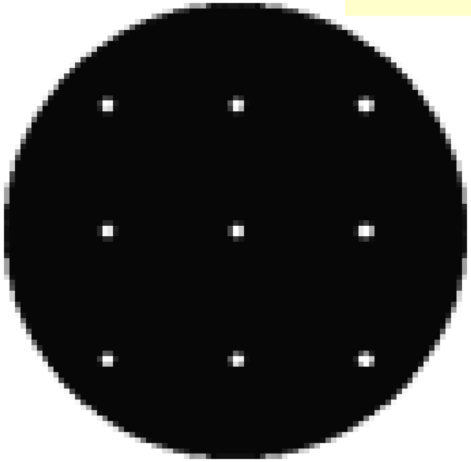
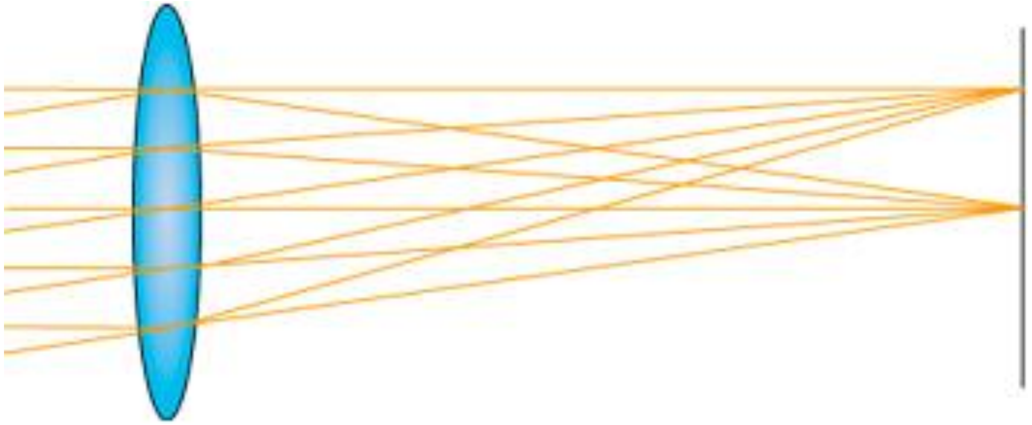
Ideal image rendering



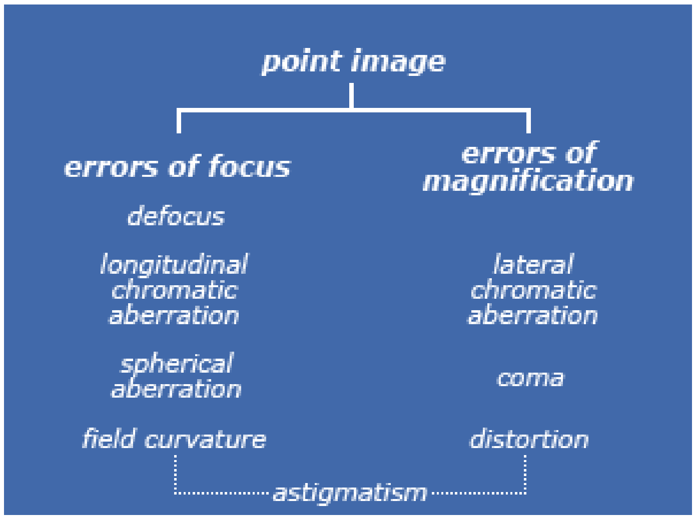


Regardless of whether the light is on the axis or off the axis or regardless of wavelength, light emitted from a point intersects in a point and forms a plane image.

In their basic design, optical systems are held to the standard of first order or **Gaussian** optics: a monochromatic "point" light source located at infinity and centered on the optical axis will appear as a "point" image at the center of a focal plane that is flat and perpendicular to the optical axis. This standard is then extended off axis to include the image of any point visible anywhere within the image area.

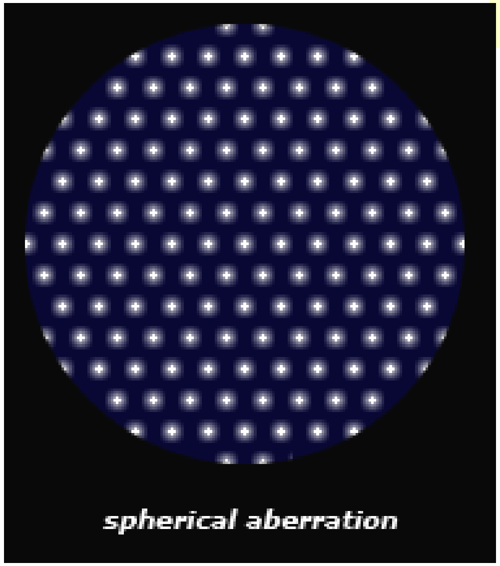
Aberrations

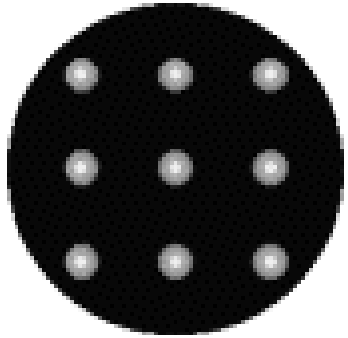
Any departure from ideal optical perfection is an *aberration.*
The five Seidel errors, in traditional order, are: (1) *spherical aberration,* (2) *coma,* (3) *astigmatism,* (4) *field curvature* and (5) *distortion.* Two types of first order (6,7) *chromatic aberration* (caused when the image is not monochromatic) are consistently included among the important aberrations.

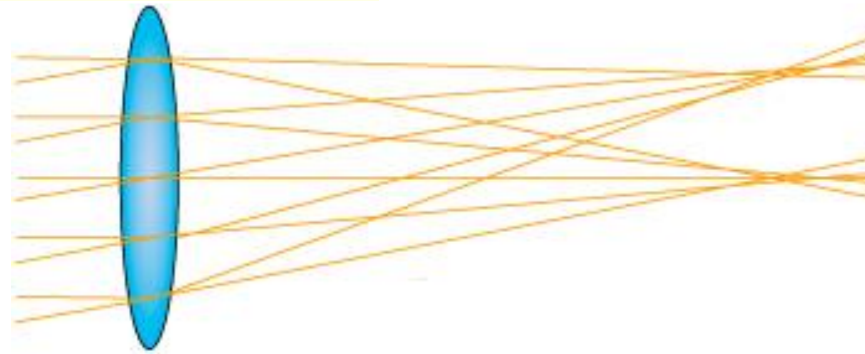


aberration	vs. aperture	vs. field angle
spherical (longitudinal)	D^2	.
spherical (lateral)	D^3	.
coma	D^2	β
field curvature (longitudinal)	.	β^2
field curvature (transverse)	D	β^2
astigmatism (tangential)	.	β^2
astigmatism (sagittal)	D	β^2
distortion (percent)	.	β^2
longitudinal chromatic	D	.
lateral chromatic	.	β

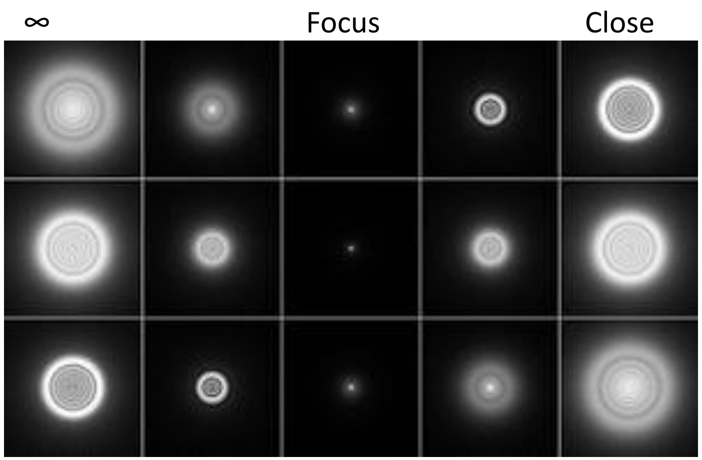
Spherical Aberration







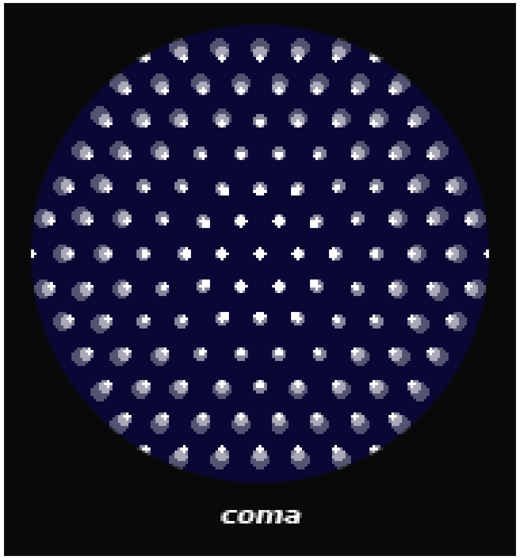
This aberration is proportional to the *numerical aperture* to the power of 3, and is independent of the width of the field of view. This is the only aberration which still appears at the center of the field of view. It appears as a circular blur, and is the source of all kinds of aberration; the more the *numerical aperture* increases, the more difficult it is to correct.

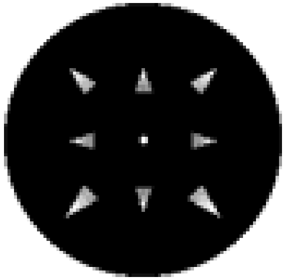


A point source as imaged by a system with negative (top), zero (centre), and positive (bottom) spherical aberration. Images to the left are defocused toward the inside, images on the right toward the outside.

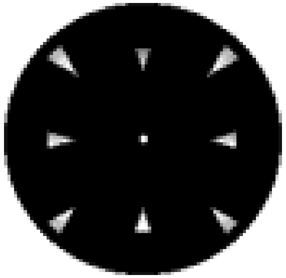
Depending how a lens is corrected for spherical aberration, the disc may be uniformly illuminated, brighter near the edge, or brighter near the center. Lenses that are poorly corrected for spherical aberration will show one kind of disc for out-of-focus points in front of the plane of focus, and a different kind for points behind. This may actually be desirable, as blur circles that are dimmer near the edges produce less-defined shapes which blend smoothly with the surrounding image.

Coma

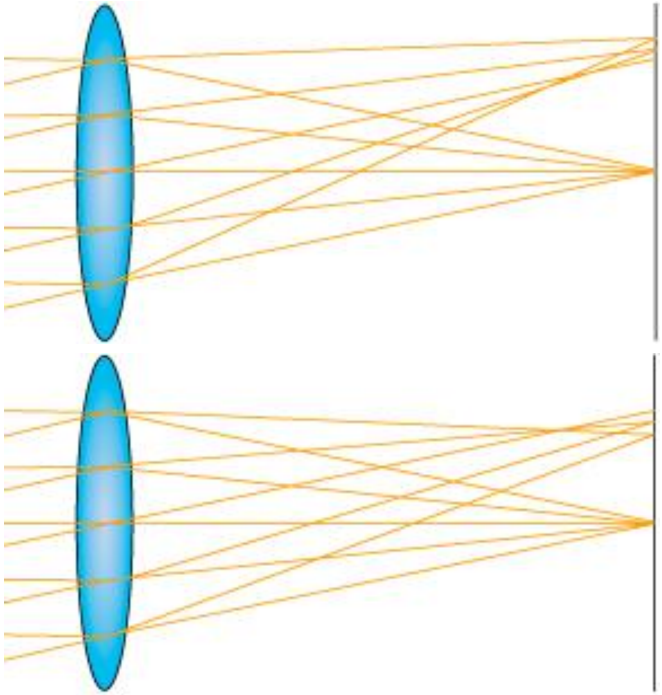




Tail pointing towards the inside

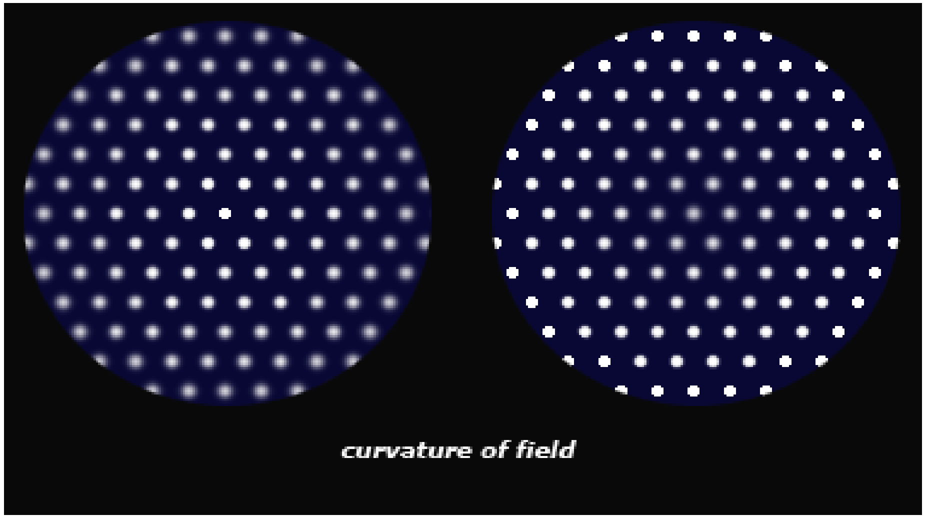


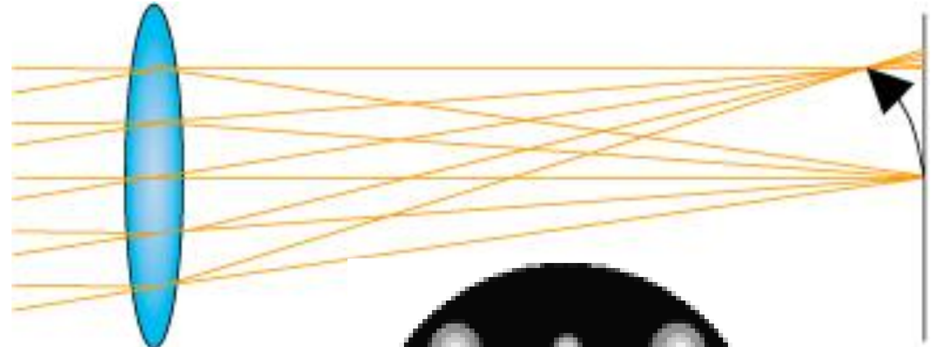
Tail pointing towards the outside

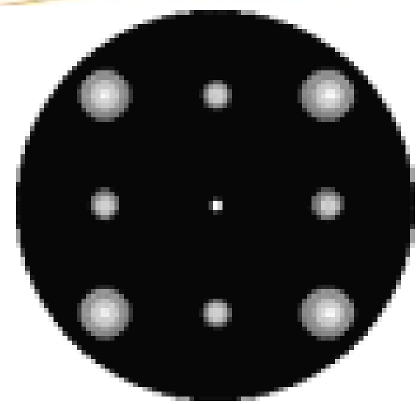


This aberration is proportional to the square of the *numerical aperture* and linearly proportional to width of the field of view. The center of the field of view is sharp, but as you approach the edge of the field of view the comet-shaped blur gets larger.

Field (Petzval) Curvature

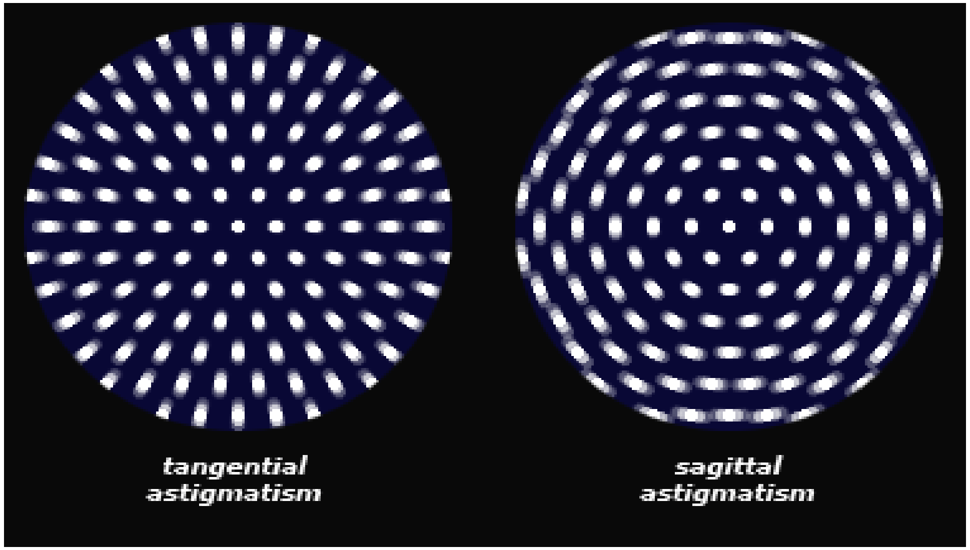


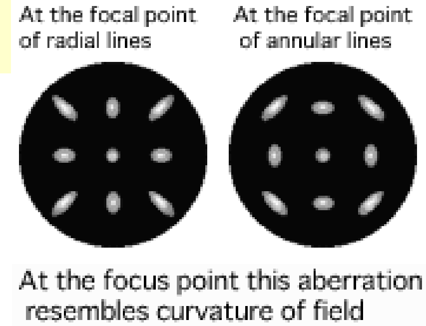


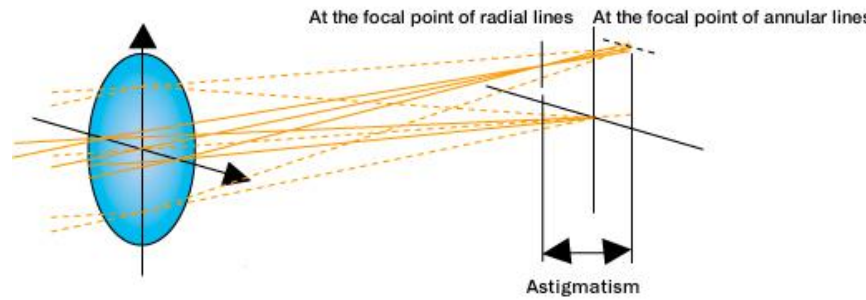


This aberration is linearly proportional to the *numerical aperture* and to the square of the width of the field of view, and it becomes very noticeable when the field of view widens. This is a circular blur, and at the center of the field of view and at the edges the focal point is moved. Even when the focal point is moved the blur remains circular.

Astigmatism

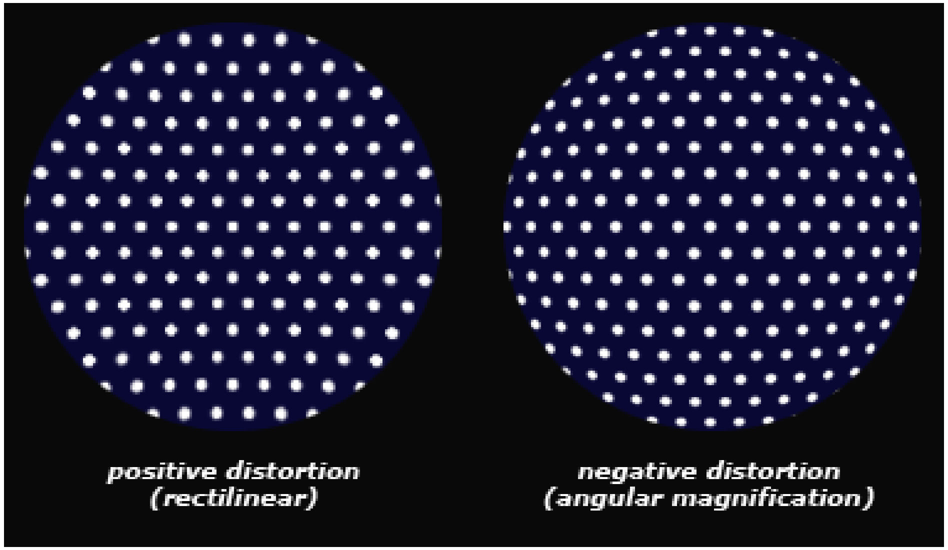


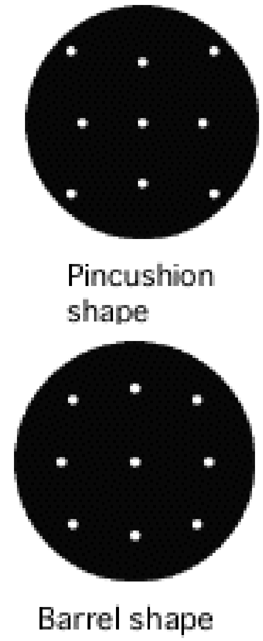


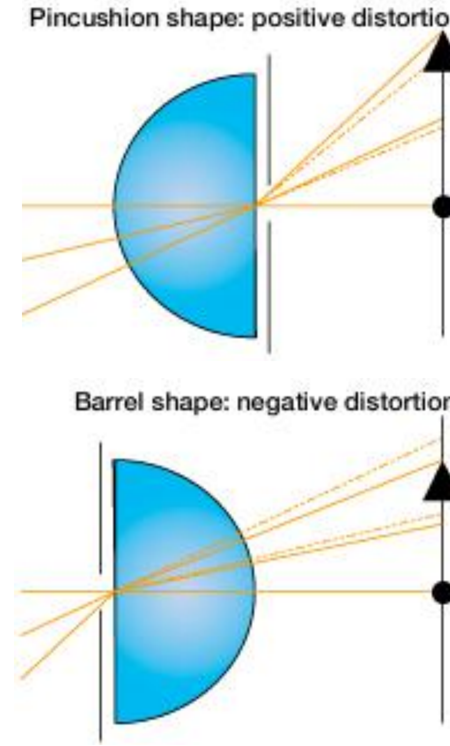


This aberration is linearly proportional to the *numerical aperture* and proportional to the square of the width of the field of view. In this aberration, for one off-axis object point there are two image points, so an image that should be a point becomes two lines at right angles to each other. If the focus is moved then the image becomes a long horizontal, a circle, and a long vertical. At the focus point this aberration is similar to curvature of field.

Distortion

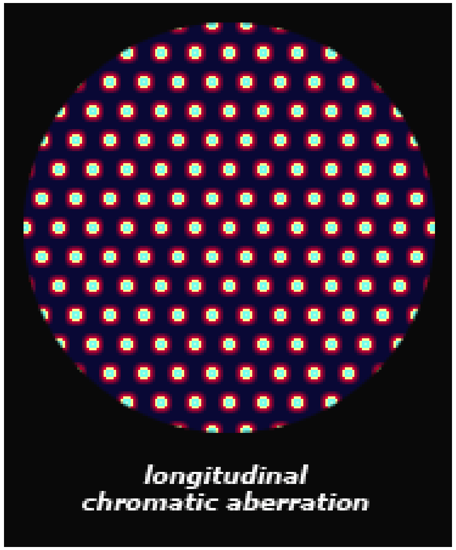


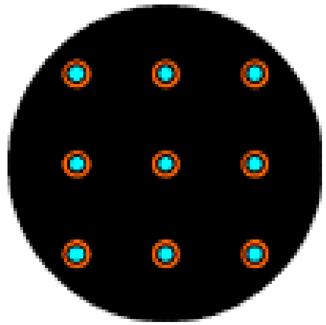


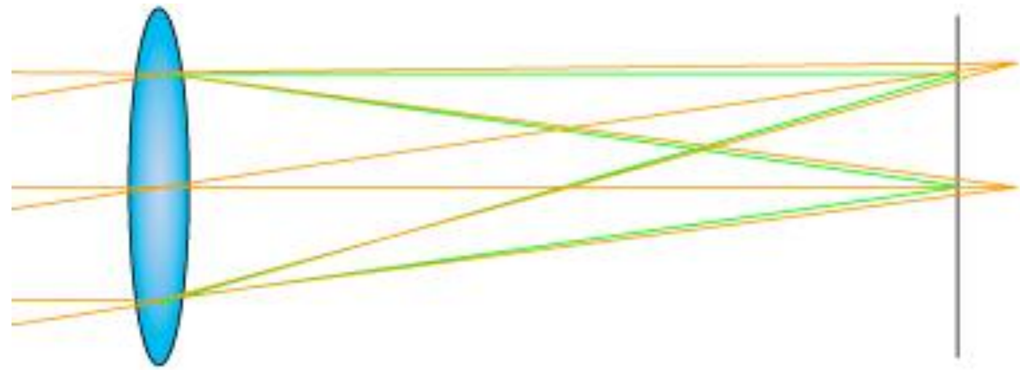


This aberration is independent of *numerical aperture* , and is proportional to the width of the field of view to the power of 3. This is the only aberration where there is no blur, and even if you reduce the *numerical aperture* the aberration still remains. Distorted rectangular shapes are formed.

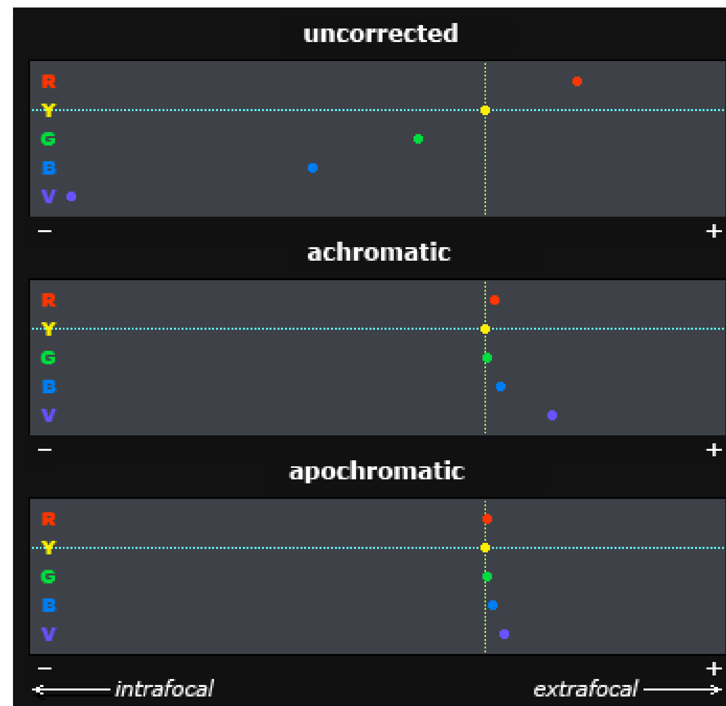
Chromatic Aberrations - Longitudinal



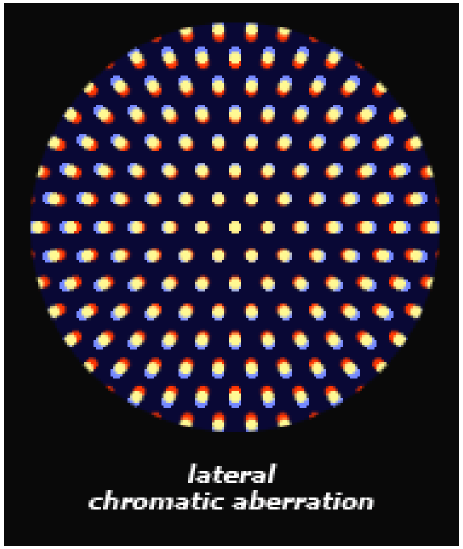


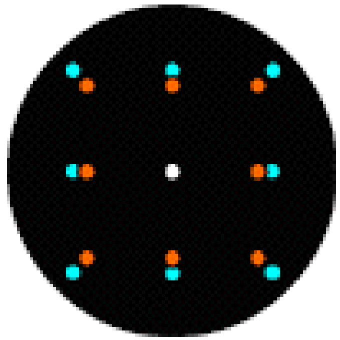


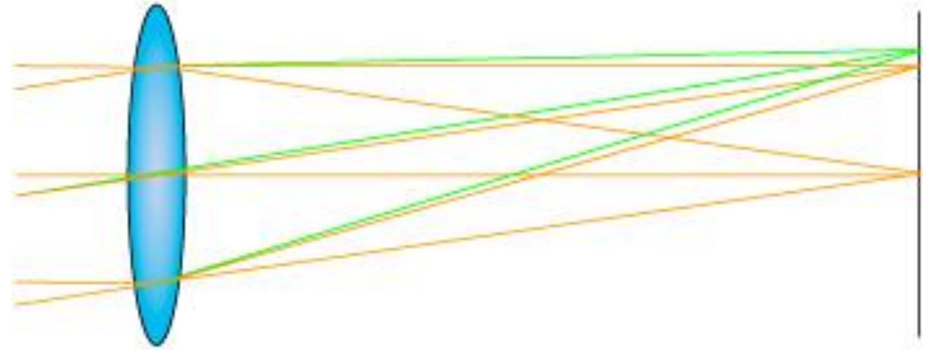
This aberration is linearly proportional to the *numerical aperture* and independent of the width of the field of view. It is necessary to correct for this in an objective. Depending upon the amount of correction it classifies into Achromat and Apochromat, etc. The focal point varies depending upon the color, so the aberration appears as a dispersion of color regardless of whether the point is on or off the axis.



Chromatic Aberrations - Lateral

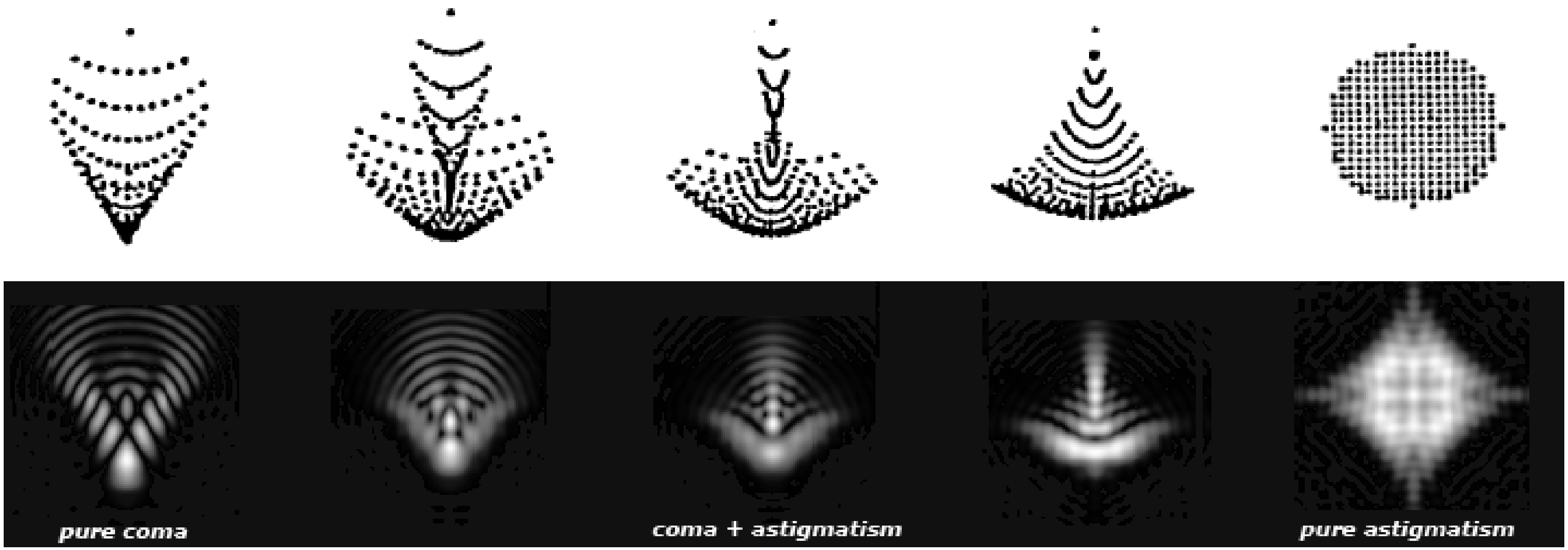






This aberration is independent of the *numerical aperture* , and linearly proportional to the width of the field of view. As the image magnification for each color is different, a bias of color appears off the axis. An objective tends to distort blue light in the radial direction because of its construction.

Astigmatism + Coma



Sources used: http://www.handprint.com/ASTRO/ae4.html
http://www.nikon.com/products/instruments/resources/tech/info/microscope_tech/aberration/index.htm
http://en.wikipedia.org/wiki/Spherical_aberration
http://en.wikipedia.org/wiki/Aberration_in_optical_systems