Astro Course Presentation by Peter Hughes 29 March 2022

Telescopes

The late, great Sir Patrick Moore used to say "The best Telescope you can buy is the one you are going to use….."

There are many different types of telescopes available for those interested in exploring the skies. Telescopes come in a variety of designs, some of which have been around since the 1600s.

The first telescope ever built, was a refractor, designed by Hans Lippershey, an optical instrument maker, in the Netherlands in 1608. Soon after that, Galileo improved on this refracting telescope design and applied its uses to astronomy. His early discoveries included mapping the Moon's surface (previously thought to be smooth and featureless!), discovery and naming of the 4 largest moon's of Jupiter (Io, Europa, Ganymede, and Callisto) and his observations of Venus, which led to the understanding that the planets orbited the Sun and not the Earth as previously thought.

Types of Telescope

The three main types of telescope are refracting telescopes, reflecting telescopes, and catadioptric telescopes. There are many variations and hybrid designs for each type.

If you are a beginner and looking to purchase your first telescope, it is recommended you have a clear idea of what you want to use it for (i.e. visual observation, photography, planetary, deep-sky, etc.), your available budget, and the level of complexity you want to take on for your equipment set-up.

The main goal of any astronomical telescope is to gather light. People often focus on the magnification of the telescope, which is actually less important than the instrument's ability to collect more light than the observer's unaided eye can.

When choosing a telescope there are many different characteristics that come into play, but arguably the two most important factors will be your desired focal length and aperture.

Key Telescope Specifications:

- Focal Length (Magnification)
- Focal Ratio (Light Gathering Ability)

- Aperture (Size of Objective Lens/Primary Mirror)

The focal length determines your field of view and will impact how far you will be able to see through your telescope. Aperture will determine how much light you will capture and the level of detail.

Here, I am going to describe the three main types of telescope, including the advantages and disadvantages, of owning them.
Before you invest in a telescope, it is worth taking some time exploring the night sky with a pair of binoculars.

Refractor Telescopes

A refractor telescope has a glass objective lens as the main focusing unit to collect light at the front of a long tube. This lens is usually made up of two or more lens elements where light is bent (or refracted), as it passes through the tube, to produce a clear image and reduce distortion.

Modern refractor/refracting telescopes come in two types: achromatic and apochromatic. Each of these are designed to reduce chromatic aberration (i.e. color fringing or color distortion/dispersion) differently, which is a common problem in any lens when colors are refracted/bent incorrectly. This happens because the lens is either unable to bring all wavelengths of color to the same focal plane and/or when they are focused at different areas on the focal plane and causes a mismatch in color at the focal point.

There are ways to reduce chromatic aberration. One method is to use multiple compensating lenses to counteract chromatic aberration. Another method is to uses a long objective focal length (distance between the focus and the objective) to minimize the effect.
Apochromats have objectives built with special, extra-low dispersion materials. They are designed to bring three wavelengths (typically red, green, and blue) into focus in the same plane. The residual color error (tertiary spectrum) can be down to an order of magnitude less than that of achromatic lens.

Such telescopes contain elements of fluorite or special, extra-low dispersion (ED) glass in the objective and produce a very crisp image that is virtually free of chromatic aberration. Due to the special materials needed in the fabrication, apochromatic refractors are usually more expensive than telescopes of other types with a comparable aperture.

Although you have to deal with chromatic aberration, refractor telescopes can be more reliable. After the initial alignment, their optical system is more resistant to misalignment than that of a reflector telescope.

The glass surface inside the tube is also sealed from the atmosphere protecting it from dust and other lens disturbances, reducing the need to clean the lens.

High-quality refractors can also provide crisp, high-contrast images with high magnification, making refractors a great telescope for astrophotography and planetary/lunar observing.

They are usually much smaller and portable than other types of telescopes too. This means that you will not require as large a mount (typically, a tripod) as you would for some of the bigger/heavier telescope types.

Reflector Telescopes

Unlike a refractor, a reflector telescope uses mirrors (that bend inward) to reflect light that has traveled down a tube, into a secondary mirror near the top of the tube directing light into the eyepiece.

A reflector telescope is said to be the best value for your money, as they offer the most aperture for your dollar. For example, a 6-inch diameter refractor telescope can cost up to 10X as much as a 6-inch Newtonian reflector.
Many reflector/reflecting telescopes are great for viewing planets (such as Mars, Jupiter, or Saturn). The simplistic design makes them easy to build and also means they are often very affordable.
The most common form of this telescope is the Newtonian reflector, which was (you guessed it) invented by Sir Isaac Newton.
A Newtonian reflector includes a curved, dish-shaped primary mirror to collect light at the bottom of the telescope. At the top of the telescope, a small diagonal secondary mirror directs the light from the primary mirror to the eyepiece, found on the side of the telescope.

The use of inward-bent mirrors in place of a glass lens also eliminates chromatic aberration as wavelengths reflect off the mirror to a single point.
The objective mirror on a reflector is supported along the back end of the telescope so the mirrors can be made very large. Compared to a refractor of the same size, a reflector telescope is cheaper to make and can therefore be cheaper to purchase.

A few disadvantages with this type of telescope are that they can easily fall out of alignment (collimation), and with an exposed/wide-open tube, the optics need frequent cleaning.
With a secondary mirror used to redirect the light into a more convenient viewing spot, this mirror can produce diffraction effects.

Catadioptric Telescopes
A catadioptric (or compound) telescope, uses both lenses and mirrors. The greatest appeal of this type of telescope is that they are very compact with their tubes two to three times as long as wide.

The result is that you can obtain a large-aperture, long-focus telescope that's very transportable. This type of telescope does need occasional optical collimation, but this is not something I have ever experienced myself.

Similar to refractors, the tubes for these telescopes are sealed to keep out dirt and dust, which is a big plus especially if you are in an environment prone to these types of conditions.
To handle dew/moisture, a lens hood (dew shield) can help to prevent moisture from accumulating on the exposed corrector plate.
A Schmidt-Cassegrain is a catadioptric telescope that combines a Cassegrain reflector's optical path with a Schmidt corrector plate to make a compact astronomical instrument that uses simple spherical surfaces.

These telescopes are great for lunar and planetary viewing, as well as terrestrial daytime use. The slower focal ratios of this type of telescope mean less light is reaching the eyepiece (or your camera) than some of the fast focal ratio telescopes out there.

A word on Mounts:
Equatorial
Alt-Azimuth
and 'GOTO'

Reference Web Links:

https://youtu.be/Thh9MKQIpeE
'Choosing your first Telescope'

https://skyandtelescope.org/observing/stargazers-corner/simple-formulas-for-the-telescope-owner/
Explanation of focal length/aperture etc.

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

Recommended Manufacturers:
Astronomers Without Borders

Celestron
Explore Scientific
IOptron
Meade Instruments
William Optics

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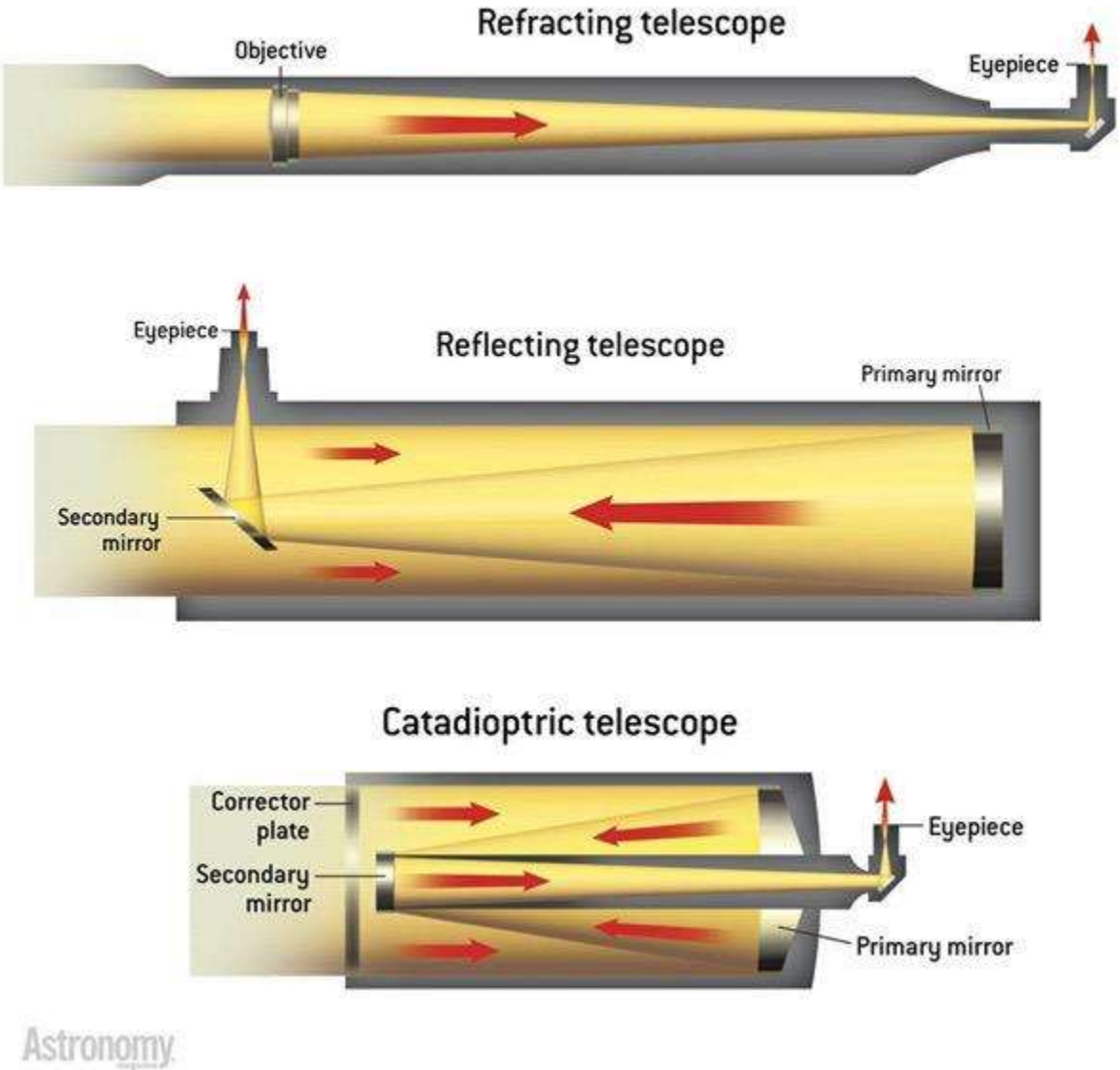
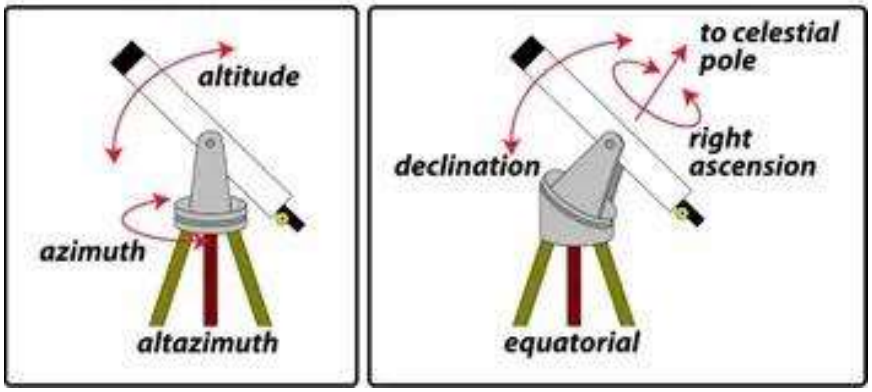
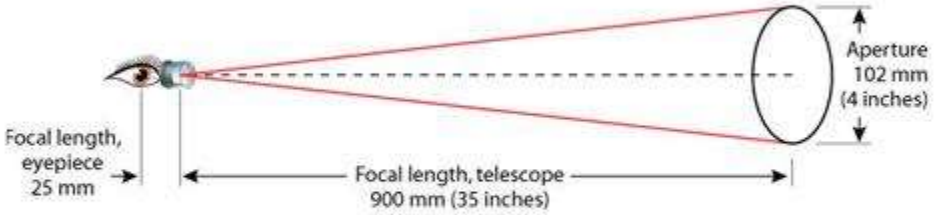


ALT-AZIMUTH MOUNT VS EQUATORIAL MOUNT

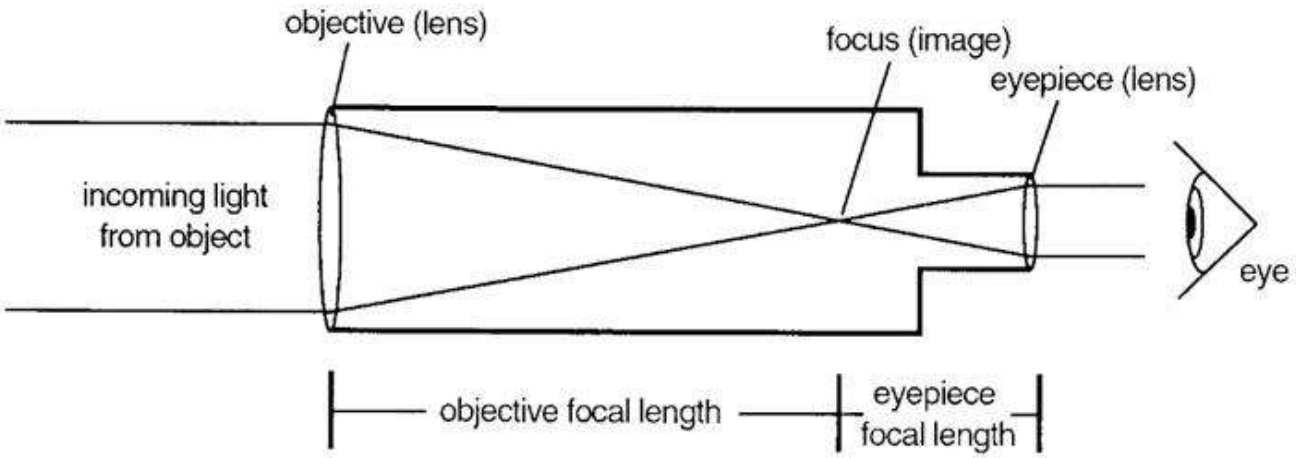


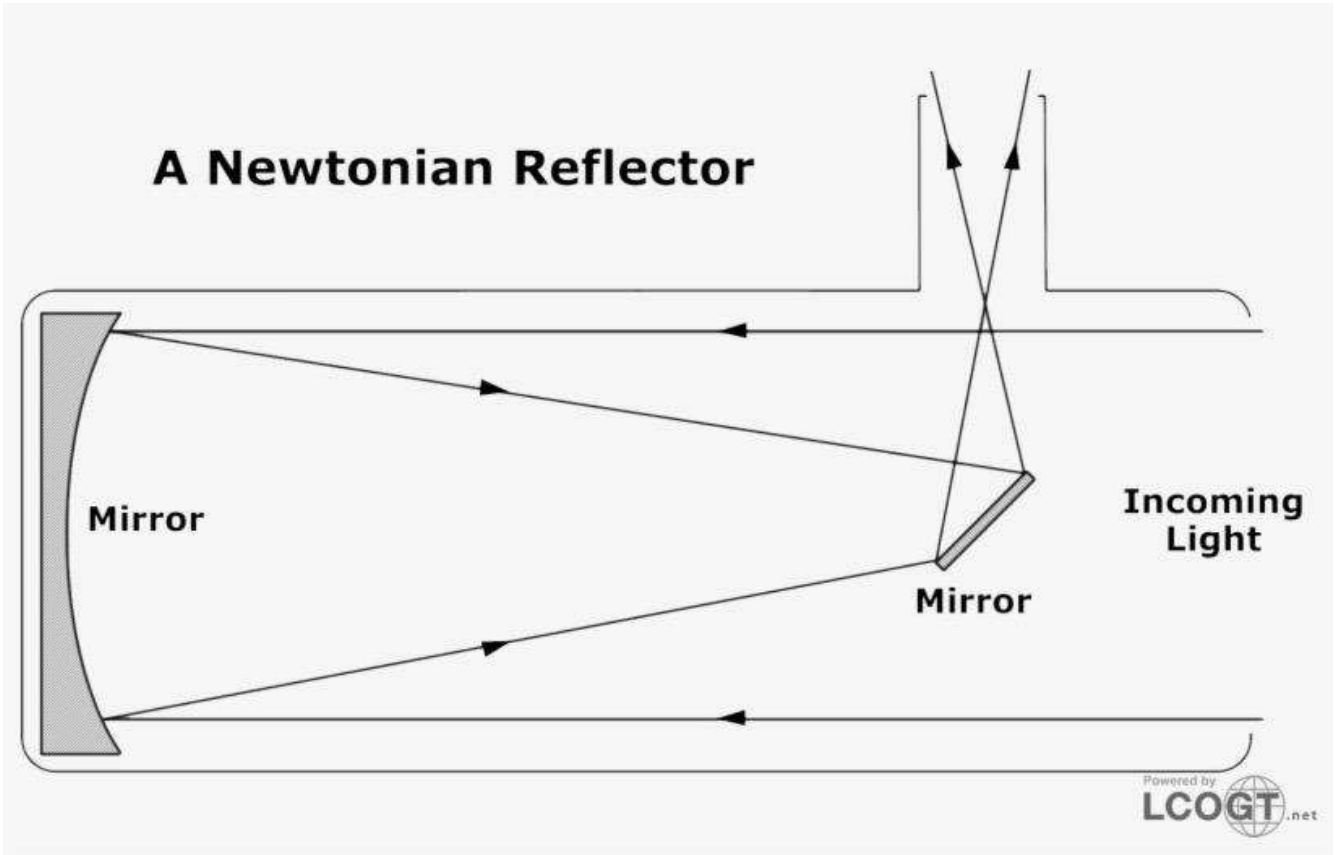
$$\text{Focal ratio} = \frac{\text{focal length, telescope (900)}}{\text{aperture (102)}} = \text{f/8.8}$$

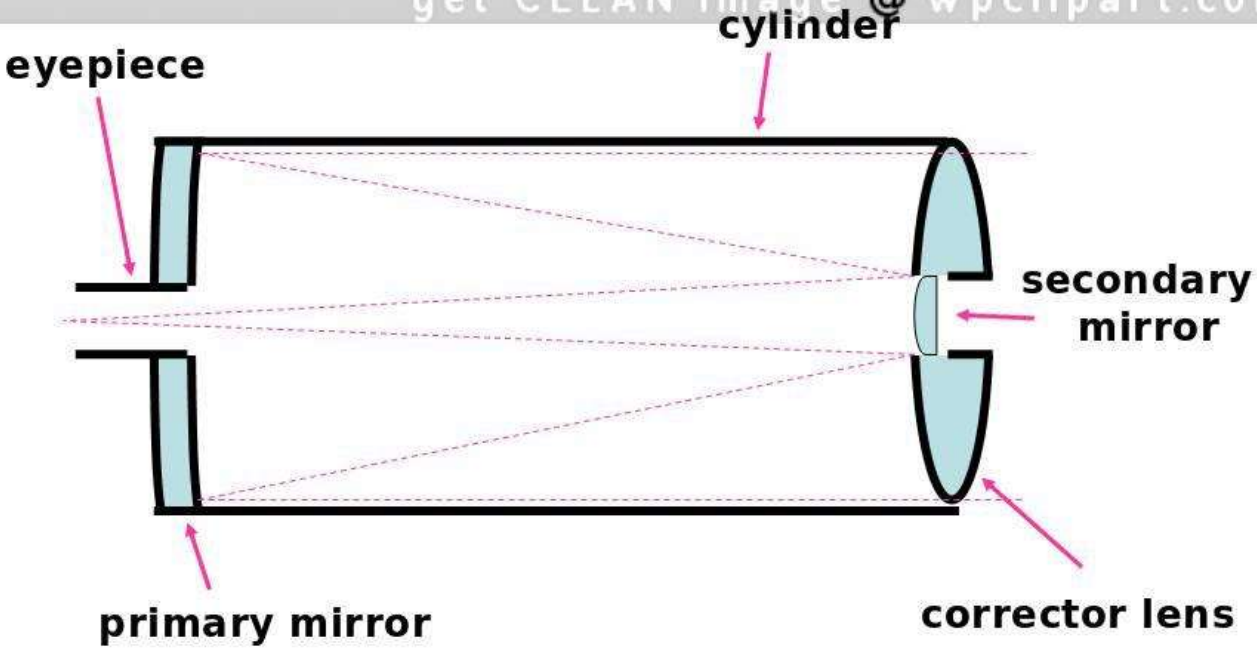


$$\text{Magnification} = \frac{\text{focal length, telescope (900)}}{\text{focal length, eyepiece (25)}} = 36\times$$

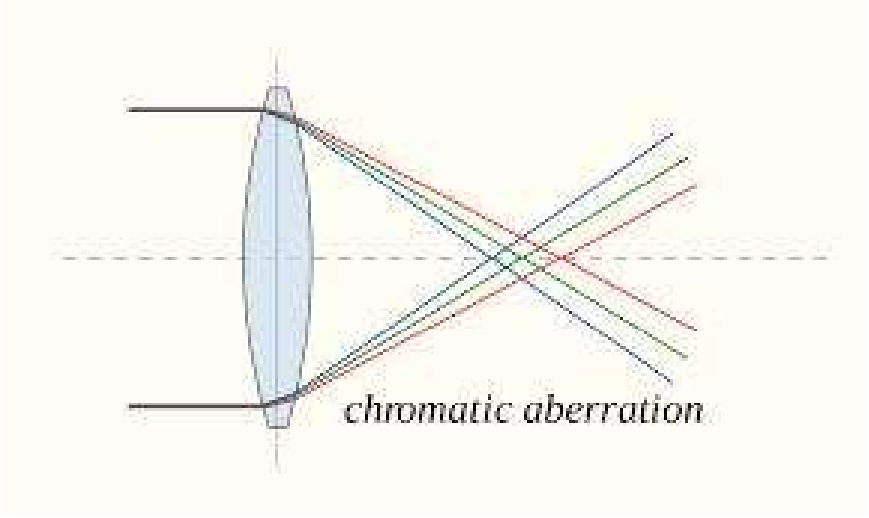
Simplified Refracting Telescope

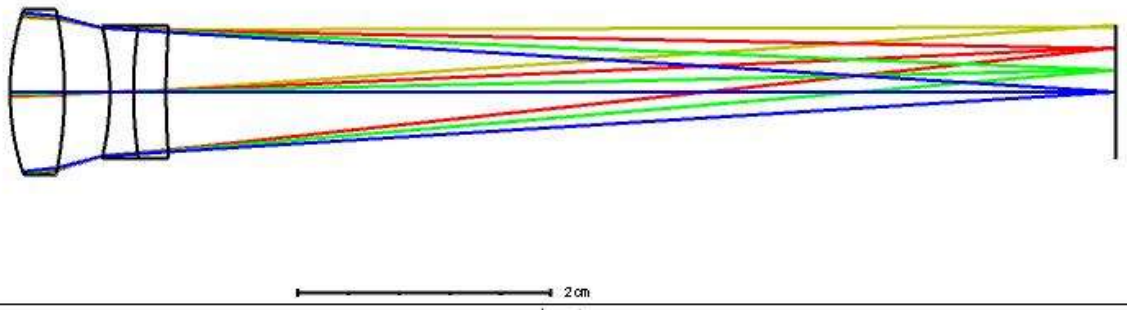






catadioptric telescope



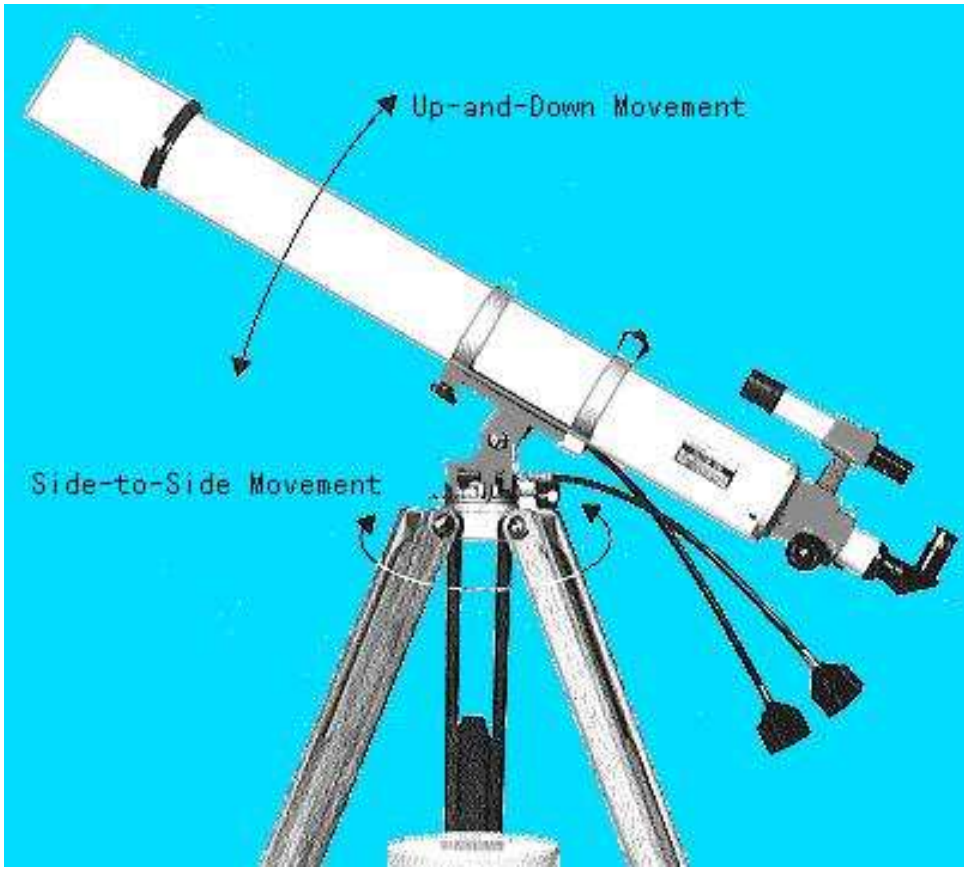


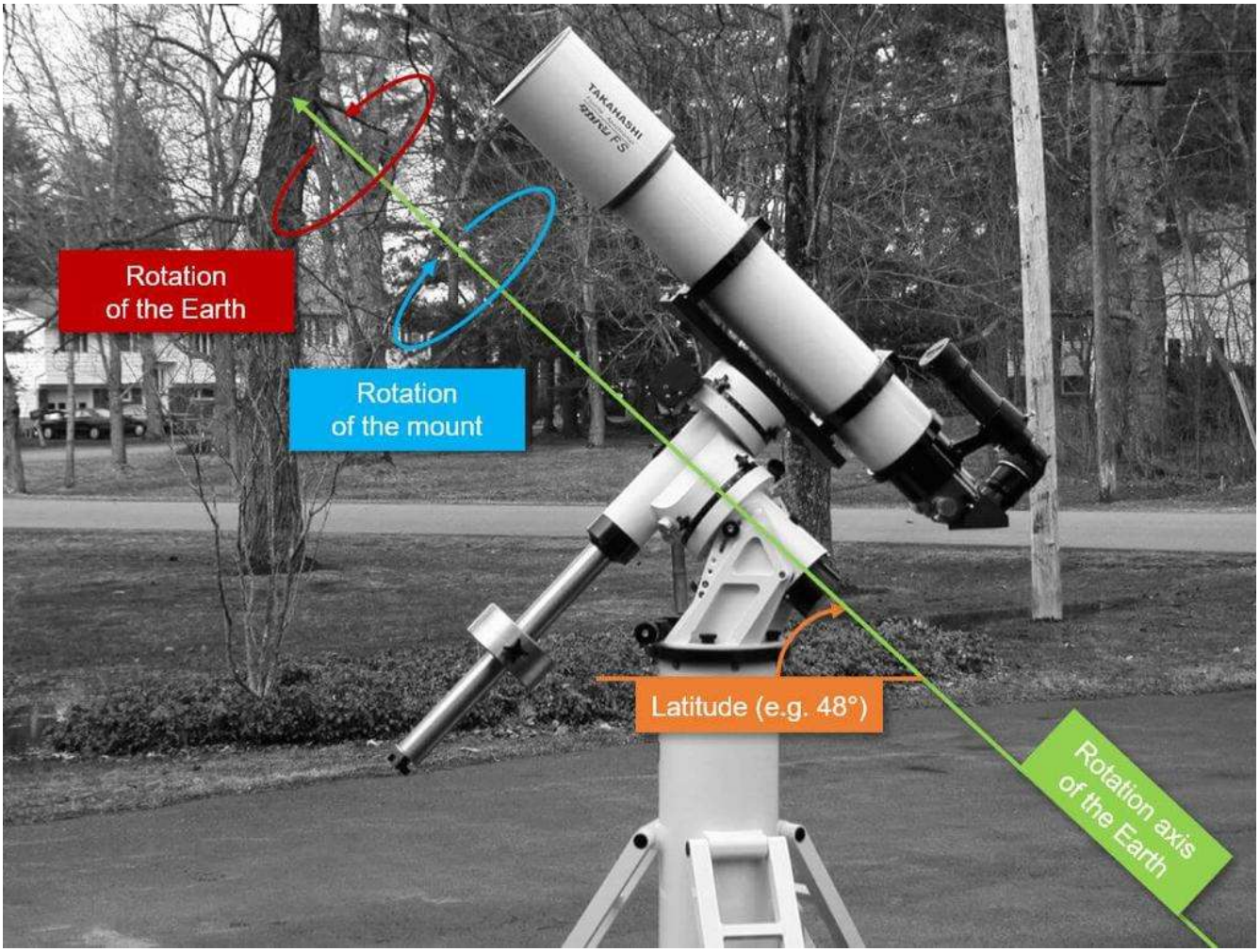
Layout

Apochromatic Objective designed by Barry Johnson
5/14/2021
Total Axial Length: 8.72531 cm

Zemax
Zemax OpticStudio 20.2.2

Apochroma4.zmx
Configuration 1 of 1




Rotation
of the Earth
Rotation
of the mount
Latitude (e.g. 48°)
Rotation axis
of the Earth