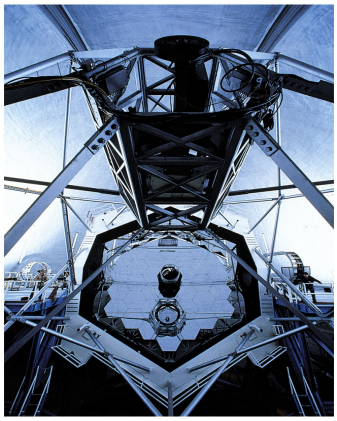
Telescopes

Lowell 24-inch Telescope



Keck 10-m Telescope

Question

If we only get light from celestial objects,
what can we do to maximize the quantity and quality?

Manipulate Light

In order for a telescope to be advantageous, it must manipulate light in a way that is beneficial to the observer. Optimal designs give the observer

(1) a magnified view (so that it appears closer),

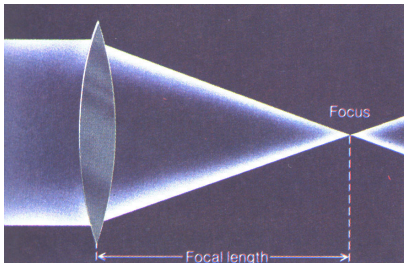
(2) a brighter view (of the dim object), and

(3) a higher-resolution view (so fine details can be seen).

There are two ways to manipulate light to our advantage:

Refraction and Reflection

Refraction



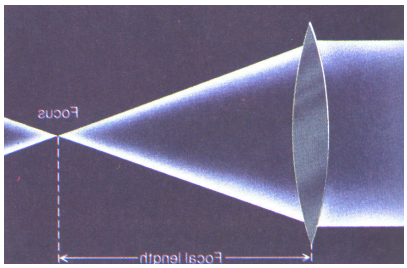
Universe by Freedman, Geller, and Kaufmann

Uses a lens to manipulate light.

Focal Length is the distance from the lens to the focus.

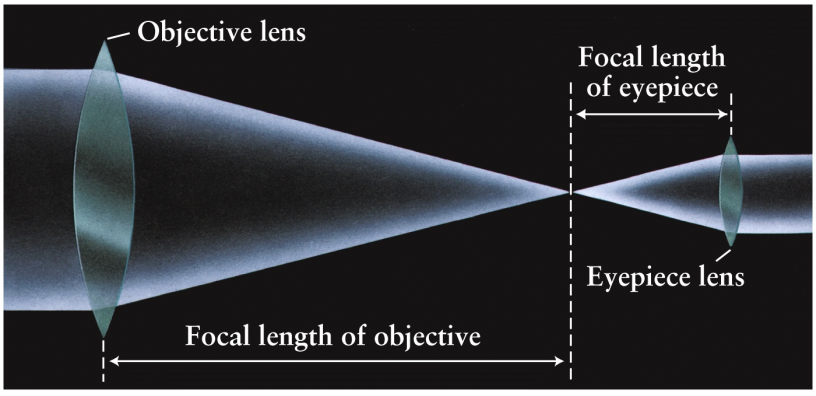
Refraction

Focal Length is the same for either side of the lens.



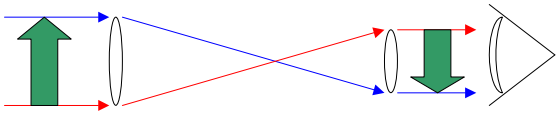
Universe by Freedman, Geller, and Kaufmann

Refracting Telescope



Universe by Freedman, Geller, and Kaufmann

1. Magnification



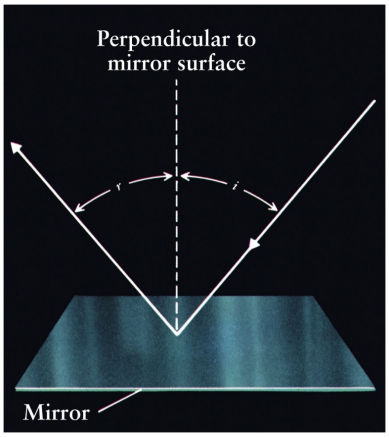
Magnification occurs because the ***angular*** size of the image on the eye is much larger than the angular size of the object. Note that the image is upside down.

Magnification = Focal Length of Objective / Focal Length of Eyepiece

$$M = F / f$$

(But you have to use the same length units for F and f.)

Reflection



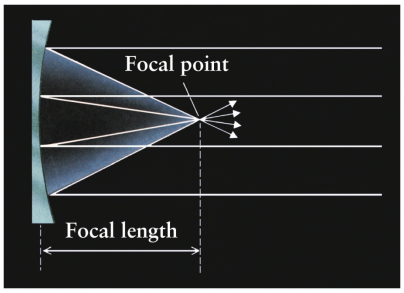
Universe by Freedman, Geller, and Kaufmann

Uses a mirror to manipulate the light.

Angle of Incidence = Angle of Reflection

But flat mirrors do not have a focal length so how can they produce a magnification?

Reflection



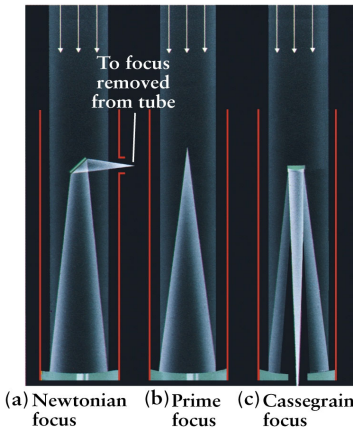
Universe by Freedman, Geller, and Kaufmann

Must use a curved (**spherical**) mirror to bring the light to a focus.

The focal length is half the radius of curvature.

Where do you put the eyepiece so the light from the celestial object is not obscured by your head?

Reflecting Telescopes



Universe by Freedman, Geller, and Kaufmann

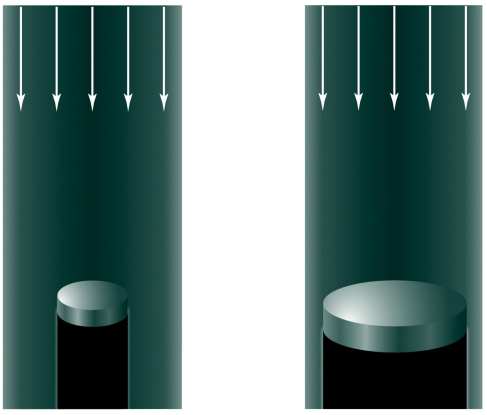
1. Magnification

Magnification = Focal Length of Primary Mirror / Focal Length of Eyepiece

$M = F / f$

(Same equation as for Refractors)

2. Light Gathering Ability



Universe by Freedman, Geller, and Kaufmann

Proportional to the Area

(The Bigger, the Better)

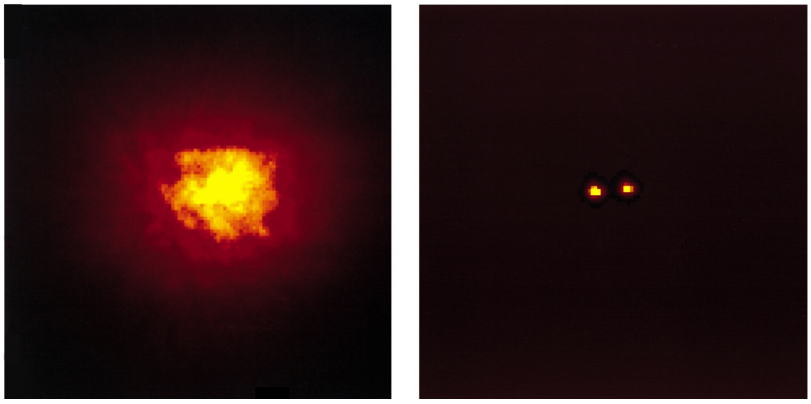
Refractors: Objective Lens
Reflectors: Primary Mirror

Area = $\pi R^2 = \pi (D/2)^2$

$LGA \propto R^2$

$LGA \propto D^2$

3. Resolving an Image



3. Resolution

Universe by Freedman, Geller, and Kaufmann

Resolution is a how small **an angle** the telescope can detect.
It is a function of the *wavelength observed* and the *diameter* of the telescope.

$$\alpha = (1.22)\,(206265)\,\lambda / D = \mathbf{2.5 \times 10^5\,\lambda / D}$$

α is in arcseconds

Resolution Example

$\alpha = 2.5 \times 10^5 \lambda / D$

Georgia Tech's 20-inch (= 0.5 m) telescope

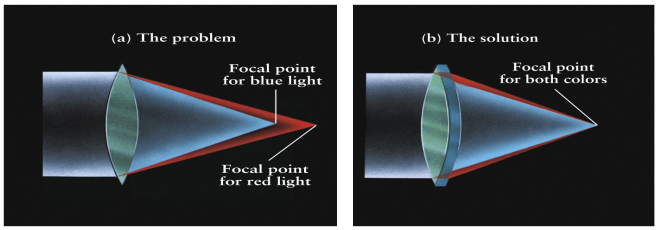
$\alpha = 2.5 \times 10^5 (500 \times 10^{-9} \text{ m}) / (0.5 \text{ m}) = 0.25 \text{ arcsec}$

The atmosphere limits all telescopes to a resolution of ~1.0 arcseconds.

Formulae

Magnification	$M = F / f$
Light Gathering Ability	LGA $\propto R^2$ (or D^2)
Resolution	$\alpha = 2.5 \times 10^5 \lambda / D$

Chromatic Aberration



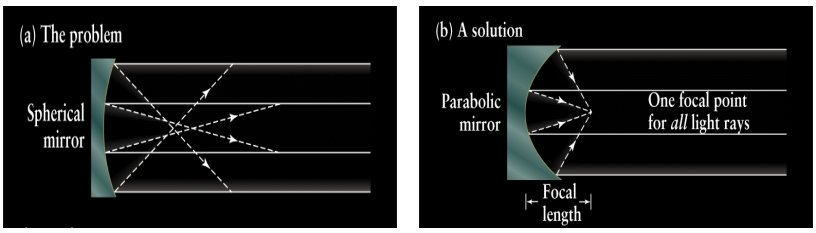
Universe by Freedman, Geller, and Kaufmann

Different Wavelengths are brought to a Different Focal Point.

The solution is to add different types of material and different shapes together.

(Only affects **Refracting** Telescopes.)

Spherical Aberration



Universe by Freedman, Geller, and Kaufmann

Different Reflections are brought to a Different Focal Point.

The solution is to use a **Parabolic Mirror**.

(Only affects **Reflecting** Telescopes.)

Comparison

Lens	Two sides to grind and polish
Mirror	One side to grind and polish
Lens	Light must travel through the glass
Mirror	Light only interacts with the surface
Lens	Only supported around the edge
Mirror	Supported on back and sizes; therefore, larger

Formulae

Magnification	$M = F / f$
Light Gathering Ability	$LGA \propto R^2$ (or D^2)
Resolution	$\alpha = 2.5 \times 10^5 \lambda / D$