Foundation of Astronomical Studies & Exploration

FOUNDATION OF ASTRONOMICAL STUDIES & EXPLORATION
FASE

OBSERVATION - 2

THARINDRA KORALEGEDARA

TELESCOPES

Telescope history

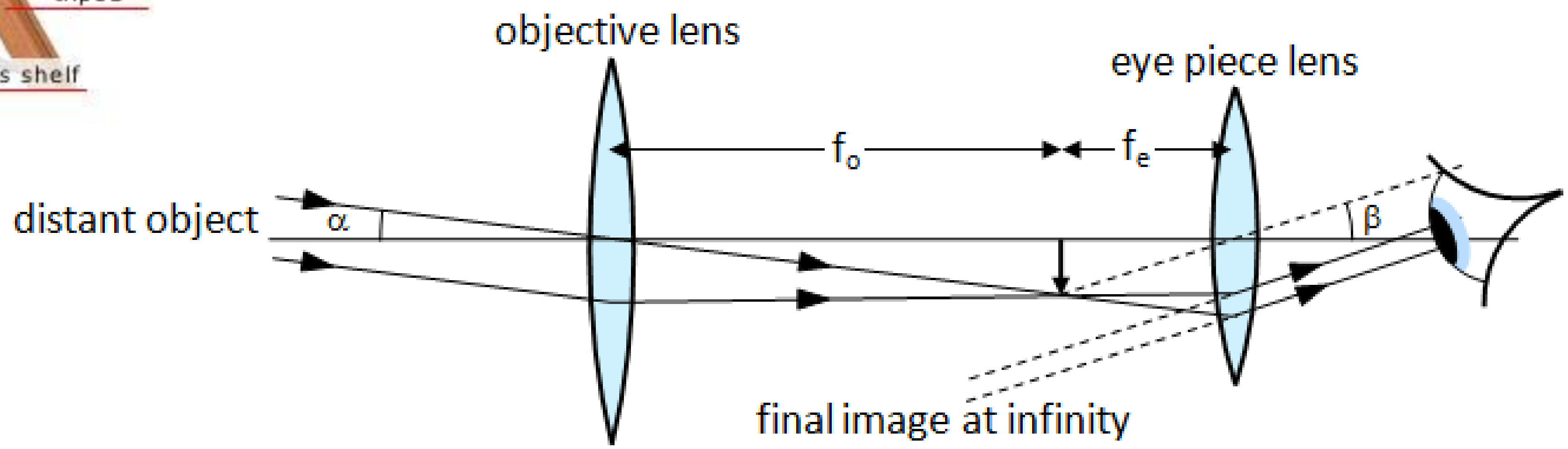
- In 1608 in the Netherlands, when a patent was submitted by Hans Lippershey, an eyeglass maker.

- [Galileo] improved on this design the following year and applied it to astronomy.
- [Isaac Newton] is credited with building the first reflector in 1668 with a design that incorporated a small flat diagonal mirror to reflect the light to an eyepiece mounted on the side of the telescope.

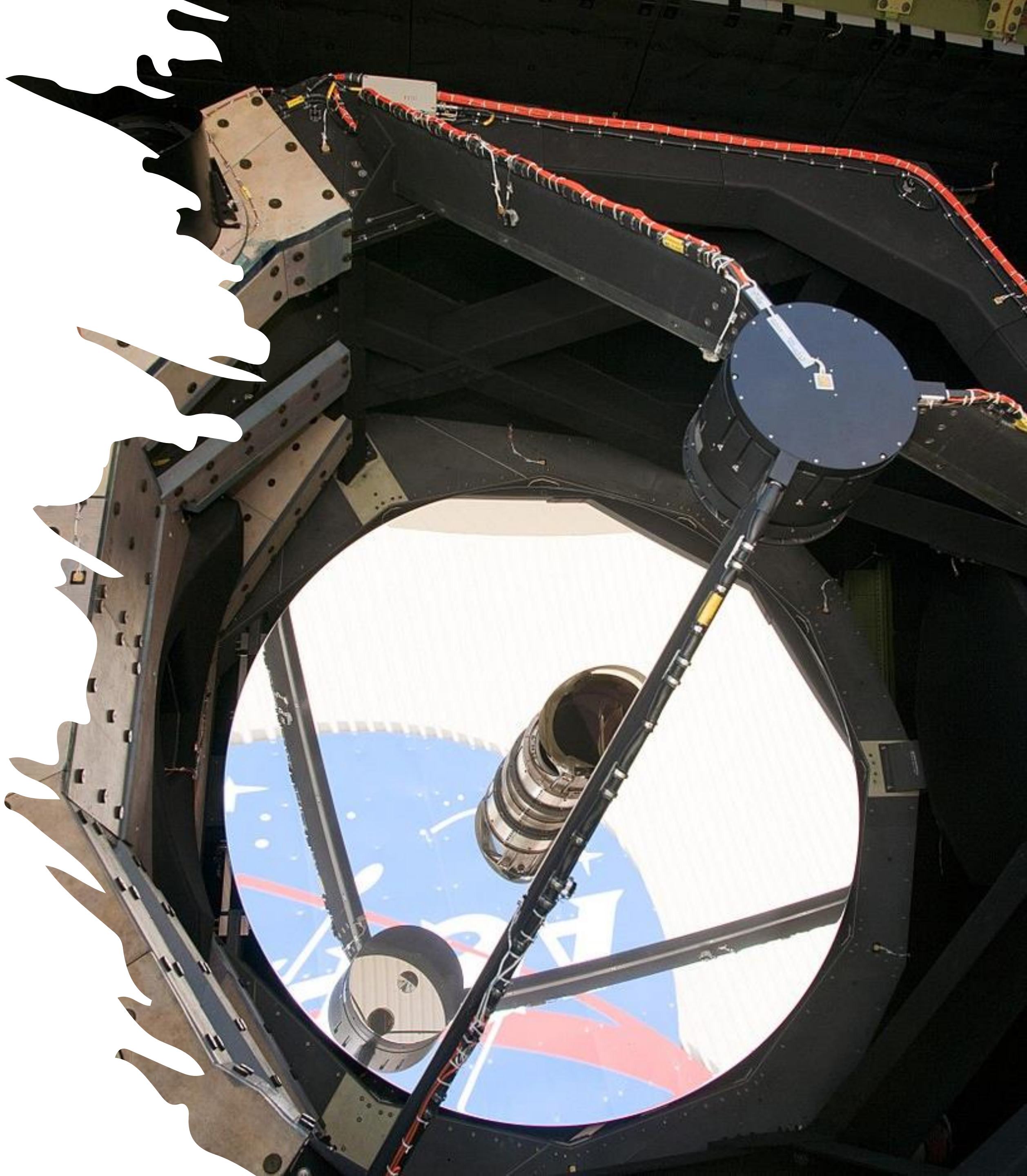
Classification of telescopes

- Refracting telescopes (Dioptrics)
  - Achromatic telescope
  - dialytic refractor
  - Apochromatic
  - Binoculars
  - Opera glasses
  - Copyscope
  - Galileoscope
  - Monocular
  - Non-achromatic
  - Galilean telescope
  - Keplerian Telescope
  - Aerial telescope
  - Superachromat
  - Baden-Powell's unilens

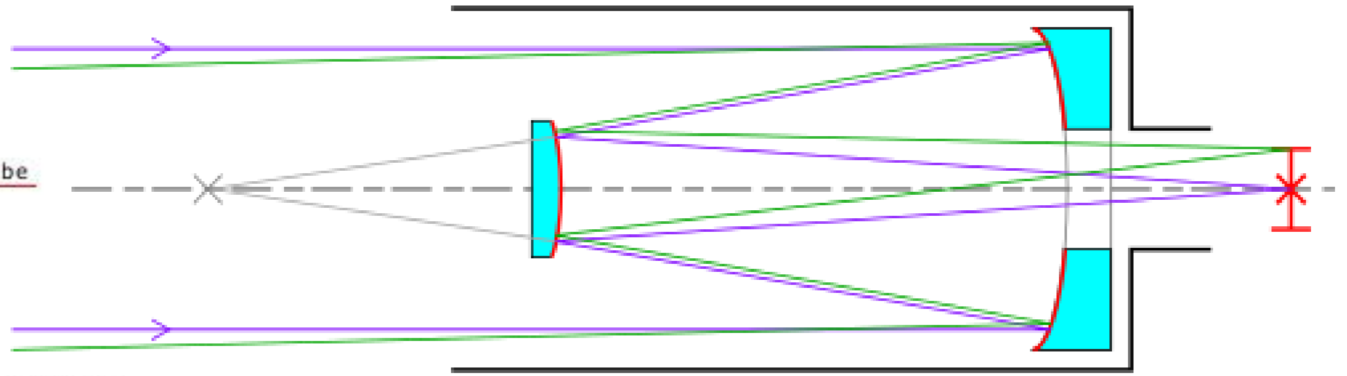

dew shield +
cradle
main tube
+ finderscope
+ eyepiece
eyepiece holder
declination setting scale +
+ star diagonal
azimuth clamp +
focusing knob
altitude clamp +
right ascension setting scale +
fork
altitude fine adjustment +
azimuth fine adjustment +
counterweight
tripod +
tripod accessories shelf

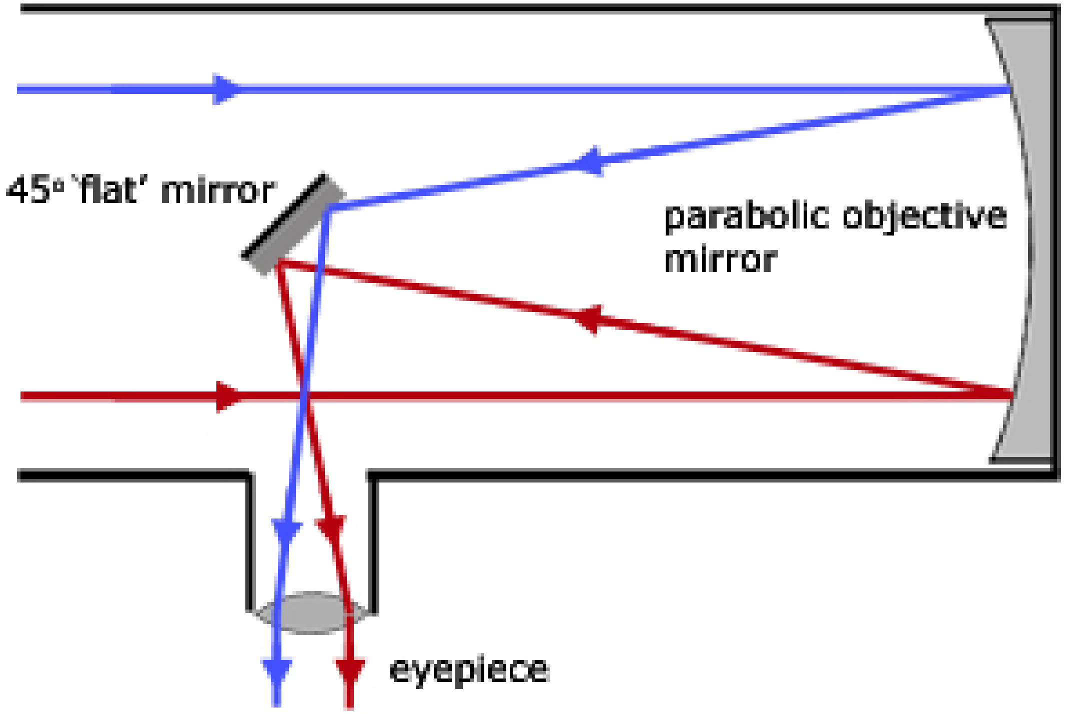

objective lens
eye piece lens
f_o
f_e
distant object
α
β
final image at infinity

- Reflecting telescopes (Catoptrics)
  - Cassegrain telescope
  - Dall–Kirkham telescope
  - Nasmyth telescope
  - Ritchey–Chrétien telescope
  - Crossed Dragone
  - Gregorian telescope
  - Herschelian telescope
  - Large liquid mirror telescope
  - Newtonian telescope
  - Dobsonian telescope
  - Pfund telescope
  - Schiefspiegler telescope
  - Stevick–Paul telescope
  - Three-mirror anastigmat
  - Toroidal reflector / Yolo telescope
  - Wolter telescope




finderscope +
support
eyepiece +
cradle
main tube
focusing knob
+ declination setting scale
+ azimuth clamp
+ altitude clamp
right ascension setting scale +
www.ikonet.com
azimuth fine adjustment +
altitude fine adjustment +




45° 'flat' mirror
parabolic objective mirror
eyepiece

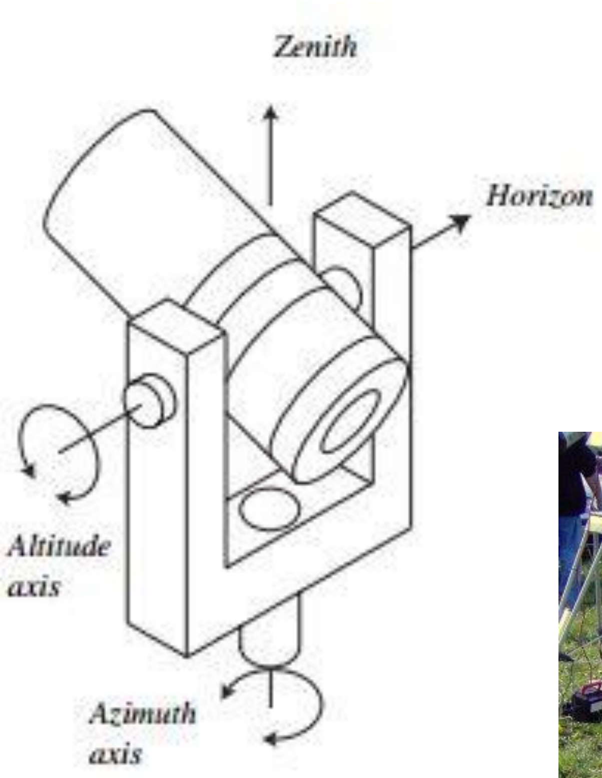
- Catadioptric telescopes (Catadioptrics)
  - Argunov–Cassegrain telescope
  - Catadioptric dialytes
  - Klevtsov–Cassegrain telescope
  - Lurie–Houghton telescope
  - Maksutov telescope
  - Maksutov camera
  - Maksutov–Cassegrain telescope
  - Gregory (Spot) Maksutov-Cassegrain telescope
  - Rutten Maksutov-Cassegrain telescope
  - Sub-aperture corrector Maksutov-Cassegrain telescope
  - Maksutov Newtonian telescope
  - Modified Dall–Kirkham telescope
  - Schmidt camera
  - Baker-Nunn camera
  - Baker-Schmidt camera
  - Lensless Schmidt telescope
  - Mersenne-Schmidt camera
  - Schmidt–Cassegrain telescope
  - ACF Schmidt–Cassegrain telescope (Meade Instruments)
  - Schmidt–Newton telescope
  - Schmidt-Väisälä camera

Telescope Mounts

- A telescope mount is a mechanical structure which supports a telescope. Telescope mounts are designed to support the mass of the telescope and allow for accurate pointing of the instrument. Many sorts of mounts have been developed over the years, with the majority of effort being put into systems that can track the motion of the fixed stars as the Earth rotates.
  - Fixed mounts
  - Fixed altitude mounts
  - Transit mounts
  - Altitude – Altitude mounts
  - Hexapod mount
  - Altazimuth mount
  - Equatorial mount

Altazimuth mount

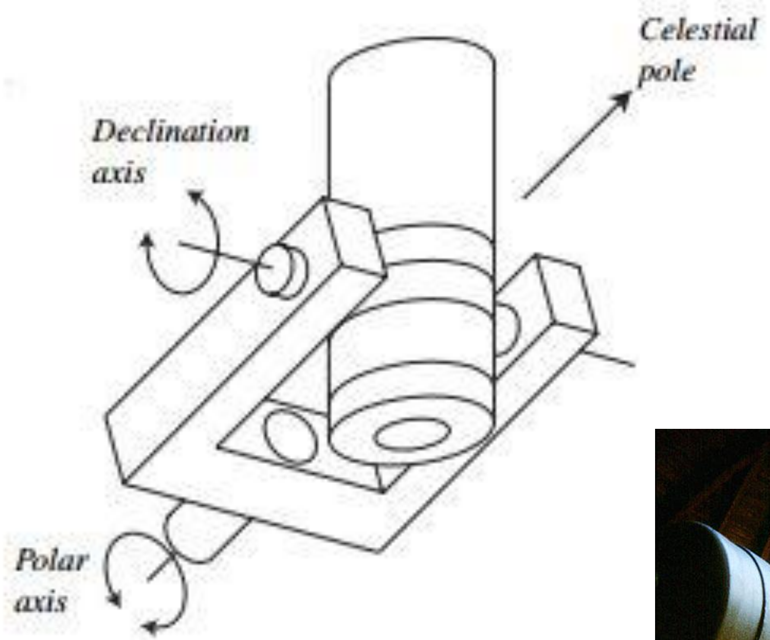
- An altazimuth or alt-azimuth mount is a simple two-axis mount for supporting and rotating an instrument about two perpendicular axes – one vertical and the other horizontal. Rotation about the vertical axis varies the azimuth (compass bearing) of the pointing direction of the instrument. Rotation about the horizontal axis varies the altitude (angle of elevation) of the pointing direction.

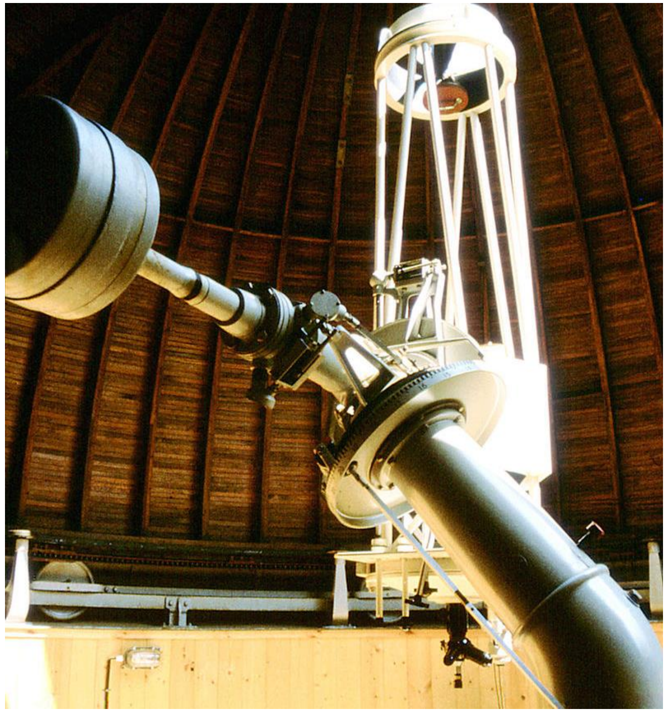


- When used as an astronomical telescope mount, the biggest advantage of an alt-azimuth mount is the simplicity of its mechanical design. The primary disadvantage is its inability to follow astronomical objects in the night sky as the Earth spins on its axis. On the other hand, an equatorial mount only needs to be rotated about a single axis, at a constant rate, to follow the rotation of the night sky (diurnal motion). Altazimuth mounts need to be rotated about both axes at variable rates, achieved via microprocessor based two-axis drive systems, to track equatorial motion.

Equatorial Mount

- An equatorial mount is a mount for instruments that compensates for Earth's rotation by having one rotational axis parallel to the Earth's axis of rotation. This type of mount i used for astronomical telescopes an cameras. The advantage of an equatorial mount lies in its ability to allow the instrument attached to it t stay fixed on any celestial object wit diurnal motion by driving one axis a a constant speed. Such an arrangement is called a sidereal or clock drive.





- In astronomical telescope mounts, the equatorial axis (the right ascension) is paired with a second perpendicular axis of motion (known as the declination). The equatorial axis of the mount is often equipped with a motorized "clock drive", that rotates that axis one revolution every 23 hours and 56 minutes in exact sync with the apparent diurnal motion of the sky. They may also be equipped with setting circles to allow for the location of objects by their celestial coordinates. Equatorial mounts differ from mechanically simpler altazimuth mounts, which require variable speed motion around both axes to track a fixed object in the sky. Also, for astrophotography, the image does not rotate in the focal plane, as occurs with altazimuth mounts when they are guided to track the target's motion, unless a rotating erector prism or other field-derotator is installed.

Telescopes as cameras

- Most astronomical telescopes are cameras – they form images of objects both on and off the optical axis in the focal plane.
- Although a telescope’s optics can be complex, we can profitably represent them with a single ‘‘equivalent thin lens’’ of matching aperture and a focal length that reproduces the image-forming properties of the telescope.

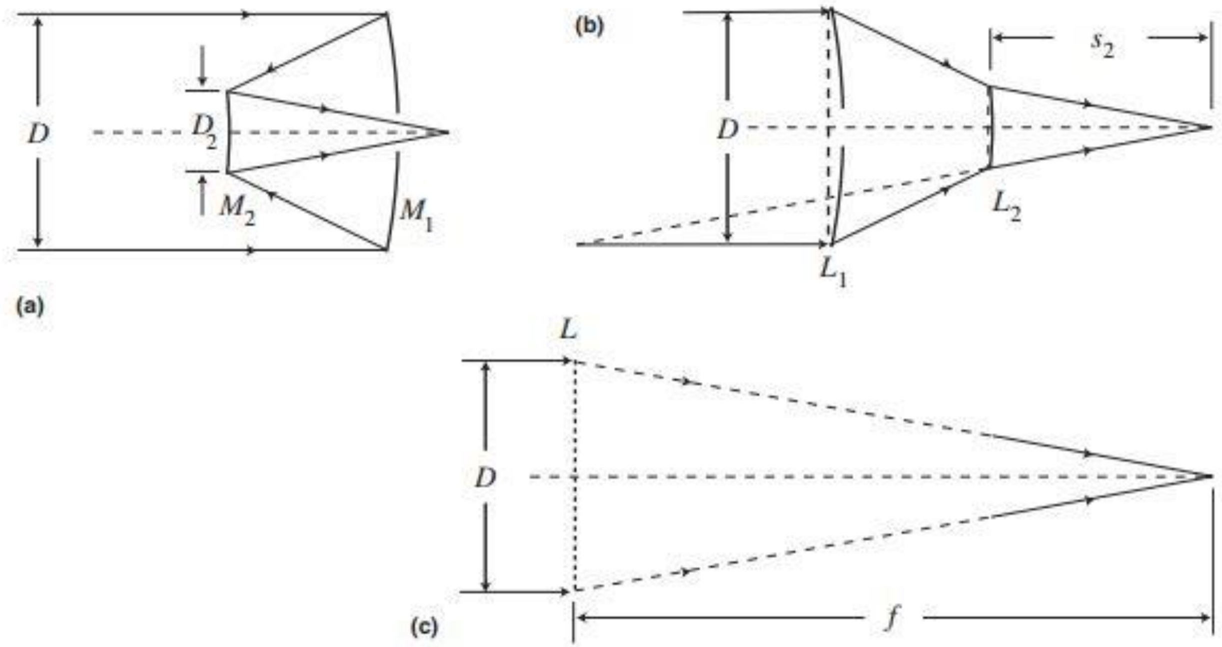


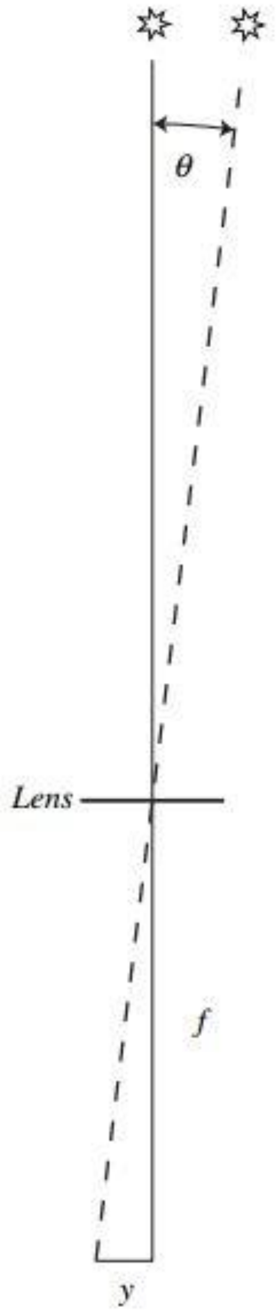
Image scale and image size

- The image scale, s, describes the mapping of the sky by any camera. The image
  scale is the angular distance on the sky that corresponds to a unit linear distance in
  the focal plane of the camera.
- Figure shows the equivalent lens diagram of a
  camera of focal length f. We draw the paths followed by two rays, one from a star
  on the optical axis, the other from a star separated from the first by a small angle h
  on the sky. Rays pass through the vertex of the lens without deviation, so assuming the paraxial approximation, ϴ=tan ϴ, it should be clear from the diagram
-

$$s = \frac{\theta}{y} = \frac{1}{f}[\theta \text{ in radians}]$$

Since it is usually convenient to express image scales in arcsec per mm, then

$$s = \frac{206,265}{f}[\text{arcsec per unit length}]$$



Focal ratio and image rightness

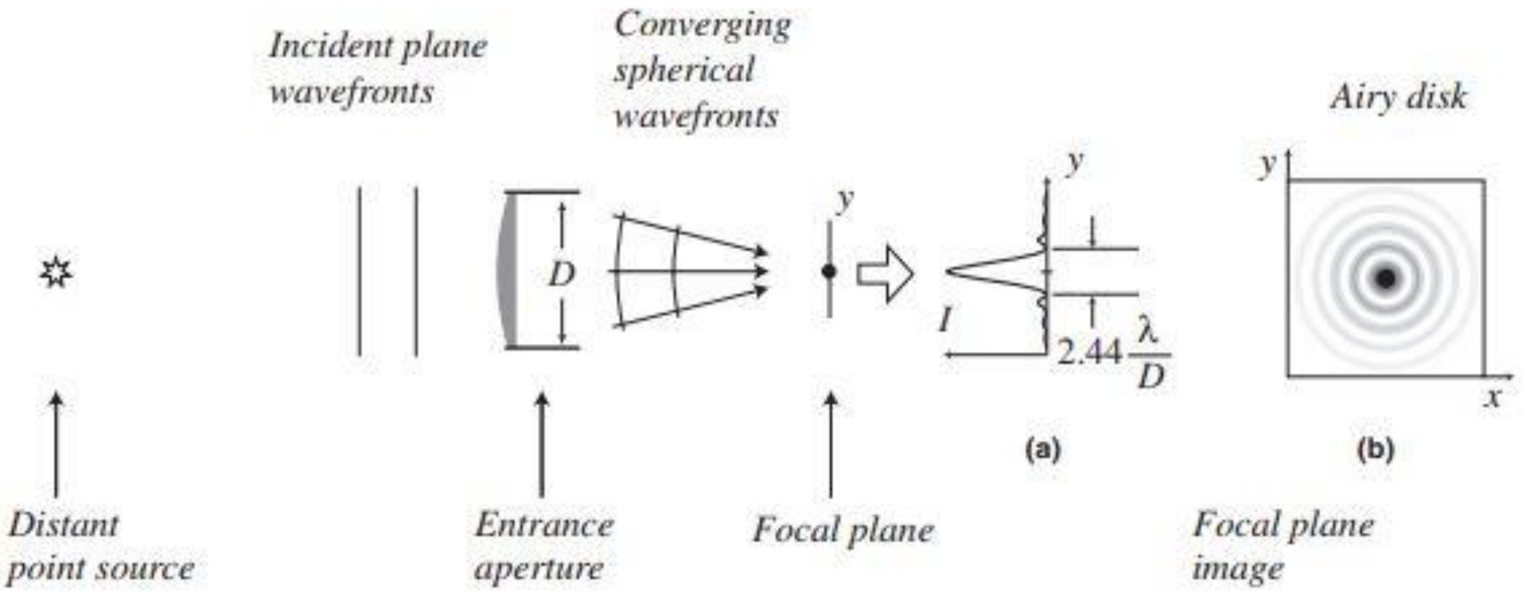
- For example, the 20-inch telescope at Vassar College Observatory has a focal length of 200 inches, so R = 10. This is usually expressed as ''f /10''.
  You can show that the brightness (energy per unit area in the focal plane) of an
  extended source in the focal plane is proportional to R^{-2},
- so that images in an f /5 system, for example, will be four times as bright as images in an f /10 system.

Focal ratio is defined as

$$\Re = \frac{f}{D} = \frac{\{\text{focal length}\}}{\{\text{diameter of entrance aperture}\}}$$

Image quality: telescopic resolution

- The wave properties of light set a fundamental limit on the quality of a telescopic image.
- Following figure illustrates the formation of an image by a telescope outside the atmosphere.

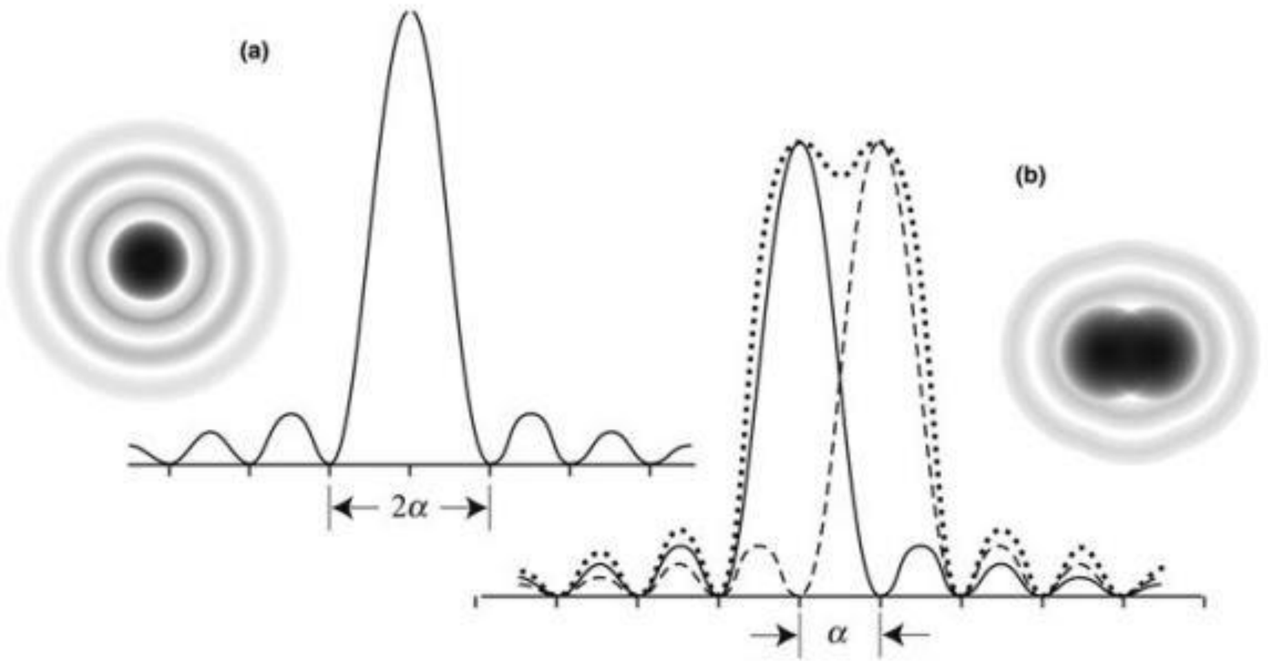


The diffraction limit

- Even though the source is a point, its image – created by a perfect telescope operating in empty space – will have a finite size because of diffraction of the wave.
- This size, the diffraction limit of the telescope, depends on both the wavelength of light and on Diameter of the telescope.
- The diffraction of a plane wavefront by a circular aperture is a messy problem in wave theory, and its solution, first worked out in detail by the English astronomer George Airy in 1831, says that the image is a bulls-eye-like pattern, with the majority (84%) of the light focused into a spot or ''disk.'' Concentric bright rings, whose brightness decreases with distance from the center, surround the very bright central spot, the Airy disk. The angular radius of the dark ring that borders the Airy disk is

$$\alpha_A = \frac{1.22\lambda}{D}\,[\text{radians}] = \frac{0.252\lambda}{D}\,[\text{arcsec m}\,\mu\text{m}^{-1}]$$

- If two-point sources lie close together, their blended Airy patterns may not be distinguishable
  from that of a single source. If we can say for sure that a particular pattern is due to two sources, not one, the sources are resolved.



Atmospheric refraction

- We can approximate the Earth's atmosphere as a series of plane-parallel plates,

  and the surface as an infinite plane.

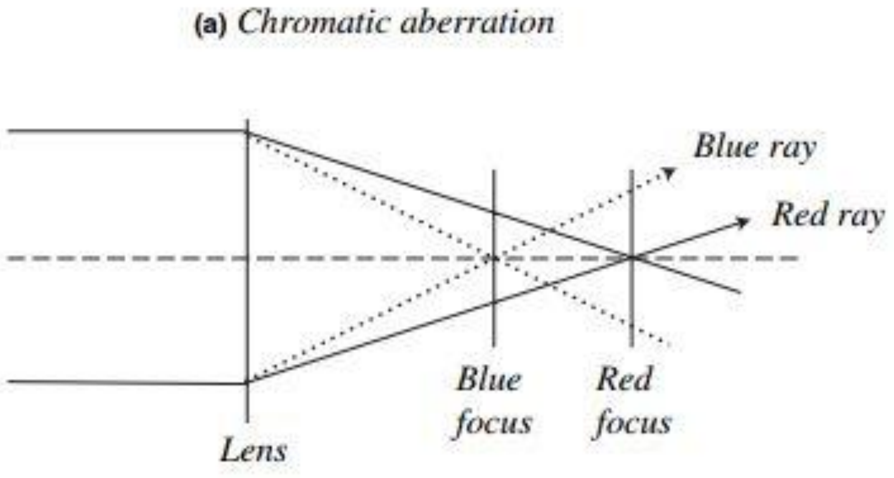
- for example, we imagine an atmosphere of just two layers that have indices, n2 >n1. A ray incident at angle a refracts at each of the two interfaces, and ultimately makes a new angle, a 1
  Da, with the surface: thus, refraction shifts the apparent position of a source
  towards the zenith.

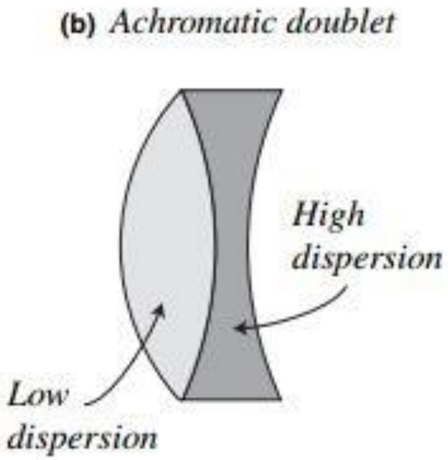
- we imagine that the atmosphere consists
  of a very large number of thin layers, so in the limit, the effect of refraction

  is to curve the path of the incident ray

Chromatic aberration

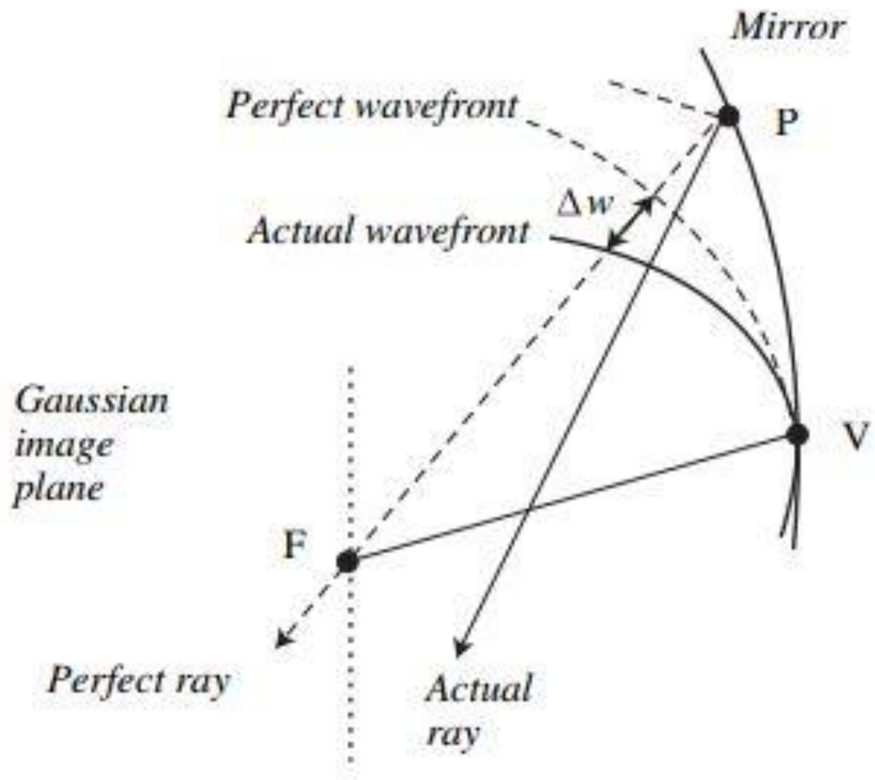
- Since n(λ) for optical glasses decreases with wavelength in the visible, then the
  focal length of a convex lens will be longer for red wavelengths than for blue. Different colors in an image will focus at different spots. This inability to obtain perfect focus is called chromatic aberration.
- Chromatic aberration will not occur in all-reflecting optics. To correct it in a lens, the usual strategy is to cement together two lenses made of different glasses, a positive (convex) lens with low chromatic dispersion, and a negative lens with lower absolute power, but higher chromatic dispersion.





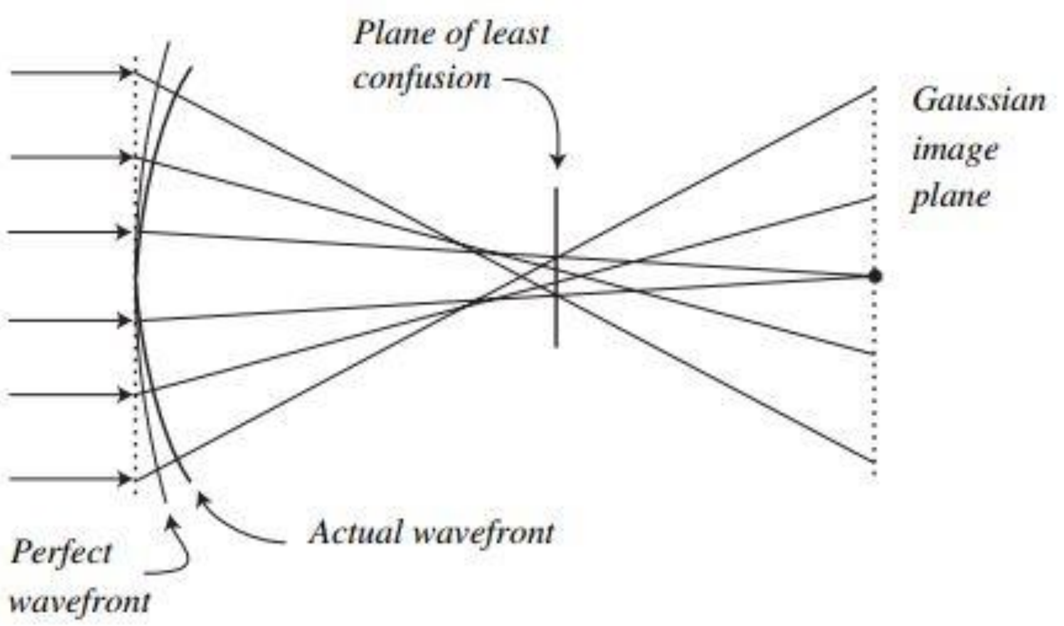
Monochromatic wavefront aberrations

- An aberration is an imperfection in telescope design that degrades an image.
- Straight lines in the sky should produce straight lines in the image plane. This mapping of the points and lines on the sky to points and lines in the
image plane is called a collinear transformation. If an optical systen fails to
produce this collinear transformation it is said to exhibit aberrations.
    - Spherical aberration
    - Coma
    - Astigmatism
    - Curvature of field
    - Distortion



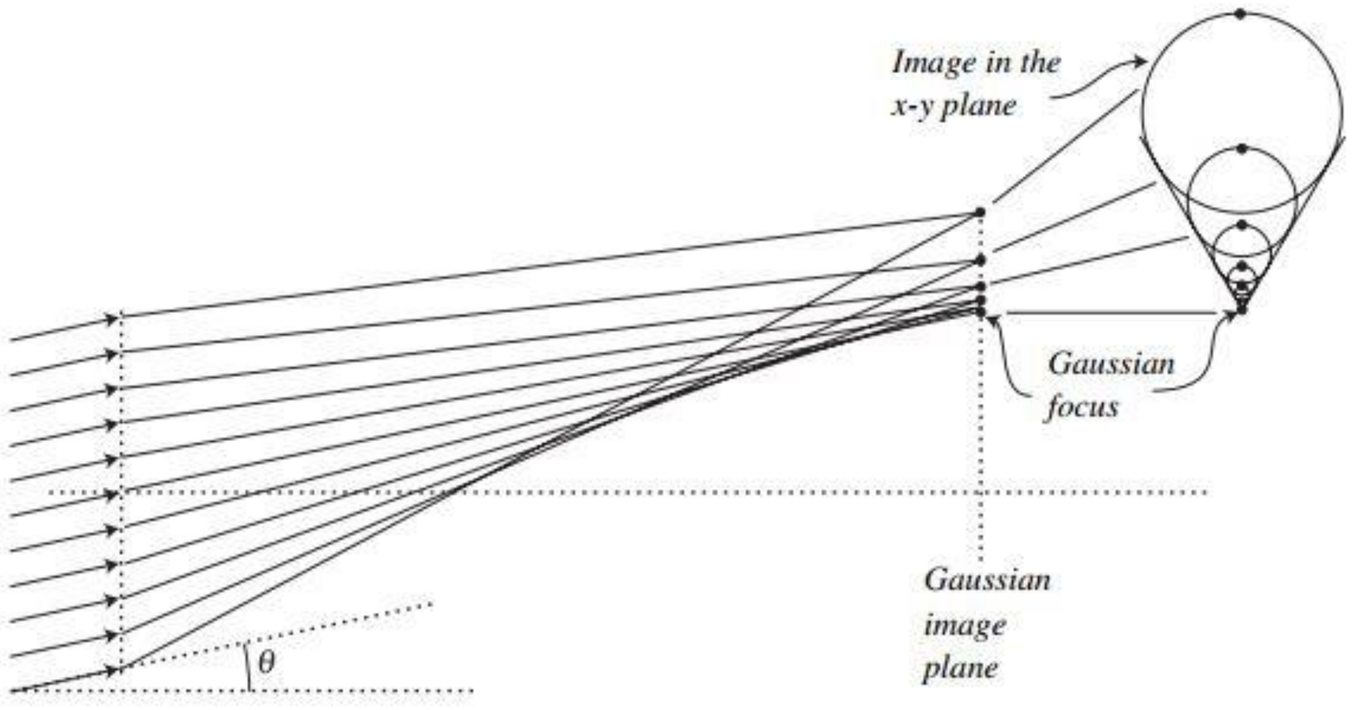
Spherical aberration

- Except for spherical aberration, all the wavefront errors in Table 5.4 vanish for sources on axis
- For visual astronomy, where one typically examines only on-axis images, SA is the only monochromatic aberration that is troublesome.

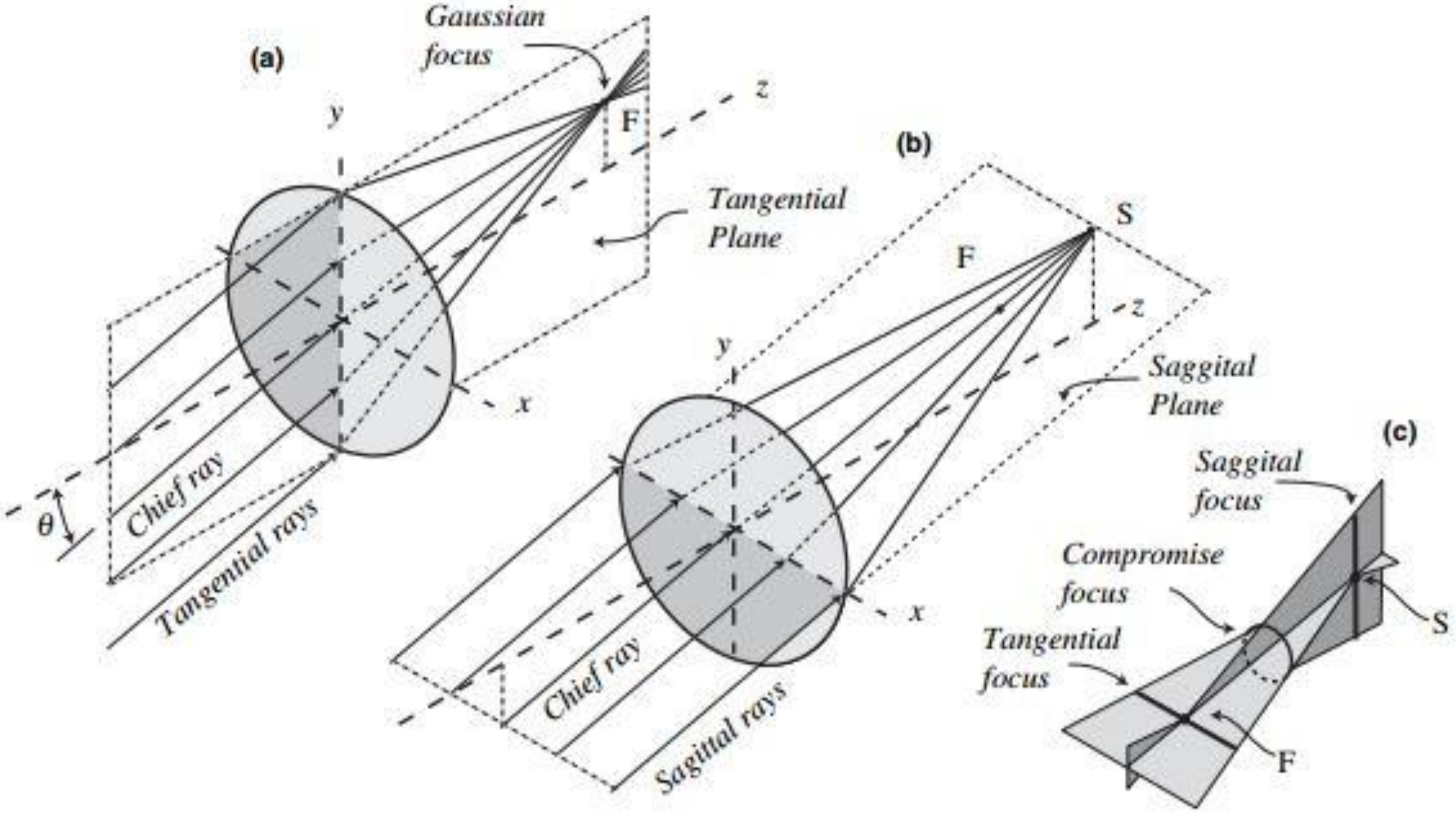


Coma

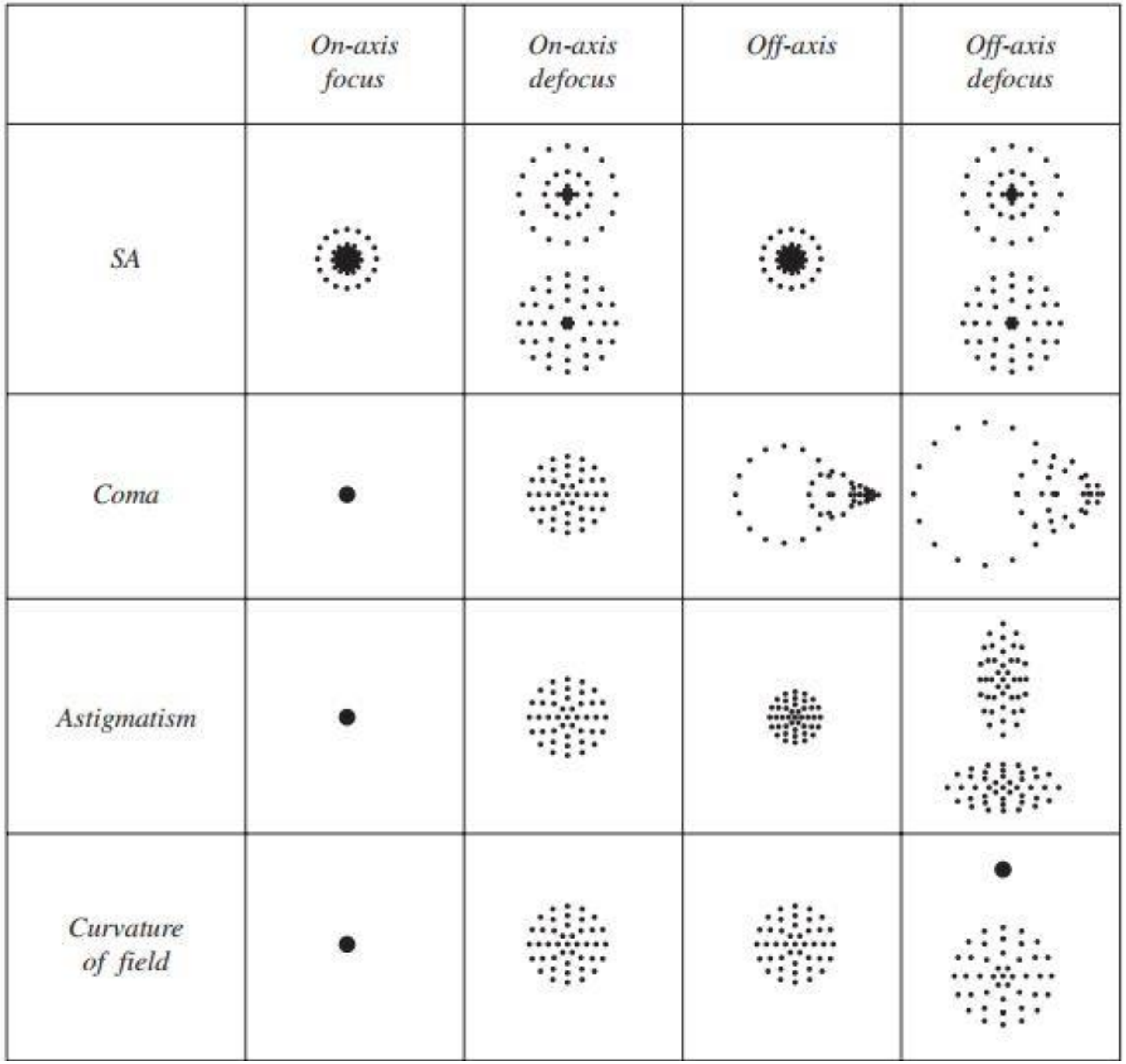
- Prior to the end of the nineteenth century, visual observers were concerned only with a telescope's on-axis performance. The advent of photography changed those concerns forever, and telescope design has since needed to satisfy more stringent optical criteria.
- Coma is the wavefront aberration which means, like spherical aberration, it is particularly a problem of large apertures. Unlike SA, coma increases with object distance from the axis.



Astigmatism



Spot Diagrams



THANK YOU !