be measured. Electron-hole pairs are also created thermally within the material ("dark current").

When a CCD is "read-out" the charge-packet corresponding to any individual pixel is transferred pixel-by-pixel along columns until they reach the horizontal register. They are then transferred down this register and each charge packet is measured one at a time. There are both systematic and random deviations in the detection of photons from pixel-to-pixel and from deviations during the process of read-out.

6.1.1 : Gain and Readout-Noise

Calibration of the inverse gain or electrons per digital number ($e^-/DN$) allows the estimation of errors due to Poisson counting statistics. Since there is approximately one electron for every photon ($\gamma$) detected, the number of independent discrete unitd of measure is simply the number of electrons, so the Poisson error is $\simeq \sqrt{e^-}$. There is an additional error on every pixel due to the process of measuring the charge packets, called the read-out noise.

To measure the read-out noise and $e^-/DN$, we take multiple zero exposure time frames (bias frames) with (in principle) zero incident light and zero dark current. From each pair of frames we can estimate the variance of the read-out noise in $DN$ by subtracting the frames and calculating the root-mean-square. Let us call this read-out variance $rov$.

We also divide two uniform light source exposures ("flat-fields") and calculate the root-mean-square in $DN$, let us call this $rms$. To obtain the $e^-/DN$ we consider the equation for the error derived from counting or Poisson statistics: $\sigma^2 = (counts)/(e^-/DN) + rov$. If the mean counts ($DN$) in the two flat-fields are A and B, and the division is D=A/B, then the equation for the $e^-/DN$ is: $[A + BD^2]/[B^2(rms) - (rov)(1 + D^2)]$. The read-out noise in electrons is then: $\sqrt{[(rov)(e^-/DN)]}$.

Note that since we are assuming counting statistics above, what we actually measure is $\gamma/DN$. The assumption of 1 $e^- \simeq 1\ \gamma$, gives us $e^-/DN$. In the far ultraviolet, this