Telescope Types

courtesy Zach Dickeson
Telescope Types

- Prime focus
- Newtonian
- Cassegrain
- Gregorian
- Schmidt-Cassegrain
- Schmidt Camera
- Maksutov
- Refractor
Image formation from an ideal thin lens

If a lens has a focal length $f_L$, a star on the sky positioned at a distance $\alpha$ from the optical axis will be offset by a distance $s$ in the focal plane where

$$s = f_L \tan \alpha \approx f_L \alpha$$

in the small angle approx.*

So the image plane has a plate scale $\alpha/s = 1/f_L$. This has units of radians/length, so in practical applications, you’ll need to convert to arcsec/mm on the detector.

* remember, when you see a bare angle in a formula, it should be measured in radians, not degrees!
Figure 5.1. The focusing characteristics of an ideal thin lens. The focal length \( f_L \) and the aperture \( d \) are each measured in meters. (a) Parallel beam arriving along the lens axis, and focusing at distance \( f_L \). (b) Off-axis parallel beam (small angle \( \alpha \)) also converging at distance \( f_L \), but displaced a distance \( s = f_L \tan \alpha \) from the lens axis. (c) Extended source subtending angle \( \alpha \) and depositing, in a fixed time, energy \( E_p \propto (d/f_L)^2 \) onto a single pixel of the image plane.
Telescope/Camera “Speed”

For an **extended** source (galaxy, nebula), the light from the source is deposited over an area that scales as $1/s^2$ (where $s$ is image size on the detector). So as the plate scale goes up (size on detector gets bigger), the energy **per pixel** on your detector drops. So it takes longer to detect an object.

But if the telescope has a big aperture, it collects a lot of light. Light collecting scales as $D^2$.

So the total energy collected per pixel scales as:

$$E/\text{pix} \sim D^2/s^2 \sim D^2/f_L^2$$

We can define the focal ratio as $R = f_L/D$, which is written as “f/R”. Then energy per pixel scales as: $E/\text{pix} \sim 1/R^2$.

**Telescope “beam speed”**

f/4 : “Fast beam”, since E/pix is large and you can build up signal fast.

f/16 : “Slow beam”, since E/pix is small and takes time to image extended sources.
The importance of pixel scale

Pixel scale: like plate scale, but for CCD pixels. The size of a pixel on the sky, in arcsec.

Big pixels
- Good for faint, extended sources: lots of light per pixel.
- Implies large field of view for the CCD
- But gives poor spatial resolution

Small pixels:
- Good for stars: accurately measures the seeing (aka “point spread function”) for doing accurate photometry
- Gives the best spatial resolution.
- But small pixels mean less light per pixel: exposure time goes up.

Always want the best resolution that the telescope and conditions can deliver.
- “Nyquist” sampling: 2 samples per highest frequency of data.
- If the seeing is 1 arcsec, no need for pixels much smaller than 0.5 arcsec or so.
- When do you need smaller?
  - Space based imaging (no atmosphere)
  - Ground-based adaptive optics (better resolution)