What telescope should I buy?
by Peter J.T. Morris

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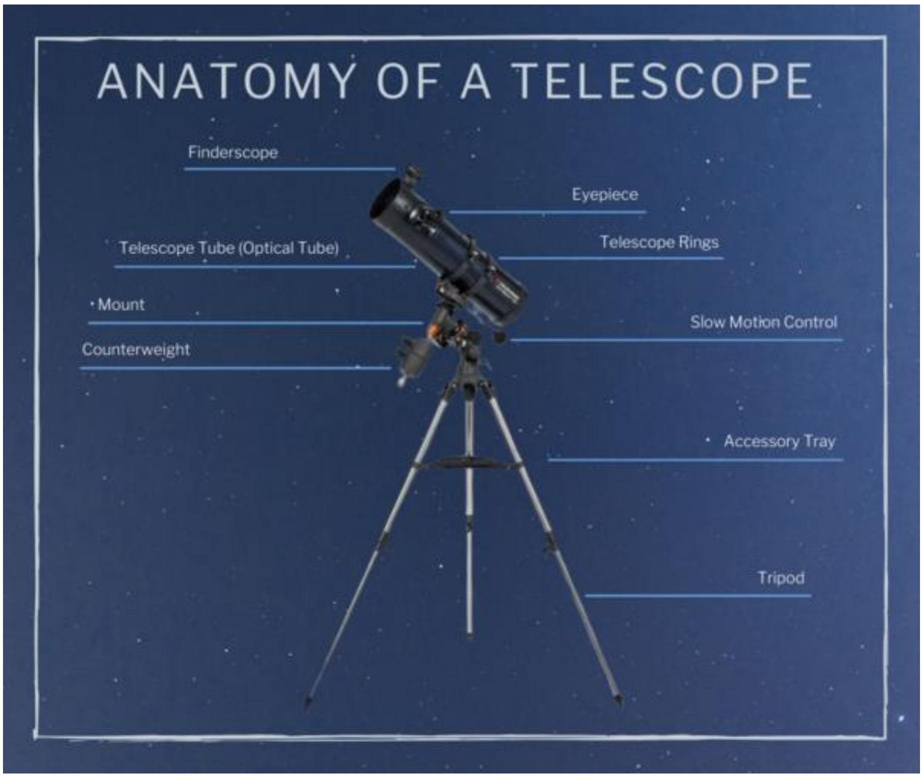
NB: the words in **bold** in the text are entries in the Glossary at the end.

Introduction

So you are thinking about buying a telescope? Please take your time before taking the plunge or you might get a telescope that you will later regret buying, I certainly did! Why do you want to buy a telescope? What do you hope to see with it? How much money are you willing to spend on a telescope? If your answer is “as little as possible” stop right here – you cannot buy a telescope that will work properly for less than £75. Make some basic preparations beforehand. How well can you see the night sky with the naked eye from where you live? Familiarise yourself with the night sky (see below for guides to the night sky) and learn to recognise the brighter planets and the more obvious constellations throughout the year. Some newspapers have a monthly night sky column which will help you to do this. Assess your local **light pollution** and find a suitable safe spot from which to make your observations. Try to use someone else’s telescope to see how you get on. Do you have somewhere to store the telescope and all the other paraphernalia involved? Are you going to be able to easily move your telescope from its storage space to the observation site? It is surprising how many people spend significant money on a telescope before making these elementary checks.

A common mistake – taken from newspaper adverts and microscope use – is to assume that magnification is the most important aspect of a telescope. To the contrary, magnification is not always the most important factor and in any case it can be varied as needed. There are no fewer than four reasons for this. Many heavenly objects are large (the Moon, the Andromeda galaxy, the Pleiades) and you will not be able to see the whole object at a high magnification. The earth’s atmosphere is a barrier between you and the object (unless you have just bought the Hubble Space Telescope second-hand from NASA ☺). Our atmosphere is like a gaseous jelly; it wobbles and hence your image will wobble too. Higher magnifications make this effect even worse. Furthermore the magnification may be too high for your telescope. As a rule of thumb, you should not use a magnification higher than twice the size of your telescope’s **aperture** in millimetres. So if you have a 70mm telescope, you should not use a magnification higher than 140 times. If you use an eyepiece which produces a high magnification, the image will be difficult to see and your eye will soon become tired (this is related to **eye relief**). In fact, the **aperture** is most important aspect of a telescope, not magnification.



Anatomy of a telescope showing its component parts. Courtesy of OPT Telescopes.

Three Questions before We Start

- Question One: Why do you want a telescope?
- Question Two: Where do you live?
- Question Three: Who is the telescope for?

Question One: Why do you want a telescope?

- **To see the night sky**

The night sky can be seen with the naked eye. We can see planets, stars, meteors, the Milky Way, star clusters and even one galaxy (the Andromeda Galaxy) with the naked eye. The problem with seeing these objects in a town or suburb is **light pollution**. A telescope can help to overcome light pollution to a certain extent, but it is not a complete solution. It is better to go to **dark sky areas** where you can see the night sky more easily; but be careful about your **safety**. Get to know the night sky, look for the planets and brighter stars, and the more obvious constellations before you think about getting a telescope or binoculars.

- **To observe the images one sees in books and magazine**

These iconic images are produced by imaging devices (cameras). These devices patiently collect photons from these heavenly objects to create their images for at least several minutes and in most cases for several hours. Even then the images have to be manipulated on a computer before they become the wonderful pictures you see in books and magazines. The human eye cannot replicate this process even through a telescope. The images you will see through a telescope will be largely colourless and much less detailed even under the best conditions (see **imaging**).

- **To look at the moon and planets**

The moon and planets are a good starting point for observing the night sky, especially in areas with **light pollution**. You do not need a large or expensive telescope to see the moon and major planets. It is a good idea to buy a telescope that is suitable for the moon and planets to gain experience looking at celestial objects in a telescope, and once you are confident about using a telescope, you can then buy a more expensive one if you wish.

- **To look at the stars**

You do not need a telescope to look at the brighter stars. The stars appear the same in a telescope as they do with the naked eye, only brighter. They form a disc in the telescope’s view, but this is a physical illusion caused by a process called diffraction. We cannot see the stars themselves in any telescope that an amateur could afford; we only see the light coming from these stars. You would need a telescope to observe very dim stars, but they are not of any great interest unless you take up the observing of variable stars. However once you have a telescope you can observe stars which are really two stars close together, which we call double stars. Some of them are very pretty, such as the star in the constellation of Cygnus (the Swan) called Albireo which is a bright yellow star and a dimmer blue star.

- **To look at Messier objects**

Some of the Messier objects are an excellent starting point for the beginner with a telescope and while some of them such as the Pleiades (M45) or (in a **dark sky area**) the Andromeda Galaxy (M31) can be seen with the naked eye, their appearance is much improved by using a telescope (or **binoculars** in some cases).

- **To look at galaxies**

Everyone has seen wonderful photographs of galaxies in books and magazines and many Messier objects are galaxies. They seem the obvious object to look at through a telescope, but here I have to disappoint you. With a few exceptions, they are very difficult to see in **light polluted** areas and having a telescope, even a big telescope, does not help very much. Even in **dark sky areas**, they are usually nothing more than faint smudges (see **imaging**).

- **To image objects**

Amateur astronomers are increasingly taking up the imaging of celestial objects, and while a telescope is necessary to take these images (in most cases), it is not an easy matter to take these without further training. However you could try taking images with a smartphone or a DSLR camera if you have one (see **imaging**).

Question Two: Where do you live?

- **In the middle of a city**

You will suffer badly from **light pollution**. It is also possible that it will be difficult to see the night sky because of nearby buildings. You may have to go to a nearby open space or park but please think about your **safety**. However people have successfully observed the night sky using a telescope in a city environment. I would advise you to buy a small telescope, at least to begin with, so you can store it easily and move it outside easily. A small refractor (see below) would be sturdy and easy to move. **Binoculars** are small and very portable, but they do not work well in light polluted area and you may be disappointed with the results.

- **In a town or suburban area**

You will probably suffer from **light pollution**, but may benefit from having a garden. However your neighbours may have outside lights and/or reactive security lights which will prevent your eyes becoming **dark adapted**. This is an increasing complication and for many people this may be a bigger problem than light pollution. Before buying a telescope go into your garden on a clear moonless night, and after about twenty minutes, see how much you can see in the sky and how many nearby light sources there are. If nearby lights are a problem you may have to use a local park or a **dark sky area**, but always consider your **safety**. Your neighbours may be worried about someone prowling around outside late at night so if you are observing, it is good idea to let them know beforehand if you can.

Light pollution in London area as seen from Space. Havering is marked with a red star. NASA image.

- **In the countryside**

You are in the best position to observe the night sky, although localised light pollution such as a nearby town or industrial works (or even a neighbouring farm) may still present a problem. You probably have more space to observe outside or at least nearby and to store your telescope outside, but make sure your telescope is **secure**.

Question Three: Who is the telescope for?

- **A child under 12**

Children are usually thrilled to see the Moon close up or to observe the rings of Saturn so a telescope may seem to be an ideal present for them. However children are also fickle in their interests and their initial excitement may wane. The temptation is to buy a very cheap telescope to begin with, but this is a false economy as cheap telescopes usually don’t work well; if they work at all. It is better to encourage their interest in the night sky using the naked eye to begin with, then buy a pair of reasonably priced small **binoculars** and only if they show a sustained interest in astronomy to trade up to a telescope. Be aware that telescopes are not intuitive to use and are quite fiddly, so it is unlikely that a child under 12 would be able to use a telescope on their own, so it is an investment of your time as well.

- **A teenager**

The early teenage years are a good time to start using a telescope, but it is best to develop their interest in astronomy first before buying them a telescope. Encourage their interest in the night sky using the naked eye, then buy a pair of reasonably priced small **binoculars** and only if they show a sustained interest in astronomy to trade up to a telescope. For a teenager of 14 or 15, it is probably worthwhile to then buy a middle-priced telescope which they will find to have a lasting value rather than compromise on the cost.

- **An adult**

As an adult you will probably have funds to buy a decent telescope from the outset, but make sure you are genuinely interested in astronomy and in observing (not the same thing, there are many happy “armchair astronomers”) before you spend any money. Be aware that to make good use of your new telescope will take up quite a bit of your spare time, but on the other hand, as we live in the UK, bad weather will often prevent you from observing.

- **An adult about to retire**

Observing the night sky and hence buying a telescope may seem an ideal retirement project. Perhaps you are someone who had a telescope when they were young (maybe a Prinz telescope from Dixons) and have since lacked the time or a good location for observing. You have probably kept up your interest in astronomy through magazines, books and TV documentaries. Before buying a telescope reflect on the difficulties of taking up visual astronomy as an older person. Are you going to be able to see celestial objects clearly? Do you wear glasses? Do you need to use glasses when using a telescope (for example if you have marked astigmatism). Are you able to stand up for long periods of time? Does your back hurt if you bend over a telescope for a period of time? Do you get cold easily outside? Are you happy to spend very cold winter nights observing for hours on end? And very much to the point, are you willing to carry on doing this for several years after you retire to justify the cost of buying a telescope in the first place? This might seem a surprising question, but so many people spend a lot of money on telescopes and then find that they are no longer physically able to observe – often soon after they start. There was a retired fund manager in California who set up two enormous refractors in a specially built observatory and yet within two years he sold his telescopes at a loss leaving him with a hugely expensive but pointless observatory.

The Basics of Telescope Buying

The most important rule in buying a telescope is to be able and willing to spend a significant sum of money. Above all do not buy one of these telescopes you see advertised in newspapers and in catalogues usually just before Christmas. They are cheap (often advertised as being drastically reduced in price just for you), but they are utterly worthless. I recently bought one via a catalogue as it was so cheap I thought it would be an interesting exercise. Some aspects of the telescope were OK if not brilliant, but to my amazement when I looked at a bright planet through it, I saw four images of the planet! I have come across double vision in a poor telescope before but never quadruple vision! Another complication is that these cheap telescopes invariably use outdated 0.965 inch eyepieces which will fit no other telescope and cannot be purchased separately. These eyepieces are also usually made of plastic and are a very primitive seventeenth century [sic] design. These sellers also make great play of the “power” of their telescopes; namely that their telescope can magnify objects by 300 times or whatever. This is a completely meaningless expression to use with a telescope (as opposed to a microscope) and you must avoid any seller who makes such a claim. **Please just don’t do it!** Also please do not buy telescopes in a department store or a supermarket; they are just not equipped to sell these things properly. And certainly do not buy a “toy telescope” which is often surprisingly expensive for what it is (i.e. plastic tat).

Range of eyepieces supplied with telescopes: on the left a 6.4mm and a 9.7mm “Super Plössl” by Meade; two 0.965” Huygens eyepieces (6 and 15mm) supplied with a cheap telescope; and a 10mm (Plössl?) eyepiece from Celestron.

You must go to a reputable telescope dealer to buy any telescope, however cheap. One major reason for this is the post-sales service that any reliable dealer will provide; this is crucial as anything can go wrong and as a beginner you will probably need advice. I would also add that no telescope comes ready to use in the box; you will need to assemble the telescope tube, the **mount** and the **tripod** before using it. There never has been telescope dealers in every high street (photographic dealers sometimes sold telescopes but they are scarce now as well) but the telescope shop has now largely disappeared altogether. This is a great shame as there is no substitute for being able to chat to the dealer in person. You will almost certainly have to buy your telescope online; a list of reputable dealers is given at the end. Also be aware that you will have to buy more than just a telescope, at least eventually, and take this into account when setting your budget for the telescope.

When you go online, you will be presented with a range of different designs of telescopes, one cannot just simply buy a “telescope”. There are three basic types of telescopes. The simplest one (and the one used by Galileo back in 1609) is the refractor. The other basic telescope design is the reflector which was invented by Isaac Newton of falling apple fame in 1668. You might think that two telescope designs are more than enough, but there is a third type, the catadioptric telescope which is a kind of halfway house between the refractor and the reflecting telescope. A modern variant of the reflector is the Dobsonian telescope which is cheap but is not without its drawbacks. There is one thing I have not yet discussed, partly because it applies to all types of telescopes and that is the go-to set up. In theory you can find your own way to your target using a finderscope and the technique of “starhopping”. In practice, most beginners find this very difficult and it is almost impossible in light-polluted skies. The modern system of go-to takes you automatically to your chosen target but makes the telescope more expensive.

Different Types of Telescopes

- **Refracting telescope (refractor)**

A refractor has a large glass disc (the lens) called the objective at one end of a tube and an eyepiece used at the other end to focus the image. In practice, one usually uses a diagonal at the eyepiece end to bend the light through 90 degrees to make it easier to see the image. To understand what the telescope does to the image, see **Telescope Image**. The key point here is that any telescope has both an objective and tube and an eyepiece. The refractor produces a sharp image, is usually fairly light, and is largely immune to knocks as long as they are not too hard! They need little attention and will last for centuries. The big problem with refractors is that they are expensive and they are strongly dependent on having a good **mount** and **tripod**. This is an issue because manufacturers often to claw back the cost of the actual refractor by skimping on the quality of the mount and/or the tripod. The cheapest refractors use a design first invented in the eighteenth century called achromatic. This means without colour, but sadly this is not the case. Achromatic refractors display coloured fringes on bright objects such as the Moon or Venus, which are usually purple. One can get a filter (see below) which can remove most of this false colour, but that is an additional cost. To be honest, it is not a huge problem; one gets used to any false colour and it is only an issue with the brightest objects. Some modern achromatic refractors claim to be colourless by using special glass (the so-called ED glass) and special coatings (e.g. fluorite coatings). These semi-apo refractors are good value not only because they have very largely got rid of the false colour, but also because they are usually better telescopes than the cheaper achromatics. But they are significantly more expensive. Then there is the crème-de-la-crème, the totally colourless apochromatic refractors. They have three very expensive lenses rather than the two used by any kind of achromatic and hence they are eye-wateringly expensive. They are not really necessary for visual astronomy (they are mainly used by imagers) and I would certainly not recommend them to beginners.

Skywatcher Mercury 707 refractor with a Az-GTe wifi go-to mount, Courtesy Optical Vision Ltd.

- **Reflecting telescope (reflector)**

The key advantage of the reflecting telescope is that it does not produce false colour at all. Compared with the cost of glass lenses, the mirror of the reflecting telescope is cheap so reflectors of a given size are much cheaper than a refractor of the same size. Unfortunately this is where the good news ends. In order to bend the light from the reflector so it can reach the eye without one's head blocking the entrance of the telescope, there has to be a secondary mirror near the open end of a reflecting telescope. This removes the need for a diagonal outside the telescope, but it does reduce the amount of light reaching the mirror; of the order of about 15-20% depending on the size of the main mirror. It is said that a reflector had to be twice as large as the equivalent refractor, which largely removes its cost advantage, and while reflectors have improved, this still largely holds true. Furthermore the second mirror has to be held in place and this produces an optical effect called "diffraction spikes" in which stars appear to have spikes sticking out from the main disc. If the telescope has a "fast" (or low) **focal ratio** the image of the stars can turn into miniature comets with tails, an effect known as "coma". This is usually not too much of a problem as long as one buys a telescope with a focal ratio of 5 or higher, but you can buy a expensive "coma corrector" to remove this effect. Unfortunately the light path between the two mirrors drifts over time or can be affected by knocks and they have to be brought back into alignment, a process known as collimation (see https://skyandtelescope.org/astronomy-resources/how-to-align-your-newtonian-reflector-telescope/). This is a fairly tricky process although one gets better at it with practice. The lower the focal ratio, the more often collimation will be required. Finally, the main mirror degrades over several years and ultimately needs to be recoated. This can be done for a price, but it is something to bear in mind and my impression is that is becoming more difficult to get the mirrors recoated. Given all these problems you might wonder why anyone bothers with a reflector, but the introduction of the cheap Dobsonian telescope (see below) has revived their popularity.

The Skywatcher Skyhawk 114 Newtonian reflector, shown here with an equatorial mount, is a good entry-level reflector. Courtesy Optical Vision Ltd.

- **Catadioptric telescope**

The earliest telescope which had similarities to the modern catadioptric telescope, the Gregorian, was first built by Robert Hooke in 1673 and was hugely popular in the eighteenth century but is no longer used in small telescopes. There are two main catadioptric designs, the Schmidt-Cassegrain and the Maksutov. I will not go into the details of these designs here, you can find them online, but they are well worth considering by beginners. Their huge advantage is that they are sealed like a refractor but do not suffer the colour problems of achromatic refractors. The Schmidt-Cassegrain design is sold by two major telescope manufacturers, Meade and Celestron, and produces good visual images (it is also a good design for imaging). It has three major problems. Schmidt-Cassegrain telescopes are expensive, relatively speaking, and they require collimation (see https://www.skyatnightmagazine.com/advice/how-to-collimate-your-telescope/) although this is both easier and less frequent than with a reflecting telescope. They also have a very high **focal ratio** which means they cannot produce wide field views of (e.g.) star clusters. The Maksutov is rather similar to the Schmidt-Cassegrain and has a similar high focal ratio but it is somewhat cheaper and does not require collimation. This is so important that I am going to repeat it: it does not require collimation and in fact can withstand quite significant knocks. This means it has nearly all the advantages of an apochromatic refractor at a fraction of the cost. The sole problem with a Maksutov (apart from the high focal ratio) is that it is rarely made in sizes above 150 mm (six inches) whereas the Schmidt-Cassegrain often has an **aperture** of 11 or 14 inches and can be made up to 20 inches or more in size. However such telescopes are well beyond the budget of a beginner.

On the left is a Celestron Nexstar6 6" Schmidt-Cassegrain with go-to and on the right a Skywatcher Skymax-127 5" Maksutov with a SkyScan Go-to mount.
Courtesy Greg Smye-Rumsby (left image) and Optical Vision Ltd (right image).

- **Dobsonian telescope**

The basic optical design of the Dobsonian is in fact the reflecting telescope as designed by Newton 350 years ago, but the exact form of the telescope was introduced by the Buddhist monk John Dobson in 1965. He designed it as the telescope for everyone as it could be self-made for very little cost and the novelty lay mostly in its mount rather than the optics. Although Dobson wanted everyone to make their own telescope, it is now available commercially. It is cheap, although not particularly cheap. It has all the advantages and disadvantages of any reflecting telescope (see above), but is perhaps more intuitive to use. The huge disadvantage is that you cannot fix it to be rigid; you can have the desired planet or other celestial object in your view and because the planet moves (due to the rotation of the celestial sphere) or the telescope droops because of the weight of the eyepiece, you lose it and have to scramble to find it again. The usual cheap form of the Dobsonian lacks a motor to move it in step with the movement of the stars, nor is it usually a go-to telescope (see below). However it can be made fairly cheaply with huge mirrors (up to 30 inch and more) to create "light buckets". This is very handy in **dark sky areas** where one can observe faint galaxies (as in parts of the USA), but of little use in the light polluted areas where most of us in the UK live. Some astronomers believe that the Dobsonian is the ideal beginner's telescope, as it is cheap, it is easy to use and you get a lot of mirror for your pounds. But I do not agree: the need for collimation, the inability to lock it into position and the lack of go-to rules it out for me. Furthermore, if you buy a Dobsonian, you will be tempted to buy the biggest one you can afford; which means you end up with a telescope which is too heavy to move easily and too unwieldy to use.

The Skywatcher Skyliner 150 5.9” Dobsonian. Courtesy of Optical Vision Ltd.

- **The Need for Go-to**

If stars remained fixed in position all night long, it would not be very difficult to observe. We would just find the star (or planet) we want using charts and then spend a long time looking at the object without any problems. However the stars (and other objects in the sky) are constantly moving across the sky. Actually it is the earth (and thus us) which is moving but in practice it is as if the stars are moving. So we need a way of moving our telescope with the stars. One simple method is to use a type of **mount** called the German equatorial mount (GEM). It is set up so that its axis is pointing at the Celestial North Pole (close to but not quite at Polaris, the Pole Star). This means we can just gently push the telescope tube along and it follows the star in question. But even if we use a GEM, and it is both rather expensive and fiddly to set up, it does not help us to find the object in the first place. Traditionally astronomers have used a technique called “star-hopping” whereby you start with a bright star and “hop” using dimmer but still visible stars until you reach the object you want. I have known some people who are amazingly good at this and they can swivel the telescope to a given star or other object within minutes. However it requires a deep knowledge of the night sky, lots of practice and above all, a dark sky. By contrast, most beginners have a very limited knowledge of the night sky, by definition no practice and they usually observe under light polluted skies. Fortunately a new electronic method has been developed called go-to. I will not go into the details here and with the advent of smartphone-based methods, it is a rapidly changing field. But you align the telescope at the beginning of the session by one method or another and then tell the go-to system where you want to go. It skews round to the correct spot and while it is usually not 100% accurate, it gets you to the right patch of sky. Furthermore it tracks the object pretty well as it moves across the sky, so it is a win-win situation. Some purists argue that beginners should start with star-hopping to get a good feel for the night sky before using go-to if ever. As most of us work with massive light pollution and we are eager to get up and running, I think this is utterly unrealistic. I would strongly urge all beginners to get a system which uses go-to of one kind or another and to start off by acquainting themselves with the system in daylight and then at night; it only takes a couple of nights to be familiar with it.

Using go-to has two major implications: it adds considerably to the cost of the telescope and it more or less rules out the Dobsonian telescope. Incidentally it also rules out binoculars. In any event, binoculars in my (frustrating) experience do not work well in light-polluted skies. Hence in this way, we have ruled out the two options favoured by many astronomers when giving advice to beginners. I also need to point out from bitter personal experience that there is one major problem with go-to telescopes (except those which work using smartphones). You need a source of electricity to run the system. Some go-to telescopes allegedly can run on AA batteries, I have never found one that was actually able to do this. So you need either an extension lead or a portable power pack. These power packs used to be acid batteries of the type used to start a car with a dead battery, but for some years now they have usually been (expensive) lithium batteries. Personally I have always used an extension lead (although using an extension lead on a dewy lawn is a bit dodgy and not officially approved) but the thin power leads from the transformer to the actual mount can become brittle in cold weather and/or get wrapped round the mount if you are not careful. Either way, the power lead itself can snap or the plug attaching the lead to the mount can at best pop out and at worst break off. So there have been many nights when I have had power problems. Another problem is that once you have aligned your telescope, you have to leave it in the same position all evening. If you are unfortunate enough to have to move your telescope across your garden to avoid trees or houses blocking your view, go-to is not very practical. All that said, I still believe that beginners observing in urban or suburban settings need a go-to telescope unless you are willing to spend frustrating hours looking for the objects you want to observe.

The go-to controller handset attached to the mount by a lead in the Skywatcher Skycan go-to mount. Courtesy of Optical Vision Ltd.

How much do You Want to Spend?

- **£60-£100**

You have relatively few options in this price range and definitely cannot afford go-to. I would suggest a good basic refractor without go-to. Please avoid anything made completely of plastic which usually comes with a flimsy tripod (or a cheap camera tripod). You can get something like this for about £60 but you will end up being disappointed. You could get a telescope by a reputable firm such as Vixen or Celestron, but the **aperture** is unlikely to be larger than 60mm (2.5 inches) and this is too small to be of much use in my opinion. Skywatcher offer the Mercury 707 70mm refractor with a tripod in this price range and this would be my recommendation (it is also recommended by David Arditti of the British Astronomical Association). There are tabletop reflectors (e.g. National Geographic) in this price range, but they are impossible to set up effectively and the National Geographic model has a very low **focal ratio** of 4.6 which makes planets too bright to observe. Only buy it if you can get it cheap; the 114mm model is said to be better than the 76mm version. The alternative would be to try and buy something second-hand, for example on eBay, but I would not recommend this as you have no post-sales service to fall back on, which is essential in my view if you are a beginner.

The Skywatcher Mercury 707 with a simple alt-azimuth mount is excellent value.
Courtesy Optical Vision Ltd.

- **£140-£200**

At this price range we are moving into realistic territory. For this kind of budget, you could buy an 80mm or 90mm achromatic refractor with a decent tripod or even a four inch achromatic with an equatorial mount at the upper edge of this budget. With luck given a sale you could afford a four inch Maksutov. You can get a Celestron Starsense (go-to which uses your smartphone) 70mm refractor for £150 and while it is on the small side, it does have the all-important (smartphone-based) go-to. This is probably the best option in this price range.

Celestron Celestron StarSense Explorer LT 70AZ. Courtesy of Celestron.

- **£240-£400**

At this price range, we are into go-to territory. A four inch achromatic refractor telescope with go-to, which I would consider to be the basic minimum needed, will cost about £330. You could buy the Skywatcher Startravel 102 with a smartphone-enabled go-to mount for about £350. As it has a low **focal ratio**, it makes an excellent “rich field” telescope, one that shows stars clusters or the Milky Way to best advantage. Even with a normal 25mm eyepiece you will get a magnification of 20x and a field of view of five moon widths (2.7 degrees). This would be the best value in my opinion. There is also the similar Celestron four inch Starsense (smartphone-based go-to) refractor for about the same price. A Skywatcher five inch go-to Maksutov will be £400 and is also excellent value.

The Skywatcher Startravel 102 with the AZ-GTe wifi go-to mount. Courtesy Optical Vision Ltd.

- **£400-£600**

If you are able and willing to spend this much money, there are many options open to you. The Celestron five inch go-to Maksutov is superb in my view and will cost about £500. Alternatively you could combine Skywatcher Startravel 102 with the excellent Skywatcher EQ3 Pro Go-to mount/tripod for about £600. I would not recommend spending more than about £600 to begin with.

Celestron Nexstar 127 SLT Telescope. It is now available in a smartphone-enabled Wifi version as well. Courtesy Celestron.

So Which One Should I Buy?

My first response is that you should read what I have said and make up your own mind. Only you can decide what is suitable for you, based on what you want to do and what you can afford. That said, I can make a few suggestions. As you are a beginner, I would rule out anything which is very expensive but I would also rule out anything very cheap. I think it is essential to have go-to and not to have to collimate the telescope. This leaves us with refractors on one hand and Maksutovs on the other. It is hard to choose between them. If you are mainly interested in the Moon, planets and double stars, I would definitely go for the Maksutov. On the other hand, if you are more interested in star clusters and if you are lucky enough to have dark(ish) skies, galaxies, a refractor would be better. The **aperture** (the size of the telescope opening) depends on your budget, but basically I would go for the largest aperture you can afford, bearing in mind that you are going to have to buy more than just the telescope. If you can afford it I would go for a three (80mm) or four inch (100mm) refractor. Alternatively go for the five inch (125mm) Maksutov which will cost roughly the same and allowing for the central obstruction about the same aperture. Given that the Maksutov is almost the optical equivalent of the hugely expensive apochromatic refractor, the Maksutov wins hands-down in my purely personal view. However at about £500, it is not cheap – but you get what you pay for. If you cannot afford this or not sure you want to make such a large investment, an 80mm achromatic refractor with go-to would be perfectly OK and would cost about £350 Also bear in mind that with its long focal length the Maksutov is not suitable for **imaging** so if you can envisage getting into imaging at some point, it might be better to get a semi-apo 80mm refractor such as the Skywatcher Evostar 80ED, although they are expensive.

The Skywatcher Evostar 80ED fitted with a dual-control Crayford focuser.
Courtesy of Optical Vision Ltd.

What Else Do I Need to Buy?

- **Eyepieces**

The eyepieces (or even just an eyepiece) that come with the telescope tend to be fairly basic although they can be reasonable. The main problem is that they usually have fairly restricted fields of view. There are two sizes of eyepieces: the 1.25 inch and the 2 inch. The 2 inch eyepiece tends to come with Dobsonians which I do not recommend. There are three basic things you can do regarding eyepieces: get one with a wider **field of view** (a so-called wide-angle eyepiece), a better one or one with a different **focal length f**rom the ones you get with the telescope. My key point here is that a decent eyepiece, especially a wide-angle eyepiece, can easily cost almost as much as the telescope, if not more. To give an extreme example, a 21mm Tele Vue Ethos eyepiece will cost about £800. To begin with, I would buy a decent 2X Barlow lens if one is not supplied with the telescope. This will halve the focal length of your existing eyepieces. So if a 25mm one is supplied with the telescope, the Barlow lens will give you one of 12.5mm at no extra cost so to speak. An important aspect of the Barlow lens is the so-called **eye relief**. In a nutshell, an eyepiece with a short focal length (high magnification) can hurt your eyes; you cannot look through them for long. They have poor eye relief. A Barlow lens gives you a short focal length eyepiece with the eye relief (comfort) of the original long focal length eyepiece. This is particularly important if you use glasses when observing.

A variety of Skywatcher Barlow lenses. Courtesy of Optical Vision Ltd.

In terms of the eyepieces you need, I work on the basis of the longest one (the one which lets in the most light), a middle one and the shortest practicable one. I am not going into details here (see **exit pupil**), but you should aim for one which has a focal length of 5 times the **focal ratio** of your telescope (35mm if f = 7), one which is three times the focal ratio (15mm if f = 7) and one which is about the focal ratio of your telescope (7mm if f = 7) or the middle one used with the Barlow lens (which would be my preference). If you have a Maksutov or a Schmidt-Cassegrain, they have very high focal ratios; about 10 to 12 which makes the first of these eyepieces impossible as there are no eyepieces with a focal length of more than 40mm. Let us assume that the eyepiece that comes with the telescope is 25mm. If you can afford it, I would then buy a wide-angle 16mm eyepiece which will give you much the same field of view as the standard 25 mm eyepiece, but higher magnification (and probably better eye relief). You can then use the Barlow lens to “make” an 8mm eyepiece with a superb field of view and excellent eye relief. The Tele Vue 16 mm 1.25 inch Nagler is superb but costs about £330! You can buy a William Optics 16mm UWAN for about £175 and a generic one for about £65-£80.

A selection of wide-angle eyepieces: the William Optics 16mm, the Tele Vue 16mm Nagler and the Celestron Axiom 23mm (now replaced by the Luminos range)

I might add that eyepieces (and objectives/mirrors) should be cleaned with extreme caution. You should clean them as little as possible and always put the caps back on as soon as you stop using them. When it is necessary to clean them (perhaps about once a year or even less), I would use a high-quality optical glass wipe from a brand like Zeiss or the Baader Wonder Fluid and cloth. Wipe very gently in a random motion (never use a circular motion which could mark the glass) and allow it to dry before putting the caps back on. Just clean the external surface; never try to clean the inner surface.

- **Finder**

Telescopes usually come with a finder, which is a good thing as you need this to find what you are looking for, even with go-to. However that is where the good news ends. They tend to either be rather low-quality finder telescopes which are a pain to use (even if you manage to see through them you get a crick in the neck) or the red-dot finders which project a dot on the sky. The latter are OK if you can see anything in the sky but if you have light pollution you won’t, and you really need the magnification that a proper finder telescope can give you. The solution is to discard the finder that comes with your telescope and buy a proper-right angle finder telescope. Apart from not giving you a crick in the neck, the big advantage of a right angle finder is that you see the sky as it really is (and not upside-down). Orion (USA, not the UK-based Orion Optics) produces an excellent one and whatever the make they cost about £100. It is well worth the money and it is a decent wide field telescope in itself.

A Celestron 127 (5”) Maksutov with an Orion (USA) right-angle finder and a William Optics star diagonal.

- **Filters**

Filters are tricky. They are very useful, but decent filters are expensive and they block the light coming from the celestial object under observation. You screw them onto the end of your eyepiece. The one filter you must buy is a Moon filter as the Moon is usually too bright to be observed directly in a telescope. You can either buy a straight-forward filter (I would go for a middling one) or a variable polarising filter – they are the best but are a little bit fiddly to use and more expensive. There are three other types of filters. There are coloured filters which are supposed to improve your view of a given planet. As a beginner I would not bother with them. They are not crucial unless you become a dedicated observer of Mars or Jupiter; then you can decide what filter or filters to buy. Then there are the elemental line filters, especially the OIII filter for observing planetary nebulae. They are very expensive if they are any good, and again I would not bother with them to begin with. If you become a devoted observer of planetary nebulae, buy an OIII filter then and only then. Hydrogen filters are of no real use in visual observing; I have tried them and they make no difference. A variant of these so-called narrowband filters are light pollution filters. Given the massive light pollution most of us suffer from, they sound a wonderful idea. The principle of these filters is that they block off the light from sodium lamps (the yellow ones and the high-pressure white ones) and to a lesser extent mercury vapour lamps. However, they also block off the light from the heavenly body in question so it becomes much dimmer which rather negates their value straight off. The other problem is the introduction of LED street lights which have reduced light pollution a bit, but these filters do not work with them and they will be no good at blocking the glare from your neighbour’s security lights. Solar filters are made from an opaque silvery material and fit on the front of your telescope. They are very good for observing the sun, but always check them for pinhole damage with a bright torch in a dark room and remember that you cannot use a catadioptric telescope to observe the sun as heat can build up inside the telescope. I would always buy a ready-made solar filter rather than make your own from a sheet of solar filter material. It is not worth the risk of letting the sun into your eyes by mistake. And never ever use one of the black glass solar filters that used to be sold with cheap telescopes – they are extremely dangerous and if you ever have one throw it away immediately. **Of course you must never look at the sun directly either with the naked eye or through a telescope**.

Skywatcher variable polarising Moon filters, 1.25" and 2". Courtesy Optical Vision Ltd.

- **Books**

If you a newbie to observing, you will need some books to help you. There are four kinds of books. The most basic books tell you want to do if you want to observe and tell you about the most interesting objects in the night sky. To find your way around the sky you need a star atlas although they have been partly superseded by planetarium software. To my mind, a good star atlas is useful when planning what to look at during your next observation session. It is often recommended to use a planisphere. This is two circles of plastic; the top one is a mask revealing an oval which is the night sky at a given date and time as marked on the edge of the lower circle. The lower circle is a map of the night sky. To be honest, they are not really worth the bother. They are fiddly to use in the dark, they only show a fraction of the objects in the sky and you have to hold them above your head to align the map with the sky. Phillips do a nice one for about £10. Then there are observing guides to help you to choose what to observe and tell you more about what you are observing. Finally there are more detailed books which advise you what kit to buy (having bought the basics) and some of the more advanced techniques. Here is a list of these books:

<u>Basic guides</u>
Paul E. Kinzer, *Stargazing Basics: Getting Started in Recreational Astronomy* (about £10)
Radmila Topalovic and Tom Kerss, *Stargazing: Beginners guide to Astronomy (Royal Observatory Greenwich)* (about £7)
Tom Kerss, *Beginners Guide to Exploring the Moon (Royal Observatory Greenwich)* (about £7)
Will Gater and Anton Vamplew, *The Practical Astronomer: Explore the Wonder of the Night Sky* (about £9)
Terence Dickenson, *Nightwatch: A Practical Guide to Viewing the Universe* (about £27)
Also look at:
Patrick Moore, *Observer's Book of Astronomy* (available cheaply second-hand)
H. A. Rey, *The Stars: A New Way to See Them* (about £10)

Sky atlases

Unfortunately right now (January 2021) there is no readily available cheap star atlas in the UK; perhaps a reflection of the move to planetarium programs.

Roger W. Sinnott, *Sky & Telescope's Pocket Sky Atlas* (this is the best but unfortunately only available second-hand, about £18)

Will Tirion, *The Cambridge Star Atlas* (only readily available second-hand, about £20)

Observing guides

Storm Dunlop and Will Tirion, *2021 (etc.) Guide to the Night Sky: A month-by-month guide to exploring the skies above Britain and Ireland* (about £6)

Heather Couper and Nigel Henbest, *Philip's 2021 Stargazing Month-by-Month Guide to the Night Sky in Britain & Ireland* (about £6)

Ian Ridpath and Will Tirion, *Stars and Planets: The Most Complete Guide to the Stars, Planets, Galaxies, and Solar System* (about £17)

Guy Consolmagno and Dan M. Davis, *Turn Left at Orion: Hundreds of Night Sky Objects to See in a Home Telescope – and How to Find Them* (about £22)

Also look at the series of handbooks on deep-sky objects written by Stephen O'Meara (about £22-£35)

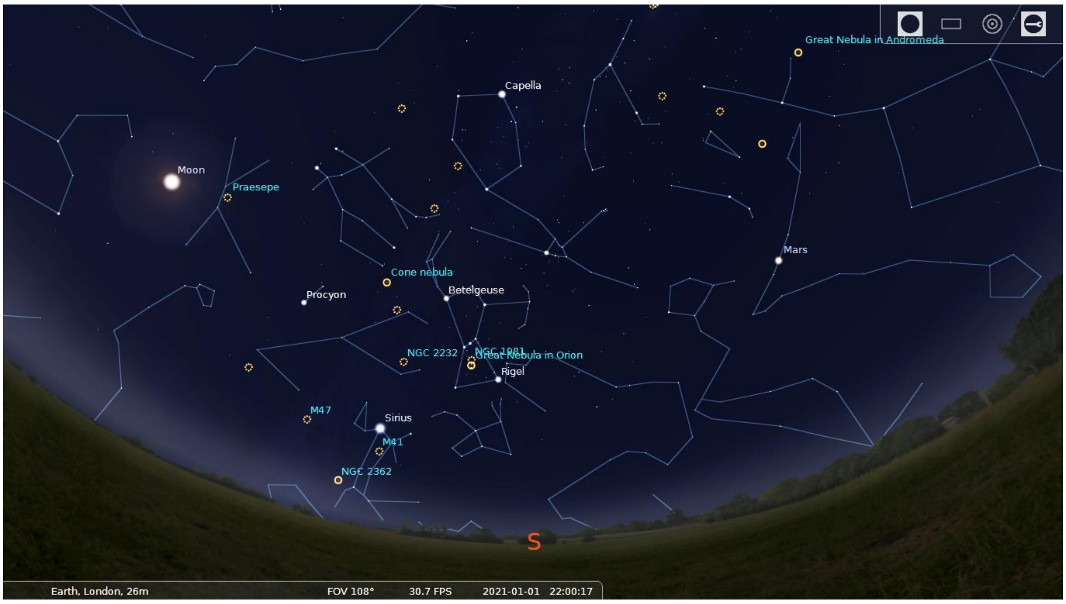
Advanced books

Terence Dickenson and Alan Dyer, *The Backyard Astronomer's Guide* (about £23)

Philip Harrington, *Star Ware: The Amateur Astronomer's Guide to Choosing, Buying, and Using Telescopes and Accessories* (about £12)

- **Planetarium software**

There are several planetarium software programs available. They produce images of the night sky which thus replace star maps and planispheres and hence are useful for finding your way around the sky. As a beginner, I would stick with Stellarium (http://stellarium.org) as it is free and easy to use. There is also Cartes du Ciel (https://www.ap-i.net/skychart//en/start) which is also free, but personally I think Stellarium is better. Once you get accustomed to using Stellarium you can investigate other programs such as TheSkyX, Starry Nights and Sky Safari, but to my mind none of them offer a decisive advantage over Stellarium. There are two important things to say about Stellarium. Especially if you have just bought a telescope, the telescope view replicator is very useful. Go into Configuration (the fifth item down on the lower left, the spanner and star icon) and select Plugins. Now choose Oculars, and when in Oculars go to configure (at the lower right). You can now select your telescope and eyepieces (make sure you choose the right **telescope image** option). Go back to the star map and select a celestial object (e.g. Mars). Now click on the circle inside a square icon at the top right, this brings up the view you should see from your telescope; magic! Using the search window (the fourth item down on the lower left, the magnifying glass and star icon, or the F3 key or just control-F) you can put in the name or identifier of the celestial object you want to go to. This search engine is now linked to the massive astronomical database at the University of Strasbourg called Simbad. So you can type in queries which work directly in Simbad (http://simbad.u-strasbg.fr/simbad/sim-fbasic). Note that when searching for double stars, you have to put ** in front of the double star designation, for example **STF 1998. For your smartphone, there is the Stellarium app, but Star Walk, Sky Safari and Sky View Free are all highly regarded. Typically with apps, you get a free basic version but have to pay for extras, even with Stellarium.



The view on Stellarium looking south at 22.00hrs (UT) on 1 January 2021.

- **Clothing**

Observing out of doors in the UK is pleasant enough during the warm summer nights, but you will still need some kind of jacket or coat. However for most of the year, you will quickly become cold standing out of doors at night, even in the autumn and spring. As you are standing still it is quite different from the kind of outdoor activities you might be used to, such as running or walking. You must wrap up well for observing. Wear several layers of clothing under a warm anorak or coat and wear a scarf round the neck. In particular wear gloves and stout shoes or boots with thick socks. Buy thin but warm gloves which enable you to turn the knobs on the telescope and handle eyepieces. Wear a cap or bobble hat on your head – the body loses much of its heat through the head. If you are in an area with a lot of stray light around you could consider wearing an anorak with a large hood, or use a scarf or cloth to cover your head like an old-fashioned photographer. You can also buy special astro-hoods on the internet, but as most of them are from America, they can be expensive. Be aware that wearing such a hood may make you look sinister to your neighbours!

Glossary

Aperture

Put simply the aperture of any telescope is the size of the hole at the front end of a telescope (make sure you get the right end ☺). More precisely, it is the diameter of the glass lens of a refractor or the mirror of a reflector (or a catadioptric telescope). The aperture matters because the bigger the aperture, the more light the telescope can collect and in theory at least the more you can see in the night sky. In a way the diameter (traditionally measured in inches and increasingly in millimetres) is misleading, because it is the area of the lens or mirror that matters, not the diameter. The area of a lens (or mirror) increases by the square of the diameter, so a 100mm refractor has 1.6 times the light gathering power of an 80mm refractor although the diameter is only 25% larger. Hence the “aperture fever” which amateur astronomers quickly fall victim to. However it is also true that the larger the aperture, the more expensive a telescope is (this is particularly true for refractors) and the heavier it becomes. So please do not automatically go for the largest aperture you can afford. In this country with its unstable atmosphere and light pollution, there is little point in a beginner buying any telescope larger than eight inches (200mm) in aperture.

Binoculars

Binoculars are often recommended as a good first astronomical instrument. They are relatively cheap, you can buy a decent pair of 10x50 binoculars for about £50; they are light and hardly take up any space. It looks like a no-brainer, but there are drawbacks. Binoculars are great for bright large objects such as the Moon or the Pleiades or even the Andromeda Galaxy. But they are difficult to hold completely steady and this means that they are not good for small point objects such as planets, double stars or planetary nebula. If you want to see the moons of Jupiter or the rings of Saturn you are better off buying a telescope. It is true that there are larger binoculars but they need a tripod, and once you get into all that, you might as well buy a telescope. Furthermore, in my experience they prove to be disappointing in light polluted areas. They lack go-to systems and hence in light-polluted areas it may be difficult to find fainter objects despite the fact that 10x50 binoculars have a field of view of 5 degrees (about 10 moon widths). In particular, people who wear glasses may find binoculars difficult to use. If you keep your glasses on, it is difficult to get true binocular vision and if you take your glasses off, you may not be able to focus the image at all (as in my own case). I am not saying binoculars are no good at all, but I would not use them instead of a telescope. Buy a light 8x42 pair to begin with as they are much easier to hold, then if you like them move up to a pair of 50mm objectives binoculars (the second figure in the AxB is the objective size). If you are younger than 30, 7x50s are fine, but if you are over 30 I would only buy 10x50s (this is because of the **exit pupil** size, which can be calculated by dividing the second figure by the first one). 7x50 and 10x50 binoculars are surprisingly heavy and hence not suitable for young children. At this stage, I would not buy anything larger as they will require a tripod. I would also avoid buying any binoculars with a high magnification. When looking at the night sky, the image in binoculars with a high magnification is impossible to keep steady, so avoid any binoculars with a first figure greater than 10 (e.g. 20x50s).

Two pairs of binoculars: Meade 10x50 and Carl Zeiss (DDR) 8x30

Dark Adaption

In daylight the eye uses the cones at the back of the retina to see. But in darkness the cones do not work well and the eye has to switch to the rods. The eye takes some time to charge up the rods, so to be speak, and this takes between ten minutes and half an hour. During this time, it is important that the eye does not detect bright light and reverts back to using the cones. So spend some time in the dark before starting to use the telescope. This time is not wasted as the telescope needs some time to cool down to the surrounding temperature as well (actually more time than is needed for dark adaption; an hour is recommended). Nowadays stray light from neighbouring houses is a major threat to good night vision. Try to observe from a locally dark spot away from other lights, as well as observing from a dark area to avoid light pollution. Some people even put a paper or cloth bag over their head before observing and you can use a large hood or a shawl over your head while observing. Or you can use an eyepatch over your observing eye beforehand and then switch the patch to the non-observing eye. To avoid destroying night vision, use a faint red torch while observing. The scientific rationale for using red light has been debated, but it does seem to work as long as it is not too bright. Your night vision continues to improve while you are in darkness. I was once on a remote Caribbean island with no artificial lights for nearly twenty kilometres around and after two hours in utter darkness I could see my shadow formed by starlight (it was mostly cloudy so the starlight was coming from one direction).

A red light to clip onto a telescope or cable (see **Safety**) and a red-light torch

Dark Sky Area

In a good dark area you can see far more than in a city or even a suburb. Spanning the sky is the white band of the Milky Way made up of thousands of stars. You will be able to see several star clusters including M44 (the Beehive Cluster) and the double cluster in Perseus looking like a pair of owl's eyes. You will see the silver disc of M31, the Andromeda Galaxy, the most distant object we can see with the naked eye, and M13, the great globular cluster in Hercules as a fuzzy patch. What will be particularly notable is the streaking of meteors (or shooting stars) across the sky at almost any time of year, but when there are meteor showers (such as Perseids in mid-August or the Leonids in mid-November), the sky will be filled with meteors like luminous rain. The advantages of a dark sky area should be obvious, but how can you find them? First check the amount of light pollution in your back garden or a nearby darker area by counting the number of stars you can see (on a clear moonless night) by looking for the four corners of Orion's body and his readily identifiable belt, made up of three bright stars in a straight line. Count the number of stars *within* the rectangle made by the four corner stars, and include the stars making up the belt. So the minimum count should be at least three! In a badly light-polluted area such as Havering, you might only see seven to ten, but in a dark sky area you will be able to see up to thirty. Alternatively look for stars within the Square of Pegasus. Even in light polluted areas you should be able to see two or three, but in a dark sky area you should see fourteen or even more. To find a darker area go to an area which is not close to large cities or conurbations or use a light pollution map – Phillips make one and there are some on the internet (e.g. https://www.nightblight.cpre.org.uk/maps/). Whenever you go to a new area, keep **safety** in mind. Alternatively go to a dark sky park, but bear in mind that you need clear skies as well as dark skies. Ireland has some of the British Isles' darkest skies, but they are also the cloudiest skies on average!

Exit pupil
This is the term for the size of the light beam leaving the eyepiece and entering your eye. You might wonder why exit pupil matters when buying a telescope and actually it doesn't (in contrast to binoculars where the eyepiece is fixed in focal length), but it is still worth noting for a couple of reasons. In theory a large exit pupil is good as it means that the maximum light enters your eye, but only up to a point. It cannot be larger than the actual pupil of your eye or the light is wasted. The size of your pupil in the dark is difficult to measure, but it decreases with age. If you are a child of ten, your exit pupil will be 7.7mm (see http://www.stargazing.net/naa/scopemath.htm), if you are 30, it will be 6.9mm, and if you are 60, it will be 5.7mm. The exit pupil is the **aperture** of the telescope divided by the magnification. This means that the exit pupil is the **focal length** of the **eyepiece** divided by the **focal ratio** of the telescope. Hence an older person cannot profitably use an eyepiece that is more than five times the focal ratio of their telescope. So if they have a 80mm telescope which is f = 5, their maximum eyepiece is 25mm. A 10 year old child by contrast can use an eyepiece up to 35mm. However if the telescope has a high focal ratio, say f = 10, you can never have an exit pupil as large as 5mm as the largest commercial eyepiece is 40mm. Now let's look at narrow exit pupils. In theory a telescope can bear a magnification up to twice its aperture (in mm). So a 80mm telescope can "take" up to 160x magnification. But this produces an exit pupil of 0.5mm and in my opinion this is literally intolerable. The effect of such a narrow beam of light (if the object is bright enough) entering the eye is alarming. Even with an exit pupil of 1mm I can see back-illuminated floaters in my field of view and it is impossible to concentrate on the object. Hence I would not recommend a eyepiece which has a focal length which is less than the focal ratio of the telescope (so 5mm in the case given here).

Eye relief
Eye relief technically speaking is the distance between the top of the lens in the eyepiece and your eye. You should never put your eye on top of the eyepiece. You not see the image properly and you will dirty the eyepiece. This seems obvious, but it is surprising how many people think you have to ram your eye right up against the eyepiece. Move your eye up and down until you see the image clearly and feel comfortable viewing it. In practice eye relief equates with comfort; the longer the eye

relief the more comfortable is the viewing. Longer focal length eyepieces tend to have good eye relief whereas short focal eyepieces have poor eye relief. One way round this is to use a Barlow lens which retains the eye relief of the original eyepiece. More expensive eyepieces (e.g. Tele Vue eyepieces) have very good eye relief but they are extremely expensive; probably more expensive than your telescope! Eye relief is particularly important if you wear glasses. as by definition you cannot get your eye close to the eyepiece. It is best not to use glasses when observing but not everyone can do this.

Field of view

The field of view is the view one gets through an eyepiece. It is the so-called apparent field of view (AFOV) which is measured in degrees divided by the magnification. The magnification for a given telescope is determined by the focal length of the eyepiece: the shorter the focal length, the higher the magnification and hence the field of view is narrower. The desirable aspect of an eyepiece is a higher AFOV (like the aperture of the telescope). Traditional eyepieces have narrow AFOVs (perhaps about 40 degrees) and poor **eye relief**. They are the type of eyepieces (usually Huygens marked H or Ramsdens marked R) that one gets with cheap telescopes; they are pretty useless even when they are made of glass. In 1860, the Plössl eyepiece was introduced with a AFOV of about 50-55 degrees and reasonable eye relief in the longer focal lengths. Most standard eyepieces are variants of the Plössl. Then in 1979 Albert Nagler introduced the Nagler eyepiece with an AFOV of 82 degrees, thus producing a “porthole” view of space. His firm – Tele Vue – later introduced the Ethos eyepiece with an AFOV of 100-110 degrees. Explore also makes 100 degree AFOV eyepieces. They are wonderful eyepieces but very expensive and also very heavy (some of them can weigh more than a kilogram) which makes them particularly problematic for Dobsonians. You can buy much cheaper generic wide angle eyepieces. With these wide-angle eyepieces one can get a field of view of two or three Moon widths even at pretty high magnifications.

OVL Nirvana wide-angle eyepieces are excellent value. Courtesy Optical Vision Ltd.

Focal length

The focal length of a telescope is the aperture in millimetres multiplied by the focal ratio. So a telescope of aperture 100mm with a focal ratio of 7 would have a focal length of 700mm. So a telescope with a long focal length can either have a large aperture or a high ("slow") focal ratio (or both!). The advantages of a high **focal ratio** are strictly speaking the result of a long focal length, but as the aperture is usually determined by other factors such as cost or portability, it is easier to discuss these advantages in terms of focal ratio. But until relatively recently it was the focal length of the telescope that mattered, not its aperture. William Herschel's famous forty foot telescope had a focal length of forty feet, not an aperture of forty feet (which was actually four feet). Eyepieces also have a focal length and the magnification is given by the focal length of the telescope divided by the focal length of the eyepiece.

Telescopes with a long focal length such as this Skywatcher Explorer 150PL (f8) reflector with a focal length of 1200mm are excellent for viewing planets and double stars, but they have very long tubes, which makes them somewhat unwieldy.

Focal ratio

While **aperture** is doubtlessly the most important aspect of a telescope, the focal ratio (abbreviated as f) also matters. When a telescope has a low focal ratio (e.g. f5), it is called "fast" but this is a term that comes from photography and has no meaning in visual astronomy – you don't see the image any faster! What it does mean however, is that the image – for a given aperture – is brighter. It also means that for a given eyepiece, the **field of view** will be wider. So a low focal ratio seems ideal, but this is only partly true (in visual astronomy; for **imaging** a faster telescope is probably always better). A telescope with a focal ratio of 5 or less may suffer from an optical effect called coma, where a star seems to develop a small tail like a comet. This can be corrected with a coma corrector, but they are not cheap. Furthermore bright planets like Jupiter may become too bright. A fast reflector will need to be **collimated** more often than a reflector with a higher focal ratio. And the depth of field, the number of turns of the focuser that the image remains in focus, is much less with a fast telescope, which makes getting a sharp image tricky. The main advantage of a high focal ratio is for achromatic refractors as this reduces false colour (achromatic aberration). High focal ratios are also supposed to produce sharper images, which is useful if you usually observe double stars or planets. But a telescope with a high focal ratio also becomes very long and unwieldy. In practice the best focal ratio for visual astronomy is probably about 6 or 7. However the focal ratio is usually set by the telescope type. A reflector will usually be between f = 4.5

and 7. A refractor can vary from f = 5 to 15 or even more, although very high focal ratios are now rare. A Maksutov is usually about f = 12. A typical Schmidt-Cassegrain is f = 10, but focal reducers are used to reduce the focal ratio to f = 6.3 for imaging.

Focuser

Once you add an eyepiece to a telescope, they have to be brought into focus using a tube which moves in and out of the main telescope. This is called a focuser. There two types of focuser: the rack and pinion type and the Crayford focuser (named after Crayford Astronomical Society in Kent). At the kind of price level we are talking about here, you will have no choice of focuser; it will depend entirely on the model you buy. Only the more expensive telescopes have a Crayford focuser, but they are more common in Dobsonians. The Crayford has a smooth motion but by the same token is easily moved out of focus, so once you have a sharp image you have to lock the focuser using a small screw underneath. The big advantage of the Crayford is that it is usually a “dual focuser” with a fine control knob in addition to the main knob. This is particularly useful in “fast” telescopes given their shallow depth of field (see f**ocal ratio**) which is presumably why they are fitted to Dobsonians. Most reasonably priced telescopes have a rack and pinion focuser. They are usually satisfactory -- they remain fixed in position once you have reached focus, but they can have problems. The teeth in the rack (the flat bit on the tube) and pinion (the circular bit that turns) can become out of sync and the teeth can become damaged. This is particularly true of a plastic rack and pinion. In cheap focusers, the movement of the tube can be rather rough, producing a jerky effect when looking through the telescope. Furthermore the rack can become detached from the tube, making it difficult or even impossible to use the focuser. Most focusers in reasonably priced telescopes can only be used with 1.25 inch eyepieces, but the Crayford focuser is usually capable of taking 2 inch eyepieces, enabling the use of wide-angle eyepieces with longer focal lengths which are invariably 2 inch eyepieces.

Close up of a 2” Crayford focuser with dual controls and the locking screw underneath.
Courtesy of Optical Vision Ltd.

Imaging
This is not the place to discuss imaging, but there are three simple ways you can start in imaging. One is to buy a cradle for a smartphone and take images using your smartphone. These images can often been surprisingly good but the smartphone is limited to the brighter astronomical objects; mainly the Moon and the brighter planets. Alternatively, you can buy a webcam eyepiece from a telescope dealer which you put into the telescope instead of an eyepiece, perhaps combined with a Barlow lens, and link it to a laptop. You then have to select and stack the numerous still images produced by the webcam using programs designed for this purpose. However this method is also largely limited to the Moon and planets. On a different level altogether is the DSLR camera which you may have anyway. You need an adaptor to connect it to the telescope but this is easily obtained. You can either take a long exposure (which will need tracking at least if not guiding) or short exposures which can be stacked like the webcam images. In fact even a short 20 second exposure can produce a pretty decent image without using stacking. Or you can get a tracker mount specifically made for a DSLR camera and use it with a telephoto lens. Again it is possible to obtain decent images of deep sky objects in this way. With this tracker mount you can also use a wide-angle lens to take images of constellations.

Light pollution
The biggest single problem with observing the night sky today is light pollution. Yet most non-observers have not come across the term, and most books on observing do not mention it or only give it one or two sentences. To understand light pollution, imagine looking at the night sky with the naked eye on a clear moonless night. In the middle of a city (e.g. Piccadilly Circus), you will struggle to see anything in the sky at all. Only bright planets such as Venus or Jupiter and the brightest stars such as Vega in the summer or Sirius in the winter will be visible. During the winter, you should be able to see the Orion nebula below Orion’s belt and the Pleiades as a fuzzy patch above Orion. However that is about all that you will be able to see. By contrast in a **dark sky area** such as a desert or a remote island without any nearby lights, you will be immediately struck by the huge number of stars, meteors and other objects you can see. Light pollution is caused by artificial lighting; before the invention of the electric light it simply did not exist (pollution in the form of smoke and peasouper fog was the main problem for observers in the late nineteenth century). More specifically it is artificial light which is either misdirected or allowed to shine upwards up into the sky. The ubiquity of modern light pollution is caused by the sheer number of artificial light sources in modern societies. You can see this light pollution by looking towards your nearest large town or city and see the light dome hanging over it. You can also see light pollution bouncing off low clouds – if there was no light pollution you would not be able to see these clouds. Severe light pollution is a relatively recent development. Fifty years ago when I was young, it was still possible to see the Milky Way from Upminster. Another increasing problem is local stray light caused by neighbours not drawing their curtains, and the illumination of nearby houses and security lights which prevents **dark adaptation**. In theory light pollution can be reduced by **filters**, but in practice they do not work well. The best solution is either to go to a **dark sky area** or to concentrate on the observation of objects which can be seen in light-polluted areas such as the Moon, planets and double stars. **Imaging** can also get round light pollution to a certain extent.

Mount
The mount is the thing which attaches the telescope to the tripod or, in the case of the Dobsonian, the "bucket" in which the telescope sits. If you are using go-to it is part of the mount. There are three basic mounts: the altazimuth mount which has separate sideways motion and upwards motion, the equatorial mount which moves in a circle perpendicular to the Celestial North Pole, and the yoke mount used mainly with Meade Schmidt-Cassegrain telescopes. If you are using a telescope for imaging, you need an equatorial mount or a yoke mount which is tilted by means of a "wedge". You cannot really use an altazimuth mount for serious imaging. The main thing I would say about the mount is that a telescope is only as good as its mount; given a bad mount, a telescope will not be much use. It is best to get a telescope which can be removed from the mount so you can use it on another mount/tripod, but this is not always possible with cheap telescopes. If you can afford to do so, I would avoid mounts that have a small yoke and the telescope tube attached to the mount by a metal rod. This arrangement is very common in cheaper telescopes such as the Skywatcher Mercury 707 (which I recommend as a cheap telescope) and it is an easy set-up to use. However from my own experience, the point of attachment of the rod can break off after considerable use, leaving you with a useless telescope. This is a pity as these telescopes are invariably refractors which will otherwise last for centuries.

A Meade refractor with a German Equatorial Mount. Courtesy Greg Smye-Rumsby.

Safety
There are two main aspects to safety during observing away from home. First and foremost, have someone else with you – it is never a good idea to observe on your own, except in your back garden. Children should always have two adults with them as one of the adults will be preoccupied helping the child with the telescope. It is very easy to fall or trip while you are in the dark. Make sure you are familiar with your surroundings beforehand – visit the site in daylight and note any potential hazards such as a dip in the ground, something sticking out of the ground and low walls. If you are not confident about the site being safe, find another site. Also be aware of where your telescope is and any cables you are using. You can buy little red lights to clip to telescopes or other equipment. I have tripped over my telescope and cables several times; it is easily done! The second aspect is the danger from other people (or in some places even wildlife). Again check out a site in daylight and perhaps

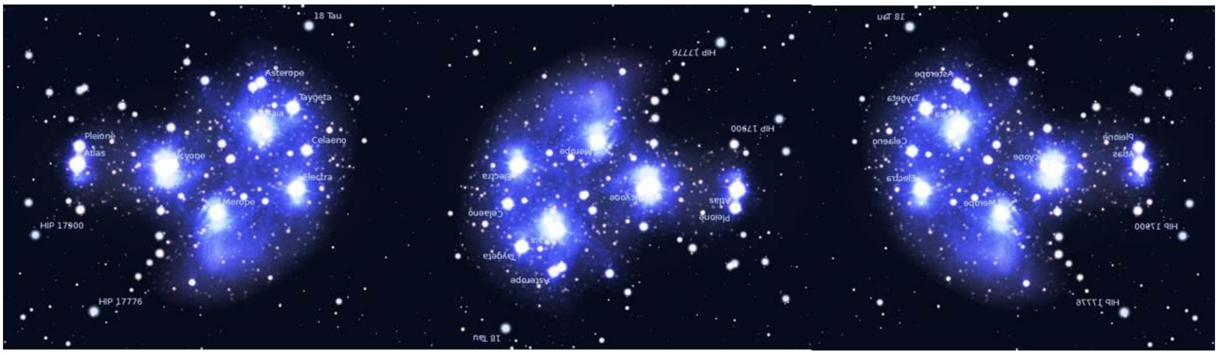
drive past in a car several times in the dark before using it. Are there people hanging around the area? Does it look safe? You may wish to take advice from the local police. Always take a charged up phone with you and make sure you get good reception at the site. Take an ordinary white torch with you in case you need it (and also to make sure you have everything with you before you leave the site). It is important that your observing partner is looking around while you are absorbed at the telescope. Always err on the side of caution: if a site does not seem safe for whatever reason, find another site or just go home.

Security

Take precautions when storing telescopes outside of the house. Thefts from outbuildings are sadly all too common. Make sure the building you are using to store your telescope is secure, with a solid door and a good strong lock. Avoid storing telescopes in unlocked garages or porches. Check to see if your household insurance covers your outbuildings and what level of cover is given. You may wish to specifically cover your telescope and equipment either within your household insurance or separately. It is also important that these outbuildings are physically suitable for your telescopes. While a garden shed may be useful for keeping the telescope at ambient temperature, thus removing the need for a cooling down period, it may not be suitable in other ways. Only use a shed which is well built, on good dry foundations and in good condition, and that is dry at all times. You will almost certainly need to upgrade the lock unless you have a high-security shed. However bear in mind that sheds often become very hot in summer.

Telescope image

You might naturally assume that you see the same view in the telescope as you do with the naked eye (in terms of up and down and left and right). Unfortunately this is not usually the case (unless you are using a spotting telescope which gives you the naked eye view, as it is intended for terrestrial use such as bird-watching rather than astronomy). Binoculars do give you the naked eye orientation, which is one of their advantages. A reflecting telescope will give you an upside down view and one in which left becomes right. So the chain of stars leading from Alcyone in the Pleiades (called Ally's Braid) will point upwards in the upper right sector of the view of the Pleiades rather than its natural position of pointing downwards in the lower left of the view. This also applies if you have a straight-through finder, which is one reason why red-dot finders are becoming more popular as it retains the natural view (as does the right-diagonal finder, which I prefer).



The Pleiades (M45) as seen through binoculars (left), a reflecting telescope (centre) and with a star diagonal (right) – note the position of Ally's Braid in all three pictures. Adapted from Stellarium.

In theory a refractor or a catadioptric telescope will give the same inverted view. However they are usually used with a star diagonal which will turn the image the right way up, **but** the image will still be flipped left to right, so Ally's Braid will now be pointing down again but in the lower right of the view, rather than the natural lower left sector.

Tripod

The tripod is often the weakest point in a telescope's set-up. The performance of many a good telescope has been ruined (or at least degraded) by a poor tripod. The problem is that manufacturers having cut the price of the actual telescope to the bone need to make a profit somehow. They do this by fitting a tripod which is not quite good enough for the telescope (but cheaper). Many telescopes (as sold) would have performed much better if they had been married to the next tripod up in a series of tripods. What is needed in a good tripod is weight and sturdiness. A light tripod with spindly legs is not likely to be a good tripod. But it is also a matter of the weight of the telescope and mount. A heavier telescope needs a heavier (and sturdier) tripod. You also need a tripod which has legs which can be moved up and down easily, but also locked into position firmly, and ideally have either narrow rubber caps or points at the bottom end. If you have bought a tripod which is too light, you can either buy a heavier tripod (but make sure that it is suitable for your telescope/mount--- you might want to buy a better mount at the same time) or put a sandbag or heavy draught-excluder (you want something soft in case you drop it on your foot) across the eyepiece tray in the middle of the tripod between the legs (but obviously not too heavy in case it breaks the tray). You could discuss this issue with your dealer and if they are any good, they might be willing to upgrade your mount/tripod to a better model and take the price of the original tripod/mount off the cost (but obviously it will be more expensive overall). This is often not possible however. Finally take into account the height of the tripod when fully extended (or conversely fully retracted). Many tripods sold with children in mind are too low for many adults and some tripods are too high for children (although this can be solved by encouraging the child to stand on a box or small step).

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Internet Links for Telescope Dealers

I have used the ones marked **

Telescope House, Kent**
https://www.telescopehouse.com/

Widescreen Centre, Cambridgeshire**
https://www.widescreen-centre.co.uk/

First Light Optics (FLO), Devon**
https://www.firstlightoptics.com/

Rother Valley Optics (RVO), South Yorkshire**
https://www.rothervalleyoptics.co.uk

Modern Astronomy, Surrey
https://www.modernastronomy.com/

365 Astronomy, East Sussex
https://www.365astronomy.com/

Tring Astronomy Centre, Hertfordshire
https://www.tringastro.co.uk/

Harrison Telescopes, Kent
https://www.harrisontelescopes.co.uk/

Altair Astro, Norfolk**
https://www.altairastro.com/

Other Useful Websites

Beginners' guides

https://ras.ac.uk/education-and-careers/for-everyone/92-getting-started-in-astronomy

https://www.skyatnightmagazine.com/tag/astronomyforbeginners/

https://skyandtelescope.org/astronomy-resources/stargazing-basics/how-to-start-right-in-astronomy/

https://britastro.org/node/20709

Other guides to buying a telescope (which may take a different view!)

https://skyandtelescope.org/astronomy-equipment/types-of-telescopes/

https://gostargazing.co.uk/which-telescope-is-best-for-beginners/

https://www.skyatnightmagazine.com/advice/a-buyers-guide-to-telescopes-choosing-your-first-scope/

https://liverpoolas.org/2019/11/05/buying-a-telescope-2019/

Guides to buying eyepieces

https://www.skyatnightmagazine.com/advice/skills/eyepieces-the-basics/

http://www.swindonstargazers.com/beginners/eyepieces.htm

Introduction to using a telescope

https://www.highpointscientific.com/telescope-users-guide

https://optcorp.com/blogs/astronomy/how-to-use-a-telescope-for-beginners

https://skyandtelescope.org/astronomy-equipment/the-art-of-using-a-telescope/

Observing lists

https://www.astronomyedinburgh.org/ase-24/

The Loughton List by our neighbouring astronomical society in Loughton
http://las-astro.org.uk/ll_page.php?GM=TMa

Telescope calculator
This is extremely useful when deciding what telescope and which eyepieces to buy (and great fun!)

http://www.stargazing.net/naa/scopemath.htm