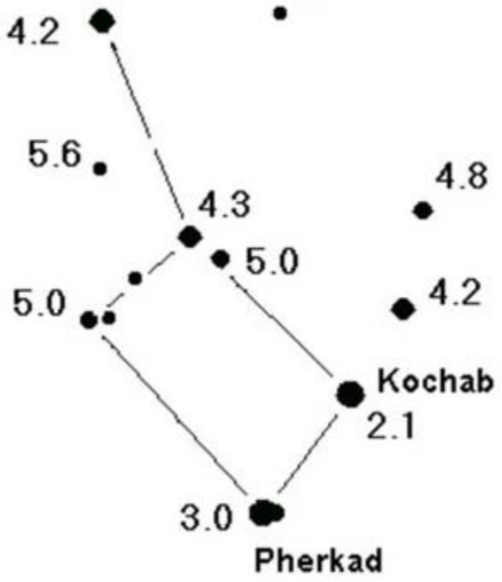
Astronomy **Summary Knowledge Organiser** – Chapter 13 (Topic 13) **Exploring starlight (i) Bayer, m & M**

<u>**BAYER CLASSIFICATION**</u> - *Greek alphabet*

The **relative brightness** of individual stars within a constellation can be given using lowercase letters from the Greek alphabet. German astronomer Johann **BAYER** introduced the system in 1603.

Alpha represents the brightest star in a constellation. **Beta** will be the second brightest star in that constellation and so on.

On the section of **star chart** shown below the star **Kochab** would be labelled as the **ALPHA star** since it is the brightest – shown by it having the <u>**lowest**</u> **value of** ***APPARENT MAGNITUDE***. **Pherkad** would be **BETA**. Only the brightest stars tend to be given a name.



<u>apparent magnitude</u> tells us '**how bright a star appears in the night sky**'. It is denoted by the ***lower case letter m***.

The table right shows the **apparent magnitude (m)** of stars in the constellation of **Scorpius**, the Scorpion.

star	apparent magnitude
α	0.9 - 1.8
β	2.6
δ	2.3
ε	2.3
λ	1.6

It is clear from the table above that sometimes the Bayer designation of the star does not match the order of star brightness in terms of its measured modern day apparent magnitude. This is because measurements of star apparent brightness have become much more accurate as time as passed since the 1600's. Also, some stars such as **Polaris**, are in fact **VARIABLE STARS** and so **periodically change brightness**.

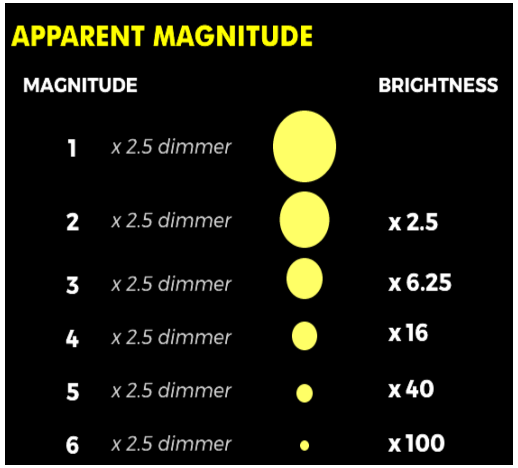
FOUR factors that effect the '**apparent magnitude**' of a star are;

The stars true **luminosity** (energy output)

Its **distance** away

The **amount of interstellar gas & dust** that reflects & absorbs light

The **amount of light absorbed & reflected by the Earth's atmosphere**



The **BRIGHTNESS RATIOs** shown above tell us that if there is a **one magnitude difference** between stars, then one star must be 2.5 times brighter than the other. A 2 magnitude difference means one star is 6.25 times brighter than the other because 2.5 squared (2.5^2) = 6.25.

The values below are the apparent magnitudes of the celestial objects you are expected to be able to recall.

Sun	-26.74
Full moon	-12.74
Venus (brightest)	-4.6
Sirius (brightest star)	-1.44
Naked-eye limit (urban sky)	+3.0
Naked-eye limit (dark sky)	+6.0
Binocular limit	+9.5
12" Telescope limit	+14.0
Hubble Telescope limit	+30.0

Astronomers use the **ABSOLUTE MAGNITUDE** of a star to describe **how LUMINOUS the star really is.**
It is denoted by an **UPPERCASE letter M.** A stars **ABSOLUTE MAGNITUDE** tells us **what its apparent magnitude (m) would be if it was viewed from a distance of 10 pc (parsec)**.
The **DISTANCE MODULUS EQUATION** (below) allows either magnitude to be calculated knowing the 'other' magnitude and the distance away the star is:

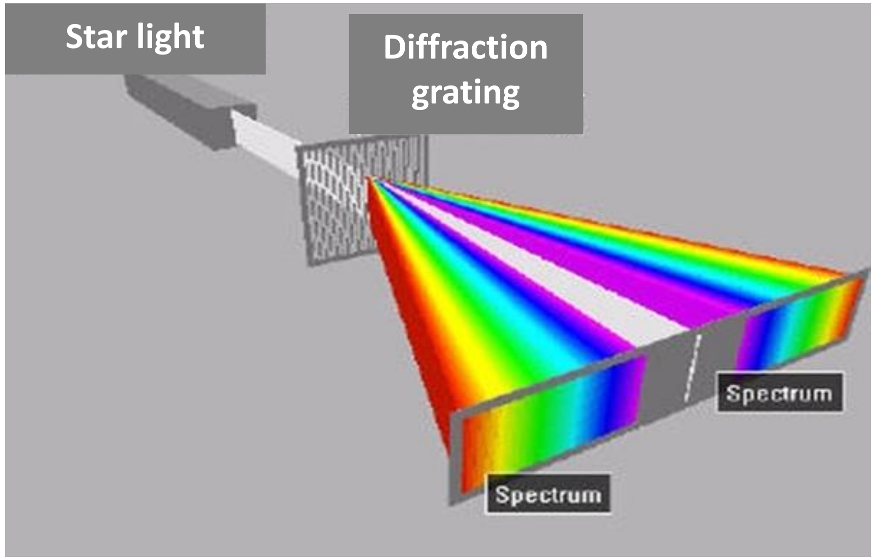
$$M = m + 5 - 5 \log d$$

where **d** is the distance to the star in **parsec**.

You may be expected to enter a distance of, say 361 pc into your calculator and find its logarithm by pressing the log (lg) button on your **scientific calculator**. You will not be required to calculate d given m and M.

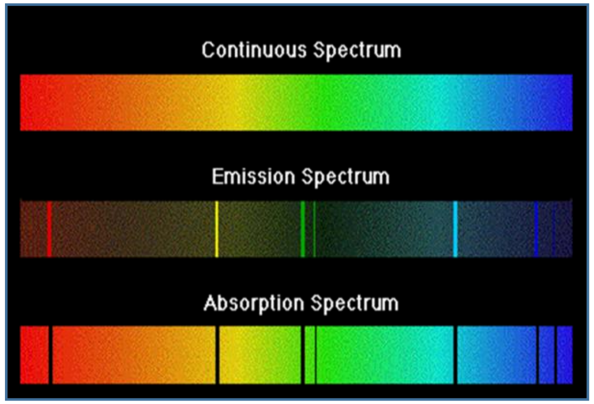
AST **Summary Knowledge Organiser** – Ch. 13 (Topic 13) **Exploring starlight (ii) Spectroscopy & the H-R diagram**

SPECTROSCOPY is the study of the Universe that involves **collecting light using a large telescope and splitting it up** with a **DIFFRACTION GRATING**. A diffraction grating **diffracts different wavelengths of light by different amounts** and therefore **disperses** the light waves creating a **SPECTRUM** of colour (rainbow effect).



Analysis of the **intensity** of the different colours (wavelengths) in a stars spectrum also tells astronomers about the TEMPERATRURE of the star. Hotter stars produce more light of a shorter wavelength (blue) whilst cooler stars have higher intensities at longer wavelengths such as red, orange and yellow. The **H-R diagram** clearly shows the link between a stars **temperature** and its **colour**.
Further analysis of the **<u>position</u>** of the **absorption lines** (spectral lines) in a spectrum can also tell us whether that star is moving towards or away from us. If a star is **moving away** from us in our line-of-sight, the **dark absorption lines will be red-shifted**. This means that the dark lines will not appear where you would expect in a spectrum, they will have 'shifted' towards the 'red end' of the spectrum. Hence the term red-shifted.
Stars **moving away** from us will have **blue-shifted absorption lines**.

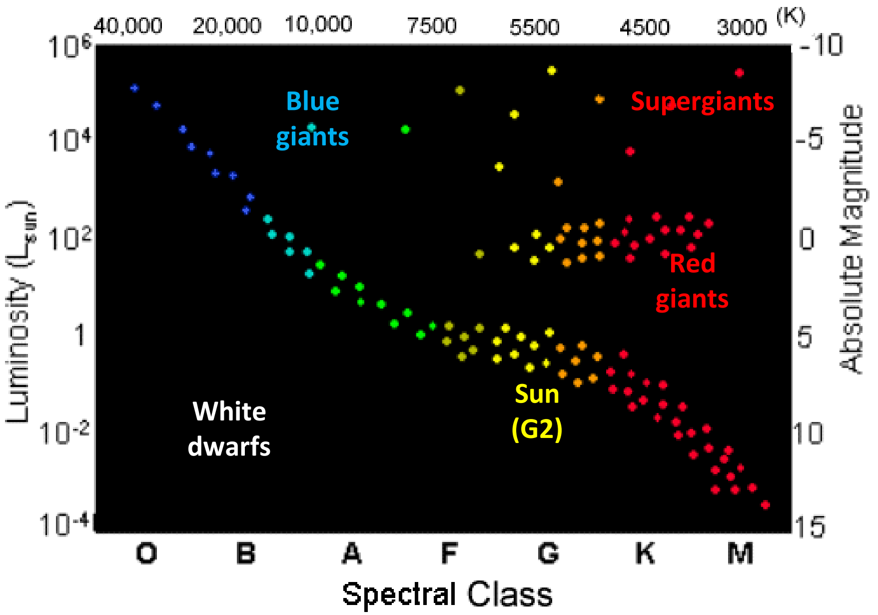
The spectrum of a star or galaxy always has a number of wavelengths at which the light is dimmer in the spectrum, these are called **absorption lines** (or **spectral lines**). They can clearly be seen below as darker lines on the **absorption spectrum**.



As the light passes through the outer regions of a star, the **chemical elements** present in its atmosphere **absorb specific wavelengths** of light and so stop it from leaving the star and travelling to Earth (hence the name ***absorption line***). Each chemical element absorbs a unique set of wavelengths of light (it is like a finger print) and so the analysis of a star's absorption spectrum can tell astronomers about its **CHEMICAL COMPOSITION**.

Once astronomers have discovered the **relative amounts (ratios) of the elements** in a star they can **CLASSIFY** the star as a particular **SPECTRAL TYPE**. 7 <u>**letters**</u> (**OBAFGKM**) are used to classify stars into spectral types, these are then further subdivided using <u>**numbers**</u> (**0-9**).

The Hertzsprung-Russell diagram

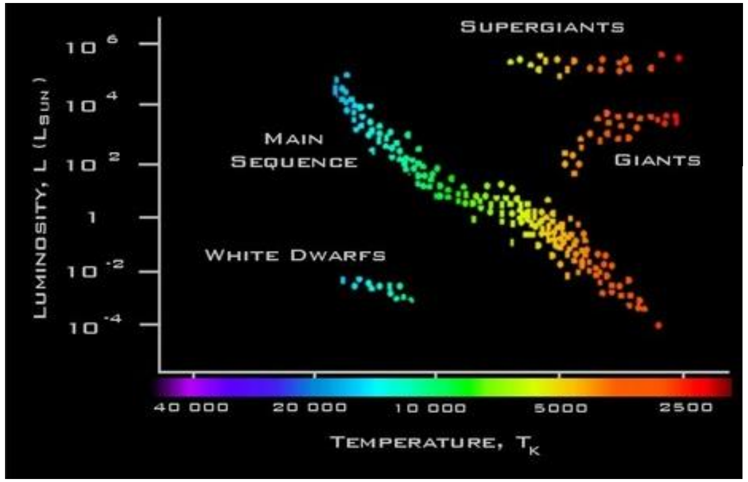


The H-R diagram is a **scatter graph** of a stars **luminosity** (**energy output**) against **temperature** (measured in **Kelvin**). After data is plotted it becomes clear that stars always fall into one of <u>**4 groups**</u>

MAIN SEQUENCE stars
(within a band that runs from top left to bottom right)
WHITE DWARF stars
(grouped in the bottom left of the diagram, due to their small surface area they emit much less energy despite being hot)
GIANT stars
(just above the main sequence band, these can be red or blue)
SUPERGIANT stars
(top right hand corner, these are usually red)

Remember the order of star spectral classes by using the phrase *'Oh Be A Fine Girl Kiss Me'*.
As you move through from class O to M (to the right on the diagram above) the stars temperature is decreasing and so colours are changing from blue to white to yellow to red.

AST **Summary Knowledge Organiser** – Ch. 13 (Topic 13) **Exploring starlight (iii) Distances & variable stars**



Astronomers can use the technique of spectroscopy to identify the temperature and so spectral type of a main sequence star (explained on previous sheet). Once they know this it is simple to read off the H-R diagram and find its absolute magnitude and luminosity (energy output). Once a stars **absolute magnitude (M)** is known, its **apparent magnitude (m)** can easily be found by simply observing the star from Earth and then the distance modulus formula can be used to calculate its **DISTANCE** away (in parsec).

Object	**Angular Size**
Sky	180°
Thumb (arm's length)	0.5°
Moon	0.5° (=30')
Naked eye resolution	~ 1'
Jupiter's disk	40"
Nearest star	0.03"

<u>Key numbers</u>

1pc = 3.26 light years

1pc = 3.1 x 10^{13} km

1l.y. = 9.5 x 10^{12} km

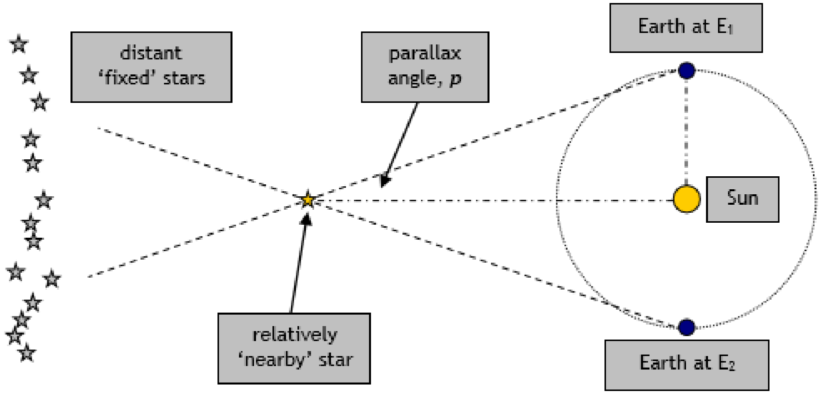
We measure an objects **angular size** in the following way:

one full circle is **360°**

1° = 60 arc minutes **(60')**

1' = 60 arc seconds **(60")**

The **HELIOCENTRIC PARALLAX METHOD** can be used to work out the **<u>distance</u>** to any 'nearby' star (<50pc). It is called '**<u>heliocentric</u> parallax**' because the **parallax effect** (nearby stars <u>appearing</u> to move relative to more distant stars) is caused by the Earth changing our **angle of view** as it orbits <u>the Sun</u>.



HALF of the **shift in angular position** of a star in any **6 month period** is called the stars **parallax angle (p)**. If we measure the change in position of a star against a **background** of **very distant FIXED stars**, over a 6 month period, we can find its parallax angle (<u>HALF</u> of its apparent movement). Then we use the **formula** below-

Distance = 1 / parallax angle

(parsec) (arc seconds)

If a star appears to change its angular position by 2' between January and July (6 months) its parallax angle is 1'. Substituting the 1' into the formula results in **1 / 1 = 1 pc** and so that star must be 1 parsec away from Earth.

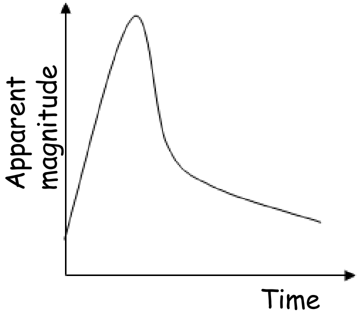
Therefore, it makes sense to **<u>define</u> a parsec as … the distance to a star that has a parallax angle of 1 arc second!**

Stars with a parallax angle >1' must be less than 1 parsec away.

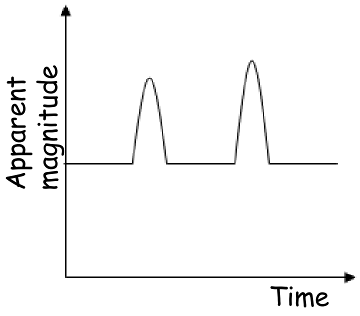
Stars with a parallax angle <1' must be more than 1 parsec away.

The graphs below show the **LIGHT CURVES** of 3 types of

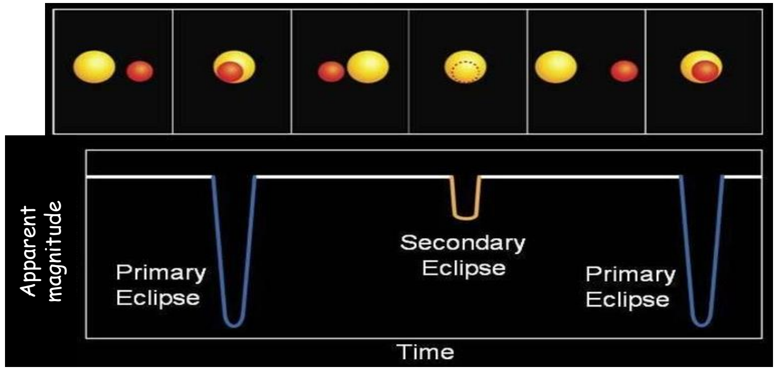
VARIABLE STARS.



SUPER NOVA – caused because a **very massive star exploded violently** at the end of its life. Its **luminosity increases suddenly** and then over a *few days* it **decreases rapidly** at first, before **fading away slowly**.



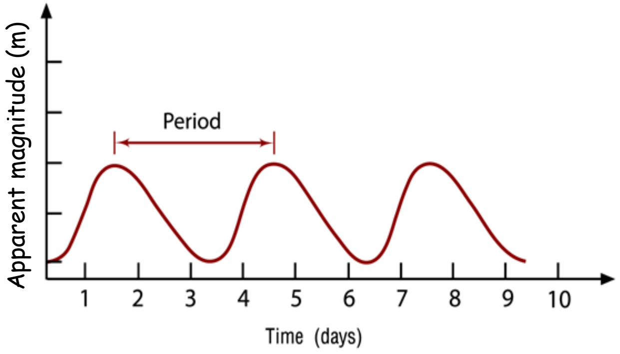
NOVA – this light curve is produced a **binary star system** when a critical mass is transferred from a normal star to a nearby white dwarf, causing an explosion. This can occur every few years to every few thousand years depending on the rate of mass transfer.

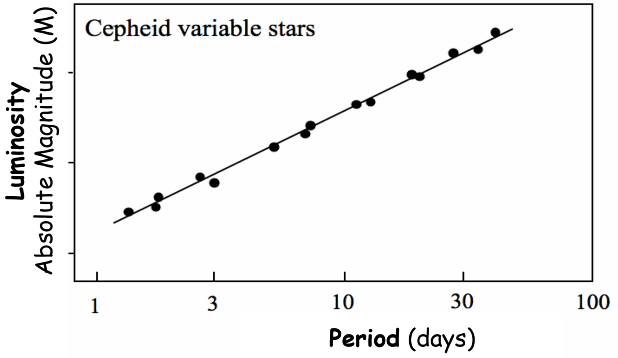


ECLIPSING BINARY – in the binary (2 star) system pictured above a **BRIGHT PRIMARY** star and a **DIMMER SECONDARY** star orbit around a <u>mutual</u> center of gravity. When the dim secondary eclipses the bright primary the brightness reduces sharply and by a large amount and vice versa.

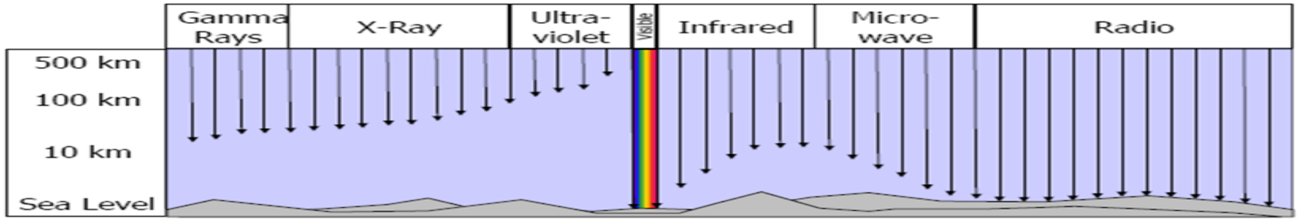
AST **Summary Knowledge Organiser** – Ch. 13 (Topic 13) **Exploring starlight (iv) Cepheids & the EM spectrum**

CEPHEID VARIABLE STARS are called '**distance candles**' or 'distance indicators' because they can be used to calculate the distance to any galaxy that contains one. If one is spotted in a galaxy it can be observed over a period of time and its apparent magnitude (observed brightness) plotted on a graph creating a **light curve** like the one shown below. The **PERIOD** of that star can then be easily found by identifying the **time between each peak** (see graph). The stars period is linked to its **physical SIZE** (**larger stars have a longer period**). Once the stars period is known, the '**period-luminosity law**' (illustrated in the second graph) allows us to find the stars **LUMINOSITY** and so **ABSOLUTE MAGNITUDE** (longer period = greater luminosity) Finally, once the absolute magnitude (M) is found the **distance modulus equation** can be used (m is already known) to calculate the <u>distance</u> to that star and <u>the galaxy it lies within</u>!



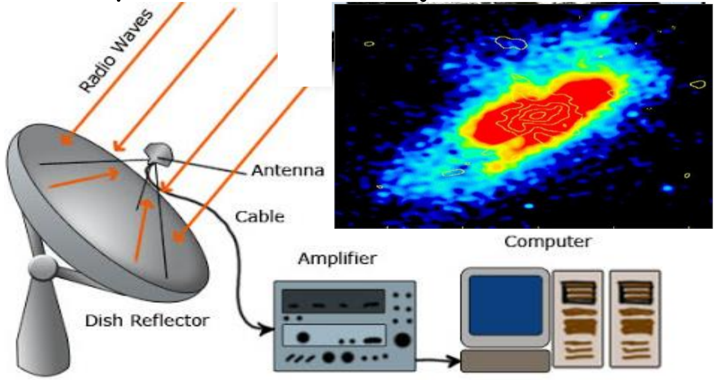


Sadly, most of the **ELECTROMAGNETIC RADIATION** emitted by celestial objects **does not penetrate** the Earth's atmosphere to ground level (as shown below **<u>only</u> visible light** and **radio wavelengths** pass through to ground level). Our atmosphere is said to have '**two windows**'!



The best position for a telescope is obviously on a **satellite orbiting Earth**. It will be above the atmosphere and so there will be **no air to blur and absorb light**, **no day-night cycle & no light pollution from sky glow.** However, **SPACE TELESCOPES** are **very expensive** and **technically difficult to construct, launch** and **maintain.** As shown above, <u>except</u> for **optical** and **radio** telescopes most need to be placed on satellites above the Earth, although **infrared** observatories can be placed on high mountains.

Radio waves can penetrate to ground level and so astronomers can observe the objects that emit them using ground based **RADIO TELESCOPES**. Radio telescopes have a **LARGE CONCAVE DISH** that **reflects** the waves to a **focus** where an **AERIAL converts the waves into an electrical signal** that can be **processed** to create a **contour map** of the radio source object.



Radio telescopes have to be very large if they are to produce a good **RESOLUTION** of the radio sources they are imaging. The resolution of a telescope is determined by the **INVERSE** of the **WAVELENGTH** it collects. Radio telescopes collect **radio waves** which have a very **long wavelength** and so the inverse rule means they produce **POOR RESOLUTION IMAGES** <u>unless</u> a huge number of waves are collected. '*The bigger the telescope, the better its resolution*'.

To solve the problem of needing radio telescopes to have large apertures we now build **ARREYs** of telescopes (see image left). Multiple telescopes are placed at different sites but study the same radio source. They are **electronically linked together** and due to a technique called **APERTURE SYTHESIS** they act as a single telescope with an aperture the same as the largest distance between the individual telescopes!

Most radio & optical observatories are located on **HIGH mountains**, such as in **Hawaii**, the **Andes** & the **Canary Islands** where the air is **dry, steady** & **transparent**.