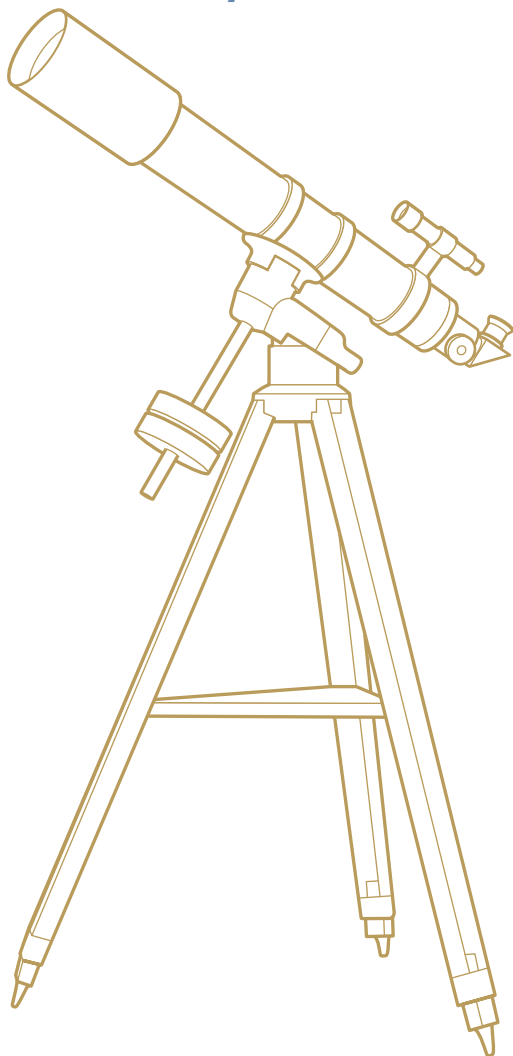


What to **KNOW**

Although they come in a bewildering range of sizes and shapes, all telescopes are variations on a few simple themes.

By **TONY FLANDERS**



TELESCOPES ARE MAGICAL — there's no other way to say it. You can enjoy years of happy stargazing with nothing but your own eyes, but telescopes add a new dimension to the experience. When Galileo first turned his spyglass to the night sky four centuries ago, he discovered marvels everywhere he looked — wonders that had been hiding in plain sight for all of history, unsuspected by any person before him. And all telescope owners ever since participate in Galileo's miracle. On any clear night we can point our scopes upward and enter an enchanted world that's completely alien to everyday experience.

There are innumerable different ways to enter this club. If you browse the ads in this magazine, or visit the websites of manufacturers and dealers, you will soon realize that telescopes come in an overwhelming variety of sizes, shapes, and prices. To make sense of this embarrassment of riches, you need to ask yourself a few basic questions.

How much are you willing to spend? How portable does your telescope need to be? Do you plan to do astrophotography? And above all, what do you hope for and expect from astronomy?

Great Expectations

Let's talk first about what you can reasonably expect. A few objects (notably Saturn and the Moon) are guaranteed to look spectacular through any reputable telescope. But it's only a matter of time before you'll want to move on to subtler pleasures. If you crave lots of quick gratification, you will probably want to see a lot of showpiece objects before you progress to the second stage. If you're a more contemplative type — the kind of person who enjoys identifying wildflowers or different species of sparrows — then you may not need those jaw-dropping sights at all, though you'll surely be grateful when you find them.

The main factors determining how impressive things look through your telescope are its *aperture* (the diameter of its main lens or mirror) and the observing conditions (the quality of your sky). Aperture is so important that it's always the first fact stated

ALL INSTRUMENT ILLUSTRATIONS: GREGG DINDERMAN



before you

BUY

when describing a telescope. When I say that I own a 4-inch scope, you know that its main mirror or lens is 4 inches across — and that gives you a pretty good idea what you'll see if you look through it. To a crude first approximation, all good 4-inch scopes are the same.

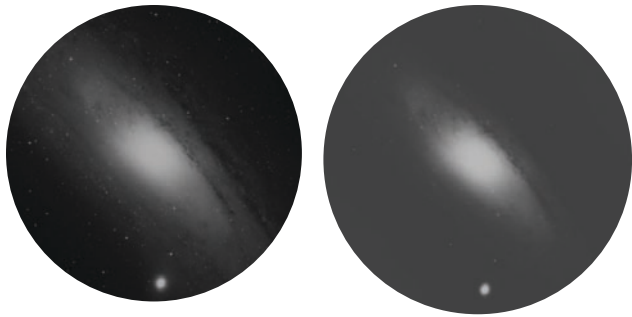
When you're observing the Moon and the planets, larger apertures let you use higher magnifications, providing more detailed and impressive views. But this statement comes with two caveats. Aperture won't help on the planets unless it's backed up by first-rate optical and mechanical quality. And on most nights, the amount of planetary detail that's visible is limited by atmospheric conditions. When the *seeing* is poor — when you're viewing through roiling, boiling air — there's no benefit to using magnifications higher than 200 \times , no matter how big and good your telescope is. Hard-core planetary observers are

Above: Few consumer commodities come in such a wide variety of sizes, shapes, and types as telescopes. Here, the author poses with his smallest, a 70-mm (2.8-inch) refractor, and his largest, a 12.5-inch Dobsonian reflector.

Photo: Carla Procaskey



These images were made by manipulating a Hubble Space Telescope photo to simulate Saturn's appearance through different size telescopes. The image at left shows how Saturn looks through a 12-inch telescope at 300 \times when atmospheric conditions are excellent. You *can* use 300 \times on a 3-inch scope, but then the view is dim and fuzzy (*center*). To get a comparably bright and crisp view through the smaller scope, you would need to use much lower magnification, as shown at right. Photo: NASA / JPL



Galaxies are too faint to stimulate color vision, so they're always seen in black and white. And they don't appear nearly as bright or crisp through an eyepiece as they do in astrophotos. Nonetheless, the Andromeda Galaxy is very impressive when viewed through a 10-inch telescope at a dark location, as shown at left. But even moderate suburban light pollution overwhelms the galaxy's faint outer sections (right). Inside a major city, only the bright central oval is visible.

Photo: POSS-2 / Caltech / Palomar Observatory

happy to wait for that one night in ten when a 12-inch scope can really strut its stuff. But if your goal is to get pretty-darned-good views of the planets on typical nights, you'll be quite happy with a high-quality 6-incher, and even a 3- or 4-inch scope might be just fine.

It's a different story when you're observing star clusters, nebulae, and galaxies, which are collectively known as *deep-*

sky objects. A handful of these are big and bright enough to look spectacular through small telescopes. But most deep-sky objects need at least 6 to 10 inches of aperture to look really impressive — at least to untrained eyes. And for the most part, bigger is better, with hardly any limit. Some hard-core deep-sky observers own telescopes with mirrors more than two feet across! However, there's more to deep-sky observing than the size of your scope.

As with planets, atmospheric conditions for deep-sky observing vary from one night to the next — or even from hour to hour. In this case, *transparency* (clear, haze-free air) is more important than *seeing* (steady air that's free of thermal currents). But light pollution is the biggest problem by far.

Anywhere near a city, artificial lights set the entire sky aglow. Diffuse objects like nebulae and galaxies are easily overwhelmed by this skyglow. Telescopes help a little, but not much — all they can do is make things appear closer than they actually are. No telescope can bring any galaxy closer than the Milky Way, which is all around us. So if the sky is too bright for you to see the Milky Way clearly with your unaided eyes, you're going to get pretty poor views of any other galaxy regardless of what instrument you use. No amount of aperture can compensate for light pollution when viewing diffuse objects.

So are big scopes useless in cities and suburbs? Not at all! For one thing, they *do* show stunning views of the Moon and

You will never see this many stars in a globular cluster through the eyepiece of a telescope. On the other hand, no photograph can capture the vibrancy of such a star swarm when you see its actual light with your own eyes. So on balance, this photograph of Messier 13, the Great Hercules Cluster, gives a fairly faithful impression of the glory of a globular star cluster when viewed through a large amateur telescope under pristine dark skies. It's no wonder that globular clusters are many star-gazers' favorite observing targets!



ROBERT LUPTON / SLOAN DIGITAL SKY SURVEY

planets when the seeing allows. And though a galaxy may not look great through a big scope from a suburb, it looks better than it does through a small scope at the same location. But more to the point, aperture *can* compensate for light pollution when you're viewing star clusters. The brightest of the globular star clusters (see the picture on the opposite page) look just about the same through a 10-inch scope in a city as they do through a 4-incher at a dark site — namely, incredibly beautiful!

Still, if you live in a city or suburb and love deep-sky observing, you'd better select a telescope that's small enough to fit in your car, so that you can take it to dark locations for great galaxy views. Even if you stay in your backyard, think twice before buying an instrument that's going to be a hassle to move outside. My 70-mm (2.8-inch) scope is nowhere near as powerful as my 7-incher, but I often use it anyway simply because I can pick the small scope up, tripod and all, and carry it easily with one hand.

Smaller apertures do have some intrinsic advantages, aside from cost and portability. One of them is field of view. It's not an ironclad relationship (we'll discuss the exceptions later), but as a rule of thumb, the bigger the aperture, the less of the sky you can view at one time. There aren't many celestial objects too big to view in a 12-inch scope, but there some, such as the Pleiades star cluster. And they include some of the sky's finest showpieces.

If you want to do astrophotography, it's much easier to learn on a small scope than a big one. And small aperture is no obstacle at all to taking great astrophotos — you just have to select subjects that are appropriate for your telescope.

Finally, most stargazers end up owning two or more telescopes, for different purposes and occasions. There's a good argument for starting small and progressing to bigger scopes later. That way, when you finally see your familiar celestial sights with lots of aperture, you will really appreciate them properly.

Bountiful Binoculars

Taking this logic to its extreme, many experienced stargazers recommend starting with binoculars. I'm talking now about conventional lightweight binoculars, not the exotic instruments (some weighing more than 100 pounds) that are used for specialized tasks such as comet hunting.

Probably the most popular binoculars for general-purpose stargazing are 10×50s. The numbers indicate that they magnify 10 times and have main lenses 50 mm (2 inches) wide. If you already own small-aperture binoculars, like 8×21s, you'll be amazed how much they show when you point them at the night sky. But if you're buying binoculars specifically for astronomy, get ones with at least 30- or 35-mm lenses, to gather as much light as possible from faint stars and deep-sky objects.

Selecting the best magnification is a tricky balancing act. Higher powers show finer details and reveal fainter objects, but they also magnify every vibration, making it very hard to get



For astronomical binoculars, bigger main lenses are better — until the binoculars become too expensive or heavy.

Photo: iStock.com/kfb

a steady view when you're hand-holding the binoculars. Most people find that 10× is about as high as they want to go, and some prefer to stick to 7× or 8×.

High powers also undermine one of binoculars' biggest advantages — their tremendously wide fields of view. A telescope at 100× shows as much of the sky as you could see through a particularly narrow drinking straw. By contrast, 7× binoculars can show a significant chunk of a constellation. That makes it much easier to find things in the sky. And some binocular-sized fields, such as Orion's Sword and Belt, are surpassingly beautiful.

Are binoculars the right way for you to start? If you're the kind of person for whom learning the constellations is a high priority, very likely yes. If you're eager to get the most glorious possible views of specific objects, probably not. And binoculars don't have enough magnification to show planets well, so if you crave great planetary views, by all means start instead with a telescope.

Under dark skies, binoculars show breathtaking views of the Milky Way and many deep-sky objects. In a city, binoculars can be disappointing for deep-sky observing, but they're great for learning the constellations. You can see far more stars through 10×50 binoculars in badly light-polluted surroundings than you could without them in the very best possible conditions.

You can get decent binoculars for very little money (less than \$100 if you shop carefully), so they're a fine way to dip your toes into astronomy without a huge financial commitment. And you won't stop using them when you buy a telescope. On the contrary, telescopes and binoculars complement each other perfectly. Moreover, binoculars are extremely useful during the daytime, for viewing anything from baseball games to birds to boats.

VISUAL OBSERVING: What to Know Before You Buy



NEWTONIAN REFLECTOR

Advantages:

- Lowest cost per inch of aperture
- Simple design, easy to adjust and modify
- Viewing from top of tube allows short tripod (or none, in case of Dobsonian)

Disadvantages:

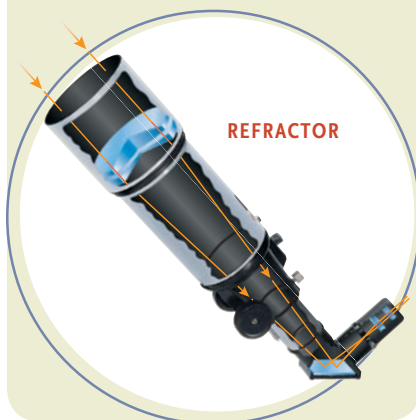
- Requires periodic adjustment (collimation)
- Open tube is prone to collect dust
- Usually biggest tube per unit of aperture

Advantages:

- Best performance per inch of aperture
- Rugged construction, sealed tube
- Usually no need for user adjustment
- Quick cooldown

Disadvantages:

- Highest cost per inch of aperture
- Long tube with eyepiece at rear requires tall mount



REFRACTOR



SCHMIDT-CASSEGRAIN, MAKUTOV-CASSEGRAIN

Advantages:

- Most compact tube per inch of aperture
- Short tube is easy to mount
- Eyepiece height varies least
- Sealed tube

Disadvantages:

- Fairly high cost per inch of aperture
- Requires periodic adjustment (collimation)
- Longest cooldown time of any design

All About Optics

We've already learned that the three things that matter most about a telescope are aperture, aperture, and aperture. But there is more to say. For instance, the full description of my second-smallest telescope is that it's a 100-mm f/6 achromatic refractor. Let's see what those other words mean.

The terms are easier to grasp if you realize that there's no fundamental difference between telescopes and camera lenses. When you do prime-focus astrophotography (see page 48), you use your telescope as a camera lens. Conversely, you can buy adapters to convert camera lenses into astronomical telescopes.

The number following the *f/* is the *focal ratio* — exactly the same measurement that photographers call “*f/stop*.” It's defined as the *focal length* divided by the aperture. So my 100-mm f/6 telescope has a focal length of $6 \times 100 = 600$ mm. A photographer would call it a 600-mm f/6 telephoto lens, because in daytime photography, focal length is more important than aperture.

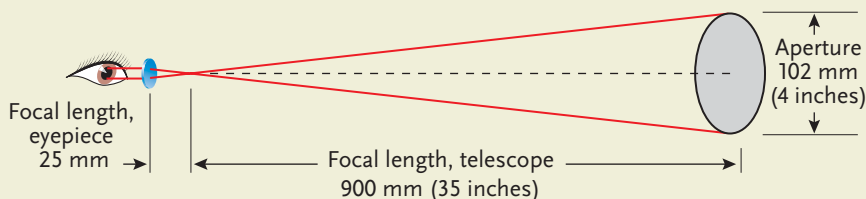
When you're taking a photograph, the focal length determines how big any given object appears in your photo. Short focal lengths yield wide-angle views; long ones yield close-up shots. And the focal ratio determines how long your exposure



Resting your elbows on a solid support is a simple but effective way to eliminate the shakiness that results from holding binoculars in your hands.

Focal View

$$\text{Focal ratio} = \frac{\text{focal length, telescope (900 mm)}}{\text{aperture (102 mm)}} = f/8.8$$



$$\text{Magnification} = \frac{\text{focal length, telescope (900 mm)}}{\text{focal length, eyepiece (25 mm)}} = 36 \times$$

needs to be. If you double the focal ratio, you need to quadruple the exposure time to get an equally bright photo. For this reason, telescopes and camera lenses with small focal ratios are called *fast* and ones with long focal ratios are called *slow*.

Focal ratio is much less important for visual observing, because there's an additional element in the optical train: the eyepiece. If you grew up in the days of film photography, you know that cameras make really small images. Photographic negatives and slides need to be enlarged for you to see any details in them. Likewise, a telescope forms a tiny image inside the eyepiece's barrel, and the eyepiece is basically just a magnifying glass that lets you put your eye close to that image so that you can see it better. The shorter the eyepiece's focal length is, the closer you can get, the more the image is magnified, and the finer the visible details are.

The net effect is that the view through a 100-mm $f/12$ telescope using an eyepiece with a 20-mm focal length is identical to the view through a 100-mm $f/6$ telescope of equal optical quality when you use a 10-mm eyepiece. You can compensate completely for the lower magnification inherent to shorter focal ratios by using eyepieces with shorter focal lengths.

However, the opposite is not true. If you take a photo of a person's whole body, you can crop and enlarge the face, but if you take a close-up of the face, you can't turn that into a wide-angle view of the whole body. Likewise, you can't get a true wide-angle view out of an $f/12$ telescope — though

A telescope forms an internal image that is then magnified by the eyepiece. The size of the image is restricted by the eyepiece's barrel. To fit more in, you either have to use an eyepiece with a larger barrel (2 inches instead of 1¼ inches) or use a scope with a shorter focal length.



Dobsonian mounts are cheap, simple, and effective, so many stargazers recommend 6- to 10-inch Dobs for beginners on a budget. Dobs can also be equipped with push-to electronics that tell you which way to push the scope to reach your target.

Skywatch photo:
Craig Michael Utter

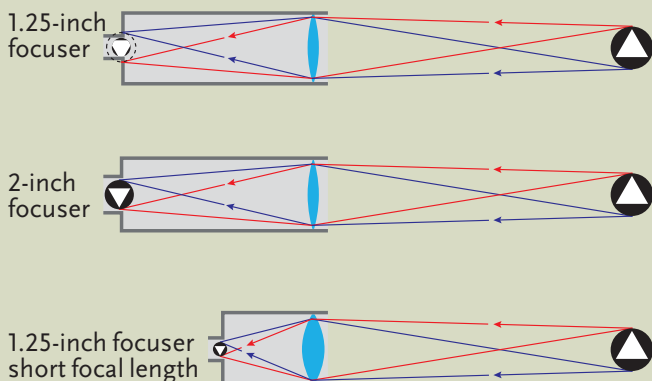
you can come close by using eyepieces with 2-inch barrels instead of the normal 1¼-inch eyepieces, as shown at left.

So for visual observing, a 100-mm $f/6$ can do everything that a 100-mm $f/12$ can, but not vice versa. In addition, the $f/6$ is probably physically smaller, because for most telescope designs, the focal length is roughly equal to the length of the tube. In that case, why make $f/12$ scopes at all? It turns out that it's harder to provide high optical quality in fast mirrors and lenses than in slow ones. That's partly due to practical manufacturing obstacles that can be overcome — at a cost. But some of the problems of fast optics are inherent and unfixable.

How about “achromatic refractor,” the last part of my telescope's description? A *refractor* gathers light with a big lens in the front, while a *reflector* gathers light with a big mirror in the back. There are also compound designs that use both lenses and mirrors, the most popular being the *Schmidt-Cassegrain* and *Maksutov-Cassegrain*. The advantages and disadvantages of these designs are summarized on the facing page.

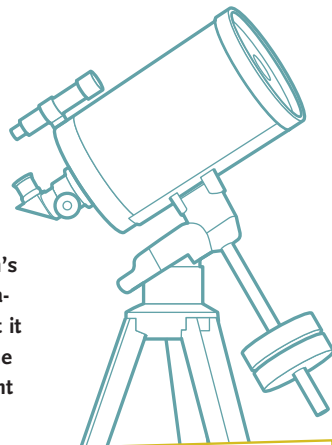
The original refractors used by Galileo and his contemporaries had a single lens up front. They showed gaudy colored fringes around all objects, because glass bends different colors

Field of View



SKYWATCH: GREGG DINDERMAN (2)

An equatorial mount is just an altazimuth mount tilted over so that one axis is parallel to Earth's axis of rotation. A German equatorial mount looks different, but it moves the telescope in the same way as the equatorial fork mount shown below.



SKYWATCH PHOTO: CRAIG MICHAEL LUTTER (2)

of light by different amounts. This so-called *false color* is inherent in all refractors, but it was greatly reduced in the 18th century by using two lenses made of different kinds of glass. These *achromatic refractors* reigned supreme until the 20th century, when *apochromatic refractors* reduced false color even more by using three lenses and/or exotic glasses. Apochromats provide the best possible performance per unit of aperture, and are also ideal for astrophotography. And not surprisingly, they're also the most expensive telescopes per unit of aperture.

In fact, refractors in general — even achromats — are prohibitively expensive in genuinely large apertures. Amateur astronomers love to argue whether refractors or reflectors are better, but this is really mostly a debate about the relative merits of small and big scopes. Refractors reign supreme at the small end of the scale, while reflectors are literally the only choice for genuinely large apertures. (That's why almost all telescopes used by professional astronomers are reflectors.) There's only serious competition between the two designs in the 4- to 6-inch range.

Compound telescopes such as the Schmidt-Cassegrain (SCT) and Maksutov (Mak) are attractive to amateur astronomers mainly because they're small and light. An 8-inch *f/10* Newtonian reflector is a monster, with a tube more than 6 feet long. But the optics for an 8-inch *f/10* SCT squeeze into a tube less than 2 feet long. In addition to making SCTs highly portable, that places much less strain on their mounts — a subject that we'll cover in the next section.

The All-Important Mount

Telescope optics are glamorous and fun to talk about. But the hunk of metal or wood that supports the scope — the *mount* — is every bit as important as the optical tube. In fact, astrophotographers sometimes spend considerably more money on their mounts than on their scopes.

The first job of the mount is to keep the telescope from shaking, which is much harder than it sounds. At high power, every little wobble or vibration is magnified so much that the whole image becomes unviewable.

A mount also has to allow the telescope to move extremely smoothly. Celestial objects don't stand still for you to look at. Or, more precisely, they do stand still, but they *appear* to move across the sky as Earth rotates underneath you. At 200× it takes about a minute for an object to cross from one edge of the eyepiece to the other. To keep an object centered, you have to move the scope frequently and in very tiny increments.

The very simplest kind of mount is the *Dobsonian* design shown on the preceding page. Dobsonian mounts do only the two tasks outlined above — keep the scope steady and let it move smoothly — and they do those two jobs extremely well, and at very low weight and cost. That makes them exceedingly popular for large reflectors, which would be impractical to mount any other way.

Many mounts have *motor drives* that track celestial objects automatically. This is essential for astrophotography and a great convenience for high-power planetary viewing. But deep-sky objects stay in view relatively long at the modest magnifications typically used to view them, so motor drive is less critical for deep-sky observing.

Many mounts are also equipped with computers that can locate celestial objects and point your telescope at them — as well as continuing to track them once they're located. These *Go To* mounts are extremely popular, because locating faint objects manually takes considerable skill and practice. (But for some people, that's part of the joy of stargazing.) Five or ten years ago, only the most expensive *Go To* mounts worked really well, but high-quality *Go To* is now becoming reasonably inexpensive.

Dobsonian mounts can be equipped with *Go To* drives as a custom add-on, but there are also now mass-market Dobs with

“push to” capability. This involves no motors, but an electronic device tells you which way to push your scope so that it ends up aimed at your intended target.

Traditionally, serious stargazers always used *equatorial* mounts, which have one axis parallel to Earth’s axis of rotation. These are the only kind that can track celestial objects automatically without a computer. But with the advent of the Dobsonian design and computer-controlled tracking, *altazimuth* mounts have gained greatly in popularity for strictly visual observing. As you can see in the photos on the opposite page, altazimuth mounts are simple and stable, while equatorial mounts are inherently off-balance (except at Earth’s poles, where the two systems are identical). That’s why all big professional scopes built in recent years have altazimuth mounts.

But equatorial mounts are still the best choice for serious amateur astrophotographers. That’s because celestial objects rotate (or appear to do so) as they move across the sky. Professionals (and a few amateurs) use special *derotators* to compensate for this. But equatorial mounts automatically keep your camera oriented the same way as the object that it’s shooting.

Smart Shopping

Okay, so now you know most of the terminology used to describe telescopes. How do you actually go about selecting one to buy?

Reading about scopes is all very well, but it’s no substitute for actually looking through one. And that’s even more true for

binoculars and eyepieces, where individual preferences are extremely important. If there are any reputable telescope dealers in your area, it’s well worth paying them a visit so that you can see a wide range of astronomical equipment firsthand.

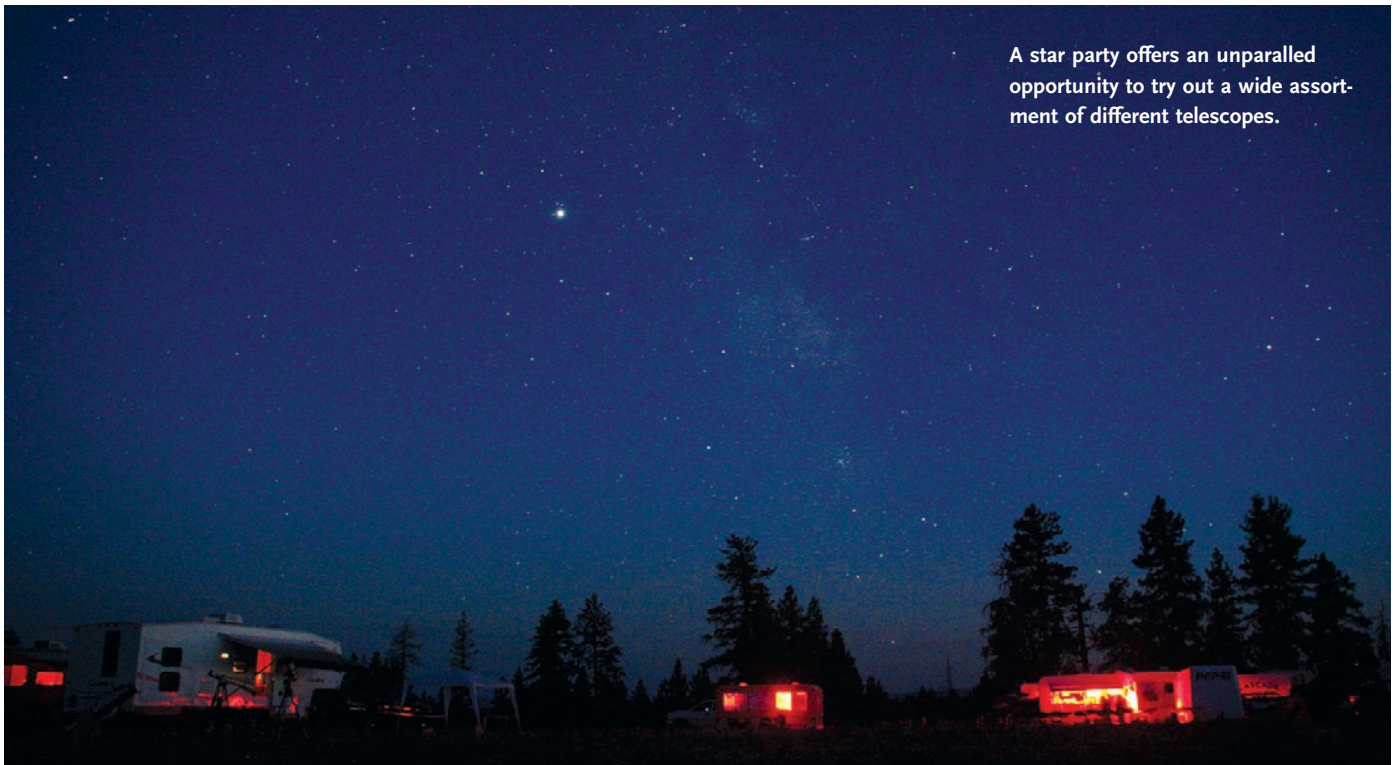
In addition, get in touch with your local astronomy club. There’s a fairly comprehensive list at SkyandTelescope.com/clubs, and an internet search may yield additional results. Most clubs have public viewing sessions, where the members will be all too eager to show off their toys to you.

As for individual makes and models, *Sky & Telescope* has reviewed many of them. You can download individual reports for a modest fee from SkyandTelescope.com/sttr.

The internet is chock-full of telescope reviews — some of the highest possible quality and others worse than useless. You can probably learn to separate the wheat from the chaff with a little practice. One “happening place” for internet astronomy these days is Cloudy Nights (www.cloudynights.com). Cloudy Nights’ Beginners Forum is particularly helpful; their motto is “there’s no such thing as a stupid question.”

Whatever you do, don’t forget to have fun. Buying your first telescope is a serious commitment of time and money. But it’s also a great opportunity to explore the wild and wonderful world of astronomical equipment. ●

Sky & Telescope associate editor Tony Flanders owns five telescopes and five pairs of binoculars.



A star party offers an unparalleled opportunity to try out a wide assortment of different telescopes.