Simple Estimate of a Signal-to-Noise ratio

Let S_o and S_s be the object and sky photon counts per pixel per unit time.

For an observing time t on an aperture with n_{pix} pixels, the numbers of photons are

$$n_o = S_o \, t \, n_{pix} \qquad \text{for object}$$

$$n_s = S_s \, t \, n_{pix} \qquad \text{for the sky}$$

Assuming that the sky has poissonian noise, we have the expression for noise:

$$N_{sky} = \sqrt{n_s} = \sqrt{S_s \, t \, n_{pix}}$$

Then the signal-to-noise ratio is given by

$$\frac{S}{N} = \frac{n_o}{N_{sky}} = \frac{S_o \, t \, n_{pix}}{\sqrt{S_s \, t \, n_{pix}}} = \frac{S_o}{\sqrt{S_s}} \sqrt{t \, n_{pix}}$$

$$\Rightarrow \frac{S}{N} \propto \sqrt{t}$$