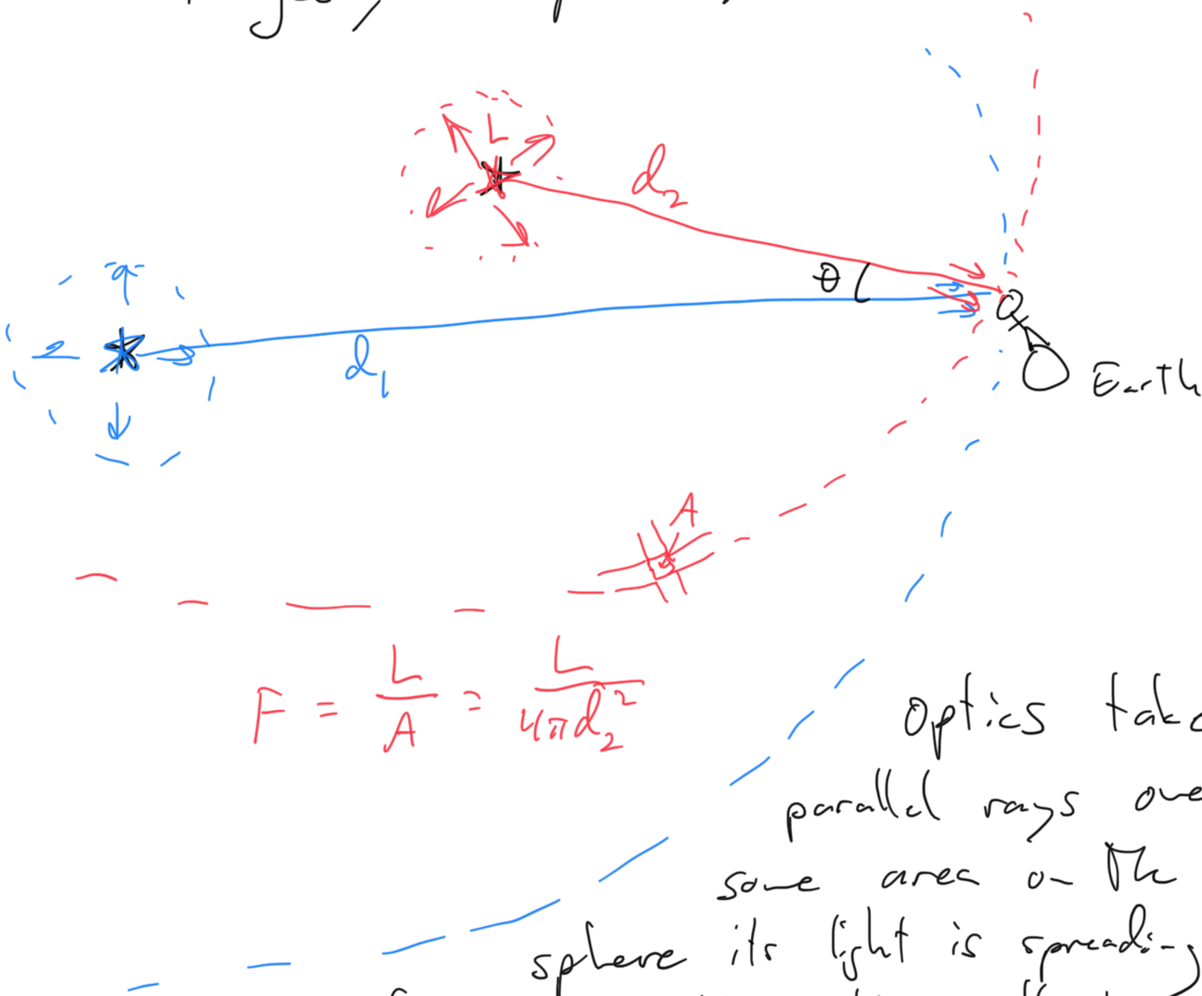
ASTR 3070 Week 5 (Ch 6)

Telescopes collect light, maybe makes images, or spectra, or both



$$F = \frac{L}{A} = \frac{L}{4\pi d_2^2}$$

Optics take parallel rays over some area on the sphere its light is spreading out from & puts it in the smallest area possible on a detector

- Two stars (or sources of light generally) will get imaged $\underline{x}$ distance apart, given by the <u>plate scale</u>

$$\frac{r}{F} = \theta \text{ (radians)} \quad \text{[small-angle approx}$$

$$= \frac{\theta \text{ (arcsec)}}{206{,}265 \text{ [arcsec/rad]}}$$

plate scale $s = \frac{\theta}{r} = \frac{206{,}265}{F}$

→ larger focal lengths F have smaller s → angular separation θ translates to smaller physical size on detector r

Actual size of point (∞ small) source depends on telescope's <u>angular resolut</u>

$$\theta_{min} \cong 1.22 \frac{\lambda}{D}$$

λ → wavelength

D → telescope diam

↳ determined by diffraction

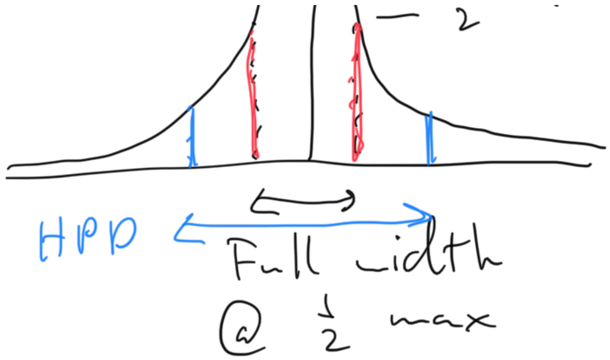
Cross-section of unresolved source

↓ "point spread function" or PSF

Half-power diam

HPD → diameter w/in which ½

of the photons la…



FWHM → 2 pixels ideal to sample PSF

[telescopes on ground may be limited by other factors]

<u>Spectrograph</u>: spreads light into a spectrum

<u>Imager</u>: collects all light allowed by filters

<u>Detector</u>: thing that records light

Measurements

Photons arrive randomly

↳ follows a Poisson dist.

if … expect 9 photons in 10s

If you expect 9 photons,

the actual # you get is $9 \pm \sqrt{9}$

9 ± 3

$\text{Rate} = \frac{N}{t_{exp}}$, "error" $\sigma = \frac{\sqrt{N}}{t_{exp}}$

How does this relate back to flux & luminosity?

$L \rightarrow J/s$, $F = \frac{L}{A} \rightarrow J/s/m^2$

☆ What is the area?

"effective" area of the telescope aperture

$F = [\#\text{photons} \cdot E_{photon}][\text{exposure time}^{-1}]$

J, s^{-1}

$\times [\text{collecting area}]$

m^{-2}

Signal-to-noise $\frac{S}{N}$ is the ratio of flux to the uncertainty in that flux

$$\frac{S}{N} = \frac{F}{\sigma_F} = \frac{\#_{photons} \cdot E_\gamma / t_{exp} / A_{eff}}{\sqrt{\#_{photons}} \cdot E_\gamma / t_{exp} / A_{eff}}$$

$$= \sqrt{N}$$

If you detect 100 photons in 100s w/ a 1m diameter tele

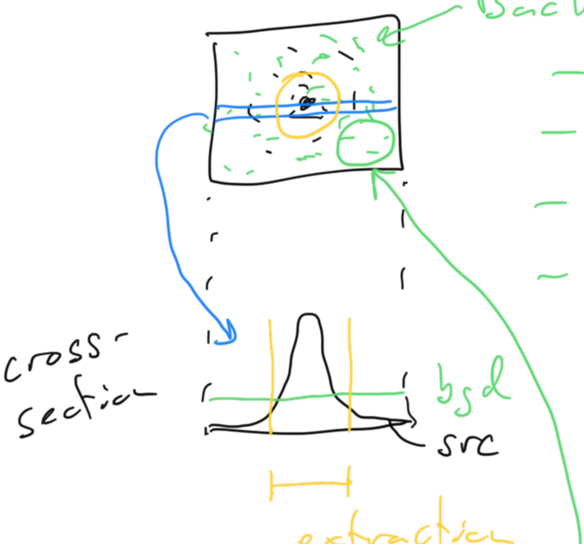
$N = 100$, $\sigma_N = 10$

$$\frac{S}{N} = \frac{100}{10} = 10$$

$$F = \frac{(100 \pm 10) \cdot E_\gamma}{t_{exp} \cdot A_{eff}}$$

$$= \frac{(100 \pm 10) \cdot h\nu}{100s \cdot \pi \left(\frac{1m}{2}\right)^2}$$

BUT, usually extra noise present



Background
- detector noise
- sky brightness
- cosmic rays
- Galaxy or zodiacal light

T = Total counts

B = Bgd counts

region

BGD region — used to estimate bgd le

$$S = T - B$$

For independent processes, can add uncertainties in quadrature

$$\sigma_{comb.}^2 = \sigma_S^2 + \sigma_B^2$$

Noise $\sigma_{comb.} = \sqrt{\sigma_S^2 + \sigma_B^2}$

$$\frac{S}{N} = \frac{T - B}{\sqrt{\sigma_S^2 + \sigma_B^2}}$$

S & ↳ B $\qquad S + B = T$

$$\frac{S}{N} = \frac{T - B}{\sqrt{T}}$$

– consider the rates μ_T, μ_B "$\frac{T}{t_{exp}}$" $\frac{B}{t_{exp}}$

$$\frac{S}{N} = \frac{(\mu_T - \mu_B)\, t_{exp}}{\sqrt{\mu_T\, t_{exp}}} \propto t_{exp}^{1/2}$$

if $\mu_B \gg \mu_S$, then in the "bgd-domin[ated]

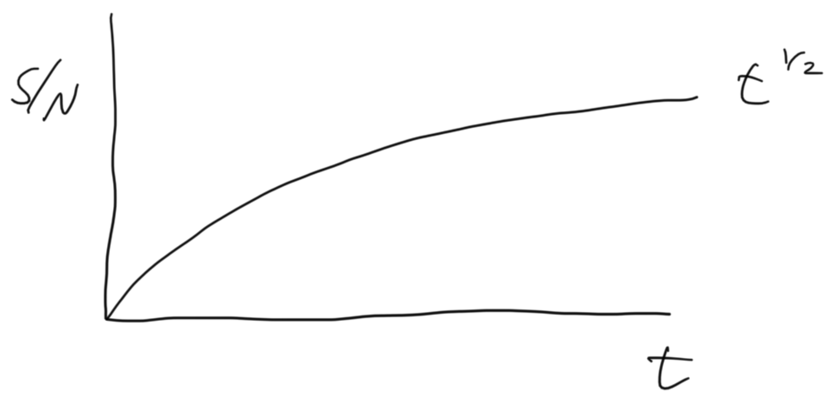
regime"

Let's say you want to **detect** stars

w/ some minimum flux → what does

this mean?

→ have a min. S/N, say 3



$$\frac{S}{N} \simeq \frac{\mu_S}{\mu_B^{1/2}} t^{1/2} = \text{const}$$

$$\mu_S \propto F_S \propto t^{-1/2}$$

Longer you observe, can see fainter

stars, but to go 2x deeper in flu[x]

need to observe 4x longer

☆ For this reason, we make telescope

... bigger & bigger!