How to Choose a Telescope

By Alan MacRobert

A pair of binoculars makes an excellent "first telescope" -- at least up to a point. Binoculars were the only optical instrument I had for my first year as a skywatcher, and this turned out to be exactly the right approach to take. But during that time I was laboring toward a bigger goal: building a 6-inch reflector. Making the telescope was the only way I could afford it. I later realized that this constraint was a blessing in disguise. It kept me from getting the telescope too soon -- before I knew what to do with it -- and led me to value it like the crown jewels despite all the things a telescope of this fairly modest size cannot do.

Sooner or later, every beginning amateur astronomer faces up to the question of what to do about getting a telescope. This is the most critical decision you will probably make in the hobby. Choose well, and the telescope will open up a lifetime of pleasurable evenings exploring the sky. Choose poorly, and it is liable to bring frustration and disillusionment and get sold off in the classified ads, "mint condition, rarely used."

What makes for the right decision? This depends more on you than on the telescope itself. If you live in a fifth-floor city apartment with tiny storage closets and are fascinated by the Moon and planets, you should get an entirely different telescope than if you live on a farm in Vermont with a nice empty shed and your true love is galaxies. The money you can spend, the weight you can lift, and the amount of observing you've already done with the naked eye and binoculars are also crucial.

A telescope's most important characteristic is its *aperture*. This is the diameter of the main lens or mirror. The aperture determines the brightness and sharpness of everything you will see. A 3-inch-aperture telescope can never show stars as faint, or detail as fine, as a well made 6-inch. The 6-inch in turn can never match a good 10-inch.

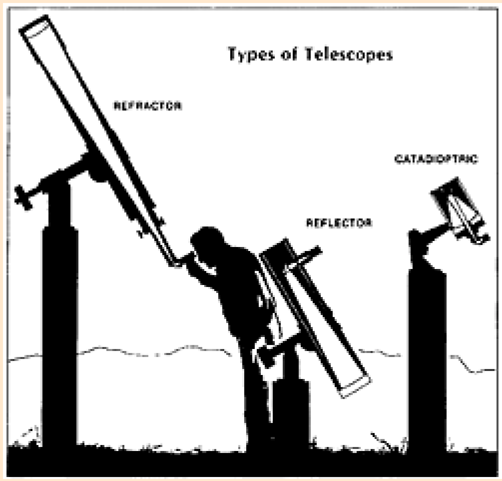
Power, or magnification, is *not* something to consider when purchasing. You can make any telescope magnify at essentially any power you want by using different eyepieces. An eyepiece is the little removable lens assembly you look into. Most telescopes come with several of them, and more can be bought separately. But it's pointless to use too high a power on a small-aperture telescope. You'll see nothing but highly magnified fuzz. Only a large-aperture scope (on a sturdy mounting!) can show a worthwhile image at 200x or more. In any case, the *lowest* powers are the easiest to use and provide the most pleasing views. You'll be using low powers the most often.

The rule of thumb is that the maximum useful power, even under ideal sky conditions, is 50x per inch of aperture. This limits you to 300x on a 6-inch, and even that's usually pushing it way too far.

Shun any telescope that is promoted for its high magnification. If you see a 2.4-inch (60-millimeter) department-store telescope advertised as "475 power!!!", you know that the manufacturer thinks you are ignorant and gullible. With that attitude he probably cut a lot of other corners too. Exaggerated emphasis on high magnification is the surest tipoff of a junky toy scope. Since aperture is so important, you might think choosing a telescope is easy -- get the biggest aperture you can afford! But in practice it's not so simple. If a scope is too massive to lug outdoors easily and too time-consuming to set up, you'll rarely use it. Even among telescopes with the same aperture, some designs are more portable, others give somewhat sharper images, and others are more economical. The following advice will help you juggle all factors to make the best decision.

Telescope Types

There are three basic kinds of telescope to choose from: the *refractor,* the *reflector,* and the *catadioptric*. Each has its strengths and weaknesses, which you should match to your lifestyle and observing desires.



These three telescopes all have an 8-inch aperture, and therefore equal light-gathering ability, despite their differences in size and weight. The tubes are cut away to show light paths.

Refractors have long, relatively thin tubes with an objective lens up front that collects and focuses the light. Refractors range from the very worst telescopes to the finest. "Department-store" refractors of the kind mass-marketed to the public are generally the worst. Their optical quality may be low, and their mountings are often so wobbly that the telescope can hardly be aimed at anything. If your astronomy budget limits you to this price range, stick with binoculars.

You say you *already got* a scope like this? Well, take heart; Galileo would have been overjoyed with it. Keep your expectations low, your patience intact, and don't blame yourself if it gives trouble. Attitude is everything. Lots of amateurs have started off successfully with department-store refractors. For bright, easily found objects (try the Moon), it may work pretty well.

Very good refractors, on the other hand, are also on the market if you are willing to hunt them out and pay for them. New, complex lens designs offered by a few companies have created some of the most superb -- and expensive -- telescopes anywhere. These lens designs are called "apochromatic," not to be confused with the ordinary "achromatic" refractor. With so much invested in the main lens, the makers generally produce a smoothly working, high-quality mounting as well.

Advantages. Refractors of all kinds are rugged, require little or no maintenance, and have sealed tubes that keep out dust and reduce image-degrading air currents. If the lenses are good, a refractor provides very crisp, high-contrast images for a given size aperture; this is especially desirable for the Moon and planets.

Disadvantages. Refractors generally have small apertures, typically 3 to 5 inches. For many astronomical purposes this is just too small; faint objects such as galaxies and nebulae will appear very dim when you can detect them at all. A refractor usually requires a right-angle mirror (a "star diagonal") at the eyepiece for comfortable viewing. This mirror flips the image right-for-left, making it hard to compare with charts. And good-quality refractors cost more per inch of aperture than any other kind of telescope.

Reflectors use a large, heavy, concave mirror instead of a lens to gather and focus the light. You look through an eyepiece on the side of the tube up near the top.

For decades the reflector was the undisputed king in amateur astronomy. Some would say it still is. From the beginner's standpoint, "reflector" means the Newtonian design illustrated above.

Advantages. A reflector offers the most telescope for the money. It is simple enough so the do-it-yourselfer can build it from scratch or tinker with a ready-made one. The optical quality can be very high. A reflector contains an even number of mirrors (two), so you see a "correct" image, not a mirror image. Dew is unlikely to condense on the optics in the night chill, a common annoyance with other designs. The mounting can be stubby and low to the ground, providing stability while the eyepiece is still at a convenient height.

Disadvantages. Reflectors may require a little more care and maintenance. The tube is open to the air, which means dust on the optics even if the tube is kept under wraps in storage (though a moderate amount of dust has zero effect on performance). The mirrors need occasional adjustment to keep them lined up exactly right, a simple but slightly tedious procedure of turning nuts on the mirror mounts. During observing, air currents in the tube are likely to fuzz up the image until the telescope comes to the same temperature as the surrounding air -- unless the tube is very well ventilated.

Different f/ratios. All telescopes, but reflectors especially, perform differently at different f/ratios. In general, the higher the f/ratio the better.

About f/numbers
What does it mean to say a telescope has an f/ratio of f/6 or f/15?
The number is simply the focal length (the distance from the objective to the eyepiece) divided by the aperture.
For example, a 4-inch telescope with a focal length of 40 inches is called f/10.
In complex telescopes such as Cassegrains, the "effective focal length" is used instead of actual distances between parts, but the principle is the same. A 5-inch Cassegrain with an effective focal length of 100 inches is an f/20.

Lower than f/6 or f/5 a reflector's secondary mirror has to be relatively large, and this slightly reduces image harpness. Distortions become more apparent near the edge of the field of view, and the entire optical system is much more sensitive to tiny misalignments. A low f/ratio mirror is harder to manufacture to high quality. Also, with a low f/ratio you have to use better, more expensive eyepieces to get sharp views anywhere but at the center of the view. For all these reasons an f/4 reflector will almost never quite match an equally well-made f/8.

On the other hand, the f/4 is much more handy and portable. It's only half as long! A 10-inch reflector at f/4 is less than four feet long and will go in the back seat of a car for jaunts to dark sites. A 10-inch f/8 is about seven feet long and a major logistical problem to transport. Everything's a tradeoff.

Catadioptric or compound telescopes use both lenses and mirrors. The most popular design is the Schmidt-Cassegrain, which burst onto the market in the 1970s and quickly gained a place for itself alongside refractors and reflectors, which had been around for centuries. The following comments apply primarily to Schmidt-Cassegrains.

Advantages. The pluses of the "Schmidt-Cass" are in portability, convenience, and special options such as advanced tracking and electronics -- not visual performance. While most people can haul an 8-inch reflector in and out of doors, it is awkward and heavy. Most 8-inch Schmidt-Cassegrains come in a padded footlocker that can be hoisted with one hand. (The tripod is separate.) The footlocker can be stowed in a car trunk or closet like a large piece of luggage, whereas a reflector tends to displace everything around it.

A Schmidt-Cassegrain's relatively short tube allows a motorized mounting to track the stars more reliably, making astronomical photography less difficult (it's never easy). These are excellent photographic telescopes. Elaborate electronic drive controls are available as options on Schmidt-Cass mountings for photographers and CCD camera users. Some can be bought with robotic computerized pointing capabilities.

Disadvantages. The image formed by a Schmidt-Cassegrain will probably be a touch less sharp than the image formed by a good reflector of the same aperture. This is most noticeable when observing planets. The cost is higher than for a reflector of the same aperture. A right-angle mirror (star diagonal) is generally used at the eyepiece to provide a comfortable viewing position, and this means your view is mirror-reversed. The focusing mechanism can be a bit sloppy and imprecise. You can't take the scope apart yourself; major adjustments mean shipping it back to the factory.

Special options. The newest options on Schmidt-Cassegrains, and on some high-performance refractors too, are robotic aiming motors controlled by an on-board computer with a database of celestial objects. Once you "initialize" the computer by aiming at a couple of known stars and doing some other setup, these telescopes will swing around to point automatically, by magic, at whatever you specify. This is supposed to make astronomy easy; you don't have to know the sky.

Computerized scopes are clearly the wave of the future, but opinions about them remain divergent. Some longtime observers rave about them, saying a computerized scope finally lets them spend more time looking *at* objects than looking *for* them. Others, including me, think a computerized scope for beginners is an expensive crutch that impedes learning and takes too much of the fun out. After all, you wouldn't want to learn to fly an airplane by being told just to push a button labeled "autopilot." And what would you do if anything went wrong?

Mountings

The best telescope is worthless if it is on a poor mounting. The tiniest wobble will be magnified into an earthquake by whatever power you are using. You can't see much in a view that's having earthquakes.

Unfortunately, almost all telescope mountings have an unpleasant amount of wiggle. Usually this is due to designers' oversights (or manufacturers' cost-cutting) at one or more key stress points. But to some degree it's the inevitable result of making any mount that's light enough to carry without a forklift.

There are two basic telescope mountings: the *equatorial* and the *altazimuth.* An equatorial mount is designed so you can easily track the motion of the sky as the Earth turns. Otherwise, the Earth's rotation carries things out of the field of view fairly quickly -- in just a minute or so at 75 or 100 power. Most equatorial mounts come with an electric "clock drive" to follow the motion of the sky automatically. Another way in which an equatorial mount is useful is that its motions indicate celestial north-south and east-west in the eyepiece. This is a great help when you're trying to find your way among the stars with a map.

An equatorial mounting must be aligned on the north celestial pole at the start of each observing session for these features to work. Fortunately, this doesn't need to be done accurately for visual observing. Just plunk the mount down so that its polar axis is aimed more or less at Polaris by eyeball judgment.

Altazimuth mounts are simpler. They just swing up-down and left-right. You have to nudge the scope along every so often to follow the stars. An altazimuth mount is both cheaper and lighter for the same degree of stability, advantages that are exploited to the utmost in the *Dobsonian* mount design for giant, low-cost reflectors. Large altazimuth telescopes, however, require the user to be a skilled pathfinder among the stars. The really big Dobsonians are best for experienced deep-sky observers hungry for aperture.

Whatever mount you get, don't compromise on its size and strength. Nothing can kill your enthusiasm like a perpetually shaky view, but a solidly mounted telescope -- one that wiggles hardly at all when you touch it and focus it -- is a joy to use.

Your Interests

Planets, the Moon, and close double stars require high power, good contrast, and sharp resolution, and if these objects are your main interest, a refractor or high-f/ratio reflector is probably the best bet.

Very faint objects like galaxies and nebulae need aperture, aperture, aperture. A big reflector is the logical choice if this will be your specialty.

If you haven't specialized and don't intend to, an all-purpose midrange telescope should serve best -- perhaps a 6- or 8-inch reflector with a focal ratio of f/8 or f/6, or an 8-inch Schmidt-Cassegrain.

One factor may force your choice of interests: light pollution. The Moon and major planets shine through even the worst light pollution unhindered. But faint objects such as galaxies and nebulae are devastated by it. The fifth-floor city dweller could clamp a small refractor to the rail of a fire escape and enjoy as fine a view of the Moon as the Vermont farmer. But most deep-sky objects would be invisible.

Your Living Situation

You don't just look through a telescope. You have to store it and carry it. You have to set it up *and* take it down at the end of a long day when most people are ready for bed. If this is a difficult chore, you won't observe very often no matter how burning your enthusiasm may be right now. Too many novices forget this and buy massive "white elephants" they end up hardly ever using.

Before drooling over the ads for giant telescopes, remember that a lowly 3-inch scope will show more of the universe than a 16-inch if you use it more.

The best scope for you is the one you'll use the most. How much fun you have, and how good an astronomer you become, depend on how much time you spend observing -- not the size of your aperture.

Figure out where you'll use the telescope and where you'll store it. The farther apart these two places are, the smaller and lighter the instrument you should get. Does the route between them involve stairs? Then think carefully before getting a reflector bigger than a 6-inch.

An enclosed, unheated porch or a well-ventilated, *dry* shed are excellent for storage. Not only will the telescope be close to where you'll use it, it will already be at the outdoor temperature when you set it up. This will save problems with the image-blurring "tube currents" of warm air that plague telescopes brought from a warm house into the cold night -- and the massive dewing that can drench a cold scope brought back indoors.

If the scope is stored in a cold location, however, be on the lookout for moisture condensing on or inside it during changes of weather. Never put the caps on a telescope unless the inside of it is dry. If there's any tendency for condensation to form on things at your storage site, leave the eyepiece tube open so the inside stays aired out, and wrap the whole scope in a blanket.

Will you have to tote the telescope around to avoid trees and lights? If you have one permanent observing site, consider installing a pier rather than lugging the tripod in and out. A large, sand-filled pipe or a cut-off telephone pole planted deep in the ground will be steadier than the most expensive tripod. The ideal solution is a shelter or observatory around the entire telescope right where it will be used.

Buying Advice

Having narrowed your choices -- perhaps to a 6- or 8-inch reflector or an 8-inch catadioptric -- get all the manufacturers' catalogs and compare details, paying careful attention to size and weight. *Sky & Telescope* magazine has ads for nearly every serious astronomical telescope. Call different dealers for the best price, but also ask the dealers' policies on returns and repairs (an unfortunate necessity for some brand-new scopes) Insist on being told a definite delivery date -- which in certain cases might turn out to be a *year* from receipt of your order! The law says a mail-ordered product must be delivered within 30 days of payment. After that the seller must either refund your money or get your agreement for a later delivery date. In my opinion, good servicing and prompt delivery are worth more than finding the rock-bottom price.

An ugly telescope can outperform a pretty one; quality of optics, firmness of mount, and ease of use are all that matter. This excellent 12-inch reflector was built by Luc Secretan of Riverdale, Maryland, who named it the Ugly Duckling. It has an equatorial mount of the rigid English yoke design and includes many conveniences, such as electric motions on both axes, a very smooth clock drive, and a rotating secondary mirror that allows the eyepiece to be used on whichever of the four sides of the wooden tube is most convenient. A weatherproof shelter encloses the telescope and folds apart to provide an observing platform.

Consider building a reflector yourself from parts -- an activity that many astronomy clubs support. If you buy the mirror rather than grinding and polishing it yourself, the most complicated tool you'll need is an electric drill. You may save money and you'll end up knowing know your telescope literally inside out.

Optical Quality

If possible, star-test a telescope before buying. This is especially important when considering a used one not covered by warranty. If you can't test before you buy, do so right after. Optical quality can vary quite a lot even among identical-looking instruments from the same assembly line. The reason is that large optical parts cannot be mass-produced with reliable quality. Each one has to be hand-finished individually by a (hopefully) skilled worker. This means you never know for sure what you're getting till you test it.

Here is a simple but very stringent test. With the optics properly aligned or "collimated" (read the instructions that come with the scope), and after the telescope has come to the same temperature as the night air (up to an hour or two after it emerges from a warm house), focus on a 2nd- or 3rd-magnitude star using very high power. Polaris is a good choice because it doesn't move.

Turn the focus knob *slightly* to one side, then slightly to the other side, of best focus. The star's fuzzy, shimmering, out-of-focus diffraction rings should *look the same* on both sides of best focus. That is, they should be the same shape and have the same distribution of light inside them.

Poor atmospheric "seeing" -- the quivering and blurring caused by the Earth's unsteady atmosphere -- may make this test difficult. Keep trying on subsequent nights until you hit a spell of good seeing.

This test is so sensitive that very few telescopes pass it perfectly. If the out-of-focus star image is *almost* the same on either side of focus, you still have a good scope. If it's obviously quite different, however, something is wrong. Before leaping to conclusions, try again on other nights and remember about giving the scope plenty of time to cool.

A telescope that fails the star test won't ever focus very sharply. At high power, the star will seem to gradually ooze or "shmush" through best focus as you turn the knob, compared to a fine scope where the star "snaps" through focus. The "snap test" is more of a judgment call that the either-side-of-focus star test, which is quite exact. All stars are rendered shmushy to some degree by atmospheric seeing. But if you get a chance to test a good scope and a poor one side by side, the shmush-versus-snap effect is plain.

Do this at high power, because uncorrectable imperfections in your own eye often make a star shmush through focus at low power no matter how good the telescope and eyepiece may be.

If a scope is definitely bad, be assertive about returning it for repair or refund. The better makers have excellent reputations for fixing problems. No matter who made the scope you have a moral right to this treatment, so act accordingly.

The best advice when considering telescopes is to seek the opinions of other amateurs. Members of your local astronomy club will be glad to offer help and frank opinions. With luck you may even get to try out a variety of their telescopes, which will help you decide whether twice the aperture is really worth four times the cost and six times the weight. The addresses and phone numbers of some 400 clubs in the United States and Canada (and many e-mail addresses) are listed in *Sky & Telescope*'s Astronomical Directory.

Happy hunting!

Alan MacRobert is an Associate Editor of Sky & Telescope *magazine and an avid backyard astronomer.*