Classnotes 7

Almost all of our astronomical observations involve the collection and analysis of 'light.' Therefore, we should spend some time discussing basic properties of light and of the telescopes we use to collect light. These topics comprise Chapter 6. After the list of 'Key Topics,' I give some notes on telescopes: the sections on 'The Reflector' and 'The Refractor' are important but the concluding section on 'mountings' is not.

KEY TOPICS FROM CHAPTER 6

Light: wave and particle (photon) properties

Basic properties of waves: speed, amplitude, wavelength, frequency, transport of energy

A key relation: wavelength x frequency = speed of wave.

The speed of light is ~ 300,000 km/s, and is same for all observers.

The Electromagnetic spectrum: note names of the principal regions and which regions are only observable from space.

Light as a wave: proofs: lunar occultations of stars (diffraction);
Young's 2-slit experiment (interference)

Reflection of light (incident = reflection angle, color independent)

Refraction of light (light bent towards normal on entering the denser medium [speed of light is lower in the denser medium], color dependent refraction)

Refractors: telescopes with lenses -- why long focal lengths are attractive

Reflectors: telescope with mirrors -- prime, Newtonian, Cassegrain, and Coudé foci. Why several foci?

Why are large telescopes reflectors rather than refractors?
Why build very large optical telescopes?

Light Gathering Power (telescope = light bucket). LGP proportional to **area** of the primary mirror (lens), i.e., to **diameter squared**.

Resolving power, the ability to see fine details, improves with increasing diameter of the primary mirror (lens) and degrades with increasing wavelength. But for optical telescopes on the ground, the Earth's atmosphere is often the limiting factor.

Special instruments.

Radio telescopes: the resolving power problem and its solution

Space astronomy: advantages and disadvantages

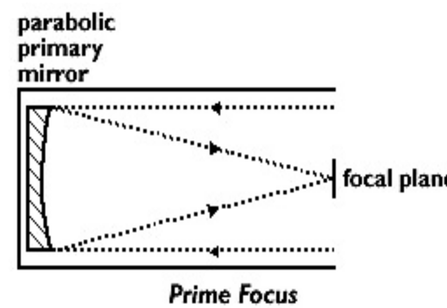
Think about the following from the end of Chapter 6:
Review Questions: 1, 2, 5, 6, 7, 8
Discussion Questions: 1, 2, 3
Problems: 1, 2, 3, 4, 5, 7

Telescopes

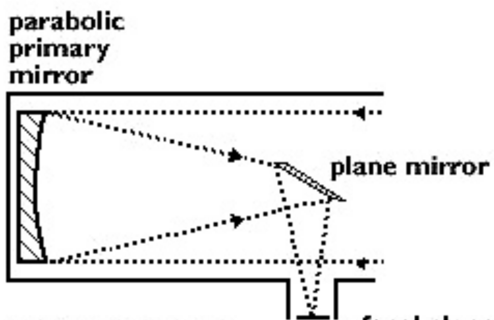
Astronomical optical telescopes are mainly of two types -- reflecting and refracting.

The Reflector

The various types of reflecting telescope are illustrated in the following diagrams. All systems have a primary mirror with the concave surface accurately formed and coated with a highly reflecting metal, formerly silver but now usually aluminum. The great advance of the reflecting as against the refracting telescope, where light passes through the glass, is that all the different colors of light that make up 'white' light come to focus at the same point. In a refracting telescope this is not so, and the telescope can be designed to be correct only for a given color ranges.

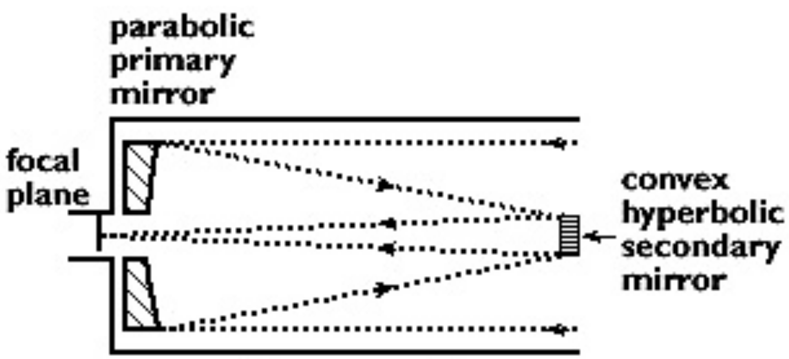


On large telescopes instruments can be put in a special cage at the prime focus and be carried around by the telescope as it is moved. On smaller telescopes it is not practical to do this, as the instruments and any structure needed to support them blocks a large portion of the light path. The Newtonian focus is commonly used to overcome this difficulty.



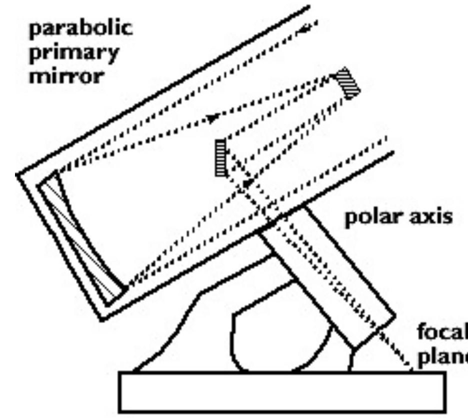
Newtonian Focus

The most popular focus on large telescopes is the Cassegrain focus (from the French inventor c. 1670). The primary mirror has a central hole through which the light beam passes. On large instruments relatively large pieces of equipment may be fitted, although still carried on the telescope. The instrumentation and the observer in this configuration do not obstruct the light beam. The secondary mirror does!

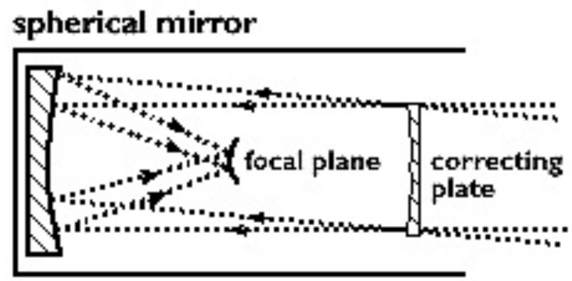


Cassegrain Focus

Another useful focal position is the coudé focus (French word for 'elbow') where additional reflections are introduced so that wherever the telescope is pointing the star image is always formed at a **fixed** position, instead of moving with the telescope. It is therefore possible to erect very substantial instrumentation at this focus.



Coudé Focus



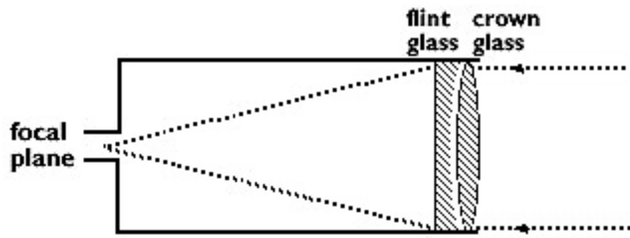
Schmidt Telescope

The Schmidt form of reflecting telescope has some very special features. The primary mirror is spherical in form. A spherical surface is easier to make than the parabolic form; the errors it introduces into the image are corrected by first passing the light through a thin glass correcting plate at the top end of the telescope tube. The focal surface so formed is slightly curved so any photographic plate used to photograph the field has to be similarly curved by clamping the plate in a specially curved plateholder. Schmidts are used for photographing large areas of sky (6° x 6°; the diameter of the Full moon is about 0.5°).

At all of these focal positions the instruments used may be simple (an eyepiece to make visual observations), or complex (a spectrograph or photometer).

The Refractor

A refracting telescope employs lenses to focus the image instead of mirrors. Star light passes through the glass instead of merely being reflected at its surface.



Refracting Telescope

It is well known that when a beam passes through a glass prism the light is split up into the colors of the rainbow -- a spectrum. When white light passes through a single lens, the same prismatic effect splits the light up similarly. This effect is known as 'chromatic aberration.' Thus a double convex lens bends the violet rays inwards more than the red rays, while the double concave lens of crown glass and a concave lens of flint glass and combining the two, the effect can be minimized; this combination is called an 'achromatic doublet.'

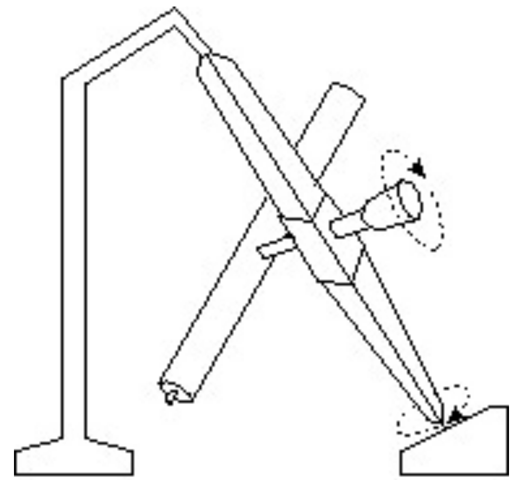
As light has to pass through the glass, the thicker the glass the greater the loss of light, so very large refractors are not practical for this and other reasons, the largest being the 40-inch Yerkes Observatory telescope near Chicago.

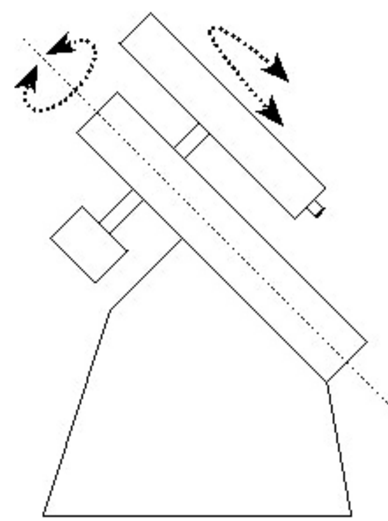
Mountings

Very small telescopes can be directed to the sky when held in the hands, but when the magnification becomes greater than six to eight times it is no longer possible to keep the telescope steady, and a support is necessary. For small instruments up to about 6 inches aperture a simple tripod is often adequate with movements in azimuth -- i.e., parallel to the horizon -- and in altitude -- i.e., at right angles to the horizon. Now the apparent movement of the stars across the sky is due to the rotation of the Earth about an axis passing through the north and south poles of the Earth, and the stars rise in altitude and fall as they pass from east to west. If a telescope is set up so that the azimuth axis is parallel to the Earth's axis then, once set on a star, rotation about this axis will follow the star across the sky without further adjustments to the altitude motion. Various types have been designed and improved upon. Some are suitable in one part of the Earth and unsuitable for other parts while some are unable to point to certain parts of the sky.

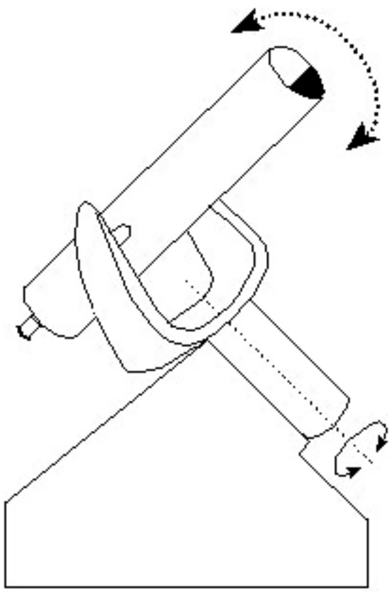
The early English mounting has the polar axis supported at each end and the telescope slung within the axis. The great defect of this type of mounting is its inability to observe the pole.

The modified English mounting gets over this problem by taking the telescope to one side of the polar axis and placing a counter weight on the other side.


Modified English Mounting


German Mounting

With the German mounting the polar axis is short and carries the altitude (or declination) axis at the top end. This form gives an uninterrupted circuit of the pole of the sky.



Fork Mounting

The fork mounting is particularly suitable for a reflecting telescope, as the length of tube below the 'horizontal' axis must be short in order that the telescope may pass through the fork.

All these mountings require only rotation about the polar axis in order to follow a star, which means one motor and one set of accurate gearing (although setting of the 'horizontal' axis may require slight adjustment during the course of an observation). With the advent of new motors, improved manufacturing techniques, and especially computers for control purposes, large telescopes are now mounted with motions in the horizontal plane and altitude since the engineering problems raised in having to support a large mass of glass are considerably reduced in this design. It is possible to use these anywhere in the world, but they require continuously variable controls in altitude and azimuth. This design is now standard for new large telescopes.

'Sir, what is poetry?'

'Why Sir, it is much easier to say what it is not. We all know what light is; but it is not easy to tell what it is.'

Samuel Johnson (1709-1784)

Physicists use the wave theory on Monday, Wednesdays, and Fridays, and the particle theory on Tuesdays, Thursdays, and Saturdays.

William Henry Bragg (1862-1942)