Chapter 2

To Buy or Build a Telescope

If you think you would like to own a telescope you are faced with the question: "Shall I just go out and buy a telescope or shall I build my own?" There are compelling arguments each way.

Buying is easier and quicker than building. Plus, over the past 20 or so years, costs for commercial telescopes have come way down. There are several reasons why this has happened. Part of it is the worldwide availability of components and assembled units. Part of it is just improved manufacturing technology. Part is competition.

However, it can be fun to build – if you have that kind of twisted mind! And, you are likely (though not guaranteed!) to learn something.

Plus, it is a nice ego trip to have folks look through something that you built and make WOW noises. If what you want is something different and/or unusual, you can do a web search on weird telescopes or go to Tom McMahon's page (Weird Telescopes), and then go from there. Note that none of those things is a first project.

Finally, you may find yourself building because you want something better than the standard manufactured scopes.

To be different a telescope does not need to be some sort of completely novel construct. You might choose to build simply to "buck the current trend." For example, before the beginning of the twentieth century, the most popular telescopes were refractors operating at speeds of about f15 and costing so much that average or even slightly rich folks could not purchase them. A 6-inch f15 refractor is a telescope at least 90 inch long that won't fit into most automobiles. These were/are very excellent instruments. If you ever get to try one you may well decide to make one. One of the example telescopes in this book is a f17 4-inch refractor instrument. Transportation requires a van or a pick-up truck, but boy does it produce nice planetary and lunar images. It has a very large "WOW" quotient.

R.L. Clark, *Amateur Telescope Making in the Internet Age*, Patrick Moore's Practical Astronomy Series, DOI 10.1007/978-1-4419-6415-1_2,

The current trend is toward reflectors operating at very fast f ratios. An f3.5 reflector with a diameter of 20 inch is on many modern-day Christmas lists. These are pretty expensive toys, so not a lot of those Christmas wishes will get fulfilled. You can get it into a good-sized sedan if you can deal with the 150–200 pounds of telescope, but it will do a very good job of pulling in galaxies known only by numbers. It will also have an appearance reminiscent of the Dardanelles gun. That will get a lot of wows even if it doesn't shoot a 2-foot stone across the Dardanelles.

Currently there are many telescope parts and items that can be used as telescope parts available on the worldwide-web. One excellent source is eBay, but there are many others, including online stores. Some of the online stores are operated by commercial manufacturers of telescopes. They offer components of their instruments, both as replacement parts and as parts for us – amateur telescope makers – to include in our projects.

Buying some parts, building some other parts – a combination approach – is the most practical route to go and the most varied. You might chose to buy optical parts and build the mechanical parts or go the other way, make your own optical components and buy mechanical parts, or a mixture of both.

A common first building effort is a copyscope. What is a copyscope used for?

A copyscope is often built to approximate a "richest field" telescope (RFT). The last chapter of the book *Amateur Telescoping Making Book Two* (ATM II) deals with the RFT concept. There are, in fact, two RFT concepts – the richest field telescope and a rich field telescope. It happens that both are covered by the abbreviation "RFT."

The intention behind both RFT concepts is to provide views with the most possible individual star images. There is sort of a formula for the design of such a telescope, and it is not a particularly difficult design to actually build. What you get is a telescope that, when pointed into the Milky Way, say in Cygnus, on a clear dark night will show you an eyeful of stars. Unless you have accidentally pointed at some special part of the sky with a lot of bright stars many of the stars you see will be perfect, faint, pinpricks of light.

The larger the aperture of a telescope the fainter the stars are that can be seen. That is because, theoretically, all the light that the telescope receives from a particular star gets concentrated into the image of the star. The bigger the objective, the more light, thus, the brighter the image. The following tables are rounded off and extracted from *ATM II*.

Diameter (inch)	Faintest magnitude
1	6.36
2.5	11
6.3	13
10	14
16	15

For example, if our telescope has an objective of 6.3 inch, we can expect to get down to magnitude 13. That assumes a clear, dark, sky.

Obviously, the higher the magnitude (the fainter the stars) the more stars there will be in a given area of the sky. Let's say you have an area of 1 square degree in the sky.

Top magnitude	Stars per square degree
8	1.6
9	3.5
10	9.8
11	25.4
12	61.7
13	141

Unfortunately the nature of the human eye limits how far we can go in increasing the aperture to increase the number of stars we can see in a single view. What stops us is the fact that, whatever light is gathered by a telescope, that light must all be pushed into a human eye if we are to be able to "see it." That light must be provided in a beam no wider than the pupil of the observer's eye. The pupil is no larger than 0.3 inch even if the observer is well "dark adapted" and reasonably young. As we age the ability to "dark adapt" becomes less.

The lower the magnifying power used the wider is the field of view, which means that lower powers will show more stars. There is a definite limit to how low we can go with the power, however. That "Limbo Stick" condition is imposed by the characteristics of the human eye. The 0.3-inch figure provides the limit.

The beam of light exiting from the eyepiece is called the "Ramsden disk." The diameter of the Ramsden disk is always the diameter of the objective divided by the magnifying power. Sometimes the Ramsden disk is called the "exit pupil." Thus a 6-inch objective used at a magnifying power of 22 gives a Ramsden disk of 0.273. That is close to our 0.3 figure for the eye, so that is almost all the light that the observer's eye can use. We could reduce the power to 21 and get a little improvement, i.e., 0.286. A little additional improvement from 22 power, i.e., 0.3, and we are done. The result, so far, is that lowering the power brings in more stars because it covers more area in the sky.

So, a 10-inch telescope operating at 33 power will give us the richest field available from any 10-inch telescopes. A 6-inch telescope operating at 22 power does it for 6-inch telescopes. A 2.5-inch telescope operating at 8 1/2 power does it for 2.5-inch telescopes.

The 2.5-inch design is the one that will show the absolute maximum number of stars in a single view. The specs to achieve that are a diameter of about 2 1/2 inch and a power of about 8 1/2. This is defined as the richest-field telescope. The other designs maximizing star counts for various diameters are called "rich field telescopes." There is a difference. For details, see S. L. Walkdens' article "Richest-Field Telescope" near the end of *Amateur Telescope Making Book II.*

On a good, dark, clear night you should see hundreds of stars any place you look in the Milky Way.

Many of the Messier objects will show up with great beauty in a RFT. The following have a lot of WOW! power.

M31	The Andromeda Galaxy	(Island galaxy)
M45	The Pleiades	(Open star cluster)
M42	The Orion Nebula	(Emission Nebula)
M44	The Beehive	(Open cluster)
M81	Island Galaxy in Big Dipper	(Galaxy)
M13	Hercules Cluster	(Globular cluster)

A nice trick for seeing the best of these objects is to locate them, get the focus really good, then move the telescope to the west just enough to get the object out of the view. Now just wait for the object to be brought into view by Earth's rotation. You will see more of the edges, etc., of the objects that way.

These are all "extended" objects; that is, they cover significant areas of the sky. The Andromeda Galaxy is "several Moons wide." Seeing these objects does not need much magnification power. It needs light-gathering power. At high or even medium power many of the neat "wow" objects won't even fit in the view.

A little Internet searching will get sky charts showing where to find these objects. If you do a web search on "copyscope" you will get lots of hits. In a test search the first 3 hits were perfectly satisfactory "how to make one" write-ups. Accordingly there is no need to go into a lot of detail here. Use the picture of it in this chapter, the ideas from the web presentations, or some combination of your own ideas and everyone else's.

On eBay we found three lenses that would work, two "very promising" and one good.

It is a little difficult to figure out what you are looking at under "telescope lens" on eBAY. You are looking for a lens with a diameter of at least 1 1/2 inch and a focal length at least 5 times its diameter. (That would make it an f5 lens.) Avoid f4 and f3 lenses. They can be very good, but good ones are very expensive and unlikely to be on eBay. The lens on this scope is 2-inch diameter and f8. (fl = 16 inch). The eBay folks don't seem to be able to differentiate between eyepieces and objective lenses. YOU ARE LOOKING FOR AN OBJECTIVE LENS. YOU SHOULD PAY NO MORE THAN $30 for a perfectly fine copyscope objective. American Science & Surplus has an f4 or so lens for $12.50. You probably would want to reduce its diameter with a black paper ring. Thus get it down to f5 or so. If you end up working with a lens with a low focal ratio you should try it at full aperture just to allow yourself to see the effect of coma and spherical aberration. Then put the black paper ring on to get the performance reasonable. A terrestrial telescope can supply perfectly satisfactory views with quite a lot of optical faults. A star image is a much stronger test of quality.

Don’t buy a lens blank. This is not a lens; rather, it is one of the two or more pieces of glass from which a lens might be ground and polished.

A search for “telescope lens” yielded the following: (Fl refers to focal length.)

Fl	Dia	f ratio	Buy now price
Abt 20 inch	2 inch	f 10	$6.95

This would make a very satisfactory, small telescope. The aperture is a bit small for a RFT, but it would be easy to build and would make a nice first telescope. Also, it would be an excellent finder for your next, larger telescope.

Fl	Dia	f ratio	Buy now price
32 inch	2.44 inch	f9	$202

This is a camera lens and should work very well. A 4-inch fl camera lens used as an eyepiece would give you a really nice RFT. With a 3/4-inch fl standard eyepiece you would get about 50 power.

Fl	Dia	f ratio	Buy now price
72 inch	6 inch	f12	$630

This lens could be the heart of a really nice 6-inch refractor. It certainly is not an RFT. It would be useful as part of a planetary instrument. It would work very well as an only telescope, but just not as a “faint fuzzy” instrument. Keep in mind that you would get a telescope almost 7 feet long and not very lightweight. To operate at all well it would need a pretty hefty mounting. It would be a bit of a struggle on a train. Telescopes in this range are, generally, several thousand dollars.

Fl	Dia	f ratio	Buy now price
26 inch	2.36 inch	f11	$7

This would make a very satisfactory small telescope. The aperture is OK for a RFT, but you would need a 3-inch focal length eyepiece to get it down to RFT power. It would make a nice first telescope. It would also be an excellent finder for your next, larger telescope.

Fl	Dia	f ratio	Buy now price
36 inch	2.36 inch	f15	$15

Used very much like the one described above except that you could get a little more magnification.

There are lots of things you can use as an eyepiece. The lens from a 35 mm camera is likely to be good. Just make sure you get one from a camera with the shutter behind the lens, not between two parts of the lens. (Try yard sales for old film-type 35 mm). If the shutter happens to be stuck, so much the better – it's cheaper. Try not to spend more than $2 or $3.

You want a relatively low power eyepiece. Something with a focal length of 3/4 of an inch to 2 inch is good. A combination of a 2-inch focal length eyepiece with a 16 inch focal length objective lens gives 8 power.

A small eyepiece used with the illustrated copyscope when doing solar projection seems to be the same as the $7.50 Cinepar at American Science & Surplus. The eyepiece normally used for observing is a 50 mm (2-inch) fl lens from a 35 mm camera.

The telescope shown has an extra back with a tube sticking out of it just 1 1/4 inch inside in diameter. This allows the use of standard eyepieces.

You can also buy a reasonably good eyepiece on eBay, which usually designates the focal length in millimeters; so a 50 mm eyepiece is 2 inch. A 20 mm eyepiece is a little less than 1 inch.

Following is a little more information on eyepieces.

There are three "standard" diameter sizes for the tube:

1 1/4 inch (the most popular standard)
2 inch (better than 1 1/4 but more expensive)
0.956 inch

The last is the standard for microscopes, and you might want to try a microscope eyepiece on your telescope. It often works pretty well and is not uncommonly found on bargain-priced telescopes.

You need to be able to move the eyepiece in and out to focus. There is a plumbing fixture designed to fit the "trap" on a sink that has an inside diameter of 1 1/4 inch. This will give you a pretty good slip fit.

You can buy a focuser on eBay for about $20–$30. Orion makes a nice one for about $30. It is mostly plastic but works very nicely.

The magnification provided by a telescope is calculated by dividing the focal length of the objective by the focal length of the eyepiece. By changing eyepieces you can change the power.

A web search will produce many pictures – diagrams – of homemade telescopes. Here is a picture of one of the author's. Some suggestions regarding physical design are as follows:

- PVC pipe is useful for the tube.
- Plywood is nice. You can build a simple box if you like.
- Borrow parts of any design you like.
- Keep optics lined up.

To get a lens mounted on a piece of plywood for the front end you may get lucky and have a lens with a flange that makes mounting it easy. Otherwise consider using an automobile hose clamp on both sides of the lens.

You can, and most likely will, get ideas for improvements as you go. You are building something for your use, not for eternity.

The black box on the back end of the scope in Fig. 2.1 is called a "star diagonal." It allows you to avoid a lot of stiff neck problems when looking up.

The advantages of using a copyscope as a first project are that you can finish in not much more than a weekend, and also that it gives you something to use while you work on your second project. The usual second project is a 6-inch or 8-inch Newtonian reflector. You can use your copy-scope as a finder for your bigger scope. The Texerau book cited in the Appendix of this book will take you through the mirror making process in a step-by-step way.

Fig. 2.1 Example of a copyscope

If you don't want to invest a minimum of 40–60 h in a mirror you will find a pretty good selection on eBay. Most 6- and 8-inch mirrors are available for less than $100. They seem to be pretty decent quality, but buyer beware!. If you are going to make your own, here are some suggestions:

- Try to make it better than any you might buy.
- Don't try to save money on the blank or blanks. Use Pyrex for the mirror and get a thick blank.
- Build a Faucault machine a la Texerau and learn to use it. (Move the lamp box forward about an inch from his design position unless you have no nose.) The steel bar from an old dot matrix printer will work very well as a slide on the machine.

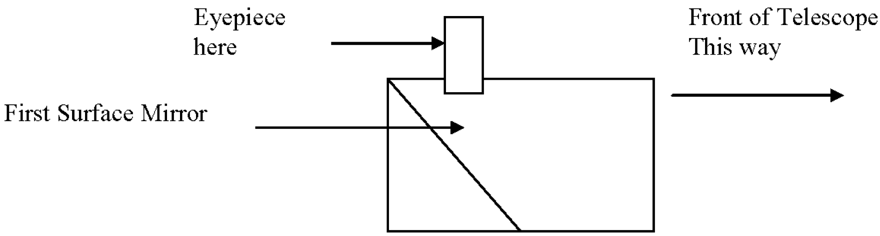

Fig. 2.2 Star diagonal

Fig. 2.3 A crop of home-built telescopes

A first surface mirror is one with the “silver” (actually aluminum) on the front side. Otherwise you will get double images. For this application, you don’t need a super high quality one. Mirrors can be salvaged from old copy machines or purchased from numerous online sources.

No telescope is going to be very much fun to use if you don’t have a solid way of pointing it and keeping it steady. You need a mount. If you have a reasonably good photographic tripod you can probably use that. The standard way to attach something like a camera or telescope is with a $1/4 \times 20$ inch thread machine screw, but this may not be steady enough. Mounts made from iron pipe work well. See www.stargazing.net/mas/scope3/htm or www.charm.net/~jriley/sky/mount1.html.

There are many other web sources of mounts. A good beginning is www.memphisastro.org/Mounts.html.

Figure 2.2 shows see what might happen to you if you get bitten by the ATM (amateur telescope making) bug!

Get involved with a local astronomy club. Some of them run mirror-making workshops that will be very helpful if you want to grind and polish your own mirror to make a reflecting telescope. You might even find a lens-building workshop. At least you will find a huge source of suggestions, help, and opportunities to share your interest and enthusiasm.

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