Hawkeye Linearity with Light Level

Alan Holmes

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Overview: the Hawkeye CCDs seem to have some non-linearity of response as the light levels increase. In this report we quantify this non-linearity and derive a correction term to linearize the data. This is different from exposure time linearity, which is discussed in a different report, whereby the effective exposure time is a function of both exposure time and row rate (interval time).

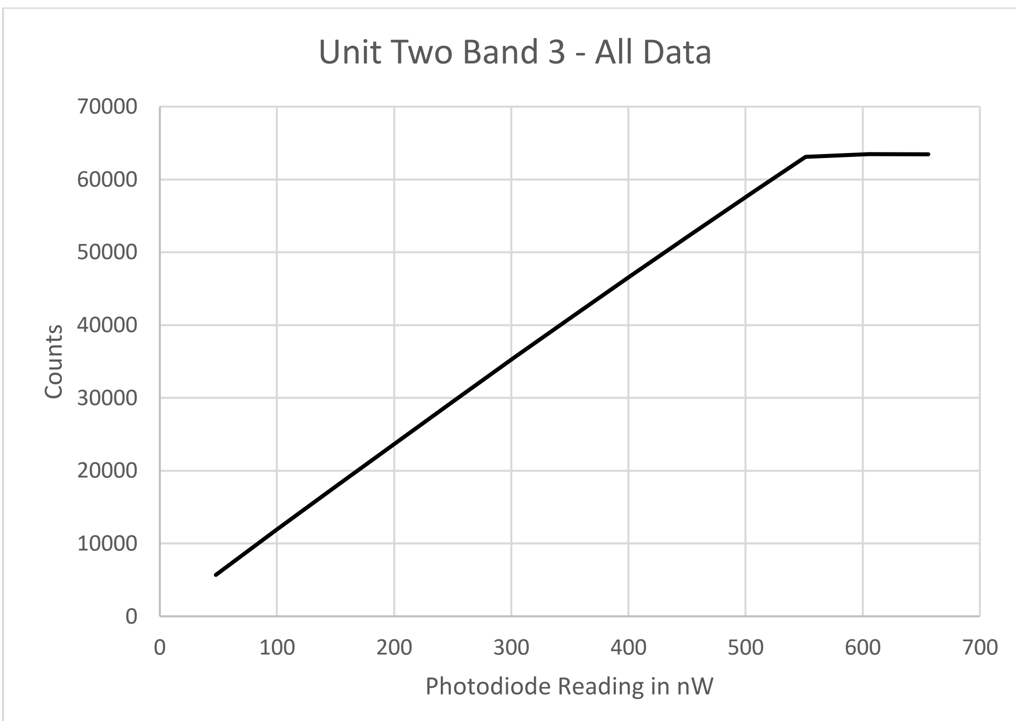
Measurement: the linearity of the CCDs to varying light levels was measured using the NASA integrating sphere. The setup is shown in Figure One below.

Figure One: Linearity Measurement Setup

The sphere is illuminated using a LED-Based microscope illuminator projecting light through the front aperture. The light level is monitored by a Newport Research Model 1830-R photodiode based light meter viewing the sphere. The photodiode is contained in a housing that restricts the viewing angle to an F/5 cone, and also holds a narrow band filter identical to the filter in the instrument. The filter was changed to match the band under test. The instrument views the sphere though the gap between illuminator and photodiode. The room lights are off during this test, and exposures of up to 120 ms per line of data were required. The data was dark subtracted upon collection, which is a bit of a controversial step. Without dark subtraction the images were very striped due to hot pixels at these long exposures. Upon collection of each exposure with the instrument the file was saved with a file name containing the light meter reading. The light meter is specified to have 1% accuracy.

An example data set is shown in Figure Two. This are the results for Unit Two Band 3. Note that the CCD output is clearly close to linear at lower levels. The CCD output saturates at a level close to 65535, the maximum count for 16 bit detection. Since this is dark subtracted data the exact point at where the CCD hits the knee varies with temperature and band by a few hundred counts. Operationally any data point above 63,000 counts should be considered to be saturated, and of unknown actual value.

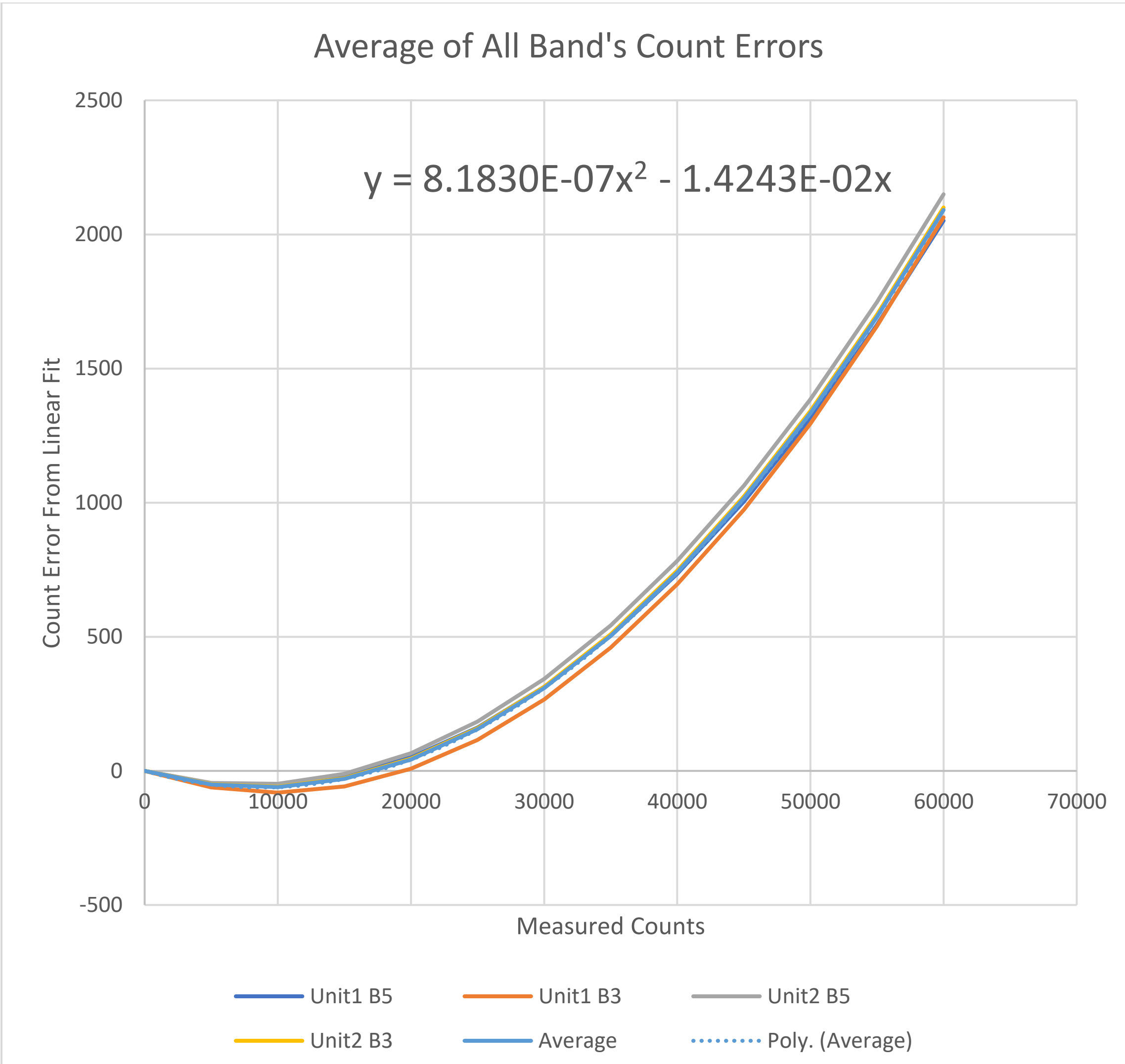
Figure Two: Unit Two Band 3 Linearity Data



Four bands were measured – Bands 3 and 5 for both units One and Two. We didn't test bands 4 and 6 because they are the same physical CCD as bands 3 and 5. The signal levels for bands 1 and 2 were too low for a good measurement, and likewise for bands 7 and 8 due to the white LED based illuminator. However, the four bands measured were very similar, and we think that a single correction algorithm will apply to all bands.

It is hard to see any error in Figure Two, but if you assume that the CCD is quite linear below 15,000 counts and extrapolate that line up to higher count levels you will see that the measured counts are about 3.5% low at 60,000 counts. The deficit for all measured bands is shown in Figure Three as a function of measured count level.

Figure Three: Count Deficit as a Function of measured Counts



Many schemes can be considered for developing an equation to correct this data, but what is shown in Figure Three is an equation for calculating the count deficit, which when summed to the measured counts, gives one an estimate of the “true” counts that would have been measured by a linear CCD. The maximum error here is about 100 counts at high levels, or 0.17%.

The files used for Unit Two data reduction are contained in the folder:

C:\FlightTwoCalibrationBackup\Alan3\Unit2\Linearity-Band35-062617

Unit One data is on a different computer and has not been archived yet.

As a side note, we did measure the gain and noise of all CCDs in a separate test, and the results for all bands are very similar. We measured an electronic gain of 2.0 electrons per count, and a read noise of

25 electrons for a single read. Note that the data subtraction values used are in general a sum of multiple reads, so this single read noise is appropriate. With 4:1 oversampling and aggregation of three chroma arrays this means our noise level in the dark is about 7.2 electrons, or 3.6 counts. At any reasonable light level (above 100 counts) this noise will disappear in the scene photon noise.