

Understanding the NICMOS Darks

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Abstract. This paper describes the characteristics of the “dark current” for the NICMOS flight detectors, namely the instrumental signal present in exposures made in the absence of any external illumination. We show how this comprises three distinct components — the shading, amplifier glow, and the true dark current. We then describe a recipe for generating “synthetic” dark current calibration reference files, which could in principle be used to generate darks for any arbitrary sequence of MULTIACCUM reads.

1. Introduction

Each readout of a NICMOS detector includes not only the desired detected signal, but also the signatures of the detector itself and the readout electronics, which would be present in the signal recorded during any exposure, even in the absence of any external illumination. These parts of the output signal must be removed to get the true detected signal.

2. Components of a NICMOS dark

2.1. Amplifier Glow

Each time the detector is read out, the readout amplifiers, which are situated near the corners of the detector, are turned on. These amplifiers emit IR radiation that is detected by the pixels in the detector — similar to having a small “light bulb” in each corner. This produces a pattern of light that is highest in the corners and decreases towards the center of the detector. This is known as “amp glow”.

A typical single readout produces about 20–30 ADUs of amp-glow in the corners of the detector, and 2–3 DN near the center (Figure 1). Since the readout time of the detector is the same each time (it takes 0.203 seconds to read the whole image), the on-time for the amplifiers is always the same for each readout, and thus the light pattern seen by the array is repeatable. So in a given readout, the amount of signal due to amp-glow in each pixel scales directly with the number of readouts since the last reset:

$$A(i, j) = a(i, j) * n_r \tag{1}$$

where $A(i, j)$ is the observed signal due to amp-glow in a given readout for pixel i, j , $a(i, j)$ is the amp-glow signal per readout (different for each pixel), and n_r is the total number of readouts of the array since the last reset. So in the corners of a full 26-readout MULTIACCUM there will be of order 500–800 ADUs due to amp-glow, along with the expected Poisson noise from this signal.

¹deceased

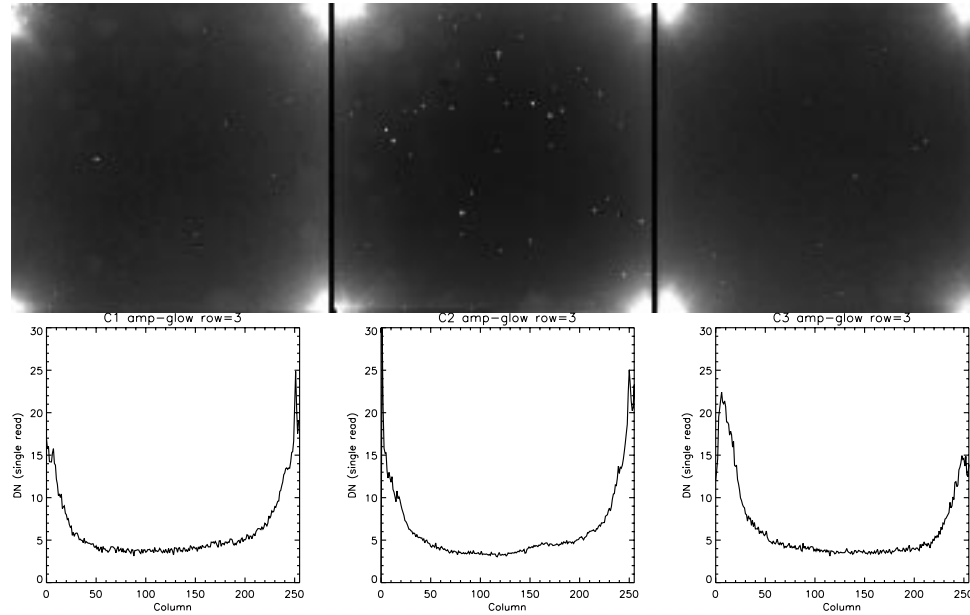


Figure 1. Amplifier glow for Cameras 1 (left) through 3 (right), on a uniform greyscale, and below a plot of row 3 (near the bottom) of each camera.

2.2. Shading

The bias level, or “DC offset”, in a given pixel in a NICMOS array is time-dependent. This is the so-called “shading”, which visually in an uncorrected image looks like a ripple and gradual signal gradient across a given quadrant. The pixels in a given quadrant of a NICMOS detector are read out sequentially. It takes a little over a msec to read a single pixel, and so with four readout amplifiers reading in parallel it takes just over 0.2 sec to read the entire 256×256 pixel detector. Considering a quadrant as an array of $i \times j$ pixels, the readout sequence consists of reading sequentially along a detector row i , clocking j from 1 to 128, then moving to row $i+1$ and clocking j from 1 to 128, and so on. Since the amplifier bias changes pseudo-exponentially with time over the course of the readout, the observed signal, in the absence of any external illumination, varies rather slowly along the rows (i), but rather rapidly along the columns (j). This signal is not accumulated in the pixels each readout, but rather is superimposed on the actual signal at the time of each detector readout.

The shading signal is not the same for each readout. Its amplitude and to some extent its shape (Figure 2) are a function of the time since a pixel was last read out (not reset). So readouts with the same DELTATIM (this is the keyword used in NICMOS data to denote the time since the previous readout) will have the same bias signal, for a given pixel. The dependence of this bias on DELTATIM is nearly logarithmic and quite repeatable (Figure 3), although there are some circumstances when this is not the case (namely in the MIF sequences it has been seen in on-orbit data that when changing from a very long DELTATIM to a very short one, the shading is not quite what is expected).

It should be possible to find a numerical fit to the shading function in DELTATIM for each pixel of each detector. Then it would be possible to predict what the bias signal is in any given pixel for any possible readout sequence. Another way to attack the problem is to make an average image of the bias for each of the DELTATIMs in the predefined MULTIACCUM sequences (Figure 4). Then to build a synthetic dark, the bias component can be had by using the bias image for each appropriate DELTATIM in the sequence:

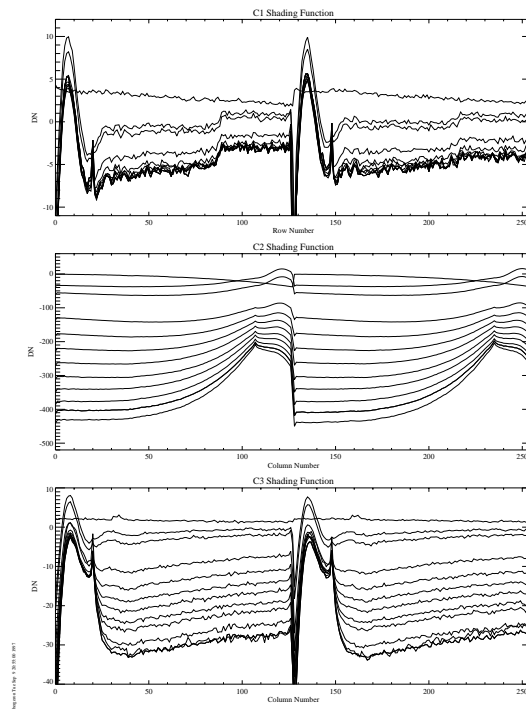


Figure 2. Representative shading functions in the slow clocking direction for each of the three detectors. These have been generated by taking medians along the fast clocking direction in order to improve S/N while filtering out bad pixels.

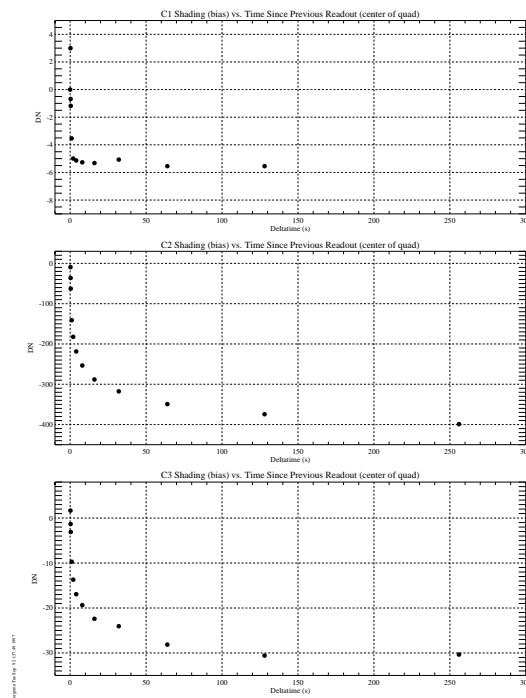


Figure 3. Amplitude of the shading signal vs. DELTATIM for a single representative pixel at the center of a quadrant for each of the three detectors.

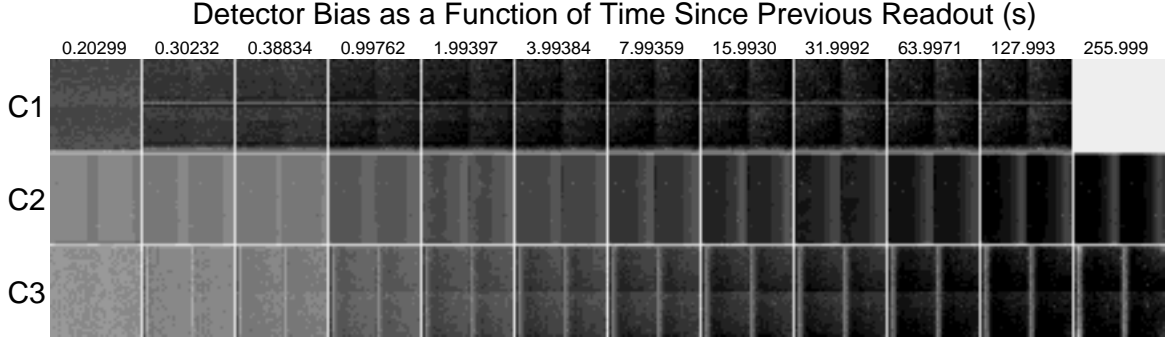


Figure 4. Images of the shading for each of the three cameras as a function of DELTATIM (indicated at the top in seconds).

$$B(i, j) = S(i, j, DELTATIM) \quad (2)$$

Where S is the bias signal in a given pixel as a function of DELTATIM.

2.3. Linear Dark Current

The linear dark current component is the traditional observed detector dark current when no outside signal is present. This component scales with exposure time only:

$$D(i, j) = T * d(i, j) \quad (3)$$

Where $D(i, j)$ is the observed dark current signal in pixel i, j for a given readout, T is the time since the last detector reset, and d is the dark current (in e^-/sec). The NICMOS dark current is extremely small and is very difficult to measure. It is approximately $0.05 e^-/\text{s}$ for Camera 2, and no larger than about half this value for Cameras 1 and 3 (we have only upper limits for these two).

3. Making a Synthetic Dark

The total “dark” signal in any given pixel of any given NICMOS MULTIACCUM readout is just the sum of the 3 components described above:

$$DARK(i, j) = D(i, j) + A(i, j) + B(i, j) \quad (4)$$

Figure 5 shows this graphically. An IDL routine has been developed to make synthetic darks. This routine uses the amplifier glow image displayed in Figures 1 and 2, and simply multiplies it by the accumulated number of reads in order to generate $A(i, j)$ for each readout. The shading as a function of DELTATIM has been populated by the technique described above, yielding an array of shading images some of which are displayed in Figure 5. An appropriate image is picked out of this array in order to generate $B(i, j)$ for each readout. Finally, it has not been possible to measure the linear dark current for each pixel. Using the on-orbit data available so far, we have been able only to generate a mean linear dark current over the whole array for Camera 2, while for Cameras 1 and 3 we have not yet obtained high enough S/N to achieve even this: therefore for the latter two cameras, the linear dark current is left as zero currently. Finally, the routine now sums the three contributions for each readout.

The calibration database has been populated with MULTIACCUM darks for all sequences which have not yet been observed on-orbit, or for which other effects, such as the

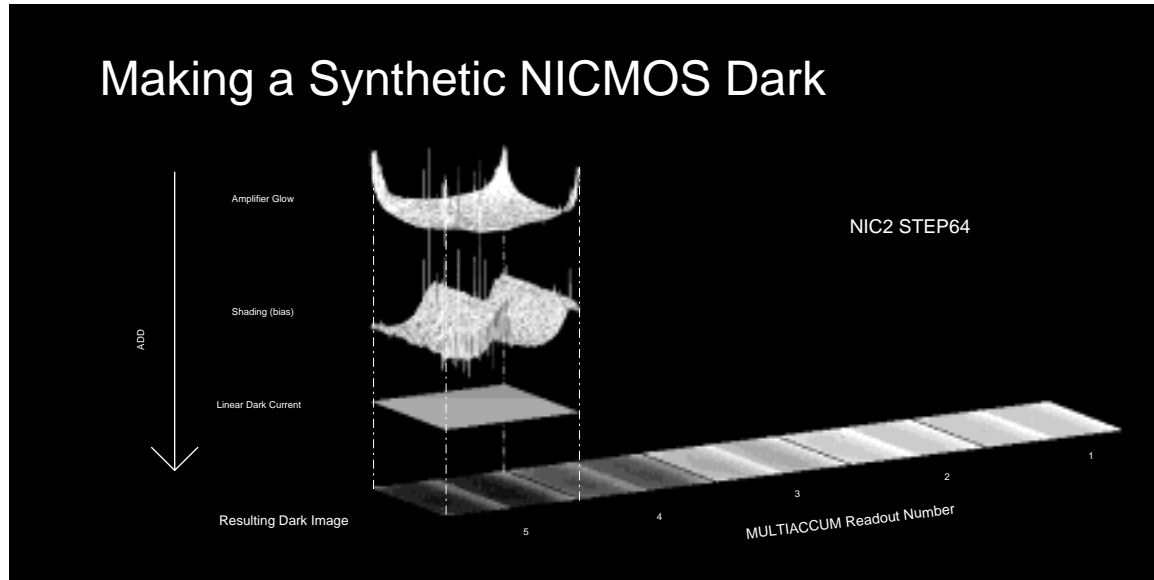


Figure 5. A graphical representation of the addition of the 3 components of a NICMOS dark to build a dark reference file for the NIC2 STEP64 sequence. The three components are shown in shaded relief to show their amplitude and spatial extent. The “spikes” are bad pixels on the array.

pedestal, have contaminated the early on-orbit dark observations. There are plans to tune up the synthetic dark algorithm somewhat (see next section) and eventually release it as an STSDAS tool in the NICMOS package.

Comparisons of on-orbit to synthetic darks show that the differences are relatively small — usually of the order of a few ADUs, with the largest differences in the corners of the detectors. Most of this can be alleviated by better characterizing the amp-glow from on-orbit data.

4. Finding More Information About NICMOS Darks

All of the information presented in this poster is available in more detail in a new NICMOS Instrument Science Report:

- NICMOS-97-026 *Characteristics of NICMOS Detector Dark Observations*

This document and others like it may be found on the NICMOS web page in the documentation section. All of the past and present dark reference files used in the calibration pipeline are available for download from one of our web pages as well, in a point-and-click tabular form. Here are the URLs:

Main NICMOS Page:

- http://www.stsci.edu/ftp/instrument_news/NICMOS/topnicmos.html

NICMOS Instrument Science Reports:

- http://www.stsci.edu/ftp/instrument_news/NICMOS/nicmos_doc_isr.html

NICMOS Reference Files:

- http://www.stsci.edu/ftp/instrument_news/NICMOS/nicmos_doc_cal_list.html