

YOUR FIRST TELESCOPE



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Introduction

So you would like to buy your first telescope, but aren't sure where to go to buy one or which style to purchase. You saw one in the toy or hobby store, but the clerk there could only tell you it costs \$99.99 and knew nothing about how it works. So you took the next step and went to a camera store and the sales person asked if you would prefer a reflector, refractor or catadioptric style; and, if he or she really knew their stuff, they began introducing terms like, focal length, focal ratio, primary mirror or objective lens. Although you kept your poise and nodded your head in an affirming manner, you really had no idea what they were talking about.

To buy a relatively good telescope at a reasonable price you really need to understand some telescope terminology so you have a feeling about what is on the market, how it might fit your needs and how to understand sales personnel who are describing the features of the scope.

The EMDSO astronomy club presents this information in the following article. We hope this information will help you in understanding telescope basics and some of the more popular designs on the market today.

One should note that all of the information presented in this document is accessible on the internet and in many publications in book stores. Nothing within this document is proprietary, but it is all gathered in one document that is meant to provide the first time telescope buyer a synopsis of what is available on the market without the pressure that some sales people might put on you as a customer.

Telescope Basics

To understand telescopes one must first understand that the purpose of a telescope is to **gather light** from the object being viewed, **focus** that light, and **magnify** it so the object's details can be seen. Notice that the first component is to gather light. If you don't gather enough light, high magnification won't matter. In fact higher magnification darkens the object every time, so your telescope needs to have enough light gathering capability for you to magnify the object.

The ability of a telescope to gather light is directly proportional to the diameter of its **aperture**, which is the opening that allows light from the object being viewed to enter the telescope optical tube so it can be focused. Generally speaking, the larger the telescope's diameter, the more objective light will be gathered, so users have to decide on the practicality of the size and cost of their ideal telescope.

The magnification of a telescope is important and is determined by the ratio of the **telescope's focal length (F.L.)** divided by the **focal length of the eyepiece (f.l.)** which is used to magnify and focus the object for our eyes to see.

$$\begin{aligned} \text{Mag} &= \frac{\text{Focal Length Telescope (mm)}}{\text{Focal Length Eyepiece (mm)}} \\ &= \frac{\text{F.L. (mm)}}{\text{f.l. (mm)}} \end{aligned}$$

Equation 1

The focal length of the telescope is determined by the light bending design of the **objective lens** or the **primary mirror** and is measured from the point where light bending or reflecting begins and ends at the **focal plane** where the light rays cross. These concepts are discussed in more detail under the different styles of telescopes presented later.

So a typical 4”(101 mm) telescope with a focal length of 24” (610 mm) and viewed through a 25 mm eyepiece will have a magnification (Mag) = 610 mm/25 mm = **24.4 X** or, rounded off, 24 power. This means the object is 24 times larger through the telescope than what your eyes can see without the telescope. If the eyepiece is changed to a 15 mm lens, the magnification will be 610 mm/15 mm = **40.6 X** or, rounded off, **40 X**, which is 40 times larger than what your eyes alone can see. But remember, the higher magnification darkens the object, so if you continue to reduce the eyepiece focal length you will eventually get to a point where the object is too dark to be seen through the telescope.

Increasing magnification also fills up the aperture window with the object being studied. This can be a serious problem in small aperture telescopes, since the turning earth tends to move the object out of the viewing window, more commonly called the **Field of View (FOV)**, as fast or faster, than one can adjust the telescope to keep the object in the FOV. Also the higher magnification forces the scope to be looking at a much smaller section of sky, which further exacerbates the effort to keep the object in the scope's FOV.

A final problem with high magnification is in focusing the object. Even if you splurge and buy a telescope with tracking capability, you still have to adjust the eyepiece to bring the object into focus. Every time you touch the focus knob, you impart a small disturbance to the telescope, which generates vibrations that blur the objects appearance. The smaller the telescope the more pronounced is this vibration and high magnification only serves to amplify this problem. So it is often very difficult to manually focus an object with a high magnification lens.

When a manufacturer designs a telescope's focal length they do so by creating curvature in the objective lens or the primary mirror. This curvature is defined by the focal ratio, which is the ratio of the telescopes focal length to its aperture. The aperture of the telescope is the diameter of the **objective lens** or the **primary mirror** and is generally close to the inside diameter of the telescope barrel. It is generally displayed as **(f/#)** and read as **(f number)**. An **f/5** design means that the focal ratio is equal to **5**. An **f/10** means that the focal ratio is equal to **10**.

$$\text{Focal Ratio (f/\#)} = \frac{\text{Focal Length Telescope (mm)}}{\text{Aperture Diameter (mm)}} = \frac{\text{F.L.}}{\text{A.D.}}$$

Equation 2

With Equation 2, one can calculate the focal length of a telescope if he or she knows the focal ratio and the aperture size.

$$\text{Focal Ratio} = f/5; \text{ Aperture} = 3" = 76.2 \text{ mm} = \text{A.D.}$$

Find Focal Length F.L.

$$f/\# = \frac{\text{F.L.}}{\text{A.D.}} \Rightarrow \text{F.L.} = f/\# \times \text{A.D.} = 5 \times 76.2 \text{ mm} = 381 \text{ mm}$$

Telescope Mounts

When viewing the skies through any telescope, it is highly advantageous to have the scope mounted on a tripod for stability. Most telescopes today are mounted on a variation of the **Alt-Azimuth tripod**, which is a tripod that allows the user to adjust both the horizontal (altitude) axis and the vertical (azimuth) axis with hand dials, electronic controls or just pushing the telescope barrel.

More sophisticated telescopes may also come with **Equatorial Mount tripods**, which allow the observer to set the telescope at the latitude of the observing location so the scope only has to be adjusted from east to west once a celestial object has been positioned in the telescopes viewing window (FOV). These mounts can be expensive since they are frequently accompanied by small DC synchronous motors that automatically move the telescope's optical tube across the sky at the same speed the earth is turning, virtually locking the object in the telescopes FOV. These mounts are called **Tracking Mounts** since they track the celestial object across the sky once they are found.

More expensive tracking mounts include a computerized hand control that features 40,000 or more celestial objects programmed onto the celestial grid. Once properly aligned, telescopes on mounts with these programmed hand controllers will move the optical tube to the sky location where the object, requested through the control, resides. These mounts are called **Go-To** mounts since they go to the object you request through the hand control.

A very popular mount used by many amateur astronomers for reflector telescopes is the **Dobsonian Mount**. This mount is actually an Alt-Azimuth mount that consists of a swivel table that sits on the ground with an easily movable telescope barrel. Most of these mounts are manually operated but some can be rigged up as a "**Tracking**" or "**Go-To**" mount.

The telescope mount that accompanies a beginner telescope is generally the Alt-Azimuth tripod mount. The adjustment knobs that move the altitude and azimuth on beginner models are generally stiff and of poor design. As the quality of the telescope increases, however, the quality of the mount generally follows. Some of the more expensive telescopes require that you buy the mount separately. Separate mounts can vary in cost from as low as \$200.00 to \$10,000 or more.

Now that we know a bit about telescope basics, it is time to look at some of the more popular designs in the market today.

Refractor Telescopes

The refractor telescope was the original design used by Galileo and people of his era around 1610 AD. The original design included just two lenses, a plano-convex objective lens in front and a plano-concave secondary lens at the rear. Plano-convex means the lens has a plane shape on one side and a convex shape on the other, while plano-concave means the lens has a plane shape on one side and a concave shape on the other. Some Galilean designs may vary the plane sides of these lenses, but for our discussion we will concentrate on the design shown in Figure 1.

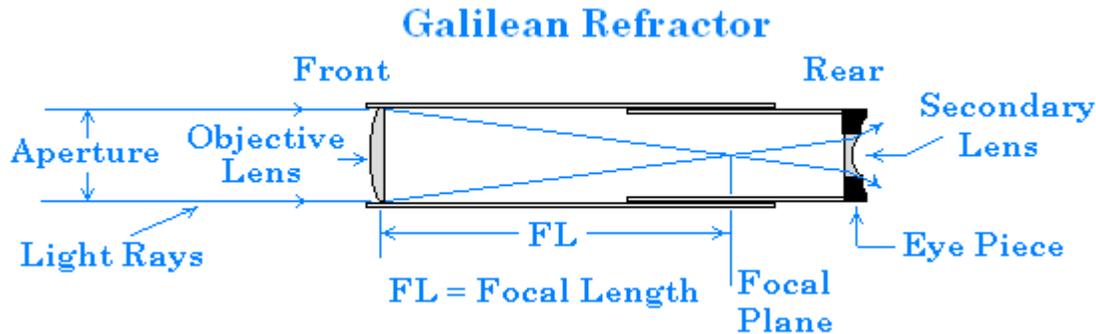


Figure 1

In this design, light from the observed object is bent as it passes through the objective lens to a focal plane inside the telescope barrel. We talk about a focal plane because light colors do not all focus at a common point. Different colors focus at different points on an imaginary plane inside the telescope tube. The light rays then continue beyond the focal plane to the secondary lens which slightly increases the bending light before entering our eyes. The bending from the secondary lens provides the magnification of the object being viewed. Since the light rays exchange places at the focal plane, top becomes bottom and bottom becomes top, the object being viewed appears upside down when observed through the eyepiece.

The original refractor telescopes had problems with objects being out of focus at the peripheral ends of the field of view (spherical aberration), as well as blue and red colors being distorted (chromatic aberration). To correct these problems, telescope manufacturers developed a compound Objective Lens Assembly (OLA) by combining a bi-convex lens with a bi-concave lens and separating them with an air space. (See Figure 2). These lenses also have different qualities of glass which help in the bending of the colored light as it passes through them.

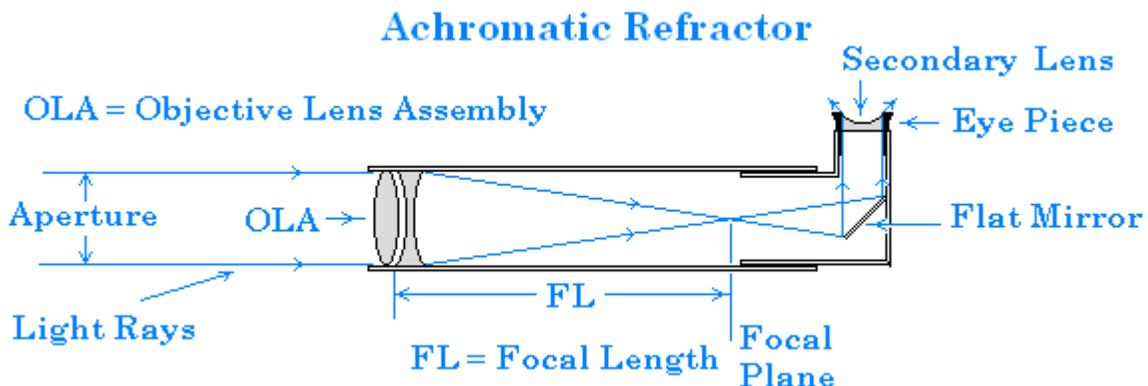


Figure 2

The first OLA's were named **Achromatic** lenses and helped reduce spherical as well as chromatic aberrations in the original refractor designs, however, they didn't remove all aberrations. So a more advanced **Apochromatic** OLA was developed, which introduced a plano-convex lens behind the bi-concave lens in the achromatic design. This addition further reduced both aberration problems and is featured in the more expensive refractors on the market today. Of course these lenses add significantly to the overall cost of the telescope.

The design shown in Figure 2 not only shows the OLA but also a revised rear design for easier viewing of celestial objects when the telescope is mounted onto a tripod or other mount. This eyepiece adaptation is called the eyepiece prism and uses a flat mirror to redirect the image so the observer doesn't have to position themselves below the telescope to make observations.

The refractor telescope design is also used in field scopes like binoculars, survey scopes, visual aids on long range hunting rifles and a host of other viewing apparatus. These field scopes introduce additional lenses or mirrors to flip the viewed object so it appears upright to the viewer. Celestial scopes, however, don't bother with righting the view since there is no upside down in space and the additional adjustments add cost and weight to the telescope.

Costs of Refractor Scopes:

The costs of refractor telescopes are very reasonable for the beginner models, but they rise at a phenomenal rate as the objective lens and the aperture increases in diameter. Beginner scopes with inexpensive lenses are available in aperture sizes of 50mm (2") to 76mm (3") in diameter, and new scopes can be purchased in the **\$100 to \$150** price range. The price for one of these scopes can be drastically reduced if they are purchased second hand. These inexpensive scopes can be purchased from retail camera stores, some toy and hobby stores and on the internet. They are capable of observing the moon, some of the planets, large nebula like Orion, the large galaxy Andromeda, and large open clusters of stars like Pleiades.

More expensive refractors also begin at around 50mm, but with the increased quality of the lenses, filters, equatorial mounts and host of other attachments, they can quickly approach **\$1,000** or more.

Some low cost telescopes checked in March of 2009 are listed below:

Orion Observer 60mm with Alt-Azimuth tripod; 2.3" Objective lens -- **\$100.00**

Orion Astroview 90mm with Equatorial mount; 3.5" Objective lens -- **\$329.00**

Celestron NexStar 102 SLT with Alt-Azimuth tripod; 4.0" Objective lens -- **\$500.00**



Inexpensive 50mm (2") Refractor Telescope
Mounted on Alt-azimuth tripod

Newtonian Reflector Telescopes

The reflector telescope design was developed by Sir Isaac Newton in 1669, to solve the problem of spherical and chromatic aberrations inherent in the refractor type telescopes. This design substitutes a spherical concave mirror in place of the objective lens of the refractor scopes. Since light does not pass through the mirror it is not subject to variations in wave length bending, therefore, chromatic aberration problems cease to exist. (See Figure 3)

Unlike the refractor telescope, the aperture allows light rays to enter the optical tube (OPT) and strike the primary concave mirror located at its rear end. The light rays are then focused by their angled reflection back toward the front end of the OPT. As the light rays near the front they are deflected by a flat mirror toward the eyepiece. The eyepiece contains a lens which magnifies the image as in the refractor scopes. The focal plane of the light rays does not occur until after the rays are reflected off the flat mirror toward the eyepiece; therefore, the total focal length of the light is measured from the primary mirror to the flat mirror plus the extra length until the focal plane is reached.

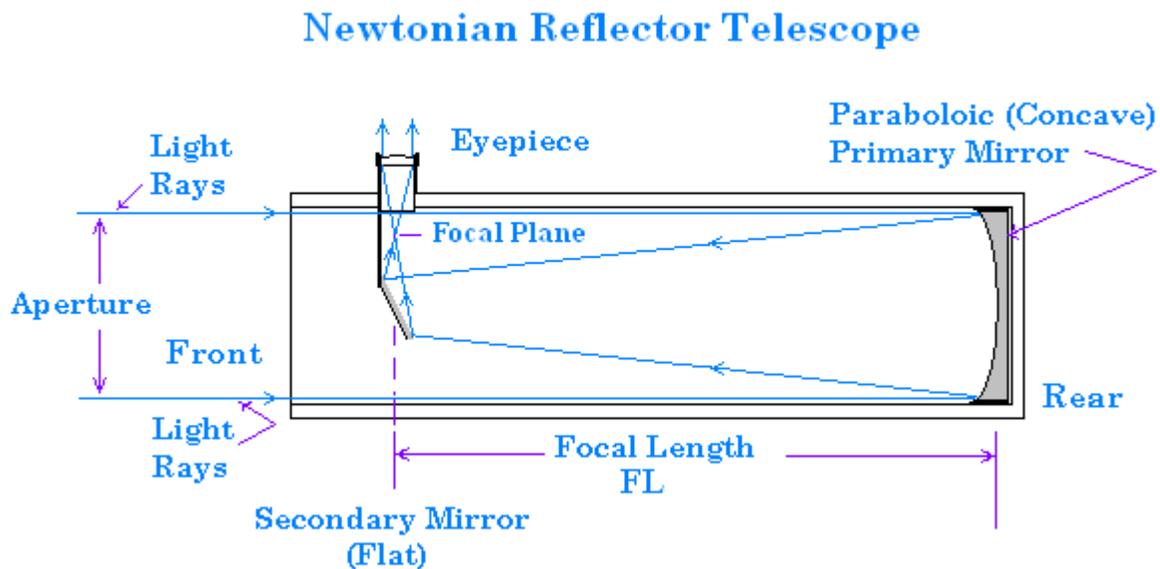


Figure 3

As with refractor scopes, this style of scope has to be mounted on an alt-azimuth or equatorial mount tripod or on a Dobsonian mount. The Dobsonian mount is an alt-azimuth type of mount which consists of a swivel table that sits on the ground with an easily movable telescope barrel. Most of the large diameter amateur reflector telescopes come on Dobsonian mounts. The main difference to the viewer, however, is that the observer views the sky through an eyepiece at the front of the telescope instead of the rear as is done on the refractor scopes.

Costs of Reflector Telescopes

The cost of a beginner reflector telescope is in the same price range of a beginner refractor scope which is around **\$100.00**. This usually includes a telescope with a 3" primary mirror and a mounting tripod. As with the beginner refractor telescope, this size scope will usually allow viewing of the

moon, some planets, large diffuse nebulas, large open clusters like Pleiades and the Andromeda galaxy (M31).

As the size of the aperture and mirror increases, the price of the scope will increase accordingly; but the increase will not be as drastic as with refractors. For this reason, many amateur astronomers upgrade from their small scopes to larger reflector telescopes. It is not uncommon to see 8" (203 mm), 12" (305 mm) or 14" (356 mm) diameter reflector telescopes at star parties. Telescopes with these size apertures open a host of dim objects in the sky like the Ring Nebula (M57), the Dumbbell Nebula (M27) and the Crab Nebula (M1), as well as the more subtle galaxies like the Whirlpool galaxy (M51), spiral galaxies like (M81) or irregular galaxies like (M82). Refractor telescopes with these aperture sizes would run in excess of **\$10,000.00** apiece, where Reflector telescopes in this range cost between **\$900.00** and **\$2,500.00**.

Below are listed samples of some inexpensive reflector type telescopes found on the internet in March, 2009:

Orion Space Probe 3 with alt-azimuth tripod – 3" Primary Mirror -- **\$100.00**
Celestron Astromaster 114 – with equatorial mount – 4.5" Primary Mirror -- **\$177.00**
Orion Starblast 6 with alt-azimuth swivel base – 6" Primary Mirror -- **\$250.00**

These examples should be an indication that larger aperture telescopes are more reasonable in the reflector designs than the refractor designs.

Catadioptric Telescopes

The catadioptric telescope design combines both refractor and reflector characteristics. It includes a front corrector plate, a combination of three mirrors and an eyepiece lens to gather, focus and magnify the light from a celestial object. Where the Refractor and Newtonian telescopes use the length of the telescope barrel one time to establish the focal length of the scope, a catadioptric telescope uses the telescope barrel twice to establish the focal length. This has the double effect of increasing the magnification of celestial objects while decreasing the length of the telescope barrel. The two most popular designs included under the catadioptric heading are the Schmidt-Cassegrain and the Maksutov-Cassegrain telescopes.

Schmidt-Cassegrain

A Schmidt-Cassegrain telescope (SCT) uses the design shown in Figure 4 to establish the above feat.

The light first enters the front of the telescope through the aperture's glass corrector plate which insures the light rays are bent in such a manner that all rays meet a common focus point after reflection. When the light strikes the spherical, concave primary mirror mounted at the rear of the optical tube, the focusing process begins. The light is reflected at an angle back toward a secondary convex mirror mounted on the interior side of the corrector plate. This mirror reflects the light a second time back towards a hole at the center of the primary mirror where the telescope's eyepiece assembly, known as a prism is located. On its way to the prism the light passes through a Baffle Tube which shields the eyepiece prism from unwanted light reflections from the primary mirror. Inside the eyepiece prism is a flat mirror that reflects the light toward the eyepiece lens. This last reflection

causes the light rays to reach the focal plane before actually entering the eyepiece lens. The focal length of the telescope begins at the primary mirror, extends to the secondary mirror, then back toward the primary mirror, through the baffle tube and ends at the focal plane. So the barrel of the telescope is traversed twice to establish the focal length of the telescope.

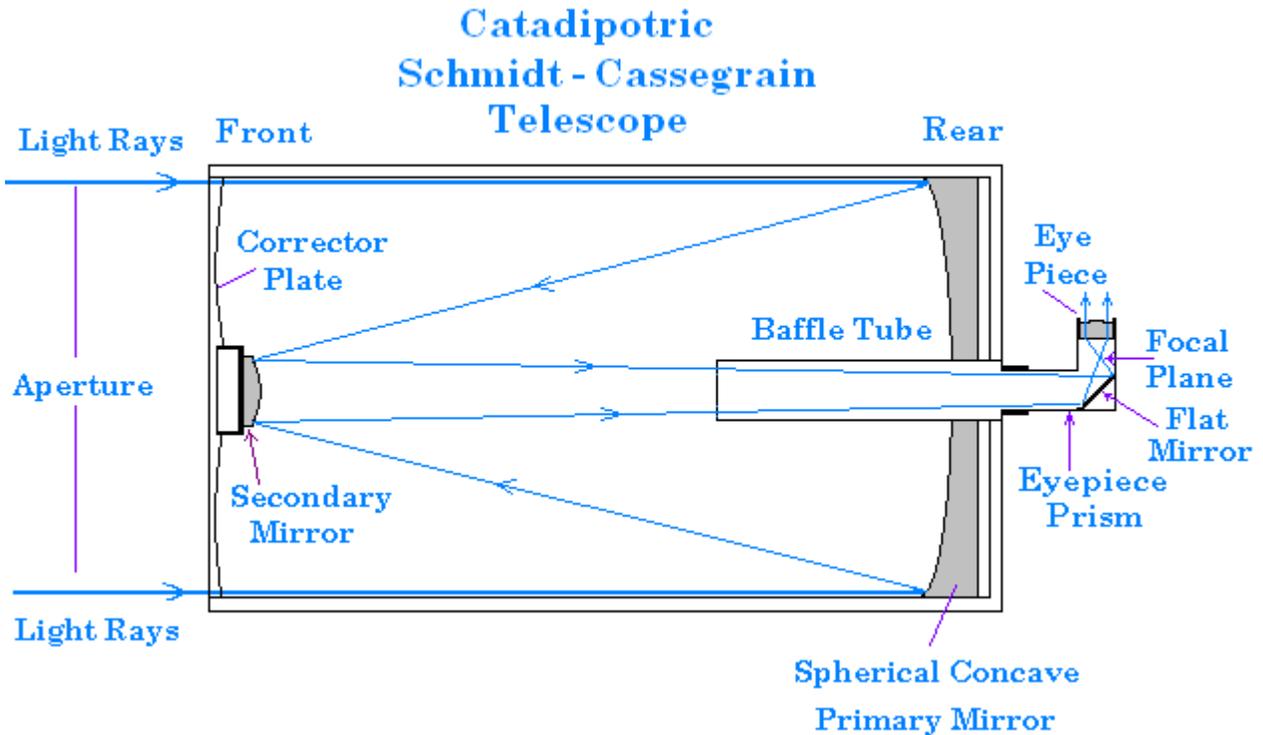


Figure 4

Maksutov-Cassegrain

A Maksutov-Cassegrain telescope is almost identical to the Schmidt-Cassegrain design except the corrector plate is a concave piece of glass that is used to correct the incoming light rays. (See Figure 5) The inside center of the corrector plate is silver coated to provide the secondary convex mirror to reflect the light from the primary mirror. Other than that, the operation is the same as the SCT.

As with both the refractor and reflector telescopes, these telescopes need to be mounted on alt-azimuth tripods, equatorial tripods or equatorial piers for some of the larger designs.

The catadioptric telescope design quickly gets into the high end telescopes for the more serious observer. Their apertures begin at around 3" (76 mm), but 8" (203 mm) through 16" (406 mm) apertures are readily available on the internet. Many of these telescopes come with equatorial mounts and have tracking and go-to capability for astro-imaging.

The biggest draw back to the large apertures in these telescopes is the weight. The optical tube of a Meade 12" diameter LX200 mounted on its Fork weighs 84 lbs and requires two people to place it onto the tripod. When mounted on a super wedge and a tripod the assembled telescope weighs over 150 lbs. For this reason many of these scopes are bought for small to mid size observatories.

Catadioptric Maksutov - Cassegrain Telescope

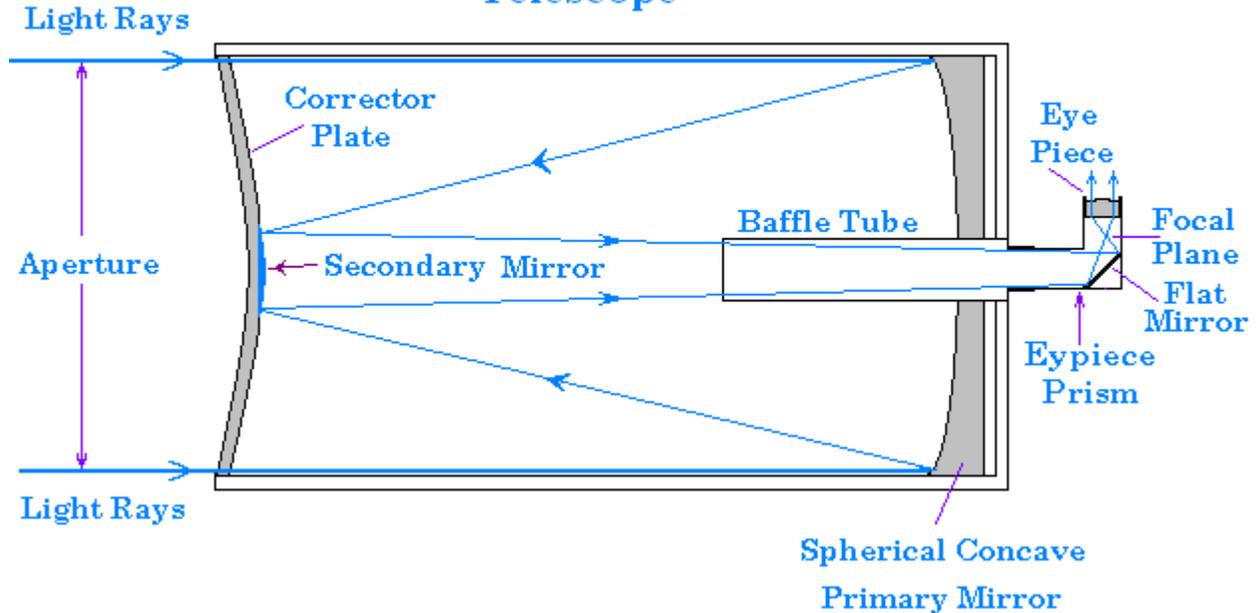


Figure 5

Costs of Catadioptric Scopes

These telescopes are generally not at the beginning end of the telescope procurement spectrum. With the glass corrector plates, two glass curved mirrors, a flat mirror, eyepiece lenses and a tripod, the cost can very quickly get into thousands of dollars particularly when their mounts include the go-to capabilities. However, there are some beginner models now showing up on the internet as shown below:

Orion – Apex 90mm Min-Eq Mak-Cass; 3.5” (90 mm) aperture, with mini equatorial mount -- **\$250.00**
Orion – StarMax 90mm; 3.5” (90 mm) aperture, f/10, with standard equatorial mount -- **\$330.00**
Celestron – NexStar 5SE; 5” (127 mm) aperture, f/5, with alt-azimuth go-to mount -- **\$800.00**

Conclusion

Hopefully the information presented in this document has provided you with a better understanding on telescope basics, some of the popular telescope designs on the market today and some of the terminology you may run across while researching the telescope that fits your life style and pocket book. So now all you have to do is go to some star parties and evaluate the scopes others have already bought and perhaps purchase one yourself. Good luck and happy viewing!