Calibration Images

① Biases

* **No** light in aperture, **no** exposure time
* Characterizes inherent noise

② Darks

* No light in aperture, **some** exposure time
* Characterizes thermal noise (dark current)
* Usually at least as long as your longest exposure science image

③ Flats

* Some light, some exposure
* Want an evenly-bright frame; normalizes
* Only need enough exposure to get similarly-bright pixels across entire frame

Combining astronomical images

① Take median of all bias frames b_n to get total bias B:

$$B = \text{median}(b_1, \ldots, b_n)$$

② Take median of dark frames d_n and subtract total (median) bias, then divide by the exposure time of each dark frame to get the total dark D:

$$D = \frac{\text{median}(d_1, \ldots, d_n) - B}{t_{dark}}$$

Notes on darks:

* CCD temp must be the same for all darks
* Only need one series of darks per night if you assume dark current is linear
* For very precise photometry (i.e. exoplanet transits), you'll need a new set of darks for every exposure

③ Subtract total bias and total dark from <u>each</u> flat f_n, multiplying the dark by the exposure time of the flat. Then, divide by the median pixel value to normalize, and take the median of the normalized flats F_n to get the total flat F:

(a) $$f_n' = f_n - B - Dt_{flat}$$

(b) $$F_i = \frac{f'_n}{median(f'_n)}$$

(c) $$F = median(F_1, \dots, F_n)$$

<u>Notes on flats:</u>

* Values should all be ~1 after processing
* Different flats necessary for each filter

④ For each science image S_i, the total science image S is given by

$$S = \left(\frac{S_i - B - Dt_{science}}{F} \right)$$

where $t_{science}$ is the exposure time.