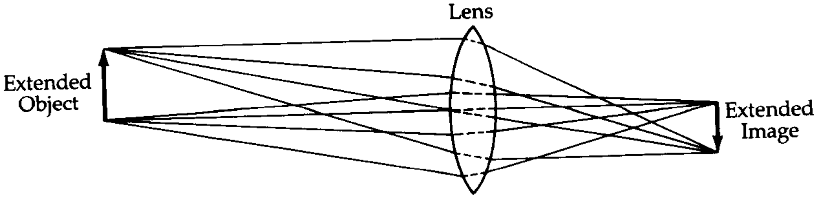
Telescopes and Detectors

Telescopes

Gather light and make an image



$$\frac{1}{o}+\frac{1}{i}=\frac{1}{f},$$ *f* = focal length, *o* = object distance, *i* = image distance.

The objective is either a lens or a mirror => refracting or reflecting telescope. May have two lenses/mirrors in general.

Reflectors: disadvantage - focus in front of mirror blocks light, but advantage - can support a large (heavy) objective from behind.

Important Properties of Telescopes

f ratio = *f/d*, *f* ratio increase (decrease) => brightness decrease (increase). For bright objects like Sun, Moon, planets, nearby stars, use high *f* ratio, *f*/12 or above. For faint objects like galaxies, nebulae, use *f*/6 or below.

Resolving power RP = $1/\theta_{min}$; $\theta_{min} = 1.22\ \lambda/d$ for circular aperture, but θ_{min} also limited by atmospheric turbulence.

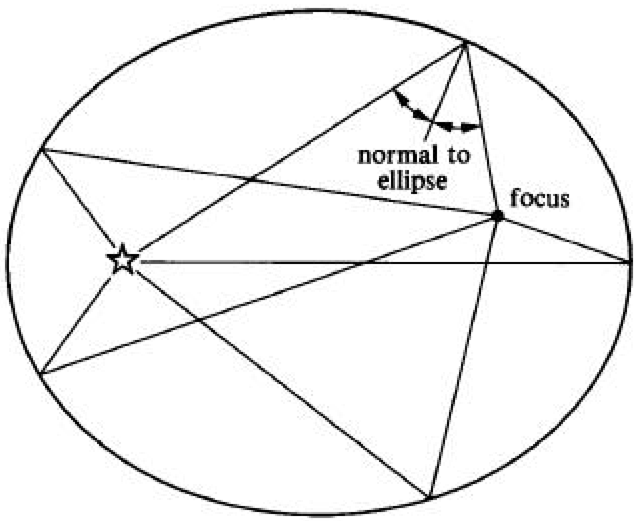
Light gathering power LGP, a relative measure of collecting area.

Hubble Space Telescope $d_{\text{primary mirror}}$ = 2.4m => θ_{min} = 0.05" for λ=500 nm.

Hale Telescope, Mt. Palomar *d* = 5m

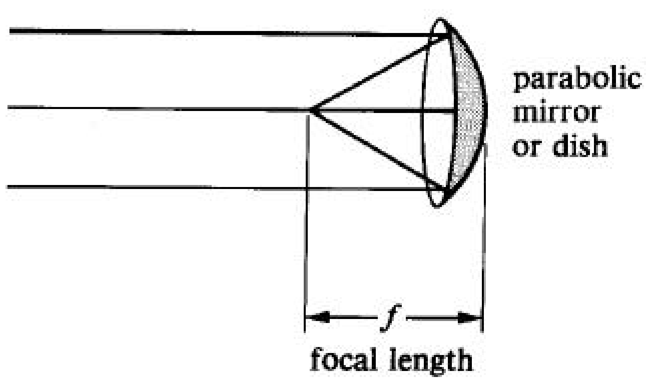
Keck Telescopes, Mauna Kea *d* = 10m => LGP = 4, 17.4, vs. Hale, Hubble, respectively.

The Principle of Parabolic Mirrors



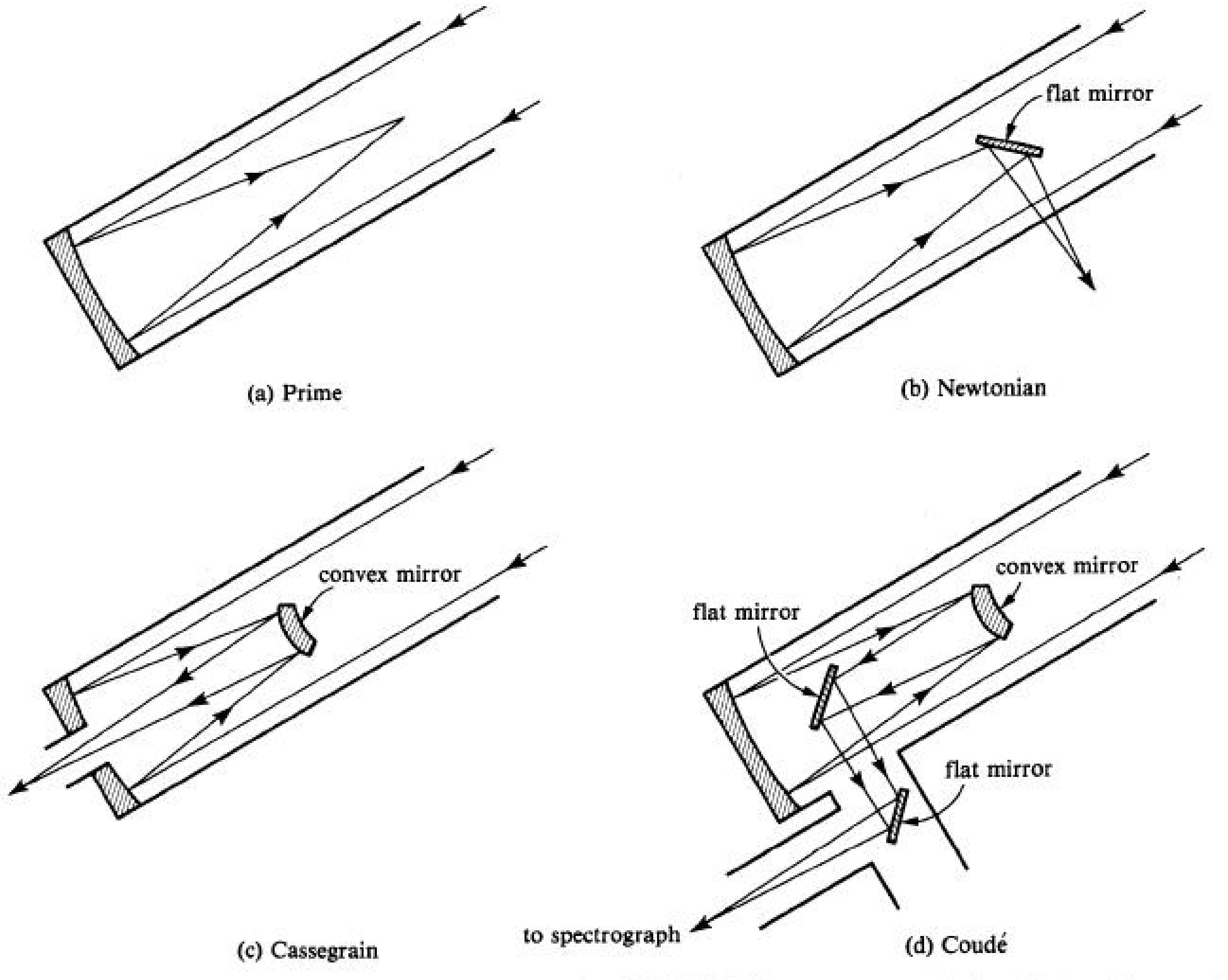
Elliptical spheroid => brings light from one focus to the other.

An optical or radio reflecting telescope is essentially one part of a giant imaginary ellipsoid. Light source (first focal point) is essentially at infinity => telescope surface is a paraboloid.



Surface irregularities must be smaller than a fraction of the wavelength being imaged.

Types of Reflecting Telescopes



Detectors

Signal to noise S/N = $\langle N \rangle / s_M$, where $\langle N \rangle$ = mean # of photons and $s_M = \langle N \rangle^{1/2}$ is the standard deviation of random errors in the counting of photons.

=> S/N = $\langle N \rangle^{1/2}$.

$\langle N \rangle = f_p \times t \times$ QE, where

f_p = # photons/time received (proportional to Area)

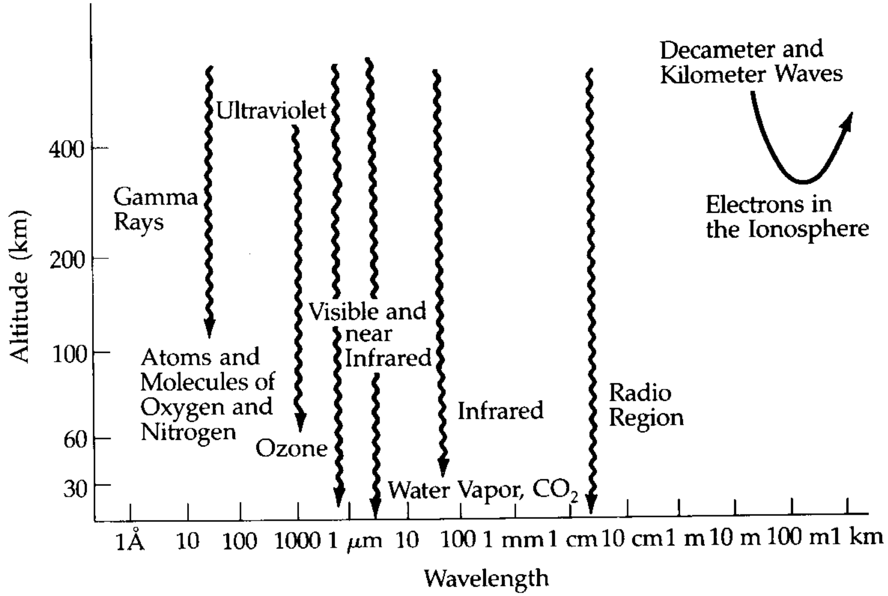
QE = Quantum efficiency = fraction of photons actually detected

Human eye, QE ~ 0.01

Photographic plate, QE ~ few x 0.01

Charge-coupled device (CCD), QE ~ 1.0

Non-optical Wavelengths



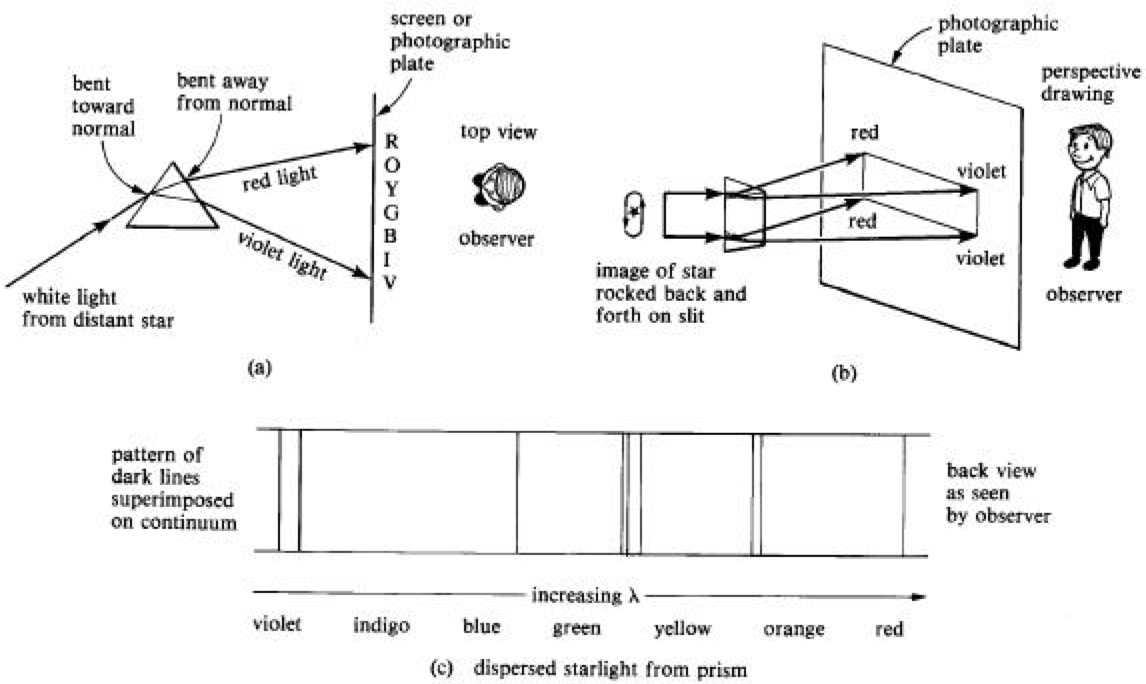
Radio: $\lambda \sim 10^5$ times visible => $\theta_{min} = \lambda/d$ very large => interferometry with multiple dishes of separation $a >> d$.

Infrared: observe at high altitude, avoid atmospheric H_2O.

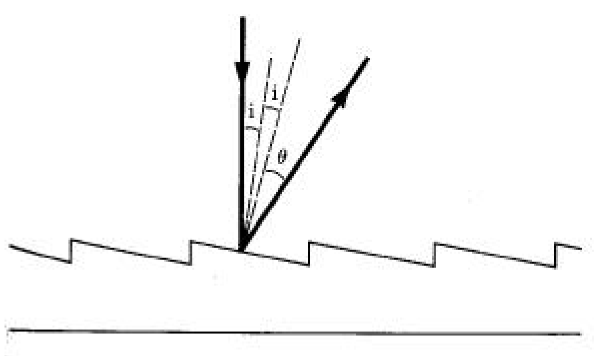
UV, X-ray, gamma ray, most infrared: space based observatories.

Spectroscopy

Analyze spectral distribution of light and spectral line profiles

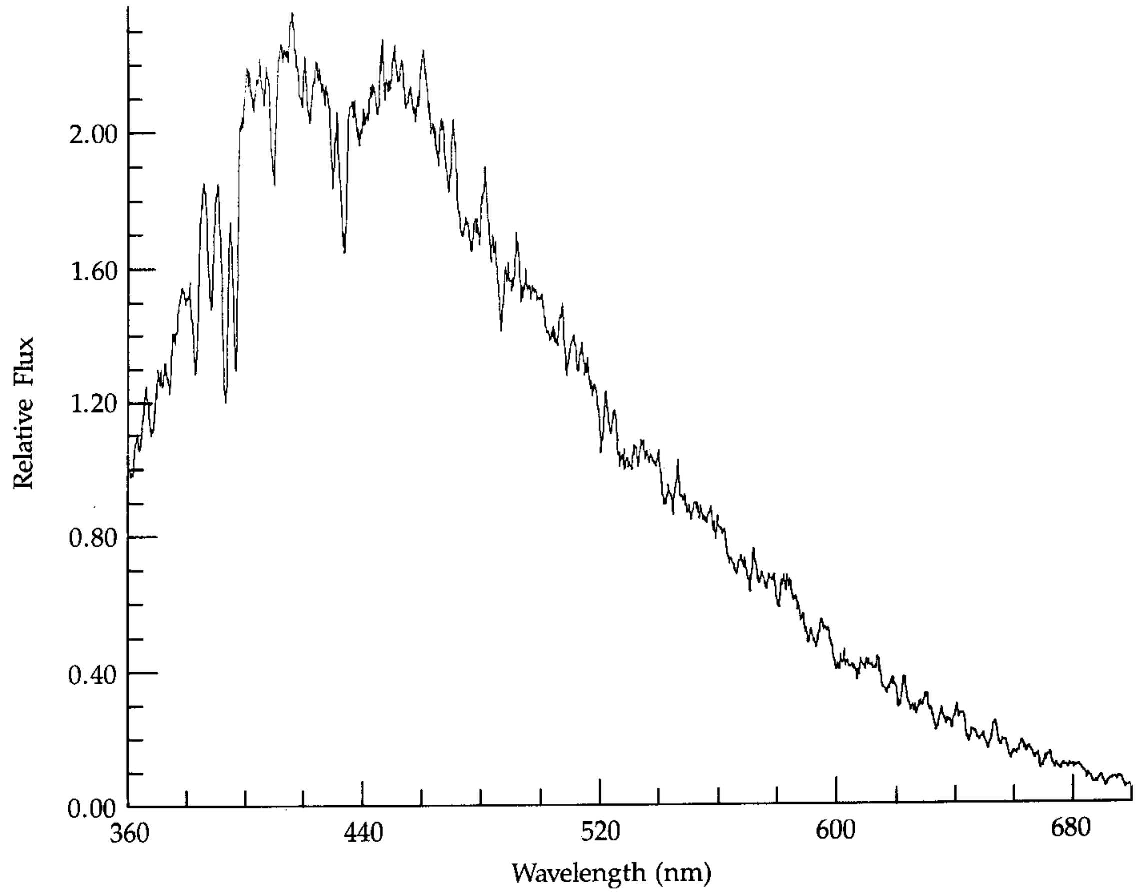


<= Prism spectograph



Grating spectrograph: etched grooves act like multiple slits => interference, i.e., different λ's add constructively at different locations => generate spectrum.

Spectroscopy



Spectrum of a solar-type star.

Blackbody spectrum with prominent absorption lines.