

Cameras and simple geometry

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A Pinhole Camera

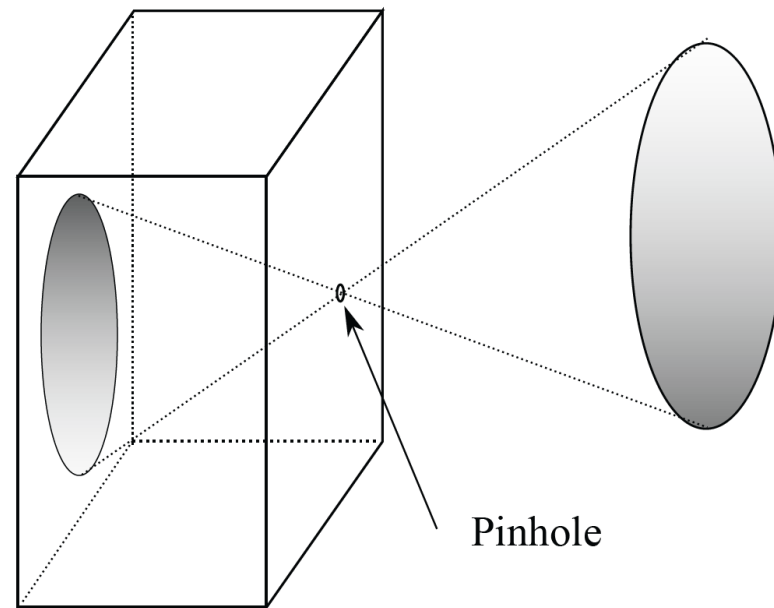


FIGURE 2.3: *In the pinhole imaging model, a light-tight box with a pinhole in it views an object. The only light that a point on the back of the box sees comes through the very small pinhole, so that an inverted image is formed on the back face of the box.*

The Pinhole Camera

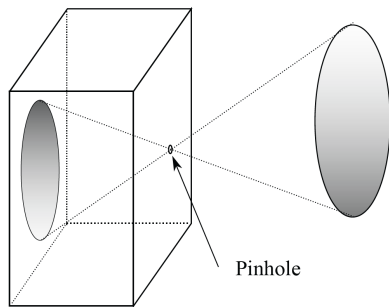


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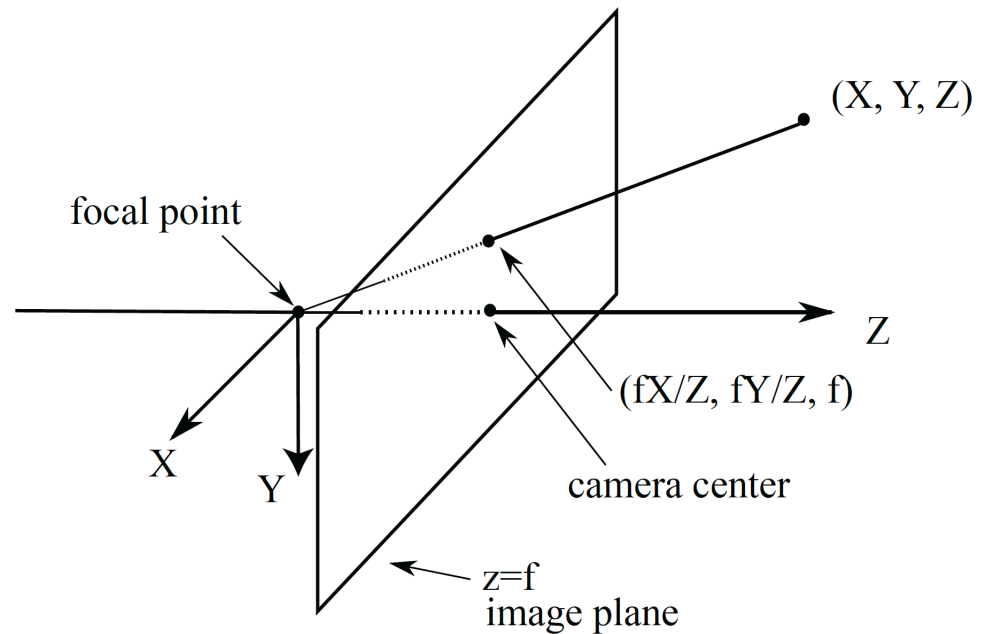
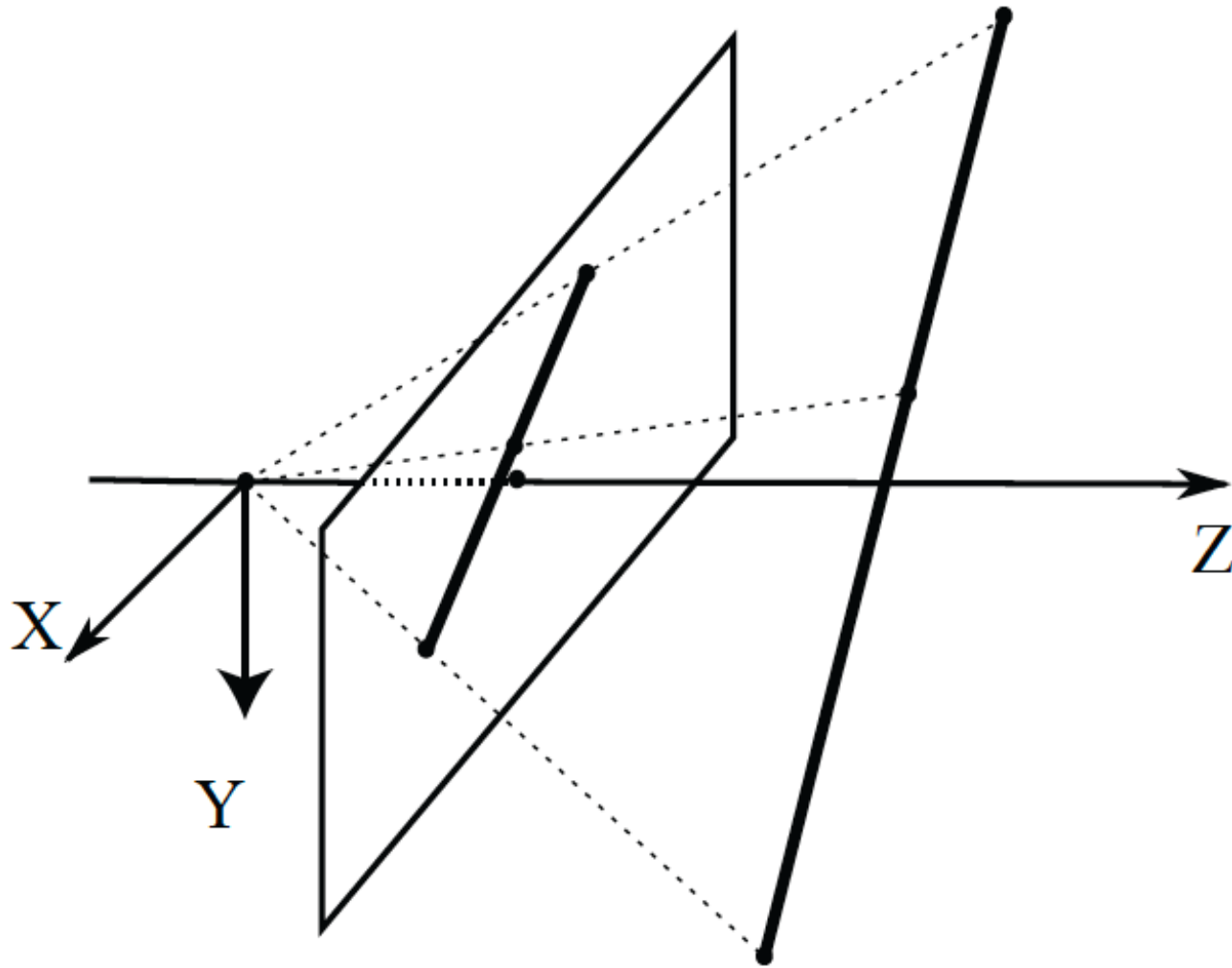
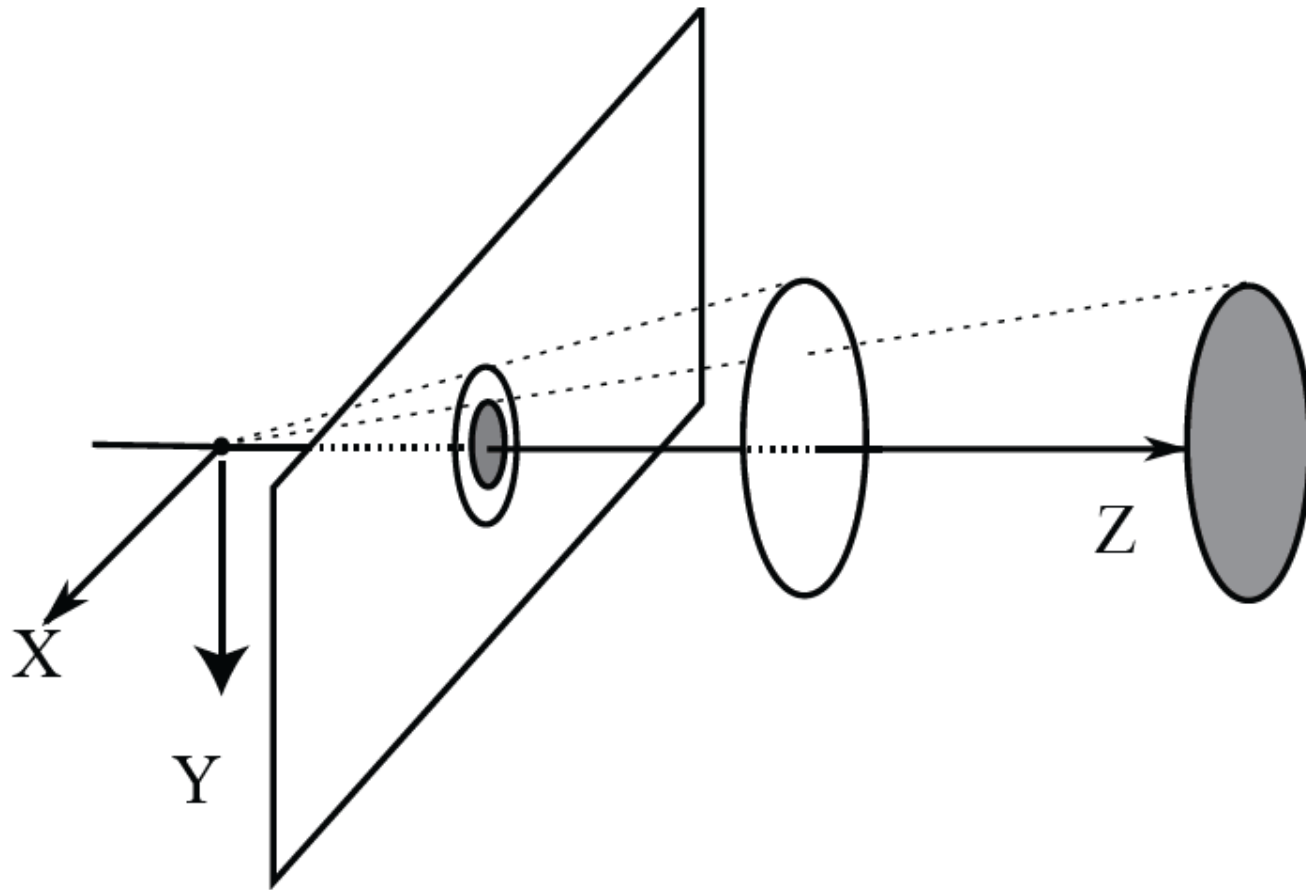


FIGURE 2.4: The usual geometric abstraction of the pinhole model. The box doesn't affect the geometry, and is omitted. The pinhole has been moved to the back of the box, so that the image is no longer inverted. The image is formed on the plane $z = f$, by convention. Notice the y-axis goes down in the image. This allows me to use a right handed coordinate system and also have z increase as one moves into the image.

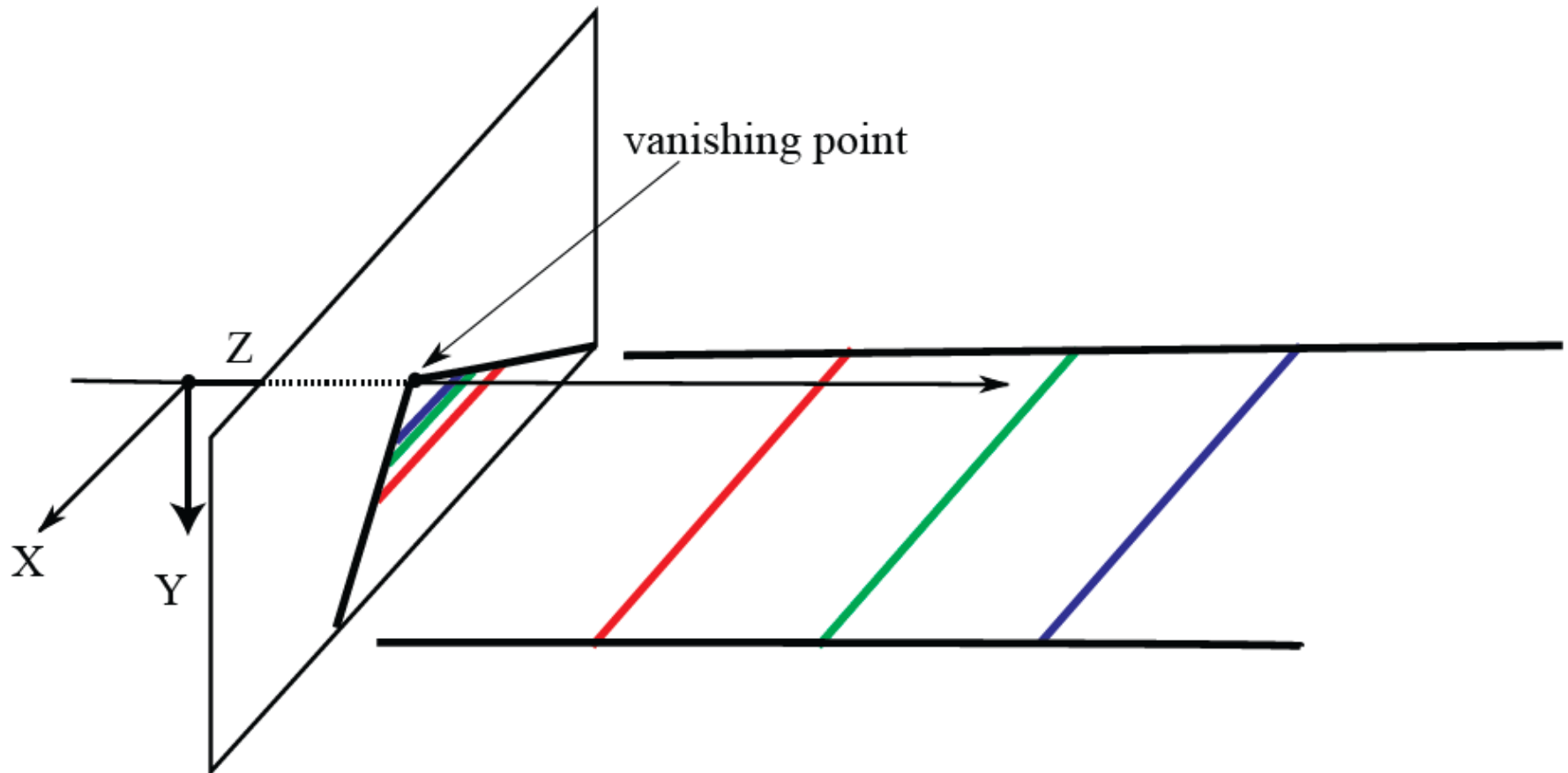
Lines project to lines



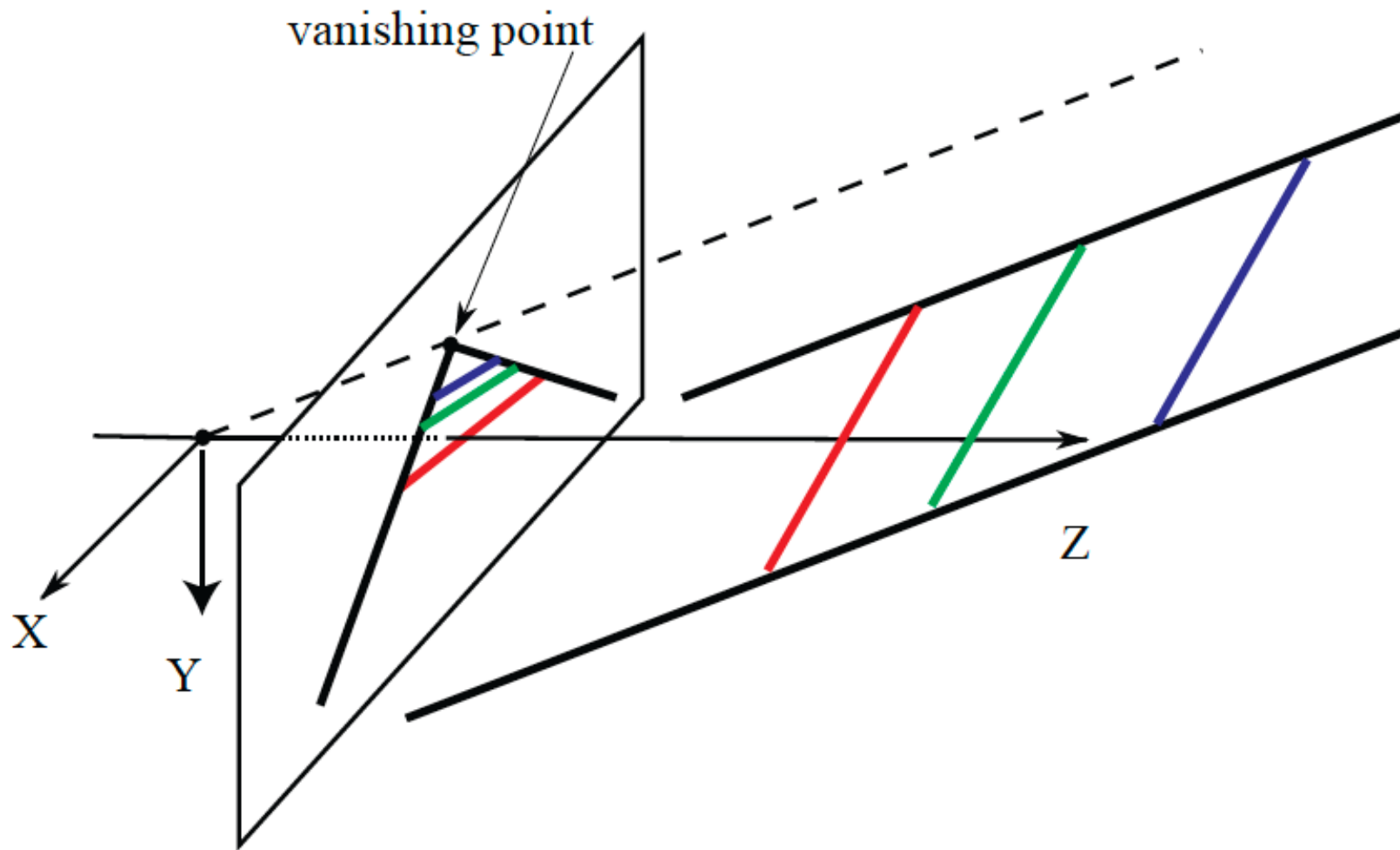
Further objects are smaller



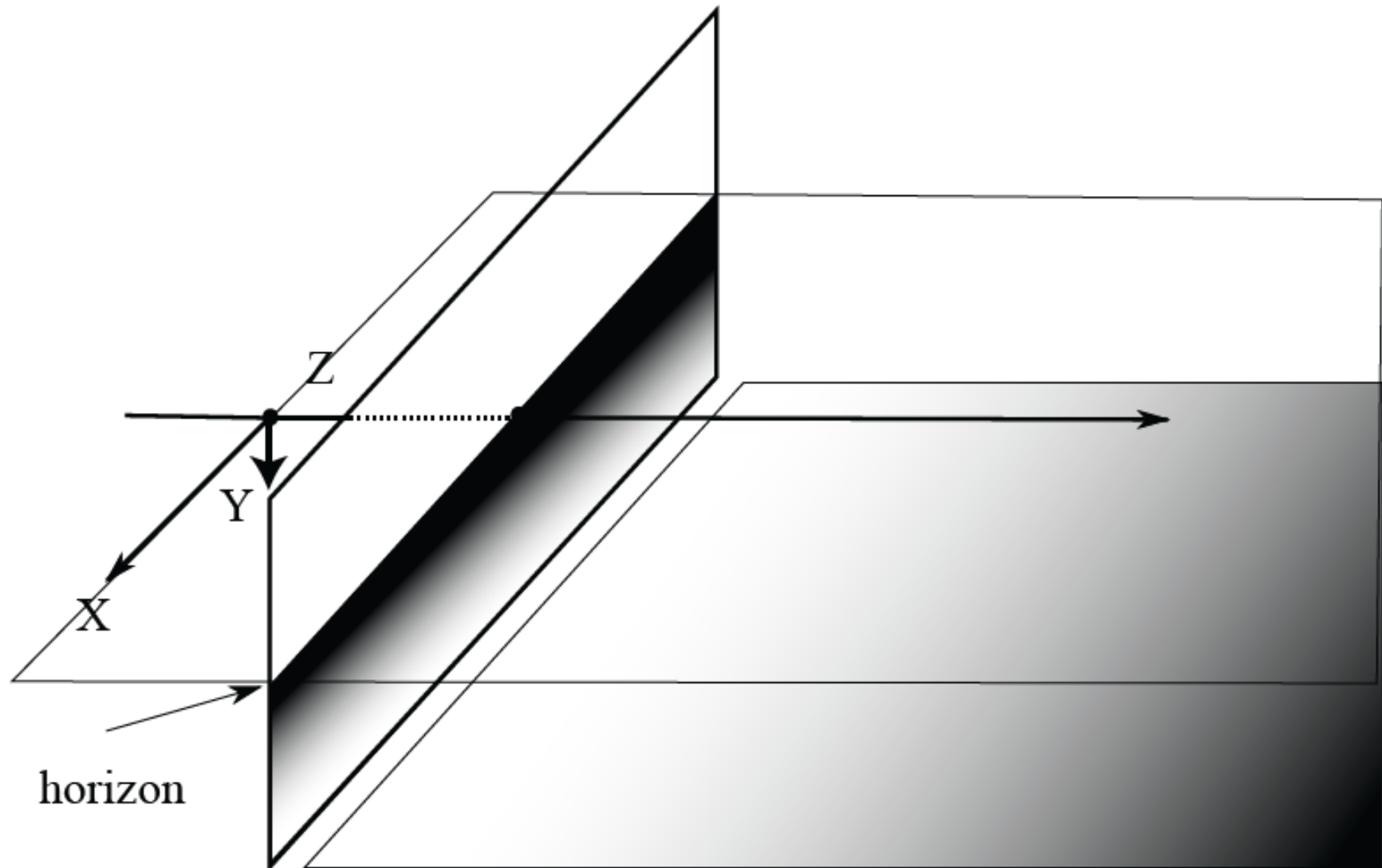
Parallel lines have vanishing points



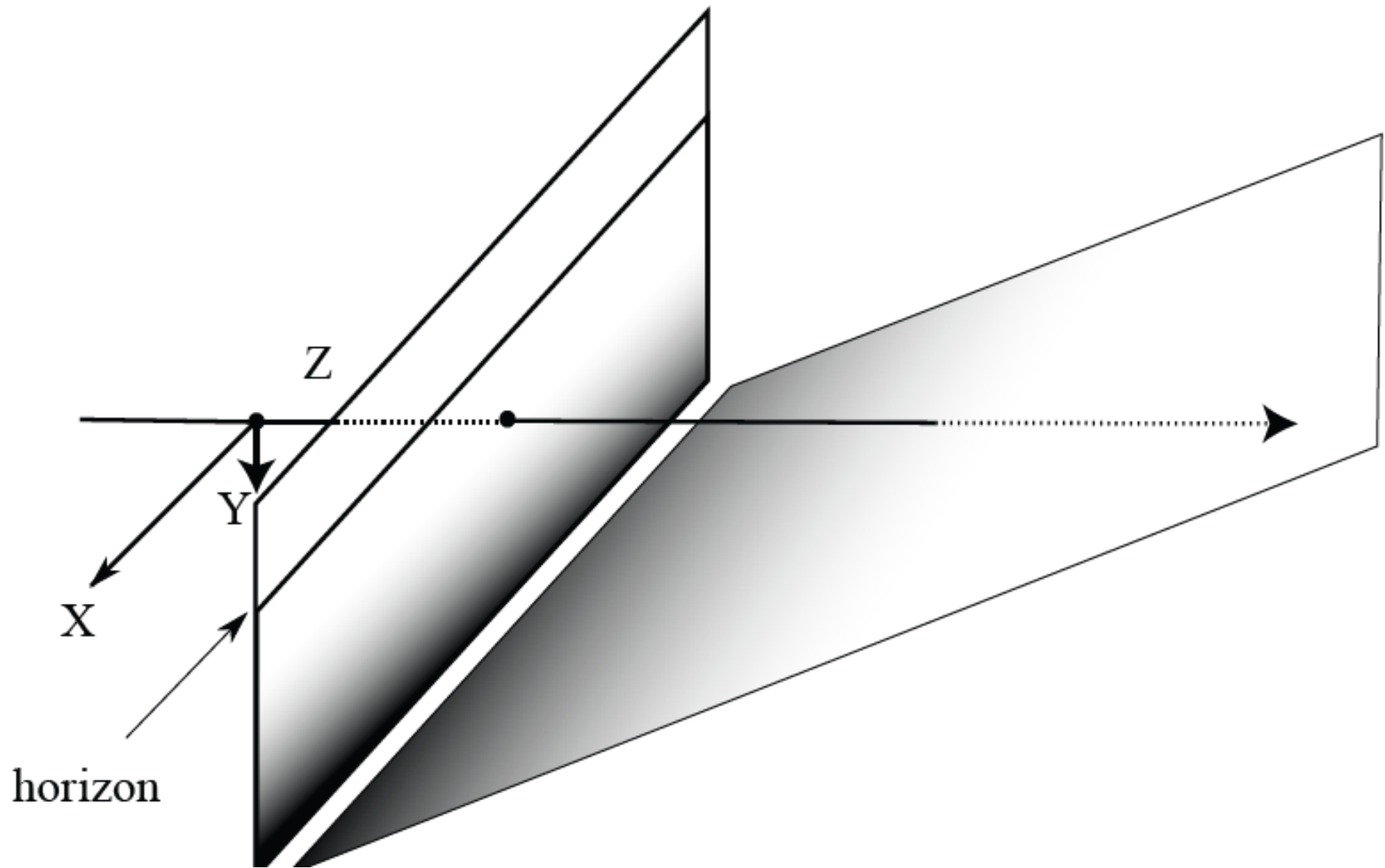
Parallel lines have vanishing points



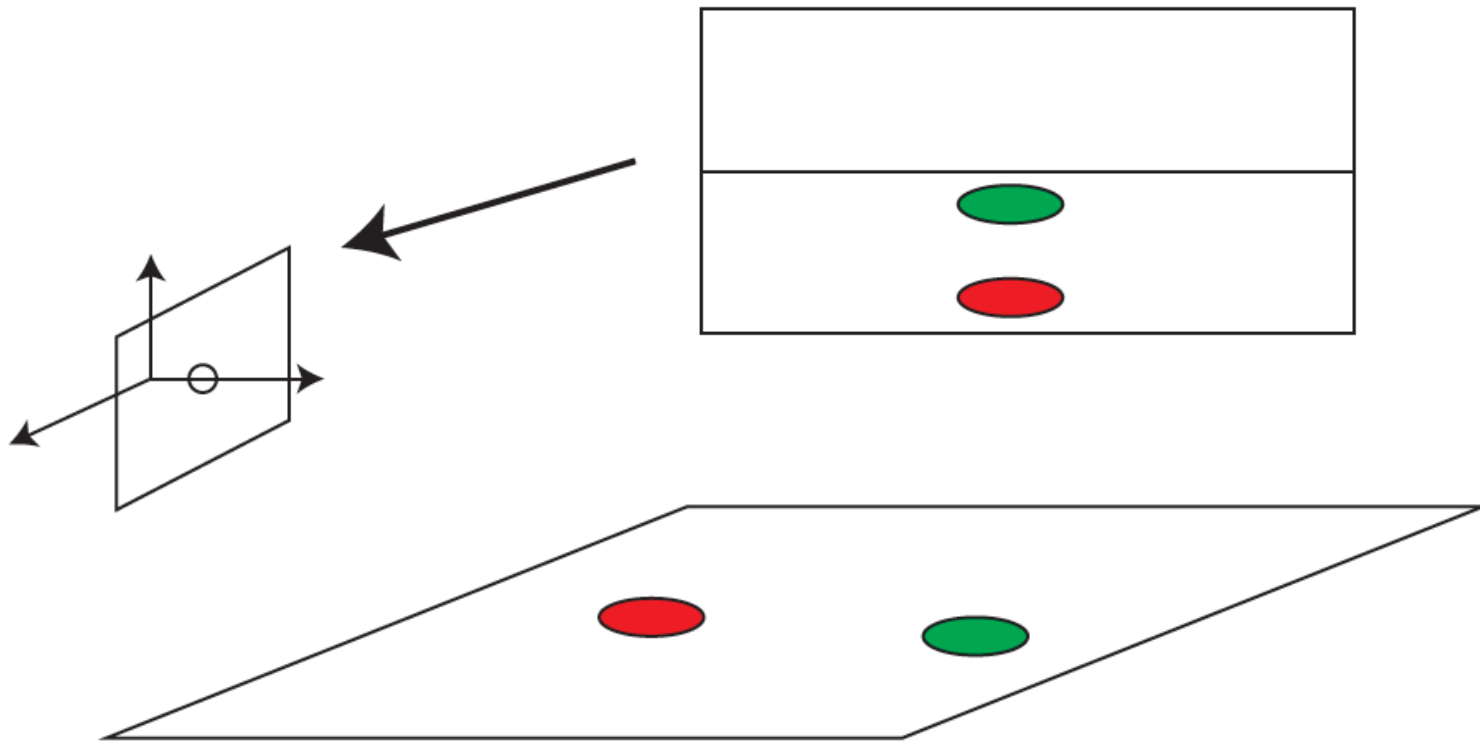
Planes have horizons



Planes have horizons



Horizons are informative - I



More about horizons

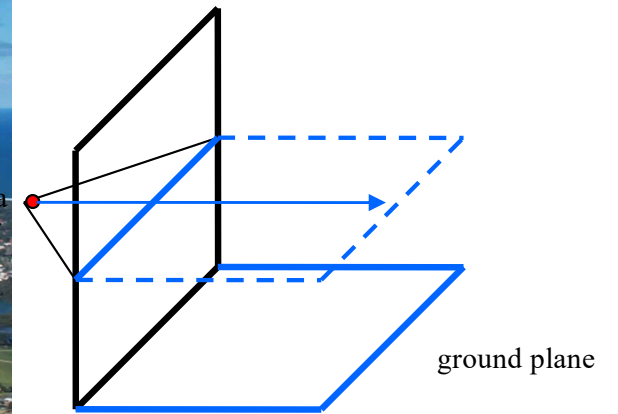
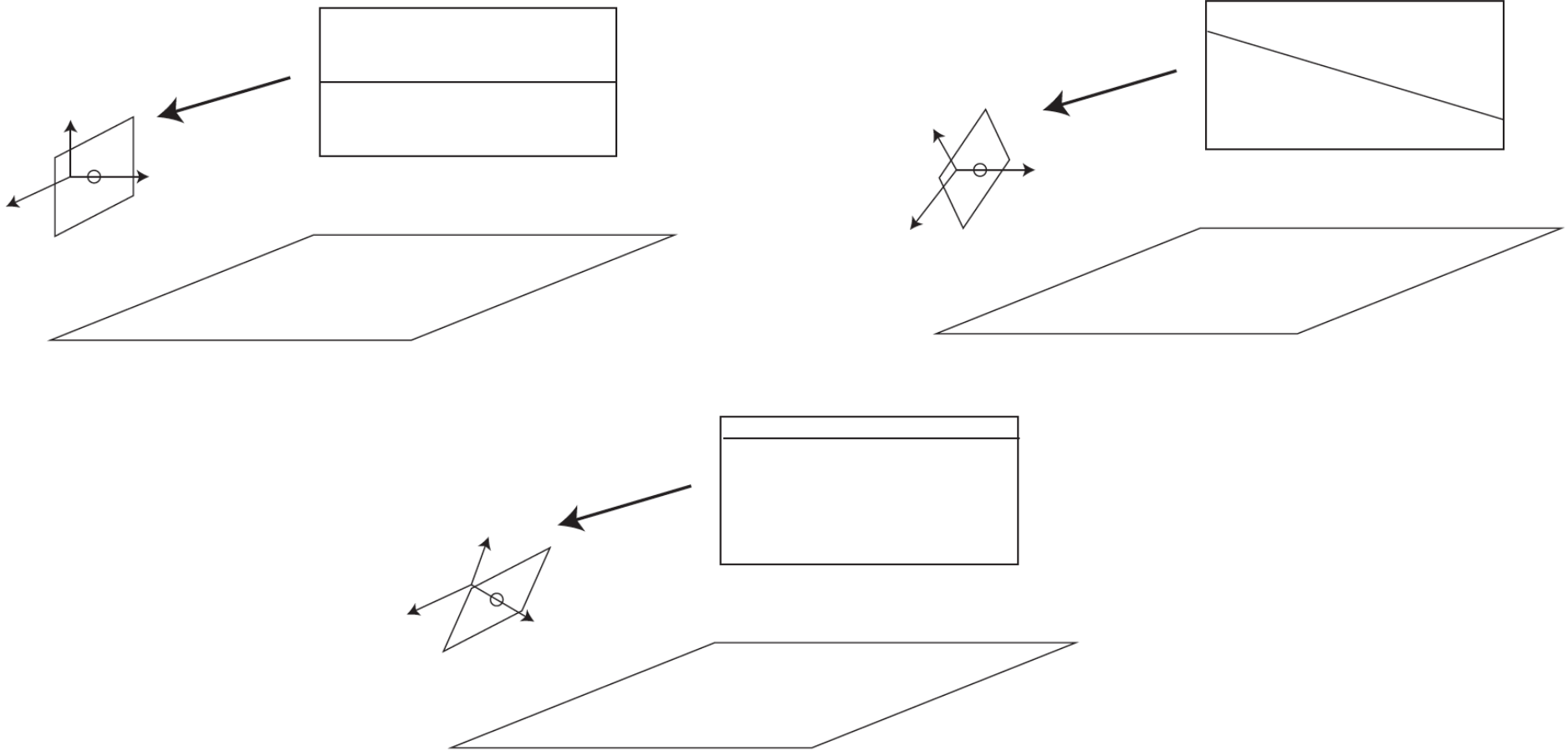


Image source: S. Seitz

Camera above or below paraglider?

Yet more about horizons



Measurements without calibration

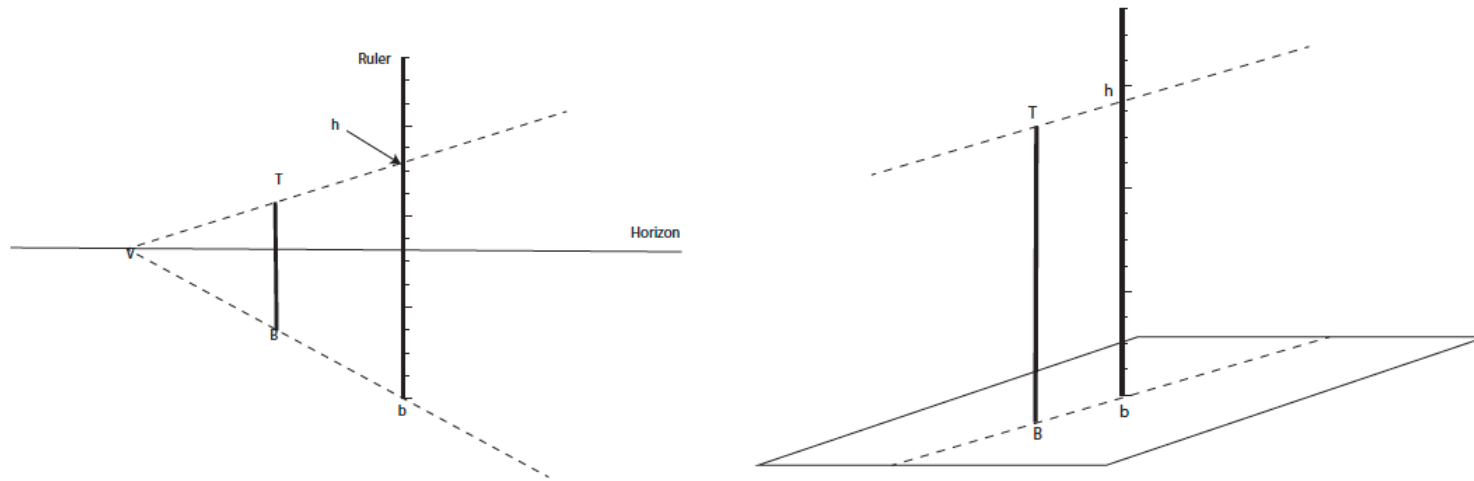


FIGURE 24.3: **Left**, an image of a ruler and an object, which just happen to be standing perpendicular to a ground plane. In an uncalibrated image like this, we can measure the height of the object. Construct the line bB , and intersect that with the horizon to get the point V . The line from the top of the object T to the true height of the object on the ruler (h) is parallel in 3D to bB . In turn, the line Th must intersect the horizon at V . So if you construct VT , it will intersect the ruler at h yielding the height of the object. **Right** shows a 3D view; the line Th must be parallel to bB , and so in the image these two lines intersect at the horizon.

Measurements without calibration

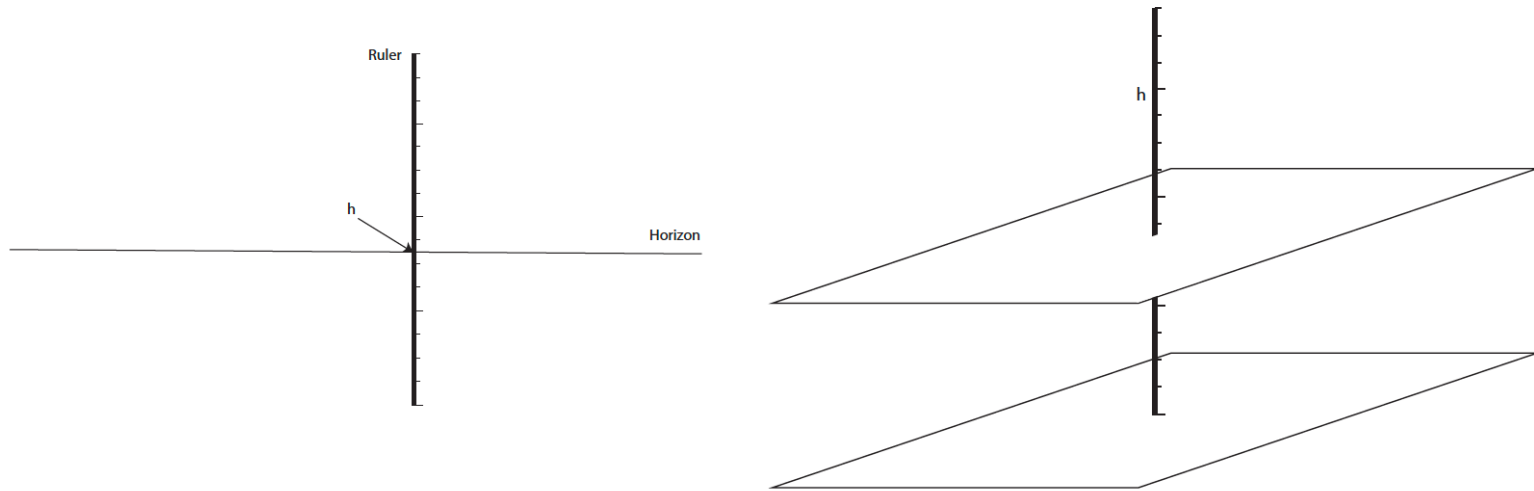


FIGURE 24.4: **Left**, an image of a ruler which just happens to be standing perpendicular to a ground plane. In an uncalibrated image like this, we can measure the height of the camera focal point above the ground plane. The plane through the focal point parallel to the ground plan (and so the same height above the ground plane as the focal point) must form the horizon, so the intersection between horizon and ruler yields the height of the focal point. **Right** shows a 3D view; the bottom plane is the ground plane, and the top plane is the plane through the focal point parallel to the ground plane.

Lenses

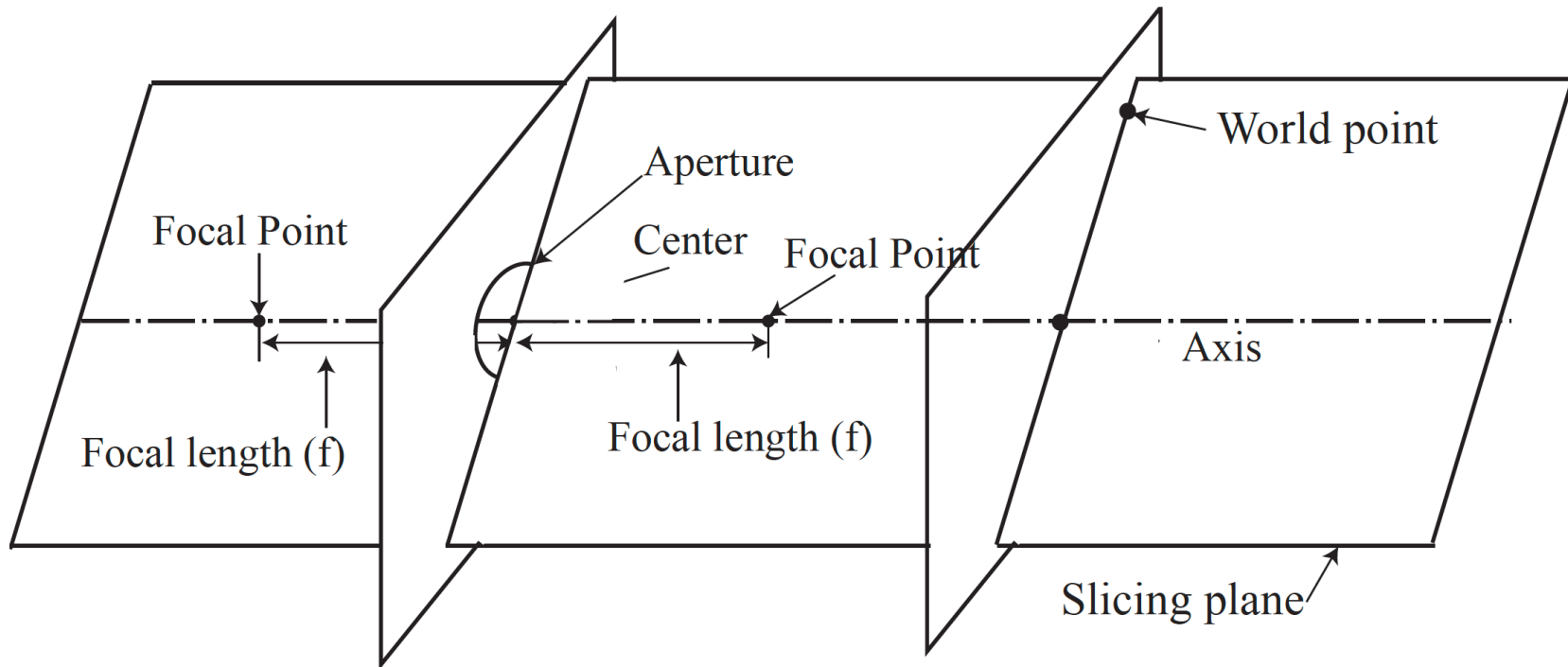
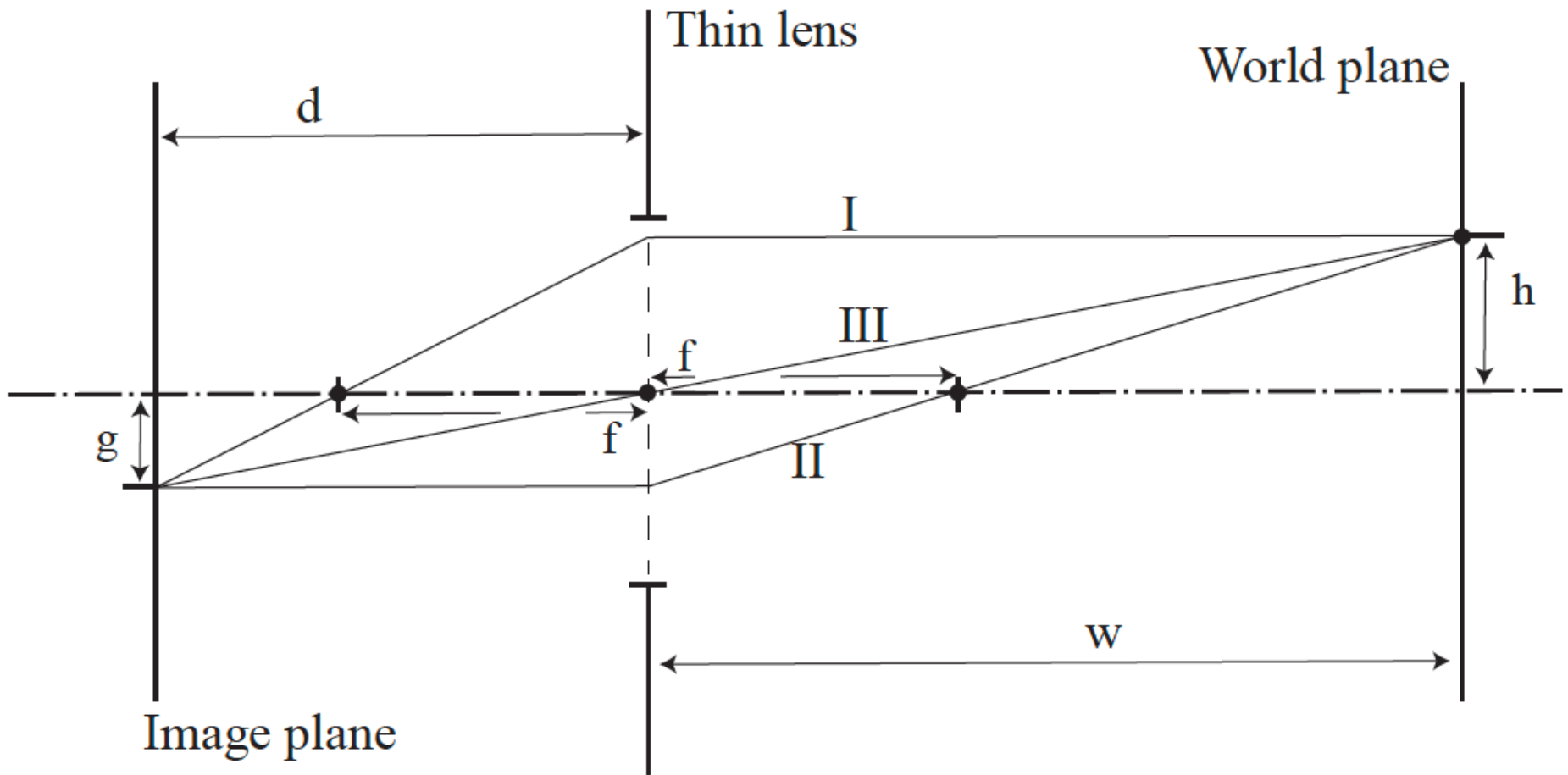


FIGURE 27.10: *The inset shows a 3D drawing of the abstract thin lens – a plane with a circular aperture and refractive material in the aperture. This is more usually drawn in 2D (as in Figure 27.11). The 2D drawing shows a section of the 3D geometry cut by a plane through the axis of the lens and the world point of interest.*

A (slice through) a thin lens

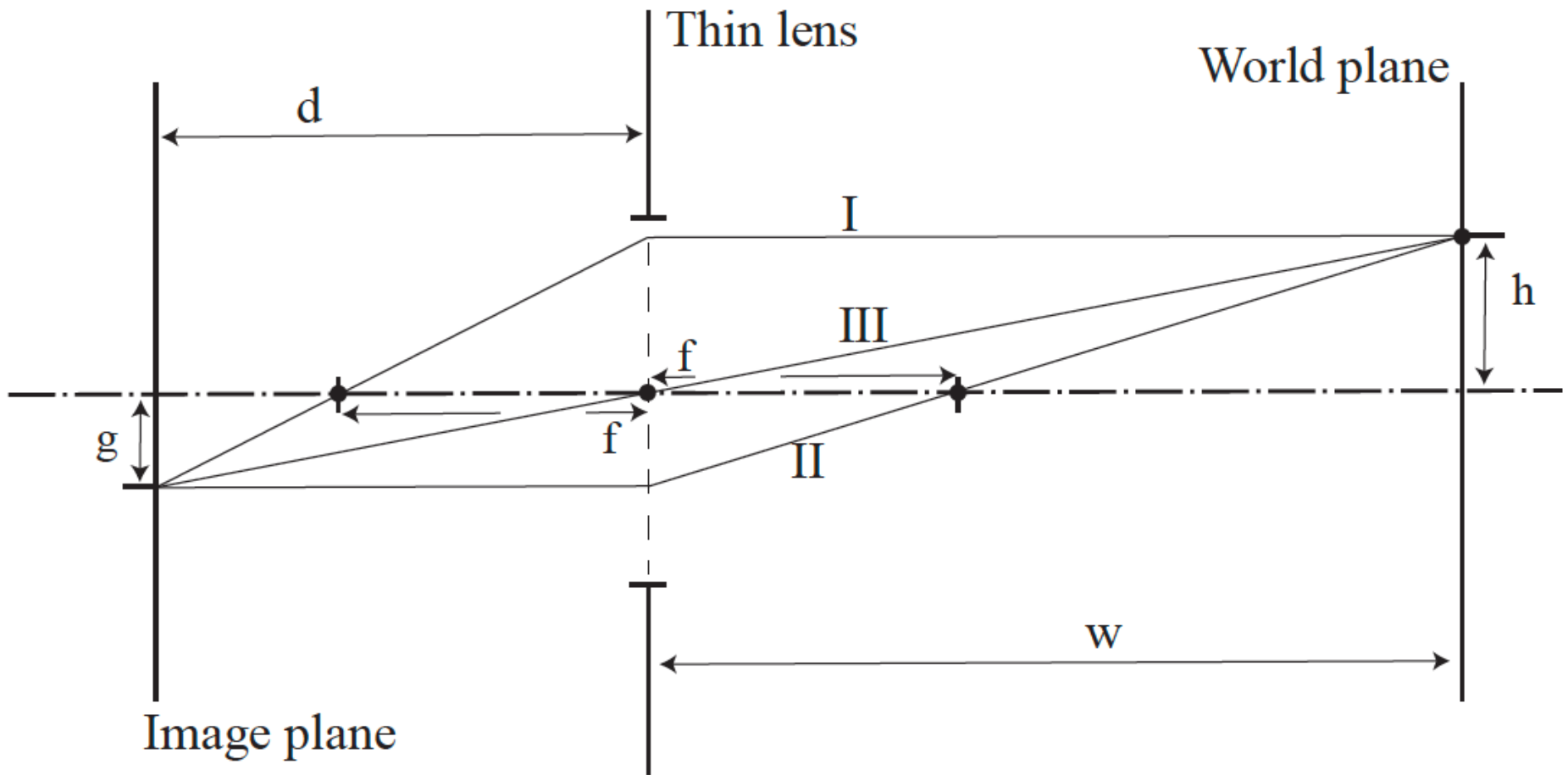


Thin lenses – the rules

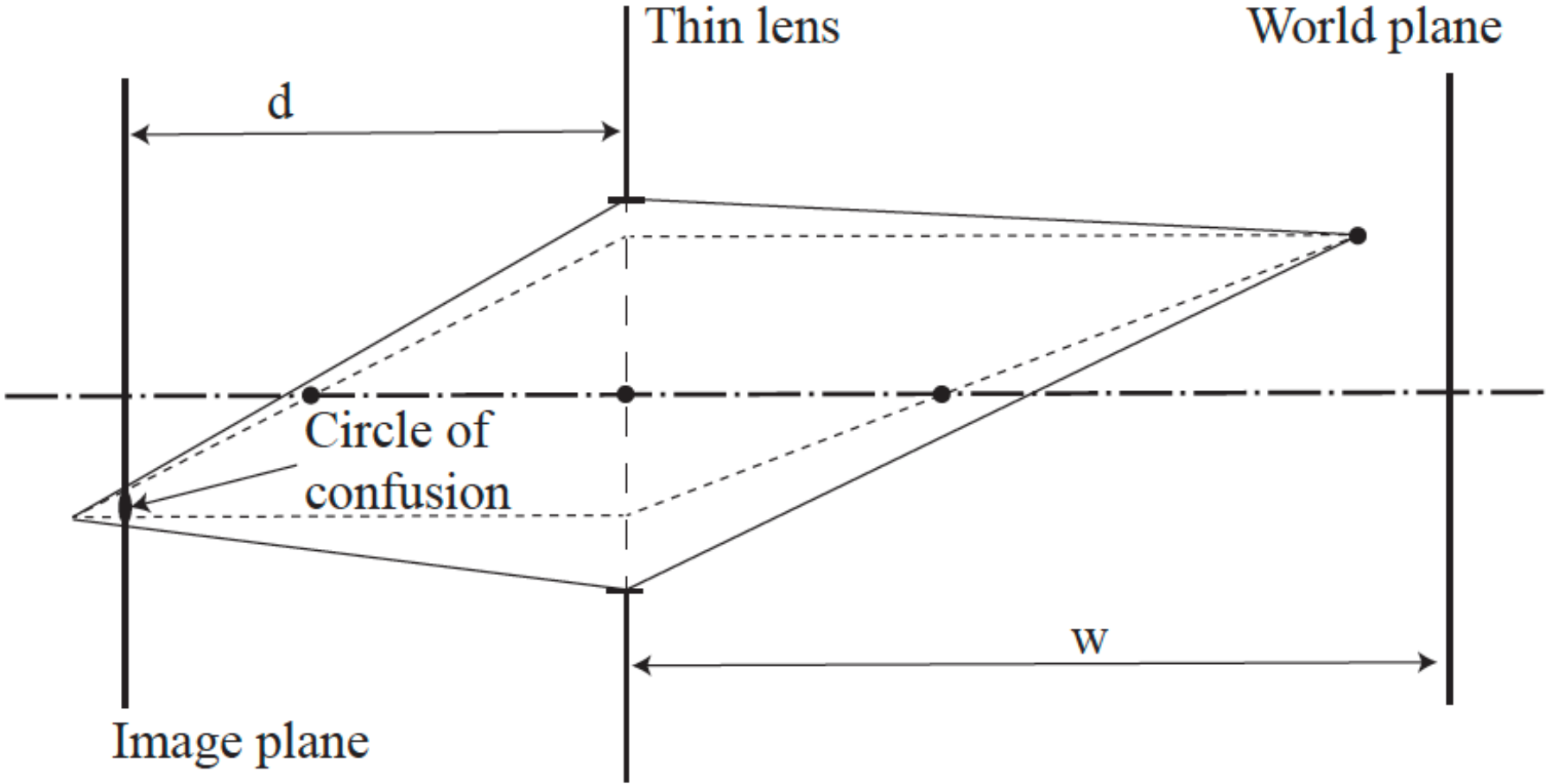
Thin lenses have three properties that apply to rays of light that strike the lens aperture.

- Any ray of light entering the lens perpendicular to the plane of the lens will emerge to pass through the focal point on the other side.
- Any ray of light passing through the focal point on one side then striking the lens will emerge parallel to the axis of the lens on the other side.
- Any ray of light striking the center of the lens passes through lens without changing direction.

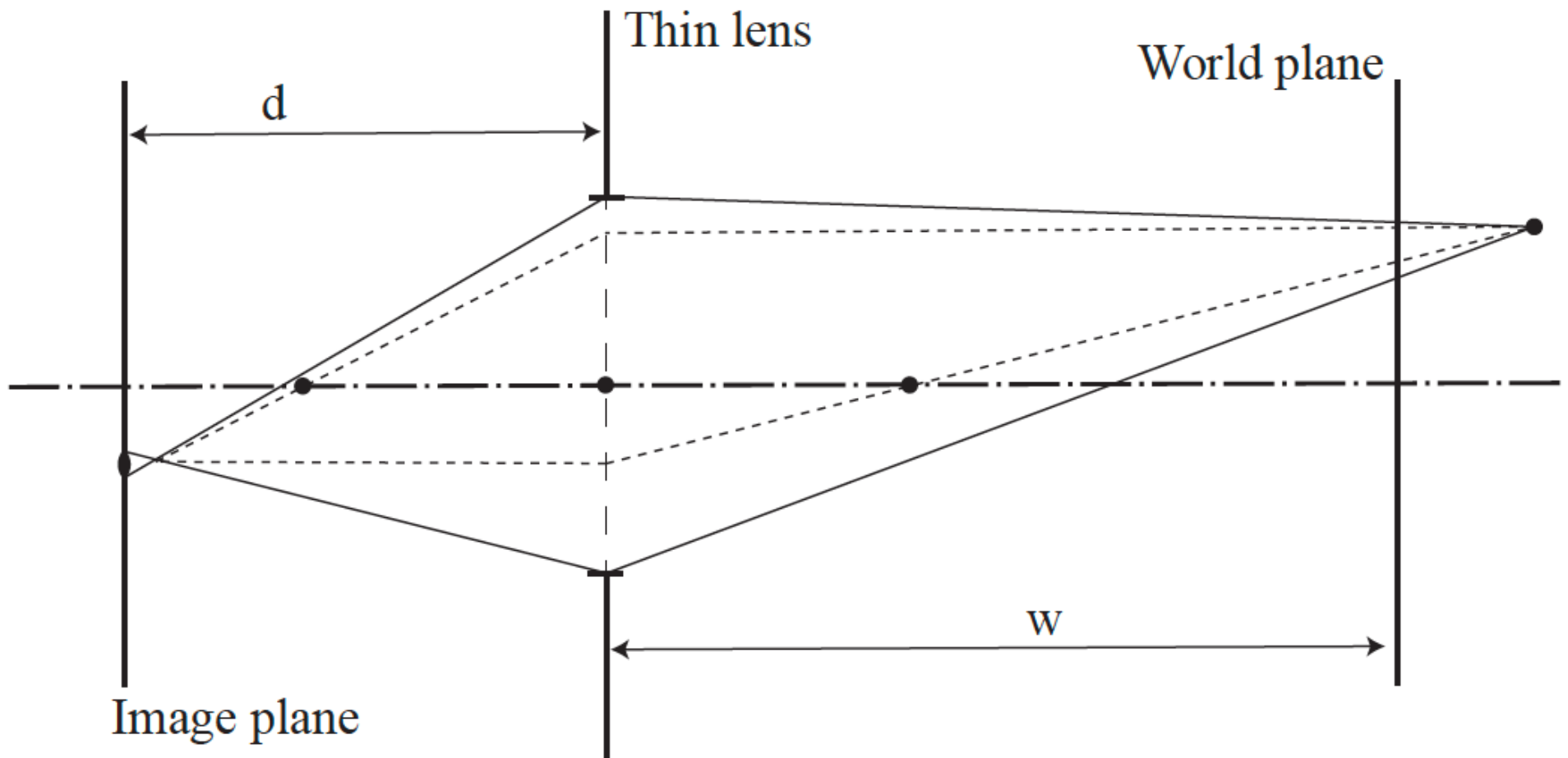
The rules and focus



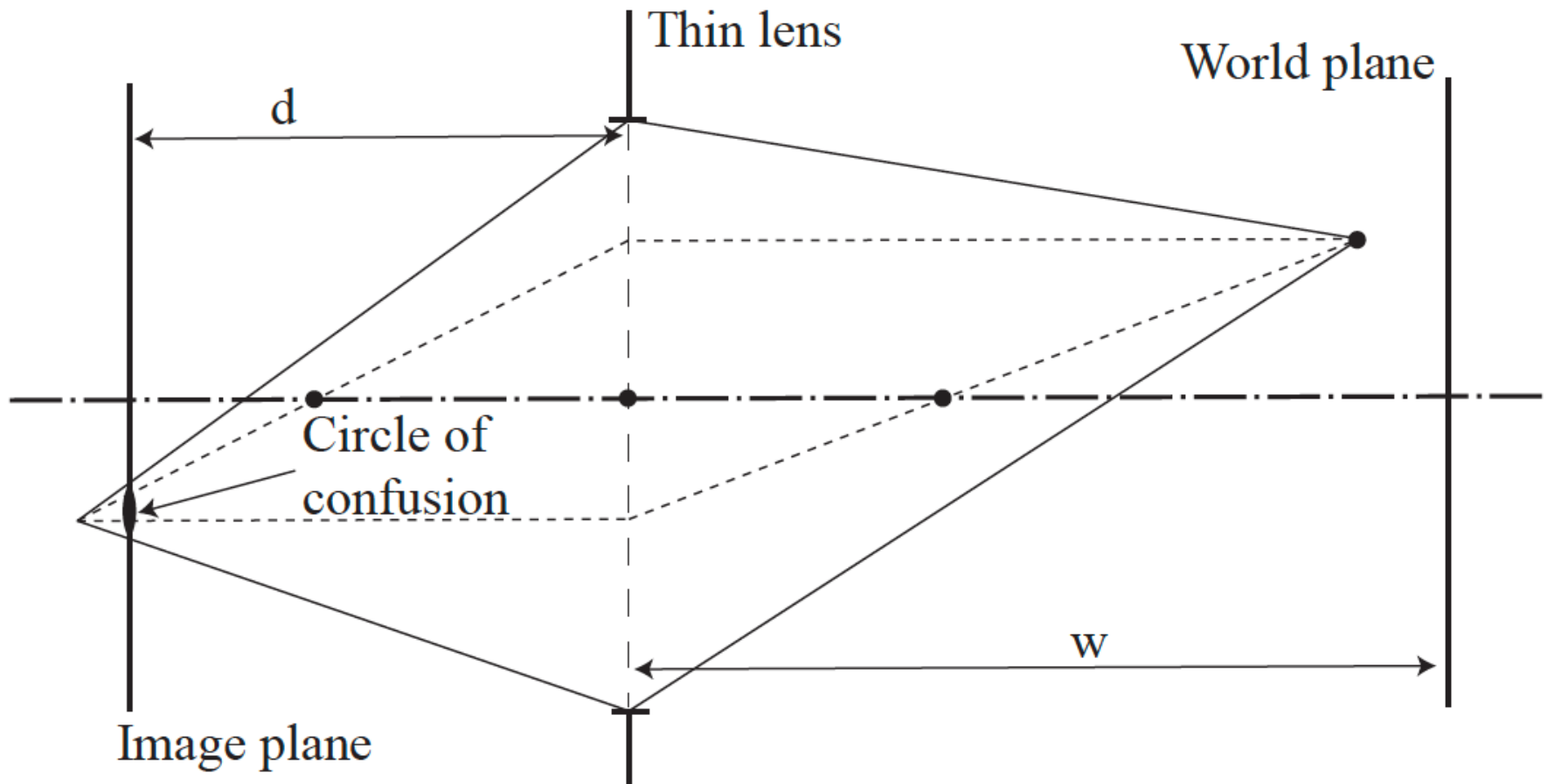
Depth of field



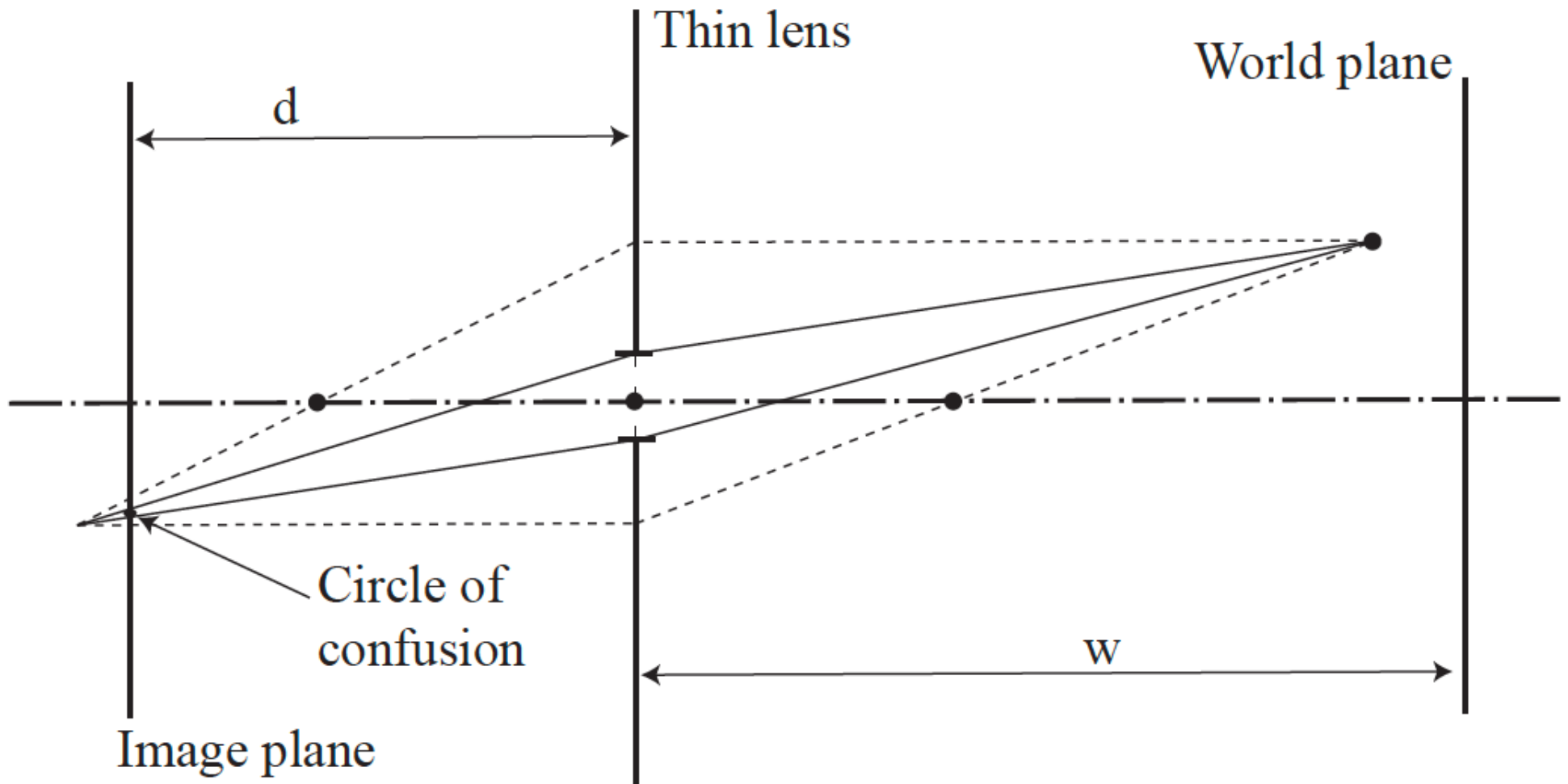
Depth of field



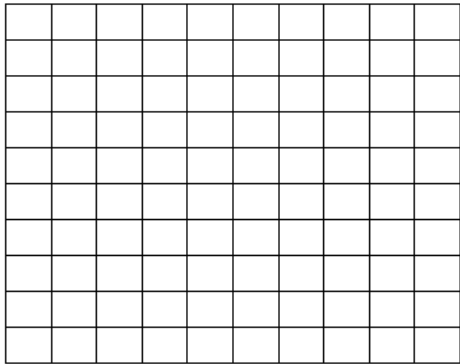
Aperture and depth of field



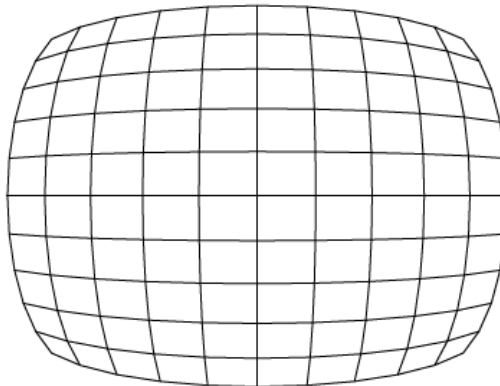
Aperture and depth of field



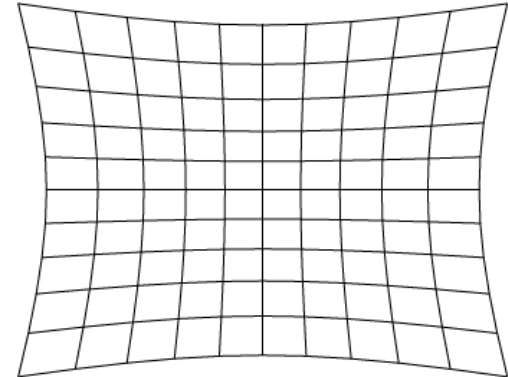
Lens distortion



Neutral grid



Barrel distortion

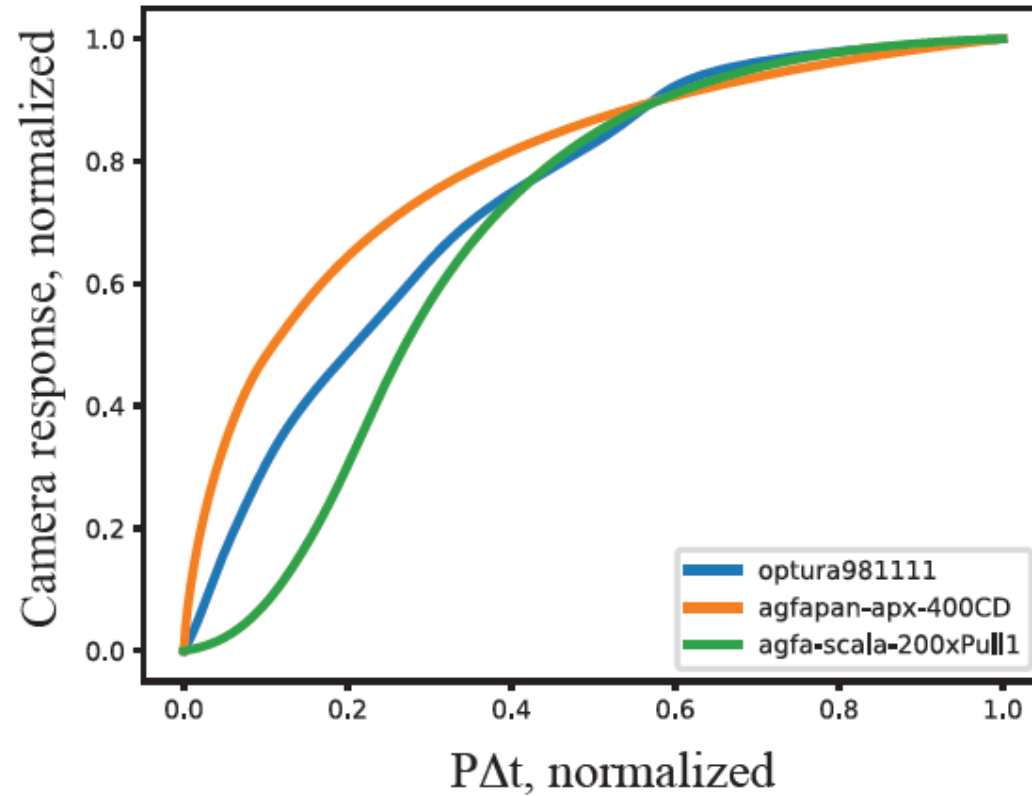


Pincushion distortion

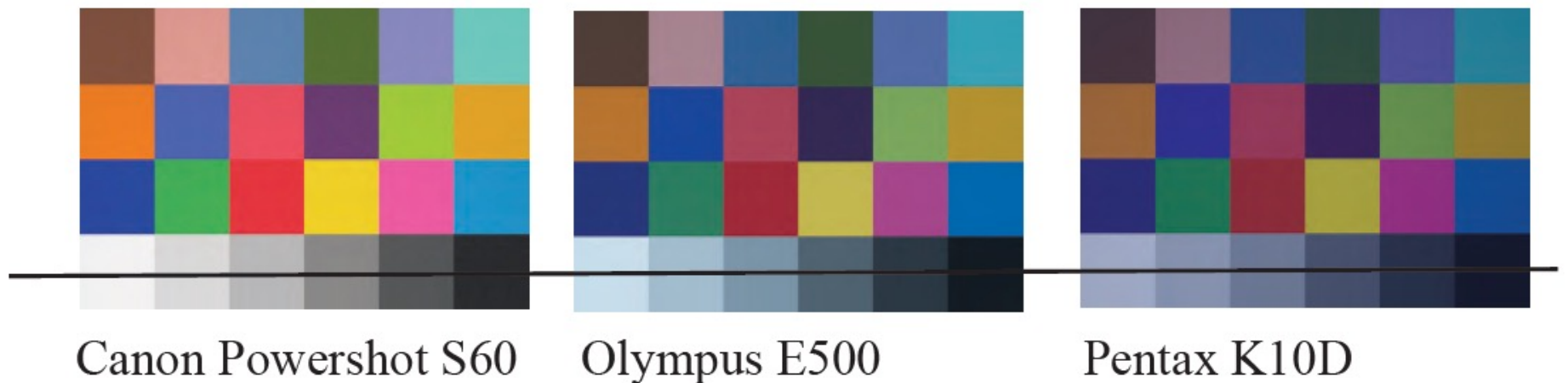
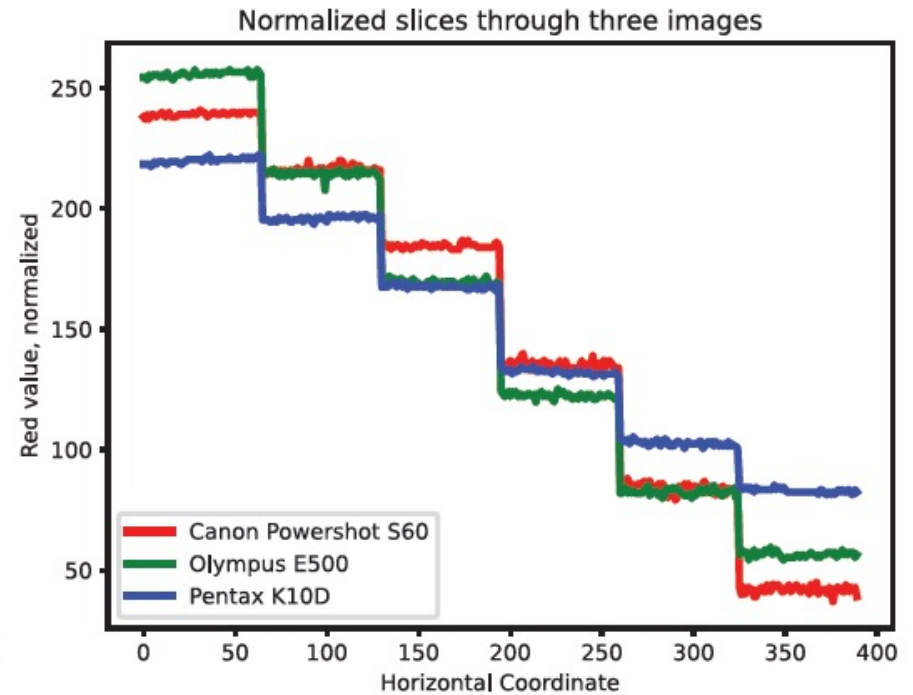
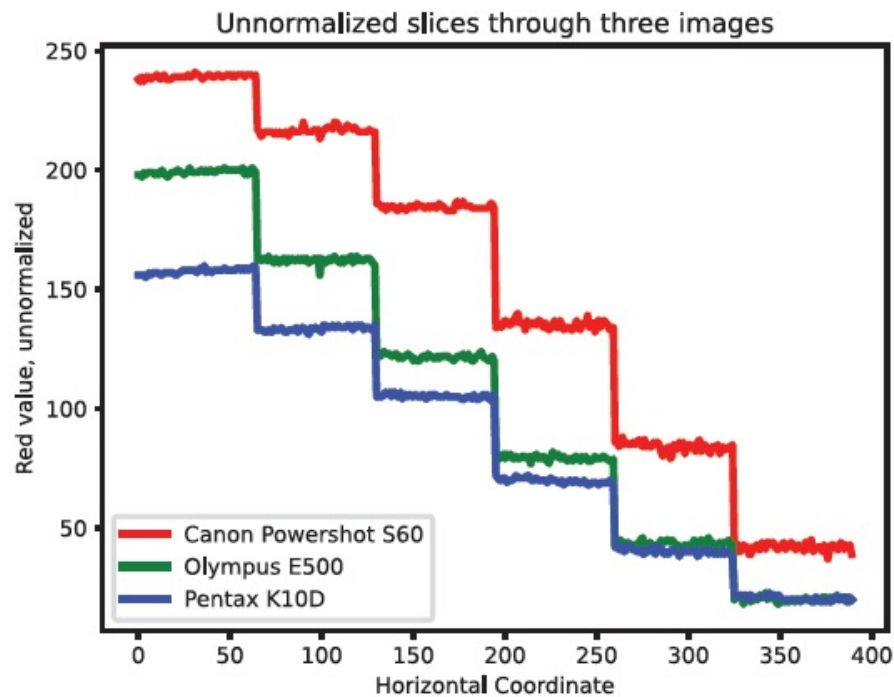
Camera response functions

- Camera sensors are almost always linear BUT
 - image dynamic range is too big for 8 bits
- Typical cameras apply a non-linearity before or during digitization – the camera response function
- This varies from camera to camera

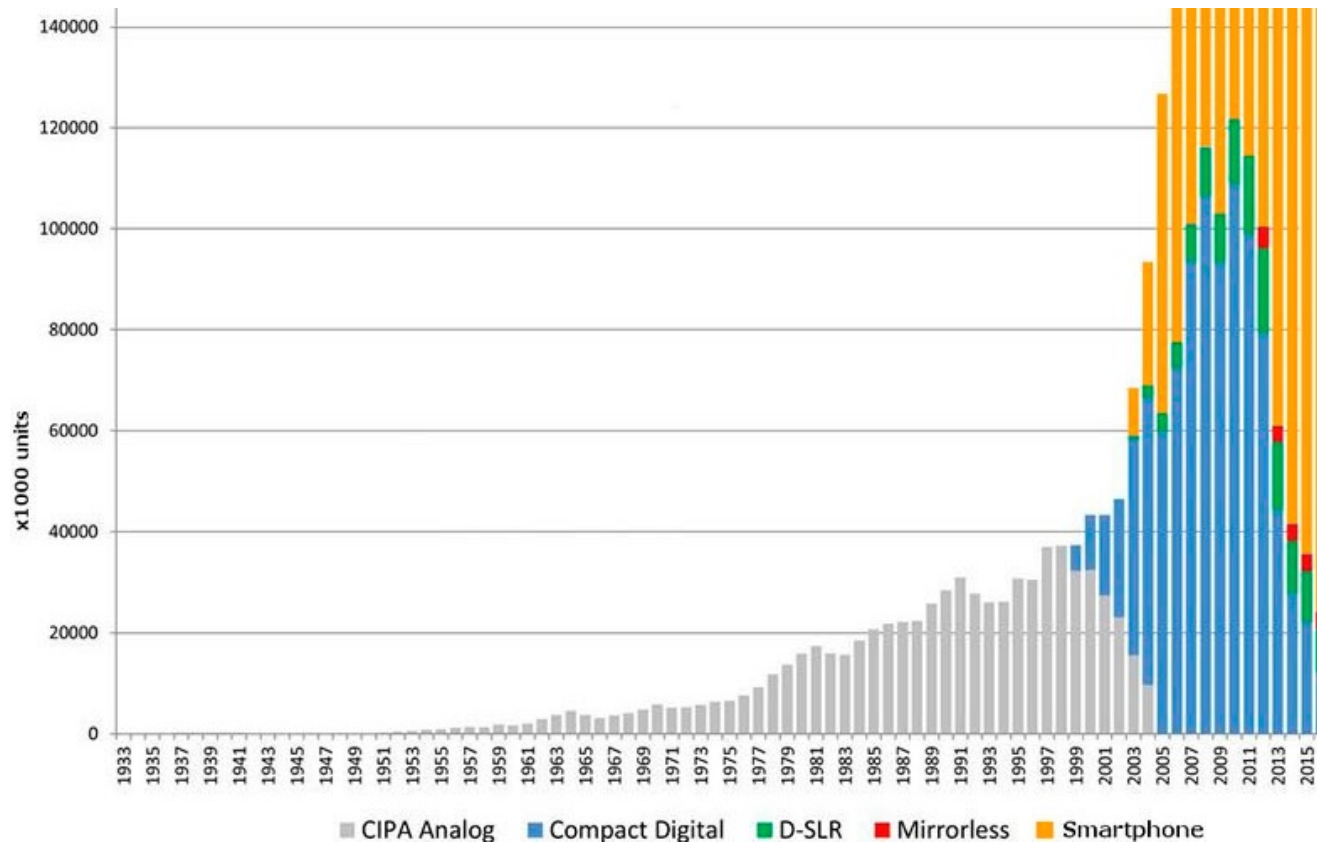
Camera response functions



Camera response function effects



Camera sales over time



[Source](#)

Camera sales over time

- The full chart...



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