Buying Binoculars & Telescopes

TCAA Guide #7

Carl J. Wenning

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VERSION 1.1

OCTOBER 14, 2017

ABOUT THIS GUIDE:

This *Buying Binoculars & Telescopes* guide – the seventh of several such TCAA guides – was created to help answer questions about amateur astronomy. The other guides, available online at http://tcaa.us/TCAAGuides.aspx, deal with a variety of interesting and useful topics:

Guide #1 – INTRODUCTION TO AMATEUR ASTRONOMY

This guide addresses the basics that everyone needs to know in order to become an amateur astronomer. It deals with the use of eyes, binoculars, and telescopes to view the night sky. It should not be mistaken for a textbook in astronomy.

Guide #2 – MEMBERSHIP AND BENEFITS

Even long-time members do not know everything they need to know about membership in this club. Many benefits are overlooked and this publication does what it can to clearly illustrate the benefits of membership.

Guide #3 – ASTRONOMY AS A HOBBY

Why is it that we don't attract as many amateur astronomers as we would like? Our club has lots of great benefits, and it's more the just lack of knowledge of benefits. Part of the problem today stems from the fact that many people don't understand the meaning of a hobby and the benefits derived from it.

Guide #4 – THE ART OF SKY INTERPRETATION

Interpreting the sky requires more than just standing in front of a group of people and talking. If it were that easy, there would be many more speakers in our club! There is an art of sky interpretation, and this guide describes it. Even if one doesn't intend to give public talks, this guide provides a wealth of information about what can be seen in the sky with the unaided eye.

Guide #5 – COORDINATING OBSERVING SESSIONS
While coordinating observing sessions might appear to be an easy task to those who attend them, there is considerable background work associated with both public and members-only sessions. Consider hosting an observing session and use this guide to assist.

Guide #6 – HAVE A SUCCESSFUL OBSERVING SESSION
This guide is a reproduction of an article by the same name that appeared in the September 2017 issue of AL's Reflector magazine. This guide provides information about the seven **p**'s required for having a successful observing session: **p**assion, **p**reparation, **p**rograms, **p**lanning, **p**erseverance, **p**atience, and **p**resentation.

ABOUT THE AUTHOR:

Dr. Carl J. Wenning is a well-known Central Illinois astronomy educator. He started viewing the heavens with the aid of his grandfather in the summer of 1957. Since that time, he has continued viewing the night sky for six decades. He holds a B.S. degree in Astronomy from The Ohio State University, an M.A.T. degree in Planetarium Education from Michigan State University, and an Ed.D. degree in Curriculum & Instruction with a specialization in physics teaching from Illinois State University.

Dr. Wenning was planetarium director at Illinois State University from 1978 to 2001. From 1994-2008 he worked as a physics teacher educator, directing the University's Physics Teacher Education Program. Retiring in 2008, he continued to teach physics and physics education courses for an additional six years. He also taught astronomy and physics labs almost continuously at Illinois Wesleyan University from 1980 to 1999. He fully retired from Illinois State University in 2014 after nearly 40 years of university-level teaching, but returned to teaching there in 2017.

Carl became associated with the TCAA in September 1978 – shortly after he was hired to work at Illinois State University. Today he is an Astronomical League Master Observer (having completed 14 observing programs to date) and received the 2007 NCRAL Region Award for his contributions to amateur astronomy. He is a lifelong honorary member of the TCAA and is a member of its G. Weldon Schuette Society of Outstanding Amateur Astronomers. During August 2017, he received the Astronomical League's *Mabel Sterns Newsletter Editor Award.*

A WORD OF THANKS

The author wishes to express thanks to fellow TCAA member Sharon MacDonald for providing valuable insights for the improvement of draft version of this publication.

Buying Binoculars & Telescopes

CAVEAT EMPTOR – LET THE BUYER BEWARE: Buying a telescope is an exciting prospect. Unfortunately, the purchase and use of a poor-quality toy telescope will result in difficulty, frustration, anger, and ultimately a loss of interest in telescopic sky watching. It is important, therefore, to know how to purchase the proper type of telescope before doing so. Avoid throwing money at the problem, and just buying the first thing that looks interesting – even if it is expensive. Many are the people who have purchased expensive, seemingly sophisticated telescopes only to end up with a useless piece of junk rather than an instrument that can serve their interest for a lifetime. The only legitimate way to enter amateur astronomy is to spend time learning about the subject and carefully reviewing what the experts have to say about which are the best telescopes to buy. Throwing money at this exciting hobby is not the way to become immersed in it. This essay will give some basic information. Please read this entire document as you endeavor to purchase your "dream" telescope. Also, very seriously consider reading other publications in this series before committing yourself to this potentially rewarding hobby.

Binoculars vs. Telescopes

Many would-be amateur astronomers are disappointed when I suggest that the first thing they should consider purchasing for sky watching is a good set of binoculars and an observing guide. They are clearly of the opinion that "high power" is all that one needs to see things in the sky. The fact of the matter is that many low-surface-brightness objects and/or objects of large angular size are best viewed using low magnification, large aperture binoculars. There are several reasons for this. But first, let's consider a number of well-known celestial objects that are best viewed by northern hemisphere amateurs using low-power binoculars rather than telescopes.

- Galactic bulge
- Barnard's loop
- Rho Ophiuchi complex
- Hyades (star cluster)
- Andromeda Galaxy
- Veil Nebular / Cygnus loop
- Helix Nebula
- Trifid Nebula
- Witch Head Nebula
- California Nebula
- North American Nebula
- Beehive Cluster
- Scutum star cloud
- Rosette Nebula
- North American Nebula
- Pleiades
- Triangulum Galaxy
- Orion Nebula
- Perseus Double Cluster
- Coma Star Cluster (Mel 110)
- Alpha Persei Cluster
- Veil Nebula

While most binoculars and spotting scopes don't have the benefit of large aperture, they do have one thing that is critical to observing low-surface-brightness objects – low magnification. This might seem counterintuitive, but consider the following two facts:

Low magnification binoculars and spotting scopes can provide a much wider field of view than will a telescope. The field of view of say a Celestron 5" f/10 spotting scope is much larger than that provide by a Celestron 11" f/10 telescope given the same eyepiece. Let's say we have an 18mm eyepiece with an apparent field of view of 52° – typical of an inexpensive Plössl eyepiece. First consider the resulting magnifications of the two instruments using this particular eyepiece which is calculated by dividing the focal length of the objective (F) by the focal length of the eyepiece (f):

$M_{11''} = F/f = 2{,}794\text{mm}/18\text{mm} = 155.2\text{X}$ $M_{5''} = F/f = 1{,}270\text{mm}/18\text{mm} = 70.6\text{X}$

Next consider the true field of view given by the following formula: true field of view of an eyepiece (T) equals its apparent field (A) divided by magnification.

$T_{11''} = A/M = 52°/155.2\text{X} = 0.34°$ $T_{5''} = A/M = 52°/70.6 = 0.74°$

Hence, the field of view is more than twice as wide (with an area 4.7X as much) in the lower-power telescope. So, larger objects can more easily be observed (and found!) in lower-power instruments due to their larger fields of view.

Low magnification binoculars and spotting scopes typically provide a much brighter image than will a telescope. This statement might be surprising to would-be amateur astronomers. With larger aperture telescope lenses and mirrors, how can this be? The explanation has to do with the effect of magnification. Consider a typical human eye fully dilated to say 8mm. In comparison, an 11" (280mm) mirror can gather about 1,225 (35^2) times more light than can the fully dilated eye. However, when an image is magnified, the surface brightness of the thing observed is reduced. For instance, with my CPC 11" I most commonly observe at 87x. An object 87 times higher and 87 times wider will have a surface brightness of only 1/7,569 that of the non-magnified image (87^2). The object is therefore 1,225/7,569 times as bright as observed with the unaided eye! That is, the object is only 16.2% as bright as the real thing when observed with this telescope. Consider the effect of a 7x50 set of binoculars on apparent image surface brightness.

With each binocular lens gathering 39 times ($(50mm/8mm)^2$) the amount of light as the eye, each objective makes a diffuse celestial object 39 times brighter than seen with the unaided eye. At a magnification of 7x, the object is reduced in brightness to 1/49 the naked-eye view. This combination results in a comparative surface brightness of 39/49 or 79.6%. Hence, in comparison with the spotting scope cited, *binoculars* will produce an object nearly five times brighter in terms of surface brightness. This is critical when observing low surface brightness objects such as those in the list above.

Of course, this presentation is rather simplistic because it does not take into account such things as secondary aperture blocking, reflection of light by eyepieces, utility of higher magnifications in seeing greater detail, and so forth. Nonetheless, it does shine light on why higher-power telescopes are not always the best instruments for viewing objects of the heavens. This goes to explain why so many amateurs have telescopes of different apertures and designs as well as a variety of binoculars. No one telescope is suitable for observing everything in the sky.

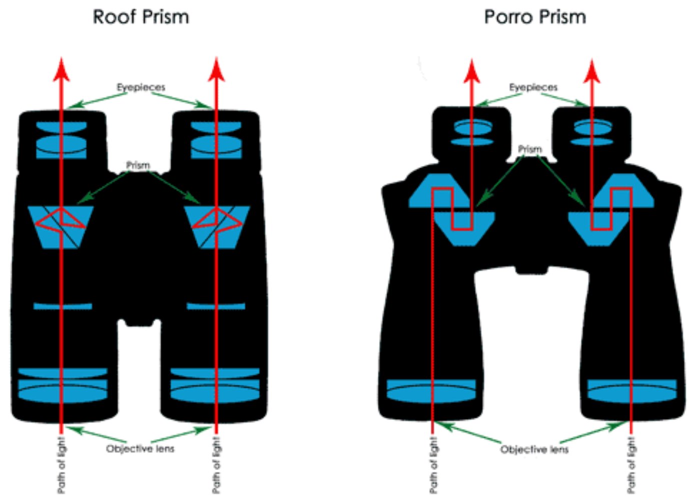
I hope that this explanation helps would-be and novice amateur astronomers gain a better understanding of the recommendation of binoculars and observing guides as the first place to start when purchasing astronomical viewing equipment. There has the added bonus, too, that binoculars can be used for much more than astronomical viewing should interest in sky watching wane.

What Type of Binoculars?

Okay, let's say that you are convinced that you want to purchase a set of binoculars and get to know the sky before buying your first telescope. This is a wise choice because binoculars have many advantages: (1) comparatively low cost, (2) wide field of view – making objects easier to find, (3) brighter images, (4) higher quality than an equally-priced toy telescope, and (5) usefulness for other purposes. Of course, there are some disadvantages: (1) no mount, (2) comparatively low power, (3) lower resolving power, and (4) harder to view directly overhead unless you are laying on the ground.

https://www.space.com/26021-best-binoculars.html

There is quite a variety of binoculars from which to choose, as well as a range of "add-ons" (e.g., image stabilization) and prices. The two basic types of binocular from which to choose are those with roof prisms and those with Porro prisms. These prisms do little more than erect an image – essentially rotate the image so that it is properly oriented. (With telescopes this is not a concern as there is no up or down in space.) Both types of binoculars are acceptable for both celestial and terrestrial use (such as watching wildlife or sporting events). It is more common in astronomy, however, to use the Porro prism form. In the images below you can see that the light passing through a roof prism reflects 5 times from optical surfaces. With the Porro prism, the light reflects only 4 times yielding a slightly brighter image. This is so because every time light reflects off a surface, some light is lost. So, if you want to be serious about observing the sky, the Porro prism type binoculars would be a better choice, though roof prism binoculars are still acceptable.



How Much Aperture?

When it comes to observing objects in the night sky, the bigger the aperture the better. Larger aperture (the size of the light gathering lens) is to be preferred over smaller aperture. (Of course, this assumes that one is viewing under a dark sky. If one is viewing under a light-polluted sky such as a town or city, one picks up more light pollution which offsets the benefits of increased aperture.) Larger aperture will allow you to see fainter objects under a dark sky, as well as to show it in somewhat finer detail. Of course, with increase aperture, comes increased cost.

The minimum aperture for viewing celestial objects should be about 50mm. Apertures smaller than this (e.g. 30mm or 40mm) are acceptable, but such binoculars are really intended for daytime use. As the size of the aperture goes up, so does the cost. I own a set of 20x100 binoculars. These essentially are two telescopes fitted side by side, and require the use of a stand due to the higher magnification. Higher magnification is better in many cases, but keep in mind that magnification not only magnifies the object being observed, but it also magnifies the "vibrations" caused by your unsteady hands.

How Much Magnification?

Common magnifications for celestial binoculars are 7X, 10X, 15X, 20X, and 25X. Magnifications generally increase with increasing apertures: 7X50, 10X50, 15X70, 20X100, 25X100 and so forth. Most beginners (and those with limited budgets) might want to stick with 7X50 and 10X50 binoculars. Any magnification above that really requires mounting brackets and observing stands (an example of which is shown to the right) that can run into the hundreds of dollars. Leave the larger aperture binoculars to the pros.

http://www.telescope.com/

Binocular Observing Programs

Perhaps you never realized it, but the Italian astronomer Galileo Galilei shook the foundations of the solar system by using telescopes with low magnification and small aperture – not much more, but certainly not as good as today's ordinary binoculars. Galileo's telescopes were of poor quality not having lenses that were free of chromatic and spherical aberrations – things you need not worry about with a good set of modern binoculars.

You can either set out viewing the night sky using a book as a guide (see below), or take advantage of the offerings of the Astronomical League. The Astronomical League – an American association and the largest group of amateur astronomers in the world – has a wonderful set of binocular-based observing programs for the budding amateur astronomer, each with its own observing guide that shows what to look for and where to find it.

The A.L.'s *Binocular Messier Observing Program* is for beginning observers as well as experienced amateurs. Beginning observers will find that it doesn't take an expensive telescope but only a simple pair of binoculars, no matter what size, cost or condition, to do serious astronomy. On the other hand, experienced amateurs, even though they may already have the A.L.'s telescopic Messier and Herschel certificates, will enjoy the new perspective binocular observing gives them as they pull back from an object and observe the area around that object as well as the object itself. Seeing the object and its relationship to the sky around it will put that object in its proper context in the sky. This program also has an observing award for those who are members of the Astronomical League. Membership in the TCAA automatically includes AL membership. (See https://www.astroleague.org/search/node/binocular/.)

There are also binocular and small telescope observing guides available at area bookstore or online. I recommend the following:

- *Viewing the Night Sky through Binoculars* by Michael E. Bakich, a free e-guide offered by *Astronomy* magazine.
- Stephen James O'Meara's *Observing the Night Sky with Binoculars: A Simple Guide to the Heavens*
- *Touring the Universe through Binoculars* by Philip Harrington

Be sure to read the closing paragraphs of this guide for information about useful assistance that can be obtained by joining a local astronomy club. Many clubs have viewing sessions at which they are willing to assist the new sky watchers. Some even offer courses in amateur astronomy. Also, don't forget to check out the other TCAA Guides to Amateur Astronomy that you can read on your own if your local astronomy club doesn't offer direct assistance.

WHAT TYPE OF TELESCOPE?

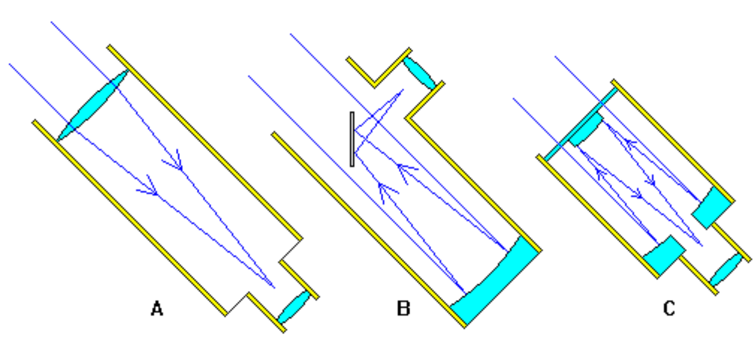
Okay, so you've decided to make the plunge and buy a telescope. Buying a good telescope requires that a buyer be well informed about what constitutes a good telescope. Not all telescopes are the same, and there are many deceptive practices used by some manufacturers and dealers to "move" telescopes. What they are doing, to some extent, is selling "snake oil." They are out to make a fast buck, and don't really care about what happens to the consumer. One of the best things that can be told a prospective telescope buyer is caveat emptor – let the buyer beware. (Fortunately, this isn't as much of a problem with binoculars.) Let's now consider the many factors that go into making a wise telescope purchase.

Terrestrial or Celestial Telescope?

Telescopes designed for sky watching are often, but not always, different from those designed for terrestrial use. Telescopes come with two basic types of mounts. Terrestrial telescopes will always come with non-motorized altazimuth mounts where the movement is up and down and left and right. Unfortunately, celestial motions are not as simple as that. Astronomical telescopes are designed to track the motion of the stars and will either come with computer assisted altazimuth mounts or equatorial mounts whose main rotation axis is aligned with that of Earth. Read about these mounts in the section **TELESCOPE MOUNTS** below.

Common Telescope Types

Telescopes come in a variety of types with a myriad of variations as shown in the figure below. The three most common telescope types used by amateur astronomers today, however, are the classical refractor (A), the Newtonian reflector (B), and the catadioptric of the Cassegrain design (C). Each type of telescope has advantages and disadvantages, and those looking to purchase a telescope should be familiar with each in order to make the best possible choice.



Reflecting telescopes have mirrors that gather light and create an image for viewing with an eyepiece. Refracting telescopes use a lens to do the same. Combinations of reflectors and refractors – catadioptric telescopes available in various designs – use combinations of lenses and mirrors to produce images for viewing. Reflectors are relatively inexpensive in comparison to refractors. A high quality 8-inch reflecting telescope might cost in the range of $1,000-$2,000; the same size refracting telescope could easily run $10,000 or more. When making a mirror for a reflecting telescope, there is only one optical surface to finish. The lens of a high-quality, color corrected (apochromatic) refractor will have 6 surfaces to finish, and the finishes much exactly match the adjoining lens' surface. The Schmidt-Cassegrain telescope (SCT) – a catadioptric – uses a single thin lens as a corrector plate and a modified mirror to accomplish the same task. The advantage of the SCT design is that one can compress a large telescope into a relatively small space. For example, a classic 8" f/10 reflector would have a tube over 7 feet long. A SCT with the same optical characteristics would be less than 2 feet long.

Telescope Type	Advantages	Disadvantages
 **A) Refracting telescopes…** are probably the most common telescope around generally speaking. They use lenses instead of mirrors and the eyepiece is located at the bottom of the telescope. Their design is similar to binoculars and most spotting scopes. Astronomical refractors typically will have a diagonal prism or mirror just in front of the eyepiece to change the path of light by 90° making it possible to look down rather than upward through the eyepiece. With the use of a diagonal prism or mirror, images are semi-inverted due to the use of an odd number of reflecting surfaces. The objective lens must be either achromatic or apochromatic to avoid chromatic aberration. A single element lens is unsatisfactory for astronomical applications because of the resulting chromatic aberration that produces color fringes around celestial objects.	Easy to use due to the simplicity of design. Excellent for lunar, planetary, and binary stargazing. Sealed tube protects optics and reduces image-degrading air currents. Rugged, needs little or no maintenance. Its sealed tube partially protects the objective's surface from contaminants. Often come with "erector prism" that can reorient images of terrestrial objects so they can be seen properly (as with binoculars or a spotting scope).	Generally available only in small apertures, typically 2¼ to 6 inches, due to high expense of production. High quality refractors cost more per inch of aperture than any other kind of telescope. Smaller apertures mean poorer viewing of faint objects such as galaxies and nebulae. Heavier, longer, and bulkier than reflector and catadioptric telescopes of equal aperture. Objective lens is subject to dew and frost without the presence of a dew shield or lens heater. Most toy telescopes are of this design. Caveat emptor – let the buyer beware.

 **B) Reflecting telescopes…** use a mirror instead of a lens to gather light and form an image. The eyepiece is located at the side of the main tube near the top. Depending on the type of mount used, the eyepiece can sometimes appear below the telescope tube necessitating the observer to rotate the telescope in its mount to bring the eyepiece to the top. The problem is acute if an equatorial mount is used. Images are always fully inverted – flipped top to bottom and left to right – due to the use of an even number of reflecting surfaces. These telescopes are commonly available with computerized altazimuth mounts (above from left to right), manual German equatorial mounts, and Dobsonian push-to mounts. Mirrors must be parabolized to at least "¼ wave" in order to avoid obvious spherical aberration which results in the impossibility of completely focusing on an extended object.	Readily available in larger apertures and at low cost compared to other telescope types. "Light buckets" usually have larger apertures providing excellent views of faint galaxies and nebulae. Short focal length systems can deliver larger fields of view and brighter images. A reflector costs the least per inch of aperture compared to refractors and catadioptrics because mirrors can be produced at a lower cost than lenses. The enclosed objective mirror is generally not subject to dew or frost while observing.	Generally, not well suited for terrestrial applications due to inverted images. The tube is open to the air, which means dust on the optics even if the tube is kept under wraps. Reflectors are more subject to optical misalignment that any other type of telescope and they require periodic collimation.
 **C) Catadioptric telescopes…** use a combination of mirrors and lenses. Two of the more popular designs are the Schmidt-Cassegrain (left) and Maksutov-Cassegrain (right). The term Cassegrain refers to the fact that the light passes through a hole in the objective mirror and light exits the back of the telescope rather than the side. When these telescopes are used in conjunction with an altazimuth mount (left) the eyepiece in in the same orientation to the ground no matter where in the sky the telescope is aimed. When used with a German equatorial mount (right), this is no longer the case. Diagonal prisms or mirrors are also used for visual observing to allow the observer to look down rather than up when peering through the eyepiece. Due to use of an odd number of reflecting surfaces in such cases, images are semi-inverted.	Most versatile type of telescope with excellent lunar, planetary and deep space observing plus terrestrial viewing and photography. Readily accommodates a telecompressor permitting owner to change the effective focal ratio. Best near focus capability of any type telescope. First-rate for deep sky observing or astrophotography. Closed tube design reduces image degrading air currents once the telescope as a whole has reached thermal equilibrium with the air. Compact and durable.	More expensive than reflectors of equal aperture. Corrector plate that holds the secondary mirror is subject to dew and frost. These telescopes almost always need to be used in conjunction with a dew shield or lens warmer.

The above table was adapted from http://www.ozscopes.com.au/guides/telescopes-guide/types-of-telescopes.html

How big a mirror or lens? While one can save money by purchasing a small aperture telescope, it would constitute a waste of money not the buy the largest aperture one can afford – up to a point. People who purchase small telescopes at the outset often come to regret it because before long they catch “aperture fever.” Larger telescopes do, in general, provide greater benefits. (See the handout **COMMON TELESCOPE TRAITS** for details.) As a general guideline, I suggest a telescope of at least 8” aperture for the serious would-be amateur astronomer. If you can afford it, an 11” aperture telescope would be even better. As an Astronomical League Master Observer with over 50 years viewing experience, I am very happy with my 11” SCT. Going larger – in light polluted Illinois – results in diminishing returns. If one views from the rural skies of Illinois, the sky is not adequately dark to take full advantage of a larger aperture. While large telescope mirrors do collect more light, they also collect more sky light much of which is produced by artificial illumination. As a result of this problem, I recently sold a high quality 18” telescope for which I paid nearly $8,000 because the views it provided relative to my 11” telescope were not all that much better – certainly not worth the trouble of dragging it out into the countryside and setting it up.

What about eyepieces? Telescopes will sometimes come with several eyepieces providing a variety of magnifications and fields of view. These are commonly inexpensive but serviceable. Still, experienced observers will typically want to replace these eyepieces with ones of higher quality. Higher quality eyepieces most commonly will provide larger fields of view at the same magnification. Certain other eyepiece will provide much better eye relief that makes them more useful for those who wear eyeglasses. Yet others are *parfocal* that means they can be exchanged with one another without requiring significant refocusing. A cluster of perhaps five good quality eyepieces along with a Barlow lens should be purchased with the use of a quality telescope. Eyepiece focal lengths should span the range from minimum to maximum useful magnification. See the handout **EYEPIECE BASICS** in TCAA Guide #1 – *Introduction to Amateur Astronomy* – for additional information.

THREE POWERS OF A TELESCOPE

When people purchase telescopes, the only power they typically think about is magnifying power. Actually, that’s probably the least important of the three powers of the telescope! Here I summarized the three powers, and provide some guidance for purchasing a suitable telescope and eyepieces.

1. **Light Gathering Power** – This power gives an indication of how much light a telescope will gather into one’s eye. LGP is often given in comparison to the light-gathering ability of the human eye dilated to a certain diameter. Like a bucket’s ability to collect rain drops in comparison with a test tube, the larger the aperture of a telescope (the size of its mirror or lens), the greater will be the LGP of a telescope. The LGP ratio between at telescope (t) and eye (e) is easily expressed in terms of a ratio of the light-gathering areas of the telescope and eye:

$$\frac{LGP_t}{LGP_e} = \frac{4\pi r_t^2}{4\pi r_e^2} = \left(\frac{2r_t}{2r_e}\right)^2 = \left(\frac{d_t}{d_e}\right)^2$$

As this equation implies, the LGP of a telescope with respect to the human eye increases with square of the diameter of the telescope objective (lens or mirror). For instance, an 11” telescope (36.4mm) telescope will gather nearly 1,600 times more light than will a human eye dilated to 7mm $(280mm/7mm)^2$.

This formula also can be used to compare the differences between telescopes as well. An 8” aperture telescope will gather four times (2^2) as much light as will a 4”. A 16” telescope will gather 16 times (4^2) as much light as a 4” telescope.

The limiting magnitude, *LM*, of a telescope (the faintest *star* a telescope can show under ‘average’ conditions depending on a number of factors such as magnification, *M*, diameter of objective in mm, *D*, the transmission factor, *t*, which is usually 0.85 – 0.9, and even sky darkness which is associated with the magnitude of the faintest naked-eye star visible, *m*) is given by the following approximation:

$$LM = m_{naked\ eye} - 2 + 2.5log_{10}(M \cdot D \cdot t)$$

An 11” telescope (D = 280) on an average night ($m_{naked\ eye}$ = 5.0) used at a magnification of 87, and with t = 0.9 will have a limiting magnitude of about 13.8. This is 8.8 magnitudes fainter than the LM, and a brightness ration of 3,300 times.

2. **Resolving Power** – Resolving power is the ability of a telescope to show fine detail. Ignoring, momentarily, the blurring of an image caused by atmospheric turbulence (seeing) and assuming no optical imperfections of the telescope, the ability to separate two stars with a telescope is given by Dawes limit as follows:

$$\alpha = \frac{116}{D}$$

where α is the minimum separation between two distinguishable stars expressed in arc seconds, and D, the diameter of the telescope objective, is expressed in mm. The theoretical resolving power of my 11" CPC telescope is 116/280 = 0.4 arc seconds – about the best that can be expected given even the best seeing conditions (addressed elsewhere).

The equation shows that, all else being equal, the larger the aperture, the better the angular resolution. Note that the resolution is not dependent upon the magnification of a telescope. Telescopes marketed by giving high values of the maximum power often deliver very poor images for a variety of reasons, not the least of which is due to imperfections in the optical system. As the aperture of telescopes increases, the resolution can drop because it is further limited by the turbulence of the atmosphere. Larger aperture telescopes gather light rays from a larger cross-section of the sky, and this increase the turbulence in the telescopic image degrading resolution. Sometimes, for instance, the best views of planets can be seen in telescopes of smaller aperture – say 4.25 to 8 inches in diameter. The best views of Jupiter the writer have ever seen were in a 6" reflecting telescope due primarily to the limits imposed by seeing. Aperture in relation to resolving then is a double-edged sword. The greater the aperture, the greater the theoretical resolving power but also the greater the problems with seeing; the smaller the aperture the less the theoretical resolving power but also the smaller the problems with seeing. This explains, in part, why many amateur astronomers have telescopes of different aperture.

3. **Magnifying Power** – Magnifying power describes how much larger and object looks in an eyepiece in comparison to the object when seen with the unaided eye. At a magnification of 10X, for instance, and object will appear to be 10 times higher and 10 times wider in comparison to the view without magnification. Magnifying power, M, depends upon two aspects of a telescope: the objective's focal length (F) and the eyepiece's focal length (f). That is,

$$M = \frac{F}{f}$$

Consider once again an 11" telescope whose objective has a focal ratio ($f/$) of 10, and an aperture of D = 280mm. The focal length is then found my multiply the $f/$ number by the aperture. That is,

$$F = f/\cdot D \; = 10 \cdot 280mm = 2800mm$$

The magnification using an eyepiece with, for example, a 32mm focal length eyepiece is then calculated from the earlier equation as follows:

$$M = \frac{F}{f} = \frac{2800mm}{32mm} = 87.5X$$

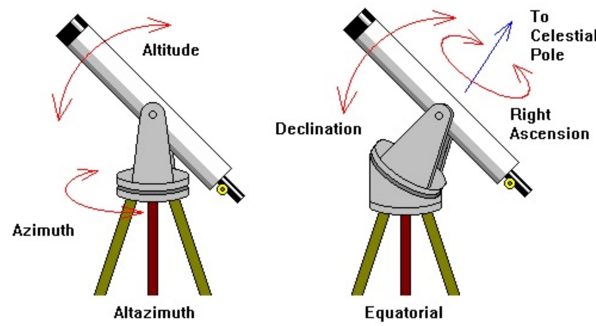
As state earlier, magnifying power is among the least important factors in the use of a telescope. Why should this be? It's because by merely swapping one eyepiece for another magnification can be changed. Longer focal length eyepieces produce lower magnifications (and typically wider angular fields of the sky) whereas shorter focal length eyepieces produce higher magnifications (and typically narrower angular fields of the sky).

Because telescope eyepieces are quite varied in terms of focal length and apparent field of view (and many other factors), these are addressed in a separate publication.

Telescope Mounts & Piers

If you are in the market to purchase a telescope, you might want to seriously think about the type of mount and pier that will come along with the telescope of your choice. They are not all equal. Keep in mind that we are not talking about "junk" toy telescopes here with their over-powered telescopes, flimsy mounts, and spindly-legged tripods. There are several legitimate types of mount/pier combinations for you as a serious observer to consider when you buy a quality telescope. But first, let's note the distinction between the terms 'mount' and 'pier' – terms that confuse some people. A mount is the device that is directly connected to the telescope and rests upon a pier. A pier is a single column or a tripod that supports the mount. The mount allows for the telescope's motion; the pier should be rock solid and should not flex. There are two fundamental types of telescope motion just as there two fundamental types of mounts.

Altazimuth mounts – These mounts – altitude/azimuth – allow telescopes to horizontally (side to side or in azimuth) with one axis and vertically (up and down or in altitude) in the other axis. This seems like a pretty reasonable way to mount a telescope until one realizes that stars don't move in this fashion. Here in mid northern latitudes the stars in the eastern sky rise moving to the right as they do so. When in the south, the stars move from left to right. When in the west the stars set moving to the right as they do so. In order for an altazimuth mount to track the stars, they need to be moved in both axes at different and changing rates depending where in the sky the telescope is pointed. These are serviceable mounts, but the best among them are driven by computer-controlled stepper motors. These motors can direct the aim of the telescope at variable rates and in changing directions.



Equatorial mounts – Are a simple solution to the problems of altazimuth mounts. The have two axes of movement 90 degrees offset from the other just as in the case of the altazimuth mount. However, rather than having the horizontal rotation axis oriented vertically, it is inclined in such a way that is parallel to Earth's rotation axis. Its right ascension or polar axis is aimed toward the north celestial pole near the North Star. This allows the telescope to be slewed east and west across the sky. So oriented, the telescope can follow celestial objects with the motion of one axis only. Only this axis need be motorized in order for it to follow celestial object, and the speed and direction of motion is constant. The other axis, the declination axis, allows the telescope to be slewed north and south in the sky.

Now there are variations on these two types of mounts, and there is even a bit of overlap in the definitions of these two types under certain circumstances as well. Consider "what if" either of the two above mounts was used at either the North or South Pole of Earth. At these locations, an altazimuth mount would be no different from an equatorial mount as the celestial pole would be located overhead! The mount's right ascension or polar axis would become an azimuth axis, and its declination axis would its altitude axis.

The above images show what is known as a **fork mount**. Due to problems with fork mounts and long telescope tubes (e.g., one can't above all the way up to the zenith with the altazimuth mount nor all the way to the celestial pole with the equatorial mount), most telescopes that use a type of azimuthal mount today use a style designed by John Dobson out in California years ago. The advantage of the **Dobson mount** is that the telescope is kept low to the ground making it accessible to the smallest of viewers. It's great for public observing sessions. Another advantage is that this style is easily and cheaply constructed. Many serviceable telescopes use this sort of mount. Unfortunately, this style of mount is not readily motorized on the cheap. Yes, there are Dobson mounts with computer-controlled drive motors, but they tend to be rather expensive. Other variations of the fork mount can be see in the Celestron CPC series of telescopes.

Much more readily motorized are the equatorial mounts. These come in several different types as well, two of which are worth mentioning. The **yoke mount** (an example of which is shown to the right) is rarely seen in the world of amateur astronomy nowadays. As the picture illustrates, the yoke has a real propensity for getting in the way when trying to view through the eyepiece. This design is perfectly acceptable for large telescopes such as the 200-inch Mount Palomar telescope, but that's because the observer can sit in a cage and view from within the telescope itself (though this is not done today with advances in observing equipment).

An alternative to the yoke mount is the **German equatorial mount**. This mount is commonly found in amateur telescopes today. The telescopes in the TCAA's Prairie Sky Observatory, for instance, are all on German equatorial mounts. Experts like these mounts, though many novices find them rather objectionable. In order to view the eastern sky, the telescope must be located on the western side of the right ascension or polar axis. When switching views to the western sky, the telescope must be "rolled over" to the eastern side of the right ascension or polar axis. Another objectionable aspect of this mount is that there are large counterweights on the declination axis to counterbalance the weight of the telescope. This is because the motors driving the polar axis don't need to lift the telescope due to the counterweights.

A **pier** supports the mount that supports the telescope that allows it to move around the sky. There are essentially two types of piers in use today – vertical columns and tripods. Vertical columns are typically massive and are meant to stay in one place. Tripods are lighter and are designed to be used in mobile situations. A generation ago it was possible to find vertical columns with three horizontal support legs associated with portable telescopes; that's no longer the case today. Good piers are heavy and solidly built; poor piers such as found with toy "junk" telescopes are light and typically quite spindly…

FINDER 'SCOPES

Traditionally, finder 'scopes are typically small telescopes that are attached to and optically aligned with the main telescope. They are used to aim the main telescope. Finder scopes are of short focal length, low magnifying power, and wide field of view. Most include crosshairs. These small auxiliary telescopes are used to find objects and center them in the field of view. Once this is done, the main telescope should be pointing at or very close to the object that the observer intends to view.

Today this is a wide variety of finders, and not all are telescopes. Not all have magnification. Shown below are a number of finder telescopes, each with its pros and cons.

Finder A) Straight through finder

Finder B) With right angle prism and illuminated crosshairs

Finder C) Telrad with zero-power heads up display

Finder D) Red dot finder

Finder A. This is an all-to-commonly-found 'cheap' finder. It typically is a 6X30 monocular, and is usually found on toy telescopes. It provides 6X magnification and has a 30mm aperture. While marginally adequate, it lacks basic features such as illuminated crosshairs. Focusing is often difficult (adjustment at the objective lens rather than the eyepiece), and the small aperture makes it difficult to see any but the brighter stars. Another drawback is its poor ability to align with the main telescope. The three setscrews on the side of the finder do provide only a minimum of adjustment. Often difficult to keep properly aligned with the main telescope. Images are inverted, which is commonly the case with standard telescopes. This is not a problem, but it does take some getting used to. Push up to go down and left to go right. I do not consider this a 'serious' finder scope. Still, higher quality versions of this type of finder can be considered quite helpful.

Finder B. This is a more serious type of finder, but it is also fraught with difficulties in this configuration. It has a larger aperture that will reveal more stars and might even show the object you intend to observe. The illuminated reticle is a definite plus. This unit is much more substantially built and provides greater latitude for alignment with the main telescope. Once aligned, this unit probably will stay aligned. The problem really begins when looking through this telescope. If you thought that an inverted field of view was difficult in the case of the above finder, this one is somewhat worse. Introducing a mirror makes the eyepiece more accessible to the observer as it is now located at right angles to the telescope. Unfortunately, introducing the mirror produces a semi-inverted field of view. Depending on its orientation with respect to the sky one might push up to go up and push right to go left. Only one of the two directions is reversed, but figuring out which one can be a real pain.

Finder C. I used to resist using this finder when I first started seeing them on other telescopes, but today wouldn't observe without it. This is a Telrad finder. It's a straight-through heads-up display with a set of finder rings instead of the traditional crosshairs. An LED projects three red rings (brightness adjustable with dimmer switch) onto the heads-up display. The observer then sees the rings projected against the sky. The view of the sky is erect (not inverted or semi-inverted). The advantages are the ultra-wide zero-magnification field of view and the tremendous eye relief. One can place one's eye several inches back from the heads-up display and still see the rings. The disadvantage is that without a light-gathering lens, it's hard to see any but the brighter stars, and is difficult to use when trying to find faint objects without any brighter nearby stars. Another drawback is that the heads-up display is strongly subject to dewing.

Finder D. More commonly found on toy telescopes these days, this is typically a cheap knockoff version of the Telrad with a considerably smaller heads up display. Instead of a series of rings, a red dot is projected against the sky. To find objects in the main telescope, merely place the red dot over the area you intend to observe. In my opinion, this is not a serious finder either. Still, better quality versions do exist that some observers find quite useful.

Which should I choose? The fact of the matter is that no one finder can satisfy all needs. For years, before I started using my goto CPC 11" telescope in 2006, I would use a combination of finder types A and C. I would use my Telrad (on the side of a 10" Coulter Odyssey telescope) to zero in on the area I was planning to observe. Once I did that I used my 7X50 straight-through finder to locate more precisely the object I was planning to observe. Then, when I looked through my main telescope, the object I was seeking was then in the main instrument's field of view.

Make Your Purchase

Okay! Now that you are more fully informed, it's time to make your purchase. Where do you go? Who do you contact? That's a matter of opinion. You can shop locally, but your choices will be very limited and you might not have access to anything other than toy telescopes. As a result, most amateur astronomers purchase their telescopes online from reputable dealers. The situation with binoculars is not so dire, as many good binoculars can be found in area sporting goods and "big box" retailers.

Here is a partial list of reputable online dealers for telescopes. But, be careful. Even reputable dealers will sometimes sell junk toy telescopes. The fortunate thing about these retailers is that they will have knowledgeable staff who can help you make a good decision. Phone them with your questions and concerns, and they will help you get the best bang for your buck.

http://www.telescopes.net (Woodland Hills Telescopes and Cameras)
http://www.telescopes.com (Orion Telescopes)
http://www.optcorp.com (Oceanside Photo and Telescope)

I'm Not Quite Ready to Purchase a Telescope…

That's perfectly fine, and might well reflect that fact that you need to spend time learning more about things of the night sky and the work of amateur astronomer. There is no better way than becoming involved with your local astronomy club. In the Bloomington-Normal, IL, area it is the Twin City Amateur Astronomers (TCAA). This is an observing club rather than a social club. The club's activities center around observing, and they host monthly family-friendly public viewing sessions. You can learn more about the TCAA, by visiting their website at http://tcaa.us.

Getting Additional Assistance

Lots of people who get involved in amateur astronomy don't want to join an astronomy club because they don't feel "qualified." That's understandable. So how can one become a skilled observer without assistance? The answer is to read, read, read. Then, after you do feel more qualified, you might want to join a group of like-minded individuals who are ready, able, and willing to assist new sky watchers. Read the following TCAA Guides in this order given below. This is the TCAA's best advice on becoming a skilled amateur astronomer.

Guide #3 – ASTRONOMY AS A HOBBY

Why is it that we don’t attract as many amateur astronomers as we would like? Our club has lots of great benefits, and it’s more the just lack of knowledge of benefits. Part of the problem today stems from the fact that many people don’t understand the meaning of a hobby and the benefits derived from it.

Guide #4 – THE ART OF SKY INTERPRETATION

This guide, designed originally for sky interpreters, provides a huge amount information about the night sky. Even if one doesn't intend to give public talks, this guide provides a wealth of information about what can be seen in the sky with the unaided eye.

Guide #1 – INTRODUCTION TO AMATEUR ASTRONOMY

This guide addresses the basics that everyone needs to know in order to become an amateur astronomer. It deals with the use of eyes, binoculars, and telescopes to view the night sky. It should not be mistaken for a textbook in astronomy.

Guide #6 – HAVE A SUCCESSFUL OBSERVING SESSION
This guide is a reproduction of an article by the same name that appeared in the September 2017 issue of AL’s Reflector magazine. This guide provides information about the seven **p**’s required for having a successful observing session: **p**assion, **p**reparation, **p**rograms, **p**lanning, **p**erseverance, **p**atience, and **p**resentation.