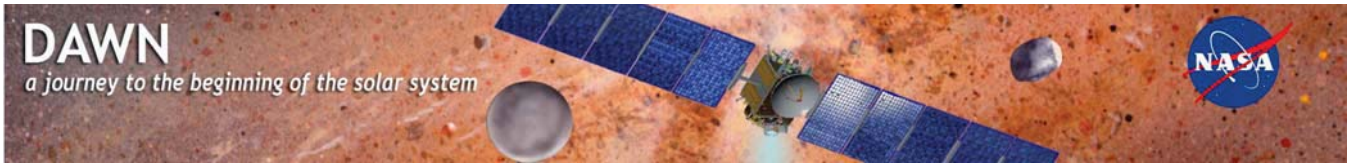
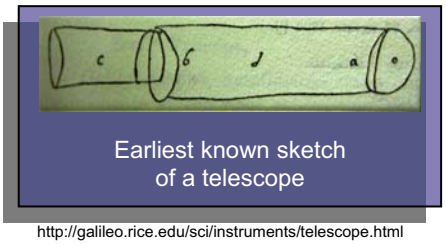


Of Glass and Light

Investigating Interactions Between Light and Glass


Earliest known sketch of a telescope

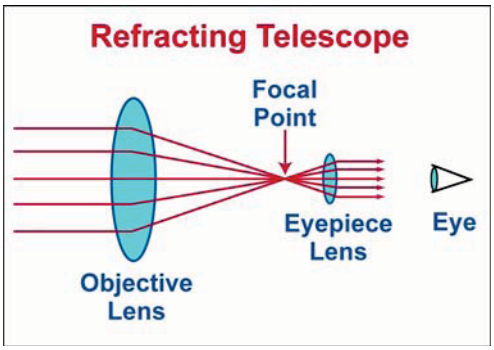
http://galileo.rice.edu/sci/instruments/telescope.html

Astronomical advances, including the search for asteroids, have been almost totally dependent on the interaction of electromagnetic radiation in the form of visible light with glass. Light is pretty old, of course, and glass has been around for a while as well. In fact, glass most likely was made first by accident, when ancient Phoenicians melted sand on beaches with their fires. Given the antiquity and ready availability of light and glass, it is not surprising that the interaction of the two attracted the attention of curious individuals of ancient history. The investigations of a host of these individuals led ultimately to the invention of the telescope in the 1600s.

Light has several properties of utmost importance to the development of telescopes. First, light travels in straight lines until it meets an object. This is an old idea that was mentioned by Euclid in approximately 300 BC. Euclid also studied the reflection of light and described the laws of reflection. During approximately the same era, Hero of Alexandria investigated light as it is reflected from a mirror. Not too many years later, Ptolemy is credited with conducting a study of the refraction of light, that is to say, how light is bent as it leaves one medium such as air and enters another such as glass.

By the 12th or 13th century the reflection and refraction of light were routinely used to explain natural phenomena such as rainbows. The magnifying and reducing properties of convex and concave transparent objects such as those made of glass were also known. Roger Bacon, for example, described his studies of the magnification of small objects by convex lenses and even suggested their use for correcting defective vision in about 1220. Clearly, those properties of light important to telescopic observations are among the oldest of the physical measurements made by mankind.

By the end of the 13th century, glass had become readily available and techniques for grinding and polishing lenses and mirrors were reasonably well developed, particularly in Italy (and perhaps in the Orient). Lenses found almost immediate application as spectacles and then as microscopes. It was not until the early 1600s that glass lenses in the form of telescopes found use in manipulating light arriving from the heavens.

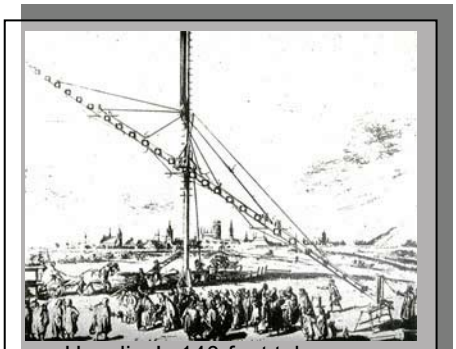


Refracting Telescopes

The first telescopes were “refracting” telescopes because they utilized convex lenses that gather light at the open end of the telescope and bend (refract) the light. The light leaves the other side of the lens and at the focal point of the lens provides an image that appears larger and brighter than it does to the naked eye. Another convex lens (the eyepiece) at the other end of the telescope allows an observer to view and magnify the image.

Unfortunately, for telescope makers light of different colors (wavelengths) is bent to different degrees as it passes through a lens. This gives rise to what optical designers call “chromatic aberration,” which must be controlled as much as possible if one is to have a good instrument. The effect of chromatic aberration is to make fuzzy multicolored blobs instead of sharp images appear in the telescope. Chromatic aberration was a large inherent problem, in addition to the fact that early telescope lenses were far from being perfectly ground. Also the lens glass usually was not of the best quality. Sometimes the glass contained tiny bubbles, and it may have had a greenish tinge from iron impurities. However, lens makers realized that one could make a flawed lens work more acceptably by grinding it with minimum curvature and, consequently, a very long focal length (the distance from the lens at which rays of light converge, see Diagram).

So, much early refractive astronomy was accomplished with flawed lenses of very long focal length. For example, in the 1670’s an astronomer named Johannes Hevelius built a telescope that was 140 feet long! Interestingly, an error during this era by the great English physicist Isaac Newton that apparently arose from his making too few measurements while investigating the details of refraction led him to doubt that it was possible to produce a color-free lens. This pronouncement from the great scientist discouraged others from even trying to make such a lens for almost a century. Clearly glass was at the heart of the problem.



Hevelius's 140-foot telescope

http://galileo.rice.edu/abo/copyright.html

Reflecting Telescopes

Later telescopes used reflecting mirrors instead of lenses to gather and reflect light to eyepiece where it is magnified and viewed by an observer. These types of telescopes suffer various shortcomings as well that arise from imperfections in the glass used in the construction.

Telescope technology has grown enormously, and today astronomers use very sophisticated and powerful telescopes. Nevertheless, these telescopes, powerful as they are, depend on the interaction of visible light with glass or other surfaces, as dictated by the laws of reflection and refraction that were discovered 2000 or more years ago.

Additional Resources

Web Sites

http://acept.la.asu.edu/PiN/rdg/reflection/reflection.shtml
A concise explanation of the reflection of light.

http://acept.la.asu.edu/PiN/rdg/refraction/refraction.shtml
A concise explanation of the refraction of light.

http://galileo.rice.edu/sci/instruments/telescope.html
Rice University provides information about the history of the telescope.

http://seds.lpl.arizona.edu/billa/psc/hist2.html
This section of *Important Astronomers, Their Instruments, and Discoveries* focuses on the history of the early refracting telescopes.

http://www.astronomynotes.com/telescop/s2.htm
This site provides a design diagram as well as lists the advantages and disadvantages of refractor telescopes.

http://www.astronomynotes.com/telescop/s3.htm
This site provides a design diagram as well as lists the advantages and disadvantages of reflector telescopes.

http://www.bbc.co.uk/dna/h2g2/A666128
The History of Optical Science

http://www.cartage.org.lb/en/themes/Sciences/Physics/Optics/briefhistory/briefhistory.htm
A brief history of optics

http://www-groups.dcs.st-and.ac.uk/~history/Mathematicians/Euclid.html
Presents a biography of Euclid of Alexandria

http://www.microscopy.fsu.edu/primer/java/reflection/reflectionangles/
Experiment with the reflection of light by varying wavelengths and incident angles.

http://www.mts.net/~william5/history/hol.htm
A History of Light and Lighting

http://www.physics.uoguelph.ca/applets/Intro_physics/refraction/LightRefract.html
This applet demonstrates the refraction of light.