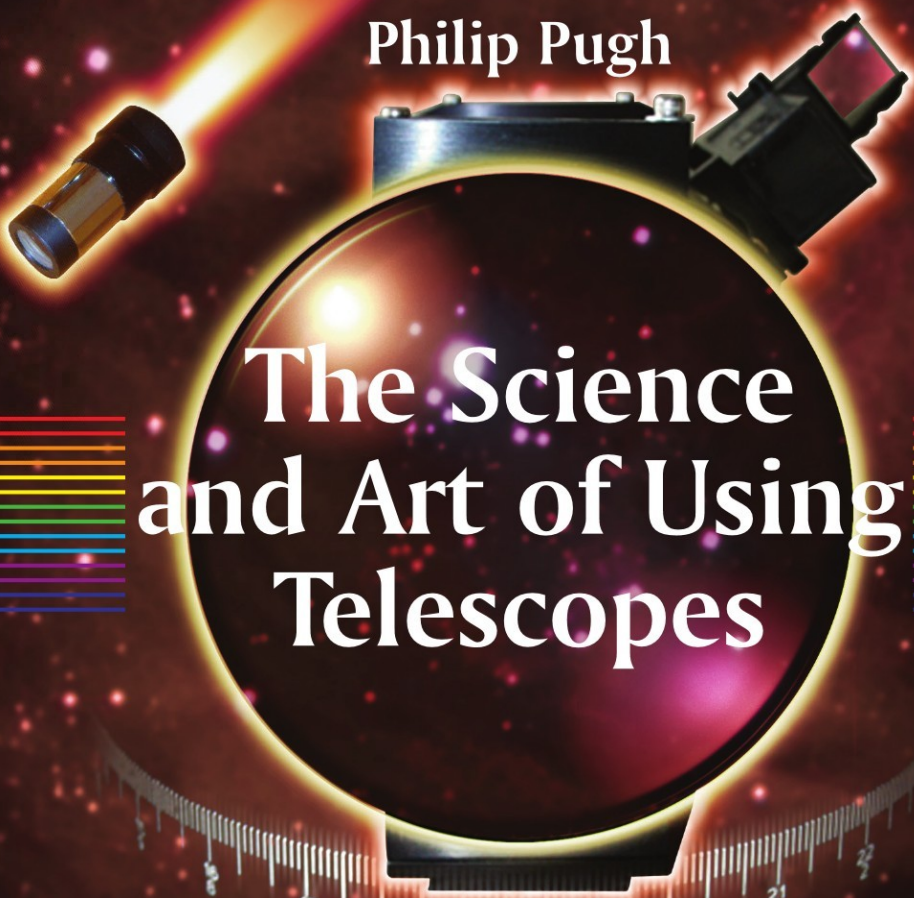
Philip Pugh

The Science and Art of Using Telescopes



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To my wife, Helga, and daughter, Marcela,
who have given me lots of encouragement in
working on this book.

Preface

Astronomy seems to be good at grabbing the attention of the general public, whether it is from seeing the exciting pictures of the rovers Spirit and Opportunity on Mars, a solar eclipse, or a feeling of amazement while looking at the night sky on a particularly clear night. Indeed, some people are so inspired they rush out to buy their own equipment. Eventually, they may have seen enough of the Moon or brighter planets and to want to do more, but the question is, how?

This book addresses how you can move on from the beginner stage. Yes, it is true that many astronomy writers have lots of expensive equipment, and yet they tell you that you do not need to. This may appear (at first glance) as much of a mystery as the missing mass in the universe.

However, many astronomy writers are financially challenged, like the rest of us, and those who do spend money on expensive equipment do so because they wish to pursue some particular branch of the hobby. The short answer is to learn how to get the most from your existing equipment and seeing how your interest develops, rather than rushing out to buy the newest "next best thing." There is not any "one size fits all" advice when it comes to buying equipment, but this book will present some of the options available.

Having a few grand to spend wisely on equipment will help you get more enjoyment from the hobby, but sometimes a smaller purchase is all that is needed or even no purchase at all, just a fresh approach.

What Is in This Book

The Introduction discusses the overall use of equipment and introduces the types of instruments available in today's increasingly complex market. It also suggests a strategy to progress beyond the beginner stage and introduces the skills and equipment required to do so. The following chapters, from "Lunar Viewing" to "Beyond the Local Group," discuss the techniques and equipment needed for each subbranch of the hobby. The "Imaging" chapters discuss astrophotography using amateur equipment from the humble digital camera to CCDs and driven mounts.

The later chapters provide supplementary information to accompany the main chapters. "Usual Suspects List" describes some deep sky objects that can be viewed using modest equipment and "Planetary Data" gives some guidance on the sizes, orbits, and brightness of planets. Finally, the Glossary is deliberately large and comprehensive but is not intended to take the place of an astronomical dictionary or encyclopedia.

Philip Pugh

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Many thanks to Anthony Glover for contributing the "Deep Sky Astro-Imaging" chapter. Thanks to his knowledge and expertise, I was able to complete the book in a way that the path from the beginner stage onwards is more clear.

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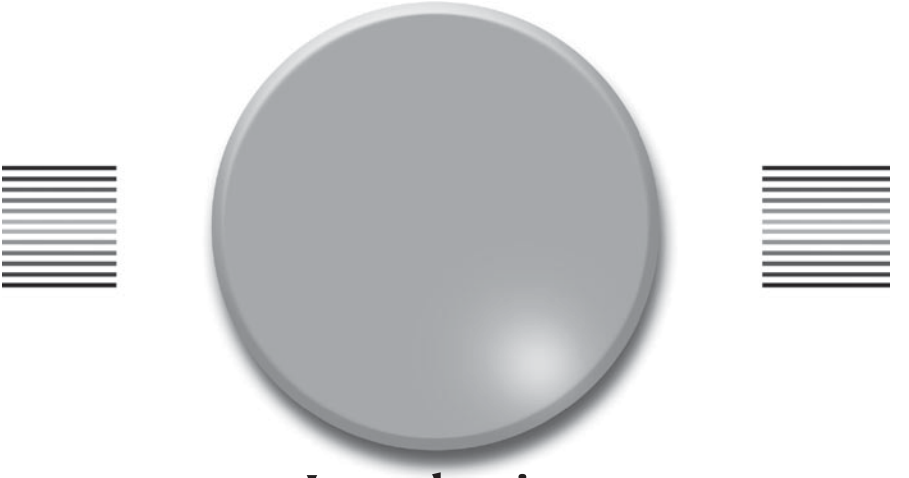
CHAPTER ONE



Introduction

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Getting Past the "Beginner" Stage

Being a beginner itself is not a bad thing. Everything is new and exciting. Seeing the lunar craters for the first time or Saturn's rings fills you with awe and wonderment. Indeed, there is something to be said for staying a beginner for life and still enjoying it, just as some are content to remain on the bottom rung in careers or are content to go fishing without the urge to keep catching more or bigger fish.

Fortunately, though not all experienced astronomers have lost their sense of wonder, there is always something new to see or do if you are prepared to look for it and prepared to fail occasionally. As an example, teasing out some detail on a photograph of the Sun in calcium K light for the first time can feel as exciting as first seeing the Moon through a telescope. Another example is photographing Alpha Centauri, which is not visible from England. Although this star is known in science fiction lore as being our nearest star (technically it is the second nearest), not only it is a double star but it is also the one with the brightest secondary component in the sky.

Now imagine that you have bought one of those "beginner" telescopes. You have managed to see the Moon and you can see loads of dark features known as "seas" and craters. You have seen it in the evening sky and possibly just after it is full. You may have found Jupiter and seen its cloud belts and moons and, like Galileo before, you may have seen some of the moons moving around the planet by watching it on a few successive nights. You may have even split some of the better-known double stars, seen Saturn's rings, and maybe even the phases of Venus or possibly Mercury. You will have possibly seen Mars and wondered what all the fuss was about!

Perhaps you started off with a pair of binoculars. If you were lucky, they would have been suitable, but there are chances that they will not have been. Nevertheless, it is still probable that you will have still seen details on the lunar surface, although fewer craters than through a telescope. You may have seen the Pleiades (Seven Sisters) and discovered that there were 20, maybe 30 of them. You may have found other star clusters, such as the Hyades and Beehive to look at, and you may well have gazed along the Milky Way on a clear night.

If you were really fortunate, you will have experience in using both binoculars and a telescope before reading this book. You may have learned that some objects are shown better in binoculars, while others require a telescope. You may have even explored the limitations of both instruments and be thinking, "What now?"

You may already be aware that, for some situations, neither a telescope nor binoculars are actually required at all! You may have seen meteors or satellites in the night sky and may have learned that not all stars stay the same brightness. Do not think there is not room for research and discovery here, either. Only recently, Delta Scorpii was discovered to be a variable star by an amateur astronomer, and some have suspected another star (Beta Ceti) to be variable.

So Where Do You Go from Here?

Before you pawn your jewelry or remortgage your house, the answer is not necessarily to buy a large telescope. Back to the point made in the Preface, astronomy writers will sometimes tell you that you do not need a big telescope, while owning several themselves. Because of one's particular needs, which is explained in a later section, owning a large telescope is not always the answer, although "small" does not necessarily imply cheap. To decide whether a purchase is a good idea or may turn out to be a disappointment, you need to be realistic about what you can do. It is not just budget that is a deciding factor but where you live and what your interests are. For example, many people live in housing complexes where there are a lot of obstructions blocking the view. It then becomes impractical to use a large telescope on a frequent basis. Although many writers point out the advantages of viewing from a dark site, in many parts of the world physical safety of the astronomer and security of the equipment are a problem. It is best to observe from dark sites in a group, unless you have a particularly secure site. Many amateur astronomers like to think of themselves as good all-rounders, but in truth, most of us gravitate toward one branch more than others. Solar astronomy, for example, is becoming more popular lately, with more affordable equipment now available.

Specializing in Subbranches

Now, it would be nice to say that we are all multi-skilled with lots of knowledge of every branch of astronomy. It would also be nice if we could say that our specialization has been motivated purely by interest. In truth, many of us are driven by other factors. If you live in a big city and are restricted by budget, the nearest you are going to get to any galaxy is looking at a photograph. Even our nearest and dearest large galaxy, the Andromeda Galaxy (or M31 in Messier's Catalogue) is a hard object to locate from city sites. Indeed, it is said that, in city locations, visual astronomy is completely useless. Fortunately, this is not strictly true. Some, even most branches of visual astronomy, are impossible from city locations. Yet, the converse of that is that there must be some branches that are possible to pursue.

Fortunately, there are two very bright objects in the sky that can be viewed from anywhere. Indeed our own Sun is so bright (and dangerous to look at!), viewing that is a challenge in itself. The other one is the Moon. By sheer persistence and practice it can be viewed and even photographed under the most appalling conditions when most sane astronomers would not be seen dead outdoors. Fortunately, we do not all suffer from that particular branch of sanity, and if one wants to observe and there is anything out there to observe, and then observe one can.

In the chapters that follow we will start with the Moon, because it can be viewed so frequently and is tolerant of poor conditions and even broad daylight. It does present its own challenges. From a scientific viewpoint, amateur lunar viewing has little value, but it is always something that can be enjoyed.

The Sun is the favorite of many. In an English summer, there are about three weeks where there is no true darkness at all (longer in Scotland) and about seven weeks where it gets dark too late for anyone who needs their sleep. The Sun and Moon may be the only objects you can see except on weekends, unless Venus or the elusive Mercury is visible in the evening sky. The other really great thing about the Sun is that it is in a state of constant change, much more so than anything else we can observe from Earth. To get the best out of it, some investment is necessary. Be warned, however, that solar viewing can become seriously addictive and ruin your bank balance.

Although the Sun and Moon can be viewed under quite poor conditions, the next subbranch to be considered needs a moderately clear sky and, fortunately, little or no outlay in equipment. Where this author lives, in southwest England, the general viewing conditions are moderate. Compared with most parts of England, the weather is quite mild, but the

downside is the risk of cloud and rain from across the Atlantic Ocean. I live in a small town, so the light pollution is medium. On a clear summer night, I can see the Milky Way without binoculars and stars down to 5th magnitude. This enables me not only to see the Sun and Moon but also to see the brighter planets and the easier deep sky objects using binoculars. This is quite typical of amateur observing conditions in the UK.

Such conditions allow naked-eye observation of variable stars and meteors. Meteors are, in themselves, easy to observe, but you need a certain amount of patience. On a clear night, you can normally see about 10 meteors per hour if you can cover the whole sky. As most of us can only see about a third of the sky at any one time, this drops to about 3. There is fortunately an alternative, and that is to watch during regularly occurring showers, where a larger number of meteors originate from a common source at the same time (known as the radiant). There are several types of variable star that can be regularly observed with no equipment whatsoever, but specialist variable observers also observe many more using binoculars. In this way, they are able to do useful scientific work, too, as professional astronomers do not have time to watch all of them. You may even discover a star that was not previously known to be variable, as happened with Delta Scorpii recently.

Following the planets by telescope does not require pristine viewing conditions, either. In fact, you can see some features using binoculars, the most notable being the four of Jupiter's moons discovered by Galileo (known as the Galilean Moons). However, planetary viewing past the beginner stage really requires a telescope and a "serious" one to really get the best out of it.

From an average suburban location, some deep sky observing is possible. The easiest objects are double stars, which are very tolerant of poor viewing conditions. The hardest are "faint fuzzies," such as galaxies and globular star clusters. Although comets are not related to either of these, visually (or photographically) the challenge is pretty similar. As an example, the Andromeda Galaxy (M31) has a magnitude of 3.7, so it should be fairly bright. As it is a relatively large object (one of the largest in the northern sky), the light is spread out over the area of 12 Suns or Moons as seen from Earth. The Andromeda Galaxy is not seen often without the aid of binoculars or a telescope. A similar challenge occurs with the Magellanic Clouds (a pair of satellite galaxies that can only be seen from south of the equator). Their magnitudes are 0.1 and 2.3, but they cannot be seen from a city location without using binoculars. They can be seen, however, from areas with little or no light pollution, such as parts of the Chilean coast.

Outside of the easier deep sky objects, you need a dark sky, good equipment, and a lot of luck.

Choosing a Telescope

OK, so you are starting out. The first question many beginners ask is, "Which telescope?" This is not always the best starting point. It assumes that one telescope will suit all of your observing needs and totally ignores the possibility of binoculars. Too many telescopes end up left to gather dust in garages or lofts and are frequently seen being advertised second-hand. You see very few pairs of binoculars on the second-hand market, as they are actually being used, maybe not always for astronomy but used nevertheless. Figure 1.1 shows the author's telescopes that are now in common use. On the left is a Skywatcher Startravel 80 with a Coronado Personal Solar Telescope (PST) piggy-backed on top. To the right is a Skywatcher 127 mm Maksutov–Cassegrain.

Fig. 1.1. The author's collection of telescopes.

There is no real simple answer, except to consider building up a range of equipment and consider the following type of questions:

- How much money is available now? Is there likely to be more in the future?

- How much time do you have available for observing? Are you likely to look on most clear nights for a few minutes at a time or are you likely to stay up all night once a month?

- What is your main interest in astronomy? Are you likely to want to specialize in one branch, such as binocular variable stars?

- Do you travel a lot for business or recreation? A lot of fun can be had observing while on business trips or holidays.

- Do you have any health problems that may affect observing? For example, frequent back problems may make using certain types and sizes of telescope difficult.

- Can you see anything from your home? Even if you can, you may still be unable to get a good view from one spot and may need to move equipment from one part of your property to another.

As a general rule, it is best to start off with some small binoculars, such as 8×30 (8× magnification and 30-mm aperture) and a small telescope (60 mm refractor or 76 mm reflector). A compact reflector is better if you intend to travel with it, while the refractor gives better images on most (but not all) objects.

It is also a good idea to watch the market, via magazines or the Internet. At the time of this writing, some seriously high quality small refractors were becoming available at moderate prices, and the trend in the United States and Europe is for prices to continue to go down over time.

Why the quotes? Is not the aim of every astronomer to buy a telescope and then, later on, to buy a "serious" telescope? The words questioned are "a" and "telescope." Many amateurs use binoculars for quick sessions grabbed during opportune moments and also own more than one telescope. It has been said that an astronomer is someone who owns a $500 telescope and spends most of his time using $30 binoculars. Although this may sound a bit of an exaggeration, many use binoculars about as much as all of their telescopes put together. Poor beginner telescopes can

find their way to the attic very quickly; good ones will enjoy several years of use before being sidelined for something better, but a very well chosen one will be used alongside more serious ones at a later date.

If you are still unconvinced about the value of binoculars for astronomy, read the advertisements for used equipment in the magazines. You will see many large telescopes for sale, but very few binoculars. For those of us who have busy lives, they are the ultimate "good to go" instrument. Apart from the really big binoculars, they are light, do not need to be mounted, and require very little set-up. There are lots of objects that you can enjoy that do not take a lot of finding. Binoculars can also fit into hand luggage when traveling by airplane. A good choice is 15×70 binoculars. These are the largest size that large people can comfortably hold in their hands, although most people would tend to go for 60 mm binoculars for the same reason. In 2002, most models cost around $150, but similar models are now available at half the price. Under average cloudless viewing conditions, they can detect stars down to 10th magnitude and faint fuzzies, such as galaxies and globular clusters, down to magnitude 8.5. They have a field of view of 4°, although only the central 2° is totally free of distortion for a typical low-priced pair.

There is some advice in each section about which types of equipment are best for lunar, solar, planetary, and deep sky viewing. As a general rule, aperture and field of view are key to deep sky viewing, whereas optical quality and magnification are key to planetary viewing. Rules are to be broken, and there are some exceptions to this rule. For example, the Ring Nebula (M57) is one of the few deep sky objects in our galaxy that responds well to high magnification.

When choosing a telescope or binoculars, however expensive they are, there will always be limitations. Some of these will be climatic and location based, but others will be inherent in the equipment itself. For example, binoculars are great at sweeping the night sky for deep sky objects, but you will never, ever see any surface detail on Mars, although some people have seen detail on Jupiter with good quality 80 mm binoculars. Alternatively, no beginner telescope bought from a catalog or camera shop will show the full extent of the Andromeda Galaxy (M31) without the purchase of some additional accessories. By buying various accessories, you can improve the performance of your equipment to overcome some of its limitations and even those of the climate. If you are clever enough in your choice of equipment, you can even move accessories between telescopes.

Choosing Binoculars

Fig. 1.2. The author's binoculars.

Figure 1.2 shows the binoculars that I commonly use: Helios Stellar 15×70. Unlike telescopes, most binocular purchases are quite similar in idea. You do not buy binoculars to look at fine planetary detail. Although lazy or busy people use larger binoculars to check solar and lunar features when they cannot be bothered to get a telescope out, their main intended use is to perform a quick scan of deep sky objects. Larger ones can also be used to hunt for comets, and once a comet reaches a large apparent size (especially after it has grown a tail), it is far easier to find it and see the entire tail. When looking at binoculars, the main considerations are:

- Aperture: Larger binoculars gather more light. However, they also gather cost, and larger ones are too heavy to hold. This loses the advantage of quick set-up time, and you have to weigh the use of tripod-mounted

binoculars against short tube refractors. Large adults can hold binoculars up to 70 mm in aperture, but for others it could be more or less. For comet discovery attempts, you really need to look at something with an aperture of at least 100 mm, although there is an alternative solution to that. The minimum sensible aperture is 25 mm, and binoculars with these can be purchased very cheaply.

- Magnification: Too little, and objects do not appear much bigger than with the unaided eye, too much and you have a reduced field of view (which makes binoculars no better than a telescope) and you cannot hand-hold them because any wobble is also magnified. A suggested maximum magnification is 15× for hand holding. The other key indicator is the *exit pupil*. This is the width of the light beam leaving the eyepiece and is derived by dividing the aperture by the magnification. It should be as close to your pupil width as possible. For example, 15×70 binoculars have an exit pupil of just under 5 mm, which is suitable for most of suburban viewing. Younger astronomers may have an exit pupil up to 8 mm at a dark site, but this is reduced with age and the amount of background light

- Optical quality: The best optical quality is achieved by using twin short tube apochromatic refractors, but not all of us are lottery winners. Most mid-aperture binoculars (50–70 mm) suffer from various types of defect. These are:

  – Chromatic aberration: The light of different wavelengths (colors) comes to focus at different points and so show false color fringes.

  – Astigmatism: Objects near the edge of the field of view appear distorted.

One feature of high-price binoculars is that they have interchangeable eyepieces. Sometimes they have barrel diameters that are particular to that of the binoculars, although some have barrel sizes common to those used in telescopes. That way they can be interchanged between equipment. They also have the advantage of having fewer defects and/or defects of smaller effect, due to the use of higher quality objective lenses and eyepieces. However, they may cost much more than regular quality binoculars, even 3 or more times as much. High quality 70 mm binoculars are of comparable price to a Coronado PST (solar telescope) or 127 mm Maksutov–Cassegrain. You will need to get a lot of use from them to justify such a purchase. Finally, there are various types of specialist binoculars, such as for solar viewing with built-in filters. Coronado did produce

some hydrogen alpha binoculars; although these have been discontinued they may possibly be found on the second-hand market.

Although this negates the idea of quick set-up, binoculars can be more effective when used with a tripod. A simple camera tripod can be used, but these are very difficult to use when viewing objects near the zenith. Although not cheap, you can get specialist binocular mounts, while others can be mounted on an equatorial tripod. There are now some large binoculars available on the market up to 100 mm aperture, with retractable nebula filters. In fact, the market for affordable large binoculars is getting better all the time.

Some sort of binocular purchase is essential for just about all astronomers, and it is recommended that you get a pair before looking too deeply into telescopes. Small binoculars are also easier to use and produce better viewing than many beginner telescopes, which is where the next bit comes in.

Before leaving the subject of binoculars, we need to say that you might already own a pair. Perhaps as many as a quarter of UK households have a pair that may not be ideal or optimal for astronomical use but may have some benefit. If you have a pair in the attic, take them down and have a go. The 12×50 binoculars are a good size, but 8×30s and 8×35s are still a worthwhile purchase.

Beginner Telescopes

The simple answer to this one is do not buy a beginner telescope, although with some guidance it is possible to make a purchase without wasting money. Quite frankly, a lot of money is spent by well-meaning relatives on equipment for children that is, at best, unsuitable and, at worst, utterly useless. There are a lot of "toy" telescopes about. Many of them are incapable of showing Jupiter's brightest four moons, which is one of the minimum requirements for a telescope. So, yes, avoid toyshops that do not actually employ astronomers!

However, there are camera shops and even some large "megastore" supermarkets that stock telescopes. If you know what you're looking for, there are some good deals to be made, but please insist that they let you look *through* the telescope as well as at it. In the United States, many of these shops have at least one astronomer on the staff, and they are more likely to sell quality equipment than in England. A common type sold worldwide is the 60 mm refractor. The biggest downfall (apart from the inherent limitations of some 60 mm refractors) is that their eyepiece barrel diameter is not standard, so its supplied eyepieces cannot be used with any other telescope.

Your best bet of all is to buy equipment from a reputable retailer. These can be found in monthly magazines, which also contain equipment reviews. Although they have a tendency to review expensive specialist equipment, from time to time, they review beginner or budget equipment as well. Retailers are usually run by enthusiasts who will give you a realistic assessment of what you can see through it and what else you may need to buy to get the best out of it.

The specifics of buying equipment for adults and children are slightly different, but here is a set of guidelines on what you should look for:

- The wow factor: It must be capable of delivering something that impresses you. If you cannot see at least two equatorial cloud belts on Jupiter and at least two of its moons at any time, just say "Thanks but no thanks." Lunar craters and Saturn's rings are also a good test.

- Aperture: This should be a minimum of 60 mm for refractors and 76 mm for reflectors. Some experts would suggest more, but these sizes are large enough to satisfy the wow factor

- Finderscope: Just try finding an object without one. Even experienced observers struggle, so what chance has a beginner?

- Ease of use: If it takes a long time to set up and find things, it will end up in the attic quite quickly.

- Defects: One would expect some degree of chromatic aberration to be inevitable, but check for astigmatism or any other defect that distorts an object.

- Mount: This must be steady. The use of equatorial mounts is not recommended for beginners, although some patient adult beginners can learn to use them. GOTO mounts, which can help you find objects, are good. However, you need to spend some time setting up your telescope before you can use them, which includes polar alignment and recording guide stars. One with a manual override will allow you to pop out for a few minutes to photograph the Moon before bedtime. Also, for those on a limited budget, a GOTO mount adds a lot to the cost of a telescope. Better, perhaps, to spend the money on a telescope with larger aperture instead. However, GOTOs are particularly useful for deep sky enthusiasts and photographers.

Young people can be remarkably enthusiastic about astronomical viewing. Astronomers sometimes take their telescopes to schools and find that the students are very enthusiastic. However, when it comes to finding the objects themselves, they have as much patience as a deep sky enthusiast on the night of a full Moon. Apart from finding things yourself and telling them a thousand times not to knock the equipment, either binoculars or a telescope with a wide field of view on an alz-azimuth mount will be good. While an adult beginner would be thrilled about splitting a difficult double star such as Castor, a child would wonder what all the fuss is about. When buying for a child, budget is more of an issue, but adults, unless they are parents, may often have more cash at their disposal. A short tube refractor is a good starting point and is likely to be kept in use for a fair while longer.

In the next section, we will look at various types of telescopes and discuss their suitability for beginner and intermediate observers.

Wide Field Reflectors

These are among the cheapest telescopes on the market, and they have been advertised at around $30 when on offer but their normal retail price is usually a bit higher. Their aperture is either 76 mm, with a focal length of 300 mm (a focal ratio of f/4) or 114 mm aperture with a focal length of 450 mm (just under f/4). They are supplied on a cradle mount or some (like the Orion Starblast) come on a simple Dobsonian mount. They are not necessarily that good for planetary viewing but are certainly capable of delivering the minimum wow factors, listed above. Most of them use the standard 31.5 mm (1.25″) barrel diameter eyepieces, so these can be interchanged with other telescopes. Although marketed for beginners, they are often bought by more experienced observers as a quick get-up-and-go telescope, for travel or for deep sky viewing. The cradle mount may cause more experienced observers to wince, but it is a very convenient way for young people to locate and follow objects. Just do not let them outside unsupervised while the Sun is above the horizon. The wide field of view allows you to see large objects, such as the Andromeda Galaxy (M31) in their entirety. You do not use both eyes with one of these telescopes, but one advantage is that you can change the magnification by using different eyepieces and accessories, which you cannot do with most binoculars. This allows you to use the higher magnification required for lunar close-ups and planetary viewing. To get the most out of this type of telescope, you need to use eyepieces that cost considerably more than the telescope itself.

If you already own a short tube refractor and/or large binoculars, you may find that this type of telescope offers you nothing new. Otherwise, it is well worth looking at, or even through.

Small Aperture Achromatic Refractors

Some cynics would say that there should be a large warning sign around this section, or it should be labeled "how to waste your money in one easy step." Others say that, with care, one of these telescopes can keep you gainfully amused until you get something better.

First of all, many of the toy telescopes are not achromatic at all. They just have an objective lens made from a single piece of glass or even plastic (keeping the price down), but the optical quality is horrific. A true achromatic objective lens is made from two lenses of different types of glass (usually crown and flint). Although both of these types of glass have chromatic aberration, by using the correct configuration, their optical defects can actually cancel each other out – well, almost! To improve beyond that, you need an apochromatic objective lens or some sort of intermediate "semiapochromatic" objective. Further to previous moans, do not consider a budget refractor of less than 60-mm aperture either. If you look at the market, most of these telescopes are in apertures of 60 or 70 mm. An 80 mm refractor usually comes with a short tube, and these telescopes will be discussed in a section of their own. There are also many 90 mm refractors available. Perhaps they are too large to be considered small, but they are certainly not large, either. However, although the light gathering and resolution of a 90 mm achromatic refractor is noticeably better than a 60 mm model, the properties are essentially the same.

At the risk of repetition, one of the biggest drawbacks of this type of telescope is that many nonastronomical retail outlets sell it. As long as you can try it out before purchase or return it easily after purchase if it fails to deliver, you are okay. Many of the 60 and 70 mm refractors and some of 80 and 90 mm use the 24.5 mm (0.965″) eyepiece barrel diameter. This restricts the range of accessories that you can use. If it is likely to be your only telescope for a long time, this is fine, but if you think you may buy other, larger telescopes later on, one that uses the 31.5 mm (1.25″) eyepiece barrel diameter is better, even though you may have to pay a bit more money.

These telescopes usually come supplied on an alz-azimuth mount, although some are available on equatorial mounts and GOTO mounts. They usually have a focal ratio of between f/10 and f/15. As an example, a 60 mm Vanguard refractor has a focal length of 900 mm, giving a focal ratio of f/15. Using such long focal ratios reduces chromatic aberration (although

just try using very high magnification and see what happens!) and allows high magnification for planetary viewing. In the time of William Herschel, many advanced astronomers used refractors with focal lengths in excess of 20 feet! However, the tube length makes that type of telescope impractical for air travel. Although these telescopes are not totally useless for deep sky viewing, due to the narrow field of view, they are not the most suitable except for splitting double stars. Like with most telescopes, buying additional eyepieces can enhance their performance. For example, Celestron makes SMA eyepieces of 25 mm and 10 mm focal length and the 25 mm one is very useful. The 10 mm one delivers under good conditions. The theoretical practical maximum magnification is twice the objective aperture in mm, so 120× for a 60 mm refractor and 140× for a 70 mm refractor. This can be increased if your telescope is of reasonable quality and being used under good conditions.

Despite the general cynicism surrounding this type of telescope, you can get a half-decent lunar and planetary telescope for a reasonable price.

Small Aperture Newtonian Reflectors

Apart from compact reflectors (which are covered in a later section), many astronomers prefer small aperture refractors to reflectors. "Small" usually refers to anything under 150 mm, which according to Patrick Moore is the minimum useful aperture for a reflector. This is not necessarily true for compact reflectors (covered later) or wide field reflectors, as they are easy to use. Traditional Newtonian reflectors can be quite useful for lunar and planetary viewing (and indeed many have enjoyed some of the views through them), but they are not as easy to use as small aperture refractors. The main disadvantages of Newtonian reflectors are:

- Effective aperture: The central obstruction of the secondary mirror and the "spider" supports block some of the light. This means that to get the same light-gathering power you need to increase the mirror size, resulting in a wider and heavier optical tube assembly than an equivalent refractor. Note, however, that in larger sizes, the size of the secondary mirror is less significant and the lighter weight of the mirror makes large reflectors lighter than refractors with the same light-gathering powers.

- The Newtonian design has the eyepiece at the top of the tube. This results in the viewing height being totally different for objects near the zenith and those near the horizon. This is also an issue with refractors, but it is not so bad.

- Maintenance issues: when in use, the mirror is exposed to the elements, and it needs to be recoated from time to time. Then there is the dreaded collimation, where the primary mirror needs to be positioned correctly, not to mention adjusting the position and inclination of the secondary mirror.

- Many budget reflectors use a spherical mirror, which introduces spherical aberration. This is not noticeable with the wide field reflectors but, like achromatic refractors, just notice the effect with high magnification. Fortunately, there are several available with parabolic mirrors, which do not have this problem. While many telescopes are advertised as such, if in doubt, it is best to ask.

Despite these limitations, it is possible to achieve nice views of planets and deep sky objects through these telescopes, and (possibly in common with binoculars and other telescope types) many improvements have been made in both quality and price over the last 2 years. There is at least one popular 130 mm Newtonian reflector with a parabolic mirror (the Skywatcher 130PM) that is very popular and has a good reputation.

Short Tube Refractors

These are sometimes known as wide field refractors or vista refractors, but their purpose is still the same. In fact, were it not for the cost implications (about 60% or more expensive than a 60 mm refractor), it is a good choice of starter telescope. To make matters even better, you will still want to keep the telescope, even if you later buy a more "serious" one later. The only telescope that you might want to replace it with later is an apochromatic refractor, which is described later.

Like all types of telescopes and binoculars, they have their limitations. Nevertheless, they have several advantages:

- They have a wide field of view, so they can accommodate objects of large apparent size, such as galaxies and comets.
- Their small physical size and weight makes them suitable for air travel.
- They are not particularly expensive.
- They are more versatile than binoculars, as you can use different eyepieces and accessories.

Most of these instruments are available with an aperture of 80 mm and have the standard 31.5 mm (1.25″) eyepiece barrel diameter. They also have a focal length of 400 mm. They are available from several different manufacturers and are usually supplied on a lightweight equatorial mount. They also have fittings to allow attachment to a camera tripod. This will not allow stable viewing at high magnification but will at least make the telescope portable by air. Even lightweight equatorial mounts and tripods can play havoc with your baggage allowance, so it is best to use a camera tripod. The maximum magnification that this setup permits is about 80× and the maximum on a steady mount is about 160×. Around this, chromatic aberration starts to kick in badly, in a way that it does not on longer focal length refractors.

The maximum effective field of view is about 4°, and this comes with a magnification of 12.5×. Although you can use certain eyepieces and accessories to push this down further, the problem becomes the exit pupil. A magnification of 12.5× gives an exit pupil of 6 mm, which is a bit on the high side for suburban skies. An increase in exit pupil can help with photography, though. It is good for photographing close conjunctions between objects, such as planets with stars.