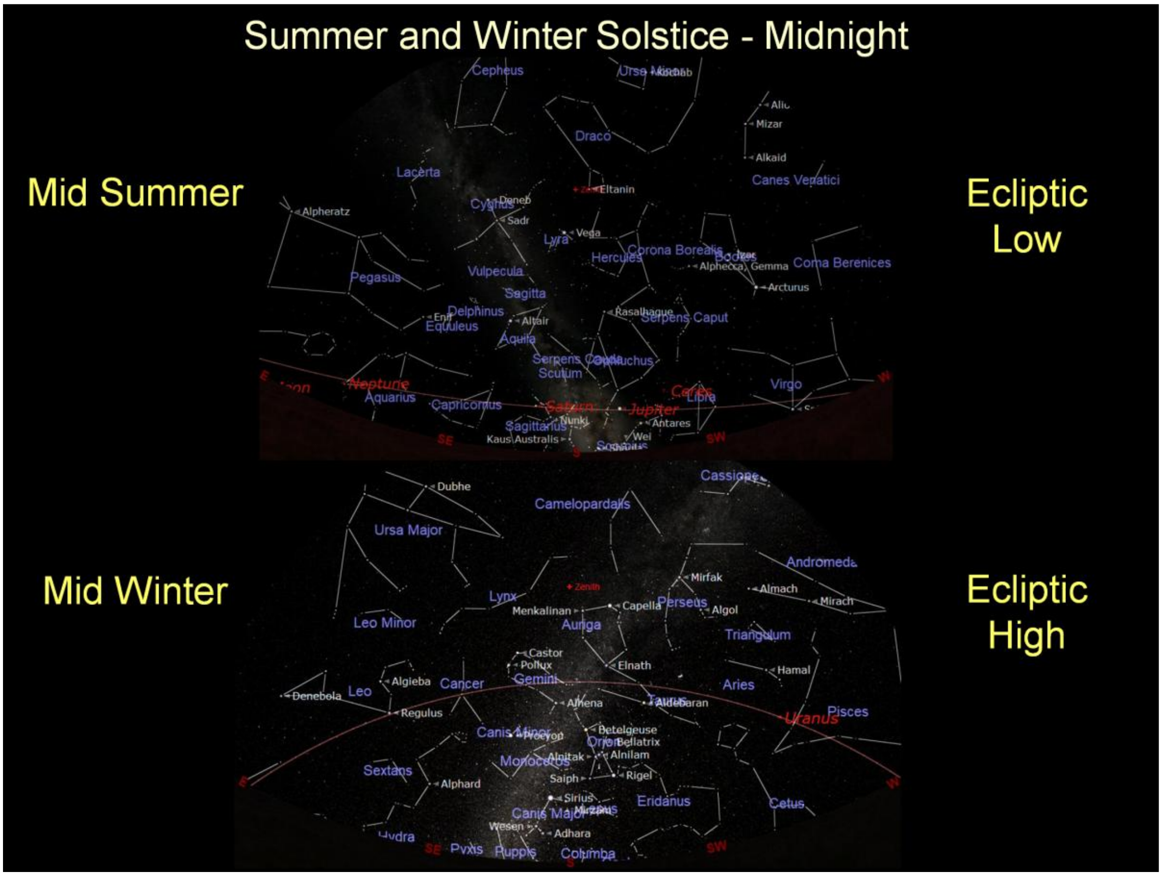
The diagram above shows the two equators that produce our tilted view of the sky. The 'Ecliptic' marked on the diagram is the equatorial plane of the Solar System. It is the equator of the Sun projected out a flat plane on which the planets, including Earth, orbit the Sun. The Celestial Equator is the Equator of Earth and is the plane through Earth, half way between the north and south pole.



As astronomers we have a rather confusing view of the sky around us due to the tilt of Earth's axis. There are however some very noticeable effects that we take for granted and barely notice. The first is: how much the position and height of the Sun above the horizon changes from summer to winter. The upper image above shows the sky at midday on Midsummer Day. The Sun is at its maximum elevation above the southern horizon (We call this the Summer Solstice). Any planets in the sky at this time will be located somewhere along the Ecliptic to either side of the Sun and therefore appear high in the sky as well.

The lower image above shows the sky at midday on midwinter day (Winter Solstice). When compared to the image at the top, it can be appreciated just how low the Sun appears from the UK in the middle of the winter.

In the northern hemisphere the north pole of Earth's axis is tilted towards the Sun during the summer season. This gives the effect of a point on the surface such as the UK being closer to the equator of the Solar System that we call the Ecliptic. As a consequence the Sun will appear much higher in the sky during the summer. It is also warmer because the Sun is almost overhead.



As Earth rotates on its axis once every 24 hours (1 day) that point on the surface of Earth (the UK) will rise up due to the tilt and the Sun is high in the sky. At midnight when the UK is looking away from the Sun the Ecliptic will be at its lowest point in the sky. The Moon and the planets will also appear low in the night sky.

The upper image above shows the how the Ecliptic appears low in the sky at midnight on Midsummer Day (Summer Solstice) when it had been high in the sky during the day. The Moon appears low in the sky during the summer nights and appears large as it rises over the horizon giving us the Harvest Moon and Super Moon effects. During the winter nights the ecliptic appears very high in the night sky as can be seen in the lower image above. In the northern hemisphere the north pole of Earth's axis is tilted away from the Sun during the winter season. This gives the effect of a point on the surface such as the UK being further away from the equator of the Solar System (the Ecliptic) during the day and closer to the north pole of the axis of the Solar System.

What effect does the tilt have on our view of the sky?

And on the telescopes we use?

We have two ways to measure positions in the sky

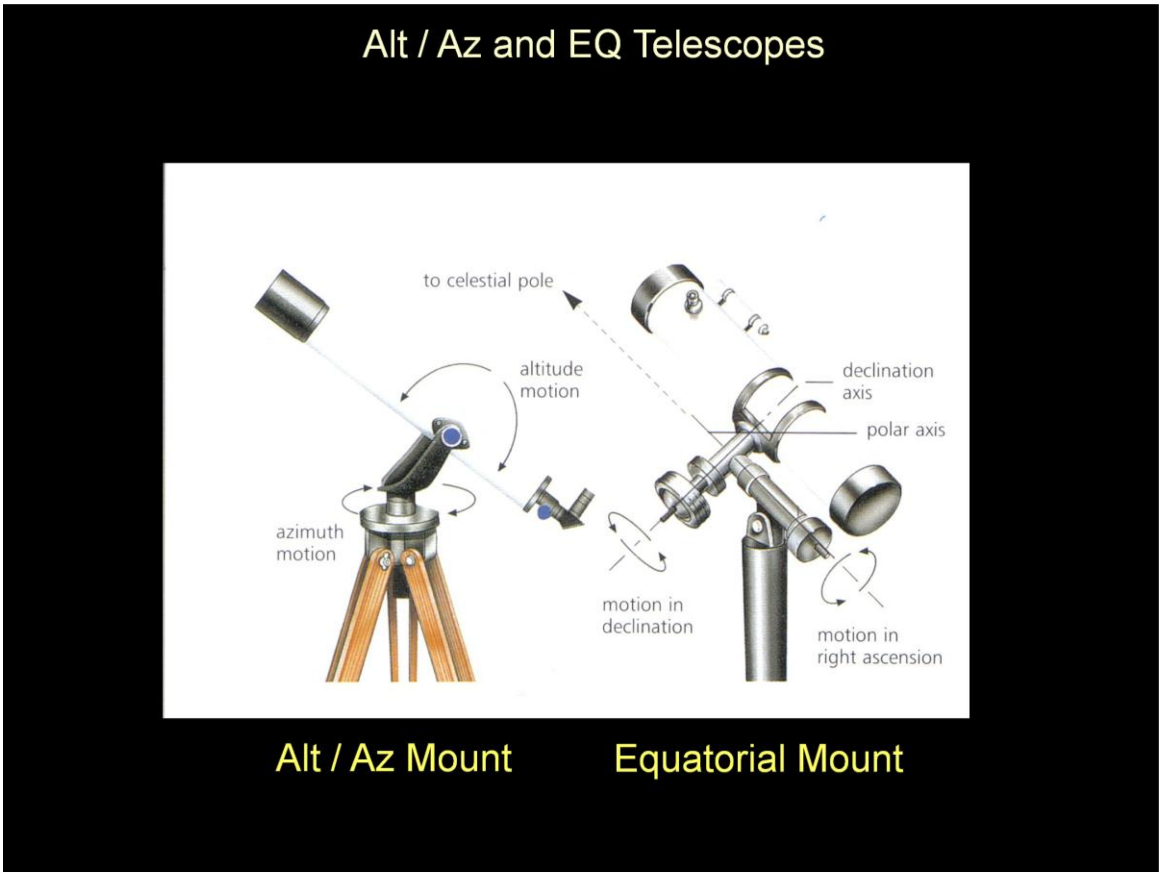
1. Altitude / Azimuth (Alt / Az)

2. Equatorial

Right Ascension (RA) Declination (Dec)

In general most people have no reason to appreciate that our Earth is tilted over at 23.4^{o} except for the seasons. However astronomers have to understand how the mechanics of the sky works.

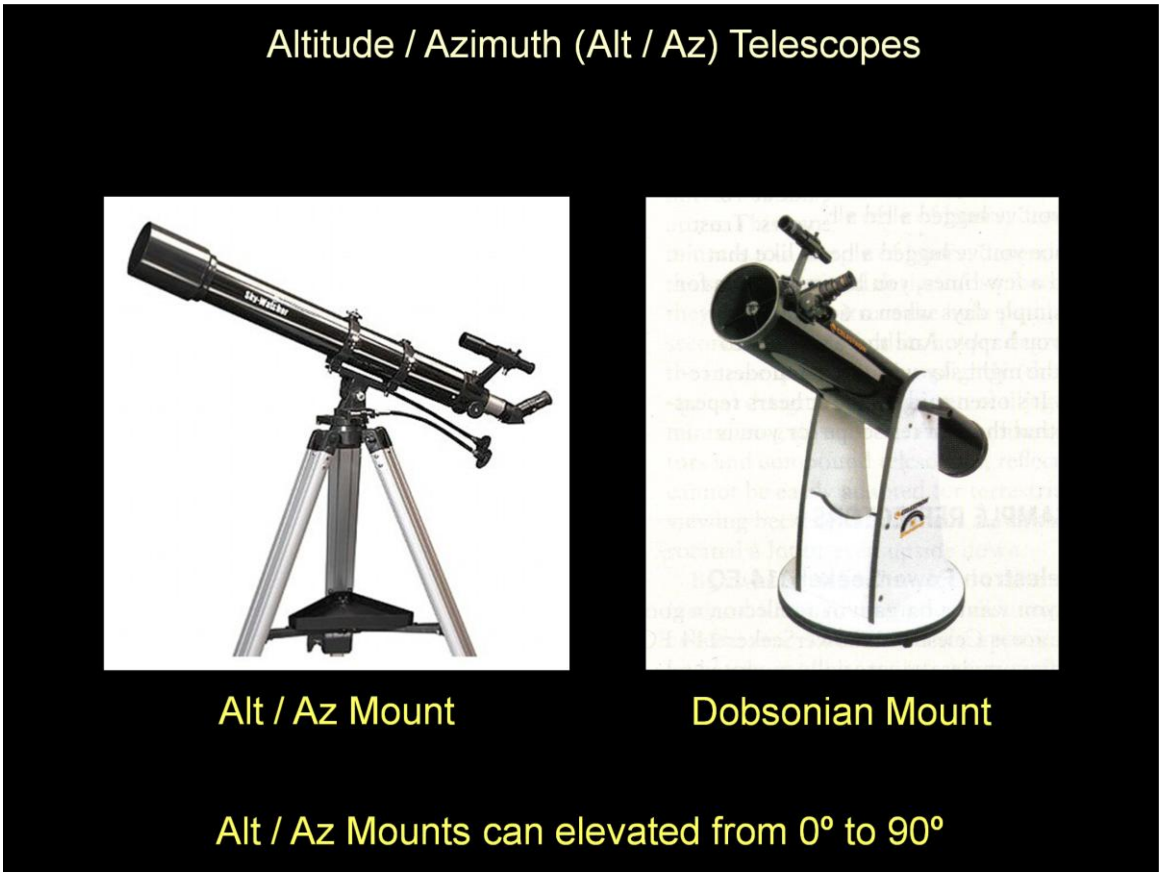
As astronomers we an have an appreciation of the rather confusing view of the sky around us due to the tilt of Earth's axis. The main effect is experienced in the way we use telescopes to observe the sky. So we have two very distinctive ways of measuring position in the night sky called Altitude (AltAz) and Equatorial (RA).



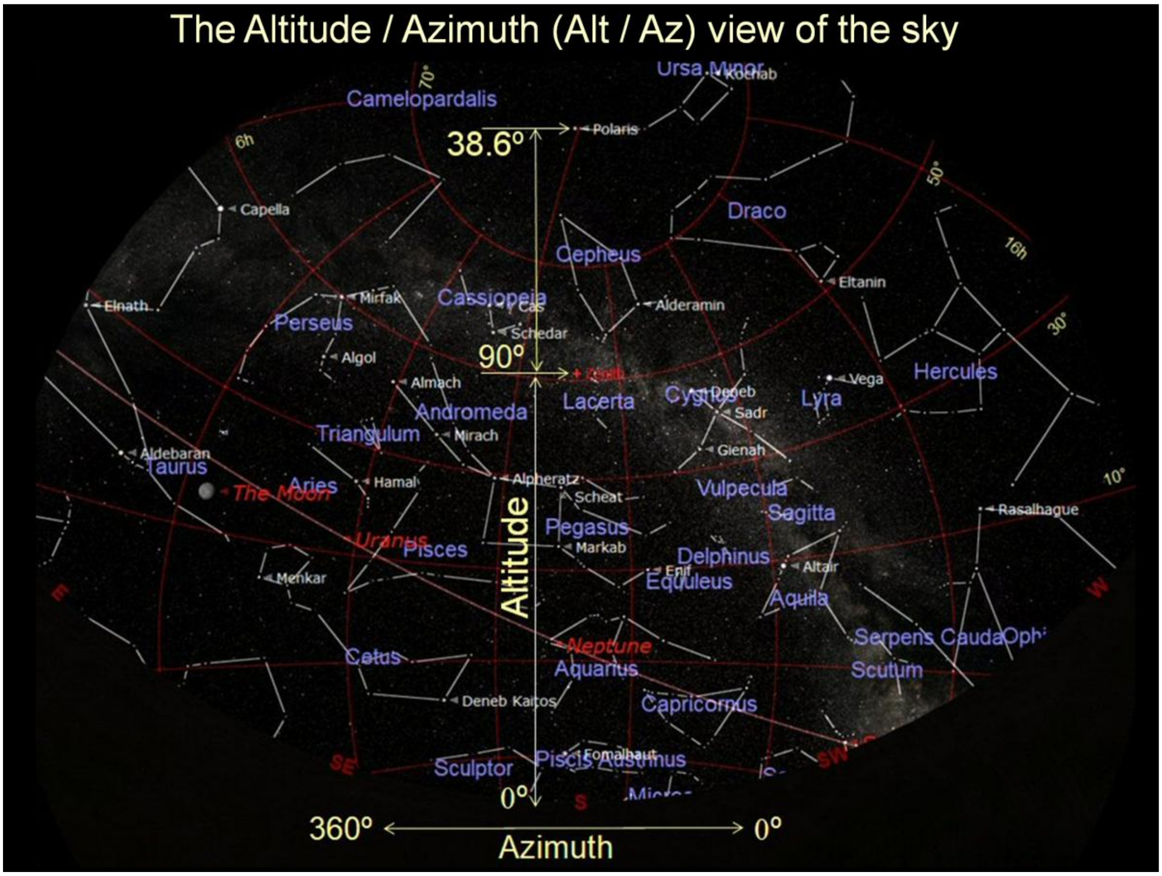
We have two kinds of telescope mounting: Alt-Azimuth and Equatorial.

An Alt-Azimuth mounting has a Horizontal rotational axis for rotation left or right (Azimuth) and a vertical mounting to allow up and down motion (Altitude).

An Equatorial mount has similar movements but the Azimuth axis can be tilted to align on the Pole Star this called the Right Ascension (RA). The telescope can be raised or lowered using a Declination (Dec) axis.



The Alt/Az is a simple up and down mount. There are two commonly used versions of Alt/Az telescope mountings these are: Tripod mounted Alt/Az and the Dobsonian Mount.

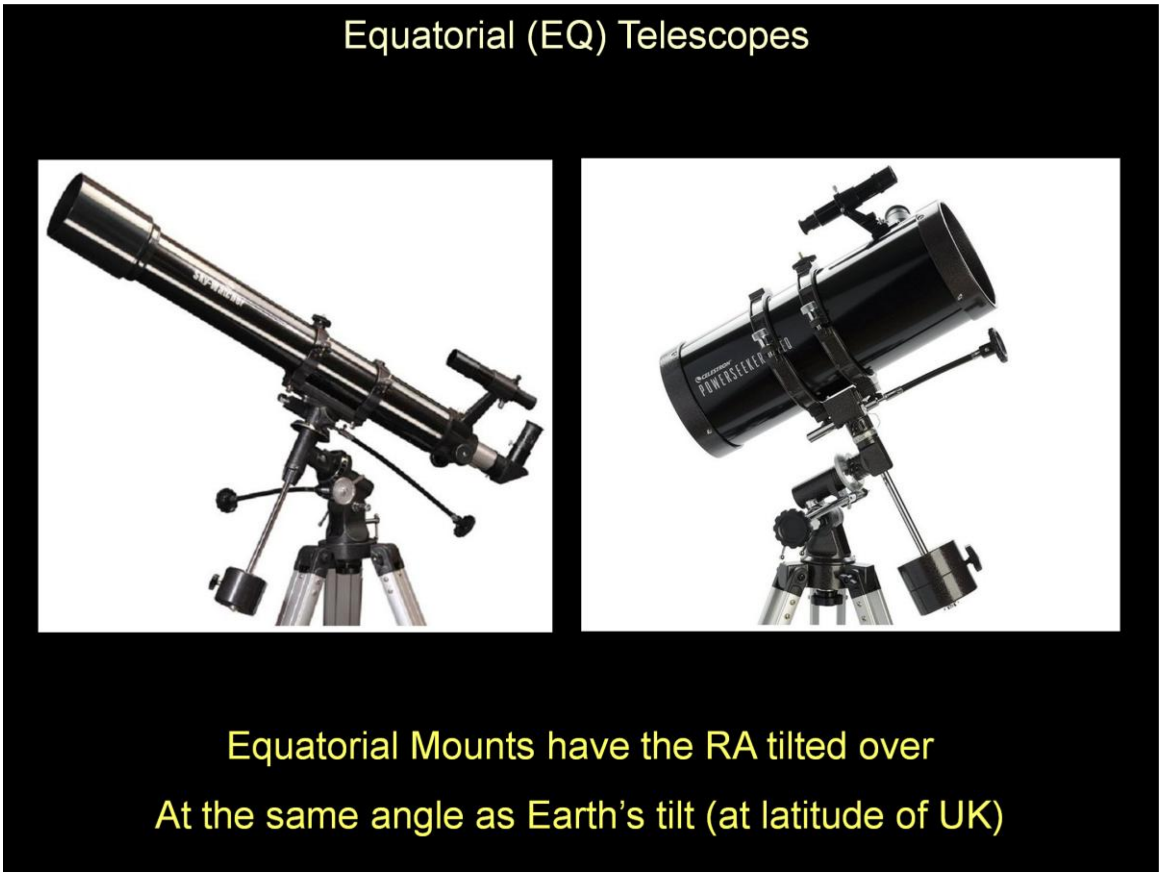


The Alt Az mount can be pointed around the sky from anywhere on the horizon (0º) and up (through 90º) to the Zenith (the point in the sky directly overhead).

The whole sky can be viewed but the tripod can prevent the sky directly overhead being observed. This is not a problem with the Dobsonian mount.

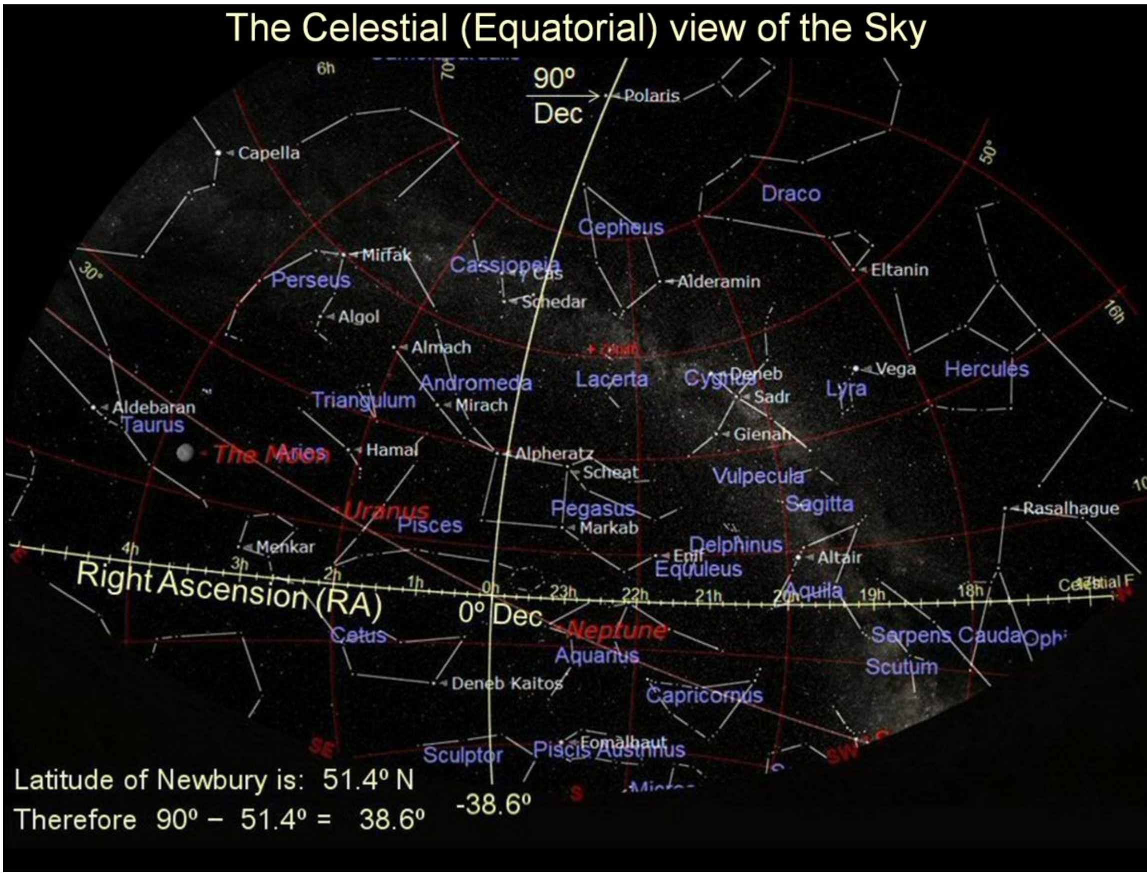
The disadvantage is the stars and planets appear to move in a arc across the sky due to Earth's tilt. It is necessary to adjust the telescope position in both directions simultaneously to track an object moving in and arc across the sky.

This is not a great problem for visual observing and manual tracking but tracking for astro-photography can be difficult.



The 23.4° tilt of Earth's axis causes the stars and planets to appear to trace an arc across the sky as the Earth rotates. Therefore to use an Alt/Az mounted telescope the Alt drive and Az drive must be adjusted together to followed the arc shaped path of an object as it appears to move across the sky due to the rotation of Earth on its tilted axis. To overcome this difficulty a special design of mounting has been developed to allow the arc shaped paths of objects in the sky to be tracked using just one drive. To do this the Azimuth axis is tilted to the same angle as the axis of Earth as measured from the observer's latitude 51.4° from Newbury. Using this type of mounting, called an Equatorial Mounting, allows just the Longitude drive known as Right Ascension (RA) to be adjusted to track an object. The telescope will trace out the same arc across the sky as the object being observed because the RA axis is at the same angle as the axis of rotation of Earth.

The image above shows a typical (but expensive) Equatorial Mount.



Unlike the Alt/Az mounted telescope that has a tangible zero point to align to (the horizon) the Equatorial mounting needs to be aligned to a point somewhere in the moving sky. There is only one point in the sky that can provide this and that is the point in the sky where the northern axis of Earth's axis of rotation points. We call this point the Celestial North Pole. It is the only stationary point and the point around which the whole sky appears to rotate. There is no star at this point in the sky but in the northern hemisphere there is a star very close by. The star Polaris in the constellation of Ursa Major (the Little Bear) is just 44 arc-minutes from the North Pole and is consequently called the Pole Star or the North Star.

When using an Equatorial Mounting we designate the North Pole position as the 90º point for elevation that we call Declination (Dec) on an Equatorial Mounting. We measure 90º down from the North Pole to 0º and this will be where the Geographical Equator of Earth circles the North Pole in the sky we call this line around the sky the Celestial Equator (Earth's Equator).

However there is no stationary point that we can use as the zero starting point of reference for aligning the Right Ascension tracking.

The Zero Datum Point of RA (Longitude)

There is a fixed point for Dec but not for RA

The sky appears to rotate once every 24 hours

So we need something in the sky we can use as zero

There are two points that we could use

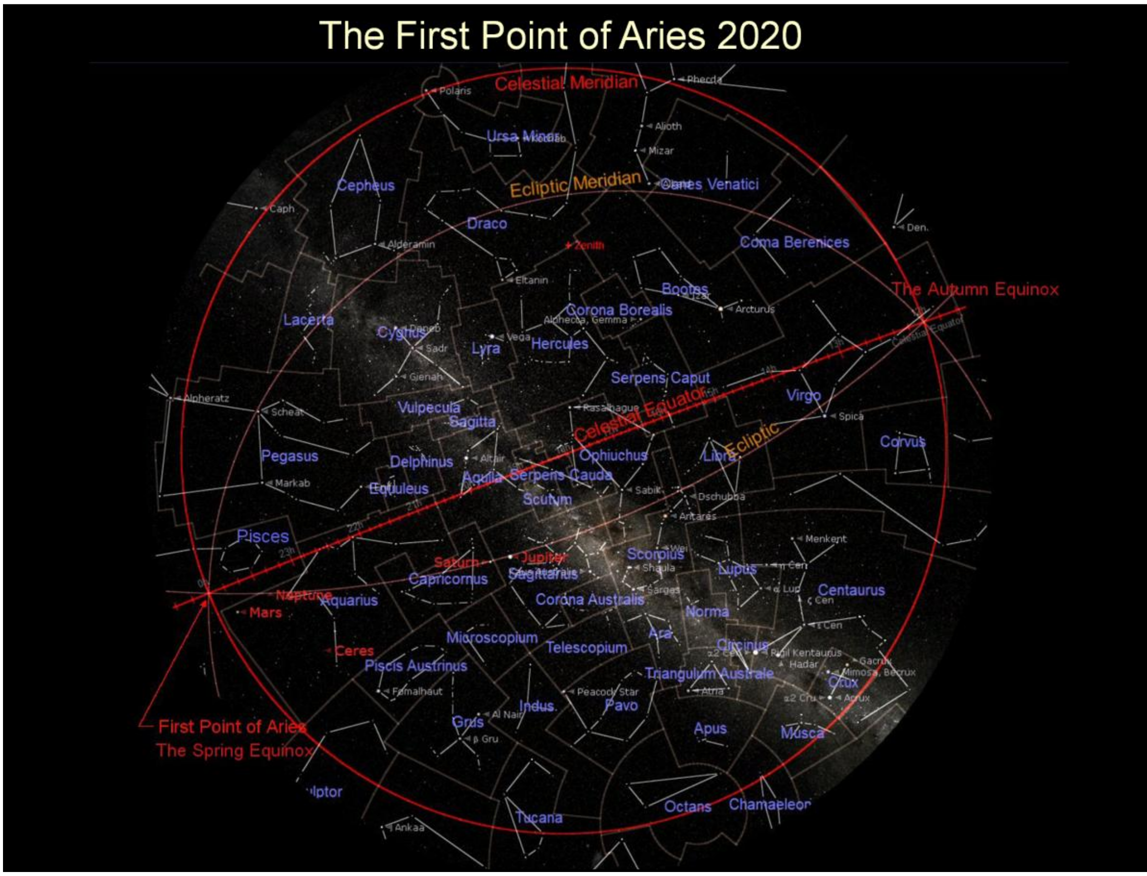
These are where the Celestial Equator and Ecliptic cross

These occur at the Spring and Autumn Equinoxes

Hipparchus defined it as the Spring Equinox in 130 BCE

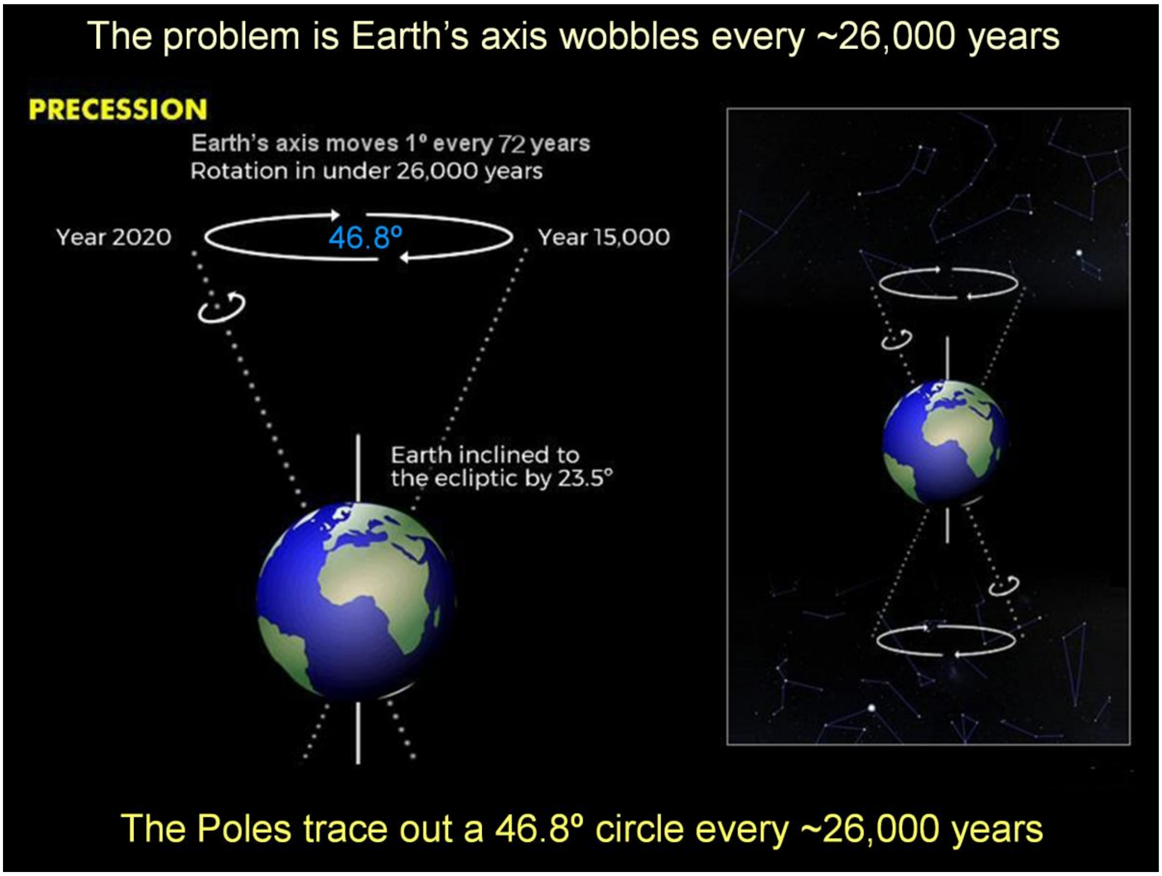
At this time it was located in the western extreme of Aries

Hence it was given the name 'First Point of Aries'

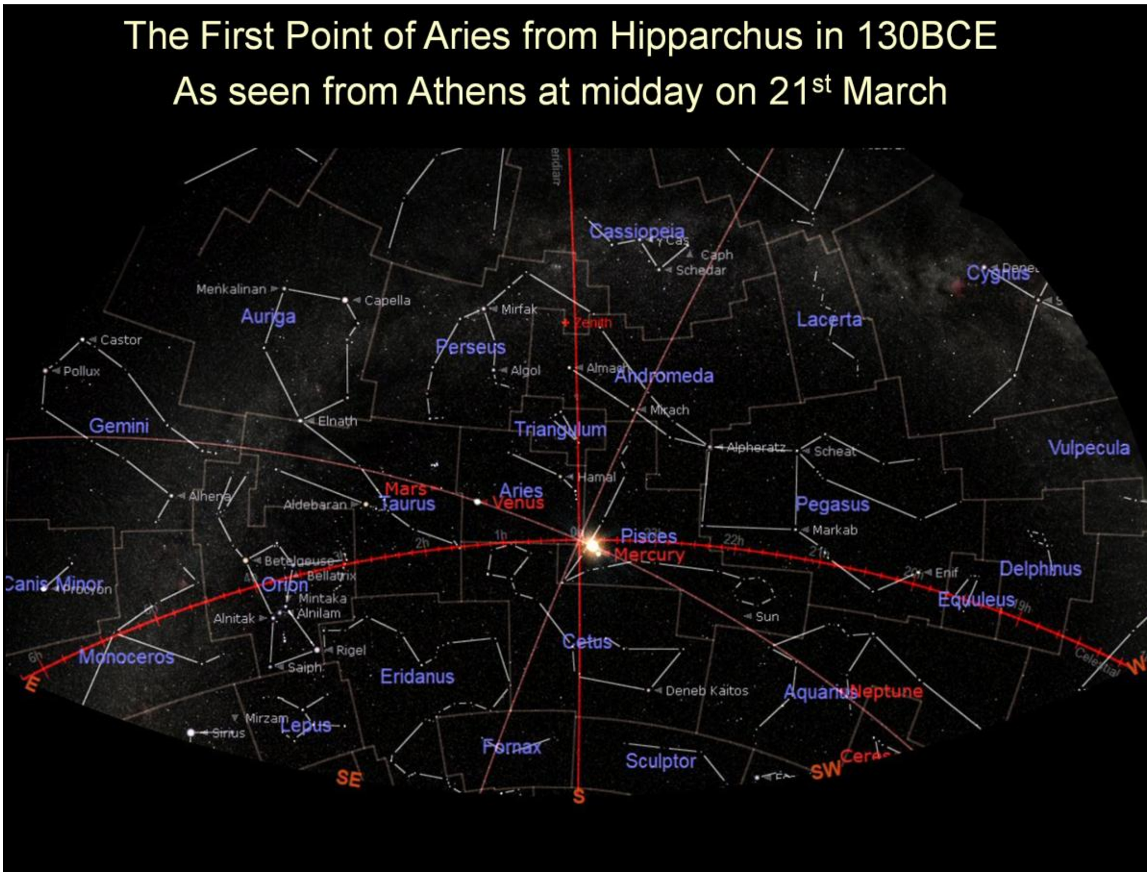


The chart above shows where the Celestial Equator and the Ecliptic (Earth's Equator) cross on the Spring and Autumn Equinoxes. So this is the time when the Sun moving North or South for Winter or summer appears to cross Earth's Geological Equator. The chart above shows Celestial Equator (Earth's Geological Equator) in red and the Ecliptic (the Equator of the Sun and Solar System).

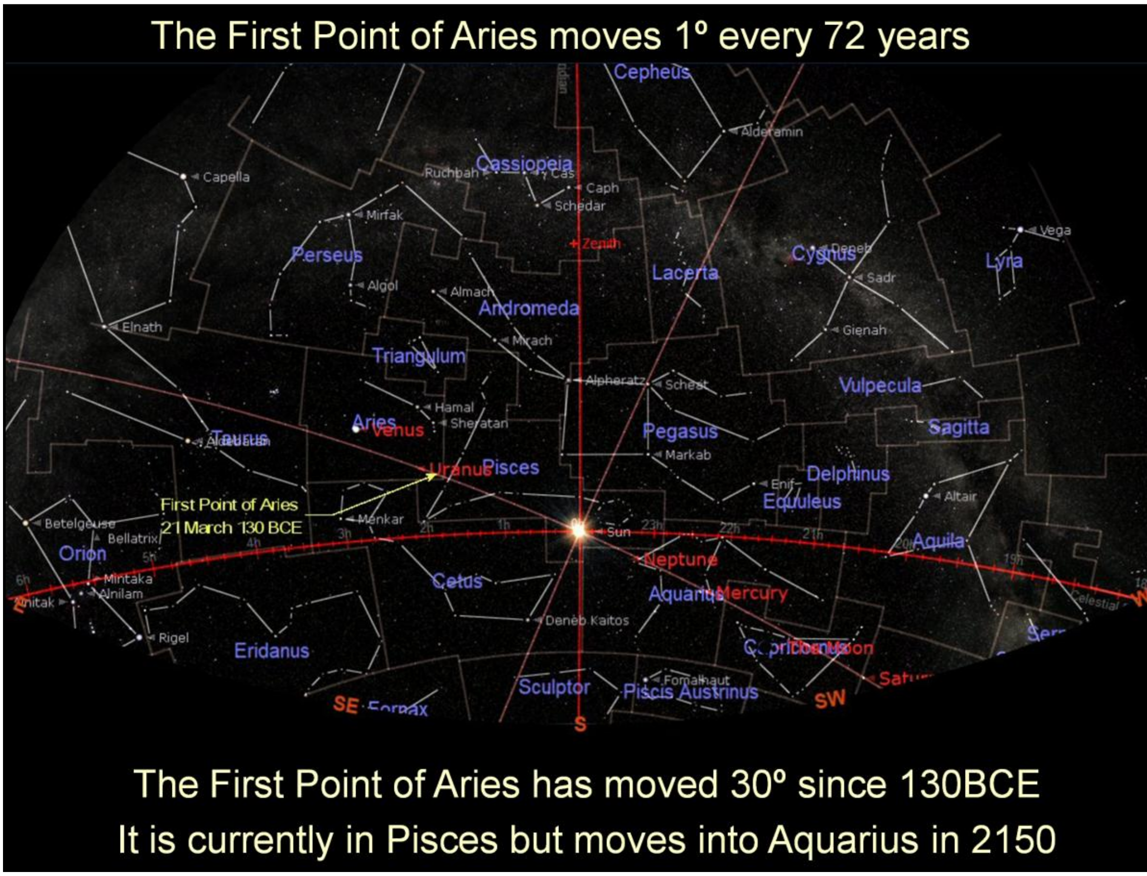
The two points where the two Equators cross are known as the Spring (or Vernal) Equinox and the Autumn Equinox. The crossing point of the equators (Spring Equinox) is used as the zero reference point for the RA in the Equatorial coordinate system. This point is known as the 'First Point of Aries' although it does not reside in the constellation of Aries.



There is a small and distant problem with using the Celestial North Pole as our 'Datum' point of reference for Declination and RA when setting up an Equatorial Mount. The problem and bad news is the Celestial North Pole moves. Earth wobbles on its axis causing the Celestial North Pole to move in a circle for each wobble. However the good news is each wobble takes about 26,000 years to complete so the Celestial North Pole moves in a circle every 26,000. The diameter of the precession circle traced out by the poles is approximately 47º this is 2 x Earth's tilt ~23.5º (actually 23.4º) .

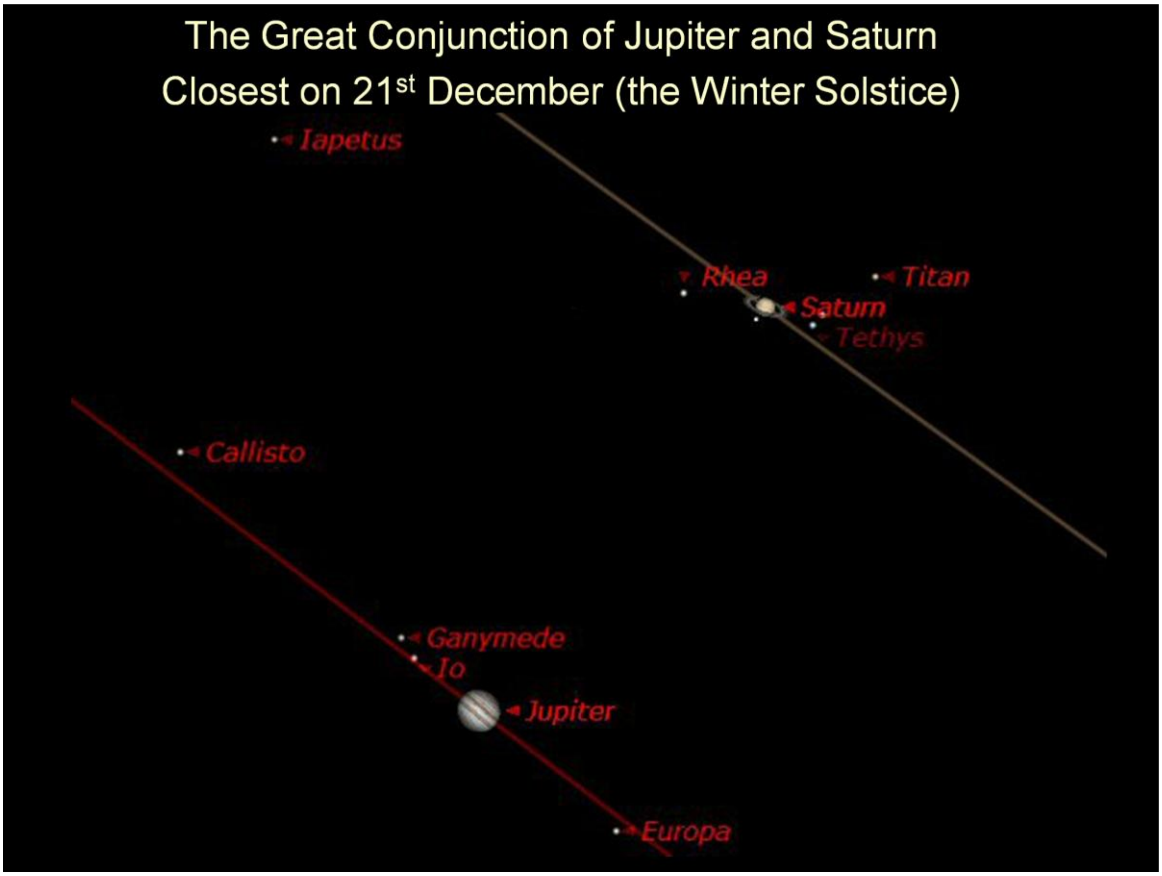


The First Point of Aries was defined by Hipparchus as the Spring Equinox in 130 BCE. At this time it was located in the lower western edge of Aries and was the point where the Sun exited the constellation. The chart above shows the sky as it appeared on the Spring Equinox in March 130BCE. The First Point of Aries is where the Sun was located at this time.



The chart above shows the location of the First Point of Aries this year at the Spring Equinox on 20th March 2020. First Point of Aries is at the conjunction of the Celestial Equator (Earth's Equator) shown in red and the Ecliptic (the Equator of the Solar System.

Due to Precession (the wobbling of Earth's Axis of Rotation) the First Point of Aries is moving to the west along the Ecliptic at 1º every 72 years. Since 130BC the First Point of Aries has moved about 30º into the constellation of Pisces where is resides today. It will continue to move and will move into the neighbouring constellation of Aquarius in 2150. In about 26,000 years it will have moved back to its original location as defined in 350BC.



Coincidentally there is a very important event occurring on the Winter Solstice this year. On 21st December Jupiter will be overtaking Saturn on their orbits around the Sun. This does happen every 20 years but this year they will appear very close together in the sky. The last time a 'great conjunction' occurred that was as easy to see as this year's was in on 4th March, 1226, though on 19th February 1961 the two planets were just 0.14º apart while 34.9° west of the Sun.

It may have been a long wait for the nest conjunction on 21st December 2040 and that is a short time until the next conjunction. There is some good news, Jupiter and Saturn will once again be just 0.06º apart in the pre-dawn sky while 43.5° from the Sun in Sagittarius so will be significantly higher up in a darker sky. The bad news is that will happen on 15th March 2080.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