How to Buy an Astronomical Telescope

Advice for the Beginner

Presented by
The York County Astronomical Society
New Telescope Clinic
Henry Hoffman & Mike Wenz, Co-Chairs

Introduction

- This presentation is to introduce you to optical astronomical telescopes intended for amateur use with the idea that you might be buying your first one in the near future

- This presentation will not cover use of optical telescopes for terrestrial viewing, use of telescopes for astrophotography, or amateur radio astronomy

Glossary

This very informal glossary of terms is provided to help understand the charts in the YCAS presentation "How to Buy an Astronomical Telescope" and is placed up front so that it can be referred to. These definitions are not necessarily scientific, but are provided as an aid to easy and basic understanding.

- **Achromatic:** Literally, "free from color". In amateur refractor telescopes, the use of a doublet objective lens to provide moderate correction for chromatic (color) aberrations in the refracted light (because all colors do not refract at the same angle).
- **Altitude/Azimuth (Alt-Az):** a type of telescope mount that permits movement straight up and down and side to side.
- **Aperture:** the effective diameter (expressed in either millimeters or inches) of a telescope's objective lens or primary mirror. This serves as an indicator of a telescope's light gathering ability. The larger the aperture, the more light that is gathered. The area of the lens or primary mirror determines the light gathering capability (and the area increases as the square of the radius for a circle), so light gathering quadruples with doubling of the aperture; e.g., an 8" diameter telescope gathers four times as much light as a 4" diameter telescope.

- **Apochromatic:** Use of more than two elements (i.e., three or four) in a refractor objective lens to provide greater chromatic aberration than in achromatic objectives.
- **Barlow lens:** The Barlow lens effectively increases the focal ratio of the optical system and therefore serves as a magnification multiplier. It fits between the eyepiece and the focuser tube. These lenses are available in strengths between 2x and 5x. They are essential for short focal ratio (e.g., f/5) optical tubes to achieve maximum magnification.
- **Binocular:** two optical tube assemblies rigidly mounted in parallel so that both eyes can receive the same image at the same magnification.
- **Catadioptric:** a type of optical tube assembly that uses both a primary mirror and a glass "corrector" lens to gather and focus light.
- ***Caveat emptor*:** Latin for "Let the buyer beware."
- **Celestial sphere:** an imaginary sph ere in the sky rotating upon the same axis as the Earth. All objects in the sky can be thought of as being projected on the celestial sphere
- **Collimation:** in a reflector telescope, the mechanical process of aligning the secondary mirror, the primary mirror, and the focuser tube (where the eyepiece is inserted) to ensure the best focused and resolved image. This is usually required periodically (and sometimes right out of the box) with Newtonians and occasionally with Schmidt-Cassegrain telescopes. It is almost never required on Maksutov-Cassegrain telescopes. In refractors, collimation is the process of aligning the objective lens with the focuser. It is usually not required unless the optical tube left the factory misaligned or the optical tube receives a sharp blow that knocks the optics out of line.

- **Collimation (Cheshire) Eyepiece:** a device that is used in the telescope's focuser tube during collimation to help align the secondary and primary mirrors with the focuser tube. It is usually used with Newtonian optical tubes.
- **Contrast:** in astronomical viewed images, the difference in light and dark between light astronomical objects being viewed and the dark background of the night sky. Note: In light polluted areas contrast is usually very poor, making objects difficult to see.
- **Cool down time:** the time needed to allow the optical tube assembly to reach the same temperature as the air outside. Until this is done, air currents swirling inside the OTA or flexing of the optical elements can disrupt the view. This process generally takes longer for OTAs closed at both ends (e.g., Cassegrain OTAs) than for open-ended Newtonian OTAs and can take between 15 to 60 minutes, depending on the type and size of the telescope.
- **Declination:** the celestial equivalent to geographic latitude as projected on the celestial sphere. It is measured 0 - +90 degrees north and 0 – 90 degrees south of the celestial equator.
- **Deep space object (DSO):** an astronomical object outside of the Earth's solar system.
- **Dobsonian (DOB) mount:** a simple alt-az mount invented by John Dobson that allows for pushes and pulls by the user's hand to move a Newtonian optical tube to desired celestial targets. This basic version represents one of the cheapest ways into amateur astronomy. Some sophisticated Dobsonian mounts now are available with electronic indictors that tell where the optical tube is pointed (in RA and Dec) or, with the aid of motors, move the tube to the target. These latter versions can be very expensive.

- **Equatorial (EQ):** The equatorial coordinate system is a widely-used method of mapping celestial objects that functions by projecting the Earth's geographic poles and equator onto the celestial sphere. An equatorial telescope mount is adjusted to align with this system, allowing the telescope to track objects accurately by moving only in right ascension (once the declination is properly set).
- **Eyepiece:** A lens inserted into an optical tube assembly's focuser tube or star diagonal to focus light images into the human eye. There are many types and designs that have been used over past years. The basic size is currently 1.25 inches in diameter, though some amateur astronomers use 2" diameter eyepieces (which require 2" focusers to use them – limiting the telescopes with which they can be used).
- **Filter:** a translucent glass disk that is colored and mounted to be able to be screwed into the bottom of an eyepiece to help bring out details in objects (such as planets) or restrict certain bands of light to enhance certain types of deep space objects (e.g., nebulae).
- **Finder Scope:** a small refractor telescope of low magnification (e.g., between 5x and 9x) mounted on the main telescope to aid finding celestial objects.
- **Focal length:** roughly, the distance between where light enters the primary optical element and where it comes to focus to produce and image. Applies to both optical tube assemblies and eyepieces. Usually expressed in millimeters for both optical tubes and eyepieces.
- **Focal ratio:** the ratio between the focal length of an optical tube and its diameter (aperture). Symbol = f/. Example: 1000mm focal length / 200mm aperture = f/5.

- **Fringing:** the effect of chromatic aberration that produces a visible red and/or blue/purple “fringe” around very bright objects – particularly bright planets. This is a problem especially in achromatic refractors, but can be controlled somewhat by a “fringe” filter (e.g., Orion V-Block filter). Fringing is seen much less in apochromatic refractors.
- **Go-to:** a type of telescope mount powered by several small batteries, a 12 volt power supply, or an AC adapter that, once properly aligned, will find celestial objects with the aid of a computerized hand controller and track them without further adjustment. Controllers often allow for interface with a laptop computer, which then allows for using software programs to select desired target objects and command the telescope to move to them.
- **Lunar:** applying to the Earth’s Moon.
- **Maksutov-Cassegrain (MAK) telescope:** a catadioptric telescope design that combines a spherical mirror with a weakly negative meniscus lens.
- **Newtonian telescope:** an optical tube open on one end that uses a primary mirror and a flat, 45-degree secondary mirror to gather and focus the light into an eyepiece mounted at the open end on the side of the optical tube.
- **Optical tube assembly (OTA):** The optical apparatus and tube of the telescope, including lenses, tube material, and/or mirrors but without eyepieces.
- **Planetary:** relating to the other planets in the Earth’s solar system.
- **Primary mirror:** in a reflector telescope, the mirror that collects and focuses the light, then reflects that light off the secondary mirror to the eyepiece (sometimes with a mirror diagonal in between). It may be either “spherical” or “parabolic” in shape, but the parabolic type produces better images in Newtonians.

- **Right ascension (RA):** the celestial equivalent of terrestrial longitude as projected on the celestial sphere.
- **Schmidt-Cassegrain telescope (SCT):** a catadioptric telescope that combines a Cassegrain reflector's optical path with a Schmidt corrector plate.
- **Secondary mirror:** a mirror that reflects the light from the primary mirror into the eyepiece.
- **Spotting scope:** a small refractor telescope of limited magnification and restricted aperture viewed usually either straight through or at a 45 degree angle that is intended primarily to assist sportsmen/women in the field or at a target range. Due to the limitations of its design, it is not generally considered for serious amateur astronomy.
- **Star diagonal:** a device containing a 45 degree mirror that fits between the focuser tube and the eyepiece on refractor and catadioptric telescopes causing the light path to change direction 90 degrees. This permits viewing comfort and avoids contorted positions required when viewing straight through a telescope. Star diagonals are not normally used on Newtonians.
- **Telescope:** For this presentation, an optical instrument that gathers light (primarily) and magnifies images (secondarily). There are principally two types: refractors (using a glass objective lens(es) at the front of the tube to refract the entering light to focus) and reflectors (using a curved primary and a curved or straight secondary mirror to reflect and focus the light).
- **York County Astronomical Society:** an astronomy club in York Count, PA.

Do You Really Need a Telescope?

- Many amateur astronomers assume that only a telescope will do

- Some amateur astronomers like binoculars
  - Cheaper way into astronomy
  - More portable than most telescopes
  - Can see not only stars but also many bright star clusters and nebulae as well as a couple of galaxies

- However, binoculars are limited in power when compared to most telescopes
  - Limited light gathering ability
  - Fixed, low magnification

What Do Telescopes Actually Do?

- Most important: collect light
  - Human eye pupil vs. telescope diameter
  - Telescope makes the invisible visible
- Secondary: magnify
  - 50 times diameter (inches) = max. magnification
  - 2 times diameter (mm) = max. magnification
  - Why not more? Limits on resolving power!
- Not all telescopes do everything well
  - Larger apertures gather more light and see fainter objects than smaller apertures
  - Longer focal lengths don’t see fields of view as wide as shorter focal lengths

Types of Telescopes

- Refractor (uses glass objective in front)

- Reflector
  - Newtonian: It's all done with mirrors (only glass is in eyepieces)

  - Catadioptric
    - Uses mirrors *and* a glass corrector lens in front
    - Two principal types:
      - Schmidt-Cassegrain Telescope (SCT)
      - Maksutov-Cassegrain Telescope (MAK)

Refractor Telescope

- Uses a glass objective in the front
  - Usually two complementary lenses (doublet)
    - “Achromatic”
    - Fairly well color corrected
    - May well show chromatic aberration
      - Bright objects may show red and/or blue rings around edges
      - Sometimes called “fringing”
  - Sometimes triplet lens (triplet: expensive)
    - “Apochromatic”
    - Very well color corrected; little “fringing”
- Objective focuses light (usually bouncing off diagonal mirror) through eyepiece

Refractor Telescope (cont'd)

Advantages

- Easy to use and reliable
- Little or no maintenance; no optical adjustment required (usually)
- Good for lunar and planetary observing
- High contrast images with no secondary mirror obstruction
- Objective lens is permanently mounted and aligned

Disadvantages

- More expensive per inch/mm of aperture than Newtonians or catadioptrics
- Heavier, longer and bulkier than equivalent aperture Newtonians and catadioptrics
- Less well-suited for viewing faint deep space objects because of relatively small diameters
- Some color aberration in achromats
- Cool-down time (waiting for temperatures inside the optical tube to stabilize with outside temperatures) longer compared to equivalent Newtonians (Temperature differences can degrade images.)

Reflector Telescopes: Newtonian

- Open front end
- Primary mirror in back
- Secondary mirror in front reflects light out the side into eyepiece
- *Note: Parabolic primary mirrors are much better than spherical mirrors*

Newtonian Telescope (cont'd)

Advantages

- Low cost per inch of aperture compared to refractors and catadioptrics
- Reasonably compact and portable up to 8-inch diameter
- Good for faint deep space objects (e.g., remote galaxies, nebulae, and star clusters) in larger sizes
- Reasonably good for lunar and planetary observing
- Low in optical aberrations (parabolic mirror)
- Short cool-down time compared to catadioptrics and refractors

Disadvantages

- Secondary (diagonal) mirror obstructs some incoming light compared with refractors.
- Mirrors are exposed to dust and air, which can lead to mirror degradation over time
- ***Requires*** periodic collimation (which you will need to learn to do yourself)
- Some new Newtonian telescopes need collimation right out of the box

Catadioptric Telescope (CAT)

- **Schmidt-Cassegrain Telescope (SCT)**
- **Maksutov-Cassegrain Telescope (MAK)**

Catadioptric Telescope (cont'd)

Advantages

- SCTs & MAKs = good optical designs
- Excellent for deep space observing in larger sizes
- Very good for lunar and planetary observing
- Closed tube design helps keep dust out
- Some are reasonably compact and portable
- Durable and virtually maintenance free
- Large apertures less expensive than equivalent aperture refractors
- MAK does not require collimation

Disadvantages

- More expensive than Newtonians of equal aperture
- Slight light loss due to secondary mirror obstruction compared to refractors
- Long cool-down time compared to Newtonians
- SCT requires periodic collimation

Mounts

- Altitude/Azimuth (Alt-Az)
  - Does not track the way the sky moves
  - Moves up and down
  - Moves side to side
  - Requires two separate movements to follow objects

Mounts (cont'd)

- Equatorial (EQ)
  - Moves the same way as the sky (when properly aligned)
  - More difficult than Alt-Az to set up.
  - Aligned with Earth's polar axis
  - Requires only one movement to follow objects when set up properly

Go-To

- Computerized/motorized
- Finds objects for you when aligned properly
  - Some are equatorial mounts
  - Some are alt-az mounts
- Tracks objects automatically
- Requires power supply
  - Batteries (e.g., AA)
  - “Power tank”/large battery
  - AC to 12 volt converter

Dobsonian (Dob)

- A Newtonian optical tube on a simple mount
- Easy to transport in smaller sizes
- Easy to use
- Usually no tracking (“push-to”)
- Basic models can be inexpensive
- Many people consider this the best first telescope design for the rank beginner

Dobsonian (Dob) (cont'd)

Advantages

- Cheap compared to almost anything else when on no-frills mount
- Reasonably compact and portable up to 8-inch diameter
- Good for faint deep space objects (e.g., remote galaxies, nebulae, and star clusters) in larger sizes
- Reasonably good for lunar and planetary observing
- Low in optical aberrations (parabolic mirror)
- Short cool-down time compared to catadioptrics and refractors

Disadvantages

- No finding/tracking unless you spend a lot more
- Ability to magnify may be limited due to no tracking capability
- Secondary (diagonal) mirror obstructs some incoming light compared with refractors.
- Mirrors are exposed to dust and air, which can lead to mirror degradation over time
- ***Requires*** periodic collimation (which you will need to learn to do yourself)
- Some new Newtonian telescope tubes need collimation right out of the box

What kind of telescope do you need?

- What do you want to look at?
  - Wide field of view requires short focal length (e.g., f/5)
  - Deep space objects require large apertures
- Do you live near city lights or under dark skies?
- Do you need portability? How much weight can you lift?
  - Some telescopes are “portable” (i.e., pick it up and walk away)
  - Some are “transportable” (i.e., you’ll need a truck or large van for this)
  - Some are neither (i.e., it isn’t moving from your observatory in this lifetime)
- How much can you afford (total, including accessories)?
- *Note: Using a non-Go-To mount **requires** learning the night sky!!!*

What do you want to look at?

- Up to 4” diameter: stars, planets, Moon, bright star clusters
- Up to 8” diameter: add larger, brighter deep space objects (DSO). Includes galaxies, nebulas, planetary nebulas. Separate more double stars/
- Larger than 8” diameter: fainter DSOs
- Note: Wide objects like Pleiades Star Cluster and Andromeda Galaxy require short focal lengths (e.g., f/5)

City lights vs. dark skies

- City lights often limit viewing to planets and the Moon, though sometimes a larger telescope permits seeing more
- Dark skies allow seeing everything in the sky (depending on conditions) for which your telescope is capable
- Conclusion: you may need to travel to dark sites to see what you want, requiring portability and finding a suitable site

Portability

- Large, heavy telescopes are hard to move & store
  - Can you lift 35 lbs (the weight of many large mounts)?
  - Do you have a vehicle that will move all your equipment and go where you need to?
  - Do you have a place to store a large telescope and mounting system?

- Is there a place to go that is dark, accessible and safe?

- *Note: A telescope that is too large to move to the selected location **won't** be used*

How much can you afford?

- Good entry-level Newtonians on basic Dobsonian mounts can be bought from around $250

- Large catadioptrics on Go-To mounts can cost up to $3000 and more.

- There is a vast array of good equipment in between $500 - $1500

What Accessories Do You Need?

- *Note: The worst optical equipment in your light path will determine your image quality*
- Eyepieces
- Barlow lenses (for extra magnification)
- Star diagonals for:
  - Refractors
  - Catadioptrics
- Filters
- Red flashlight

Eyepieces

- "Kelner" or "MA" are barely acceptable for entry level eyepieces
- Cheap telescopes usually come with poor to mediocre eyepieces (plan to upgrade)
- When upgrading, buy "Plossl" eyepieces or better
  - Beware that most 4mm - 6mm Plossls have almost unusable eye relief
  - Meade and Celestron both sell sets of eyepieces, potentially reducing costs
  - It is better to buy 2 or 3 excellent eyepieces (and an excellent Barlow lens) than a lot of cheap eyepieces
  - Consider wide-field eyepieces, if you have a good telescope and can afford them
  - Consider long-eye relief (e.g., 20mm eye relief) eyepieces if you *must* wear glasses *(Note: Many people observe without their glasses)*

Barlow Lens

- Multiplies the magnification of an eyepiece
- Available in different strengths (e.g., 2x, 3x)
- Cost varies with quality (but there are good inexpensive ones)
  - E.g., Celestron “Ultima”
  - E.g., Orion “Shorty-Plus” (but not the plain “Shorty”)
- Can extend your eyepiece collection
  - The right 2 - 3 eyepieces plus a good Barlow lens will give you a variety of possible magnifications – possibly all you need
  - Can reduce costs (with planning)
- A poor quality Barlow lens can ruin your image
- Many cheap telescopes come with a very poor Barlow lens (plan to upgrade)

Star Diagonals

- Must-have for refractors and catadioptrics
- Vary in quality and cost
- A poor star diagonal will ruin your image
- Many new telescopes come with a poor to mediocre star diagonal (plan to upgrade)

Filters

- Moon filter useful for reducing blinding glare of Moon (especially with larger apertures)
- Color filters for enhancing planet images (optional: many people don’t use them)
- Narrow-band filter (e.g., Orion “Ultrablock”) makes nebulas more visible
- Fringe filter (e.g., Orion “V-Block”) reduces color “fringing” in achromatic refractors

Red Flashlight

- Necessary to see equipment and star maps without losing night vision

- Not having one will make you *very* unpopular at star parties and public observing sessions (or literally leave you in the dark)

What else?

- Star maps
  - To learn the night sky and find objects during observing sessions
  - From the Internet
  - Purchased as books
- Collimation (Cheshire) Eyepiece
  - For Newtonians only
  - Must-have tool to collimate a Newtonian
- Computer software
  - Commercial for sale
  - Freeware from Internet
  - *Note: Some can guide a Go-To telescope with a laptop computer*
- Power supply for Go-To telescopes
- Sighting aid (such as TELRAD or Rigel Quikfinder)
- Astronomy books, to learn about what you'll see and how the Universe works
- "Bob' Knobs" for SCT collimation

How to decide what to buy

- Decide how much you can spend
  - Generally, you get what you pay for
  - Buy the best equipment you can afford for long-lasting and pleasurable results
  - Remember, a good introductory telescope will serve as a good second telescope if/when you buy a larger/better one in the future

- Determine needed objective/aperture diameter
  - In order to see what you want
  - To fit portability requirements
  - *Remember, the bigger the aperture, the more you can see, but the heavier the telescope and mount will be*

- Determine whether refractor, Newtonian/Dob, SCT, MAK

- Determine what mount you want
  - Must be sturdy enough to support weight of telescope
  - Should be free of vibration
  - Decide whether Go-To or non-Go-To

How to decide what to buy (cont'd)

- Determine what accessories/upgrades you need from the start
- Read specifications on the Internet
- Look at telescopes in specialty stores (if you can) or at star parties/public observing sessions
- Shop for good brands (e.g., Celestron, Meade, Orion) from reliable sources
- Don't rush your decision and don't settle for something you don't really want

What To Be Wary Of

- Any cheap, off-brand telescope (e.g., Baytronix, “white tube”)
- Telescopes in department stores/discount stores
- Any telescope with a flimsy, shaky mount
- Any telescope with .96” diameter eyepieces (must be 1.25” diameter)
- Any telescope with Huygens/“H” eyepieces or Ramsden/“SR” eyepieces
- Any refractor with non-glass or uncoated objective lens

What To Be Wary Of (cont'd)

- "Short-tube" Newtonians
- Any telescope with a finder scope with plastic lenses or poor view
- Any telescope from a fly-by-night dealer (*Caveat emptor* on the Internet, including eBay!)
- "Spotting" scopes

What to Do When You Get Your New Telescope Home

- Open the box
- Read the instruction manual (***all*** of it!)
- Check that ***ALL*** the parts are there
- Gather any tools needed
- Assemble the telescope and mount carefully; do not over-tighten anything
- Align the finder scope (best done in daylight)
- (Collimate, if necessary – esp. Newtonians)
- Read about astronomy to learn about what you see through your telescope
- Join an astronomy club
- Use your telescope and have a lifetime of fun

Q: How many telescopes does an amateur astronomer need?

A: Two more than he/she already has.

The best telescope you can buy is the one you will use the most.

The York County Astronomical Society, Located in York, Pennsylvania