A Non-Standard but Cleaner Approach to Image Calibration

We presume that pixel i has the following response:

$$O_i = \alpha_i I_i + \beta_i T + \gamma_i$$

For the lights $I_i = L_i$, $O_i = O_{L,i}$
for the flats $I_i = F$, $O_i = O_{F,i}$

T is the exposure duration. α_i, β_i, and γ_i are unknown, pixel-dependent constants. F is also unknown, but its important feature is that it is pixel-independent.

We choose to expose our darks for the same duration T as the lights. The darks have $I_i = 0$ and $O_i = O_{D,i}$

Because the darks have the same T, if we subtract, the $\beta_i T$ and the γ_i terms disappear, and we learn

$$O_{L,i} - O_{D,i} = \alpha_i I_i$$

For our biases, we choose the same exposure time as the flats. This time is usually quite short relative to T! For example, the lights and darks might have $T = 30s$. Our darks and biases typically have exposure duration $t = 1s$.

$$O_{F,i} = \alpha_i F + \beta_i t + \gamma_i$$

$$O_{B,i} = \beta_i t + \gamma_i$$

We subtract and learn

$$O_{F,i} - O_{B,i} = \alpha_i F$$

Now we divide and learn

$$\frac{O_{L,i} - O_{D,i}}{O_{F,i} - O_{B,i}} = \frac{\alpha_i I_i}{\alpha_i F} = \frac{I_i}{F}$$

We call the LHS the calibrated image.

$$C_i \equiv \frac{O_{L,i} - O_{D,i}}{O_{F,i} - O_{B,i}}$$

It still has the unknown F in it, but because F is pixel-independent, If we consider another pixel, j, then

$$\frac{C_j}{C_i} = \frac{I_j / F}{I_i / F} = \frac{I_j}{I_i}$$