Von Braun Astronomical Society

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Telescope Buyer's Guide for New Observers

Introduction

Astronomy is a fun and exciting endeavor that can carry interest from childhood to old age. It's one of the few areas of science in which the amateur can and does make significant contributions; discovering comets, making precise measurements of occultations, and observing meteor showers as examples.

Choosing a first telescope for yourself or a loved one can be a daunting task. There is literally no limit to the amount of money that can be spent on telescopes and related equipment. Luckily, modern development of quality optics on simple, stable mounts and more recent advancements in low cost electronics and software means that the price of an entry level telescope can be quite affordable.

A Note On Binoculars

Simply put, a pair of binoculars should be every ameteur astronomer's first telescope. Binoculars can be effective telescopic devices for observing the night sky and have the added benefit of being useful during the day for all sorts of purposes from birding to sports!

When selecting binoculars for astronomy, it's important to understand the designation used for sizing them. The customary designation is in the form:

A X B, where
A = The magnification of the lens system
B = The diameter of the lens in mm where the light enters the binoculars (a.k.a. The aperture)

For example, binoculars designated as:

- 12 X 25, means the magnification is 12X and the diameter of the aperture is 25mm
- 10 X 50, means the magnification is 10X and the diameter of the aperture is 50mm

Choosing binoculars for astronomy is an exercise in compromise. While it may seem desirable to have higher power, the higher the power, the smaller the field of view (the amount of sky you can see). Likewise, the astronomer wants to gather as much light as possible, so the tendency is to look for large apertures, but the larger the aperture, the heavier the binoculars and thus the harder they are to hold steady.

I recommend 7X50 or 10X50 binoculars. This size gives good magnification and light gathering power while still relatively lightweight. They are a common size that can be found for around $50, and often for less.

The Measure of a Telescope

Walk into a department store or science center that sells telescopes and you'll often find a box containing a telescope that has something like "Up to 500X Magnification!" written in bold letters across the side. When you see this - walk away! Theoretically, any telescope can be pushed to any power with the right eyepiece. Physical optical considerations limit the effective magnification. A good rule of thumb is to magnify no more than 50X per inch of aperture (or 2X per mm). You will find, however, that most observing is done at 25X to 100X power - this power is good for most objects and tends to produce high contrast bright steady images of various astronomical targets.

Aperture

Aperture, or the diameter of the lens or mirror is THE measure of a telescope. It determines how much light is gathered by the system and thus how much you can see through the scope. Although there are other measures that are important, all telescopes are fundamentally described by their aperture size, usually measured in inches or mm. The area of the mirror or lens is proportional to the square of the diameter. So a 120mm diameter scope doesn't gather twice the light of a 60mm scope, it gathers four times that of the 60mm!

Focal Length

Another important measure of a telescope is its focal length. The focal length is the distance from the main mirror or lens at which the image focuses. The focal length determines the magnification and field of view of the telescope with various eyepieces. The focal length is usually expressed in mm.

Magnification

The magnification, or power, of a telescope is a function of the focal length of the main (fl_m) mirror or lens divided by the focal length of the eyepiece (fl_e). Both are typically measured in mm. Note that the magnification is *independent of the aperture*. The function to compute magnification is:

$Mag = fl_m/fl_e$

For example: If the focal length of the telescope is 900mm and the focal length of the eyepiece is 25mm, then:

$Mag = 900 / 25 = 36$

F-Ratio or f/

The F-ratio or, commonly "f/" is the ratio of the focal length to the aperture. When computing this, keep in mind that units must be the same (e.g. both mm or both inches). The significance of the f/ ratio is that it defines the "speed" and field of view capability of the telescope. Lower f/ ratios tend to cost more, but will provide a wider field of view and have brighter images than a longer f/ ratio for any given eyepiece. A lower f/ ratio is good for observing deep sky objects such as galaxies, star clusters, and nebulae. Higher f/ ratios allow high magnification with lower cost optics; good for lunar and planetary observing.

Example:

A telescope with a 127mm diameter mirror and a 762mm focal length has an f/ ratio of:

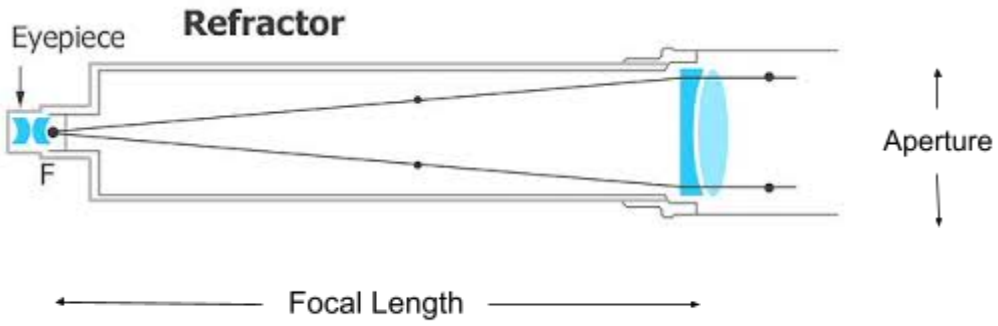
f/ = 762 / 127 = 6.0
Or, f/6

Optical Designs

There are two basic optical designs for telescopes, the refractor (or lens type), and the reflector (or mirror type). There are numerous variations of each of these designs, but the beginning astronomer need only know about these two basic types. A third basic type, the catadioptric, combines both mirrors and lenses.

Refractors

Galileo Galilei was the first to use a refractor for astronomical viewing (he was the first to use a telescope this way, but he was not the inventor of the telescope). He made his first telescope in 1608. The refractor is the iconic classical telescope.

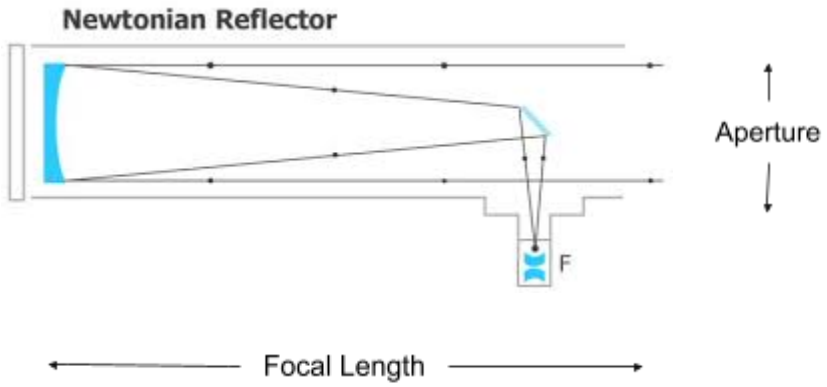


Reflectors

Refractors, especially early models in the 17th century, exhibit a problem known as “chromatic aberration”, the effect of different colors of light focusing at different distances, thus producing poor images. Modern refractors can nearly eliminate this problem through multiple lens systems, but it was a serious limitation to early astronomical telescopes.

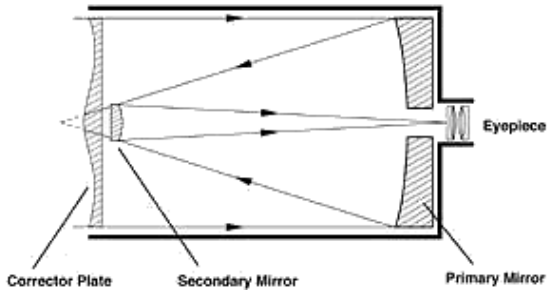
Isaac Newton realized that chromatic aberration could be eliminated completely by focusing light by reflection rather than refraction and to prove his concept he invented the reflector telescope in 1668.

Today, there are several designs employing two or more mirrors, but the Newtonian reflector is by far the most commonly used for its image quality, simplicity, and low cost.



Compound or Catadioptric

A modern design that has gained popularity due to its compactness and low maintenance is the Compound or Catadioptric system. These systems combine both lenses and mirrors in a folded optical path that results in a telescope with a short tube that has a long focal length. They are usually rather expensive, have larger apertures, and are thus considered more advanced. Typical designs are known by the names: Schmidt-Cassegrain, Schmidt-Newtonian, and Maksutov-Cassegrain.



Mount Designs

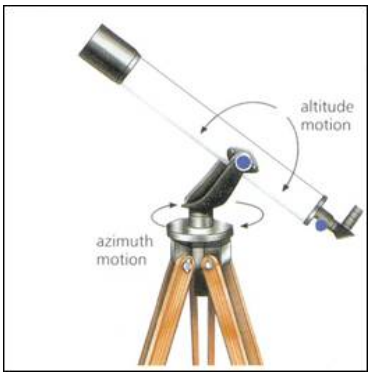
A good telescope needs an even better mount to hold the scope steady and allow easy pointing to specific targets. Like optical designs, there are two basic types of mechanical mounts, the Altitude-Azimuth (or Alt-Az), and the Equatorial. Once again, there are several variations of each type.

A good mount holds the telescope steady, while allowing movement in two axes to provide the ability to point the telescope at any position in the sky.

A good rule of thumb is to spend about as much on the mount as you do on the optical tube.

Alt-Az Mounts

These are the simplest and lowest cost mounts. Altitude is measured in degrees, where 0° is when the scope is aimed at the local horizon and 90° is when the scope is aimed straight up (zenith). Azimuth corresponds to the compass position measured clockwise from North. However, rarely do you ever need to know coordinate positions when using an Alt-Az mount. Usually, you just push the scope on the mount until you are aimed at the target object.



Dobsonian Mount

A specific type of Alt-Az mount is called a Dobsonian mount, named after John Dobson, an amateur astronomer who lived in the San Francisco area. He is a cofounder of the San Francisco Sidewalk Astronomers in 1967 and an avid promoter of bringing the wonders of astronomy to the people. Dobson is credited with the quote: “The importance of a telescope is not how big it is, it's not how well made it is, it's how many people less fortunate than you got to look through it.”

The Dobsonian mount is simple (two basic pieces - tube and base), stable, and low cost.

Dobsonian Mounts

Advantages of Alt-Az Mounts

- Low cost
- Light weight

Disadvantages of Alt-Az Mounts

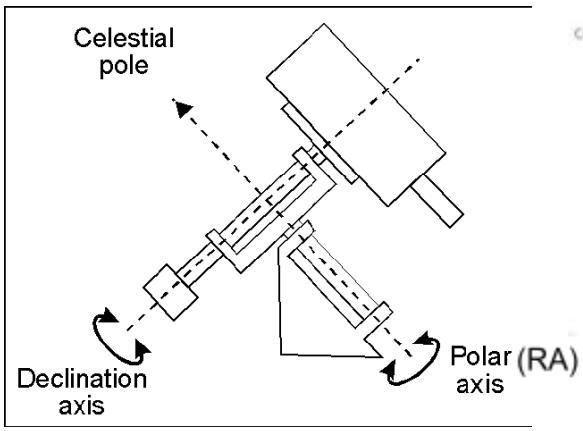
- Requires motion in two axes to track objects
- Can't be used for long exposure photography

Equatorial Mounts

In this type of mount, one of the two axes of the mount is tilted to be parallel with the axis of the Earth. Rotating perpendicularly around that axis follows the equator of the Earth projected into the sky, thus the name "equatorial". The coordinates in the equatorial system are different from the Alt-Az coordinate system. In equatorial systems, the altitude measurement is called Declination (Dec) and the azimuth is called Right Ascension (R.A.) and is measured in hours, minutes, and seconds instead of degrees. Hey, don't blame me, the Equatorial system is very old! But that's not the biggest difference; the main difference is that the Alt-Az coordinate system is local to the telescope being used, whereas the Equatorial system is global. That is, if you and I are operating telescopes located in different states, and we both aim our telescopes to the same Alt-Az coordinate, we will be looking at two different locations in the sky. If we're using an equatorial mount, then if we both aim our telescopes to the same Equatorial coordinate, then we'll both be looking at the same target.

Thus all sky charts are mapped in Equatorial coordinates of (R.A., Dec).

The main advantage of an Equatorial mount is that since one axis is parallel to the Earth's axis, tracking an object in the sky only requires rotation about that single axis (to counteract the Earth's rotation about its axis). An Alt-Az mount requires motion about both axes to track an object in the sky. This makes equatorial mounts critical for long exposure photography.



Advantages of Equatorial Mounts

- Needs only one axis of motion to track targets.
- Required for long exposure photography
- Able to use sky chart coordinates to aim the scope at a target.

Disadvantages of Equatorial Mounts

- Heavy: usually requires counterweights
- Requires polar alignment each use for proper tracking
- Higher cost than Alt-Az/Dobsonian mounts

Determine Your Preferences

"Telescopes are either good or cheap, not both", Sir Patrick Moore.

Selecting a telescope, especially your first telescope, doesn't need to be a complex endeavor. But neither should it be a hasty decision. Answering a few simple questions will help you make a wise choice that you will be happy with for many years.

1. **Set a Budget.** While this may sound like a banal place to start, deciding what you're willing to spend determines the range of choices you have. You should consider $150 to be about the lowest level of budget that will provide a telescope you'll be happy with for more than the first few weeks of use. A budget of $300 opens many options and some surprisingly good scopes

can be found in the $500-$800 range. Of course, there's really no limit to how much can be spent on telescopes and accessories, so setting a budget is important to eliminate many options and make your decision easier.

2. **Decide on an optical design.** Refractor or reflector, the choice is up to you. For your first scope, I recommend a reflector. For any given aperture, a reflector is usually much lower cost than a refractor. Put another way: for any given budget, you can buy a larger reflector than refractor. And remember: Aperture is king.
3. **Decide on a mount design.** Alt-Az, equatorial, Dobsonian, computerized, GoTo, the choice is wide. I recommend a Dobsonian mount for stability and low cost.
4. **Assess the Accessories.** New telescopes should come with at least two eyepieces; one about 25mm for wide field views and one about 8-12mm for high power views. You will also need a finder scope, which will either be a small very wide field optical finder or a "red dot" reflex finder. Your new scope should also come with a sturdy tripod or mount. Another nice accessory is a star chart or booklet.

Make Your Selection

Now that you've made your decisions, it's time to shop. My recommendations are as follows:

- Select a Newtonian reflector of 4" (100mm) or larger. For any given budget, a reflector will allow you to select a larger aperture than a refractor. Larger aperture = more light.
- If you choose a refractor, select one of 70mm aperture or more. Avoid the commonly found department store 60mm refractor.
- Prefer a Dobsonian mount. These are the most stable, portable mounts for the money.
- Avoid low cost computerized telescopes. They may seem like a good bargain, but unless you are willing to spend upward of $800 or more, you're paying mostly for the mount and electronics rather than the optics. The result is typically a telescope made of mediocre quality optics and flimsy plastic mount components that will not perform or hold up well.
- Avoid tabletop telescopes; prefer scopes with a proper tripod or stable base. The tabletop models may save you money, but you'll find that you need a very sturdy table and you may go to an observing site that has no available table and you'll have to bring a table or tripod anyway.

Resources and Vendors

The Society does not endorse or promote any telescope vendor and we certainly don't benefit financially in any way from recommending vendors. Here are some vendors known to be quite reputable, with good products and service:

Telescope Vendors

- Astronomics: https://www.astronomics.com
- Explore Scientific: https://explorescientificusa.com
- High Point Scientific: https://www.highpointscientific.com/
- Orion Telescopes: https://www.telescope.com
- Sky-Watcher USA: http://www.skywatcherusa.com/
- Celestron (direct): https://www.celestron.com/
- Meade (direct): https://www.meade.com/

Resources:

- **VBAS**: Your local source for Astronomy! http://www.vbas.org/
- **Cloudy Nights**: A community of amateur astronomers, buyers, and sellers. https://www.cloudynights.com/
- **The Sky Searchers**: Another community group. https://theskysearchers.com/
- **Sky And Telescope Magazine**: The essential magazine of current astronomy. https://www.skyandtelescope.com/
- **Astronomy Magazine**: The magazine of popular astronomy. http://www.astronomy.com/
- **The Sky At Night Magazine**: The essential magazine of astronomy in the U.K. http://www.skyatnightmagazine.com

General Recommendations

Here are a few good choices, ordered by price, and where they can be found. Due to the Covid-19 pandemic and an increased interest in astronomy and telescopes during this time, prices have increased significantly since last year, typically 15% to 40%.

- National Geographic CF700SM 70mm f/10 refractor $120
- Celestron Powerseeker 127 EQ (5" mirror) $220
- Explore FirstLight 114mm Newtonian $230
- Sky-Watcher Classic 150P / Traditional Dobsonian 6" $460
- Orion SkyQuest XT8 Classic Dobsonian $650
- Meade ETX-90 Highly portable computerized Maksutov-Cassegrain $560
- Explore FirstLight 130mm Newtonian with iEXOS-100 Equatorial Mount $800
- Celestron StarSense 8" Dobsonian with computerized object locator $800
- Orion SkyQuest XT8i 8" Dobsonian with computerized object locator $900 [unavailable]
- Explore FirstLight 127mm Doublet Refractor $1000
- Celestron NexStar6SE 6" Catadioptric with computerized mount $1100
- Meade 8" ACF LX90 8" Schmidt-Cassegrain w/ GPS computerized mount $3100
- Celestron CGX-L 11 Inch EdgeHD 11" Schmidt-Cass w/ computerized mount $6800

In addition to new telescopes, you can often find good used telescopes on several websites. As always, let the buyer beware. Those sites dedicated to astronomy and telescopes tend to be more reliable sources. A few such sites are:

- Ebay.com: Of course you can find scopes here, but be careful.
- Cloudynights.com: Look in the "Classifieds" section for scopes for sale. In addition to the Classifieds section, this site has forums for posting questions, as well as a Articles & Reviews section. You can sign up as a member for free.
- Astromart.com: This site has both "Classifieds" and "Auctions" sections as well as articles, reviews, and forums. The cost to be a member is $15/year. You must be a member to buy or sell.

My Personal Recommendation

I'm often asked to recommend a telescope for first time buyers. I know everyone wants a good quality telescope at an affordable price that is easy to use, with a mount that automatically finds difficult targets, and produces images that make the Hubble Telescope weep. Sorry… it ain't gonna happen.

While I understand the need to keep costs low, I also don't want to see someone spend $200-$300 on a telescope that produces poor images or that they'll outgrow in a year or two and then decide to spend another $1000 on something more substantial. Either way, the poor first scope ends up stuffed in a closet for the rest of eternity. Likewise, if you spend too much and buy an expensive large automated telescope before you have experience in navigating the night sky, you may end up spending most of your time trying to figure out how to set up your scope and get it to work while a simpler scope will get you observing quickly.

I also know that the difficulty of finding faint objects and the frustration that it can cause will often lead to giving up on astronomy. I hate to see someone leave it simply due to having expectations set too high in the beginning. Astronomical observation takes time and patience to master, but with the right guidance and equipment, learning can be fun and building on success in using your new telescope can be very rewarding.

The scope I recommend is the Orion SkyQuest XT8i IntelliScope Dobsonian Telescope.

This scope and the entire line of IntelliScopes are currently not available or in limited supply due to supply chain issues! An Orion support person told me they plan to offer them or similar scopes in the future once the issues are resolved.

It has an 8" mirror, which is big enough to enjoy for a lifetime. It's built on a Dobsonian mount that provides good stability at low cost. It has a computer assistant that allows you to find advanced level objects with ease. The computer assistant doesn't have motors to make your scope "Go To" its target. Instead, when a target is entered into the computer assistant, the display provides a numerical readout that tells you how far to push the telescope to find your target. Once you "Push To" the correct spot, the readout will display "0, 0" and you're on the target. The scope can also be operated completely manually without computer assistance. It breaks down into only two pieces, each about 20 lbs, so setup is easy. The computer assistant uses only a 9V battery that lasts a long time since it doesn't have to power motors to move the scope for you.

The XT8i is currently priced at $900, which is a significant increase in price from a year ago when it was less than $700, there is an image below. You can find it here:
https://www.telescope.com/Telescopes/Dobsonian-Telescopes/IntelliScope-Dobsonians/Orion-SkyQuest-XT8i-IntelliScope-Dobsonian-Telescope/pc/1/c/12/sc/27/p/102012.uts?refineByCategoryId=27

2022 Recommendation: Celestron StarSense Explorer 8” Dobsonian

The optics are very similar to the Orion Intelliscope and the push-to operation is also included, but even easier! Instead of using a dedicated handpad controller for the push-to, the StarSense line uses sky recognition technology through your smartphone to analyze star patterns overhead and calculate the telescope’s position in real-time. It breaks down into two pieces, each weighing about 20lbs, so it’s rather easy to transport.

The price is $800.

References

1. “Have Telescopes, Will Travel with John Dobson” Part One, video, YouTube: https://www.youtube.com/watch?v=ght_w7BAHaA&feature=youtu.be&t=8m27s
2. The Historical Development of Celestial Co-Ordinate Systems”, John Wooley, Astronomical Society of the Pacific, 1942, http://adsbit.harvard.edu/full/1942PASP...54...77W