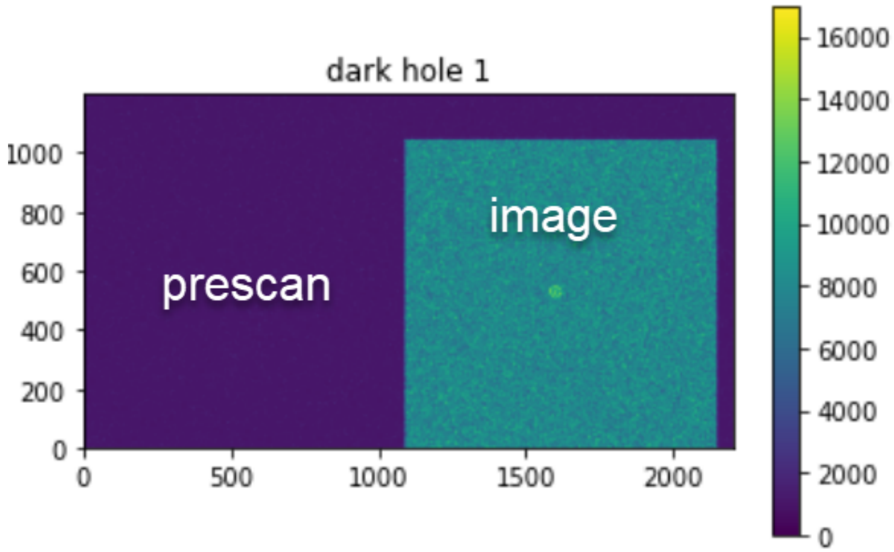
Calibrating electron multiplication gain and clock induced charge for the Roman Coronagraph detector

Bijan Nemati
Tellus1 Scientific
1/19/2023

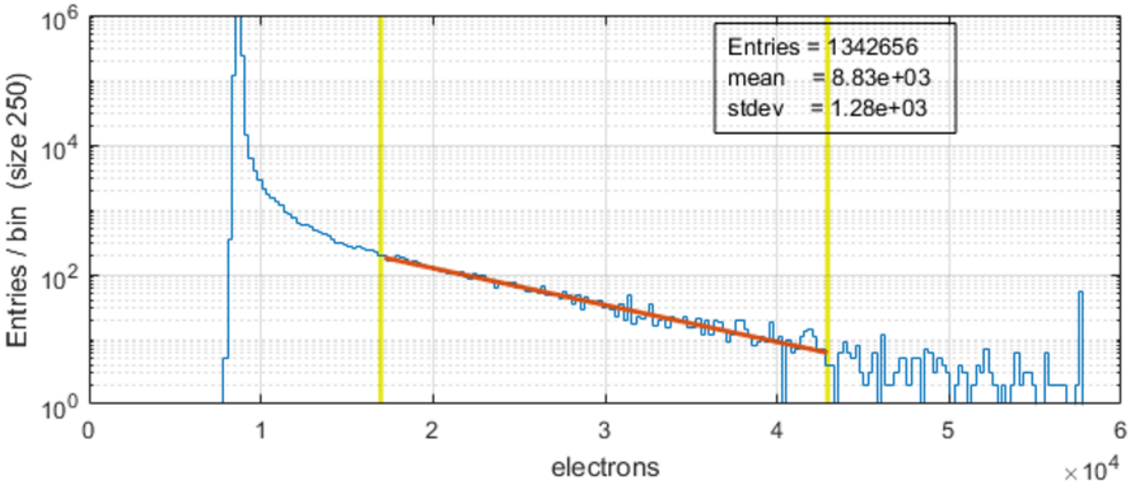
Accurate knowledge of the electron multiplication (EM) gain is necessary for obtaining a correct estimate of the EMCCD generated images processed as ‘analog’ (proportional) frames. In these cases the collected images are divided by the known EM gain to obtain the image, in electrons, as generated on the sensor. To a lesser extent, photon-counted frames also depend on EM gain. This is because the thresholding efficiency is a function of the applied EM gain, so correcting ‘back’ requires calibration of EM gain. The simplest way to obtain the gain, when it is high (that is, numerically at least a few times the read noise in electrons) is to use the ‘prescan’ part of the raw frames from CGI. These appear on the raw frame as an extended portion of the CCD image area but are really readings of the part of the serial register that need to be flushed out before each row of the CCD could be read out.



The clocking of this serial register occasionally creates ``clock-induced charge’’ (CIC), at a rate much less than 1 electron per pixel per frame. These CIC electrons go through the gain register and result in an EM amplified signal. Since the EM gain process has a distinct probability distribution function (Basden 2003), fitting a histogram of the observed serial prescan CIC counts to the known distribution can provide both the EM gain and the average CIC rate.

Complicating this fit are two additional distributions. The first is read noise, which is essentially a zero-mean Gaussian. Most of the serial prescan pixels have no CIC electrons and no EM amplification, and these pixels only show read noise. The second is more challenging, as it arises from CIC events that initiate *inside* the gain register. These events, which almost always are single-electron at origin, get amplified partially, and are called *partial CIC* events. Since they do experience some EM gain, partial CIC events have a tail that extends into the high-counts region. As a result, a fit to the high-counts part of the histogram that would otherwise have been purely serial CIC events with the same expected gain is now polluted with partial-gain events. This causes a systematic error in the calibration of the EM gain.

Below is a histogram of prescan counts after EM gain, on a log scale. The peak is read noise, and the 'shoulder' is partial CIC. The yellow vertical lines represent minimum and maximum limits for a fit. The line fit to the histogram can be used to obtain the EM gain.



For the threshold demonstration, these effects are tolerable, but going beyond threshold more sophisticated calibrations are needed.

A simple model of partial CIC assumes that the probability of the random CIC event is uniform across the entire EM register. There are 604 'gain stages' in the EM register. The first stage of the EM register virtually sees the full EM gain, and the last stage sees almost no EM gain, with all the intervening pixels seeing intermediate gains. A normalized probability distribution made of the sum of all these 604 probability distributions is a first approximation to the partial CIC probability distribution.

A maximum likelihood fit to all the observed counts in the prescan, incorporating a minimum threshold, and the probability distributions for read noise partial CIC and full CIC should give a better estimate of the EM gain than a simple fit to the full CIC with a very high minimum threshold.

References

A. G. Basden, et al., *Photon counting strategies with low-light-level CCDs*,
Mon. Not. R. Astron. Soc. 345, 985–991 (2003)