Guide to Astronomical Telescopes

By Chuck Hawks

This article is intended to be a general guide to selecting a telescope appropriate for your level of experience as an amateur astronomer. As with any such general guide, there is a lot of overlap between categories and price points within any category. There are suitable beginner telescopes priced from a couple of hundred dollars to a couple of thousand dollars. (All prices mentioned in the course of this article are in 2011 dollars.) Most users can adapt to moving up or down a category without too much trouble. However, an advanced amateur astronomer will likely be frustrated by a beginner's telescope and a beginner might be equally frustrated trying to use an advanced telescope.

Your first telescope will not be your last telescope and you should not expect it to be. Do not buy a first telescope expecting it to satisfy your observing needs for the rest of your life. As nice as that would be, it is an unrealistic expectation. Beginner and intermediate telescopes should allow you to see a little bit of everything, but they are unlikely to be optimum for specialized applications. As your skill at using a telescope increases and your ability to use your eyes to really *see* increases, as well, your telescope needs will evolve. So will your interests, likely in unexpected directions. You may become fascinated with deep space objects, searching for comets, observing planetary details, or solar observing. All of these require more sophisticated types of telescopes and mounts, so your equipment needs will evolve as your experience increases.

A good beginner scope should allow you to observe the moon, bright planets and the brightest deep sky objects. Actually, all of the planets in our solar system except Neptune and Pluto, plus the entire Messier catalog of 108 deep space objects (the most popular deep space objects in the night sky) are visible through a modest (60mm clear aperture) beginner telescope operating at no more than 40x magnification, but to get the most pleasure from observing deep space objects, a more sophisticated telescope is desirable.

To get the maximum benefit from this article, you must also realistically evaluate your experience level as an amateur astronomer. Everyone is a beginner at some point, but few have the interest, dedication and commitment to become Experts. That's okay, the point of any hobby is to have fun, so progress to whatever level matches your interest and commitment. I, for example, would rate myself as an intermediate level amateur astronomer with maybe an advanced level of knowledge about telescopes and optics. The latter is partly because I spent many years as a professional photographer, where I learned about optics. I was also the Manager of a camera and telescope dealership and I naturally tend to research things that interest me. In addition, I am an equipment junky. The instruments themselves are an enjoyable part of the hobby for me.

To start, we need to define beginner, intermediate, advanced and expert level telescopes. The folks at Orion Telescope (www.telescope.com) have formulated what I think are good definitions, so I will use them here, slightly modified for the purposes of this Guide:

Level 1 - Beginner: Telescopes suited for beginners are easy to set-up, use and maintain. Very good optical and mechanical quality. A great first telescope that will show you the moon, planets, star clusters and nebulas. Great for families, young people and folks who don't want to mess with equipment, but just want to take a look. Most 60-90mm achromatic refractors and most reflectors up to 115mm will fall into this category, usually on alt-azimuth mounts, but there are exceptions. A 2.4"/60mm clear aperture is the minimum appropriate for any astronomical telescope.

Level 2 - Intermediate: Telescopes for the intermediate user are more robust in features and performance. Excellent quality in optics and mechanics, but more complex in use than Level 1 telescopes. They typically take longer to

learn and require some set-up or adjustments. An intermediate telescope will allow an enthusiast to "grow" in the hobby. Includes most AZ and EQ mounted achromatic refractors up to 6"/150mm and ED doublet (semi-APO) refractors up to 4.3"/110mm. Most intermediate reflectors have clear apertures up to about 6"/150mm, but a few 8" and 10" models are included. A minimum 3.2"/80mm clear aperture is required.

Level 3 - Advanced: Advanced telescopes are high performance, with exceptionally-fine optics and mechanics. They may require a longer set-up time and more skill to master and appreciate. Some advanced telescopes are easy-to-use, but large and heavy. Technically inclined folks will love these scopes. An advanced telescope is a purchase for a lifetime. Typically includes apochromatic triplet refractors from 4"/100mm to 5"/130mm, 4.5"/115mm and larger ED doublet refractors, various 7" to 12" CAT's and 8" or larger Newtonian reflectors. The minimum required clear aperture is 4"/100mm.

Level 4 - Expert: Expert telescopes offer uncompromising optical and mechanical quality for the most demanding amateur astronomer. They may be technically involved or designed for specialized use, such as flat field astroimaging or detailed deep sky observation. They carry a premium price, but are designed to provide the ultimate in performance. These are the finest amateur telescopes that money can buy. Required, for our purposes, is a minimum 5.5"/140mm clear aperture.

It would be impossible for me to include every make and model of telescope available in each class, so what I will do is list representative telescopes of various types (refractor, reflector and catadioptric) in each category. These examples are chosen from the well known Celestron, Meade, Orion, Parks, Questar, Sky-Watcher (Synta), Stellarvue, Takahashi, Tele Vue and Vixen lines. To be sure, there are other, probably equally suitable, brands available. Just because a particular make and model is not included does not mean it is no good. Remember, the telescopes listed below are intended to serve as *examples* of suitable instruments in each category; this article is not intended to be a comprehensive list of all the telescopes available in each category or even from any one manufacturer.

Note that no "department store" telescopes are included. This is because scopes from importers such as Tasco, Jason, Bushnell and department store house brands are rarely satisfactory for any serious astronomical purpose. Nor is any telescope that is marketed of the basis of its theoretical maximum magnification listed, or any telescope not intended for use with at least 1.25" mounting barrel diameter eyepieces. The telescopes that fall into these excluded categories are intended to take advantage of uninformed consumers. This article will, hopefully, help you to become a better informed buyer and avoid such junk. No telescope with a clear aperture of less than 60mm (2.4") is included, because smaller telescopes are so limited in their light grasp that they are unlikely to prove satisfactory.

A word about mounting systems. The mounting system is as important as the telescope itself. Even the most sophisticated telescope cannot be used on an inadequate mount that does not hold it steady for focusing and observing. In general, alt-azimuth (AZ) mounts, which move the telescope in straight lines left/right and up/down, are simpler than equatorial (EQ) mounts for entry level telescope buyers to set-up and use. AZ mounts are also natural for terrestrial viewing. Equatorial mounts move the telescope in an arc across the sky, following the apparent motion of the stars and planets as the earth turns. Intermediate, advanced and expert level astronomers use both AZ and EQ mounts of increasing sophistication, depending on their personal preference and equipment requirements.

Either type of mount can be motorized and may include a computerized "go-to" system that allows the mount to find objects for the observer. Some people find these computerized mounting systems to be a great advantage and others find them difficult or impossible to master. Go-to mounts, even of the AZ type, must be aligned before use, usually by pointing at known stars in the night sky and recording their locations as reference points for the go-to computer system. Go-to mounts are often recommended to beginners, but a great drawback is that someone who starts with a go-to mount is unlikely to learn the night sky, since they never really learn to locate objects for themselves.

Finally, I suggest that you read my article "Telescope Basics," which can be found on the *Astronomy and Photography* index page, before buying any telescope. If you are not familiar with telescope terminology, and every hobby has its own lexicon, see "Definitions for the Amateur Astronomer," also on the *Astronomy and Photography* index page.

Okay, here are examples of some Beginner, Intermediate, Advanced, and Expert level telescopes:

Level 1 - Beginner Telescopes (2.4"/60mm minimum clear aperture)

- **Celestron Astro Master series -** Includes entry level 70mm and 90mm achromatic refractors as well as 76mm, 114mm and 130mm Newtonian reflectors on manual, light duty, alt-azimuth and German equatorial mounts. The Astro Master refractors are designed for both terrestrial and astronomical use.

- **Celestron NexStar GT series -** The NexStar 60 GT achromatic refractor and NexStar 114 GT Newtonian reflector are sold with computerized go-to (motorized) AZ mounts.

- **Celestron NexStar SLT series -** Celestron's more advanced NexStar SLT line, also computerized, includes 60mm, 80mm and 102mm achromatic refractors plus 114mm and 130mm Newtonian reflectors. This line is a step up in quality and price from the NexStar GT series.

- **Meade ETX Series -** 90mm (3.5") aperture f/13.8 and 125mm (5") aperture f/15 Maksutov-Cassegrain optical tubes on plastic swing-through, dual-fork, go-to mounts with included field tripod. Very good optics on truly inferior mounts with a frustrating go-to system.

- **Orion Observer 70 -** This 70mm achromatic refractor is available on a light duty AZ (Observer 70 AZ) or EQ (Observer 70 EQ) mount.

- **Orion Star Seeker 80 -** A 3.2" go-to achromatic refractor on a computerized AZ mount.

- **Orion StarMax 90mm and 102mm -** These are 3.5" and 4" clear aperture Maksutov-Cassegrain telescopes on light duty German equatorial mounts.

- **Orion SkyQuest XT Classic series -** Newtonian reflectors on Dobsonian AZ mounts. Orion recommends the 4.5" and 6" clear aperture models for beginners.

- **Parks PRT1, PRT2 -** 60mm f/12 achromatic refractor telescope with 700mm focal length sold with choice of AZ mounts on wooden tripods. PRT2 mount features slow motion controls.

- **Parks PRT46 EQ System -** 60mm aperture, f/15 achromatic refractor telescope with 900mm focal length. Sold with small equatorial mount featuring RA and Dec. slow motion controls and wooden tripod.

- **Parks PRT813 -** 80mm f/11 achromatic refractor telescope with 900mm focal length. 1.25" focuser. Sold with manual EQ mount featuring slow motion controls and a wooden tripod.

- **Parks 4.5" f/5 OTA -** 4.5", short focal length Newtonian reflector sold only as OTA. Features the same high quality components and craftsmanship used on larger Parks Newtonian telescopes.

- **Sky-Watcher Refractor BK707AZ2 -** 70mm, 700mm focal length, achromatic doublet refractor with 1.25" rack and pinion focuser. Features aluminum main tube with dew shield. Includes 1.25" star diagonal, two 1.25" oculars,

6x24mm finder scope. Supplied with AZ-2 lightweight alt-azimuth mounting system. Recommended by Sky-Watcher for first time buyers.

- **Sky-Watcher Refractor BK909AZ3 -** 90mm, 900mm focal length, achromatic doublet refractor with 1.25" rack and pinion focuser. Features aluminum main tube with dew shield. Includes 1.25" star diagonal, two 1.25" oculars, 6x30mm finder scope. Supplied with AZ-3 alt-azimuth mounting system. Recommended by Sky-Watcher for serious beginners.

- **Sky-Watcher BK90MAKEQ1 -** 90mm clear aperture, 1250mm focal length Maksutov-Cassegrain scope sold as OTA or with lightweight EQ-1 German equatorial mounting system. OTA includes red-dot finder, 1.25" star diagonal and 1.25" eyepiece. Recommended by Sky-Watcher for beginning astronomers.

- **Sky-Watcher BK102MAKEQ2 -** 102mm clear aperture, 1300mm focal length Maksutov-Cassegrain scope sold as OTA or with EQ-2 German equatorial mounting system. OTA includes red-dot finder, 1.25" star diagonal and 1.25" eyepiece. Recommended by Sky-Watcher for beginning astronomers.

- **Sky-Watcher BKP1145EQ1 -** 114mm clear aperture, 500mm focal length Newtonian (parabolic) telescope sold with EQ-1 lightweight German equatorial mounting system. Rolled sheet steel main tube with 1.25" focuser. Includes red-dot finder and two 1.25" eyepieces. Recommended by Sky-Watcher for beginning astronomers.

- **Sky-Watcher BKP13065EQ2 -** 130mm (5.1") clear aperture, 650mm focal length Newtonian (parabolic) telescope sold with EQ-2 German equatorial mounting system. Includes 1.25" focuser, red-dot finder and two 1.25" eyepieces. Recommended by Sky-Watcher for beginning astronomers.

- **Stellarvue SV70ED and SVR70ED Raptor -** 2.75" short tube (f/6) ED doublet (semi-apochromatic) refractors with 2" dual speed Crayford focuser. Excellent optical quality in a small, lightweight package. The Raptor model comes with carbon fiber main tube and dew shield. Sold as optical tube only or with the M1 alt-azimuth mounting system.

- **Takahashi FS-60C -** A 60mm ED doublet (semi-apochromatic) refractor, sold with the Tak "palm size" EQ mount. Suitably compact for airline travel.

- **Tele Vue-76 -** A 76mm (3") ED doublet (semi-apochromatic) refractor. Suitably compact for airline travel. 2" rack and pinion focuser. Very good quality. Recommended for Tele Vue Tele-Pod or Panoramic AZ mounts.

- **Vixen A70Lf -** A 70mm achromatic refractor sold as a package with Vixen's lightweight Porta Mount system or, for $100 more, the beefier Porta II Mount system--a worthwhile upgrade.

- **Vixen A80Mf -** My favorite beginner telescope, a very good 80mm achromatic refractor available as a package with Vixen's solid Porta II Mount system.

- **Vixen VMC95L with Porta II Mount -** This 95mm (3.7") clear aperture modified Cassegrain telescope incorporates a small Maksutov type corrector lens in front of the secondary mirror and is available as a package with the light duty Vixen Porta Mount.

- **Vixen VMC110L -** A 110mm (4.33") clear aperture modified Cassegrain telescope with a small Maksutov type corrector lens ahead of the secondary mirror. Available as a package with the Porta II AZ mount or with the Skypod computerized go-to mount.

- **Vixen R130Sf with Porta II Mount -** A very good entry level 130mm (5") clear aperture Newtonian reflector on a solid AZ mount.

Level 2 - Intermediate Telescopes (3.2"/80mm minimum clear aperture)

- **Celestron NexStar SE series -** This is a line of single-fork arm mounted, go-to Schmidt-Cassegrain telescopes; available apertures include 4", 5", 6" and 8", with the 4", 5" and 6" versions solidly in the Intermediate category.

- **Celestron Omni XLT series -** 102mm, 120mm and 150mm achromatic refractors plus a 127mm Schmidt-Cassegrain, 150mm Newtonian reflector and 102mm ED (semi-apochromatic) refractor, all on Celestron's medium-weight CG-4 German equatorial mount. Prices vary, but these are good scopes on a good mounting system. My favorite intermediate telescope line.

- **Celestron Advanced Series GT computerized telescopes -** 6" SCT, 6" achromatic refractor and 6" Newtonian reflector on Celestron's medium weight CG-5 German equatorial go-to mount. Reasonable prices for intermediate scopes on a very solid mount.

- **Celestron C6 Starbright XLT -** 5.9", 1500mm focal length SCT available as an OTA or with the Nexstar go-to fork mount or the CG-5 German equatorial mount. Celestron OTA's come with mounting rail, finder scope and bracket, visual back, star diagonal and 1.25" ocular. A review of this telescope can be found on the *Astronomy and Photography* index page.

- **Meade LXD75 Series -** 8" SCT; 6", 8" and 10" Schmidt-Newtonian; 5" and 6" achromatic refractors on Meade's medium size LXD75 German equatorial go-to mount with AutoStar system. Also a 6" Newtonian reflector with an inferior plate glass mirror on the same basic mount, but without AutoStar (not recommended).

- **Orion Sirius 80ED -** 80mm refractor with ED doublet objective on Orion's medium-size German EQ mounts (standard or go-to).

- **Orion AstroView series -** 100mm and 120mm short tube achromatic refractors and a 6" (150mm) Newtonian reflector on German equatorial mounts.

- **Orion SkyView Pro 120 -** 120mm achromatic refractor on a medium-size German equatorial mount; also available with a go-to system.

- **Orion StarMax 127 EQ -** 5" Maksutov-Cassegrain scope on a lightweight German equatorial mount.

- **Orion SkyView Pro 127 and 150 -** 5" and 6" Maksutov-Cassegrain CAT telescopes on standard or go-to German equatorial mounts.

- **Orion SkyQuest XT Classic series -** Newtonian reflectors on Dobsonian AZ mounts. Orion recommends the 8" and 10" clear aperture scopes for intermediate users.

- **Parks 6" f/6 OTA -** 6" (152mm), short focal length (910mm), Newtonian reflector available as OTA or bundled with Parks portable pier Astrolight AZ and EQ mounts. Features the same high quality components and craftsmanship used on larger Parks telescopes.

- **Parks 6" f/8 OTA -** 6" (152mm), 1220 mm focal length, Newtonian reflector available only as OTA. Features the same high quality components and craftsmanship used on larger Parks telescopes.

- **Questar 3.5 Standard -** Premium 3.5" Maksutov-Cassegrain scope on a precision machined, swing through, motorized, dual arm, equatorial fork mount with table top legs. Portable piers available in heights for sitting or standing viewing. Also available as optical tube only. Touted as the best personal telescope in the world.

- **Sky-Watcher Pro 80ED APO -** 3.2", 600mm focal length ED doublet refractor with 2" dual-speed Crayford focuser. Features Schott glass crown element and FPL-53 ED element in a baffled, seamless aluminum main tube with dew shield. Sold as optical tube with 2" dielectric star diagonal, two 1.25" oculars, 8x50mm RA finder scope and aluminum carrying case. Includes tube rings and Vixen type mounting rail to fit most mounting systems. Includes tube rings and Vixen type mounting rail to fit most mounting systems. Marketed by Celestron. The same telescope is marketed by Sky-Watcher as the Black Diamond ED100.

- **Sky-Watcher Refractor BK1021EQ3-2 -** 4", 1000mm focal length, achromatic doublet refractor with 2" rack and pinion focuser. Features aluminum main tube with dew shield. Includes 2" star diagonal, two 1.25" oculars, 6x30mm finder scope. Supplied with EQ-3 German EQ mounting system.

- **Sky-Watcher Pro 100ED APO -** 4", 900mm focal length ED doublet refractor with 2" dual-speed Crayford focuser. Features Schott glass crown element and FPL-53 ED element in a baffled, seamless aluminum main tube with dew shield. Sold as optical tube with 2" dielectric star diagonal, two 1.25" oculars, 8x50mm RA finder scope and aluminum carrying case. Includes tube rings and Vixen type mounting rail to fit most mounting systems. Marketed by Celestron. The same telescope is marketed by Sky-Watcher as the Black Diamond ED100.

- **Sky-Watcher Equinox 100 OTA -** Deluxe 4", 900mm focal length ED doublet refractor. Features a deluxe seamless aluminum main tube with 2", Dual-Speed, machined Crayford focuser that is 360-degree adjustable. Graduated scale on drawtube for fast and precise focusing with CCD or DSLR cameras. Includes integral Vixen finder shoe, retractable dew shield, tube rings and Vixen type mounting rail to fit most mounting systems. Sold as optical tube only with an aluminum carrying case. Optical system is identical to Black Diamond ED100.

- **Sky-Watcher Refractor BK1201EQ5 -** 4.7", 1000mm focal length, achromatic doublet refractor with 2" rack and pinion focuser. Features aluminum main tube with dew shield. Includes 2" star diagonal, two 1.25" oculars, 9x50mm finder scope. Supplied with EQ-5 German EQ mounting system.

- **Sky-Watcher BK127MAKNEQ3 -** 127mm (5") clear aperture, 1500mm focal length Maksutov-Cassegrain scope with 2" visual back. Sold as OTA or with EQ-3 German equatorial mounting system. OTA includes red-dot finder, star diagonal and two eyepiece. Recommended by Sky-Watcher for deep sky observing.

- **Sky-Watcher BKP15075NEQ3 -** 150mm (5.9") clear aperture, 750mm focal length Newtonian telescope sold with EQ-3 German equatorial mounting system. Includes 1.25" focuser, 6x30 finder and two 1.25" eyepieces.

- **Sky-Watcher Refractor BK15012EQ6 -** 5.9", 1200mm focal length, achromatic doublet refractor with 2" rack and pinion focuser. Features aluminum main tube with dew shield. Includes 2" star diagonal, two 1.25" oculars, 9x50mm finder scope. Supplied with EQ-6 German EQ mounting system.

- **Sky-Watcher Signature Series BK150MAKSP -** "Professional quality" 150mm (5.9") clear aperture, 1800mm focal length Maksutov-Cassegrain scope with 1.25" visual back. Sold as OTA with Vixen type mounting rail. Includes 9x50mm finder, 1.25" star diagonal and two eyepieces.

- **Stellarvue SV80ED, SVR80ED Raptor -** 3.2", 560mm focal length ED doublet (semi-apochromatic) refractors with 2" dual-speed Crayford focuser. SVR80ED Raptor features a carbon fiber main tube and dew shield. Sold as optical tube only or with the M1 or M2 alt-azimuth mounting systems. Also available with Celestron German equatorial go-to mounts.

- **Stellarvue SV102ED -** 4" ED doublet refractor with dual speed Crayford focuser. Sold as optical tube only or packaged with the M2 alt-azimuth mounting system. Also available with Celestron CG-5 or CGEM computerized German equatorial mounts. A review of this telescope can be found on the *Astronomy and Photography* index page.

- **Stellarvue SV110ED-BV-** 4.3" ED doublet refractor with dual speed Crayford focuser. Sold as optical tube only or packaged with the M2 alt-azimuth mounting system. Also available with Celestron CG-5 or CGEM computerized German equatorial mounts.

- **Takahashi FCL-90 (Sky 90) -** A 90mm (3.5") ED doublet refractor, sold as an optical tube with 2" focuser and finder scope, that is suitable for medium size mounting systems and compact enough (504mm focal length) for airline travel.

- **Tele Vue-85 -** An 85mm (3") ED doublet (semi-apochromatic) refractor. 600mm focal length. Suitably compact for airline travel. 2" rack and pinion focuser. Very good quality. Recommended for Tele Vue Panoramic or Gibralter AZ mounts.

- **Tele Vue-102 -** A 102mm (4") ED doublet (semi-apochromatic) refractor. 880mm focal length. 2" rack and pinion focuser. Very good quality. Recommended for Tele Vue Gibralter AZ mount.

- **Vixen ED80Sf -** A 3.2" ED doublet refractor that is suitable for Vixen's Porta II AZ mount or the German equatorial GP2 and Sphinx (go-to) mounting systems.

- **Vixen ED81S -** 3.2" ED doublet refractor with dual speed rack-and-pinion focuser that is available packaged with Vixen's Porta II AZ mount or the German equatorial GP2, GDP2 and Sphinx SXW (go-to) mounting systems.

- **Vixen ED100Sf -** A 4" ED doublet refractor that is suitable for the Porta II AZ mount, German equatorial GP2 and Sphinx (go-to) mounting systems.

- **Vixen ED103S -** A 4" ED doublet refractor with dual speed rack-and-pinion focuser. Available packaged with the Porta II AZ mount, GP2 German equatorial mount, heavy duty GDP2 German equatorial mount or the Sphinx SXW and SXD go-to EQ mounts.

- **Vixen R130Sf with GP2 Mount -** The R130Sf (5") Newtonian reflector on Vixen's medium-size GP2 German Equatorial mounting system.

- **Vixen R150S -** A 6" Newtonian with either the medium-size GP2 or Sphinx (go-to) German Equatorial mounting systems.

Level 3 - Advanced Telescopes (4"/100mm minimum clear aperture)

- **Celestron Advanced Series GT computerized telescopes -** 8", 9.25" and 11" SCT's; 8" and 10" Newtonian reflectors on Celestron's medium weight CG-5 German equatorial go-to mount. Reasonable prices for advanced scopes on a good mount, although the CG-5 is actually about optimum for the C8 SCT optical tube (54.5 lbs. total system weight).

- **Celestron C8 Starbright XLT -** 8", 2032mm focal length SCT available as an OTA, with Nexstar or CPC go-to fork mounts, or Celestron CG-5 and CGEM German equatorial mounts. OTA's come with mounting rail, finder scope and bracket, visual back, star diagonal and 1.25" ocular. A review of this telescope can be found on the *Astronomy and Photography* index page.

- **Celestron C9 Starbright XLT -** 9-1/4", 2350mm focal length SCT available as an OTA, with CPC go-to fork mount or Celestron CG-5, CGEM and CGE Pro German equatorial mounts. OTA's come with mounting rail, finder scope and bracket, visual back, star diagonal and 1.25" ocular.

- **Celestron C11 Starbright XLT -** 11", 2800mm focal length SCT available as an OTA, with CPC fork mount, or the CG-5, CGEM and CGE Pro German equatorial mounts. Celestron OTA's come with mounting rail, finder scope and bracket, visual back, star diagonal and 1.25" ocular. Assembled in USA.

- **Meade Series 5000 ED APO Refractors -** 102mm (4") aperture 700mm focal length and 127mm (5") aperture 952.5mm focal length ED triplet refractors sold as OTA's only. Feature 2" dual-speed Crayford focusers; supplied with 2" star diagonals.

- **Meade LX-90 Series -** 8", 10" and 12" aperture f/10 SCT's on swing-through, dual-fork, go-to mounts with included tripod. ACF (advanced coma-free) versions of these telescopes are available at extra cost.

- **Orion SkyView Pro 180 -** 7" Maksutov-Cassegrain CAT telescope on standard or go-to German equatorial mount.

- **Orion SkyView Pro 8 -** An 8" Newtonian reflector on standard or go-to German equatorial mounts.

- **Orion Sirius series -** 120mm ED doublet refractor on Orion's medium-size German EQ mounts (standard or go-to), 180mm (7") Maksutov-Cassegrain on a go-to EQ mount and an 8" Newtonian reflector on a go-to EQ mount.

- **Orion Atlas 10 EQ-G -** As the nomenclature suggests, a 10" Newtonian reflector on a heavy German equatorial go-to mount. Not for weaklings or people with bad backs!

- **Orion SkyQuest XX12i and XX14i -** These are 12" and 14" truss tube Newtonian reflectors on computerized go-to Dobsonian AZ mounts. Lots of light grasp for the dollar, but a hassle to set-up and collimate. Not for those who are impatient to start observing.

- **Parks 8" f/6 OTA -** 8" (200mm), 1220mm focal length, Newtonian reflector available as OTA or bundled with Parks portable pier Astrolight AZ and Superior System EQ mounts. Features the same high quality components and craftsmanship used on larger Parks telescopes.

- **Parks 10" f/5 OTA -** 10" (250mm), 1270mm focal length, Newtonian reflector available as OTA or bundled with Parks Superior System EQ portable pier mount. Very good quality components and craftsmanship.

- **Sky-Watcher Pro 120ED APO -** 4.7", 900mm focal length ED doublet refractor with 2" dual-speed Crayford focuser. Features Schott glass crown element and FPL-53 ED element in a baffled, seamless aluminum main tube with dew shield. Sold as optical tube with 2" dielectric star diagonal, two 1.25" oculars, 8x50mm RA finder scope and aluminum carrying case. Includes tube rings and Vixen type mounting rail to fit most mounting systems. Includes tube rings and Vixen type mounting rail to fit most mounting systems. Marketed by Celestron. The same telescope is marketed by Sky-Watcher as the Black Diamond ED120.

- **Sky-Watcher Equinox 120 OTA -** Deluxe 4.7", 900mm focal length ED doublet refractor. Features a deluxe seamless aluminum main tube with 2", Dual-Speed, machined Crayford focuser that is 360-degree adjustable. Graduated scale on drawtube for fast and precise focusing with CCD or DSLR cameras. Includes integral Vixen finder shoe, retractable dew shield, tube rings and Vixen type mounting rail to fit most mounting systems. Sold as optical tube only with an aluminum carrying case. Optical system is identical to Black Diamond ED120.

- **Sky-Watcher Signature Series BK180MAKSP -** "Professional quality" 180mm (7") clear aperture, 2700mm focal length Maksutov-Cassegrain scope with 1.25" visual back. Sold as OTA with Vixen type mounting rail. Includes 9x50mm finder, 1.25" star diagonal and two eyepieces.

- **Sky-Watcher BKP2001HEQ5 -** 200mm (8") clear aperture, 1000mm focal length Newtonian telescope sold with motorized EQ-5 German equatorial mounting system. Includes 2" focuser, 9x50 finder and two 1.25" eyepieces.

- **Sky-Watcher BKP25012EQ6 -** 254mm (10") clear aperture, 1200mm focal length Newtonian telescope sold with motorized EQ-6 German equatorial mounting system. Includes 2" focuser, 9x50 finder and two 1.25" eyepieces.

- **Stellarvue SV105 and SVR105R Raptor -** Premium 4" APO refractors with triplet objective lens using Ohara FPL-53 ED center elementand 3" Feather Touch dual speed focuser. SVR105R Raptor comes with carbon fiber main tube. Can be packaged with M2 or M7 alt-azimuth mounts or Celestron CG-5 or CGEM German EQ mounts. A review of the SV105R can be found on the *Astronomy and Photography* index page.

- **Stellarvue SV115EDT -** 4.5" APO triplet refractor with Ohara FPL-51 ED center element and 3" dual speed Crayford focuser. Sold as optical tube only or packaged with the MG alt-azimuth mounting system. Also available with Celestron CGEM computerized German equatorial mount.

- **Stellarvue SV115T -** Premium 115mm (4.5") APO triplet refractor with Ohara FPL-53 ED center element and Feather Touch dual speed focuser. Can be packaged with Stellarvue M2 or M7 alt-azimuth mounts; alternatively with Celestron CG-5 or CGEM computerized EQ mounts. A review of this telescope can be found on the *Astronomy and Photography* index page.

- **Stellarvue SV130EDT -** 5" APO triplet refractor with Ohara FPL-51 ED center element and 3" dual speed Crayford focuser or optional 3" Feather Touch dual speed focuser. Can be packaged with Celestron CGEM computerized EQ mount.

- **Takahashi TSA 102 -** Premium 102mm (816mm FL) triplet apochromat refractor, sold as optical tube only or as a set with accessories and Tak German EQ mount.

- **Takahashi TSA 120 -** Premium 120mm (900mm FL) triplet apochromat refractor, sold as optical tube only or as a set with accessories and Tak German EQ mount.

- **Tele Vue NP-101 -** A short focal length (540mm, f/5.4), 101mm (4"), Nagler-Petzval APO refractor. 2" rack and pinion focuser. Recommended for Tele Vue Gibralter AZ mount.

- **Tele Vue NP-127is -** A short focal length (560mm, f/5.2), 127mm (5"), Nagler-Petzval APO refractor designed primarily for flat field imaging, but also very good for viewing. Focusmate 2.4", dual speed, rack and pinion focuser. Recommended for Tele Vue Gibralter AZ mount, but requires special mount head.

- **Vixen AX103S -** Premium Apochromatic 4" refractor with an ED triplet objective and a rear field corrector lens. Available packaged with the entire series of Vixen German equatorial mounts.

- **Vixen ED115S -** A 4.5" ED doublet refractor with dual speed rack-and-pinion focuser. Available packaged with the GDP2 German equatorial mount, go-to Sphinx SXW or Sphinx SXD EQ mounts.

- **Vixen VMC2000L -** A 2000mm (8") clear aperture catadioptric scope with an open tube design. The meniscus corrector lens is placed just in front of the secondary mirror. Available packaged with the German equatorial GP2 or GDP2 mounts or the computerized go-to Sphinx mounts.

- **Vixen R200SS -** A very bright 8", f/4 Newtonian reflector packaged with your choice of GP2, GDP2, Sphinx SXW (go-to) and Sphinx SXD (go-to) equatorial mounts.

Level 4 - Expert Telescopes (5.5"/140mm minimum clear aperture)

- **Celestron Edge HD series -** Premium 8", 9.25" 11" and 14" aplanatic Schmidt-Cassegrain telescopes sold as OTA's or with Celestron's CGEM or CGE Pro German equatorial mounts. The Edge HD optical tubes are designed for flat-field CCD imaging and visual use and produce diffraction limited stars across the entire field of view. Incorporates Schott glass sub-aperture corrector/field flattener in central baffle, mirror locks, filtered cooling vents and removable secondaries for f/2.0 Fastar CCD imaging. These are Celestron's finest telescopes and probably the world's best SCT's. Asembled in USA.

- **Celestron C14 Starbright XLT -** 14", 3910mm focal length SCT available as an OTA or with a heavy-duty CGEM or CGE Pro German Equatorial mounts. Celestron OTA's come with mounting rail, finder scope and bracket, visual back, star diagonal and ocular. Assembled in USA.

- **Meade MAX -** 20" aperture, 4064mm focal length, f/8, LX400-ACF Modified SCT on massive MAX robotic German EQ mount. Mount is made in USA and weighs 329 pounds without a pair of 35 pound counterweights (included). Telescope features carbon fiber main tube and weighs 190 pounds; requires five 35 pound counterweights (included). MAX scope and mount retail for approximately $65,000 together; also available separately.

- **Parks 12.5" f/5 OTA -** 12.5" (317.5mm), 1588mm focal length, Newtonian reflector available as OTA or bundled with Parks Superior System (125 pound) or Observatory System (375 pound!) EQ pier mounts. Very good quality components and craftsmanship.

- **Parks 16" f/5 OTA -** 16" (406mm), 2032mm focal length, Newtonian reflector available as OTA or bundled with Parks Observatory System (375 pound!) EQ pier mount. Very good quality components and craftsmanship.

- **Questar 7 Astro -** Premium 7" clear aperture, 2400mm focal length, Maksutov-Cassegrain scope. OTA incorporates many special features, weighs about 20 lbs. Sold as optical tube assembly (mounts to 1/4x20 or 3/8x16 tripod heads) or with a precision machined, swing through, dual arm, equatorial fork mount with worm driven sidereal clock, synchronous DC drive. Portable and fixed piers available. The hot set-up is the 7 Astro in the swing through fork mount on the Questar Large Astro Pier. Lots of accessories and upgrades available; bring your platinum card! Made in USA.

- **Stellarvue SV160 -** Premium 160mm (6.3") APO triplet refractor with Ohara FPL-53 ED center element and 3.5" Feather Touch dual speed focuser. Can be packaged with Celestron CGE Pro computerized EQ mount or Mountain Instruments MI-250 EQ pier mount. Assembled in USA.

- **Takahashi M Series -** The Mewlon Series of Dall-Kirkham (Cassegrain) Telescopes with 210mm (2415mm FL), 250mm (3000mm FL) and 300mm (3572mm FL) models. Sold as OTA's or sets with Tak German EQ mounts incorporating polar axis alignment finder scopes. Made in Japan.

- **Vixen NA140SSf -** 5.5" Neo-Achromatic refractor with an ED doublet objective and a Petzval design doublet at the rear of the optical tube. Available packaged with the GDP2 German equatorial mount, either Sphinx go-to mount or the Atlux go-to mount. Made in Japan.

- **Vixen VC200L -** 8" modified Cassegrain with VISAC (Vixen's Six-Order Aspherical Cassegrain) aberration correction for the most discerning observer and astrophotographer. Open tube design with fixed, aspherical primary mirror and triplet corrector lens in central baffle tube. 2" Crayford focuser behind rear cell does not move primary mirror; dual speed focuser optional. Available packaged with the GDP2 or either of the Sphinx go-to German equatorial mounts. Perhaps the ultimate 8" CAT. A review of the VC200L can be found on the *Astronomy and Photography* index page. Made in Japan.

- **Vixen VMC260L -** A 260mm (10.2") clear aperture, f/11.5 modified Cassegrain telescope with 2" focuser and open tube design. Available as an OTA or packaged with Vixen's heavy-duty Sphinx SXW go-to mounting system. The VMC260L telescope is also available with Vixen's even larger Atlux go-to German equatorial mount/tripod. Made in Japan.

- **Vixen VMC330L -** This is Vixen's biggest scope, a 13", f/13 modified Cassegrain with dielectric coated mirrors, two corrector lenses located in front of the secondary mirror and an open tube design. Available as an OTA ($14,999) or with a Gaiax pier mount. If you fly to Saipan and stay at the Palms Resort, you can borrow one for an evening. Made in Japan.

Dobsonian Telescopes

By Philip Rastocny

Dobsonian telescopes are Newtonian designs with a low-cost mount called a base. Unlike the telescope already mentioned this style of telescopes is very different and requires an intermediate command of the night sky. Most do not come with electronics to locate stars and few have the ability to track an object once you locate it. However, the cost per inch of mirror is the lowest in the industry because of their uncomplicated design. If you want a really big telescope, you may want to consider a Dobsonian.

Some Dobsonians can be disassembled and are called TRUSS-style. Here, the telescope consists of four pieces: the base, the top ring, the mirror housing, and the truss tubes.

Highly portable and requiring no polar alignment, more large Dobsonain telescopes find their way into the trunks of cars than any other style. Using a base that sits flat on the ground to spin and tilt (called an Alt-Az), they are not suited for photography but are suited for viewing many different objects quickly. If there is a downside, it is that very large mirrors are also heavy and a van, truck, or large SUV is needed to move them to events. Heavy Dobsonians usually support wheel-barrow styled handles and wheels to make them easier to move about.

Although tracking bases are available, they can only track objects for an hour or so and must be “reset” if longer observations are desired. Such tracking bases also require polar alignment like any other mount.

For beginners, limit yourself to 6-8” mirrors; intermediate users can easily graduate to 12”; advanced up to 16” and experts, well this is where Dobsonians shine since they are available in sizes up to 48”.

Features to look for are bearing styles where inexpensive models use Teflon glides and better models use ball and/or roller bearings. Mirror cells are also more complicated since larger mirrors require a greater number of suspension points to keep the mirror from distorting. 9-point mirror cells are common and go up in number from there where in general the higher number of suspension points a mirror has is better.

Larger mirrors use exclusively truss designs and smaller mirrors use tube designs. Truss designs may be more desirable if you have a limited amount of space to store your telescope. Smaller mirrors are easier to move around and so while you may e tempted to buy a big mirror, think about how much effort it will take to move it around. For a quick peek, nothing beats a small Dobsonian and for viewing very faint deep-sky objects, nothing beats a big mirror. It all depends upon your strength and your tolerance level to move heavy things around as to how big of a mirror will suite you best. Remember, a big seldom-used telescope is not as good of a buy as a smaller well-used telescope.

So here are a few of the manufacturers I would recommend for quality optics:

- **Meade Lightbridge series**. Offers RA roller bearings and two-speed focusers (a must especially for larger mirrors). Three truss-tube models available: 10”, 12”, and 16”. Nice scopes for low prices but the mirrors are sort of hit and miss. When they are good, they are very good. When they are bad, they perform like a mirror 2” smaller than their diameter.

- **Orion SkyQuest Series**. Offers good optics in tube-style designs. In 1999 Orion changed over their dobsonian line to a completely new model, the XT. At first they were supplied only as a 6" f/8 and 8" f/6 version. These telescopes were provided with a metal optical tube with aluminum end rings, mirror cell and 1 1/4" focuser. The secondary was supported by a three vane spider with adjustable mirror support. A unique feature of these scopes was the adjustable spring tensioner for the altitude bearing. This allowed applying bit of extra friction when heavy eyepieces tend to cause the tube to fall forward. Also included with the package was a 6x30 finder, 2 eyepieces, dust cap and eyepiece caddy.
  In 2000 a 4.5" model was added. This dimunitive telescope carried the same features as its larger cousins, but weighed less than 20 pounds.The same year the larger XT10 also came to market. Again, it had the same basic features as the original telescopes, but the focuser was upgraded to a 2" size with 1 1/4" reducer and the finder grew to 8x50.
  Most recently the line has been readjusted to include a more stable four vane spider instead of three, and a dovetail bracket is included with all finders except for the XT10. Meanwhile the 2" focuser has become standard on the XT8.

- **Jims Mobile**. Offers a wide variety of large-aperture designs up to 48”. The NGT-12.5 was introduced in 1996. This is an astonishing telescope for the money. The optical system is a 12.5" f/4.5 Newtonian truss tube design with a rotating nose assembly for comfortable viewing. It has a 2" low profile focuser, 8x50 finder, computer with over 300 objects and is mounted on a split ring equatorial mount with a DC drive in both axes. The drive is capable of four tracking rates, guiding and slewing rates and had periodic error correction. All of this is in a package that weighs about 100 lbs and can be broken down and carried in a large back seat. When you find these on the used market it is usually because someone is upgrading to a larger model of the same telescope.

- **Obsession**. These telescopes use some of the highest-quality mirrors available yielding breathtaking views. All feature excellent craftsmanship, no-tool setup, handles for moving the telescope, fans for quick cool-down of the primary mirror and 2" Crayford-style focusers. The telescopes have been provided in 15" through 32" diameter, but because of their high cost only the smaller ones are considered here. The smallest of the line is a

15" f/4.5 telescope. It has the same features as all the rest of the line except that separate "wheely bars" are not supplied with it. The next two sizes include the 18" f/4.5 and the 20" f/5. They are available with Galaxy Optics or Nova mirrors.

- **Hubble Optics** – My personal favorite. This company offers a series of ultra-light Dobsonians that builds truly portable large aperture telescopes. Models include 14” f/4.6, 16” f/4.5, 16” f/5, 18” f/4, 18” f/4.5, 20” f/3.7, and 20” f/4.2. Also available are GOTO bases and a load of accessories.

- **Starsplitter** – No longer in business. These scopes used quality materials for smooth movement, low profile focusers and Telrad finders. No tools were required for setup, and handles were provided for moving the telescope. This line was available in optical configurations of 14" f/5.2 and 17.5" f/4.5. Later 15" f/4.5, 16" f/4.7, 18" f/4.5 and 20" f/5 versions made up the Starsplitter II category. Larger telescopes up to 30" diameter were also made.

- **Telescopics** – No longer in business. The RFT-6 was a compact 6" f/5 telescope suitable for table top observation. The telescope tube was supplied with a 1 ¼" focuser and was mounted in a small wood box with altitude bearings. This was then placed on the wood rocker box. Wood parts were made with cabinet grade oak. The rest of the line had the same construction, but included 2" focusers. The models included the RFT-8 with a 8" f/5 optical tube, the RFT-10 with 10" f/5 optics and the RFT-14 with 14 ½" f/5 optics.

Part 2 – Accessories

The purchaser of an astronomical telescope quickly discovers that there are several additional items, not usually supplied with new (or used) telescopes, that he or she needs to enjoy amateur astronomy. This little article is intended to briefly explore the most common and useful of these.

Tripods and mounts

The mounting system is as important as the telescope itself and often costs as much. Telescope mounting systems can be alt-azimuth (trains up/down and right/left, like a camera tripod) or equatorial (traverses in an arc that matches the movement of objects in the night sky, plus up/down). The lateral arc movement of an equatorial mount is called right ascension (RA) and the up/down movement is called declination (DEC). Equatorial (EQ) mounts require more set-up effort than alt-azimuth (AZ) mounts, but they make compensating for the earth's rotation easy.

The two most common forms of EQ mounts are called "German equatorial" and "swing-through fork." A complete mounting system consists of a mount head (German equatorial, for example) and something to support it, such as a tripod or pier. Either type of mounting system can be designed for manual operation or for locating astronomical objects by means of a computerized/motorized system called "go-to" my most amateur astronomers. Go-to mounting systems are more complicated to learn how to use and usually more expensive.

Many astronomical telescopes come with a freestanding tripod/mount or portable pier for field use, but some (like most Stellarvue refractors, Tele Vue refractors, Questar Standard 3.5 and others) do not. If yours did not, chances are that the manufacturer of your telescope offers a complete mounting system (at additional cost, of course). My advice is to buy it. Table top tripods and ordinary camera tripods are not suitable telescope mounts.

If you built your telescope yourself or somehow acquired one without a mount, Celestron, Apogee, Tele Vue, Stellarvue, Vixen, Meade, Questar and Losmandy sell mounts separately. The Celestron CG-5 is a popular "go-to" German

Equatorial mount suitable for use with a wide variety of telescopes, while the Vixen GPD2 is a similar size manual German equatorial mount. Both are good quality mounts and reasonably priced.

Solid and easy to use AZ mounts for telescopes of various sizes are available from Celestron, Stellarvue, Tele Vue and Vixen, among others. A good AZ mount should have some provision for accurately aiming the telescope, usually in the form of "slow motion" controls. AZ mounts are quick to set-up in the field and easy to understand and use. Many experienced amateur astronomers have both AZ and EQ mounting systems, choosing the mount most suitable for the purpose at the time.

Heavy duty, professional video tripods with fluid heads can sometimes serve as satisfactory field mounts for compact spotting scopes or very short focal length refractors, such as the Stellarvue NightHawk, Celestron C-90 and Questar 3.5. These, however, usually cost as much or more than the manufacturer's tripod/mount designed specifically for your telescope and lack slow-motion controls. Bogen and Gitzo are good sources for professional photo tripods and fluid heads.

Finder scopes

Most astronomical telescopes come with some sort of finder scope. If yours did not, you will need to purchase one. Without a good finder scope it is nearly impossible to find objects in the night sky. Even if your telescope came with a finder scope, it may not be easy to use or of sufficient quality. Don't put up with an inferior finder scope; replace it with one you like. A good finder scope is a joy to use and, once it is aligned with the optical axis of your telescope, a great help in aiming your telescope at the target. A bad finder scope is a constant source of irritation.

I prefer a right angle, correct image finder scope. The right angle eyepiece makes the finder much easier to look through when the telescope is aimed skyward. It is natural (at least for me) to move my telescope in the direction I want to go according to the finder image, rather than in the opposite direction (as required if the finder image is reversed or upside down). Whatever kind of finder you prefer, get it.

Most experienced observers recommend at least a 6x finder scope (like a 6x30mm) with a thick, easily seen crosshair that allows the telescope to be aimed at objects invisible or difficult to see with the unaided human eye. A magnifying finder scope is the most accurate way to manually aim a telescope in the field. Many prefer an 8x50, 9x50 or higher magnification finder to aid in "star hopping." I have used optical finder scopes from 4x to 9x and find that, for me, the magnification is less important than bright, sharp optics and an easily visible crosshair. Some finderscopes have an illuminated crosshair and that is a very nice feature. Celestron, Orion and Stellarvue are good sources for magnifying finderscopes.

Serving the same purpose as a finder scope, but without magnification, are red dot sights from Telrad, Celestron, Orion, Stellarvue, Tele Vue and others. These project a red circle or dot on a glass, like a "Holosight" gun sight and are easy to aim at a visible target in the night sky, since you can aim your scope with both eyes open. They can be mounted to the telescope's mount rings, rear cell, or by simply sticking them to the telescope tube with double stick tape and they can be used alone or in conjunction with a conventional (magnifying) finder scope.

A third form of finder is a small, green laser pointer that projects a laser beam into the night sky. Mounted and aligned with the optical axis of the telescope, they are perhaps the fastest and easiest to use aiming system of all, although not quite as accurate as an optical finder. I have all three types of finders on my telescope, a Stellarvue Deluxe red dot, Orion 9x50mm right angle/correct image optical finder scope and a Jasper Laser pointer.

Dew shields/ Lens hoods

Refracting and catadioptric (CAT) telescopes have a propensity to collect dew on their front lenses, which, after all, are usually pointed skyward. Dew is a serious problem at night; I have seen it form on the primary mirror at the bottom of Newtonian reflectors, which have tubes far deeper than any dew shield for refracting and CAT scopes. A lens hood, called a dew shield in astronomy, can reduce, but not eliminate, this problem. Refractors often come with a lens hood, but CAT's seldom do.

If your telescope did not come with some sort of dew shield, you must buy one. Usually they are available from the manufacturer of the telescope, but if not, they are available on the aftermarket. Kendrick, for example, offers flexible dew shields in a variety of sizes to fit telescopes from 3.5 to 14 inches. I used one of these on my Meade ETX-90 and it worked fine. Kendrick also sells a dew remover system, which is a heating system to prevent the formation of dew. It is available in sizes to fit most telescopes, oculars and even the Telrad red dot finder.

Star Charts, planispheres and electronic sky maps

In order to find your way around in the night sky, you need a map. Celestron, Orion and others publish an economical set of maps that show the night sky during each season of the year. Along with each map is a brief description of the most important and interesting objects in each visible constellation. This is very useful information, and no one should be without a set of star charts. They are printed on heavy, water resistant stock, and are intended to be taken into the field.

Star charts usually have a planisphere on the front cover. If not, a planisphere can be purchased separately. A planisphere is a handy rotating representation of the night sky placed behind a large oval window that represents your field of view (assuming a flat horizon). You rotate it to set it for the date and time you are observing; it then shows you the major visible stars, constellations and where they are in the night sky. Planispheres can be purchased for a few dollars at most book stores.

More sophisticated maps of the night sky with thousands of objects are available for notebook computers and tablets. (Also for smart phones, but the screen of these is really too small to be adequate for serious astronomy.) Celestron offers an excellent night sky program called "Sky-X First Light." I find a tablet with about an 8"x11" screen to be ideal for use in the field. If you rely exclusively on electronic map programs, make sure you don't run out of battery power!

Red lens and red LED lights

In order to read your sky maps, make adjustments to your telescope and generally find things in the dark, you need a flashlight. Because you don't want to ruin your night vision when you use it, it needs to have a red lens or use red LED's as a light source. It happens that red light affects your dark adaptation less than other colors. Your astronomical flashlight should not be too bright; this is one instance when a dim flashlight is better than a bright one.

Pelican offers the versatile "Mity Lite Mini System" flashlight. This comes as a kit with a replacement halogen bulb, two AAA alkaline batteries and both clear and red lenses, all packaged in a plastic box. It is completely waterproof and also makes an excellent travel flashlight. (Always take along a small, high quality flashlight when you travel; it will come in handy and can literally be a lifesaver in an emergency.) The price is quite reasonable. The major telescope companies, Celestron and Orion for example, offer red LED lights and batteries will last a very long time in them. Celestron offers a disposable Red Astro Lite flashlight for about half the price of a Pelican Mini system or a red LED flashlight. LED Lenser, made in Germany and distributed by Coast Products in the US, has a couple of models with switchable red or white LED's, as do several other manufacturers of "tactical" grade flashlights.

LED Lenser also offers a Headband Light with a red LED and a rheostat so you can turn down the brightness. Remington Arms, Ray-O-Vac and others also offer headband lights with switchable red and white LED's. These headband lights are very handy for field use, perhaps the most convenient of all red lights to use.

If you don't use a red LED headlamp when out telescoping, a battery powered lamp with a red filter is a useful accessory for your folding table (see below under "Portable folding table"). Stanley Tools offers a "MaxLife 369" LED lamp with a self-contained, folding 7" tripod and a set of three colored filters (inc. red) that works well. The light head tilts through an arc of about 100 degrees. You can choose to use one, three, or all 6 of the lamp's LED's. Three batteries fit in each leg of the tripod and the light will run on three, six, or a full complement of nine batteries! It runs for up to 200 hours on a set of nine AA alkaline cells. The discount retail price is around 20 bucks.

Binoculars

Right behind a Star Chart in usefulness for finding objects in the night sky is a decent binocular. Binoculars are really just two small, low power, telescopes mechanically linked together. Because they provide a wide and correctly oriented view, they are very handy for locating objects at which to aim your telescope.

Binoculars for astronomy should be standard size, hand holdable, sharp and from 6x to 10x magnification. Avoid sub-compact binoculars, they are not bright enough at night. They should have an exit pupil (the light pencil you see when you hold your binoculars at arms length and look through the eyepieces) of from five to seven millimeters. This insures that sufficient light reaches your eyes to let you see dim objects.

To determine the exit pupil, simply divide the diameter of the front (objective) lens by the magnification. For example, 7x35mm binoculars have a magnifying power of 7x and 35mm front objectives. Thus, the exit pupil is 5mm (35 / 7 = 5). 6x30, 7x35, 8x40 and 10x50 binoculars all have 5mm exit pupils. 7x50, 8x56 and 9x63 binoculars have 7mm exit pupils. All of these are standard size binoculars and all of these will serve the amateur astronomer well. Top of the line stabilized binoculars are the best of all, but very expensive.

Good binoculars are available from many manufacturers, at many price points. It is best to avoid cheap department store brands (like Jason, Bushnell and Tasco), although almost any binocular will help in a pinch. Most of the standard size binoculars from the major optical companies are quite good. These include Leupold, Nikon, Minolta, Pentax, Canon and Fujinon. Swarovski, Zeiss and Leica, from Austria and Germany, are among the very best. Some telescope companies, like Vixen and Celestron, also offer good binoculars. For more information about binoculars, I strongly suggest reading my article "Binocular Basics," which can be found on the *Photography and Astronomy* index page.

Oculars (eyepieces)

Your telescope probably came with one, or possibly two, eyepieces (called "oculars"). Unfortunately, you will probably find that you need at least four of these complex little magnifying lenses. A good starting array would be one short focal length/high power ocular, two medium focal length/medium power oculars and one long focal length/low power ocular. Because the actual focal lengths of the oculars you need depends on the focal length and clear aperture of your telescope, I cannot make specific recommendations here. I have written an article which does, however. Its title is "Ocular Recommendations" and you will find it on the Astronomy section of the *Photography and Astronomy* index page.

Filters

Filters work by subtracting, or blocking, part of the light spectrum. Most filters are designed to screw into the bottom of your star diagonal or oculars. These are the most affordable kind and perfectly suitable for most applications. Others are designed to drop into or screw onto the back of specific telescopes, or (in the case of solar filters) cover the entire front of the telescope.

The most common filter and the only one virtually everybody needs is the neutral density (ND), or "moon" filter. This is usually the kind of filter that screws into your star diagonal and oculars. Since your telescope gathers over a hundred times more light than the unaided human eye, looking at the brightly lit moon is a blinding experience, akin to staring into a halogen flashlight. The neutral density filter is a gray filter that merely reduces the total amount of light reaching your eye, so that you can look at the moon without discomfort. It is like sunglasses for your ocular. Celestron, Meade, Tiffen, Orion, Tele Vue and others offer moon filters at reasonable prices.

Another common eyepiece filter is the polarizer. It serves much the same purpose as the (cheaper) moon filter, cutting glare, reducing the total amount of light reaching your eye and is available from the same sources.

A useful filter for city dwellers is the light pollution reduction filter (LPR). These can be the type that screw into oculars, or the type that fit the visual back of certain telescopes. There are broad band and narrow spectrum LPR filters. What they do is cut down on the sky glow from certain types (frequencies) of outdoor lighting common in cities. These filters are quite a bit more expensive than the moon filter mentioned above, but worth it if you must view from a light polluted site. They are offered by Celestron, Meade, Orion, Lumicon, Tele Vue and others.

Another useful filter, and one which MUST (for safety) cover the entire front of your telescope, is the solar filter. These visually opaque filters can be made of either glass or mylar (both work well). They allow you to safely look at the sun, the only star you will ever be able to examine closely. You will be able to see sunspot and the granulation of the surface of the sun, which looks rather like an orange to me. Because of their size, solar filters are relatively expensive. Thousand Oaks Optical and Celestron, among others, offer good solar filters at fair prices.

As the stickers plastered all over your new telescope warned, NEVER attempt to look at the sun without a solar filter which covers the entire front of your telescope. The sun is not something to toy with; it is a mainline star undergoing nuclear fusion. Your telescope gathers over a hundred times more light than the unaided human eye and if you look through it when it is pointed at the sun, you will be instantly and permanently blinded. The light and heat of the sun will melt the inside of your finder scope, if it is not covered while your telescope is pointed at the sun. Ultimately, the build up of heat from the sun will melt the inside of your telescope. Eyepiece solar filters are not sold by reputable manufacturers because they are not safe!

There are also colored filters, often sold in sets, much like those available for camera lenses, which screw into your eyepieces. Various colors are supposed to enhance your view of certain planets. I have tried these filter sets, but not found them to be very useful. Some observers, however, like them. Celestron, Meade, Tiffen, Orion and others offer colored filters.

Distributors like Lumicon, Celestron, Orion, Stellarvue and Tele Vue offer specialized filters for exotic purposes that cut or pass very specific frequencies of light. These tend to be expensive filters, but they are necessary for observing certain phenomena, such as faint planetary nebula, that are otherwise invisible to the human eye. Try the Oxygen III (O-III) filter for observing dim planetary nebulas.

Accessory cases

A plastic or aluminum hard shell travel case lined with closed cell polyfoam is an excellent place to carry your oculars, filters, red flashlight and other small accessories. It will also serve to keep them organized while in the field. Doskill, Winchester, Pelican, Zero-Halliburton and others offer such cases at prices ranging from low to substantial. These can be purchased at discount sporting goods stores (check out the multiple pistol cases), camera stores and astronomy dealers.

Hard cases and soft Cordura Nylon cases lined with closed cell foam are normally used for transporting and storing portable telescopes. Either type can work well to protect your telescope. I prefer the padded, Cordura type soft cases, as they generally take less space. Hard cases for specific models of telescope are generally available from the manufacturer.

Some manufacturers, such as Vixen, offer fitted hard cases for their equatorial mount heads. There are also cases, usually the Cordura Nylon type, for tripod legs. Orion Telescope is a good after market source for hard and soft cases for accessories, telescopes and mounts at reasonable prices.

Collimators for Newtonian reflectors

These are devices to aid in the optical alignment of Newtonian reflector telescopes. If you have a Newtonian telescope, you would be well advised to purchase a collimation aid, since these telescopes usually need to be collimated every time they are used. These devices allow the user to align a Newtonian reflector much more accurately than is possible by the "eyeball" method. Celestron sells an inexpensive tool which will help you get close and Tectron sells a (much more expensive) three tool set including a Sight Tube, Cheshire and Autocollimator, plus a booklet explaining collimation. This set will really let you dial in a reflecting telescope and is the way to go if you are serious about your astronomy.

Portable chair or stool

Standing up half the night gets tiring and bending over to look through a telescope eyepiece for an extended time is hard on the back. A portable, folding chair or stool will be much appreciated when you are out telescoping. Folding, three-leg camp stools are very economical and can be purchased in most sporting goods stores. They are not optimum, but they are better than nothing. A three leg stool works better than a four-leg stool on uneven ground. Another possibility is a two-step, folding kitchen ladder. These provide two seating heights, but are not as comfortable as a real stool.

Star Bound sells a well-made, steel frame, four-leg Viewing Chair designed expressly for use with a telescope. Its padded seat is easily adjustable in height from 9 to 32 inches and the four-tube steel frame serves as a backrest. This is the best and most versatile observing chair that I have encountered, but unfortunately it is not cheap. It took me a good many years to decide to order mine, but I'm glad I did.

Even more expensive than the Starbound is the three-leg Tele Vue Air Chair, which resembles a short, padded, bar stool. This chair's seat rotates through 360 degrees (a good feature) and height adjustment is easy, but limited in range to between 21-28".

Orion sells a folding, three leg camp stool and two models (standard and deluxe) of their three-leg, adjustable height, padded stools that loosely resemble the Tele Vue Air Chair. These do not appear as well made as the Tele Vue Air Chair and they don't adjust as easily, but they sell for about 1/4 and 1/3 the price, respectively.

Portable folding table

Surprisingly convenient in the field is some sort of folding camp table to hold your star chart, note pad, ocular case, etc. One type is canvas and usually has a couple of built-in cup holders. One of these cost me $5.95 on sale at the sporting goods department of my local Bi-Mart department store. Orion offers a better "Roll-Up" folding table with a wooden slat top specifically for astronomers. Bi-Mart and other department stores carry similar roll-up tables among their camping supplies. It is convenient to have a folding camp stool of appropriate height (not your viewing chair) specifically for use at the folding table.

Part 3 – Binocular Basics

Binoculars are one of the handiest and most widespread of all optical instruments. Virtually anyone who spends much time outdoors owns (or should own) a pair of binoculars. They are almost a necessity for the astronomer, hunter, saltwater fisherman, boater, sports fan, and experienced traveler.

This article is intended to help the person who needs some basic information about binoculars. I hope to explain the specifications and terms commonly associated with binoculars. For those needing a more in-depth study of the subject, I recommend the excellent little book *How To Choose Binoculars* by Alan Hale.

Perhaps the first thing to understand is that binoculars are really just two small telescopes mechanically linked together. All of the facts and formulas that help you to understand telescopes also pertain to binoculars. (You will find telescope information on my *Photography & Astronomy Page.*) Each side of a pair of binoculars has a prime focal length, an objective lens, an ocular (eyepiece), an exit pupil, and so forth.

Binoculars are designed to give a correctly oriented, right side up view. This makes them ideal for terrestrial viewing, or for locating astronomical objects in the night sky. A good pair of binoculars is one of the handiest accessories for the astronomer, hunter, sportsman, traveler, birdwatcher, and nature lover. So whether you want to get a better view of the local football game, or find a big buck across a canyon, a good pair of binoculars is often indispensable.

Quality

Note that I wrote "good pair of binoculars" in the paragraph above. What I meant by "good" is quality, both optical and mechanical. Quality is the most important "feature" of binoculars. A product that is well made of high quality components is "good," and it is always worth the extra money over shoddy "popular priced" binoculars. Quality control costs the manufacturer (and you) money, but it is worth it because the result is a better performing pair of binoculars that can last a lifetime.

Many things affect both the quality and the price of a pair of binoculars. These include optical considerations like the type of glass selected for binocular lenses and prisms, the design of the eyepieces, the size and type of prisms, care in grinding and polishing the glass elements, and the type and coverage of anti-reflection coatings. Important mechanical considerations include the material the lens barrels themselves are made of, the construction of the lens barrels (one or two piece), the way the lenses and prisms are mounted and retained in place (by sticky tape, glue, or threaded retaining rings), the focusing mechanism, and the outside finish of the binoculars.

In many cases the brand name is a guide to quality. Companies like Celestron, Leica, Minolta, Nikon, Pentax, Steiner, Swarovski, and Zeiss have spent decades earning a reputation for high quality optical products, and they are unlikely to produce a clearly inferior product. Other companies, like Tasco, Jason, and Bushnell have built a reputation on low price. You usually get what you pay for.

The dealer you buy from matters, as well. A good binocular dealer can help you select the binoculars that best fit your needs. Specialty astronomy shops, camera stores, and sporting goods stores (the traditional kind that sell guns, fishing tackle, and binoculars, not the kind that sell apparel and shoes) are usually the best sources for both good quality binoculars and good information.

Many sales clerks know virtually nothing about binoculars, sometimes not even how to focus them correctly. Do not buy from a clerk or a store that cannot provide the information you need to make an informed buying decision. If the sales person does not know at least as much as you do after reading this article, shop elsewhere.

Buy where you get the help and information you need. Good service usually costs a little more. Experienced and knowledgeable employees deserve higher salaries, and locally owned specialty stores probably have higher overhead costs than department stores and chain outlets. But it is well worth a few extra dollars to deal with people who will make the effort and take the time to see that you get the right binoculars. Good binoculars are a lifetime investment.

Prisms

Prisms are what let you see a correctly oriented image when you look through a pair of binoculars. There are two types of prisms in common use, Porro prisms and roof prisms.

Roof prisms are essentially in line inside the optical tubes, and make for a more compact set of binoculars. Roof prism binoculars have straight tubes (the front/objective lens is in line with the rear/ocular lens), and are therefore more compact, an important consideration for the sportsman. They usually have two pivot points between the tubes, and are more difficult to adjust to the spacing of your eyes. Roof prisms can give an optical image equal to the best Porro prisms, but for technical reasons they usually do not. To be really good, roof prism binoculars have to be in the high price class. Do not attempt to economize on roof prism binoculars.

Porro prism binoculars can be identified by their offset tubes; the objective lens is not in line with the ocular lens. The front lenses are usually closer together than the rear lenses, but the reverse can also be true, particularly in compact models. The Porro prism design is usually optically superior to the roof prism design, especially in medium priced class binoculars. Porro prism binoculars have a single pivot between the two halves of the binocular, and are therefore easy to adjust for the distance between your eyes.

Like roof prisms, not all Porro prisms are created equal. BAK-4 prisms are the best; they are made of superior optical glass that produces clearer images. These are what you want in your binoculars. BK-7 prisms are also used, usually in lower priced binoculars. These are satisfactory, but they are inferior to the BAK-4 prisms. Some manufacturers will not tell you what kind of prisms they use, usually because they are of inferior quality.

Lens coatings

Most binoculars have antireflection coatings on their air to glass surfaces. These coatings assist light transmission. They are what produce the blue, red, or green reflections you see when you look into the front (objective) lens of a pair of binoculars.

But note how the manufacturer describes his coatings. "Coated" means a single layer antireflection coating on some lens elements, usually the first and last elements--the only ones you can see. "Fully Coated" means that all air to glass surfaces are coated. This is good. "Multi-Coated" means that at least some surfaces (again, usually the first and the last) have multiple layers of antireflection coatings. (The others presumably have single layer coatings.) Multiple layers are about an order of magnitude more effective than a single layer. "Fully Multi-Coated" means that all air to glass surfaces have received multiple layers of antireflection coatings, and this is what you want in your binoculars.

The latest fad in coatings is ruby or red multi-coatings. These are intended to reduce glare in bright light.

Collimation

Collimation refers to the optical and mechanical alignment of the binoculars. If a pair of binoculars is out of collimation, after prolonged use it may feel as if they are trying to suck your eyes out of your head.

Cheap binoculars are often (perhaps usually) shipped from the factory out of collimation. Good binoculars are carefully collimated, often with laser instruments. This requires time and expense at the manufacturing level, and raises the price at the retail level.

Magnification (power)

Binoculars are commonly described by using a pair of numbers, as in "7x50" or "8x25." The first of these numbers refers to the magnification offered by the binocular. Magnification is why most people buy a pair of binoculars. In the examples above, "7x" means the binocular makes whatever you look at appear seven times closer than it does to the unaided human eye. "8x" means the binocular makes whatever you look at eight times closer than the unaided human eye. "10x" makes things look ten times closer, and so on. The first number used to describe binoculars always refers to their magnification. Common binocular magnifications are 6x, 7x, 8x, 9x, and 10x.

There are also variable power (zoom) binoculars, such as 7-21x50. These almost always perform much better at the low power setting than they do at the higher settings. This is natural, since the front objective cannot enlarge to let in more light as the power is increased, so the view gets dimmer. At 7x, the 50mm front objective provides a 7.1mm exit pupil, but at 21x, the same front objective provides only a 2.38mm exit pupil. Also, the optical quality of a zoom binocular at any given power is inferior to that of a fixed power binocular of that power. In general, zoom binoculars are not the bargain they seem to be.

Remember that everything (including movement) is magnified when you look through a pair of binoculars, especially your own shakes and tremors. So the higher the power, the harder it seems to hold the binoculars steady. 6, 7, or 8 power binoculars are easier for most people, even those with very steady hands, to hold reasonably still. The higher powers sound like a good deal, but often result in jiggly, blurred views. This is why 7x binoculars are chosen by so many experts, including the military.

Power affects brightness. Other things being equal, the higher the power, the dimmer the view. And power also affects the field of view of the binoculars. Again, everything being equal, the higher the power, the smaller the field of view. So, as you can see, power must be balanced against other desirable characteristics when choosing binoculars.

Objective lens (diameter)

The second number most commonly associated with binoculars refers to the diameter of the objective lens in millimeters. Thus in "7x50," the "50" means that the front lenses of the binoculars are 50mm in diameter, which is large for hand held binoculars.

This is very important information, because the larger the diameter of the front objectives, the more light can enter the binoculars and be focused to your eyes. Thus, other things being equal, you can see better in dim light with binoculars that have large front lenses. For example, 7x50 binoculars are often called "night glasses" because they seem so bright in dim light. Read more about this under "Exit pupil." Of course, a large front objective makes for larger, and heavier, binoculars. Which is why compact binoculars always have relatively small front lenses.

Exit pupil

The magnification and the diameter of the objective lens determine the size of the exit pupil. The diameter of the exit pupil determines how much light is transmitted to your eye. The exit pupil can be seen by holding the binoculars at arm's length and looking through the eyepieces. The pencil of light you see is the exit pupil.

The actual diameter of the exit pupil is easily computed. Divide the diameter of the front objective lens (in millimeters) by the magnification of the binocular. For instance, take a pair of standard size 7x50 binoculars. Divide 50 (the diameter of the objective) by 7 (the magnification) and you get approximately 7.1 (50/7=7.1). 7.1mm is the diameter of the exit pupil for 7x50 binoculars. Now let's figure the exit pupil of a pair of compact 8x25 binoculars. Divide 25 by 8 and you get 3.1 (25/8=3.1). So the exit pupil of 8x25 compacts is only 3.1mm. A lot less light reaches your eye from compact binoculars than it does from standard size binoculars. Light is what you are sacrificing to get compact size and weight.

Why does the diameter of the exit pupil matter? It doesn't as long as there is enough ambient light so that the pupils of your eyes are smaller than the exit pupils of your binoculars. But when the ambient light gets dim, and the pupils of your eyes adapt by enlarging, the exit pupils of your binoculars may become the limiting factor. With the 8x25 compacts in the example above, when it gets dim enough for the pupils of your eyes to exceed 3.1mm in diameter, the binoculars are restricting the light available to your eyes. Ideally, human eyes in excellent condition can achieve about a 7mm pupil opening, so a 3.1mm exit pupil from your binoculars can be quite limiting in dim light. You can probably see more without your binoculars. But the 7x50 binoculars in the first example above have 7.1mm exit pupils, as large as young, fully dark-adapted human eyes, so they never limit what you can see, even at night.

The human eye loses its ability to adapt to dim light as it ages, so a middle-aged person's maximum pupil size is typically down to around 5mm. Elderly eyes are often limited to about a 4mm pupil maximum pupil. So as we age, the exit pupil size we need decreases.

Field of View

The field of view is the area seen through your binoculars. It is properly measured in degrees. The larger the field of view the more area you can see. Field of view is particularly important when observing moving subjects, like animals or birds, or at sporting events.

Relative brightness index (RBI)

RBI endeavors to measure image brightness. It is computed by squaring the exit pupil. For example, 7x35 binoculars have a 5mm exit pupil (35/7=5). So their RBI is 25 (5x5=25).

A RBI of 25 or greater is considered good for use in dim light. Since you already have learned (above) how to compute the actual exit pupil size, and what it means, RBI is largely redundant.

Twilight factor

This is a somewhat subjective measurement that purports to reveal how much detail you can see in twilight conditions (however that is defined). It tends to favor magnification, which is good for binocular sales.

For instance, Celestron computes the twilight factor of 7x50 binoculars as 18.7, and the twilight factor of 10x50 binoculars as 22.4, even though the former has a 7.1mm exit pupil, and the latter only a 5.0mm exit pupil. The increased magnification presumably makes up for the decrease in brightness in "twilight conditions" (when the eye is not yet fully

dark-adapted). This rather artificial measurement can be useful to the hunter and birdwatcher, since animals are often spotted just before sunrise, and just after sunset.

How to focus binoculars

It is surprising how many people do not know how to focus binoculars correctly. There are two common focusing systems used in binoculars.

The first is individual eyepiece focus. This system is simple to understand, and easy to manufacture. It also lends itself well to sealed optical tubes, and thus is usually the focusing system used for waterproof binoculars. Individual eyepiece focus means that to focus the binoculars to your eyes, you simply focus the left eyepiece to your left eye and the right eyepiece to your right eye. There is no centrally located focusing mechanism. It is done like this. Look at something in the distance. Close the right eye (or cover the front of the right binocular), and focus the left eyepiece to your left eye. Close the left eye (or cover the front of the left binocular), and focus the right eyepiece to your right eye. You are finished, until you need to look at something at a different distance, in which case you need to repeat the process.

Because individual eyepiece focus is time-consuming, center focus is more common. Unfortunately, very few people understand how to correctly use center focus binoculars. Here is how it is done. Aim your binoculars at something in the distance. Close the right eye (or cover the front of the right tube), and focus the left side of the binocular to your left eye using the center focus control, which is concentric with the pivot shaft between the binoculars. (Note: the left eyepiece itself does not focus on center focus binoculars.) Next, close your left eye (or cover the front of the left tube), and focus the right eyepiece to your right eye. DO NOT touch the center focus control while you are focusing the right eyepiece to your right eye. Now you are finished. What you have just done is adjust the binoculars for your individual eyes. (Practically everybody's left and right eyes are different.) From now on, you only need to adjust the center focus control when you look at things at different distances. Center focus is faster and easier to use than individual eyepiece focus, once you have initially set the binoculars for your eyes.

Binoculars for Travel

Travel binoculars need to be light and compact so that they will fit easily into carry-on luggage, or even a pocket. This is where the compact roof prism type of binocular really comes into its own. Great light grasp can be sacrificed for portability, since travel binoculars will ordinarily be used during daylight hours. Magnification must permit handheld viewing as aids to steady support will be few and far between. Something between 7 and 10 power would be a reasonable choice. Very high optical quality helps make up for limited light gathering ability.

My personal travel binoculars are compact 9x Leupold roof prism glasses. I would not have them any more, nor much less, powerful. 8x might be even better. They came with a soft leather pouch case that has a convenient belt loop, and that is how I most often carry them, although they will also fit into a shirt or jacket pocket.

Binoculars for astronomy

A good pair of binoculars are very handy for locating objects in the night sky. Once an object has been located with binoculars, it is easy to train a telescope on it for a more detailed view. The binocular astronomer needs very high quality, very bright binoculars. For general hand held use 7x50, 8x56, and 9x63 binoculars will serve very well. Pick the highest power that you can hold steady.

Giant binoculars are in a class by themselves for binocular astronomy. These require a solid tripod mount, but reveal spectacular views of large objects like open star clusters. The 20x80 size is the most popular, and perhaps represents the best compromise between magnification, brightness, and field of view for general astronomical observing.

Binoculars for hunting and fishing

For finding things in the field, you need fairly bright binoculars. The navies of the world generally use 7x50 binoculars on their ships. These offer a 7.1mm exit pupil and gather all the light young eyes can use. They also offer a good field of view and as much magnification as is practical from a moving vessel. However, they are comparatively heavy and bulky. This is not a problem for a fisherman operating from a boat and 7x50 marine binoculars are the first choice for the salt water fisherman. However, the hunter needs something more compact.

For field applications a 4mm to 5mm exit pupil is usually satisfactory and 6x30, 7x35, 8x30, or 9x35 binoculars are probably the most useful compromise for hunting. They are bright enough to allow the observer to see into shadowed areas, or in dim light, and compact enough to not be an excessive burden to carry. Higher power binoculars are hard to hold steady without external support and objective lenses of 40mm or larger tend to make for heavy and bulky binoculars that are a burden to carry.

The woods hunter will be well served by a glass with a generous field of view, like a 6x30. The mountain hunter will probably favor higher power, since he will use them to spot game at greater distances. 8x30 or 9x35 binoculars will do well. A pair of the common 7x35 size binoculars is probably about as good for all-around field use as any. Whatever magnification best fits your needs, be sure to buy top quality binoculars and you will not be disappointed.

Part 4 – Ocular (Eyepiece) Basics

Oculars (the correct term for "eyepieces") are probably the first accessory purchased by most telescope buyers. Additional oculars (beyond the one or two supplied with most telescopes) make visual observing much more enjoyable. Like camera lenses, they determine the field of view and magnification seen through your telescope. Having a proper selection of oculars adds greatly to the versatility of any telescope.

Before buying accessory oculars, it is wise to learn some basic facts about these expensive little magnifying lenses that slip into the focuser or star diagonal of your telescope. There are also some terms that it is necessary to understand. (Additional astronomy and telescope definitions can be found in the article "Definitions for the Amateur Astronomer.")

Focal length

Like telescopes themselves, oculars have a focal length, which is expressed in millimeters. In oculars, focal length is measured from the optical center of the ocular (called the rear nodal point) to the point of focus in space where you put your eye. Astronomers seldom talk about oculars in terms of magnification; they usually refer to them by their focal length, just as photographers do when talking about their lenses.

Focal length is important because it determines how much the ocular magnifies the image sent to it by the telescope. The shorter the ocular's focal length, the more it magnifies the image; while the image is larger at higher power, it is also dimmer and the actual field of view is smaller. The longer the ocular's focal length, the less it magnifies the image, but the image is brighter and the actual field of view is larger. Image brightness and field of view decrease as magnification increases.

Apparent field and actual field of view

Apparent field of view (AFOV) is the angular size of the light cone covered by the ocular. Good apparent field makes an ocular enjoyable to look through, more like looking through a porthole than a knothole. Apparent field is not the same thing as the actual field of view (FOV) of your telescope, which is the angular field of view (the area) visible through your telescope. The true field of view through your telescope probably seldom exceeds 1 degree and is often less. Actual field of view can be computed by dividing the apparent field of view of your ocular by the power of your telescope/ocular combination. For example, a telescope with a prime focal length of 1000mm with a 10mm ocular in place is operating at 100 power (1000/10=100). If that 10mm ocular happened to be a Plossl with an apparent field of 50 degrees, the actual field of view of the telescope would be .5 degree (50/100=0.5).

Exit pupil

The diameter of the pencil of light leaving the ocular of a telescope is called the exit pupil. The exit pupil should not exceed the maximum, dark adapted, diameter of the pupil of the viewer's eye, which averages about 7mm for young eyes in good condition. As we age, our maximum pupil size gradually decreases. Middle aged people frequently have about a 5mm maximum pupil size. This sets the minimum practical power for your telescope, which is whatever power produces an exit pupil equal to what your eye can accept. The formula for computing exit pupil size is simple. Divide the clear aperture of the telescope (in millimeters) by the magnification. For example, a 6" (150mm) scope operating at 50 power has a 3mm exit pupil (150/50=3).

Eye relief

Eye relief is the distance, usually measured in millimeters, from the ocular element to the eye. It is important, because viewing through an ocular with insufficient eye relief (only a few mm) is difficult. Eye relief is particularly important for eyeglass wearers. Fortunately, unless you have astigmatism, it is not necessary to wear your glasses when viewing through a telescope; the telescope itself is focused to your eye.

Magnification

Magnification is determined by dividing the prime focal length of the telescope (in millimeters) by the focal length of the ocular (in millimeters). In any given telescope, a shorter focal length ocular will give higher magnification and a longer focal length ocular will give lower magnification.

Ocular barrel diameter

There are three common ocular barrel diameters. These are .965", 1.25" and 2". 1.25" oculars are the size most often supplied with good quality astronomical telescopes. A few good telescopes are supplied with .96" oculars and conversely, some low quality telescopes are supplied with 1.25" oculars. The folks who distribute cheap telescopes are becoming wise to the fact that 1.25" oculars are a feature semi-informed buyers use to differentiate between "good" and "bad" telescopes and have begun to supply the larger size with their inferior scopes to deceive such buyers. The optical quality of an ocular is more important than its nominal diameter.

0.96” Oculars

.96" oculars are used in many popular "department store" telescopes and some more advanced models, such the famous Celestron C-90 spotting scope. The primary advantage of .96" oculars is simply that they are smaller and usually

less expensive than their larger brethren. They balance well in small telescopes and if they are of good quality they can perform well. Most experts consider them more difficult to look through than larger size oculars.

I once asked Alan Hale (then President of Celestron International) why he persisted in supplying .96" oculars with the C-90 and he told me that he personally preferred the smaller size oculars in the (physically small) C-90 telescope. (Note: the new G-3 astro telescope version of the C-90 comes with a 1.25" ocular.) I prefer the larger 1.25 size oculars and one of the first things I have done with my C-90 telescopes is adapt them to this size ocular. The selection of .96 oculars is reasonable, but not as large as that of 1.25" oculars.

1.25" Oculars

The most common ocular size for astronomical telescopes is 1.25" diameter. These are supplied with the great majority of "serious" amateur telescopes and are one of the hallmarks of a high quality instrument. Many manufacturers offer comprehensive lines of 1.25" oculars. The principle advantage over .96" oculars is a larger opening into which to peer. The principle advantage over 2" oculars is lower weight. The large 2" oculars and associated 2" star diagonals are simply too heavy for many amateur telescopes. 1.25" oculars are also less expensive than 2" oculars and more readily available.

2" Oculars

The big 2" oculars are wonderful to view through, but for the reasons mentioned above, they are best reserved for the larger sizes of amateur telescopes. 2" oculars are most commonly found in medium to long focal lengths (17mm and up) and they are excellent for wide sky views. Shorter focal lengths (higher magnifications) are usually reserved for the 1.25" size oculars. On the amateur market, 2" oculars are less widely distributed than 1.25" oculars and the selection is smaller. The focusers or visual backs of most advanced amateur and professional telescopes are designed for 2" oculars and they can be adapted to many other amateur telescopes. These big oculars are usually excellent performers, the limiting factors being weight, expense and availability. The latter is slowly improving.

Ocular designs

There are many different designs, or optical formulas, for oculars. Like camera lenses, inside of every ocular you will find a group of individual lens elements. Oculars usually consist of two or more elements. Two element optical designs are called "achromats" (or achromatic). They focus the long and short wavelengths of visible light, red and blue, to a common plane, but green light is not properly focused and typically creates a noticeable fringe of color around bright objects. Two element oculars are to be avoided; their only advantage is low price. Some common names for, or descriptions of, two element optical formulas are Ramsden, Huygenian and just plain "achromat" These cheapies are usually found in the .96" size.

Since it requires at least three elements to focus all three primary colors of light (red, green and blue) to a common point, all but the cheapest and most inferior designs have at least three lens elements. Oculars designed to the Kellner formula have three elements, as do the similar Modified Achromat (MA) and Super Modified Achromat (SMA) types. (The modification appears to be the addition of a third lens element.)

Kellner type oculars generally have an apparent field of view of about 40 degrees, with moderate eye relief. They have good center sharpness, but exhibit some evidence of field curvature and astigmatism. They are most useful for terrestrial, planetary and lunar viewing. These are the least expensive practical oculars and are offered in focal lengths from about 6mm to 40mm. I have found the moderate 16mm to 25mm focal lengths to generally be the most useful in the .96" Kellner oculars I have owned. Kellner and other three-element ocular designs are available in .96", 1.25" and 2" diameter oculars.

In practice, a forth element is usually required to "bring it all together" and produce sharp views without intrusive aberrations. (All ocular designs have some residual aberrations.) Four element oculars are very common and generally perform very well. Orthoscopic and Plossl oculars are common types that feature four elements. The Orthoscopic design is asymmetrical and the Plossl is a symmetrical design.

The Ortho is a good design for oculars used to view bright objects. It has very good center sharpness with only a small amount of field curvature and astigmatism. Perhaps because of its asymmetrical design, it is less susceptible to internal reflections (ghost images) than the Plossl design. Orthos have an apparent field of about 45 degrees and more eye relief than Kellners. I have owned Orthos in both .96" and 1.25" size and found them a very good choice for planetary and lunar viewing. Orthos are most common in focal lengths from about 4mm to 25mm. I have found the 9mm to 12mm focal lengths most useful in the telescopes I have owned.

The Plossl design has become the mainstay of the ocular business and probably represents the best value in terms of performance and price in medium and long focal lengths. Plossls are most common in the 1.25" and 2" sizes, but I believe there is at least one company offering .96" Plossls. It is a well corrected design that uses four elements in two symmetrical pairs. Plossls typically have about 50 degrees of apparent field.

If well made, Plossls are bright and contrasty, with a flat field and excellent sharpness. They offer marginally better eye relief than Orthos and are available from many suppliers in a wide range of focal lengths in 1.25" diameter, typically from about 6mm up to 45mm. In addition, Plossl oculars are usually parfocal within a given manufacturer's line, which means that when one is in focus, they are all in focus. The longer focal length Plossls provide adequate eye relief for eyeglass wearers.

Plossls are useful for most purposes, from short focal lengths designed for planetary views and splitting double stars, to long focal lengths designed for spectacular deep sky views. A 50-56mm Plossl in 2" diameter is spectacular for wide field, deep sky viewing. Plossl oculars are available from Celestron (Omni), TeleVue, Meade (Super Plossl), Orion (Sirius), Vixen and others.

The Erfle is a 5-element design which features a wide apparent field of view of about 60 degrees. These are usually available only in 1.25" and 2" size. Meade QX 1.25 and 2" oculars are probalby the best known Erfles today. Offering a similar apparent field in both sizes are the premium, 6-element designs called Super Wide Angle by the Meade Instrument Company, which fulfil the same role as traditional Erfles.

Erfles have a nice, flat field from edge to edge, although sharpness is slightly inferior to the Orthoscopic and Plossl designs. They also feature long eye relief, especially important for eyeglass wearers. This combination of features makes these oculars excellent for wide sky viewing of open clusters, starfields, etc. They are usually found in focal lengths in the 18mm to 32mm range. I have used 1.25" Erfles in 24mm and 32mm focal lengths, where they give a greater field of view than Plossl type oculars. In 1.25" diameter, the Meade Super Wide Angle oculars are available in focal lengths from 13.8mm to 24.5mm and the QX in 15mm and 20mm focal lengths.

Some modern ocular designs incorporate more elements than Plossls, Orthos and Erfles for improved correction of aberrations, increased eye relief and a wider apparent field of view. The upscale TeleVue Radian, Tele Vue Panoptic, Celestron X-Cel, Celestron Ultima, Burgess/TMB Planetary and Meade 5000 Series ocular lines (to name a few of the better known brands) are priced higher than standard designs and are available in a variety of focal lengths.

Some premium ocular designs incorporate extra low dispersion glasses with rare earth elements to improve performance. The Celestron X-Cel, TeleVue Nagler and TeleVue Radian are examples of well known ocular lines that incorporate various types of ED glass elements in their design. The Vixen Lanthanum-LV oculars, all of which have an eye relief of 20mm, regardless of focal length, use a Barlow lens in front of the main 5-element group, one of which is made

of glass incorporating the rare earth element Lanthanum. The total number of elements in these oculars reportedly varies from 6 to 8, depending on focal length and Barlow design. These Lanthanum-LV oculars are available in focal lengths from 2.5mm to 25mm.

TeleVue's Radian oculars have a 60 degree apparent field of view and are primarily intended for high magnification purposes. They range in focal length from 3mm to 14mm, in 1.25" size only. TeleVue's premium Panoptic oculars have a 68 degree apparent field and are available in both 2" and 1.25" barrel diameters. There are three focal lengths in the 1.25" size: 15mm, 19mm and 22mm. Celestron Ultima LX oculars have an apparent field of 70 degrees and are offered in focal lengths from 5mm to 32mm.

There are some premium specialty oculars that feature extra wide apparent fields of view and long eye relief. Prominent among these are the TeleVue Nagler, Meade Ultra Wide Angle (8-element) and Celestron Axiom LX designs. Naglers have an astonishing apparent field of 82 degrees, the Meade Ultra Wides 84 degrees and the Celestron Axiom LX 81 degrees! The Meade and Nagler ultra-wide designs are primarily used for short focal length (high magnification) applications, because short focal length necessitates short eye relief and tiny openings in conventional ocular designs. Focal lengths run from 4.7mm to 14mm (1.25" Meade Ultra Wide Angle series) and 4.8mm to 16mm (1.25" TeleVue Nagler series). Celestron offers their Axiom LX line in a wider range of focal lengths, ranging from 7mm to 31mm. These are all expensive oculars to buy, but for the person who does a lot of high magnification viewing, they may be worth it.

Ocular (Eyepiece) Recommendations

The focal length of your telescope, as well as the focal length and apparent field of view (AFOV) of the ocular, determine both the actual field of view and the magnification of that view. For reasons of time and space, it is impossible to give specific ocular recommendations for telescopes of every focal length. What I can do is to make some specific recommendations of ocular lines and brands that have served me well. (Note: there are other brands and lines with which I am not familiar and therefore do not mention in this article, but that does not mean they aren't good.)

I can also suggest some appropriate ocular focal lengths for a couple of common telescope prime focal lengths with which I am personally familiar. These are: 900mm (common for various 80mm-105mm aperture refractors and 4.5" aperture reflectors) and 2000mm (the classic Celestron C8, Meade LX-10/50/200 and others). The recommendations in this article assume oculars with standard 1.25" diameter mounting barrels.

Recommended ocular types, brands and lines

Most amateur astronomers are using oculars that are widely available from the major telescope manufacturers, distributors and retailers. The common ocular brands include Celestron, Meade, Orion, TeleVue, Takahashi, Pentax, Burgess and Vixen; each of these brands offers multiple ocular lines. Major online retailers include the manufacturers/distributors themselves, as well as discount retailers specializing in telescopes and astronomical accessories, such as Optics Planet, Astronomics, Woodland Hills Telescope, Anacortes Telescope, OPT (Oceanside Photo & Telescope), Orion and others. Some of these retailers private label generic Chinese made eyepieces.

Usually the lower priced ocular lines from the top manufacturers are of conventional Orthoscopic or Plossl design, with the Plossl being the most popular ocular design today. These are four element oculars that offer good sharpness and contrast and, especially in medium and longer focal lengths, adequate apparent field and

eye relief. The Ortho is a good design for high magnification lunar and planetary viewing, while the Plossl is preferred for deep space and general observing and offers greater eye relief and apparent field of view.

The TeleVue Plossl, Celestron Omni Series, Orion Sirius, Vixen NPL and Meade Series 4000 Super Plossl lines are widely distributed Plossl oculars. (The Meade Series 5000 "Plossls" are really Erfle type oculars; why Meade persists in deceptively calling them Plossl eyepieces is hard to understand.) Plossls generally perform well and are sold in a wide range of focal lengths from 4mm to 45mm in the common 1.25" barrel diameter size. The apparent field of view usually runs about 50-52 degrees (depending on brand) in all but the longest focal lengths. Short focal length Plossl oculars of conventional design have limited eye relief and a small ocular lens, however, which makes them hard to look through. There are better designs for short focal length oculars.

I have owned and used 1.25" Plossl's as short as 7.5mm and as long as 45mm. These days I feel that Plossls are best reserved for focal lengths above 15mm and they are *most* useful in focal lengths from 25mm to 45mm. I use long focal length Celestron and Tele Vue Plossls, but Vixen NPL and Meade Series 4000 Super Plossls are also well respected.

Celestron X-Cel LX oculars are available in the 18mm and 25mm sizes, in addition to shorter focal lengths. These six-element ED oculars offer excellent sharpness, flat field, 20mm eye relief and a very useable 55-degree apparent field of view. They cost more than Celestron Omni Plossl's, but are economical compared to other premium oculars and are worth every penny of their relatively modest price. Higher priced alternatives in medium focal length oculars include the TeleVue Panoptic (68-degree apparent field), Baader Planetarium Hyperion (68-degree apparent field), Vixen Lanthanum Wide (65-degree apparent field) and Vixen NLV (60-degree apparent field).

For shorter focal length oculars, meaning oculars of about 15mm and less, I prefer to spend the extra money for sophisticated designs with a wider apparent field of view and greater eye relief than offered by Ortho and Plossl oculars. I have used others in the past, but as I write these words I am using Tele Vue Radian and Burgess/TMB Planetary oculars in the short focal lengths. These deluxe oculars have a wide, but not excessive, apparent field (60-degrees) and long eye relief (20mm in the case of the Radian and 16mm in the case of the Planetary). They are much easier to look through than conventional Orthoscopic and Plossl oculars, especially for eyeglass wearers. Other good choices in short focal length oculars include the Pentax XF, Vixen Lanthanum Wide, Vixen NLV, Tele Vue Nagler, Baader Planetarium Hyperion and Celestron X-Cel LX lines.

Building a personal ocular system

When building your personal ocular system, you first need to decide what focal lengths and types best fit your needs. The telescope(s) you own and the viewing that you intend to do, along with any special requirements, should guide your selection. If you view while wearing eyeglasses, for example, you will need oculars that offer a generous amount of eye relief regardless of focal length; you might decide to eschew oculars with less than 20mm of eye relief. Having decided how many oculars you can afford, at approximately what focal lengths, you can then ponder the best way to acquire them.

I have built a reasonable collection of oculars over the years by "cherry picking" (mix and match) from different brands and lines. This is what happens if you base your selections on focal length, suitability for purpose and price without much regard for brand or line. The result is that in the short to medium focal

lengths I now own 4mm, 7mm and 9mm Burgess/TMB Planetary oculars plus 8mm, 12mm, 14mm and 18mm Tele Vue Radians. In the longer focal lengths I am using a 25mm Celestron X-Cel, 32mm Tele Vue Plossl and 40mm Celestron Plossl. As a "catch all" ocular, I acquired a Tele Vue 8-24mm Click-Stop Zoom. This rather eclectic ocular collection does a pretty good job!

Rather than mix and match brands and lines, you might choose a favorite *brand* and select oculars from its various lines. For example, you could not go wrong by deciding to standardize on Tele Vue 1.25" oculars. You might decide to buy Nagler 6 oculars in the shortest focal lengths, such as 5mm and 7mm. You could switch to Radians for your 8mm, 12mm, 14mm and 18mm oculars. In the longer focal lengths, a 24mm Panoptic plus 32mm and 40mm Plossl oculars would serve nicely for deep sky viewing. You would be using different optical designs optimized for different purposes, but they would be similar in quality and appearance/graphics. The members of your local astronomy club would be impressed with your knowledge, discrimination and style.

It is worth noting that the Tele Vue Plossl, Celestron Omni Series Plossl, Baader Planetarium Hyperion and Meade Series 4000 Super Plossl eyepieces, among others, are available in a wide range of focal lengths, from short to long. Most of the oculars within these individual Tele Vue, Celestron, Orion and Meade lines are parfocal, meaning that they all come into sharp focus at the same distance, eliminating all but the most minor need for re-focusing. Years ago I had a complete set of first generation Celestron Plossl oculars, from 7.5mm to 45mm. Economic circumstances eventually forced the sale of my telescope and I foolishly sold my oculars along with it, thus learning an important, if bitter, lesson: never sell your oculars! If you want to stay with one brand and line for the sake of uniformity, the ocular lines mentioned in the first sentence of this paragraph might be worth considering.