Measuring stars

Properties of stars

Few things appear less substantial than the stars. They seem mere faint glimmers of light in the night sky. They have no definable size; they give too little light to read by, no heat to warm us. The most remarkable thing about them is that they are always there, from wherever you look on Earth, every night of the year, and every day if we could only see them in the day-time. They usually twinkle very prettily, but twinkling turns out not to be a property of stars at all. Many people would agree with the poets' portrayal that a clear starry night is a beautiful sight indeed. In my view, that beauty is enhanced many-fold when you realise what the stars actually are – our immediate experience of the rest of the Universe, and what a 'rest' it turns out to be. The stars seem so insubstantial that it's little wonder Copernicus' view that the stars stayed at rest and the Earth turned beneath them seemed plain wrong to his contemporaries, the Earth itself being too huge for most of us or his contemporaries to get our heads around. Yet when we realise what the stars actually are, Copernicus' view not only makes sense but becomes a necessity.

We see all stars except one as points of light. That one star is our Sun. The Sun and a star seem so different to our senses as to be completely different objects. The Sun is gigantic, over 1.5 million km in diameter; it is unbelievably energetic, so much so that even at 150 million km distance we can't look directly at it and it burns our skin; without cloud it would frazzle our landscape. Are the pinpoints of light we see as stars really other Suns? Well, 'yes' and when we start measuring their properties we find that some make the Sun look like a dwarf.

The Sun tells us that stars are much more complicated than points. Any theory of how stars work is going to have to take that into account. Stars, including the Sun, have comparatively simple global properties that we can deduce in spite of their being a long way off. They are round and therefore have diameters, surface areas and volumes. They have mass and therefore density. They are hot and therefore have a temperature and emit energy at a definite rate. Some stars are variable in their energy output and we see the light from them fluctuating on a timescale that may be only milliseconds in some cases or hundreds of days in other cases. They have a location in space and therefore direction and distance. They are moving in space and therefore have velocity components. They may be in local orbit with other nearby stars and hence be part of a binary or even a larger grouping. Can we even tell what these apparent points of light are made of? The answer is '*yes*'.

You can see that, without even asking about any complicated internal workings, there are a good many properties stars have that make them individual, that distinguish one star from the next. Stars may look pretty much all alike. They aren't.

Measuring the light from stars

The amount of light we receive from a star defines its *apparent magnitude*. This is determined both by how far away the star is and by how much light the star emits. Is the star intrinsically bright, or dim? Is it like a 150 watt bulb or a 15 watt bulb? The total amount of energy emitted by a star is called its *luminosity* and is indeed measured in watts. The wattage of stars is truly astronomical. The Sun's output, as we'll see, is more than 10^{26} W.

Apparent magnitude is determined by the luminosity of a star and how far away it is. In some cases stars may be dimmed by an intervening absorbing medium. It is absorbing inter-stellar dust that deprives us of a clear view of the centre of our galaxy. In other directions there is no significant absorbing medium at all and we can see a very long way indeed, to objects that are more than 1000 million light years distant.

One of the most perceptive astronomers of the classical era was Hipparchus, who lived around 150 BC. He classified the stars into 6 levels of apparent magnitude. Brightest stars were those of the first magnitude, less bright of the 3rd magnitude, and so on. The classification is like that of Honours degrees. First magnitude are the best. This sounds quite natural and later astronomers have kept to this idea but it turns out to be a bit of a humbug. It means that the larger the number associated with apparent magnitude, the less bright is the star. In modern science, larger numbers are usually associated with more of a given property, not less of it. The next slide shows how the modern apparent magnitude scale works.

Apparent magnitude, m

When modern quantitative instruments were used to measure the amount of light coming from stars, it was found that 5 of Hipparchus's brightness steps corresponded to a change in the amount of light reaching us by a factor of about 100. The modern apparent magnitude scale is set up to make 5 steps **exactly** a factor of 100. The change in amount of light for each step is made a fixed ratio, which must therefore be the fifth root of 100, or 2.512. For each step in the brightness scale, the amount of light received increases by a factor of 2.512. Five steps involve a change of $2.512^5 = 100$, as required. The symbol m is used in astronomy to denote apparent magnitude.

The humbug is that the less light we receive, the bigger the apparent magnitude. For example, a magnitude 2 star ($m = 2$) gives us 2.512 times more light than a magnitude 3 star ($m = 3$). Correspondingly, we measure 2.512 times **less** light from a magnitude 2 star than a magnitude 1 star.

The least consistent set of magnitudes in Hipparchus's catalogue were those of the brightest stars. Modern instruments have shown that the stars Hipparchus judged to be equally the brightest are in fact not so. Labelling a typical 1st magnitude star by m = 1, a few stars are significantly brighter. One step brighter than $m = 1$ has to be $m = 0$. One step brighter than $m = 0$ is $m = -1$, and so on. The apparent magnitudes of bright objects have negative values of m. The brightest star in the sky is Sirius, which has apparent magnitude $m = -1.47$. This highlights that apparent magnitudes need not be integers. They can be real numbers. -1.47 is 2.47 steps brighter than first magnitude. 2.47 steps implies $2.512^{2.47} = 9.73$ times as much light. Hence Sirius gives us 9.73 times as much light as a star labelled as exactly magnitude 1.0 (such as the conspicuous star Spica).

Range of apparent magnitudes

The chart on the slide is split into two regions. On the right are example objects with positive magnitudes. With a pair of binoculars you see many more stars than with your naked eye. If you've never done so before, look at the starry sky through a pair of binoculars and you'll experience something of the 'wow!' factor that Galileo must have felt when he turned his telescope to the stars. A typical pair of binoculars will let you see stars to $m = 10$. You still won't see the planet Pluto, which has m = 15. The faintest stars and galaxies are recorded on time exposure images that get to least m = 34.

In the other direction, on the left-hand side of the chart, you see that the brightest objects in the sky have negative apparent magnitudes. You should now understand what this means.

Magnitude comparisons

There are two calculations on the slide. The first shows how to calculate the ratio of the amount of light received from two stars if you know their apparent magnitudes, m.

The second shows a similar calculation with less easy numbers.

Stellar temperatures

By the simple expediency of measuring the magnitude of a star in more than one part of the spectrum, astronomers can estimate the temperature of a star. They measure a star's magnitude in the blue region, calling it **B** and also in the yellow region, calling it **V** (for the normal visible magnitude). The insert on the slide show the colour of a star expected at different surface temperatures. Cool stars are red: very hot stars are blue. Our Sun is somewhere in between. [The fact that we don't see stars strongly coloured is a feature of human night-time vision. The rod receptors we use at night give us no colour perception at all. The only colour sensors we have are the cone receptors in our eye, which are responsive under daylight illumination.]

Very hot stars emit more light in the blue than in the yellow, which makes their blue magnitude **less** than their yellow magnitude. Hence **B - V** is negative. Cool stars on the other hand emit less light in the blue, which makes **B - V** a positive number. [Remember the humbug factor allocates a greater magnitude to dimmer appearance]. Star catalogues will typically quote **B - V** under the name *colour index*. The colour index is a measure of the temperature of a star. Thus we have got at a property that normally requires a close up and personal measurement with a thermometer simply by using a filter and measuring apparent magnitude. Astronomy is the ultimate in remote sensing science. I am continually amazed at how much can be deduced about stars. It used to be that we knew more about how the Sun worked than about the science of our Earth. It may even still be true.

Stellar parallax

I shall come back to stellar magnitudes soon. It's hard to imagine how far away stars are. If you travel at the legal speed limit on British motorways of 70 mph (~110 km hr^{-1}) without stopping then it will take you about 7.5 hours to journey from Aberdeen to London. Non-stop at the same speed it would take you 150 years to reach the Sun. To get to the just the beginning of the rest of the Universe, our neighbouring stars, will take you 40 million years. The stars are truly an enormous distance away. It is hardly surprising that our distant ancestors had absolutely no concept of deep space.

First, a digression on how we can now actually measure some stellar distances. The most fundamental technique is to use the parallax method, mentioned as the method that let people find the distance of the Moon. This method is based on knowing a baseline and extending the distance scale using simple plane geometry. Parallax, you'll remember, is the change in angle of view when you change your point of observation. For the stars, you need to change your observation point not just across the Earth but right round the Earth's orbit. There is, then, between spring and autumn just a small measurable difference in the angle you need to point a telescope at nearby stars. The difference in angle is very small.

The mathematician and astronomer Friedrich Bessel was the first to measure convincingly this stellar parallax, in 1837. He chose to examine a star that he though might be close to us because it can be seen to move visibly against the background of more distant stars. In fact it is one of the fastest movers, changing location at 5 seconds of arc per year. 61 Cyg, the star Bessel looked at, is a visible binary pair. Subtracting out the annual motion, Bessel found the parallax of 61 Cygni over a half a year was ⅔ seconds of arc (⅔" arc). That's a very small angle. The modern figure is 0.29" arc over a period of 3 months.

It wasn't really possible to measure such small angles until precision, machine divided, scales were produced by instrument makers from the late 18th century onwards. In addition, to measure such a small angle it is not just a matter of having accurate positional scales on your telescope. You need to devote a lot of attention to both the design of the apparatus and how you use it. One reason why special care is needed to detect parallax is that there is another effect that makes the apparent positions of stars move around in ellipses during the year.

If you think about it long enough, you might expect this other effect. Imagine standing with an umbrella in a rain shower that is coming straight down. You hold your umbrella up vertically for maximum effect. Now run forward and you can see that you'll have to tilt your umbrella forward to meet the raindrops at right-angles. A similar effect happens with starlight. The Earth's motion changes the apparent direction of the incident starlight raining down on us. This effect is called *stellar aberration* and was discovered by James Bradley, the third Astronomer Royal, in 1727 while he was looking for stellar parallax. Bradley's stellar aberration can cause the apparent position of stars in the sky to move around once a year by about 20" arc. You can see why Bradley discovered this effect and not stellar parallax. It is small, but much bigger than parallax. Stellar aberration is of course a final clinching phenomenon that confirms the Copernican view that our Earth is going round the Sun. It is the reality of the Earth's motion that gives rise to stellar aberration. No motion, no stellar aberration. However, that's a slight digression from measuring stellar distances.

Stellar parallax is a measure of how much parallax there is when your baseline is 1 astronomical unit (1 AU), about half the diameter of the Earth's orbit. The distance of a star that produces a parallax of 1 second of arc is called a *parsec* (abbreviated *pc*). Geometry will tell you that 1 pc = 2.063×10^5 AU = 3.26 LY. Astronomers quote distances in light years or parsecs. By chance a parsec is longer than a light year by almost the same amount that a metre is longer than a foot. This gives us a simple comparison between the two units, at least for those who have a feel for the length of a foot ruler.

Stellar distances

In fact no stars are as close to us as 1 pc. The further away a star is, the less parallax it has. Hence a star at 10 pc exhibits a parallax of only 0.1" arc, a very small number. Apart from the Sun, there are only 9 stars within 3 pc of us. Only 2 of these are visible to the naked eye, namely Sirius and α-Centauri. α-Cen isn't visible from Aberdeen. The rest of the nearby stars are small, cool and dim. When you look out to a starry sky, you aren't getting a view of all the stars in our vicinity. Our view is biased towards the brighter stars, some being a very considerable distance away. For example the star Wezen (δ Canis Majoris), which is a decently visible star not far from Sirius, with m = 1.84, is some 550 pc distant; Deneb (α Cyg), a conspicuous star in the summer, has m = 1.25 and may be about 800 pc distant.

Measuring stellar parallax is the most accurate way of finding the distance to stars. If you can measure parallaxes to 0.01" arc, then you can measure a distance out to 100 pc. Unfortunately, stars when seen through the Earth's atmosphere appear to wobble about due to density fluctuations within the atmosphere. You have no hope of measuring angles to 0.01" arc, no matter how good the divided angular scale is on your telescope. However, all is not lost. A very successful ESA satellite that was designed to measure stellar parallax above the Earth's atmosphere was operated through much of the 1990s. The project was called the Hipparcos Survey. It measured parallaxes to 0.001" arc, which is unbelievably small. That angle is the angular size of a golf ball held up here and viewed from New York, on the other side of the Atlantic. Unbelievably small. Some 120,000 stars were measured. Hipparcos changed out view of stellar distributions, not just for moderately close stars but actually of the Universe at large. Distances of some nearby stars are used to extend the distance scale outwards. I'll mention later in the course one kind of star used for this - namely Cepheid variables. Hence revisions to nearby star distances could have an effect on revising distances of much more distant stars. They did. In general Hipparcos showed astronomers that they had underestimate stellar distances and hence the whole universe was enlarged as a result of the Hipparcos survey.

Updating these notes in 2018, the Gaia mission is still on-going as a sequel by ESA to their Hipparcos mission. Astrometry has been a keen interest of European astronomers, at least since Bessel's time. The Gaia mission is successfully measuring parallax to some three orders of magnitude better than Hipparcos. The net result has already been to obtain position and brightness of over 1.5 billion stars, mainly in our galaxy. In addition, proper motions (from parallax changes over the observing time) for 1.3 billion stars, surface temperatures deduced for more than 150 million stars, radius and luminosity for half that number, radial velocities for over 7 million stars, and more. The next few slides and pages of notes describe how some of these results could be deduced. All were announced in the second Gaia data release of April 2018. They are one of the astronomical achievements of the decade and the final results of the Gaia mission are unlikely to be significantly updated for decades to come. We really do know now where we our in our galaxy, what stars are with us, where they are and what they are doing. There is a lot more to learn but what we now know would have astonished our ancestors. It even astonishes me.

Absolute magnitude, M

Stars further away give us less light than similar stars that are much closer, because of the inverse square law of illumination. This says that the illumination from a point source of light decreases as the square of its distance from us. This 'inverse square law' is mentioned in detail in the chapter on the Sun. You should recognise this law. It is effectively a statement of conservation of energy as the light expands outwards from the source. Stars, for all their huge size, behave as point sources because we are so far from them. Even the Sun is effectively a point source for this purpose.

Distance, apparent magnitude and luminosity are therefore related. If you know any two, you can find the third. In order to compare stars that might differ in intrinsic brightness quite a lot, astronomers compare the amount of light that the stars would give to us **if they were all**

at the same distance. The distance chosen is 10 pc. The amount of light we would get if a star were at 10 pc is called its **absolute magnitude** and given the symbol M. Since no stars are at exactly 10 pc, you need to work out what M is from a combination of the apparent magnitude and the inverse square law applied to the known distance of the star. We'll see how this works.

Absolute magnitude sketch

In this sketch, the Earth is at the centre and the circle represents a sphere of radius 10 pc around us. The sketch shows examples of calculating the absolute magnitude of stars. For example, Aldebaran is a bright reddish star that is the eye of the bull Taurus. It is 21 pc distant and has apparent magnitude $m = 0.9$. If it were located at 10 pc then it would appear even brighter by a factor that can be calculated from the inverse square law as $(21/10)^2 = 4.41$. This figure lets you work out what its magnitude M would be at 10 pc and the answer is –0.7. The number is less because Aldebaran would be brighter at 10 pc than we actually see it. look at the other figures on the slide. Sirius would be dimmer at 10 pc than we see it, and so would α Cen. Other examples on the slide are Procyon, one of the bright winter triangle of stars, and Castor, one of the twins in the constellation of Gemini.

Absolute magnitude example

The slide shows the detail of the calculation for Procyon (α CMi).

Luminosity & absolute magnitude

The Sun provides the link between absolute magnitude (M) and luminosity (L). The Sun has an absolute magnitude of 4.83 and luminosity of 3.9×10^{26} W. That's the connection. You can now convert any absolute magnitude into a luminosity. For example, Aldebaran has M = -0.7, as we've just calculated. Compared with the Sun it is (4.83 – (-0.7)) = 5.53 steps brighter in magnitude. Hence Aldebaran emits more light than the Sun by a factor of $2.512^{5.53} = 163$. Therefore its luminosity is $163 \times 3.9\times10^{26}$ W = 6.4×10^{28} W.

You might think it's just a coincidence but our neighbour α Centauri is a very similar star to the Sun, with a similar absolute magnitude. This hints that stars like our Sun could be very common. They are.

There is a slight complication with the simple calculation above. The calculation assumes that the visible light we receive is proportional to the luminosity of a star, which is the total energy it emits. However, for stars that are at a much different temperature than our sun, the fraction of radiation that is visible light will differ from what we experience in sunlight, where about 44% is visible light. To be properly accurate, we need to make a temperature dependent correction to the figure derived above. I'll mention this again later.

Temperature, luminosity and diameter

If you know the luminosity of a star, you can work out its diameter. This at first seems an amazing feat but it is possible because all hot bodies emit radiation according to the same law, the Stefan-Boltzmann law. The meteorologists in the class have already met this law. For a body like a star (a so called 'black body') the rate of emission of energy per m^2 measured in watts is given by the Stefan-Boltzmann law as σT^4, where σ is Stefan's constant (= 5.67×10^{-8}

W m^{-2} K^{-4}). Hence if you know the temperature of a star (and remember that **B-V** gave an estimate of this) then from the luminosity in watts you can calculate how many square metres the star must have. Since stars are the next best thing to spherical, you can calculate the diameter of the star from its surface area. In fact the area of a sphere in terms of its diameter is simply πd^2. This line of argument makes the link between luminosity, temperature and diameter.

Stellar diameter calculation

To show how the method works, look again at Aldebaran. Taking its temperature as 3950 K and using the Stefan-Boltzmann law tells us that Aldebaran radiates at the rate of $\sigma\times3950^4 = 13.8\times10^6$ W m^{-2}.

From its luminosity of 6.4×10^{28} W, you can calculate that Aldebaran must have a surface area of $(6.4\times10^{28}/13.8\times10^6) = 4.64\times10^{21}$ m^2. Hence this calculation shows that its diameter, d, is $(4.64\times10^{21}/\pi)^{½} = 3.84\times10^{10}$ m ≡ 38.4 million km. This is 27.6 times the diameter of our Sun.

This answer is in fact approximate because of the technical error in the calculation, not in the arithmetic but in the assumption that luminosity is proportional to visible magnitude. Cooler stars like Aldebaran have a smaller fraction of their total radiation in the visible than does our Sun. The inverse square law told us that Aldebaran emitted 163 times more visible light than the Sun but because it is cooler its total energy output and hence its luminosity is actually more than 163 times that of the Sun. Aldebaran emits a greater fraction of its radiation as infra-red than the Sun does. Making the appropriate correction (I'm not going into the details here, for they are too specialist for this course), the diameter of Aldebaran is in fact about 40 times that of our Sun – a true giant of a star.

Binary stars

Many stars are not sitting in comparative isolation like our Sun but are part of a binary group of two stars orbiting each other, or sometimes part of a larger group. If a star is one of a binary pair then you can deduce more about it than you can if it is sitting by itself. Since many stars are one of binary pairs then thanks to binaries we know much more about stars than we'd otherwise do.

Binaries show up in several different ways. There are some good Java applet simulations of the topics in the rest of this chapter that you can find on our astronomical web page. The simplest way is that you can observer two stars in orbit around their common centre of mass over a period of years by looking at their change in position on a sequence of photographs or images. Kuhn shows a sequence of pictures for the *visual binary* Kruger 60 that has a period of 45 years. Binary stars rotate around their common centre of mass. The two stars are always on opposite sides of the same point, the line joining the stars passing through this centre of mass. Both stars therefore rotate around in the same time. The smaller mass star has the wider orbit and therefore swings around at a faster speed, since it has longer to travel in the same time. The more massive star has a smaller radius orbit and moves around more slowly.

If two stars in binary orbit are each about as massive as our Sun and have a 45 year period they would go around in an orbit of radius about 20 AU. That's not much – about the distance between the Sun and Uranus. If you remember, I mentioned that the nearest star to us is about 250,000 AU away so you can see that binary stars with a period that we're likely to detect are very much nearer to each other than any neighbouring star we experience. You can also appreciate that to see a gap between visible binaries on a photograph, they must be pretty close to us. The visible binary pair 61 Cyg mentioned earlier have a rotational period of 653 years and a separation of 85 AU. They are 3.5 pc away.

If we can measure the period of a binary pair and know from their distance away from each other the size of their orbits, Kepler's law, in the form mentioned in the chapter on the Sun, lets you find the sum of the two masses of the stars. If you can determine the ratio of the distances of each star from their common centre of mass, then you can find the individual stellar masses. Getting a direct measurement of a stellar mass is not possible for a single star but it can be managed with binary stars.

Eclipsing binaries

There are other ways of detecting binary groupings even when we can't see the gap between the two stars. Basic physics tells us that two stars must orbit each other in a plane, just as the Earth orbits the Sun in a plane. One method works for the special case in which we lie in the plane of the orbiting stars, which I'll call A and B. Once every period, star A will come in front of star B and half a period later star B will come in front of star A. The light from the pair of stars will dim when this happens because the star covered up in whole or in part will be eclipsed. The pair are called *eclipsing binaries*. The example everyone quotes is Algol (the ghoulish star), the second brightest star in Perseus (β Per) for most of the time. Every 2.87 days it dims to only 30% of its normal light for a few hours as a close, dark, giant companion goes in front of it. By examining the light curve of this eclipsing pair, given in the textbook, it is possible to work out both the masses of the two components and their dimensions.

Another eclipsing binary is RS Canum Venaticorum in the little constellation of the hunting dogs that lies below the great bear. The two stars rotate around each other once every 4.8 days and are tidally locked together like a rotating dumb-bell. The same fate will happen to the Earth-Moon system, eventually. Thousands of eclipsing binaries are known about, which itself is evidence that binary stars are very common indeed.

Could the same technique be used to detect a planet moving in front of a star? The answer is 'yes', if you have very stable and accurate photo-detector pointing at the star. In fact this technique is the basis of a mass hunt for extra-solar planets in a collaborative project involving 7 UK institutions known as 'SuperWASP', WASP being the **W**ide **A**ngle **S**earch for **P**lanets. One of our graduates is part of the superWASP team at the Open University.

Stellar Spectra

The spectrum of light from every star shows characteristic dark lines. They arise because light generated just within the star is absorbed by material in the outer atmosphere of the star. The darkness and position of the lines in the spectrum tell us a great deal about the nature of the star. When stellar spectroscopy was first developed, in the last quarter of the nineteenth century, it became obvious that there were a wide variety of stellar spectra. Why was this? Was it because there was a wide variety in the material that made up stars? It turned out not to be so. The main reason for the wide variety of stellar spectra is the range of temperatures of stars. I'll take up this subject later.

Spectra come into the story of binary stars because the positions of spectral lines in the spectrum shift with the radial velocity of the star. In reality the shift is not very great but it is easily detectable. As a pair of stars rotates around each other, their spectral lines move backwards and forwards, as shown in exaggeration in the applet on the slide. Such a pair is called a *spectroscopic binary*.

Spectroscopic binaries

Spectroscopic binaries can be detected at any distance. Many binaries orbit in a matter of days, weeks or months. Sometimes the period is years. You don't see the spectral lines moving before your eyes. You have to compare their positions over the period of rotation of the pair of stars. What is conspicuous is the appearance of doubled spectral lines, one from each component of the binary that is moving at speed in a different direction from its partner. When the orbital motion is taking the star away from us, its spectral lines are shifted in the direction of the red end of the spectrum; when the star is moving towards us, its lines are shifted towards the blue end of the spectrum. From this shift the varying velocity of the components can be plotted. On other occasions when one star is much brighter than the other, only the brightest component is seen and then it is the motion of the spectral lines over weeks or months that tells you there is another faint orbiting star.

Deductions from spectroscopic binary stars

In this case study from the literature I've plotted the light curves of the two components of 72 Piscium using Excel. They orbit each other in 50.4 days. The ratio of their velocities gives the ratio of their masses, in this case close to 1:1. The shape of the curves is determined by the eccentricity of their elliptical orbits, in this case e = 0.5. Both orbits have the same eccentricity, i.e. their shape is fundamentally the same. The orbits are just a different size, the ratio of their sizes depending on the ratio of their masses, the larger mass going around the smaller orbit.

The period tells us the sum of their masses and the size of the orbits, usually within an unknown inclination factor if we don't know the inclination of the plane of their orbits to us, which we generally don't. However, it all adds up to being able to tell a lot more about binary stars than we can about single stars. If we can find the orbital inclination one way or another, then we can obtain a measure of the two stellar masses and that is something that can't be measured in singleton stars.

Spectral Classes

Finally in this section, which is part of the content of chapter 12, I'll come back to the topic of classifying spectra.

The early classifiers of stellar spectra assigned different letters of the alphabet to different looking spectra. When it was finally realised that the spectra could be ordered sensibly according to the temperature of stars, the already assigned letters came out in the order **O, B, A, F, G, K, M, R, N, S**, when the temperatures were ordered from the highest to the coolest. Each letter corresponds to a *spectral class*. Each class is divided into 10 subclasses, denoted by a digit 0 to 9. Thus our Sun is a G2 star. Deneb is an A2 star, Spica a B1 star, Aldebaran a K5 star.

The spectral class of a star tells you what the spectrum looks like, what temperature the surface of the star is and in broad terms what state of ionisation the material is in the outer reaches of the star. Spectral classification tells you not only about global properties of the star but also something about the working of the star. Star catalogues will tell you the spectral classification of many of their stars. It is an appropriate topic to finish this section with, since this section is mainly about global properties of stars.

JSR