Summary Notes - Topic 6: Celestial Observation (Part Two)

6.8 Understanding Local Sidereal Time & Hour Angle

Meridian

A meridian is an imaginary line between north and south poles through the observer's position. Your meridian right now is slightly different to the person next to you etc.
The prime meridian is used as a reference for time conventions. It is a meridian from which others are measured.
The meridian is where the sun will be highest at local midday. This is local sidereal time so someone on a meridian in London will see the see culminate earlier than someone in Bristol, 2° to the west.

Hour Angle

This is the angle between the meridian of the observer and the meridian line on which the star is. We call this line the **Hour Circle**. We don't use angles of degrees; as these might not be appropriate depending on the position of the star. We calculate how long it will take for that star to transit the meridian of the observer, so use hours, minutes and seconds instead.

Let's say an observer is looking at a star due west of their position at 9pm. The star transits the observers meridian at 11.30pm. This is easy – there is a difference of **2 hours 30 minutes**. That's the hour angle.

So how far is this star?

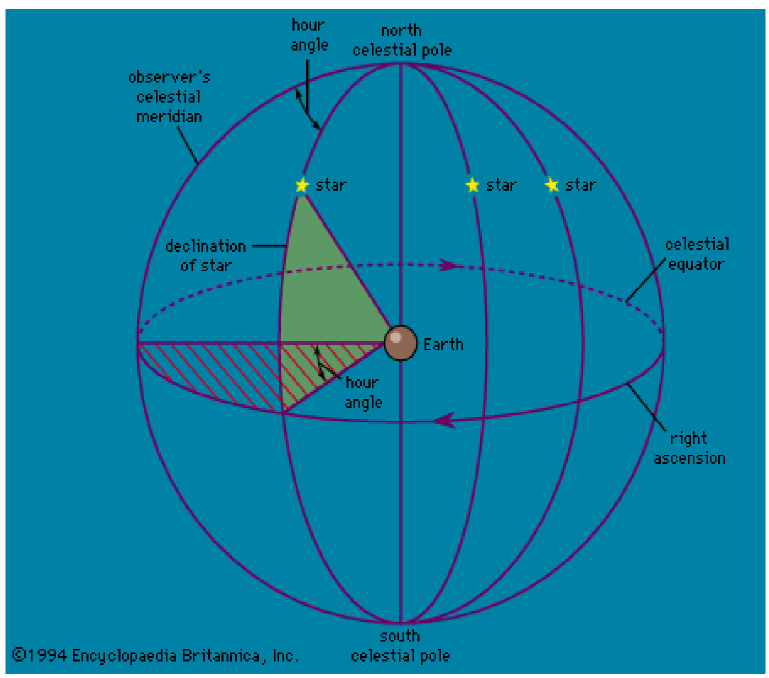
- 24 hours = 360° **->** 360/24 = 15° of arc (1 hour)
- 2.5 hours x 15° = 37° West

We only calculate westwards so if a star is 1 hour east of the meridian it will be a difference of 23 hours.

To find the hour angle use this formula:

Hour Angle of star = Local Sidereal Time- Right Ascension of star

HA=LST-RA.

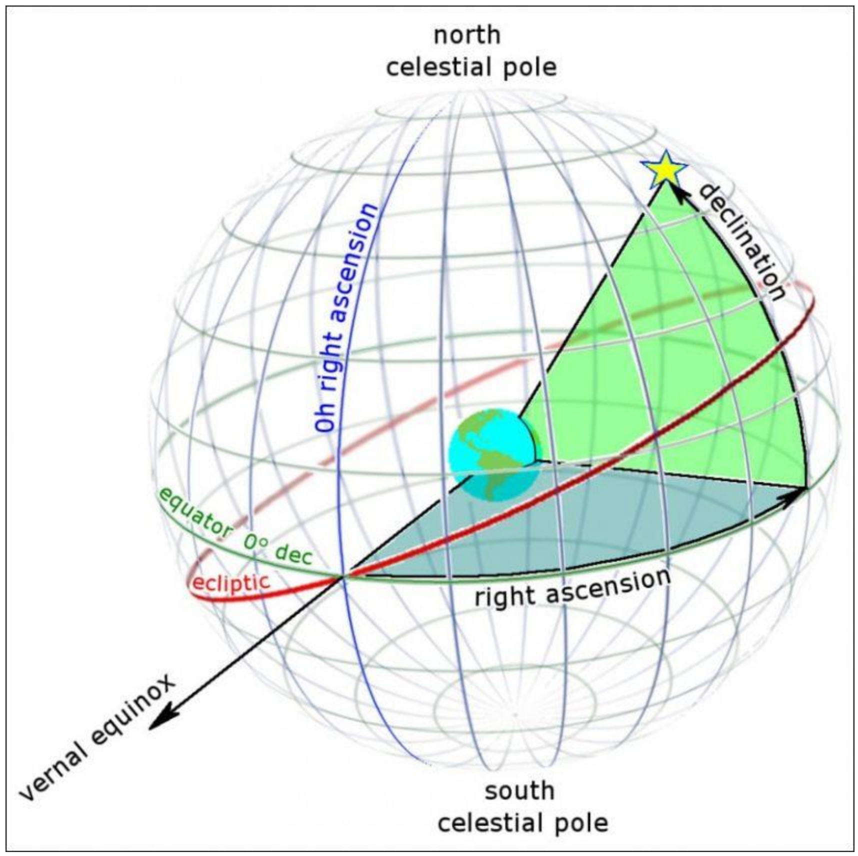


6.6 Understanding Celestial Coordinates, 6.7 Linking Observer's Latitude to Celestial Coordinates

The Celestial Sphere is an imaginary sphere around Earth. We can imagine that all natural objects in the sky can be plotted on this so we can measure and understand their apparent positions.

Our poles are projected outwards to the sky and known as celestial poles. Likewise our equator is projected outwards and known as the celestial equator.

We know that the point at which the sun on the ecliptic crosses the celestial equator at the vernal equinox is known as the 'First Point of Aries' and where it crosses the equator at the autumnal equinox is known as the 'First Point of Libra'.



There are two coordinate systems we use in astronomy:

Equatorial: Right Ascension and Declination

Horizontal: Altitude and Azimuth

Let's consider the **SUN**:

An observer is located at a certain place, between the equator and poles, they will see stars below and above the celestial equator as the ecliptic is at an angle of 23.5° in the sky. When the Sun is at the highest point in daytime at noon we can work out its altitude:

Sun Altitude = Sun Declination + (90° - Latitude of Observer)

So for London (51°N) in late June this might be Sun Altitude ->

20° (Declination) + (90°-51° =39) = 59°.

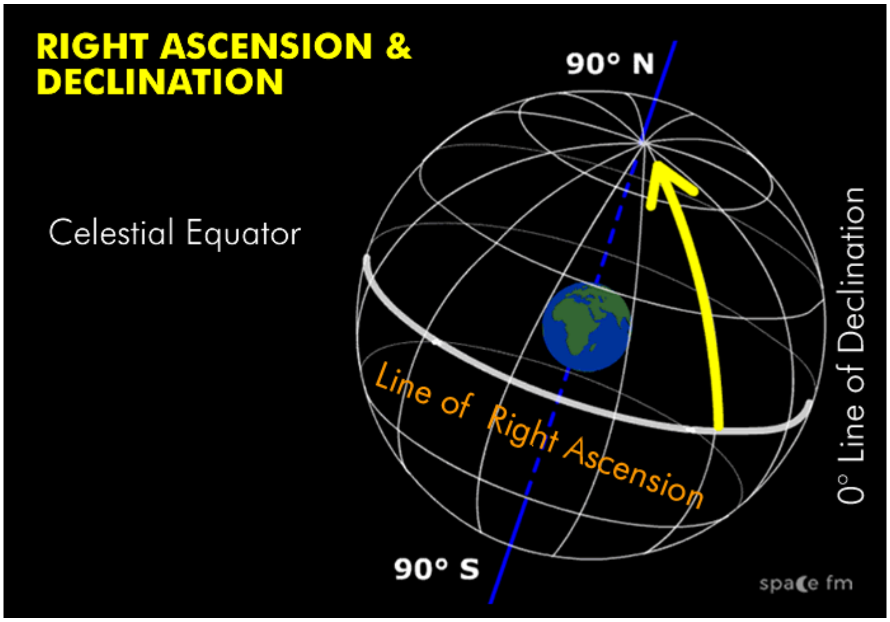
In December this would work out as ->

23° (Declination) + 39 = 16°

We need a reference to say where the position of a star is, so we use Right Ascension and Declination.

Declination
Declination is the latitude of a star in the sky measured from the Celestial Equator.
If the star is given a declination of +45° then you would see it from the equator at 45° in the sky.

Declination measured in degrees (°), arc minutes (‘) and arc seconds (“) and is abbreviated as **dec** or **δ**.



Right Ascension
Right Ascension is the equivalent of longitude in space.
We need a marker that everyone on Earth can use. On Earth we measure longitude from and have defined a prime meridian as the First Point of Aries.
(Where the Sun crosses celestial equator along the ecliptic at the vernal equinox)

Right Ascension is measured in hours (h), minutes (m) and seconds (s) and is abbreviated as **RA** or **α**.

If a star lies on a line between where the Sun crosses the Celestial Equator in spring and north (or south) then it will be said to lie at 0h 0s 0m° RA. If it lies 90° to the east* it would be located at 6h RA (360/90 = 4. 24/4 = 6).   [East rather than West as in the hour angle.]

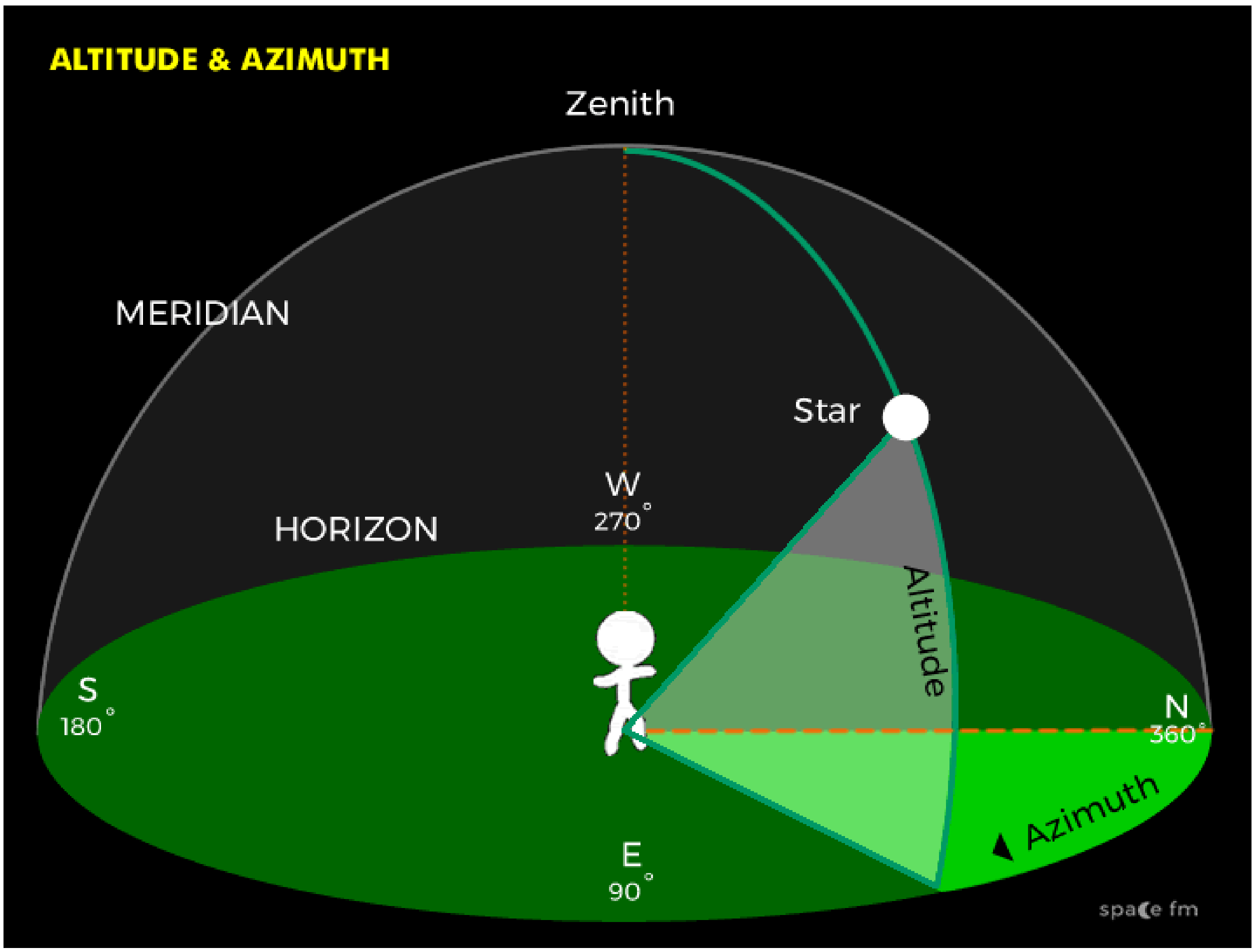
RA and DEC
Most stars have their right ascension and declination published. These are usually abbreviated to RA and DEC. Star maps and planispheres feature gridlines for the observer to follow. In a star map you would see a star listed in this format: Arcturus: RA: 14 15 40 DEC: +19 10 57

Then our **horizon** coordinates are:

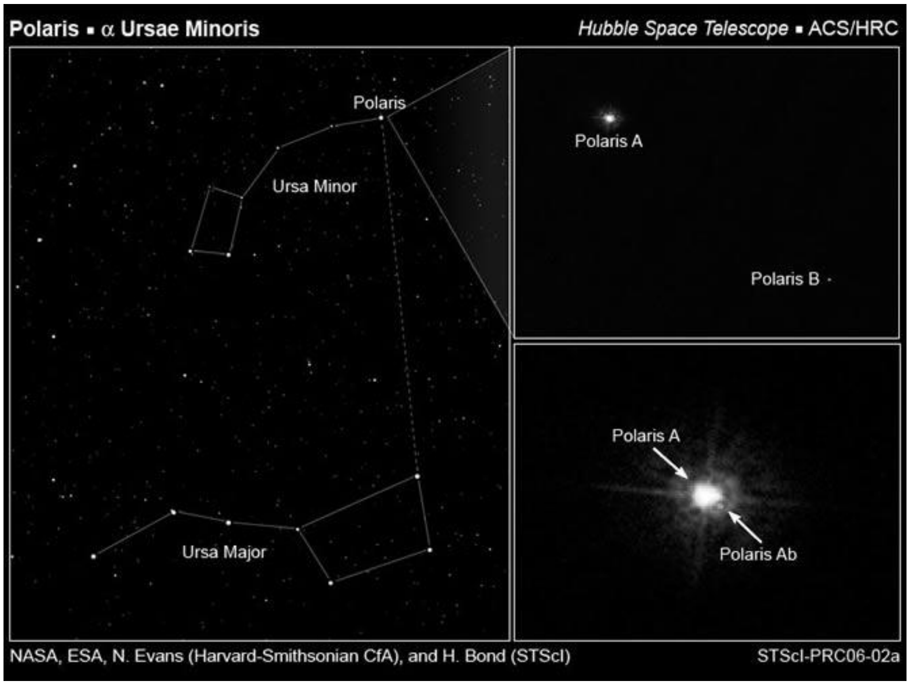
Altitude
We can measure how high in the sky an object is from any location on the horizon in degrees from 0° at the horizon to 90° at the zenith. An observer can find their latitude by the angle to the Northern Celestial Pole (NCP) marked by the star Polaris.
Altitude of NCP = Latitude of Observer

(In **London (~51°N latitude)**, Polaris appears ~51° above the horizon.)

Azimuth
We can also measure its direction along the horizon. We take north as 0° and travel eastward increasing the angle until we reach 360° north again. An observer can fairly easily use this system if they have a reasonable grasp of estimating angles and know how to find north.



6.12 Finding Latitude Using Polaris



Polaris is located at very close to 90° in the sky.

This is the Northern Celestial Pole. If you stood at the North Pole and looked up, it would be directly above your head.

Because of this we can find our latitude in the Northern Hemisphere by measuring the angle of Polaris in the sky.

Polaris is doubly useful as it appears fixed in the sky and other stars seem to rotate around it. It always points north and lies less than 1° to the North Celestial Pole. This is often abbreviated to NCP.

An easy way to find an observers latitude is to measure the angle of Polaris:

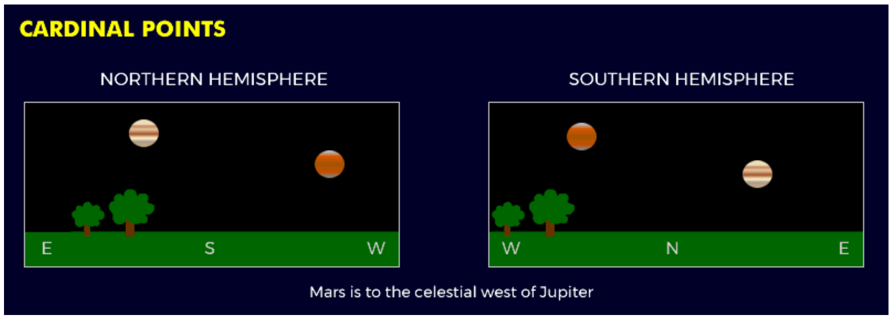
Altitude of NCP = Latitude of Observer

If you were slightly north of the Equator you may be able to see Polaris on the horizon looking north.

From London you can see Polaris at approximately 51° north.
(There is no bright star that represents the Southern Celestial Pole)

6.10 Key Astronomical Terms

- **Cardinal Points**
  A cardinal point is the same as compass points. We refer to north as celestial north, south as celestial south etc.



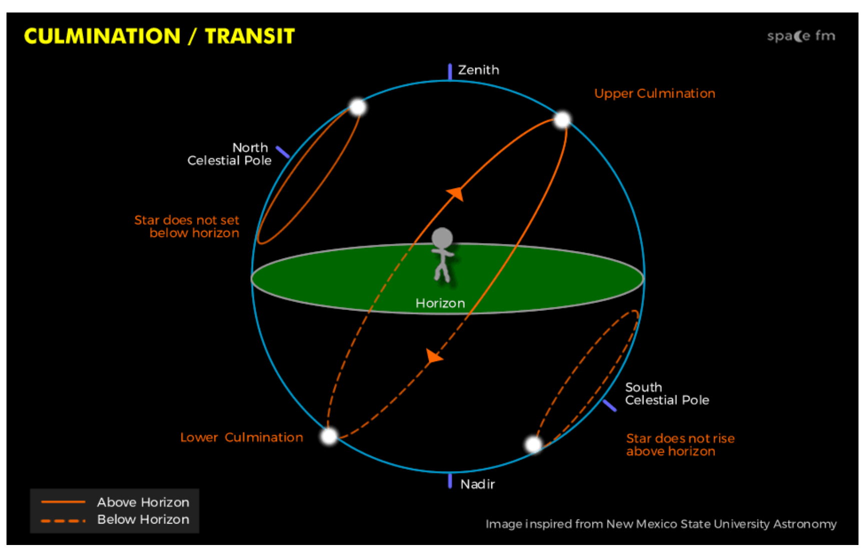
- **Culmination**
  Culmination is when a star (or other body) reaches the observer's meridian.
  A star will do this twice each day.

  At upper culmination (also known as culmination above pole) it has an hour angle of 0h.
  At lower culmination (or culmination below pole) it is passing between the pole and the horizon, and has an hour angle of 12h.

  These will mean different views depending on the location of the observer.
  A circumpolar star will be reach upper and lower culmination in the sky.
  A seasonal star will reach upper culmination in the sky and lower transit below the horizon.

  Exam tip: When you are asked 'when a star culminates...' it means upper culmination.

  (n.b. A star never visible from a location will technically culminate but both types will be beneath the horizon)



- **Co-declination**
  This is the distance between North Celestial Pole (NCP) and Star **= 90° - Declination**
  An object's altitude (*A*) in degrees at its upper culmination is equal to 90 subtracted by the observer's latitude (*L*) and added by the object's declination (*δ*):

  $$A = 90° - L + \delta.$$

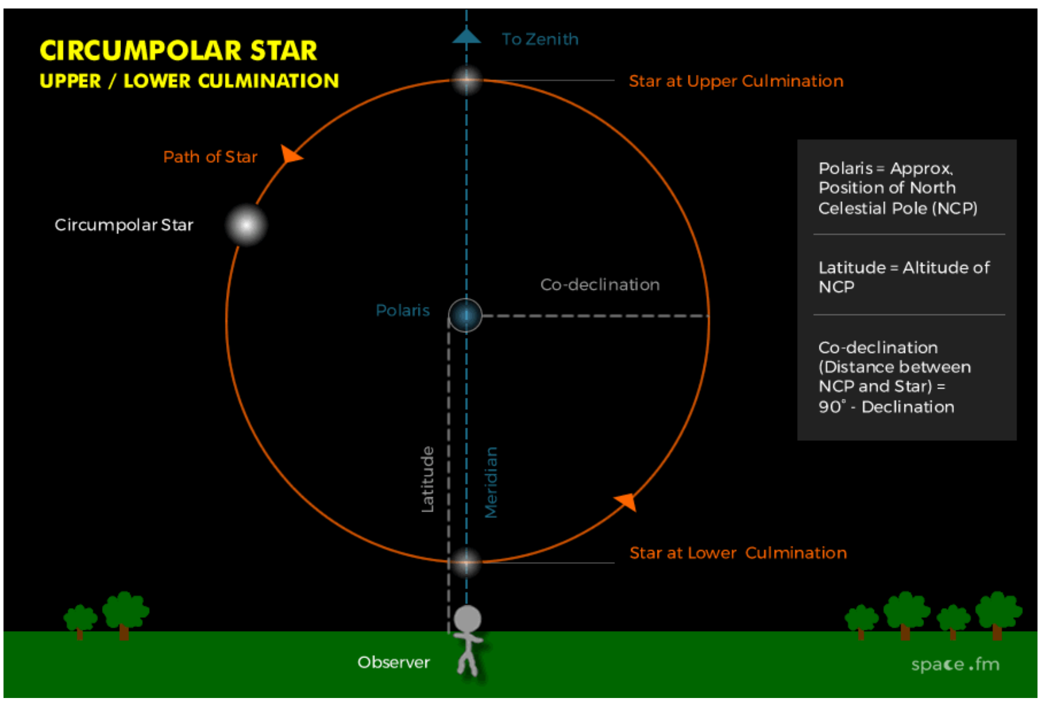
  Upper Culmination takes place when **Right Ascension = LST**

- **Meridian:** Imaginary line passing from N to S through the zenith. (covered above)

- **Zenith**
  The **Zenith** is the point directly above the observer's head. 90° perpendicular to the ground.

  The opposite of Zenith is the **Nadir**, the point directly below the observer's feet. Imagine if the Earth was transparent and you could see the stars directly below you.

- **Circumpolarity**
  Circumpolarity is when a star never sets below the horizon from a certain latitude.



6.9 Predicting the Best Time for Observations

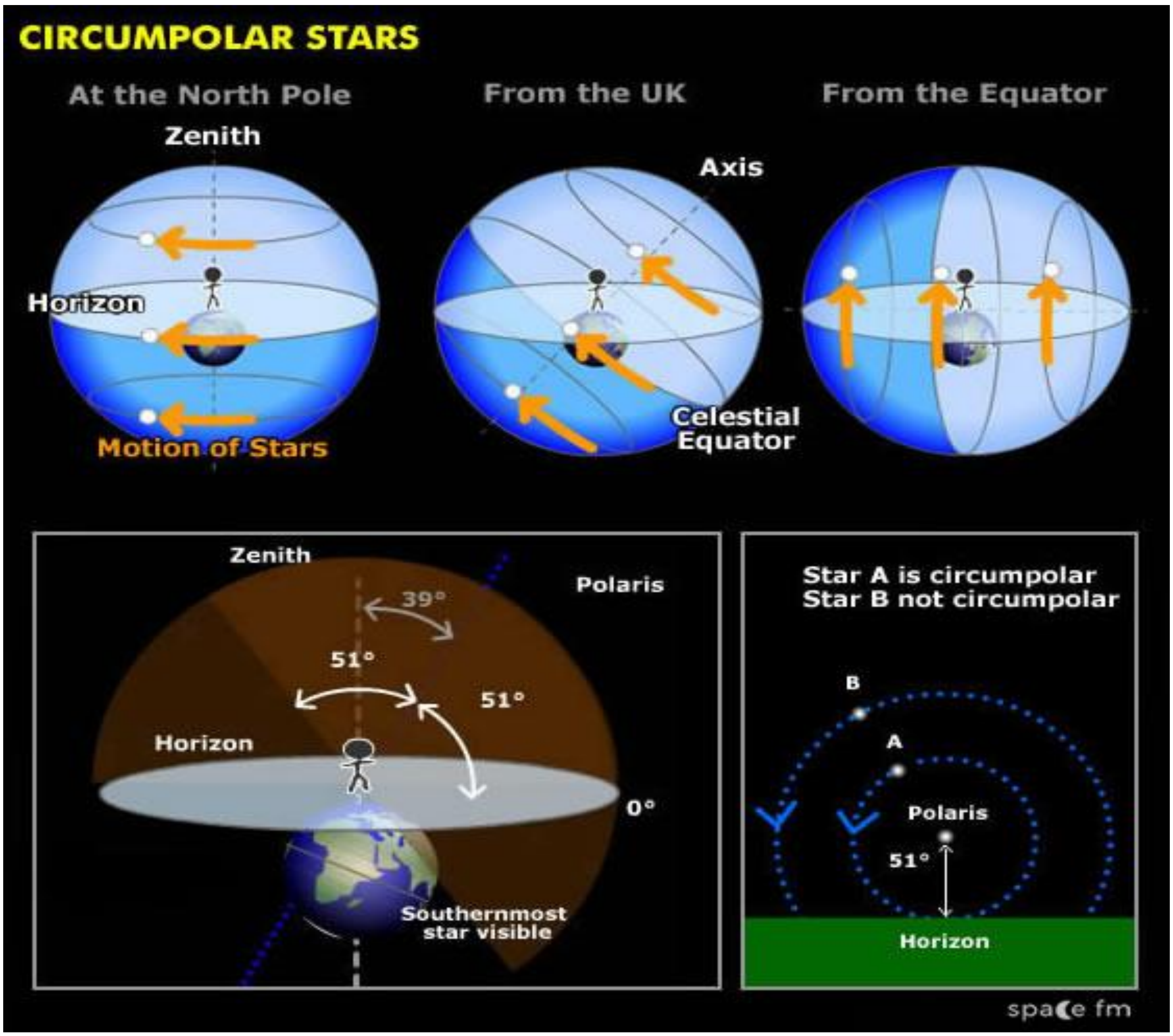
- Use **star charts or apps** to determine when objects are highest in the sky (culmination).
Best viewing conditions occur when an object is **near the meridian** (highest altitude).

6.11 Understanding Diurnal Motion & Circumpolar Stars

If you lived at the Poles you would see the same stars throughout the year.

However in the UK (between latitudes 50 and 60° north) we see circumpolar constellations, such as Ursa Major throughout the year and some constellations, such as Orion, for a few months of the year.

This is caused by the same factors that govern the seasons on Earth (the Earth's 23.5° axial tilt to the ecliptic). This results in us seeing some constellations throughout the year and some only part of the year. The amount of daylight also has an important part to play in this.



Orion is visible from October to February in the night sky. It is in the sky in June but we can't see when it rises as it is daylight. By the time evening comes it is set whereas Ursa Major has not set, it is visible in the night sky.

Circumpolar stars are stars that can be seen from one location throughout the year. Other stars are usually only seen for a month or two.

They are stars that never seem to set below the horizon, so the nearer you are to a pole, the more stars you'll see that are the same throughout the year, and the less seasonal stars. When you're nearer the Equator you'll see less circumpolar stars but more seasonal stars.

Stars appear to revolve around Polaris in the Northern Hemisphere. As the Earth rotates stars appear to revolve around that star because it is above the Earth's northern axis.

In the exam you may be asked to determine:

- *Which stars are circumpolar and which are not.*
- *What latitude you would have to be at in order to see a certain star*
- *The smallest or largest Declination a star would be at from a given latitude*

Think back to **culmination** for the upper and lower transits of circumpolar stars. (Upper culmination when it is at the highest point in the sky)

A star is circumpolar if the following formula is true:

Declination of Star >= 90° - Latitude of Observer

Example:

Megrez (Ursa Major) has a declination of 57°.

Our observer in London is at 51° North.

90°-51° = 39°.

57 is greater than 39 so Megrez is circumpolar from London. Another way to do it is to say **Declination > Co-latitude** which involves the same mathematics = 90°-51° = 39°. 57°>39°.

What if we don't know a stars declination?

We can measure its **altitude** at upper and lower culmination we can tell if the star is circumpolar by using:
Observer's Latitude ± Co-declination of star

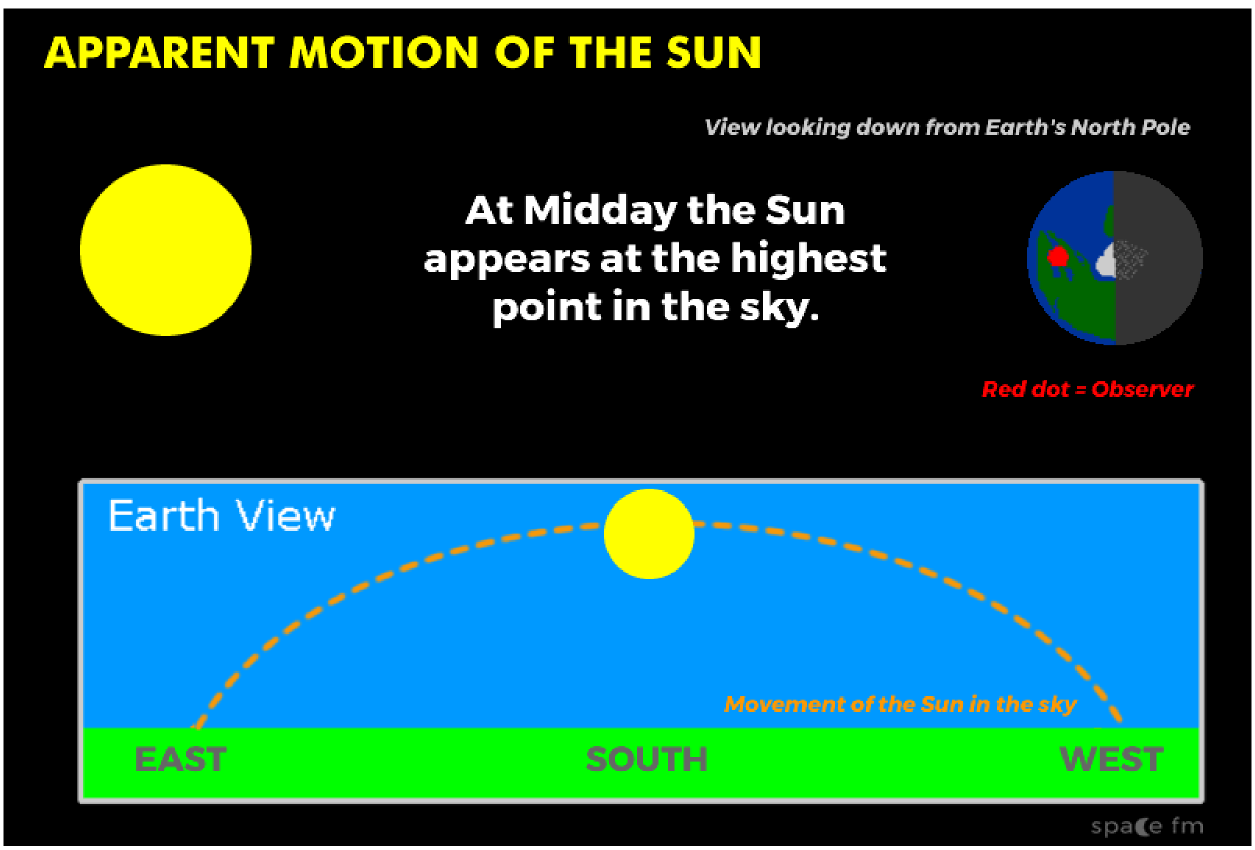
Motion of the Sky

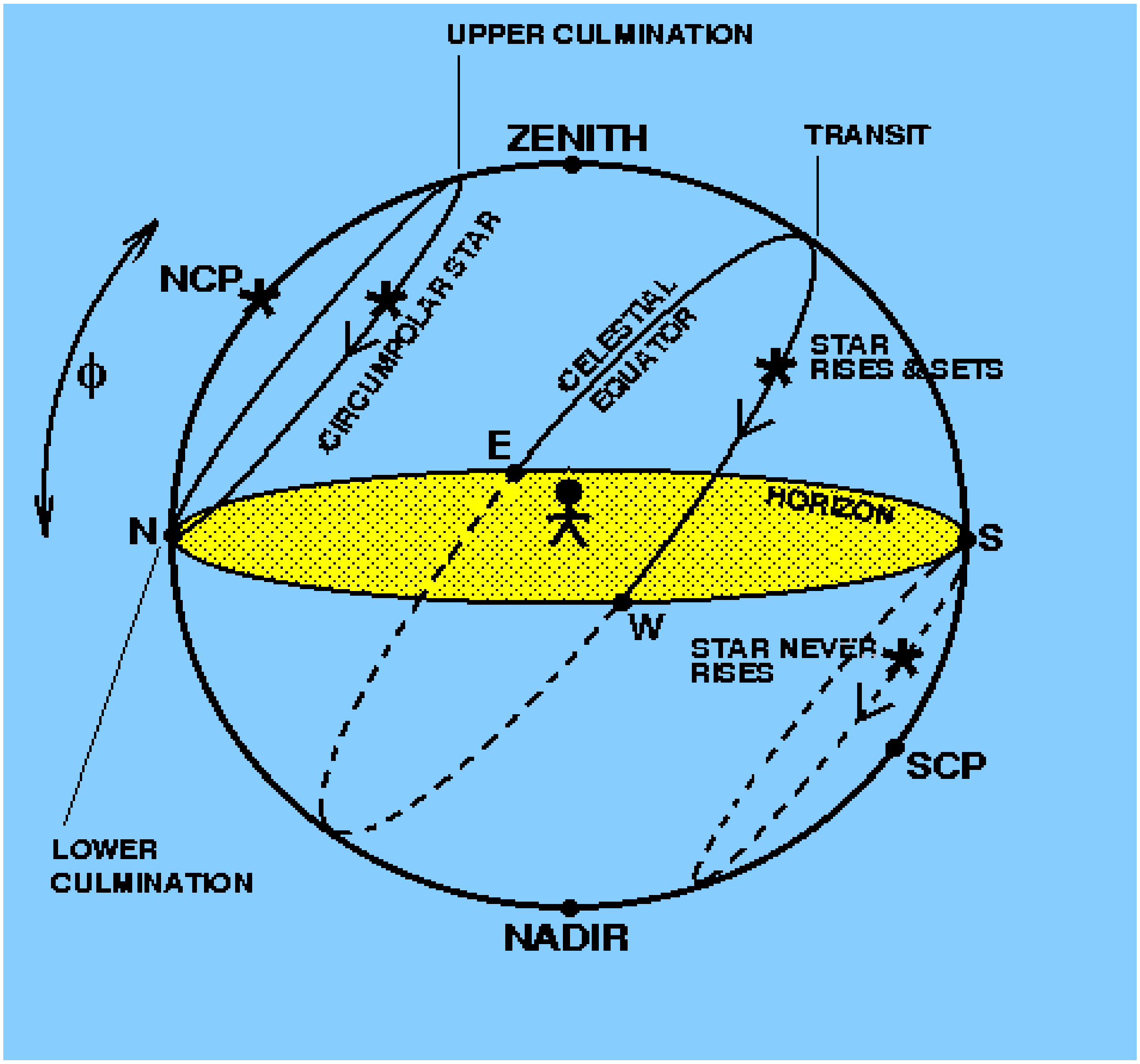
Astronomical objects in the sky move through the course of the day and night and move position through the course of the year.

Imagine you are facing south. Now think of a ball moving from left to right (east to west). This is the direction the Sun appears to move in the sky.

We know the Earth goes around the Sun and not the other way around.

Diurnal motion is the apparent daily motion of celestial objects, like stars and the Sun, across the sky from east to west. This motion is caused by Earth's rotation on its axis from west to east, which makes the celestial sphere appear to move in the opposite direction.

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ZENITH
TRANSIT
NCP
CIRCUMPOLAR STAR
CELESTIAL EQUATOR
STAR RISES & SETS
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