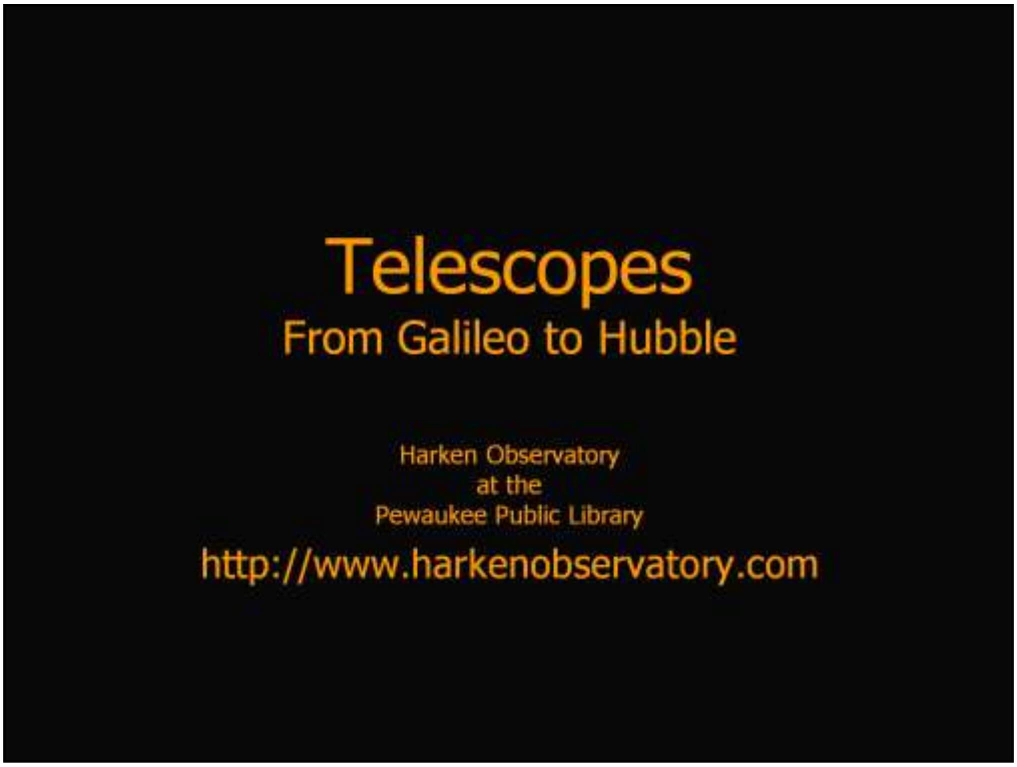
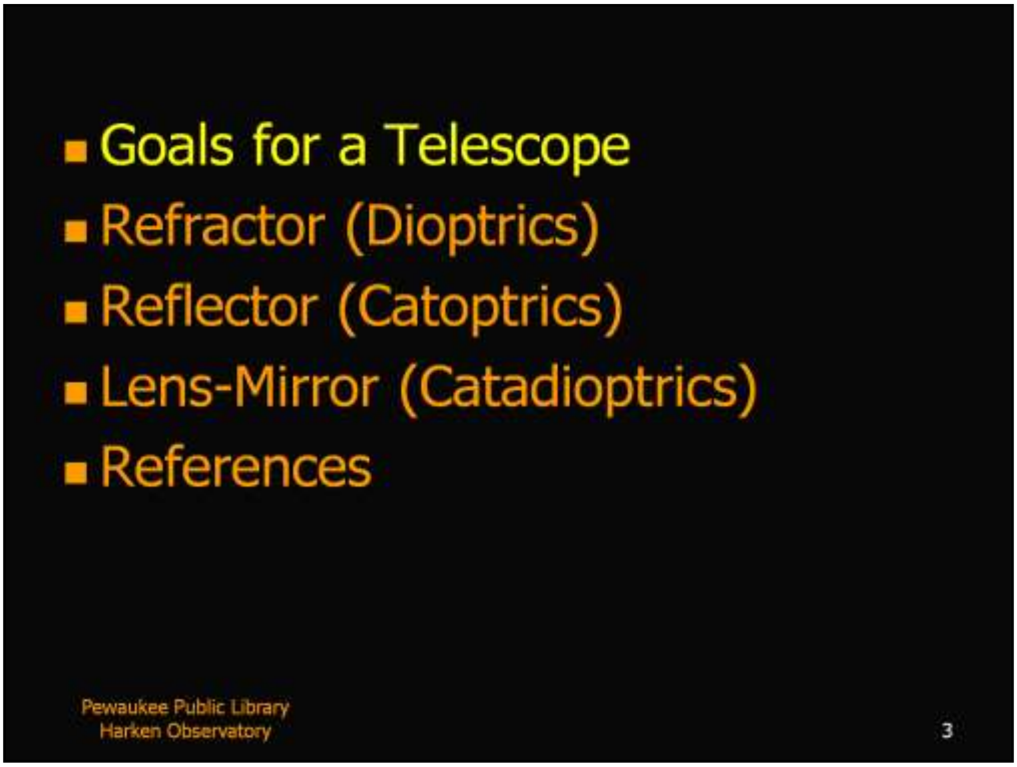


Written by Scott Berg. First presented by Scott at the Harken Observatory public open house on January 13, 2007.

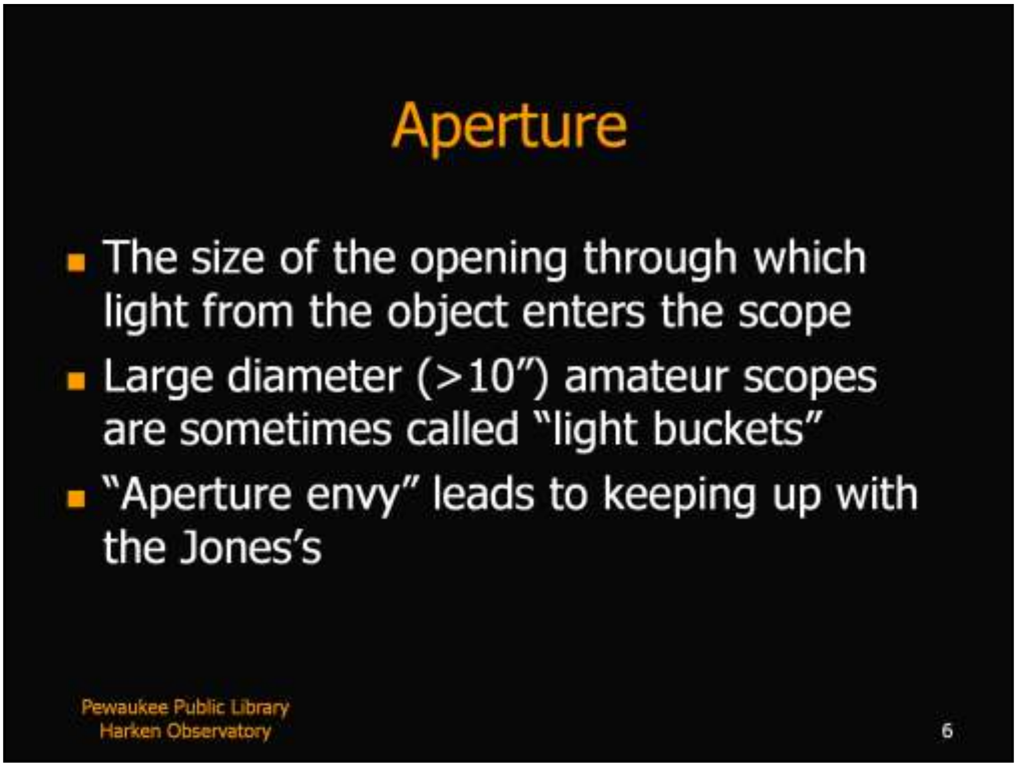

A **telescope** is an instrument designed for the observation of remote objects.
From the Greek:
tele = far
skopein = to look or see
teleskopos = far-seeing
Supposedly, it was coined at a dinner party for Galileo in about 1610.


Goals for a Telescope
Refractor (Dioptrics)
Reflector (Catoptrics)
Lens-Mirror (Catadioptrics)
References
Pewaukee Public Library
Harken Observatory
3

These are Scott's list of goals. Many others are possible.

1 - Gather Light

- Astronomical objects are far away and very dim.
- A telescope gathers light from a large area (aperture) and concentrates it into a small area (eyepiece), making the image brighter.


Aperture
The size of the opening through which light from the object enters the scope
Large diameter (>10") amateur scopes are sometimes called "light buckets"
"Aperture envy" leads to keeping up with the Jones's
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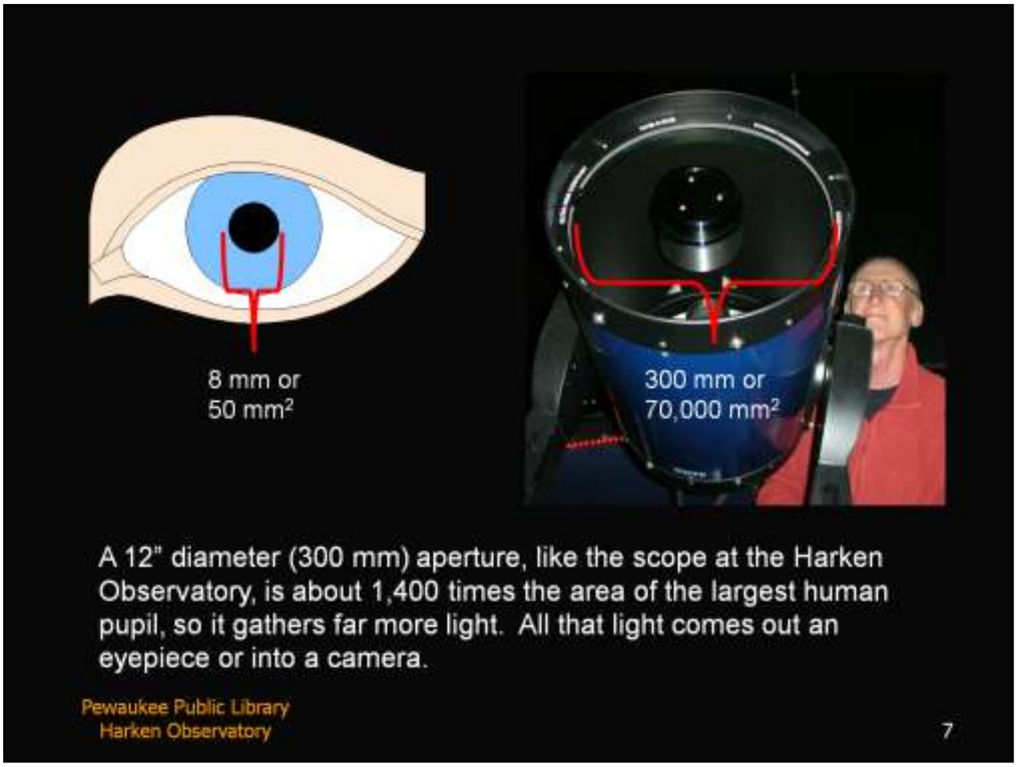

Pupil size table may be found at: http://www.sizes.com/people/pupil_size.htm

A human eye pupil diameter for an average 20 year old in the dark is 8mm or a hole of 50 mm^2 Maximum pupil diameter gets smaller with age, reducing night vision.

2 - Accurate Image

- Chromatic aberration – Is what you see the actual color(s) of the target?
- Spherical aberration – Is what you see really the shape of the target?
- Many other distortion types

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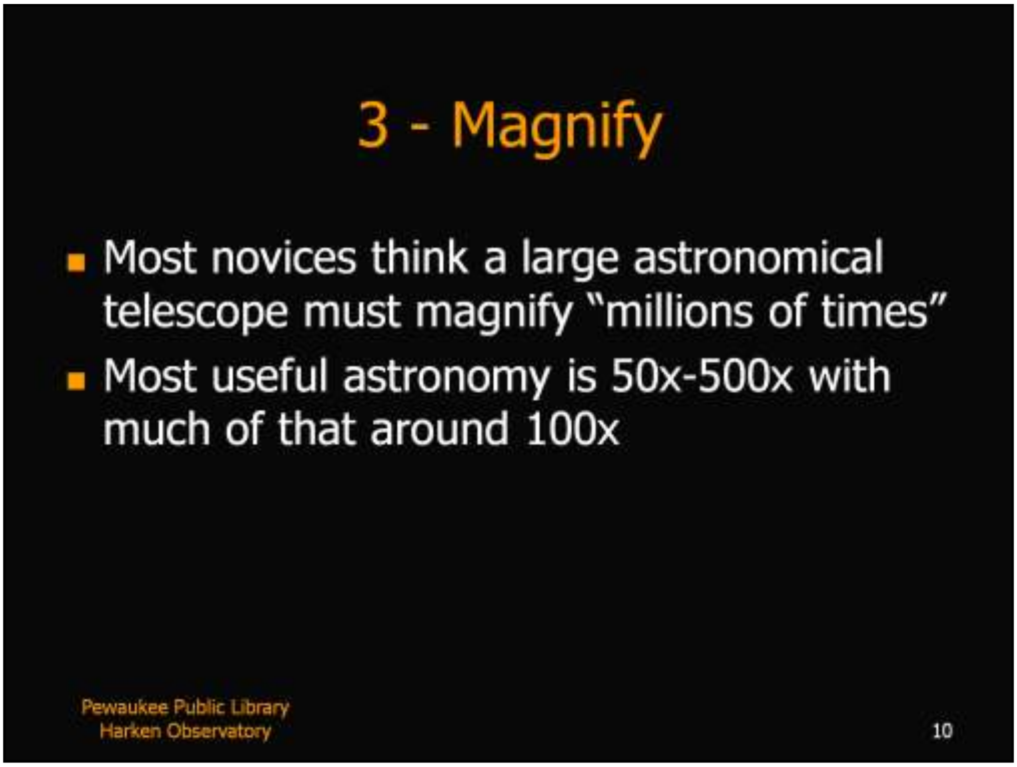
3 - Magnify
Most novices think a large astronomical telescope must magnify "millions of times"
Most useful astronomy is 50x-500x with much of that around 100x
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Harken Observatory
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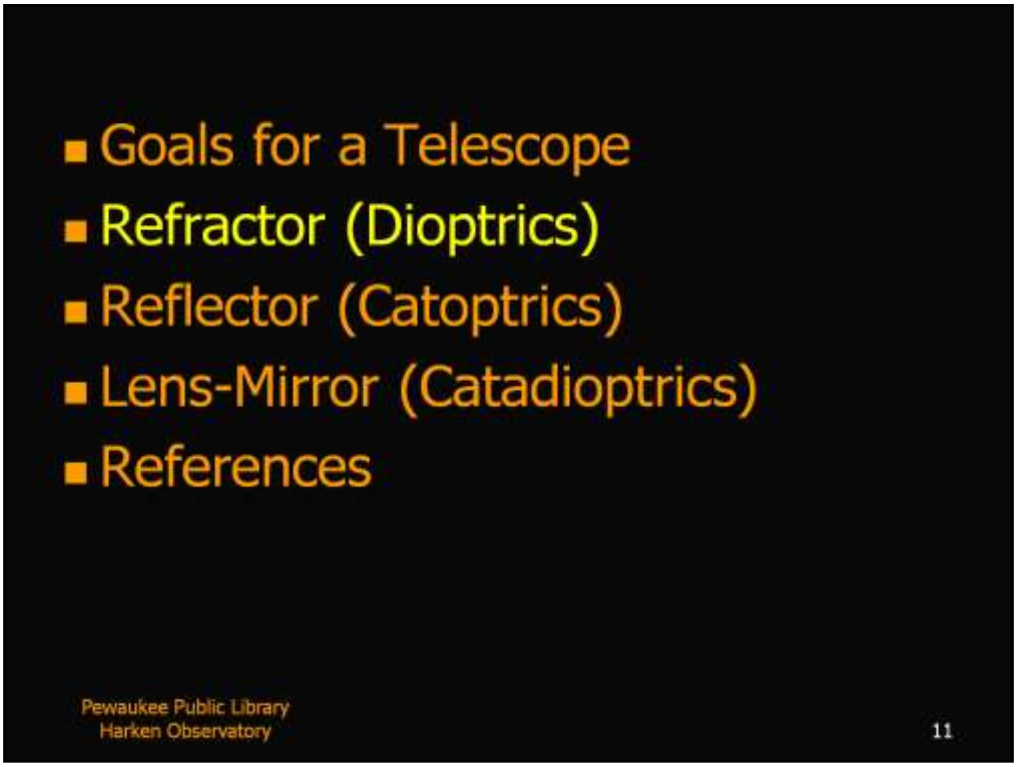
Goals for a Telescope
Refractor (Dioptrics)
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Lens-Mirror (Catadioptrics)
References
Pewaukee Public Library
Harken Observatory
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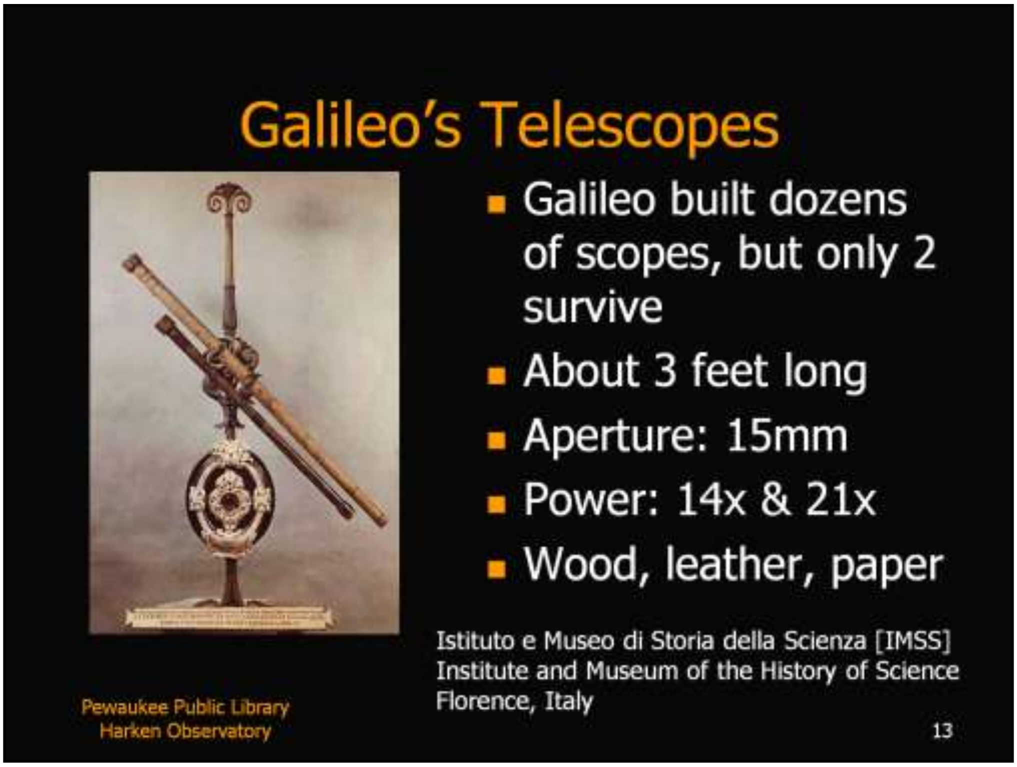
Refractors

- A refractor scope uses only lenses.
- Discovered by many people independently in early 1600's. e.g. Patent applied for by Dutch optician Hans Lippershay (1570-1619) in 1608.
- Prominent Italian scientist Galileo Galilei (1564-1642) was the first to publish and publicize his version of the telescope in 1610.



http://www.imss.fi.it/index.html

http://brunelleschi.imss.fi.it/museum/esim.asp?c=405001

This telescope, attributed to Galileo, comprises a main tube and two smaller housings in which the objective and the eyepiece are mounted. The main tube consists of two semicircular tubes held together with copper wire. It is covered with paper. The objective measures 51 mm in diameter, and is biconvex, but the radii of curvature of the surfaces of the two faces are not equal; the focal length is 1,330 mm, the thickness at the center 2.5 mm. The eyepiece is plano-concave and measures 26 mm in diameter; the concave side, facing the eye, has a radius of curvature of 48.5 mm; the thickness at the center is 3.0 mm, the focal length -94 mm (the negative focal length means that the lens is diverging). The instrument's magnification is 14 and its field of view 15'. The attribution to Galileo is due to the fact that some of its elements—in particular, the characteristic concave eyepiece—are typical of the telescopes that he produced in great numbers between 1610 and 1640. In 1611, Prince Federico Cesi, founder of the Accademia dei Lincei, suggested calling this instrument *telescopio* [from the Greek *tēle* ("far") and *scopeo* ("I see")].

http://brunelleschi.imss.fi.it/museum/esim.asp?c=405002

Original telescope made by Galileo consisting of a main tube with separate housings at either end for the objective and the eyepiece. The tube is formed by strips of wood joined together. It is covered with red leather (which has become brown with the passage of time) with gold tooling. The plano-convex objective, with the convex side facing outward, has a diameter of 37 mm, an aperture of 15 mm, a focal length of 980 mm, and a thickness at the center of 2.0 mm. The original eyepiece was lost and was replaced in the nineteenth century by a biconcave eyepiece with a diameter of 22 mm, a thickness at the center of 1.8 mm, and a focal length of -47.5 mm (the negative focal length means that the lens is diverging). The instrument's magnification is 21 and its field of view 15'. It is registered in the 1704 inventory of the Uffizi Gallery as "A telescope of Galileo 1 2/3 *braccia* [973 mm] long in two pieces to lengthen it, covered with leather of several colors and gold tooling, with two lenses, of which the eyepiece is at an angle": the eyepiece was thus still present, but loose in its housing. By the end of the eighteenth century, it was missing. In 1611, Prince Federico Cesi, founder of the Accademia dei Lincei, suggested calling this instrument *telescopio* [from the Greek *tēle* ("far") and *scopeo* ("I see")].

http://www.pacifier.com/~tpope/index.htm

http://www.scitechantiques.com/Galileo_telescope/

e have replicated, with great care, Galileo's two internationally famous Telescopes. The two originals which are attributed to Galileo are on display at IMSS in Florence Italy. We constructed INV # 2428. complete with its gilded leather covering even duplicating its very unusual internal construction, something that has not been done before. We made this instrument for the Griffith Observatory for their 2006 renovation. We also constructed INV#2427 The equally interesting laboratory type telescope for the Adler Planetarium. It has a split wood tube covered with paper painted and reinforced with copper wire bands along its barrel. We took great care with both telescopes reproducing each part of the instruments to be as close as possible to the originals. Each telescope was also been assembled by hand as they were in Galileo's day. Our dimensional accuracy has been kept to within a few percent in all cases and in some instance's to fractions of a millimeter of the originals. We also chose not to antique them but to show them as they would have looked when new..

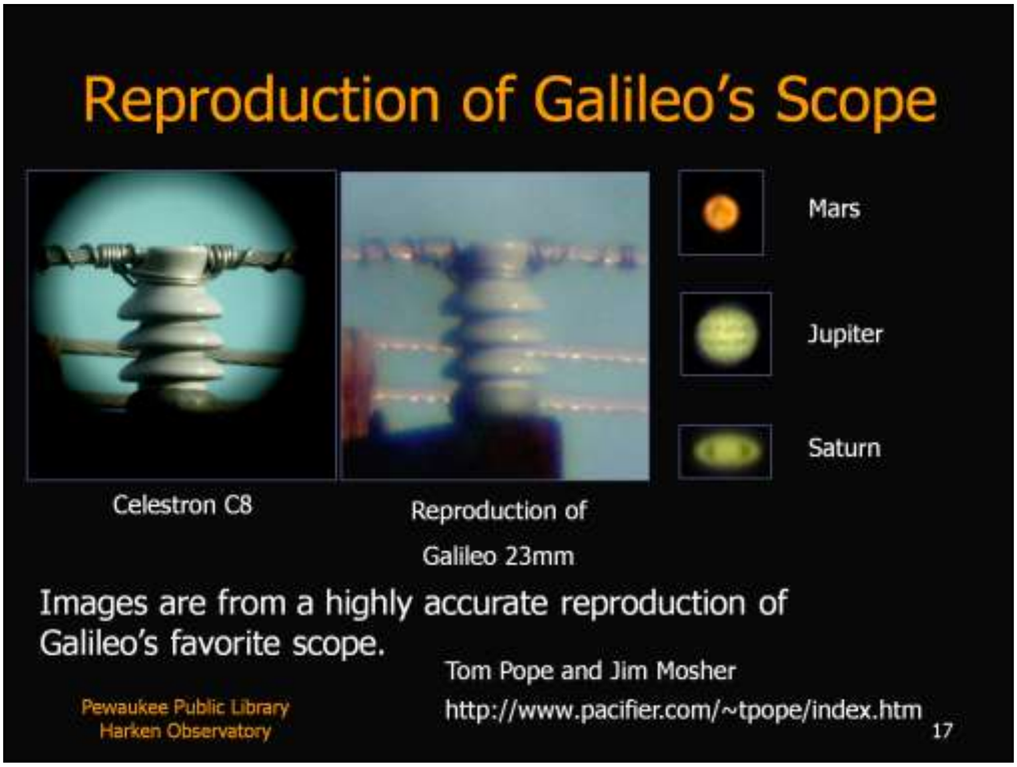
Our replicas are accurately reproduced therefore particularly useful as research, teaching, and display tools. One can see, feel them, and operate them as Galileo saw felt and operated them. This tactile experience high lights more accurately their virtues and their faults giving a more muture insight into 1609 telescope making and use that Galileo his associates and customers experienced.

The telescopes are high museum grade replicas and very rare. The leather covered telescope, the replica of IMSS inv #2428, has over 100 pieces and is embossed with over 400 gilding die strikes. It has very unusual construction features both inside and out, with an optical power of 21. The replica of IMSS inv. 2527 represents a construction style commonly used in research / field grade telescopes for that time period. It has nearer 17 pieces and a power of 14. The pair complement each other, one a presentation piece destined to one of power and influence the other a field type instrument for customer or colleague.

Galileo's Historical Record

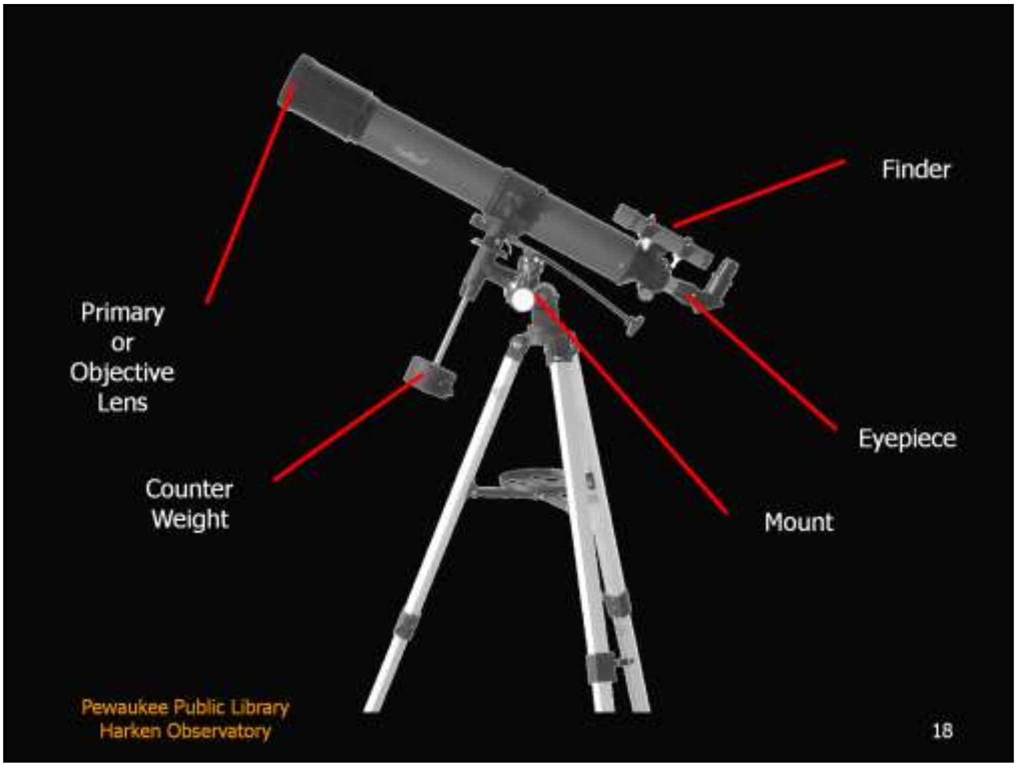
- Making refractors was a profitable business for Galileo.
- Galileo published astronomical observations, but never a highly detailed cookbook for scope building.
- Lots of academic debate about details of his scopes.

But how well did Galileo's telescopes work?



http://www.pacifier.com/~tpope/index.htm

Endless discussion and high powered analysis of the optics of Galileo's scope at:
http://www.pacifier.com/~tpope/Photo_Drawing_Comparison_Page.htm



Scope shown in an Orion 120mm ED Apochromatic Refractor OTA

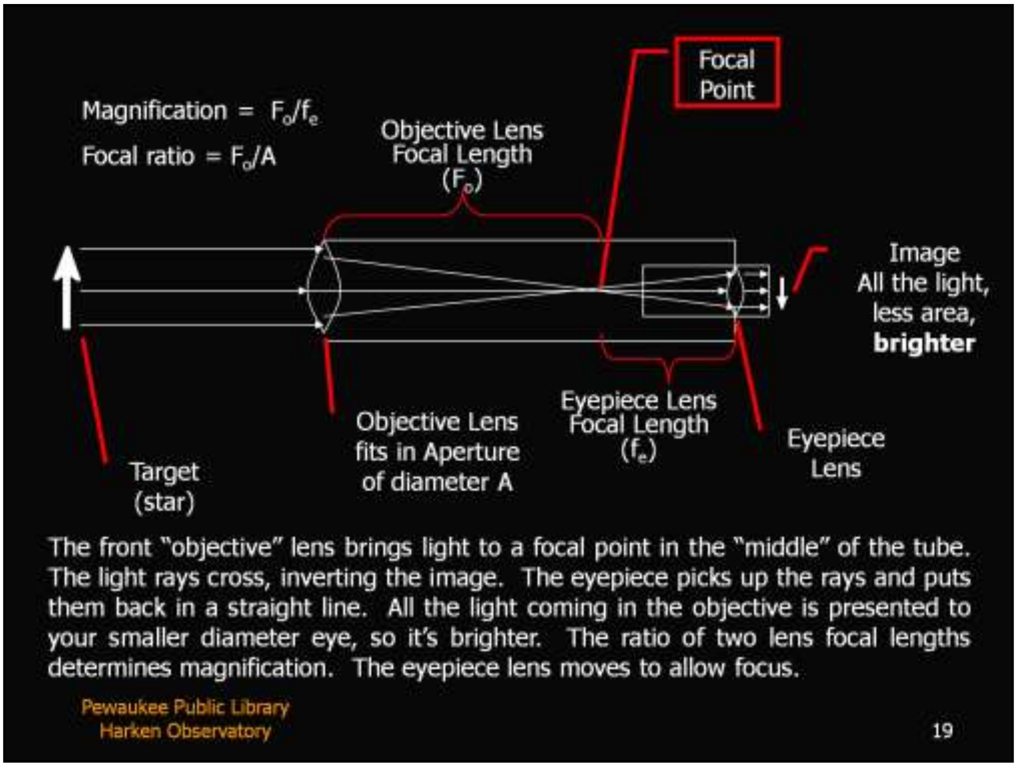
120mm aperture, 900mm (35.4 inch) optical length, 37.5 inch actual, f/7.5

This big-aperture, premium f/7.5 APO takes imaging to a new level of excitement and affordability
The 120ED is a breakthrough in performance at this low price, offering optical quality, workmanship, and attention to detail you'd expect to find on scopes costing thousands more. If you've shied away from high-end refractors because of the cost, you should consider the 120ED.

Superb apochromatic optics set the 120ED apart. The 900mm focal length (f/7.5) is great for planetary work and fast enough for faint galaxies and nebulas. FPL-53 extra-low dispersion (ED) glass in one of the two objective lens elements and multi-coating on all air-to-glass surfaces means light passes to the eyepiece or camera without color fringing. Besides providing more light-grasp for deep-sky imaging 43% more than a 100mm scope the optics easily handle high magnification.

Included are a 2" Crayford-style focuser that accepts 1.25" or 2" accessories, aluminum focus knobs, and a molded-in dovetail base that accepts any Orion finder scope. One year limited warranty.

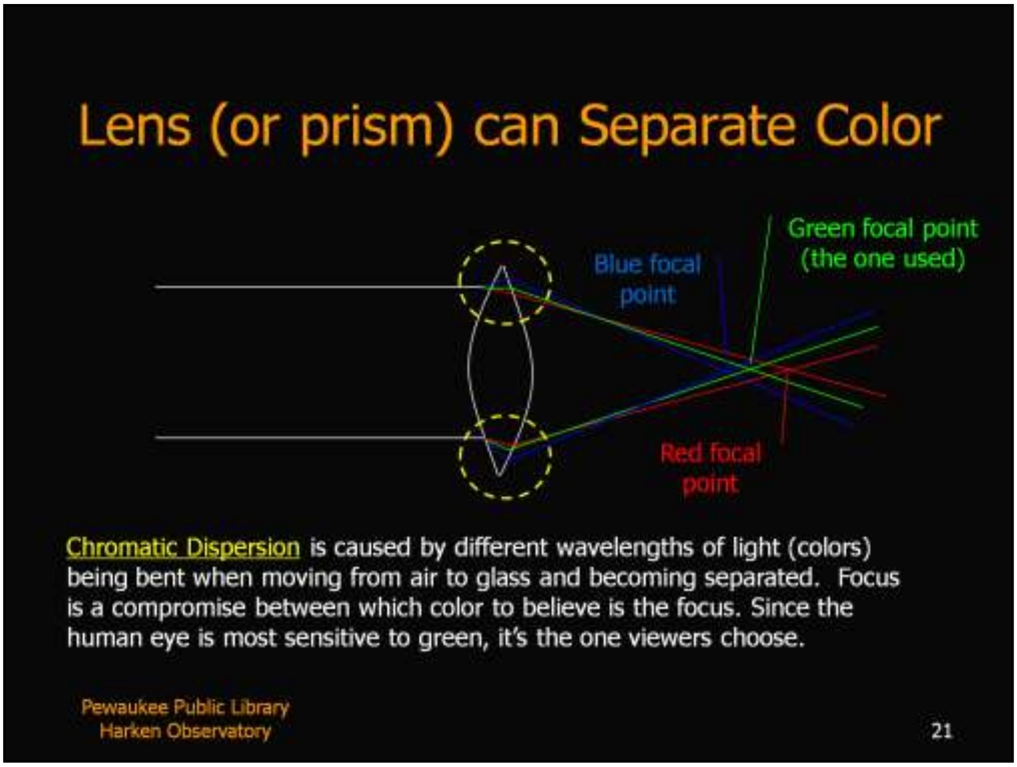
Item 09976, list $1,999.95 in Dec, 2006



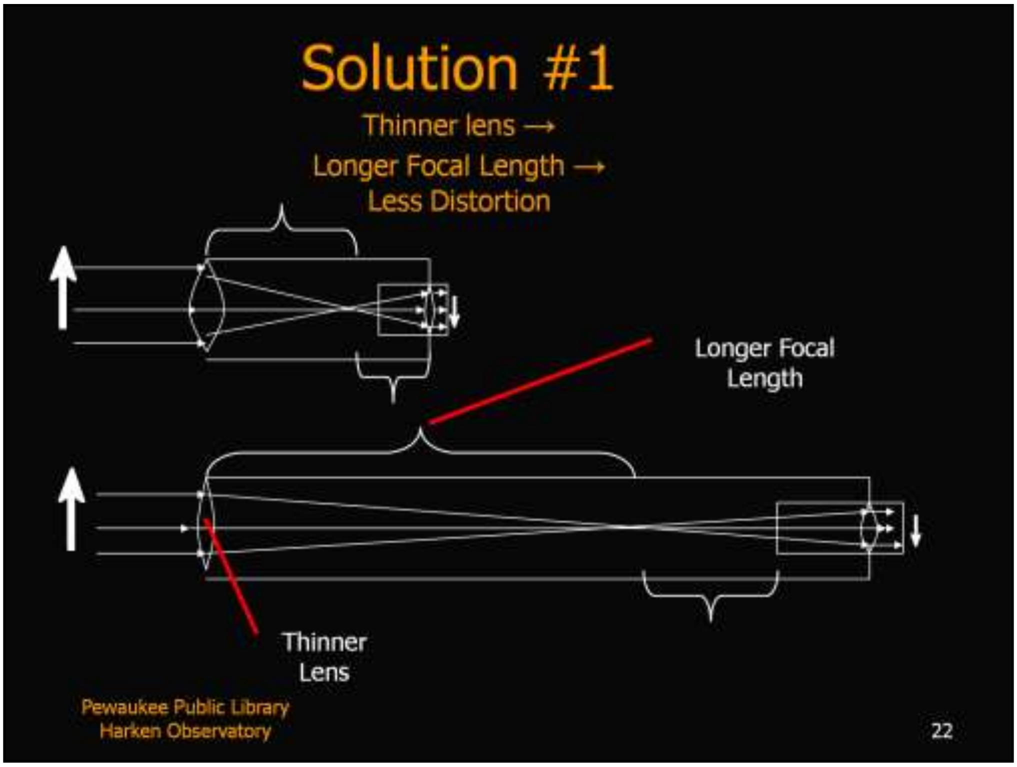
Drawing by author

Chromatic aberration

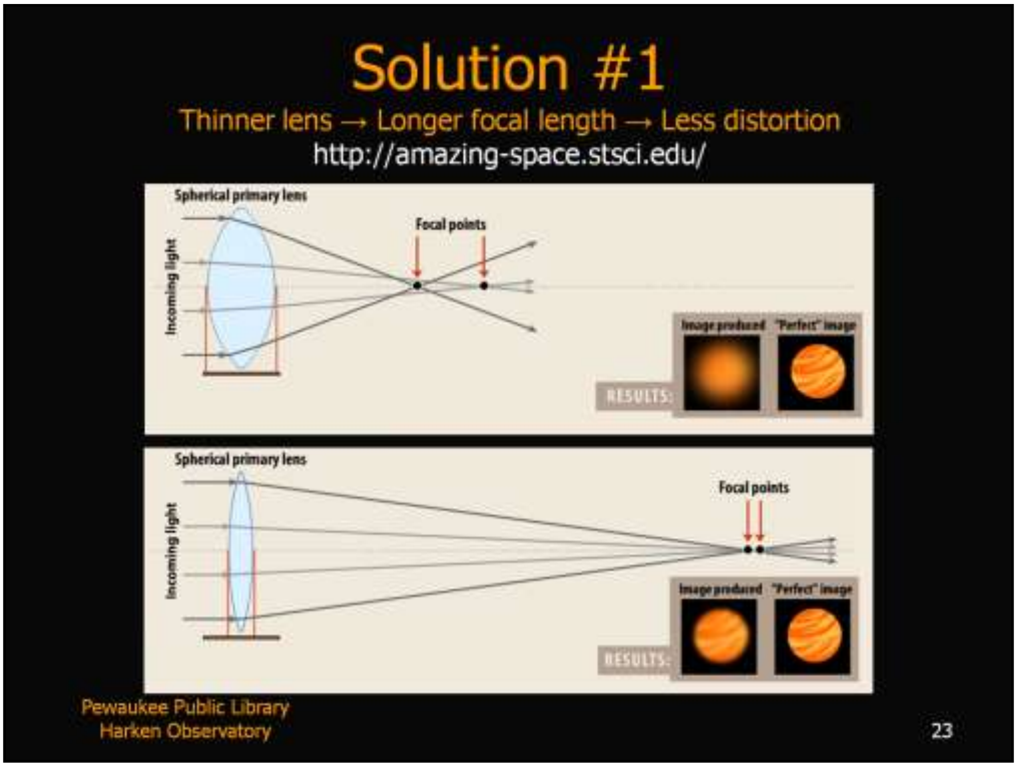
- This simple type of refractor distorts the color of the image.
- The previous diagram shows the ideal case of a beam of white light passing through the lens and being bent perfectly.
- However, blue light bends slightly more than red light.



Drawing by author



Drawing by author



http://amazing-space.stsci.edu/resources/explorations/groundup/lesson/basics/g13/index.php

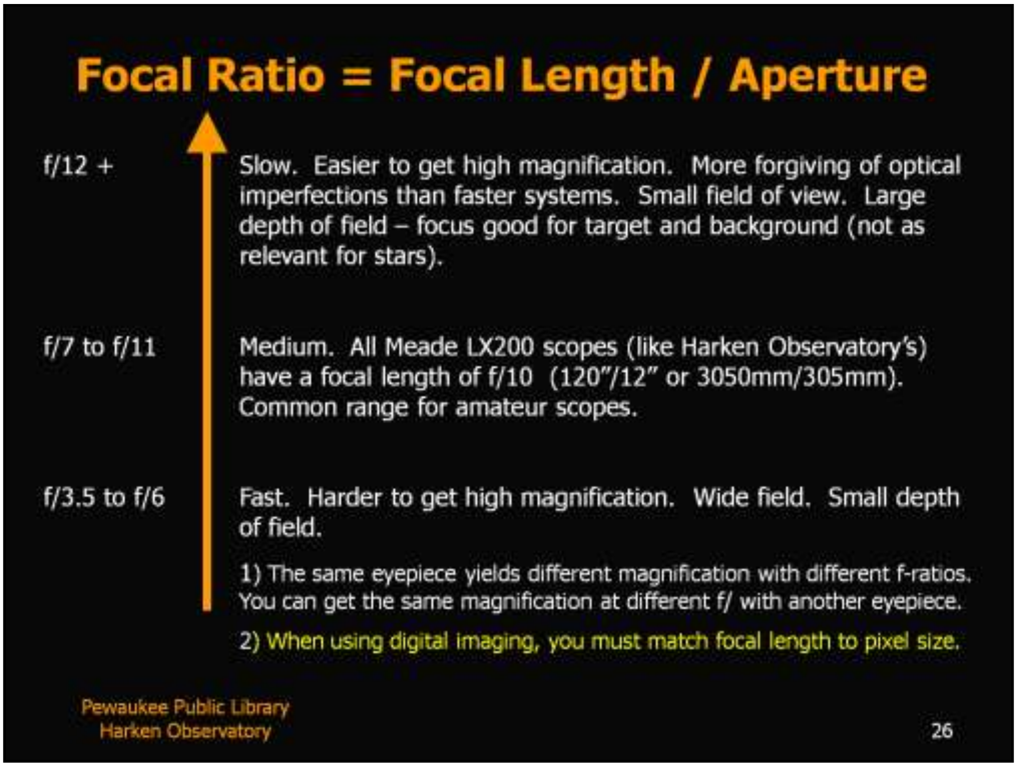
"Six to eight feet—that was the length of a good astronomical telescope in 1645. Five years later it was 10 to 15 feet. Ten years after that, 25 feet. Ten years after that, 40 to 50 feet. By 1673, [Polish astronomer] Johannes Hevelius had constructed a telescope 150 feet long on the shores of the Baltic Sea....One astronomer cheered the coming day when aerial telescopes would have a focus of 1,000 feet and human spectators could marvel at the antics of the animals on the Moon."

Seeing and Believing: How the Telescope Opened Our Eyes and Minds to the Heavens, by Richard Panek

http://www.pbs.org/wgbh/nova/galileo/telescope.html

http://amazing-space.stsci.edu/resources/explorations/groundup/lesson/scopes/hevelius/index.php?return=true

Hevelius was a Polish astronomer and made many contributions to lunar observation



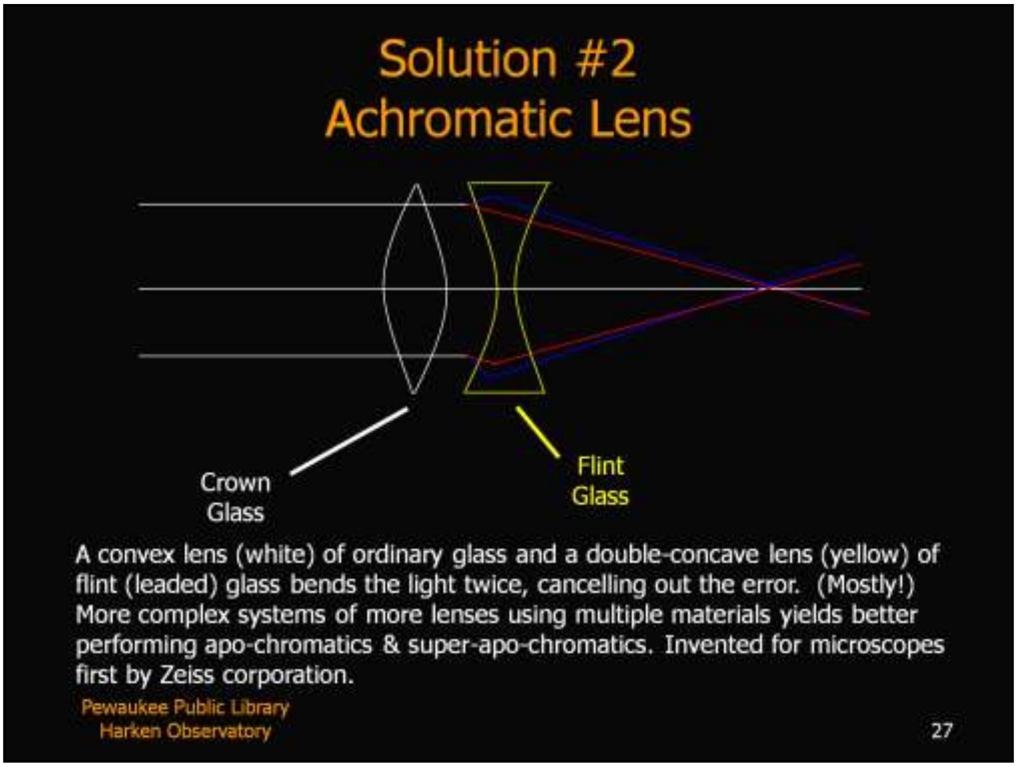
http://www.astronomy.net/articles/26/

Understanding how power, or magnification, is calculated when using a telescope will require the understanding of a relationship between two independent optical systems - the telescope itself and the eyepiece you are using. To understand this we must first understand the term Focal Length.

http://www.ghg.net/akelly/telescop.htm

The pixel size of your CCD should be matched properly with your telescope's effective focal length. There are many considerations that should be accounted for in this coupling of scope and camera. One significant trade off is speed versus resolution.

When imaging a bright object like a planet or the moon you are less concerned about the photographic speed (focal ratio) of the camera than the resolution needed to capture fine planetary detail. In this case resolution should be maximized since the planets/Moon are bright enough that speed is not a significant factor. Nyquist sampling theory states that when transferring spatial information from one medium to another, two samples must be acquired of each datum in order to capture all the information present. In telescope resolution terms, this means that the resolution of your CCD's pixels should be twice as precise as the resolution of your scope. For example a 5-inch scope has a diffraction-limited resolution of about one arcsecond. To capture all the information present in the planetary image, the CCD's pixel's FOV should span no more than 0.5 arcseconds. This assumes that seeing conditions are not a limiting factor. At most imaging locations used by amateurs, seeing conditions limit sky resolution to considerably more than 1 arcsecond for CCD integrations longer than a second or so; but the good news is that the very short integrations used for bright planets and the Moon,



Flint glass includes lead and has a higher index of refraction, causing greater bending.

Discovered in 1750s by English optician, John Dolland.

http://www.aip.org/history/cosmology/tools/tools-refractors.htm

Focus Issues

- You will see this concept again and again.
- Light from the target does not focus to a precise point.
- There are many other optical defects including coma, astigmatism and field curvature.

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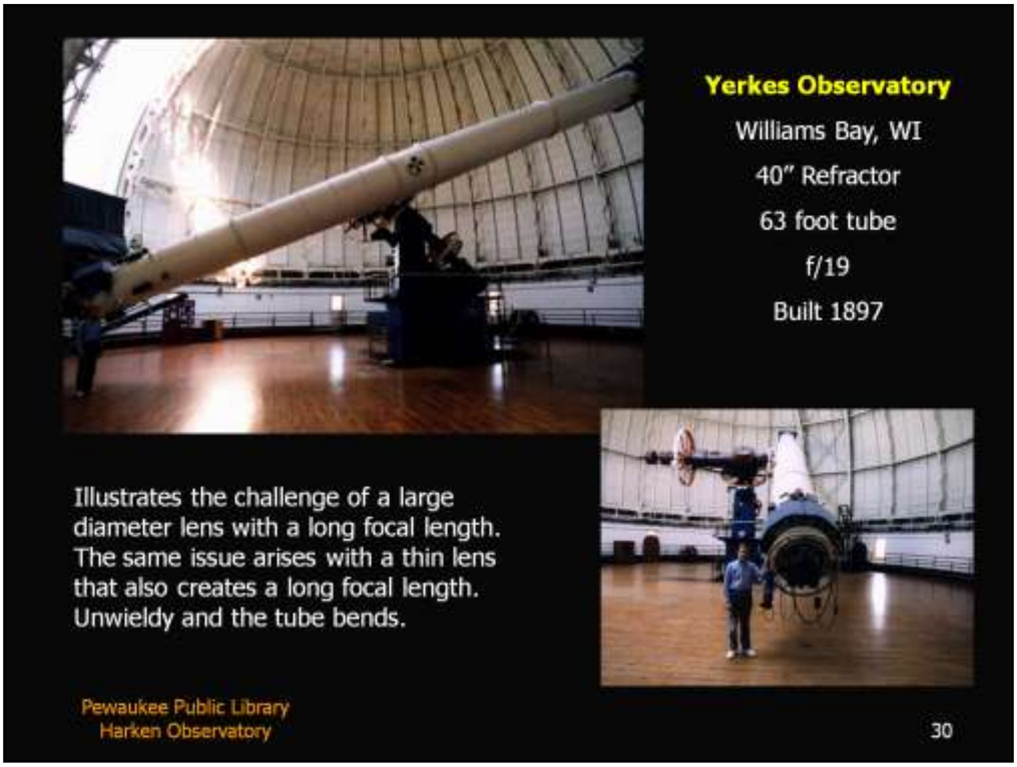
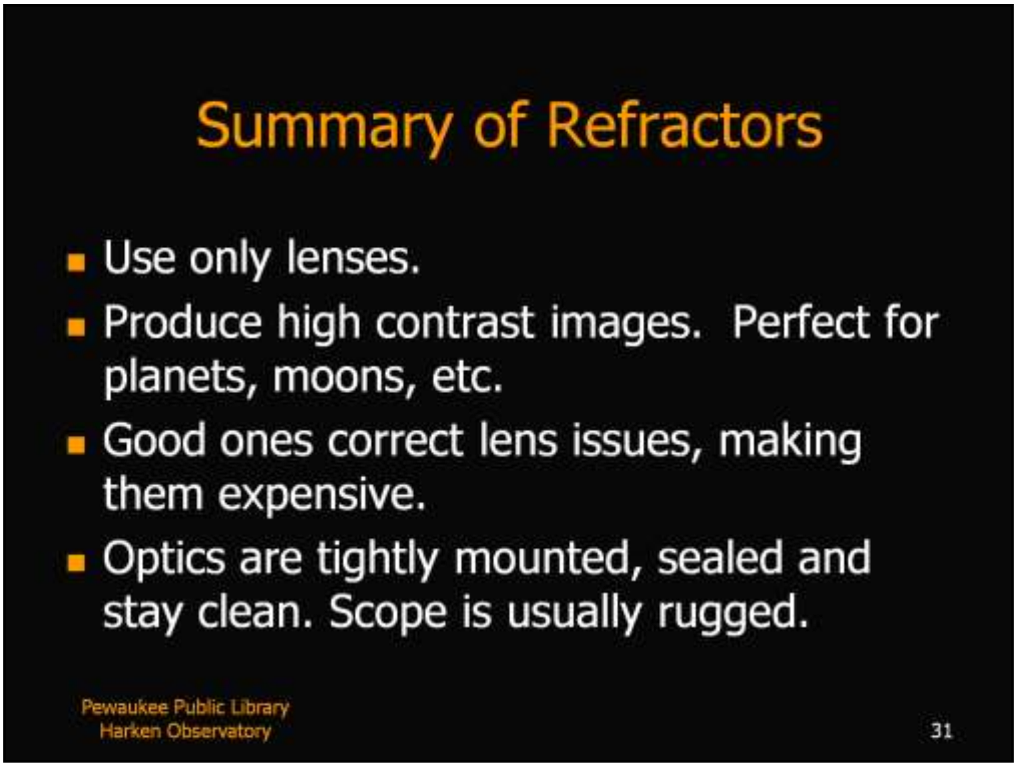
Eyepieces

- Eyepieces come in many designs and may incorporate many lenses (8 or more) of different materials and shapes
- Many trade-offs: focal length, eye relief, aberrations, expense, diameter, field of view, …
- Eyepiece types include: Plössl, Huygens, Ramsden, Kellner (or achromatized Ramsden), Orthoscopic (or orthographic) and more
- CCD imagers are another set of issues



Yerkes official web site http://astro.uchicago.edu/vtour/40inch/


Summary of Refractors
Use only lenses.
Produce high contrast images. Perfect for planets, moons, etc.
Good ones correct lens issues, making them expensive.
Optics are tightly mounted, sealed and stay clean. Scope is usually rugged.
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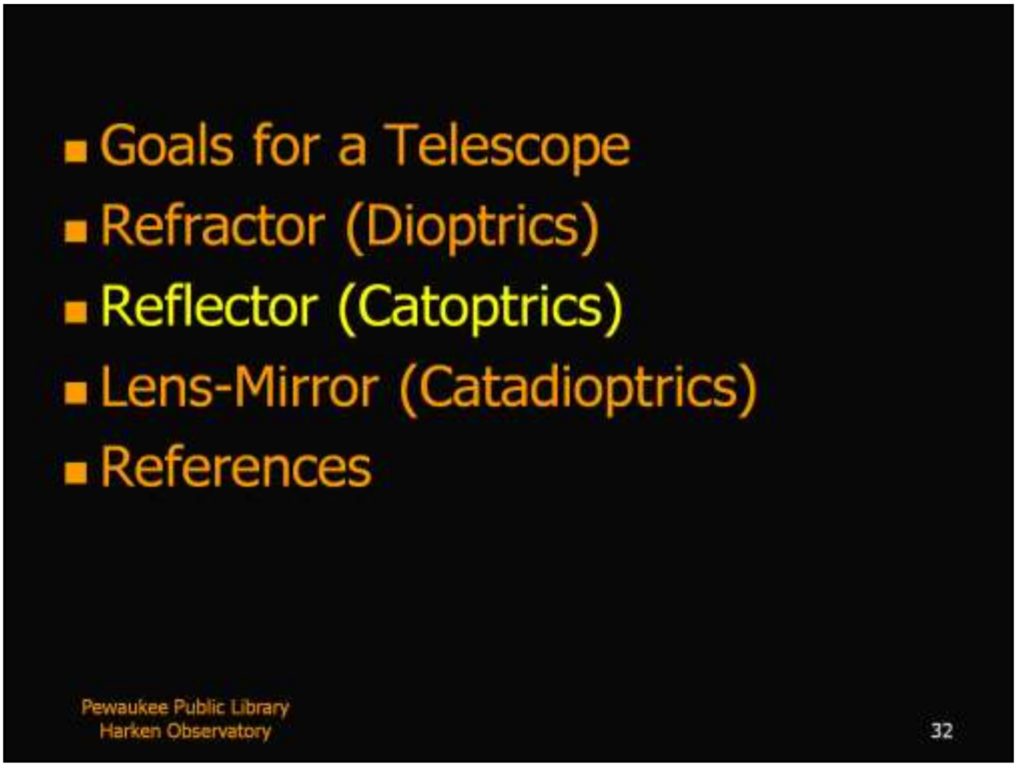
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Reflector Telescope

- Lens based scopes had been around for about 50 years and were limited by size, lens aberration, glass quality, etc.
- Several people speculated mirrors could bypass the issues – but how?
- Isaac Newton invented the first real reflector telescope in 1668

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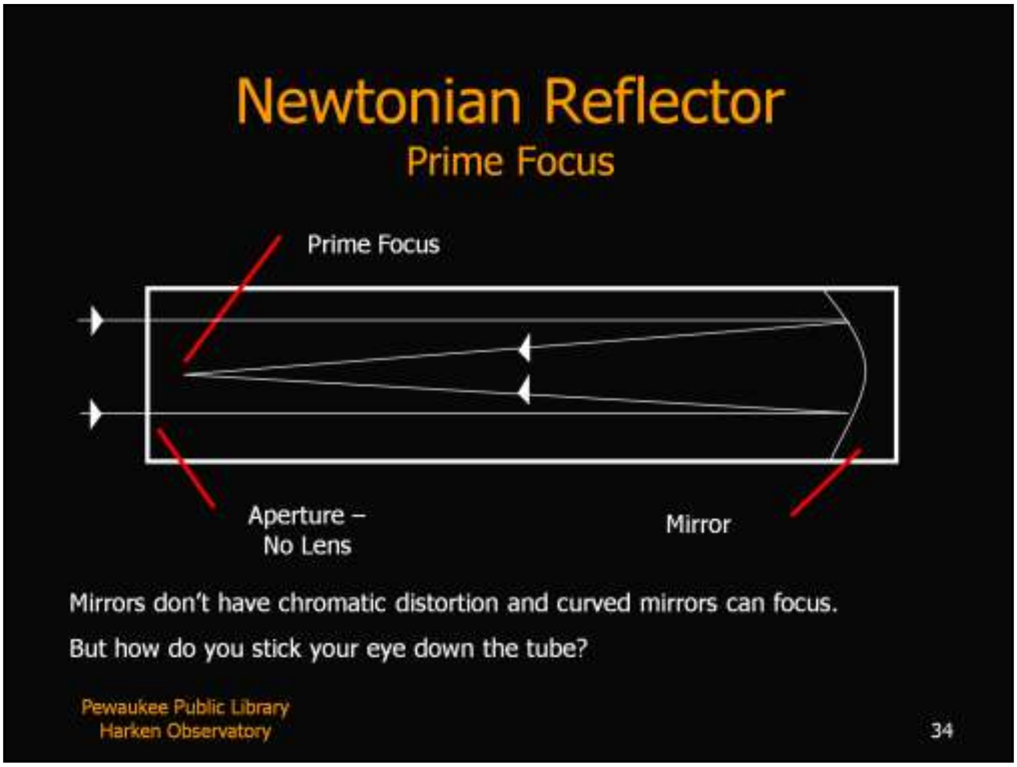
Newtonian Reflector
Prime Focus
Prime Focus
Aperture –
No Lens
Mirror
Mirrors don't have chromatic distortion and curved mirrors can focus.
But how do you stick your eye down the tube?
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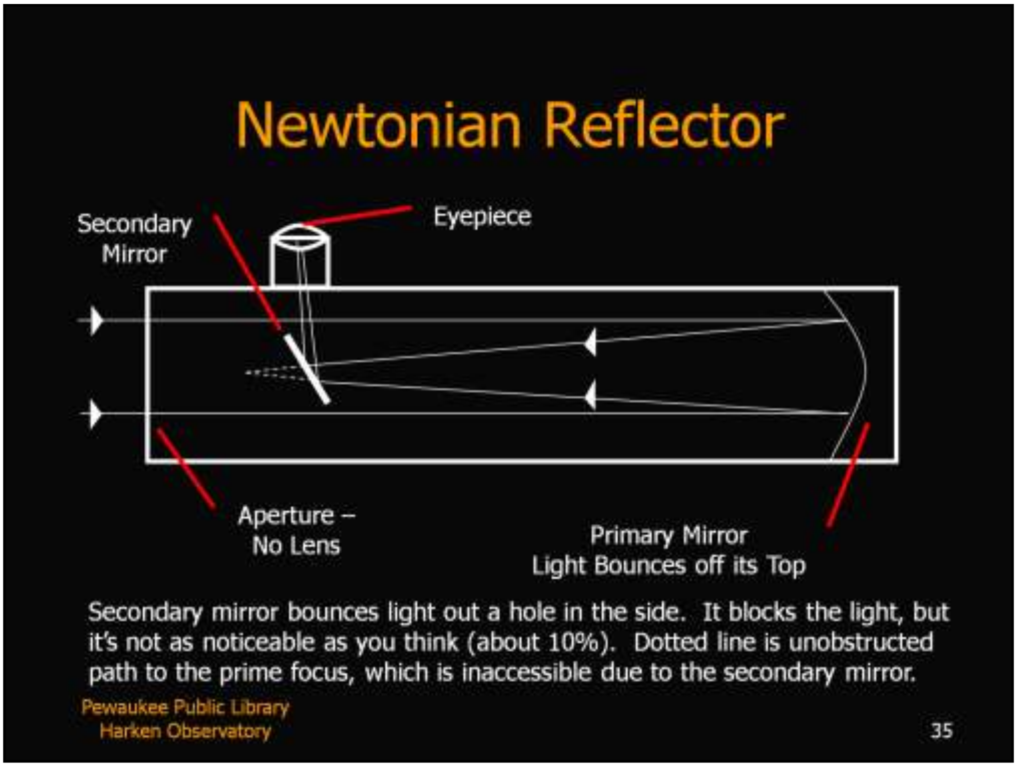
Newtonian Reflector
Secondary Mirror
Eyepiece
Aperture – No Lens
Primary Mirror Light Bounces off its Top
Secondary mirror bounces light out a hole in the side. It blocks the light, but it's not as noticeable as you think (about 10%). Dotted line is unobstructed path to the prime focus, which is inaccessible due to the secondary mirror.
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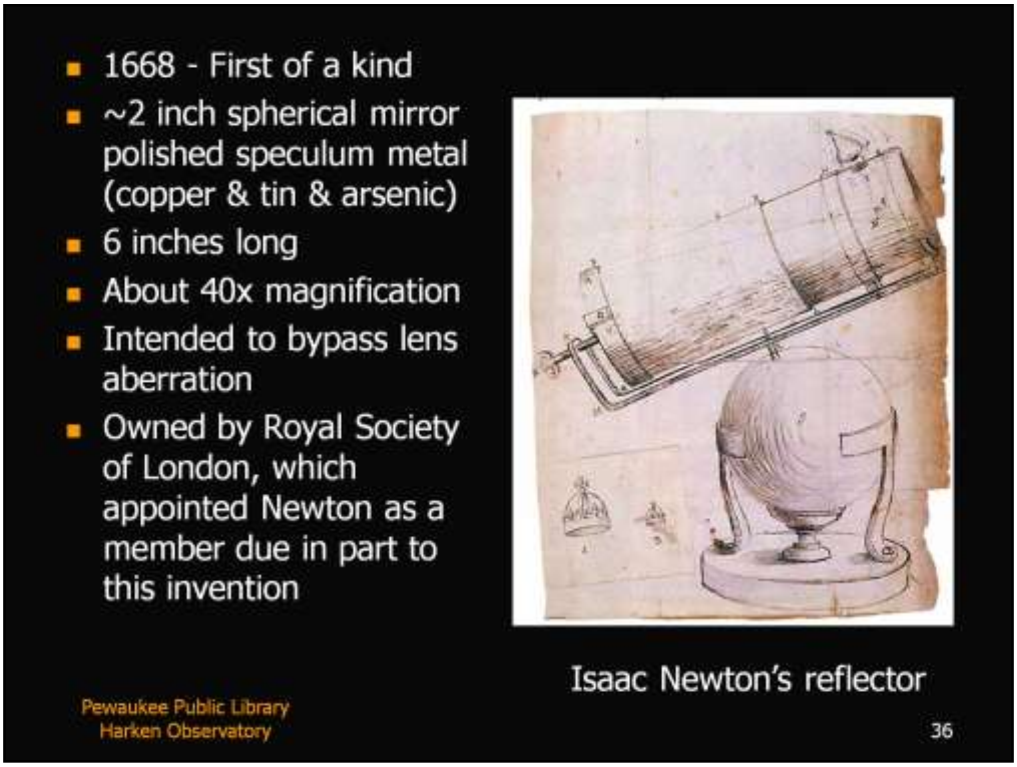


drawing photo from http://www.antiquetelescopes.org/newtonscope_drawing.jpg

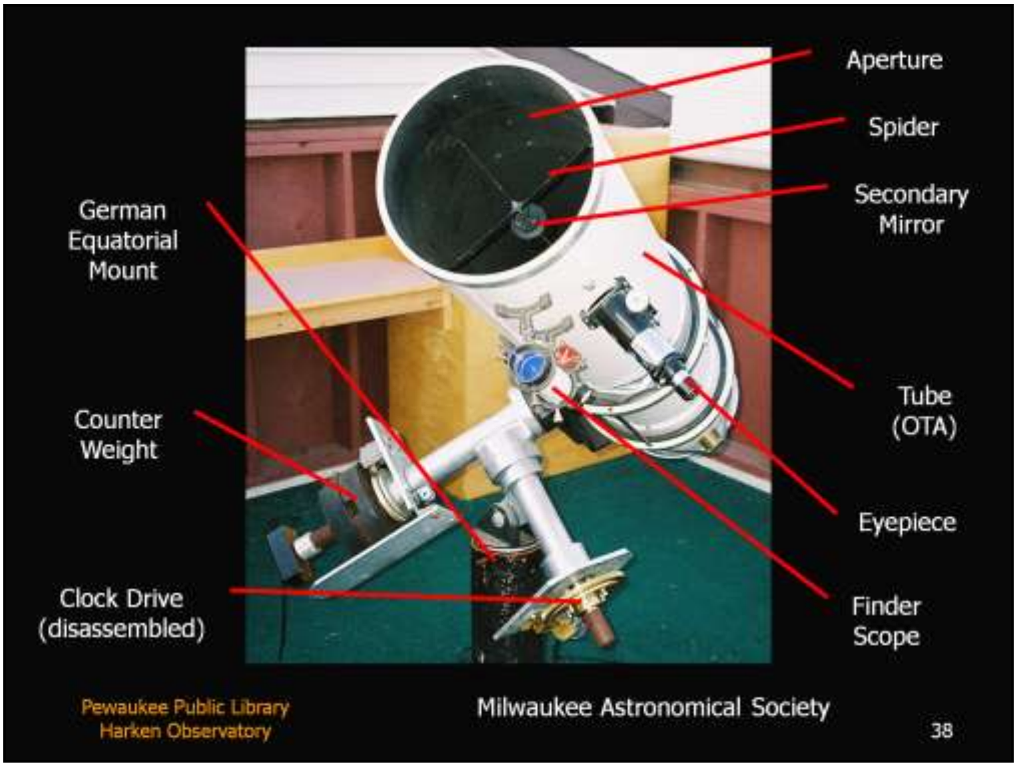
scope photo from http://www.departments.bucknell.edu/History/Carnegie/newton/telescope1.html

also: http://www.pbs.org/wgbh/nova/galileo/telescope.html

drawing photo from http://www.antiquetelescopes.org/newtonscope_drawing.jpg

scope photo from
http://www.departments.bucknell.edu/History/Carnegie/newton/telescope1.html

also: http://www.pbs.org/wgbh/nova/galileo/telescope.html



This photo is the Milwaukee Astronomical Society's Albrecht scope.

Newtonian with German Equatorial Mount (GEM) and a Clock Drive

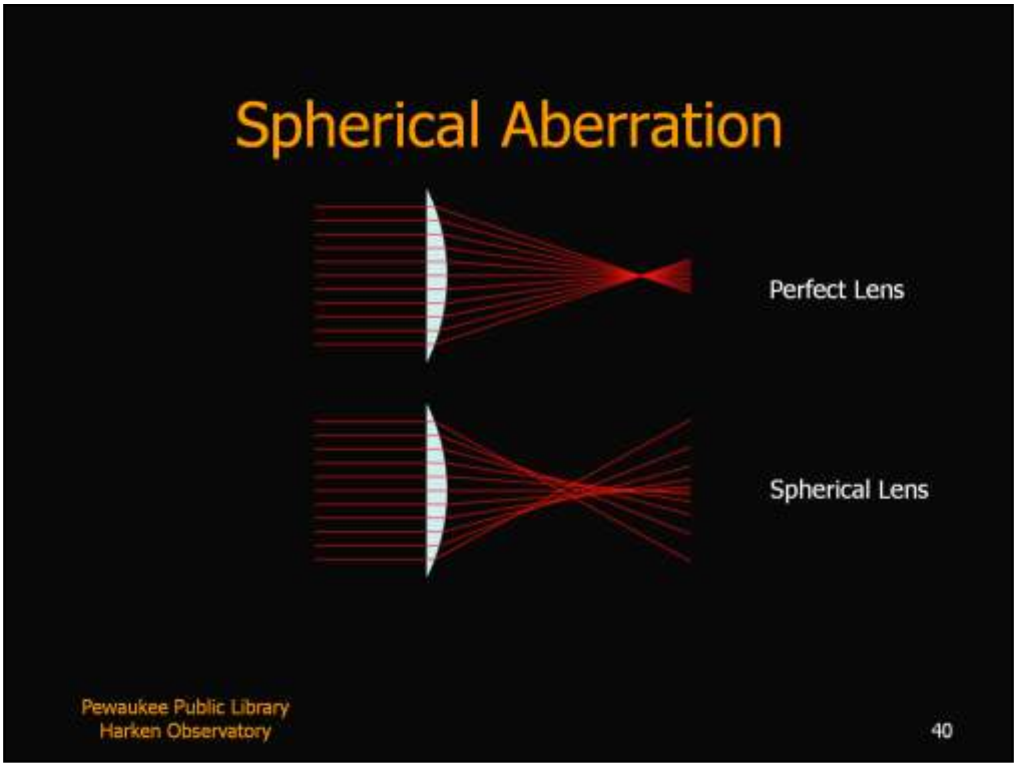
Aperture is 254 mm (10 in)

Focal Length 1524 mm (60 in) and Focal Ratio 6.0

Often used for variable star observing

Spherical Aberration

- Newton used a mirror shaped like part of a sphere.
- There was no chromatic aberration since light bounced off the top of the mirror
- Spherical optics, whether mirrors or lenses, introduce other types of distortion


Spherical Aberration
Perfect Lens
Spherical Lens
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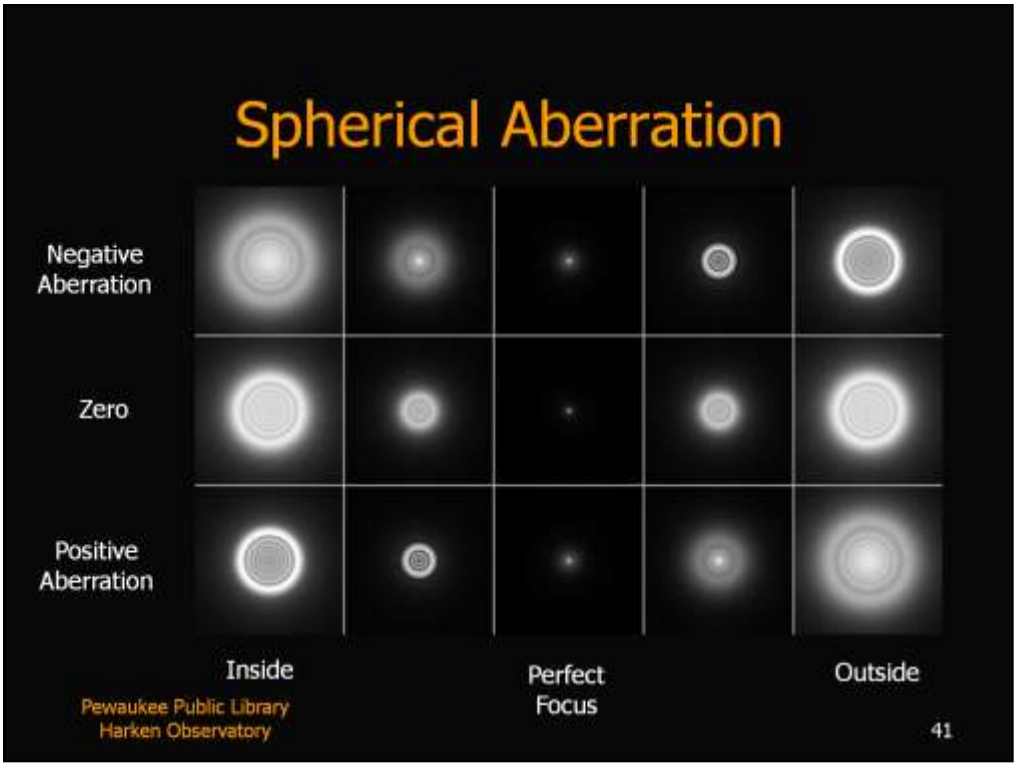
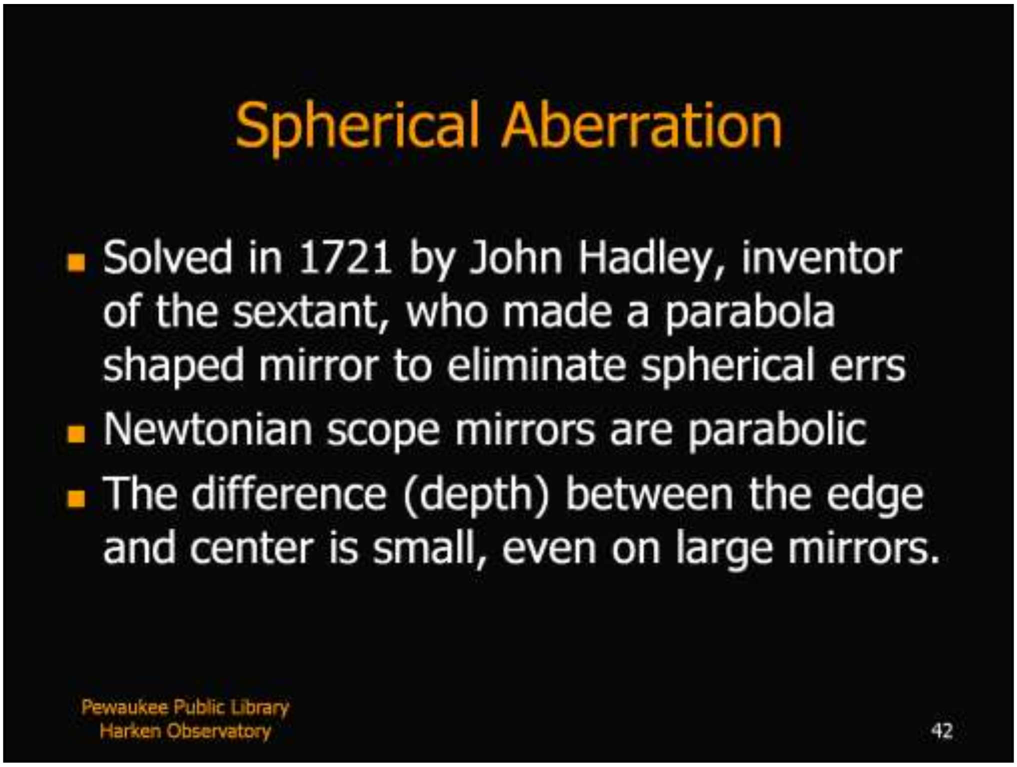


http://en.wikipedia.org/wiki/Image:Spherical-aberration-disk.jpg

A simulation of spherical aberration in an optical system with a circular, unobstructed aperture admitting a monochromatic point source. The top row is over-corrected (half a wavelength), the middle row is perfectly corrected, and the bottom row is under-corrected (half a wavelength). Going left to right, one moves from being inside focus to outside focus. The middle column is perfectly focused. Also note the equivalence of inside-focus over-correction to outside-focus under-correction. See the corresponding longitudinal sections.


Spherical Aberration
Solved in 1721 by John Hadley, inventor of the sextant, who made a parabola shaped mirror to eliminate spherical errs
Newtonian scope mirrors are parabolic
The difference (depth) between the edge and center is small, even on large mirrors.
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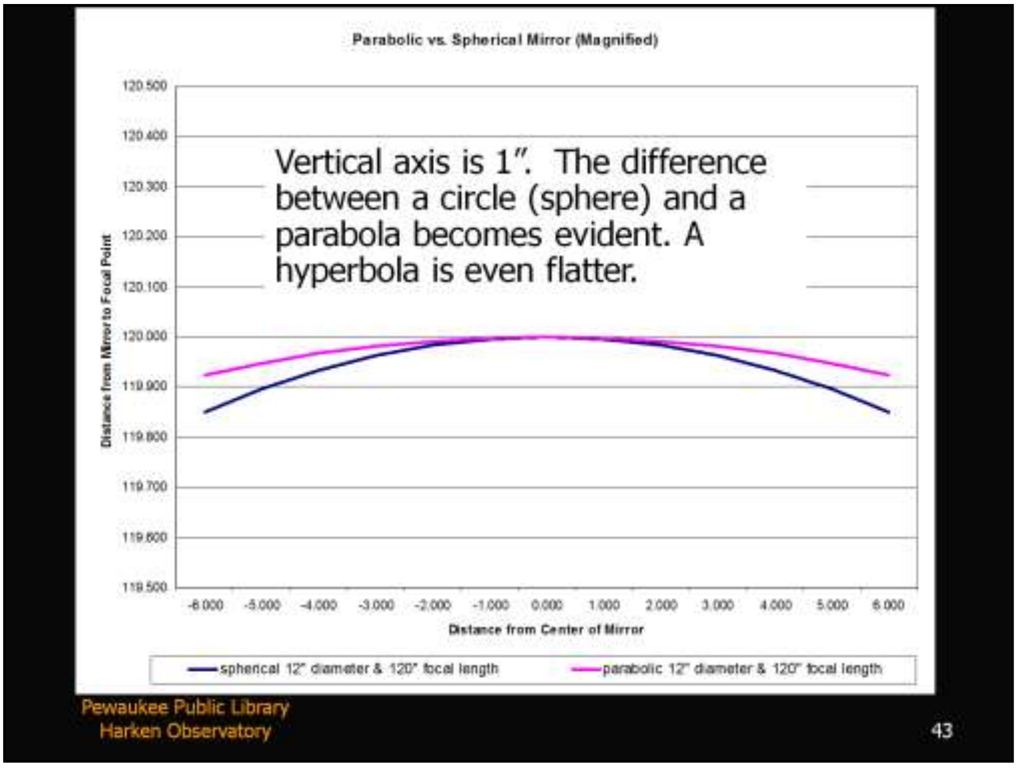
Parabolic vs. Spherical Mirror (Magnified)
Vertical axis is 1". The difference between a circle (sphere) and a parabola becomes evident. A hyperbola is even flatter.
Distance from Mirror to Focal Point
120.500
120.400
120.300
120.200
120.100
120.000
119.900
119.800
119.700
119.600
119.500
-6.000 -5.000 -4.000 -3.000 -2.000 -1.000 0.000 1.000 2.000 3.000 4.000 5.000 6.000
Distance from Center of Mirror
spherical 12" diameter & 120" focal length
parabolic 12" diameter & 120" focal length
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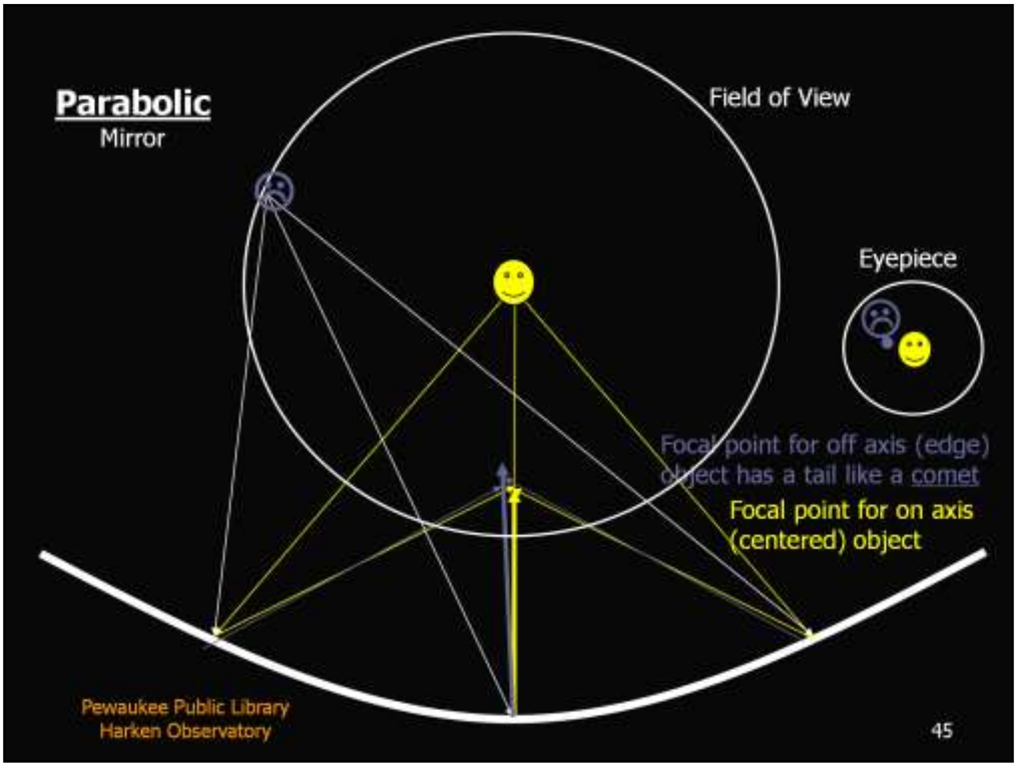
Off Axis Coma

- A defect of an objective mirror or lens in which rays of light, striking the objective away from the optical axis are not brought to focus in the same image plane.
- The result is that star images toward the edge of the field of view appear to have comet-like tails spreading radially out from the optical axis (*negative coma*) or in toward the axis (*positive coma*).
- Common in parabolic curved mirrors used in Newtonian reflectors.


Parabolic
Mirror
Field of View
Eyepiece
Focal point for off axis (edge) object has a tail like a comet
Focal point for on axis (centered) object
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Harken Observatory
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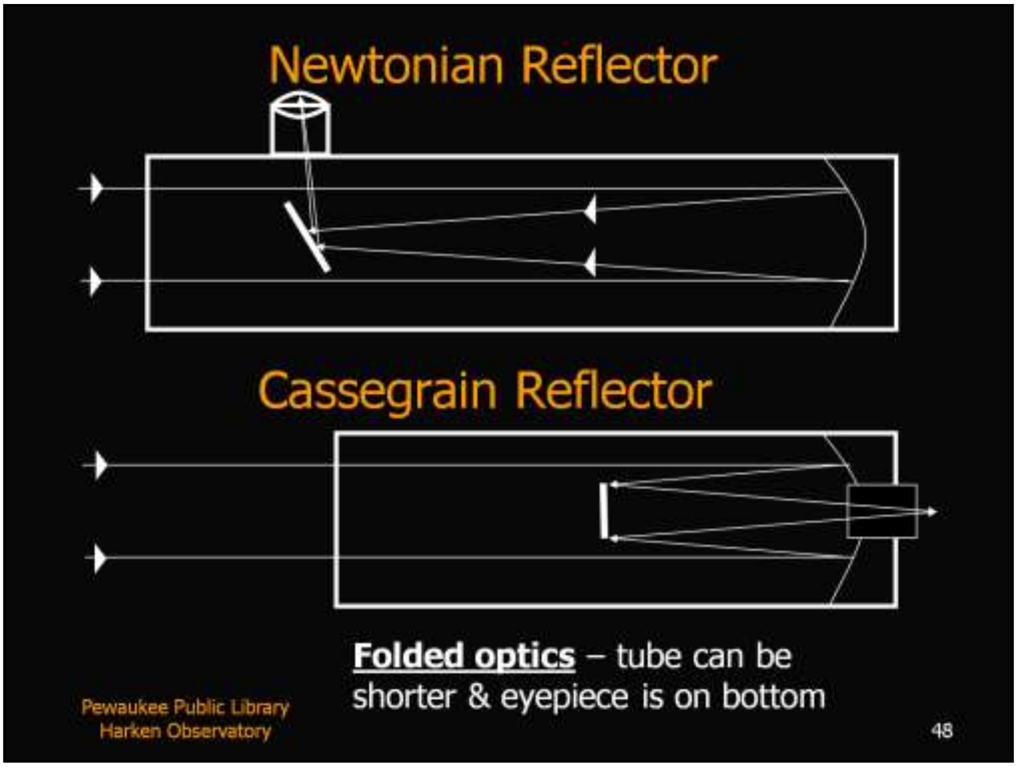
Mirror Coating

- Original scope mirrors were shiny metal. It was hard to make a smooth surface with perfect curvature.
- Glass mirrors are ground like a lens with very high precision.
- The reflective coating is on top of the glass, not on the back. It was originally silver. Now everyone uses aluminum. It is easy to scratch, so it rarely gets cleaned.

MAS A scope

Note eyepiece is about twice as high as Bob is tall. Ladders required


Newtonian Reflector
Cassegrain Reflector
Folded optics – tube can be shorter & eyepiece is on bottom
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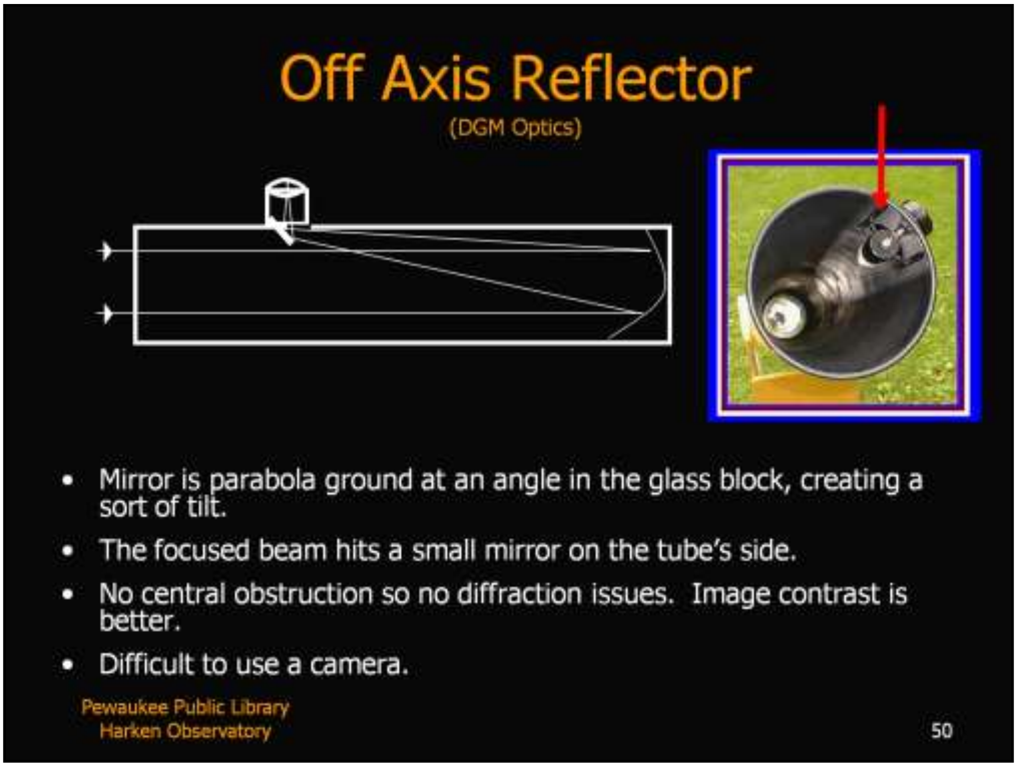
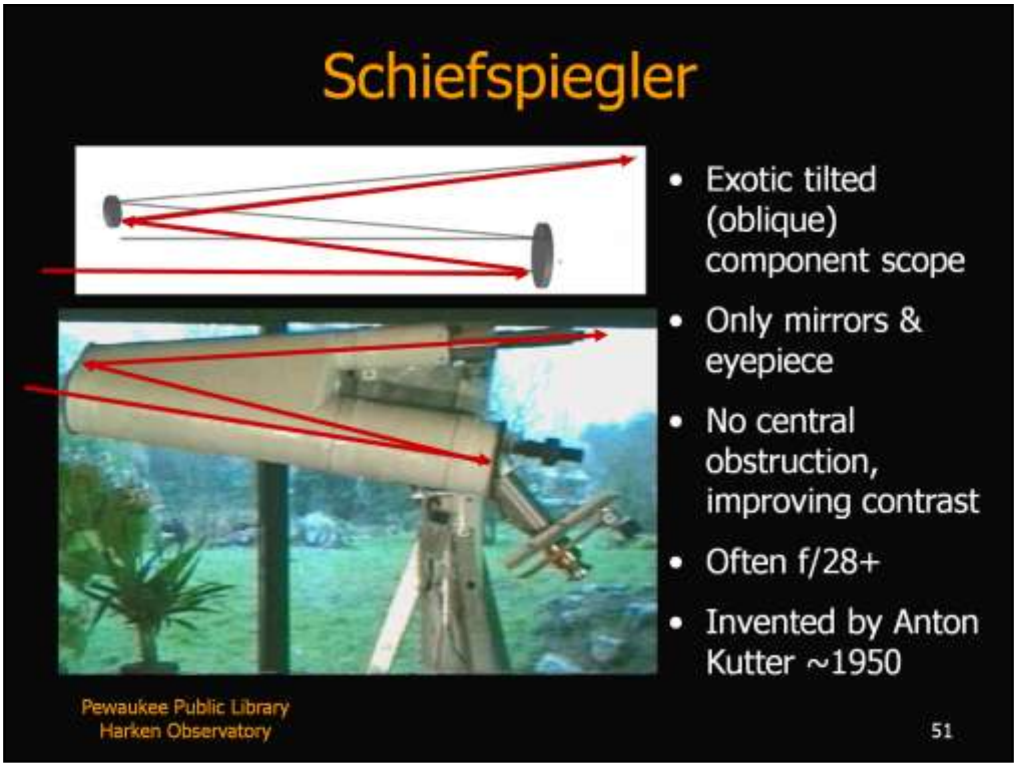
- Milwaukee Astronomical Society
- 25″ Cassegrain reflector
- Prime focus big enough to hold camera
- Focal Length: 112″, f/15
- Note Alvin Clark refractor



http://users.erols.com/dgmoptics/indexwelcome



http://www.seds.org/~spider/scopes/schiefv.html

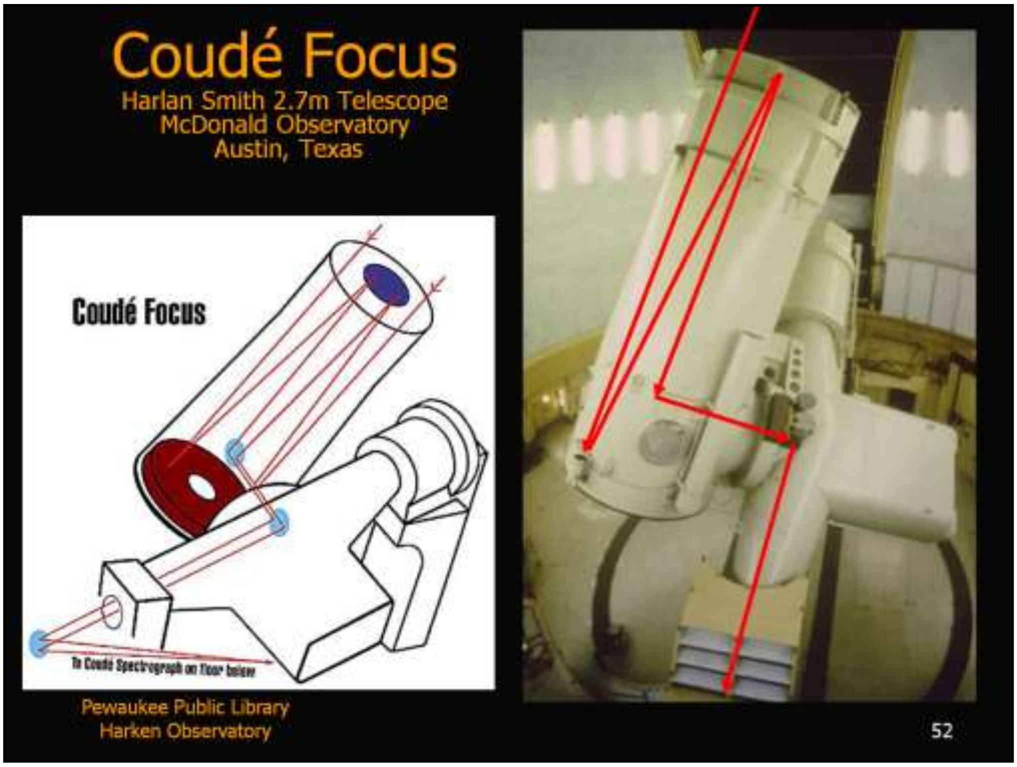
http://telescopemaking.org/schief.html

All mirrors. Optical errors cancel each other out.

Simple to construct.

Very high focal lengths: f/28+

Original 1958 Sky & Telescope story found at
http://www.atmsite.org/contrib/Holm/bulletina/index.html



http://mcdonaldobservatory.org/research/telescopes/telescope.php?t_id=16

2.7-meter Harlan J. Smith Telescope

The control room of the 2.7-meter Harlan J. Smith Telescope.McDonald Observatory's Smith Telescope was third largest in the world when completed in 1969. Its light-gathering power is a quarter of a million times greater than that of the unaided human eye.

The telescope was built under terms of a joint contract between NASA and The University of Texas, at a total cost of about $5 million. Planning for the telescope began late in 1964, when it became clear that more large telescopes were needed to pave the way for the emerging Space Age. Soon spacecraft would explore the planets, but not before telescopes explored them first from Earth.

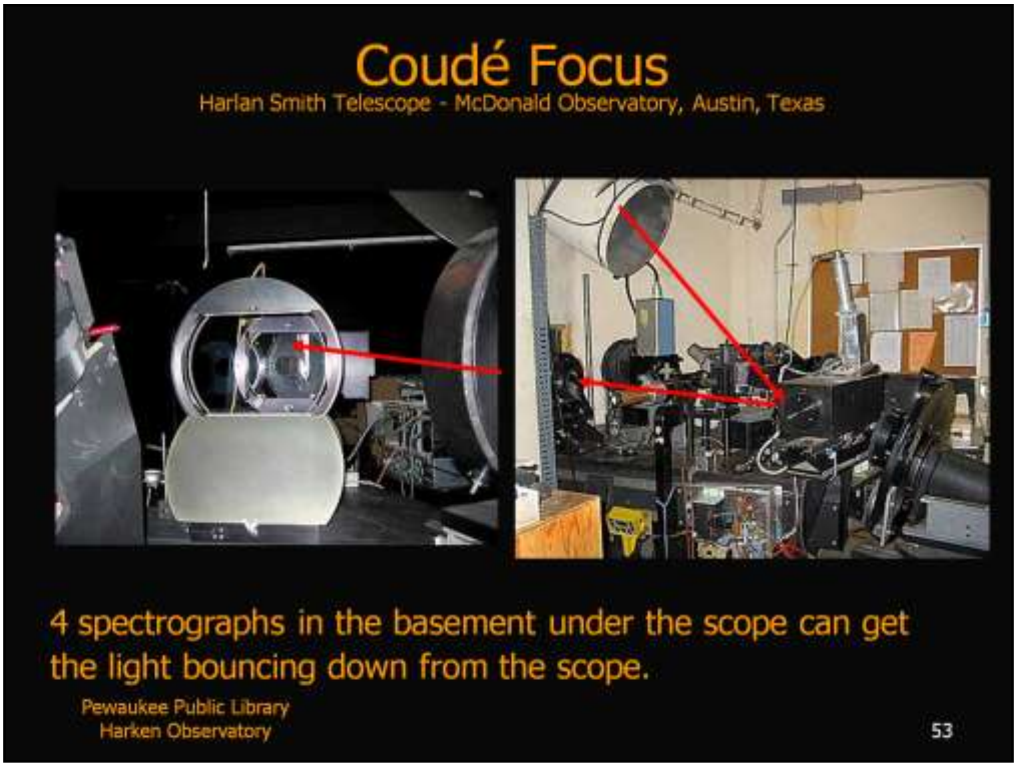
This telescope was built in part to serve as "eyes" on the solar system. The information gathered in McDonald's planetary program played a significant part in preparing for more detailed exploration of the solar system by manned and unmanned spacecraft and in understanding the results sent back by them.

Since its dedication in November 1969, the Smith Telescope has been in steady use every clear night. It is now used for a full range of astronomical research.

Telescope Facts
Primary Mirror
Diameter
2.72 meters (107 in.)
Weight
3540 kg (7800 lbs.)
Thickness
31.8 cm (12.5 in.)
Material
Fused silica

Telescope Tube
Diameter
3.66 meters (12 ft.)
Length
9.75 meters (32 ft.)

Telescope weight
160 tons



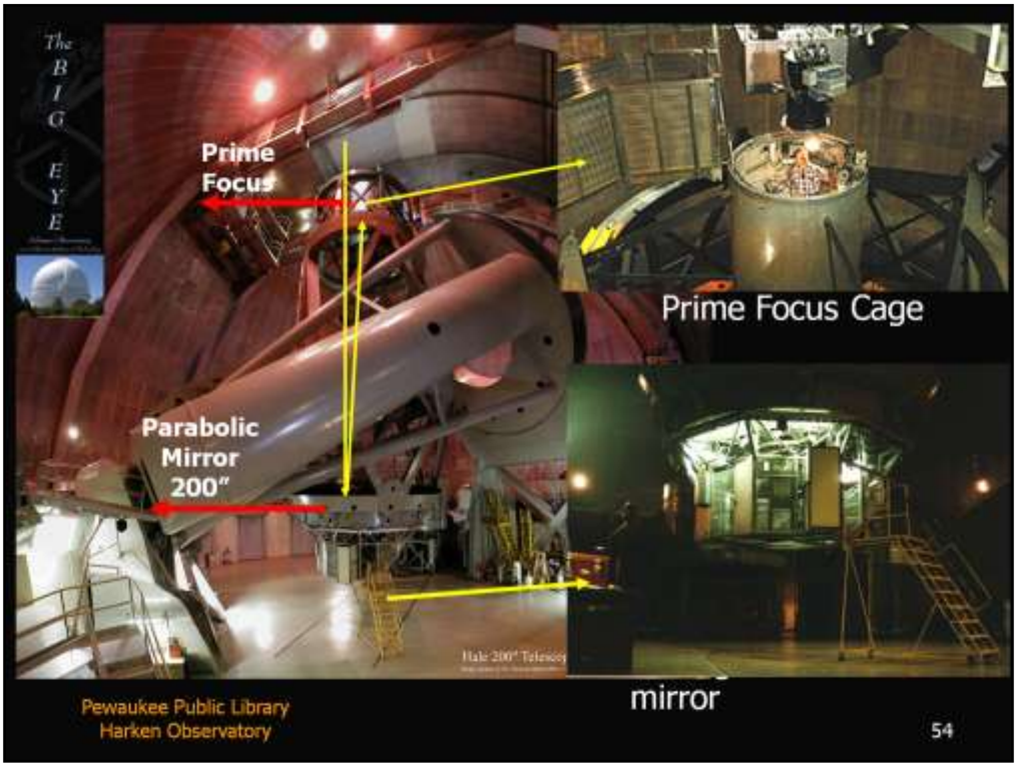
http://mcdonaldobservatory.org/research/instruments/instrument.php?i_id=17

The "slit room," part of the Smith Telescope's Coudé Spectrograph. Light comes from the telescope through the "pipe" in the upper left to fall on the slit in this room before being reflected into the Coudé room to the left. Light enters the large Coudé room and is reflected by a mirror (as shown in this image) to the diffraction grating and then to the CCD detector.
Above right: Smith Telescope light path to Coude focusThere are four different configurations of the Coudé Spectrometer on the 2.7 meter Harlan J. Smith Telescope. The configurations are cs11, also known as the 6-Foot Camera, cs12, also known as the Long Focus camera, cs21, and cs23. The instruments are spectrographs, meaning they separate light into its component colors, creating a spectrum for astronomers to study.

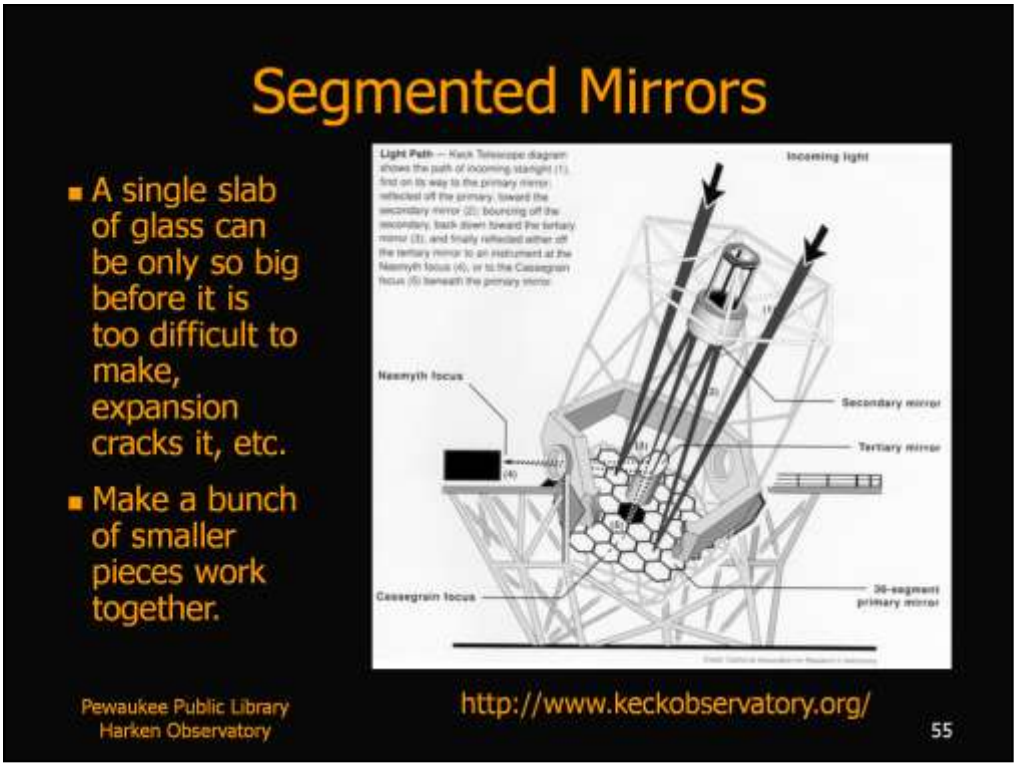
All of these instruments are located at Coudé focus. Light is collected by the telescope and reflected by four mirrors down the telescope axis and into a room known as the Coudé slit room. A pivoting mirror at the base of the telescope axis allows an astronomer to decide which spectrograph entrance slit to use. One spectrograph slit allows the incoming light to follow the 6-Foot Camera and the Long Focus Camera light path. The other spectrograph slit allows the incoming light to follow the cs21 and the cs23 light path. These light paths are inside the Coudé room, which is essentially the inside of an astronomical camera that happens to be large enough to allow people to walk around inside. It is a long room painted entirely black, and it contains many pieces of optical equipment. The optical equipment directs light from the spectrograph slits to the diffraction gratings, lenses, prisms and mirrors that make up the 6-Foot Camera, the Long Focus Camera, cs21, and cs23. At the end of the optical path, light is detected by a charged coupled device (CCD) camera.

The difference between the different configurations is that they provide varying degrees of resolution, or spreading of light into its component colors. The 6-Foot Camera is a medium to high resolution spectrometer, while the Long Focus Camera is a very high resolution spectrometer. Cs21 and cs23 are both medium to high resolution spectrometers. There are five different diffraction gratings and two different echelles that can be used with the instruments. An echelle is a special type of diffraction grating with fewer grooves per millimeter than a normal diffraction grating. Different combinations of echelles and diffraction gratings provide different degrees of resolution and allow astronomers to study different ranges of wavelengths.

The instruments at Coudé focus on the 2.7-m Harlan J. Smith Telescope provide the highest resolution available at McDonald Observatory. The instruments were designed for spectroscopy of the atmospheres of stars and planets, and they are most often used for this purpose.



http://www.astro.caltech.edu/palomar/hale.html
http://www.astro.caltech.edu/palomar/images/palomar_big_eye.jpg


Segmented Mirrors
A single slab of glass can be only so big before it is too difficult to make, expansion cracks it, etc.
Make a bunch of smaller pieces work together.
Incoming light
Nasmyth focus
Secondary mirror
Tertiary mirror
Cassegrain focus
36-segment primary mirror
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http://www.keckobservatory.org/
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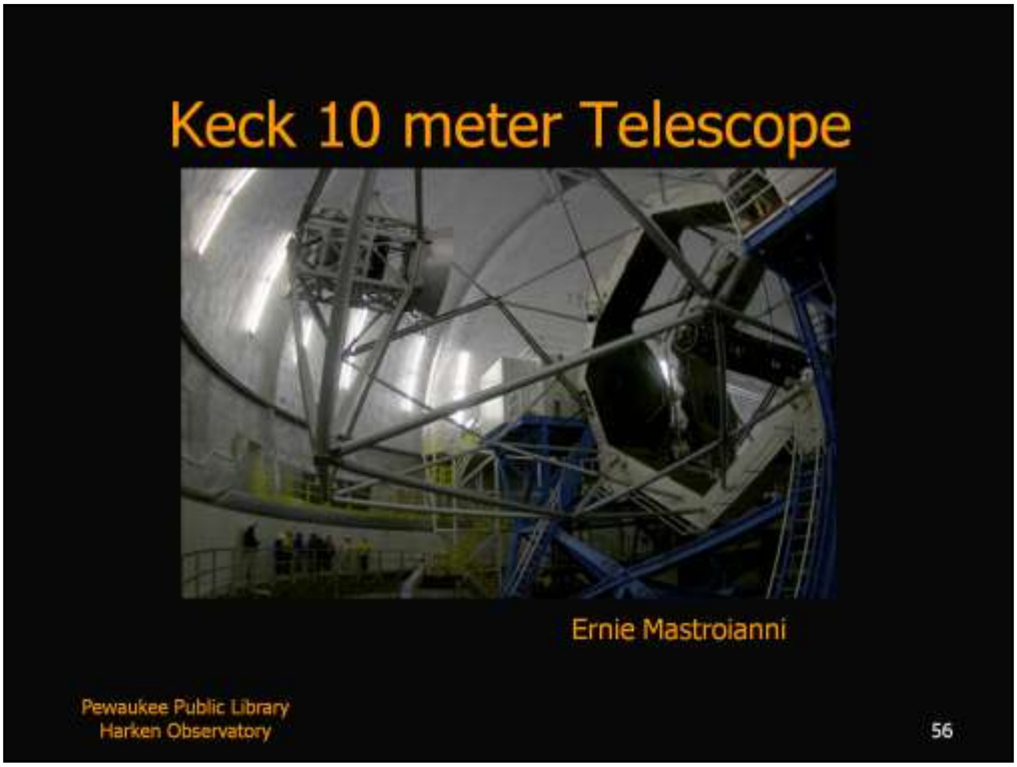


http://home.wi.rr.com/astrophotography/scene%208.5.htm

Primary mirror diameter: 10 meters (33 feet)

Mirror curvature: f/1.75 hyperbolic mirror

Focal length: 17.5 meters (57.4 feet)

Primary mirror design: Segment

Number of segments: 36

Segment shape: Hexagonal

Segment diameter: 1.8 meters (6 feet)

Segment weight: 880 pounds

Segment material: Zerodur (low-expansion glass-ceramic)

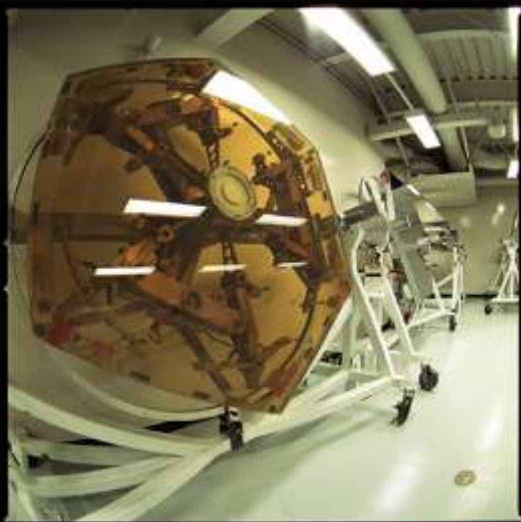
Light-collecting area: 76 square meters (818 square feet)

Total weight of glass: 14.4 metric tons (15.9 tons)

Telescope mount: Altitude-Azimuth

Overall telescope height: 24.6 meters (80.7 feet)

Total moving weight with mirrors: 270 metric tons (298 tons)



- 36 mirrors on scope
- 6 sided
- 1.8m (6'), 880 lbs.
- Recoated every 2 years
- >$1 million each
- f/1.75 hyperbolic

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Summary of Reflectors

- Easy to make large aperture scopes
- Newtonian has open aperture, so inside (mirrors) can get dirty
- Long focal lengths mean long tubes
- Folded optics can shorten tubes, making scope shorter, lighter, portable

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- Goals for a Telescope
- Refractor (Dioptrics)
- Reflector (Catoptrics)
- Lens-Mirror (Catadioptrics)
- References

Mirror & Lens Systems
Catadioptric

- By combining mirrors and lenses, a scope can be powerful and compact (short tube)
- Aberration issues can be minimized
- Mirrors and lenses are usually sealed up in the tube
- More complexity and expense since they are harder to make (high precision)

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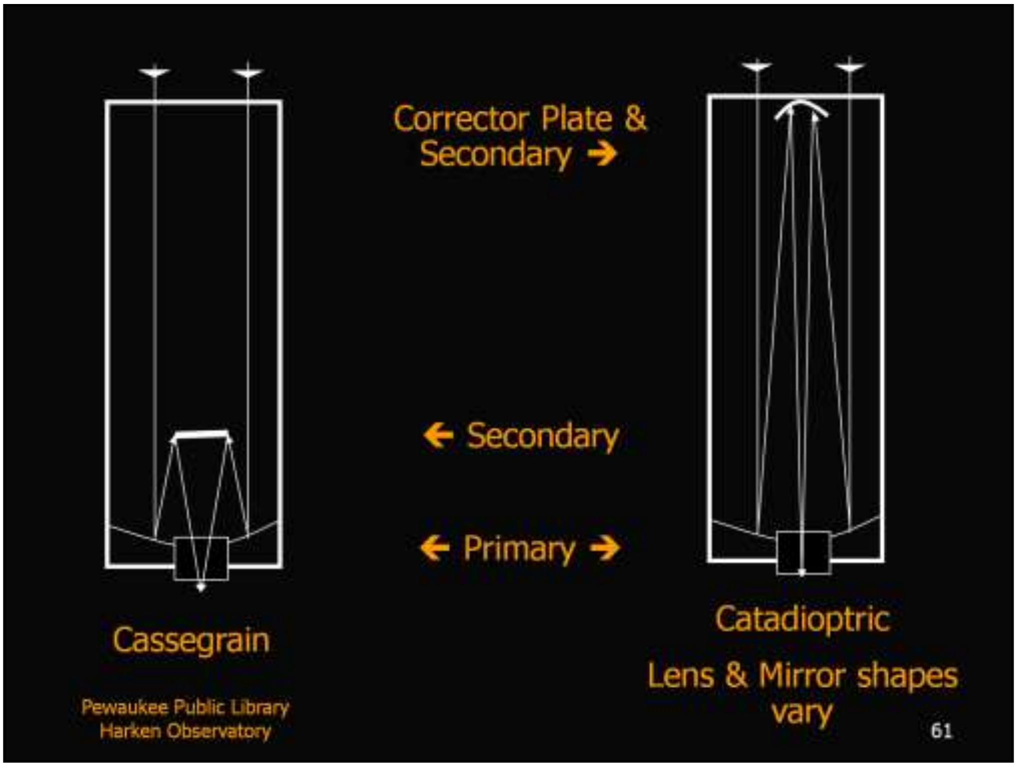
Corrector Plate &
Secondary ➔
← Secondary
← Primary ➔
Cassegrain
Catadioptric
Lens & Mirror shapes vary
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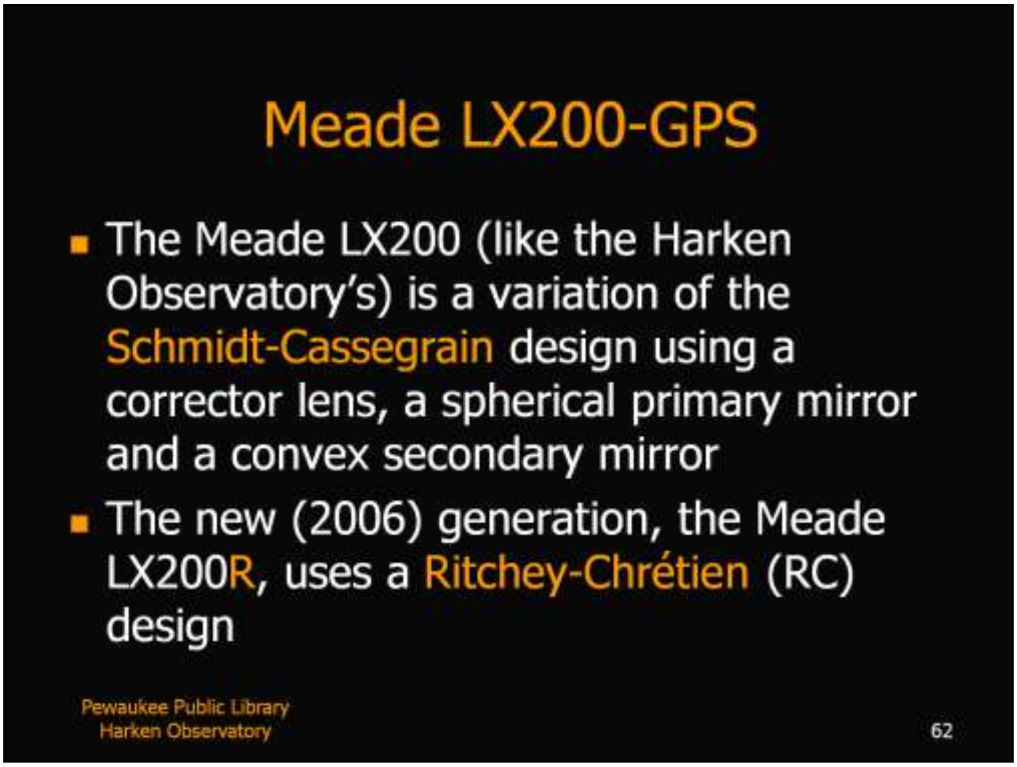
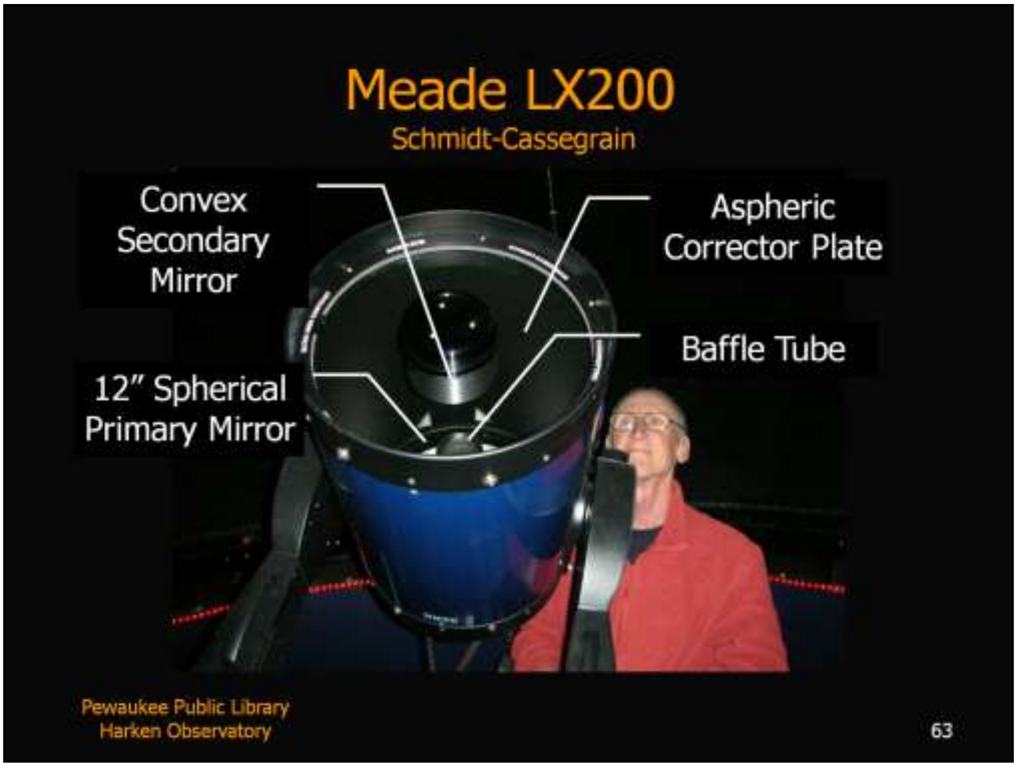


Chrétien also invented wide screen movie format used in Cinemascope


Meade LX200
Schmidt-Cassegrain
Convex Secondary Mirror
Aspheric Corrector Plate
Baffle Tube
12" Spherical Primary Mirror
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Common Catadioptric Designs

	Schmidt Cassegrain (SC)	Ritchey Chrétien (RC)	Maksutov "Mak"
Corrector	Aspheric	Aspheric or Flat	Convex-Concave or Aspheric
Secondary	Convex	Hyperbola	Hyperbola
Primary	Spherical	Hyperbola	Spherical
Notes	Popular for high end amateur (LX200GPS)	Common for new high end (LX200R)	Very compact Modest apertures

Easy ➔ Hard : Spherical ➔ Parabolic ➔ Hyperbolic

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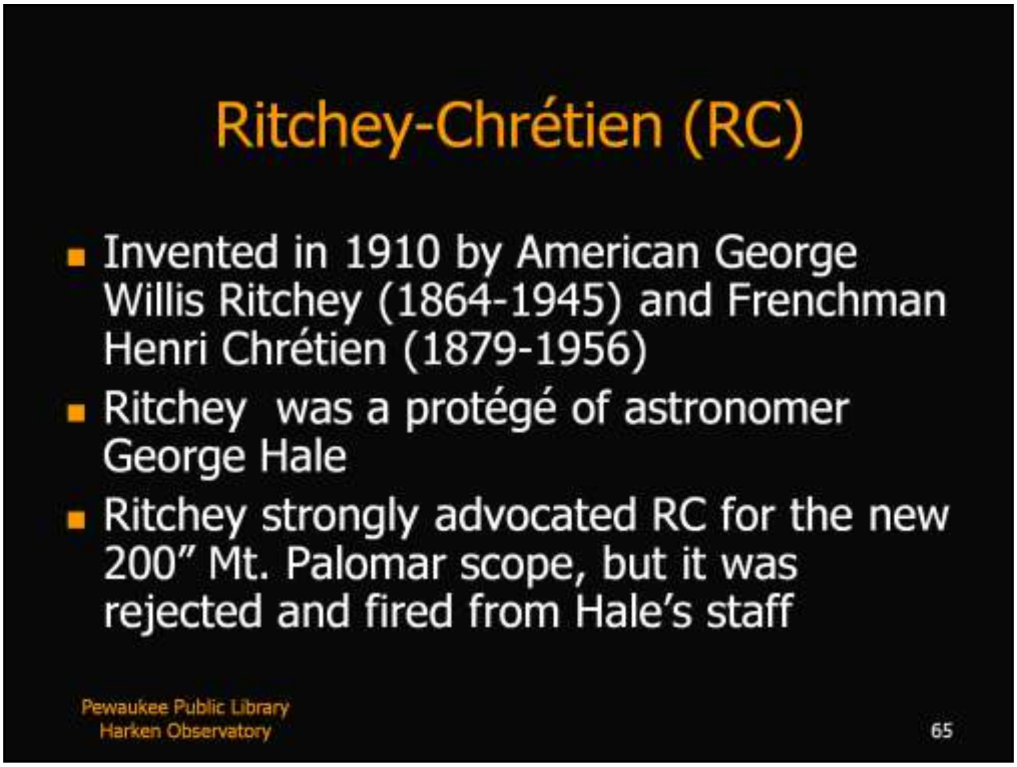
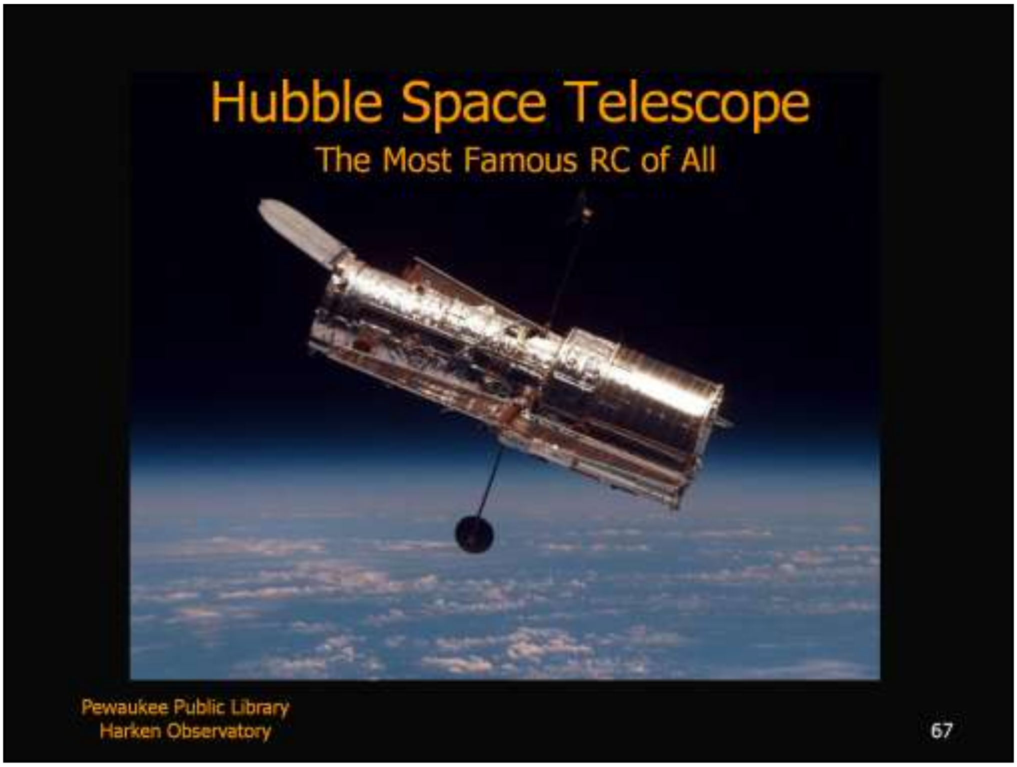


Chrétien also invented wide screen movie format used in Cinemascope

Chrétien also invented wide screen movie format used in Cinemascope


Hubble Space Telescope
The Most Famous RC of All
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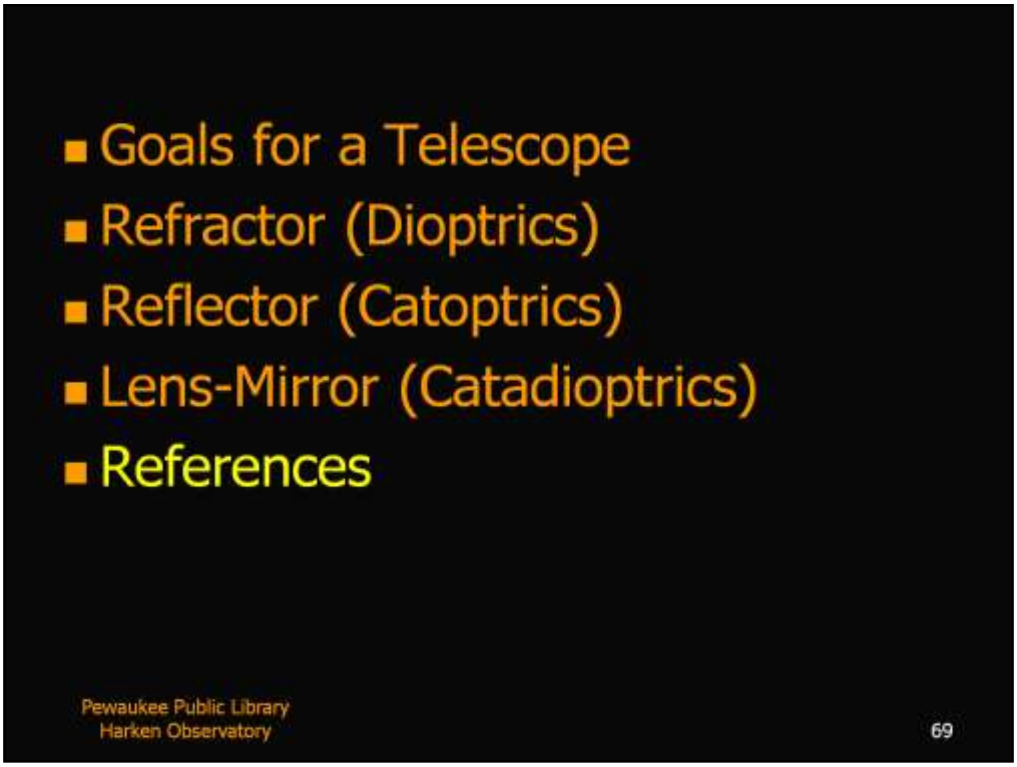
Summary of Catadioptrics

- Combination of lens and mirror. Many variations of shapes for mirrors and lenses
- Focal length is folded, so optical tube is short tube, making scope portable
- Complex shapes for optics, so expensive
- Common for modern high end scopes


Goals for a Telescope
Refractor (Dioptrics)
Reflector (Catoptrics)
Lens-Mirror (Catadioptrics)
References
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- "Stargazer – The Life and Times of the Telescope", by Fred Watson, ©2004, Brookfield Public Library (available by interlibrary loan).
- "Unusual Telescopes", by Peter L. Manly, ©1991, Milwaukee Astronomical Society library (members only).


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http://en.wikipedia.com
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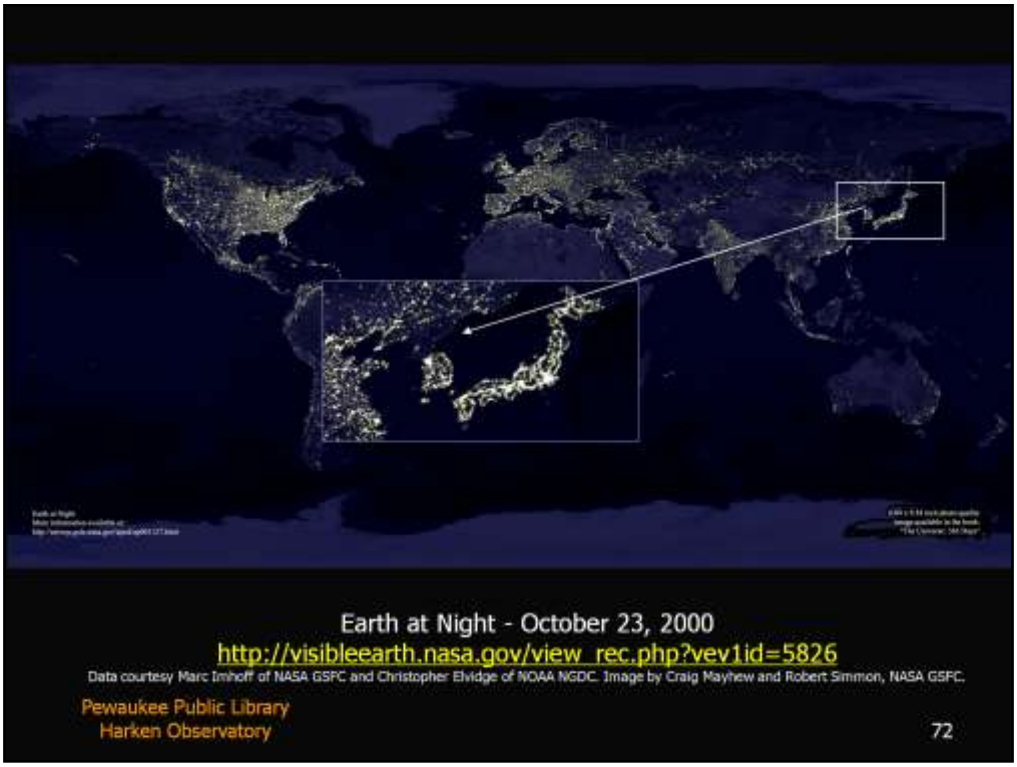

http://visibleearth.nasa.gov/view_rec.php?vev1id=5826

or

http://antwrp.gsfc.nasa.gov/apod/image/0011/earthlights_dmsp_big.jpg

Earth lights (composite photo)

Credit

Data courtesy Marc Imhoff of NASA GSFC and Christopher Elvidge of NOAA NGDC. Image by Craig Mayhew and Robert Simmon, NASA GSFC.

This image of Earth’s city lights was created with data from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS). Originally designed to view clouds by moonlight, the OLS is also used to map the locations of permanent lights on the Earth’s surface.

The brightest areas of the Earth are the most urbanized, but not necessarily the most populated. (Compare western Europe with China and India.) Cities tend to grow along coastlines and transportation networks. Even without the underlying map, the outlines of many continents would still be visible. The United States interstate highway system appears as a lattice connecting the brighter dots of city centers. In Russia, the Trans-Siberian railroad is a thin line stretching from Moscow through the center of Asia to Vladivostok. The Nile River, from the Aswan Dam to the Mediterranean Sea, is another bright thread through an otherwise dark region.

Even more than 100 years after the invention of the electric light, some regions remain thinly populated and unlit. Antarctica is entirely dark. The interior jungles of Africa and South America are mostly dark, but lights are beginning to appear there. Deserts in Africa, Arabia, Australia, Mongolia, and the United States are poorly lit as well (except along the coast), along with the boreal forests of Canada and Russia


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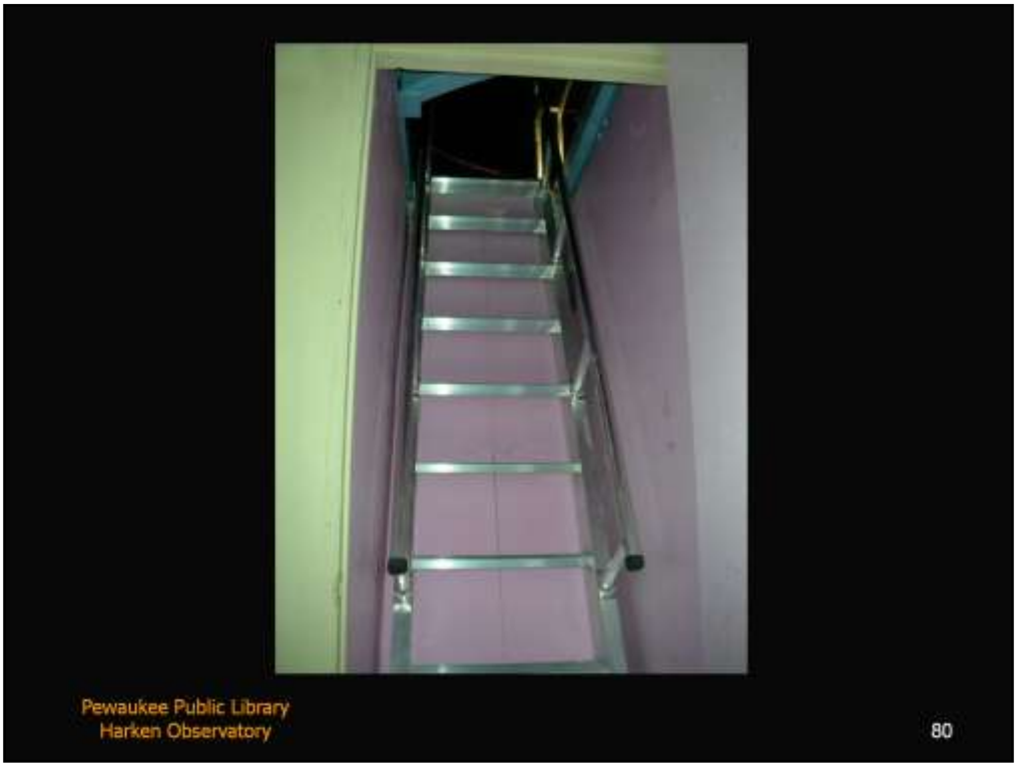
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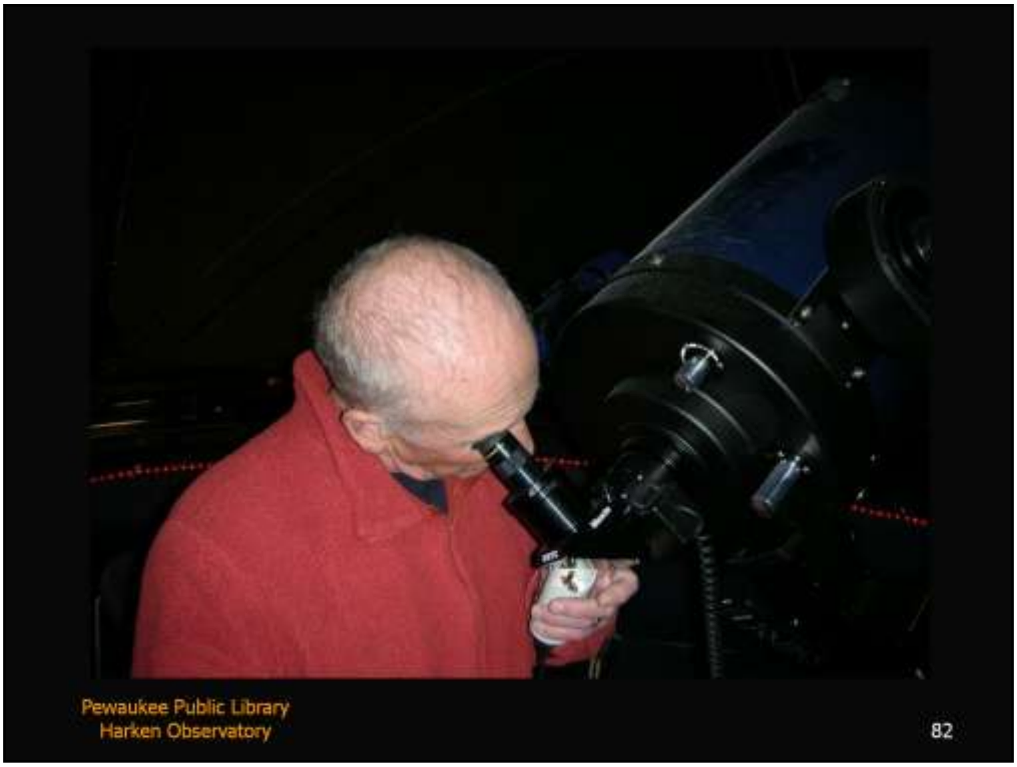

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Thank You!

- This is a volunteer group. All equipment is donated. There is no tax funding.
- Monthly club meetings are the 2nd Tuesday of each month
- Public presentations and viewing is every Saturday, weather permitting