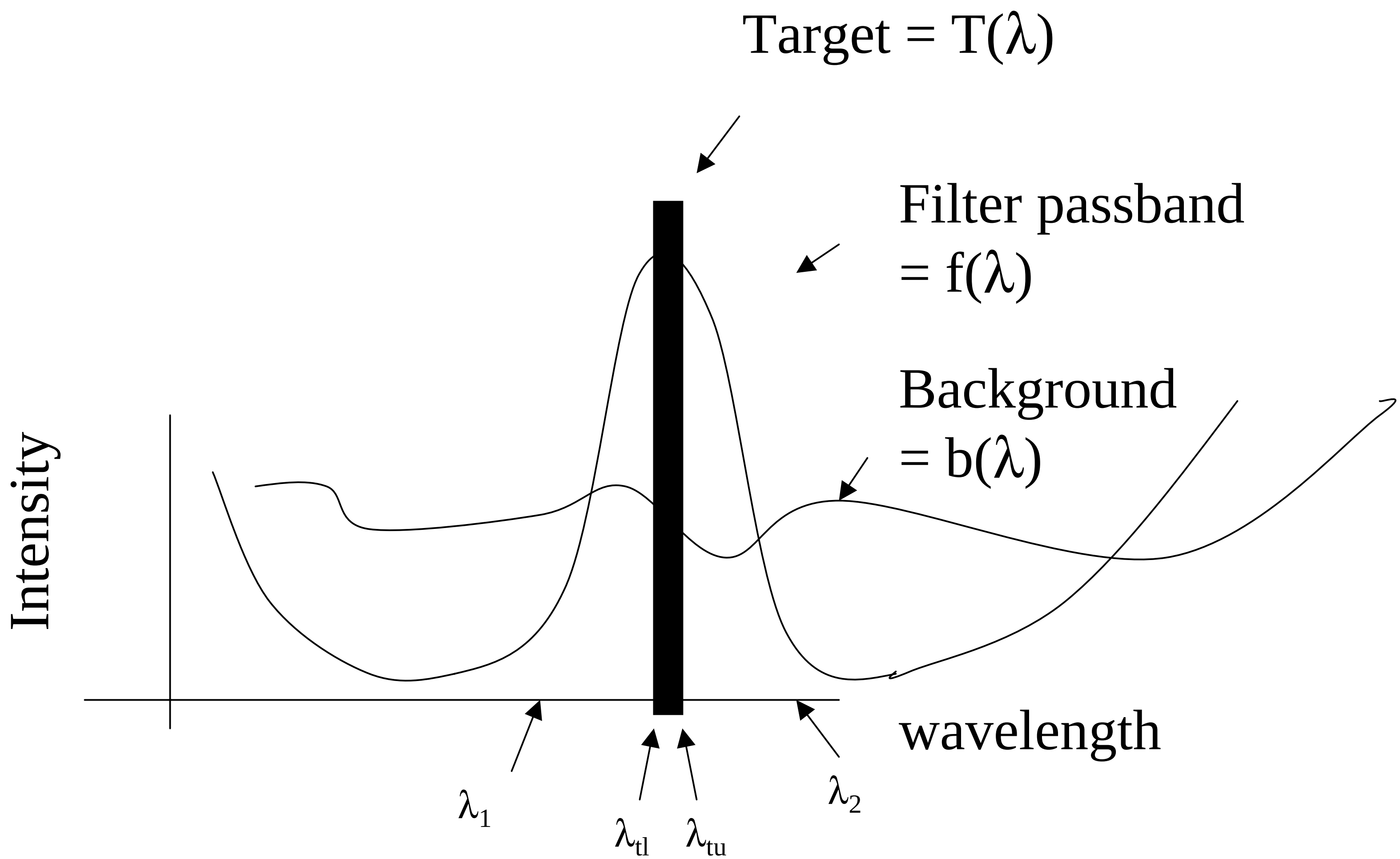
Signal to noise comparisons using empirical data

Goal: develop a method to calculate the signal to noise ratio of each pixel using empirical data.



R.Crisp 3/31/2007

$$\text{Signal\_to\_noise\_ratio} = \text{SNR}^{(2,3)} = \frac{\text{Signal}}{\text{Noise}} = \frac{\int_0^\infty f(\lambda)s(\lambda)d\lambda}{\left(\int_0^\infty f^2(\lambda)b^2(\lambda)d\lambda + N^2\right)^{1/2}}$$

where:

$s(\lambda)$ = signal(λ)
$f(\lambda)$ = filter response(λ)
$b(\lambda)$ = background(λ)
N = system read noise

(2) W. D. Montgomery, "Some Consequences of Sampling in FLIR Systems", Institute for Defense Analyses, Arlington, Va. , Research Paper P-543, September 1969
(3) W. D. Davenport and W. L. Root, "Random Signals and Noise" McGraw-Hill, New York, N.Y., 1958.

Application of the Theory

$$\text{SNR} = \frac{\int_0^\infty f(\lambda)s(\lambda)d\lambda}{\left(\int_0^\infty f^2(\lambda)b^2(\lambda)d\lambda + N^2\right)^{1/2}}$$

Example 1:

$\int_0^\infty f(\lambda)s(\lambda)d\lambda = 311.3(e-)$ = Pixel value(x,y) measured from image (in electrons)

$\int_0^\infty f(\lambda)b(\lambda)d\lambda = 50.58(e-)$ = Reference background Pixel value(x,y) measured from image (in electrons) (use the average value for a 25 x 25 pixel box free of stars, galaxies or nebulae)

Read Noise = 10(e-)
SNR = 6.0377

	CS Ha (3nm)	AD Ha (6nm)	CS O3(3nm)	AD O3 (6nm)	CS S2 (3nm)	AD S2 (6nm)
Target e-	311.3	461.67	81.08	169.25	83.25	135
Bkgd e-	50.58	84.83	58.25	136.36	48.91	92.08
read noise e-	10	10	10	10	10	10
SNR	6.037736446	5.404871901	1.37186243	1.23787554	1.66760748	1.457546302

Example 2:

$\int_0^\infty f(\lambda)s(\lambda)d\lambda = 461.3(e-)$

$\int_0^\infty f(\lambda)b(\lambda)d\lambda = 84.83(e-)$

Read Noise = 10(e-)
SNR = 5.40(e-)

By working with empirical data, this overcomes the concerns about evaluating difficult integrals since nature has done the integrations for you by the time you receive the data from the object to your ccd detector through the optical system. You use the analytical expression for design optimization and the empirical data for system characterization (optics, camera, filters, sensors, cooling etc)