Chapter 2

Instruments and Techniques

One of the hardest questions usually asked by newcomers who want to make a start with visual work is: *What type of telescope should I buy?* The question is difficult because the choice of telescope depends entirely on the circumstances of each individual. The best telescope for you is the one that suits your needs. The first thing to be done is to buy a pair of binoculars and learn your way around the sky. This is a major introductory step (and one that seems to be skipped all too often these days). It is true that many telescopes come with 'go-to' devices, but there is no substitute for familiarity with the sky.

Learning your way around the night sky will do two things for you. Firstly you will learn the constellations and become familiar with where things are situated. We all know how much quicker it is to get around a city if you know where all the back roads are. Yes you can use SatNav, but it is far more rewarding to *know* where things are. You are going to be spending a lot of time out there in the universe, so it is best to get acquainted with it. Secondly, being out there learning your way around the night sky will help make up your mind if you are going to be a causal amateur or someone who intends to invest a great deal of time in the subject. This is another consideration when buying a telescope; there is little point in buying a giant telescope and then having it sitting in doors collecting dust because it is too heavy to move about or because you haven't the time to use it.

For the rest of this book, I am going to assume that you have become familiar enough with the night sky and intend to make a proper start on visual observing. In the next section we shall look at the different types of telescope that are available along with the various choices of mounts, eyepieces and filters. After this we shall go on to look at some basic types of observatory that might be considered. In the final section of this chapter, we shall look at the tools and techniques needed to become a reliable observer.

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Telescopes

Although telescopes come in many shapes and sizes, it is possible to group them into three general categories – refractors, reflectors and catadioptrics. The term catadioptric can be confusing, but it simply implies a mixture of reflecting and refracting elements. The most popular modern form of catadioptric is the Schmidt-Cassegrain or SCT, but there are others, too, such as the Maksutov. Essentially, both these designs are similar to Cassegrain reflectors, with an extra transparent element designed to correct optical aberrations. It was only when Celestron's Thomas J. Johnson worked out how to mass produce large Schmidt corrector plates, in the late 1960s, that affordable SCTs became a reality for the amateur astronomer. Each types of telescope has its good and bad points, all of which must be weighed up before a telescope is purchased.

Refractors

This is the simplest form of telescope (see Fig. 2.1) and was the first type of telescope to be invented. It has a large primary objective convex lens (consisting of two or more elements) at one end whereby the light from a celestial body enters and is brought to a focus. This light forms an image at the focal plane that can be magnified and inspected by an eyepiece.

The main advantage of this telescope is that it is essentially maintenance-free. So long as the telescope is aligned carefully during manufacture and the lens cell is robust the refractor should remain in good alignment. Refractors also tend to have a large focal length (focal length is the distance from the primary lens to the point where the light is brought into focus, as is shown in Fig. 2.1). Longer focal lengths are useful because eyepieces perform better at long f-ratios and there is more eye relief, so spectacle wearers can observe more comfortably. It has to be said though, that refractors are very expensive telescopes. The smallest size of refractor useful for visual work is probably a 4-in. refractor, and this will cost more than a reflector of the same aperture. However, the real problem is if you want an aperture greater than 5 or 6 in.; at this point the cost of the instrument rises exponentially.

The main problem that affects the refractor is chromatic aberration. This occurs because white light is really a mixture of all possible colors from red through to blue. A glass lens refracts red light slightly less than it does blue light. The end result of this is a false color image; the object in the eyepiece will appear to have a purplish halo surrounding it. This was a big problem for the early refractors, but there have been many advances in optical production in recent years, and today, all refractors have a primary achromatic doublet objective lens. The doublet lens is essentially two lenses 'cemented' together, and the chromatic aberration of one lens cancels out that of the other, thus reducing the effect. All refractors in the medium price range will have a tolerable degree of chromatic aberration. There are a

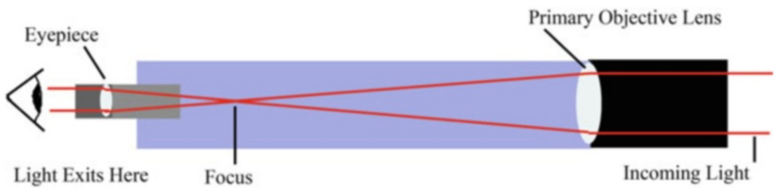


Fig. 2.1 A refracting telescope

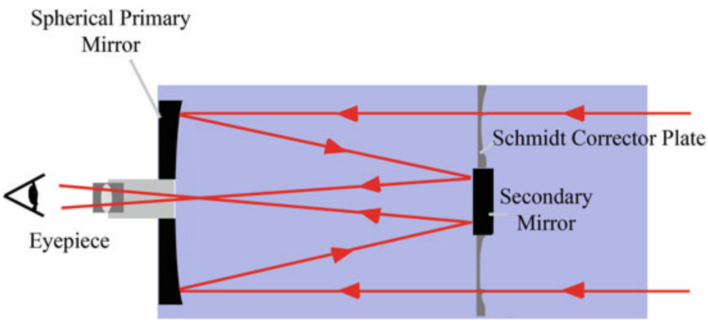


Fig. 2.2 A Schmidt-Cassegrain telescope

number of high end manufacturers who use exotic forms of glass in their refractors that eliminate the effect completely. However such telescopes are very expensive.

A further consideration is that the standard refractor requires a lot of room, and a 6-in. refractor is basically not portable. I was once loaned a 4.5 inch refractor by the British Astronomical Association back in the 1990s; it was an excellent instrument, but the optical tube was longer than me! These days refractors come with much shorter tubes, but at considerable cost and apertures of 5 in. or more, however the cost of smaller refractors has come down in recent years. Although they look splendid remember it is aperture (size of the telescope) that is the most important. Ideally, you should get the largest telescope you can for your money

Schmidt-Cassegrains

These types of telescopes are probably the most complicated for the beginner to understand and are based upon the principle of folded optics. A diagram showing how this type of telescope works is given in Fig. 2.2. Essentially, light from a celestial body enters the telescope through the corrector plate (which corrects for spherical aberration introduced by the primary spherical mirror); it then hits a spherical primary mirror at the back of the telescope. This light is then reflected

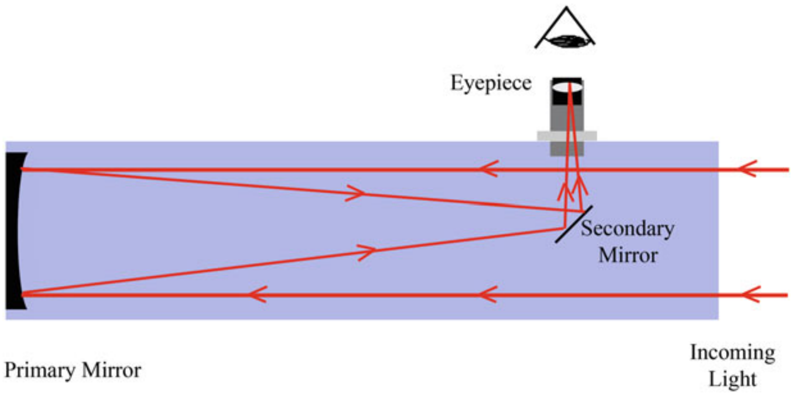


Fig. 2.3 A Newtonian reflector

back up the tube to a convex secondary mirror and then back down through a tube to the eyepiece. The eyepiece is fixed to a tube that goes through the center of the primary mirror (so one looks ‘up’ the telescope like a refractor). The tube is sealed, and the telescope is brought into focus by moving the primary mirror back and forth.

The good thing about these telescopes is that they are very short. This means you can have high focal lengths, but the tubes are nowhere near as long as a refractor of equivalent focal length would be. This type of telescope does tend to be favored by imagers for this reason. There are however a few drawbacks. Schmidt-Cassegrains are rather expensive, they are also prone to losing their collimation (collimation means that the optics are correctly aligned). Moreover there is a loss of contrast due to the large secondary mirror diameter, which is far bigger than the hole in the primary.

Newtonian Reflector

The Newtonian reflector is a popular and reliable telescope. Money-wise they are cost effective, and most importantly you can obtain a large aperture telescope for a reasonable sum of money.

The Newtonian telescope is named after Sir Isaac Newton who designed the telescope and presented it to the Royal Society in 1668. The design is a simple one (see Fig. 2.3). The light from a celestial object enters the telescope tube and hits the large concave primary mirror at the bottom of the tube. The light is focused by the mirror and reflected back up the tube to a flat secondary mirror and is then reflected into the eyepiece. This type of telescope will need collimating from time to time (which is a simple enough process), but not as often as the Schmidt-Cassegrain.

As the tube is not sealed, the mirror will also have to be re-aluminized occasionally. There is zero chromatic aberration with the Newtonian telescope so color and filter work can be undertaken.

It is true the Newtonian's can come with long tubes if a longer focal length and high focal ratio is required (focal ratio is the focal length of the telescope divided by the diameter of the telescope and is written *f*/number). Although you will hear it said high focal lengths and ratios (example, f/7, f/e, etc.) are desirable for planetary work, telescopes with a focal ratio of f/5 can be very satisfactory. In end you must weigh up all of the factors and choose the telescope that really suits you and your needs.

The biggest advantage of having a long focal ratio Newtonian is that you can keep the collimation perfect over long periods of time. Newtonians suffer from an optical aberration called coma which increases exponentially as the f/ratio gets smaller. Not only does this lead to tadpole-shaped stars at the field edge, it means the region in the center of the drawtube, where the telescope image is perfect, can become very narrow. Independent of aperture this so-called 'sweet spot' is a blissful 11 mm across at f/8, a tolerable 5 mm across at f/6 and just over 1mm across at f/4. So, at f/4, if your drawtube rattles by more than 1 mm you are never collimated! Also, at f/6 and longer f-ratios, a telescope can be collimated in daytime, with a so-called Cheshire sighting eyepiece, without a star test being essential. The main disadvantage of a long f-ratio is that the telescope size can become very user-unfriendly.

There are many telescope manufacturers and suppliers today, and since a telescope is a large investment, it is strongly recommended you do some research first. Most (if not all) telescope makers have websites, and it is wise to read up about the construction and performance of a telescope. You might also find it useful to consult astronomy magazines and forums to get reviews from people who have used various brands of telescope. Your local astronomical society is another good place to go to. The members there will probably have many years of experience with telescopes, and you will be able to see the various sizes of instrument and use them for yourself. This will help you narrow down the choice of telescope that is suitable for you.

Mounts

"Your telescope may have the best optics built by human hand, but if the mount it is as steady as a jelly, it will be practically useless!" These were the words of wisdom from Sir Patrick Moore many years ago, and never was a truer word was spoken! The mount is, of course, the structure the telescope sits on, and it must be firm and rigid. If it is not, then the slightest breeze will make it shake, and your image of the planet will dart around in the eyepiece, making useful observation impossible.

There are two categories of telescope mount. The first type is an alt-azimuth, the second is an equatorial mount. We shall look at the alt-azimuth mount first.

Fig. 2.4 A Dobsonian mount

Alt-Azimuth Mountings

This is the simplest type of mount a telescope can have. It generally comes in the form of a tripod, and the telescope moves in altitude (up and down) and azimuth (left to right). This type of mount is very easy to set up; you simply find some firm level ground, set the telescope down and you're ready to go. A good example of this type of mount is the Dobsonian mount (see Fig. 2.4). The Dobsonian mount is very popular with deep sky enthusiasts. Firstly, this type of mount doesn't take up too much room and so quite large telescopes can be mounted in this way (it is not uncommon to see 20″ Dobsonians at star parties). The Dobsonian is also very quick and easy to set up, and you can move from one part of the sky to the other very quickly.

The main drawback for this type of mount is the fact that it is not usually driven and therefore does not follow Earth's rotation (drives are available for Dobsonian mounts, but they are very expensive). All celestial bodies in the sky gradually move through the sky during the course of the night; as Earth rotates, objects rise in the east, culminate (reach their highest point) and then set in the west (unless they

Fig. 2.5 Equatorial mount. The mount is set up so that the polar axis is pointing in the same direction as the North Pole (or South Pole if you live in the southern hemisphere). The counter weights are there to make sure the telescope is balanced

are circumpolar, which means they never rise or set and are visible all year around, like the plough in the UK for example). As a result, when you turn the telescope towards an object (Saturn, say) you will find the planet slowly drifts out of the field of view of the eyepiece.

If you use a high power, the speed which this happens can be rather quick, and you may find yourself only getting a 20-s view! Slow motion controls can be added so that you can keep moving the telescope in small amounts, but to do this and make a drawing requires more hands than the human form is equipped with! If you have a small garden and want a big telescope, and don't mind frequently shifting the telescope a little, this maybe a suitable telescope mount for you.

Equatorial Mounting

This type of mount is more complicated (and more expensive). It moves the telescope in two directions, right ascension and declination. All celestial objects have coordinates measured in terms of right ascension (denoted α) and declination (denoted δ), and this is the coordinate system of the sky used by all professional astronomers (and indeed, go-to telescopes). As can be seen in Fig. 2.5, the polar axis of an equatorial mounting points in the direction of the pole star (and so is aligned with the rotational axis of Earth). As a result when the telescope moves in right ascension it is moving in the same plane as Earth's equator, and so with a

motor driving this axis at a rate of one revolution every 23 h, 56 min and 4 s objects will stay in the field of an eyepiece.

Before we discuss the equatorial mounting further, it will be useful to remind ourselves on what is meant by right ascension and declination. Of course, you don't need to know anything about right ascension and declination to use an equatorial mount; to use it effectively you simply need to align it with the pole star. The main benefit is that a drive can be fitted so that the telescope rotates at the same rate as Earth (i.e., it keeps sidereal time), so once you have locked on to an object, it will remain in the eyepiece rather than drift off after a few seconds. Having said that, understanding the coordinate system used by astronomers is a great advantage, and since it is a relatively simple idea, we shall briefly look at how it works.

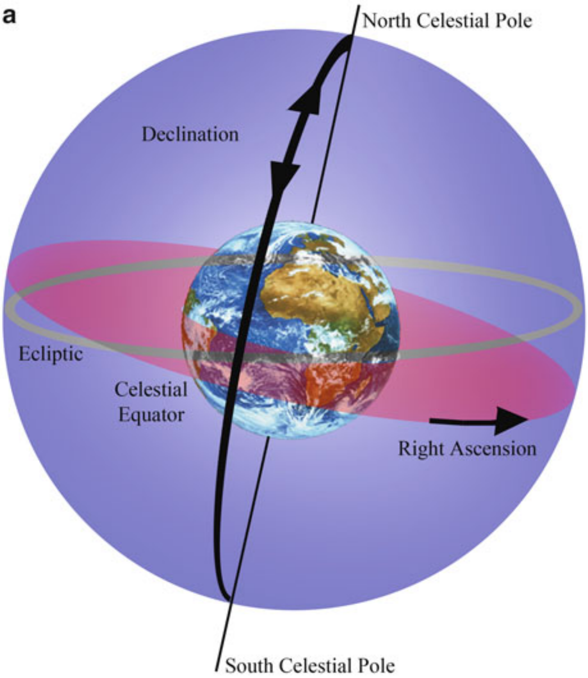
Imagine (or rather, pretend) that the whole night sky, including the stars, lie on a sphere surrounding Earth (completely unrealistic, of course, but for the point of choosing a coordinate system this doesn't matter!). This sphere is called the celestial sphere. We can now put some useful things on the sphere (see Fig. 2.6a). First we can put on the celestial equator, as well as the north celestial pole and the south celestial pole. We measure right ascension in the horizontal direction (so it is equivalent to longitude here on Earth), and we measure declination in the vertical direction (and so declination is equivalent to terrestrial latitude).

Declination is the simplest coordinate of the two. Declination is measured in two directions – up (north) and south (down). It is measured in degrees (°), minutes (′) and seconds (″). Each degree is composed of 60 min, and each minute is further composed of 60 s. Anything on the celestial equator has a declination of 0°. Everything north of the celestial equator will fall into the range 0° (equator) to the north pole located at +90°. In the other direction (below the equator), an object can have a declination ranging from 0° to −90° (the south celestial pole). Thus a '+' indicates that the object is above the celestial equator, while a '−' indicates it is below the celestial equator. There will be objects in the southern hemisphere that cannot be seen in the north (and vice versa). For example, astronomers in the UK and northern Canada will never be able to see the magnificent constellation of Centaurus simply because it is too far south and never rises above the horizon (thus we are denied the splendid sight of the magnificent globular cluster Omega Centauri).

Right ascension is a circle in the horizontal direction on the sphere, and it's split into divisions whose chosen units are hours (h), minutes (m) and seconds (s). One complete circle is 24 h in length; each hour contains 60 min, and each minute is broken down into 60 s. The circle starts at 0 h, half the circle is covered after 12 h, and after a full 24 h we are back at the start of the circle. On the right ascension circle, we start at 0h and move east (to the right, in Fig. 2.6b) 1 h, 2 h and so on. We can specify the right ascension of any object on the celestial sphere, with its coordinates given in hours, minutes and seconds (for example, Vega is located at about 18 h 36 m 56 s). As a coordinate system this is simple enough, but we have to decide where we put the 0 h.

The ecliptic is the path the Sun makes across the sky over the course of a year. In Fig. 2.6b we have included the ecliptic and the celestial equator. As can be seen,

a



b

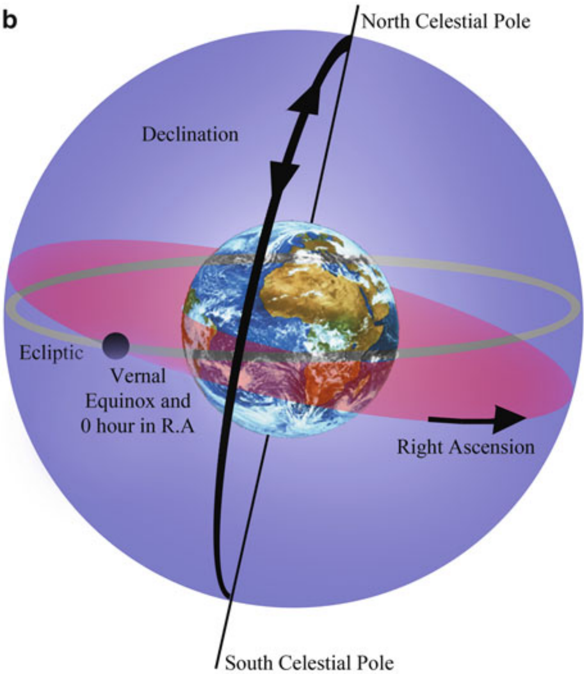


Fig. 2.6 (**a**) The celestial sphere. The celestial equator, poles and RA and dec are shown. (**b**) The ecliptic and equator intersect at the equinoxes. 0 is the point of the vernal equinox. (**c**) Vega's location on the celestial sphere

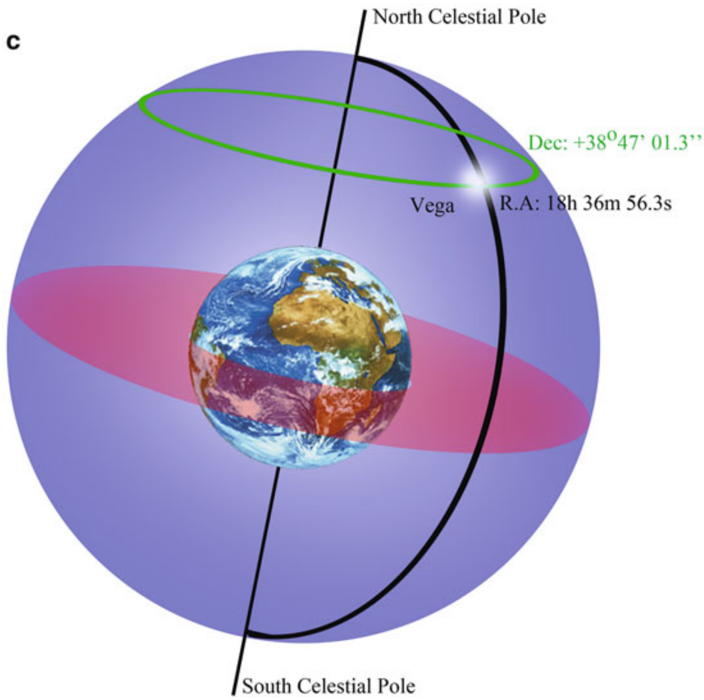


Fig. 2.6 (continued)

the ecliptic intersects the equator at two points, the spring equinox and the vernal (or autumn) equinox. Astronomers choose to measure 0 h of right ascension to be the point of the vernal equinox (also known as the first point of Aries).

Very often in books giving right ascension and declination of objects, you will see ‘Epoch 1900’ or in more recent texts ‘Epoch 2000.’ This is there to take account of the effect of precession. Precession occurs because Earth isn’t a perfect sphere (it bulges at the center), and the gravitational effects of the Sun and the Moon cause Earth to wobble slightly on its axis. This means that the current North Pole star (which at the moment is Polaris in Ursa Minor) will not always be the pole star, due to precession; in 8,000 years time it will be the bright star Deneb in Cygnus, and in 12,000 years’ time it will be Vega in Lyra. Polaris will return to being the pole star in around 26,000 years, which is the length of the cycle. This obviously has an effect on where the equinoxes occur, and due to precession, they shift slightly, even over the course of a century. As a result, right ascension has to be regularly updated for every object (once every 50 years is enough), and this is what is meant by Epoch. Epoch 2000 means the right ascension coordinates are given from the position of the equinox in the year 2000.

Now, what does all this have to do with telescope mounts? The answer is: everything! The equatorial mount is designed to make full use of the right ascension and declination coordinates. On simple ‘non go-to’ mounts you should find a setting

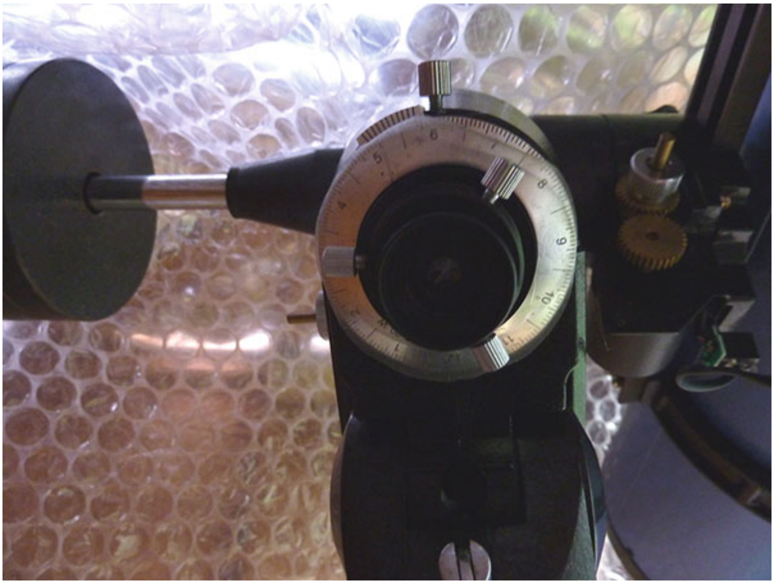


Fig. 2.7 A polar telescope. Simply look through it and adjust the mount until Polaris enters the polar 'scope. Once you have it, place it in the desired position (as indicated in your telescope's manual)

circle for right ascension axis that measures right ascension in hours, minutes and seconds, while on the declination axis you will hopefully find a declination circle to measure declination in degrees, minutes and seconds. If you know the coordinates (in RA and dec) of a faint object such as Uranus you can turn the telescope to these coordinates straightaway (hence having to avoid a search of an obscure area of the sky with no easily recognizable stars!).

To set up the equatorial mount, first make sure you have read the instructions that came with the telescope. Next, the polar axis needs to be pointing towards Polaris. Most equatorial mounts today have a polar telescope (Fig. 2.7). This is a small telescope located in the polar axis of the mount. You simply point your mount towards the north and in the direction of Polaris, and when it appears in the polar 'scope you move into position. (Polaris is not quite at the north celestial pole, so most polar 'scopes indicate the position where you should put the pole star once you have it. In some models there is a black circle in the polar telescope, and the pole star has to rest anywhere on that, depending on the month and time.) The telescope is now ready to use. If it is motor driven you will notice that once the drive is on, any object placed in the eyepiece field will stay there because the telescope is tracking it.

If you wish to find an object by using its RA and dec, then first find a bright star and turn the telescope onto that (Vega is a good choice in summer, Sirius in winter). Turn the RA circle so it reads the RA coordinates of the star, then turn the dec circle

so it now reads the dec of the star. (The dec circle may be fairly close to the correct declination as delivered.) All you have to do then is to move the telescope to the RA and dec of the object you wish to observe. If your telescope is driven, you may only have to do this once per night, assuming the drive is not switched off. However, life is not always that simple! If you move to another object by using the fast slew button on the handset you may find that the setting circle RA position does not change at all, so studying how the RA circle can be clamped or released from the polar axis, and watching what happens will help understand its operation. Sadly, many modern telescopes are not designed with the setting circle user in mind and some simply use go-to, which can require a tedious multi-star alignment procedure. However, if the telescope is fixed on a plinth in an observatory you will never have to alter the declination setting circle and that, in itself, is a huge advantage, especially when searching for objects in twilight.

For many, the equatorial mount is ideal for visual observing. It is true that it can take about 15 min to set (make sure the telescope and the counter weights balance, and it is aligned with Polaris), but the advantages of having a planet steady in the eyepiece without any drift far outweighs the work in setting it up. All of your energy can be spent observing and recording, rather than having to make adjustments to the telescope every minute or so.

Computer Drives

The option exists today for a telescope on any mount to be controlled by a computer drive. The difference between a clock drive and a computer drive is that a clock drive will simply turn the telescope at the same rate as Earth, whereas a computer drive has a go-to system, and so all you have to do (in theory) is connect the telescope to the computer and tell it where you want to look.

Go-to systems are not too difficult to set up, but it has to be said they do drive up the cost of a telescope; so much so that even a small telescope on such a mount is bound to be costly. These drives are ideal for deep sky enthusiasts who wish to track down faint elusive objects, and photograph them for long periods of time, but planets are bright and easy to spot, so one has to question whether much use will be gotten out of them for the planetary observer. The would-be telescope buyer might be wise to invest the money in a bigger aperture (since this is more important) rather than a computer-driven telescope mount. However, in general the mounts that can cope with instruments of a 10- or 12-in. aperture do tend to have 'go to' as standard these days, and so many planetary observers will simply bypass the date, time and multi-star alignment menu routines, go straight to the sidereal (or lunar) tracking command and just align the 'scope very roughly on the pole. Even crude marks on the patio telling you where the tripod feet should go will suffice for a quick set-up and, in the cool, overcast climate, a quick set-up is often vital to beat the clouds!

Eyepieces and Filters

Once you have a telescope, a selection of eyepieces is essential. To start off with, it's best to have three eyepieces, a low power one for hunting down faint planets including Uranus and Neptune, a medium power one that will provide reasonable views in medium seeing, and finally a high power one that will give close up views of the Moon and planets when the seeing is good. It should be stressed that even the lowest power eyepiece is no substitute for a decent finder telescope and a high quality finder makes life much easier. Many experienced amateurs have two finders, a zero power laser-type finder and one with an aperture of 50 or 60 mm. Such an arrangement is a 1,000 times more useful than a small 'toy' finder of 20 or 30 mm aperture.

Before we look at the different eyepiece types, let's review magnification and how to work it out. Simply put, magnification is the amount by which an eyepieces increases the *apparent* diameter of an object. So if your eyepiece is ×50, then when you use it on the Moon, the Moon will appear 50× larger than when you see it with the naked eye. Magnification depends on two quantities: the focal length of the eyepiece f_E (see Fig. 2.8) and the focal length of the telescope f_T, and they are related to magnification by the expression:

$$magnification = \frac{focal\,length\,of\;telescope}{focal\,length\,of\;eyepiece} = \frac{f_T}{f_E}.$$

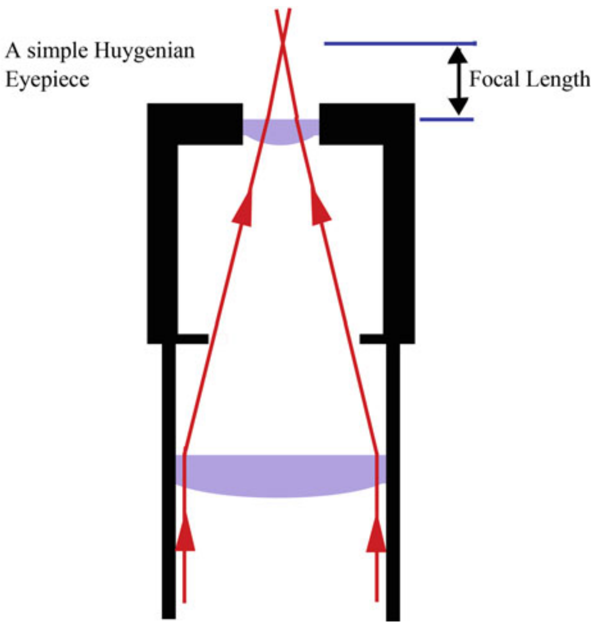


Fig. 2.8 Focal length of eyepiece

Table 2.1 This shows the maximum usable magnification for various-sized telescopes. Values are approximated for convenience

Telescope size	Maximum usable magnification
3 in. (76 mm)	152×
4 in. (102 mm)	204×
5 in. (127 mm)	254×
6 in. (150 mm)	300×
8 in. (203 mm)	400×
9 in. (230 mm)	460×
10 in. (250 mm)	500×
12 in. (305 mm)	610×
16 in. (406 mm)	812×

The focal length of your telescope will be given with its packaging and instructions. My telescope is of focal length 1,000 mm, so my 5 mm eyepiece will give a power of 200× since

$$magnification = \frac{1{,}000}{5} = 200$$

However on a telescope with a focal length of 1,500 mm we find that

$$magnification = \frac{1{,}500}{5} = 300.$$

So, you need to remember that if you use your eyepieces on a different telescope, unless the focal length is the same as your own telescope, the magnification will be different. Note also, both the focal length of eyepiece and focal length of telescope must be in the same units (mm is the most common).

Magnification is also dependent on the size of your telescope. You will find that as you increase the power, the image becomes dimmer and harder to focus. If you have a 150 mm reflector, you will find that an eyepiece that gives a power of ×500 gives an image that is practically useless! There is a maximum usable magnification for each telescope, and this maximum will only be achieved on very good nights with excellent seeing (Table 2.1).

The general rule of thumb for working out the optimum magnification is to take the diameter of your telescope (in mm) and multiply it by 2. Thus a 14-in. (356 mm) telescope will have an optimum magnification of

$$356 \times 2 = 712 \text{ times.}$$

Seeing conditions will also affect what magnification you can use. One scale used by astronomers to assess the seeing is the scale introduced by Eugene Antoniadi. The scale ranges from Ant I (Perfect) to Ant V (Unusable):

Ant I: Perfect seeing, image rocky steady with no turbulence and undulations. High powers of magnification can be used for long periods of time.

Ant II: Good seeing, some quivering in the image and occasional loss of image definition, but medium to high powers can be used without too much difficulty.

Ant III: Average seeing, almost equal moments of good definition and poor definition. High powers can be used occasionally.

Ant IV: Poor seeing. Some steady moments, but largely the image frequently quivers and blurs. Image definition may be poor even in medium powers. All fine details are lost, very little can be done.

Ant V: Bad seeing. Nothing can be done at all, the image 'boils' away in the eyepiece, and it is impossible to focus; very few (if any details) seen on the object in the eyepiece.

Only in the good seeing of Ant II or more will you be able to use a high power on your telescope, and in some cases you may be able to exceed the maximum usable magnification.

Choosing an Eyepiece

Nearly all of the standard manufacturers of telescopes include eyepieces with the telescope, but it is always worth buying a few extra. In times gone by there were many different types of eyepiece available, and some of them were very poor. Today, nearly all eyepieces are of a good quality and can be purchased at a reasonable price. Cost is likely to be the most significant factor, followed closely by eye relief (the distance the eye needs to be from the eyepiece). You might want to have a range of eyepieces, from the cheapest to the most expensive such as a wide field planetary eyepiece (see Fig. 2.9). Certainly one can spend a lot.

A wide field eyepiece allows you to see more of the field surrounding an object. This is ideal if you're using a medium power and examining the galaxies of the Virgo cluster, but there is no great advantage in having a wide field eyepiece for planetary use (unless of course you wish to see all of the moons of Saturn in the field). The difference between the *real* field of an eyepiece and its *apparent* field can sometimes confuse the beginner, but it is best explained with an example. The Moon is roughly half a degree across, as seen with the naked eye. Imagine you are looking through a telescope at the full Moon, and it fills the eyepiece perfectly, at a magnification of 120×. The Moon is still half a degree across, which means that the real field of the eyepiece/telescope system is half a degree. However, the apparent field of the eyepiece must be 60°, because even at 120× magnification a half degree object can still fit into the field. Some enormous apparent field eyepieces are now available if you have deep enough pockets. For example, the TeleVue Ethos range now allows apparent fields of 100°, so that the Moon would still fit in the field

Fig. 2.9 A selection of eyepieces

at 200×! The view is literally like floating in space, but the cost of each eyepiece is enough to buy an entire telescope.

When it comes to selecting an eyepiece, start by looking at the websites of various telescope dealers. Very often you will find the firm that manufactures eyepieces has a website, and you can read all about a particular eyepiece that interests you. It is wise to do this preliminary research, as you can find out useful information about eye relief, or what the eyepiece is best suited for.

Barlow Lenses

A Barlow lens is an extra lens that boosts the magnification. It is fitted between the drawtube and an eyepiece. A common Barlow lens may be a ×2 (though ×3 are becoming increasingly common), and it effectively doubles the magnification of an eyepiece. Barlow lenses are very useful and well worth investing in; if you have three eyepieces and a ×2, then effectively you have six possible choices of magnification. They enable medium focal length eyepieces to be used at high powers, which usually gives a far more comfortable eye position for the observer. Beyond Barlows are the range of TeleVue Powermates, which allow a ×5 increase in effective focal length. These are especially useful to planetary imagers, as they enable a Newtonian of f/5 to perform like an f/25 system, enlarging the disk of a planet so it almost fills the imaging CCD.

Filters

A visual filter is normally a piece of glass (or plastic) coated in a material designed to block certain wavelengths and allow others to pass. Filters can be screwed into the eyepiece or used in a filter wheel, and they permit the study of objects in certain parts of the visible EM spectrum. This has numerous advantages for visual work; a blue filter will help enhance the white clouds of Mars, while a red filter will help to bring out the faint festoons of Jupiter's turbulent equatorial zone.

As we shall see in the subsequent planetary chapters there is a lot one can do with filters, and filter work will form part of the general investigative work that the visual amateur can undertake. Some telescope manufacturers include a set of filters with the eyepieces they provide, and the filters themselves are easily applied; one simply screws them into the base of the eyepiece (Fig. 2.10).

Filters can be found from many telescope manufacturers and dealers, and a simple online search will give the names and details of suppliers. You will find that each filter has a unique Wratten (W) number. The Wratten number was named for Frederick Wratten, a British inventor who, along with C. E. K. Mees, had a business that developed the range of optical color filters that they then sold to Kodak in 1912. The W is written on the side of the filter, and this corresponds to the color of the filter and the wavelengths it transmits. Filters really extend what the visual amateur can do. Throughout this book we will be referring to filters by their Wratten number and their colors.

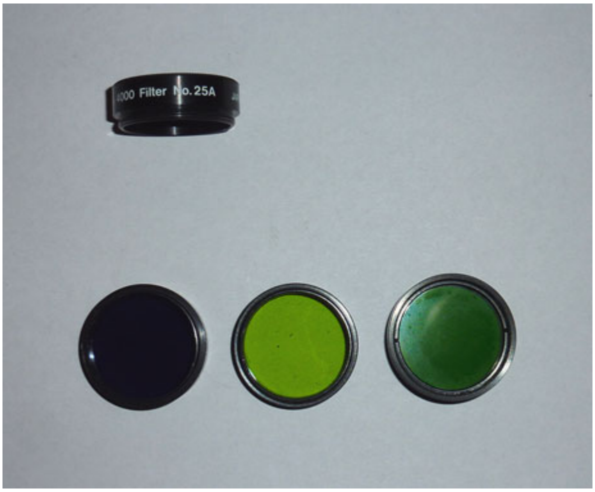


Fig. 2.10 A selection of some filters; the W# is written on the side

Observatories

An observatory is not an essential requirement for the serious amateur, but it does make life considerably easier! Part of the problem with heavy mounts and large telescopes is that it can take some effort to haul the telescope and equipment outside and get it set up (especially if polar alignment is required), by which time the clouds have swamped the night sky. This can not only be disheartening but actually off-putting. A number of people have told me how their astronomy interests began to wane after several such occasions. You can exploit even half an hour of clear sky if you're ready to go in a few minutes.

Traditionally, an observatory takes the form of a large white dome. The telescope is enclosed within, and a shutter in the dome is opened when the telescope is to be used. Although one can purchase domes of various sizes for amateur telescopes, it is not the only option available. If you decide to have an observatory, the first thing it must have is a stable floor. If the floor is in the least bit unsteady, every minor tremor will be picked up by the telescope. The standard method with a dome is to have the telescope pier completely isolated from the floor, so observers moving about don't affect the instrument. Normally you have a concrete pier, set deep in the ground, and it comes up through a hole in the floor. A wooden floor is best as it does not store megawatts of heat, which then happily destroys the seeing all night long!

Dome seeing can be a problem in summer time. Heat can collect in the dome, and when you come to observe you find the air is as steady as jelly. If you intend to get a dome, make sure you open it a few hours before you plan to observe.

Today, there are many suppliers of readymade observatories, and if you have the funds available, then it is certainly worth considering getting one that is readymade. If on the other hand this is out of the question then don't despair; you can join the many amateurs who made their own observatories by creating or modifying existing garden structures.

As you might imagine, there are many different types of observatory one could create, and many people have come up with ingenious creations. Indeed there are now books devoted to the subject. With that in mind, we shall just go through some of the common types that are easy to assemble. The simplest type is known as a run-off shed (see Fig. 2.11). A run off shed is composed of one or two parts that sit on rails and enclose the telescope when not in use. When the telescope is needed, the covering section is simply pulled back, and the telescope is ready to use. Although it is beyond this author's carpentry skills (which are incredibly poor!) such a shed could be constructed out of hardboard quite easily and cheaply. A set of wheels and rails would be needed to make sure the shed runs smoothly along the ground. Anyone who is particularly good with their hands might be able to modify some of the smaller plastic garden sheds for such a purpose. This type of observatory has the advantage that the telescope can be accessed quickly, although one is still exposed to the elements!

a

b

Fig. 2.11 (**a**) Sir Patrick Moore's 12.5-in. reflector. Moore's run-off shed was composed of two wooden sections. The two sections enclose the telescope and sit on rails. You simply pull them apart when you want to use the telescope. (**b**) Martin Mobberley's run off shed. Mobberley's run-off shed is a more modern system based on a plastic garden shed where the floor has been modified and six wheels added

Another option to explore is the run-off roof or fold back roof design (see Figs. 2.12 and 2.13). Essentially it is a normal garden shed, but the roof has been replaced with a lightweight plastic object. The roof is hinged and folds back when the telescope is in use. In other cases, the roof rolls back on wheels instead. Either way it is a good system, and one that has the added bonus of providing insulation against the wind. The observatory cannot of course be heated, since the heat would destroy the seeing, but it feels a good deal more sheltered than just being out in the

Fig. 2.12 The observatory that houses the author's 203 mm (8-in.) reflector

garden. You can add a small desk and some shelves to store equipment, and this is another bonus of having an observatory with everything all in one place. Run-off roof buildings are often used for Schmidt-Cassegrains or refractors mounted on a high pier, as sometimes using them with Newtonians can block a lot of the sky at low altitudes, which is of little use, for example, to the comet observer.

Drawing Equipment

Once you have a telescope, eyepieces and filters (and perhaps an observatory), the next thing to invest in is some drawing equipment. The first thing to get is a set of quality pencils that range from HB to 6B. Some of the heavier pencils (like 4B, 5B and 6B) are very good for dark markings and can be smudged very easily. Good quality drawing paper is essential, and it should be quite thick so that it can cope with various heavy pencils and ink. You will find it far easier to print planetary blanks onto your paper, rather than draw them free hand. A planet such as Saturn has at least six different ellipses to be drawn accurately! You can get planetary blanks from the British Astronomical Association website, and you should print all blanks onto good quality paper. It is worth experimenting with your printer to determine the thickest paper it will print on. Use the thickest paper possible so it absorbs the inks and water without distorting the paper. You may find it

Fig. 2.13 Gary Poyner's observatory

best to start making your drawings in black and white so you can experiment with various styles and techniques.

If you do decide to go to color, permanent water color crayons can be very good. You will need to experiment with them to get the correct tones (again this is why thick paper is essential as very often a dab of water is required to blend in the colors). You might also find Indian ink very useful. You can use this on lunar drawings for shadows, along with the shadows of the Jovian moons. You can find all of these sorts of materials at a local art shop. It is well worth shopping around, however, as you will find some stores charge substantially more than others. Since this is a recurring cost over time, it is good to know where the reasonable suppliers are!

Some other equipment that you may find useful includes a clipboard (useful when drawing or making notes), a red light and a good white torch as packing stuff away in white light seems to be far easier than in red!

Observing Practices and Record Keeping

It cannot be stressed enough how important it is to keep an accurate record of your observations. Not only will your log book provide a useful commentary and demonstrate how your drawing and observing skills have advanced as time progresses, they will also become scientific documents in their own right. They will be your scientific records of what was observed on a particular night and just as importantly, what was *not* seen. If someone wishes to check a specific planetary feature on a given date and time, you will be able to go straight to it if you have recorded your observation in a log book.

You might have several log books. First, there is the observatory log book, taken out to the telescope every time you observe, and into it you can put all of your rough observations, notes and drawings (along with notes of any meteors or fireballs that may happen in the night) during the course of a night. Then you might have separate notebooks inside for neat drawings. You might want to keep things separate, so you might have a book for Venus, Mars, Jupiter, Saturn and Uranus, as well as books for the Moon and the Sun. Into these books you can put the neat color drawings and the pertinent notes from each observation. Make your drawings on separate pieces of good quality drawing paper and stick them into the books after they are finished.

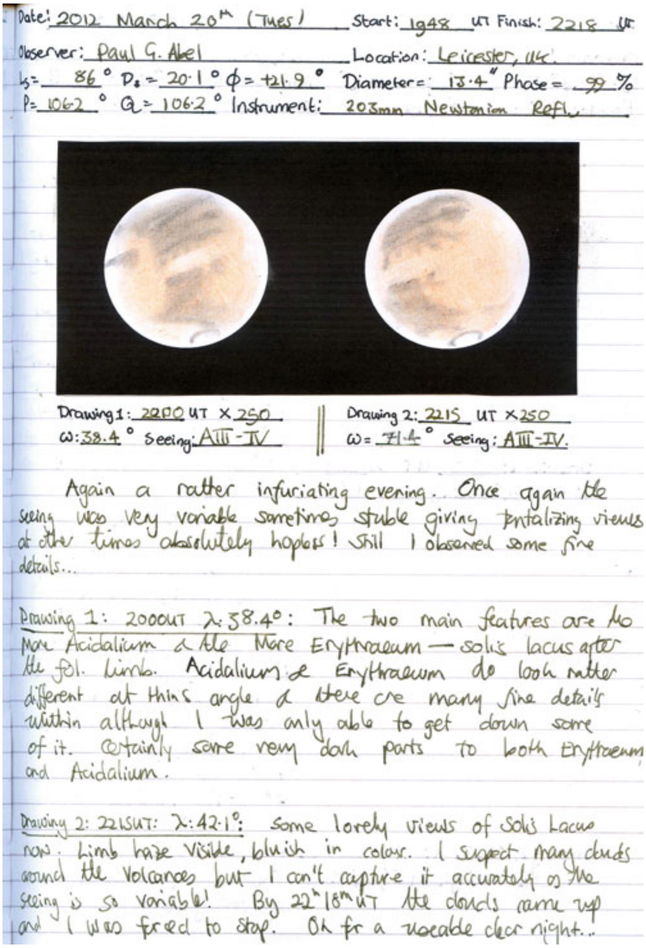
Your log books need to be sturdy, as they are going to be used quite frequently, and it is worth spending a little money on them so they don't fall apart.

Whether you decide to keep your observations in one book or separate books, it is a good idea to have a separate book for your finalized observations. One thing that should be mentioned is the temptation to use ring binders and loose leaf A4 paper to record and store your observations. This should be avoided since it's only a matter of time before the ring binders open accidentally and a decade's worth of observations become mixed up in a matter of moments!

It's a matter of personal choice how much you record in your log book, but here are some details that must be included if the observation is to have any merit:

- *Date*: day, month and year when the observation was made.
- *Time*: This should be Universal Time (UT), which means in summer time in the UK you will have to remove an hour.
- *Telescopes, eyepieces and filters*: those used to make the observation.
- *Seeing conditions*: You should record the seeing conditions using the Antoniadi scale mentioned earlier where Ant I is perfect seeing and Ant V is very poor.
- *Weather conditions*: It is always useful to record what the weather conditions are like during the time you are observing, for example if there is low scattered cloud or if it is windy, as this might affect the quality of the observation (Fig. 2.14).

All of these above details should be included in your rough observations and your final neat observations. For planets, it is also worth recording the longitude of the central meridian (note some planets such as the gas giants have more than one



Date: 2012 March 20th (Tues) Start: 1948 UT Finish: 2218 UT
Observer: Paul G. Abel Location: Leicester, UK
Ls = 86° Ds = 20.1° φ = +21.9° Diameter = 13.4" Phase = 99 %
P = 106.2° Q = 106.2° Instrument: 203mm Newtonian Refl.

Drawing 1: 2000 UT ×250 ω: 38.4° Seeing: AIII–IV
Drawing 2: 2215 UT ×250 ω = 71.4° Seeing: AIII–IV.

Again a rather infuriating evening. Once again the seeing was very variable sometimes stable giving tantalizing views at other times absolutely hopless! Still I observed some fine details...

Drawing 1: 2000UT λ: 38.4°: The two main features are Mare Acidalium & the Mare Erythraeum — Solis lacus after the fol. limb. Acidalium & Erythraeum do look rather different at this angle & there are many fine details within although I was only able to get down some of it. Certainly some very dark parts to both Erythraeum and Acidalium.

Drawing 2: 2215UT: λ: 42.1°: Some lovely views of Solis Lacus now. Limb haze visible, bluish in colour. I suspect many clouds around the volcanoes but I can't capture it accurately as the seeing is so variable! By 22h 18m UT the clouds came up and I was forced to stop. Oh for a useable clear night..!

Fig. 2.14 A page from the author's Mars log book. All the observing details are recorded, and the neat color drawing is fixed onto the page

of these, as we shall see) so you can keep track of certain features on the surfaces and atmospheres of planets.

One last thing to mention is telescope cooling. If you store your telescope in the house, then it will need time to cool down. When you use your telescope it should be at the same ambient temperature as the environment you are observing in. If it is not, you will find that the air inside the telescope is warmer, and this will create unsteady seeing within the telescope tube (unless it is an open tube system). The telescope will be practically useless, so make sure you give it plenty of time to cool down before you start observing.

Draftsmanship and Artistic Techniques

It is appropriate to mention a few things about drawing in this chapter since it is one of the main activities of the visual observer. Before we start, the first thing to know is that there is a great deal of difference between draftsmanship and art. When producing a work of art, you are free to be as subjective as you like, emphasizing one particular feature and choosing to represent certain features in whatever style you wish. A scientific drawing is the complete opposite to this. It must be made with as much objectivity as possible. There is no room in a scientific drawing (such a drawing of a planet, for example) for the subjective emphasis of certain features. We must put all preconceptions aside and record as objectively as possible what is seen in the eyepiece. We may borrow artistic techniques of shading and coloring, but strictly for scientific purposes.

You do not need any artistic ability to make a drawing (any more than you do to construct a complicated circuit diagram), but you may find some of the drawing techniques used by artists helpful. It might be worth doing a little reading if you feel you are a complete beginner, but to be honest, the only way to hone your draftsman skills is to start drawing at the telescope. The more you draw at the telescope, the better you will become at it. Experience counts for everything. However experienced you become, make sure you never lose your objectivity and draftsmanship. The road from scientific drawing to space artist is a quick and easy one. It is recommended that you learn to draw the planets in black and white.

Do not be disheartened if it takes you a good few months or so to produce a drawing you are happy with. Don't forget, it is not only your drawing skills you are developing but also learning to use your visual system in a more precise way. It does take practice to get the latitudes of the belts right on the gas giants, or accurately place the elusive clouds of Venus, but as you gain more experience and confidence, you will find that your drawing skills will improve quite rapidly.

A final word on the subject of equipment: the user of the equipment is more important that the equipment itself! In fact, for some people, telescopes and flashy equipment are of more interest than actual observing The important thing is that you find a telescope you can use when you want to and you come to understand its abilities and limitations. Don't be put off by the goading of other people to obtain some enormous light bucket. It's easy to fall into the trap of buying 'bigger and better' (aperture fever, as it has come to be known), but when that happens you will spend most of your time learning to use a new telescope rather than sharpening your observing skills.

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