Astronomical Data Analysis Software and Systems IX
ASP Conference Series, Vol. 216, 2000
N. Manset, C. Veillet, and D. Crabtree, eds.

Residual Bias Removal in HST NICMOS Images

H. Bushouse, M. Dickinson, R. P. van der Marel

Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218

Abstract. Software tools have been developed to allow observers to examine and correct NICMOS images for the presence of residual bias signal. The NICMOS detector bias can drift between and during exposures, due to small changes in temperature. Subtraction of a standard calibration frame can therefore leave residual bias signal, which then results in the presence of a flat field imprint in processed images. Correction routines have been developed that determine the residual bias signal by iteratively solving for the signal level that minimizes the flat field imprint.

1. Introduction

The detector bias levels in the Hubble Space Telescope (HST) Near Infrared Camera and Multi-Object Spectrometer (NICMOS) are very sensitive to small ($\sim$0.1 K) changes in temperature. The NICMOS on-chip readout amplifiers are frequently switched on and off before, during, and after an observation. Therefore the level of heat input to the detectors is often changing, which results in bias drifts during an exposure. This has the effect of leaving a residual bias signal in the data after subtraction of the first image in a set of non-destructive readouts that comprise a typical NICMOS exposure (known as a "Multiaccum" exposure). Each quadrant of the NICMOS detectors is read by a separate amplifier, therefore the residual bias signal level can vary from quadrant to quadrant, but appears to be constant within a given quadrant.

The presence of this residual bias signal has several deleterious effects on the data. First, because the bias drifts can be non-linear with time, a series of non-destructive readouts can be left with an apparently non-linear accumulation of source counts as a function of time, leading to incorrect photometry (see Figure 1). Second, automated NICMOS data processing procedures reject cosmic-ray hits in a series of readouts by identifying outliers from a linear fit to the accumulating counts in each image pixel. If the accumulation of signal is not linear, these schemes fail to produce reliable results. Finally, because the residual bias signal is spatially constant within each image quadrant, application of a flat field frame introduces a residual flat field pattern in processed images (see Figure 2). This limits the ability to detect and measure photometry for faint sources.

2. Software Tools

A set of software tools has been developed in the IRAF/STSDAS environment to address these problems. The list of tasks that are available in the STSDAS `nicmos` package is shown in Table 1. The `mosdisplay`, `pstack`, `pstats`, and `sampinfo` tasks are intended for data analysis and examination only. They are useful for examining data sets for the presence and magnitude of residual bias effects. The tasks `biaseq` and `pedsky` apply corrections for different types of residual bias effects and are discussed in more detail in the following sections. As explained below, these tasks are designed to accept as input data sets that have been only partially processed through various stages of the routine pipeline processing task `calnica`. The `nicpipe` task offers a convenient and automatic way for users to prepare and run data sets through these processing stages.

Table 1. STSDAS `nicmos` Tasks[a]

Name	Function
biaseq	Equalize bias levels between Multiaccum readouts
mosdisplay	Display a mosaic of Multiaccum readouts
nicpipe	Process images through subsets of `calnica`
pedsky	Subtract "pedestal" and sky from single images
pstack	Plot a stack of pixel values from a Multiaccum image
pstats	Plot a stack of Multiaccum image statistics
sampinfo	Print sample information for a Multiaccum image

[a]These tasks are available in STSDAS v2.1 and later.

3. The `biaseq` Task

The `biaseq` task is designed to remove any non-linear changes in bias level from readout to readout within a Multiaccum exposure sequence. The task takes as input a partially-processed Multiaccum exposure, where the data in all readouts has been dark-subtracted and corrected for non-linear detector response, but has not been flat fielded. It estimates the average count rate per pixel in the observation by combining a user-selected subset of readouts. Residuals images are formed by subtracting the average count rate image from each readout. The median within each quadrant of the residual images is computed and subtracted from each readout in order to force the sequence to have linearly-accumulating signal as a function of exposure time. The output from the task is a new Multiaccum file with corrected readouts. An example of the uncorrected and corrected accumulating counts from a source is shown in Figure 1. Note, however, that this process only removes non-linear components of the bias offset and leaves a linear bias offset that must be removed with the `pedsky` task.

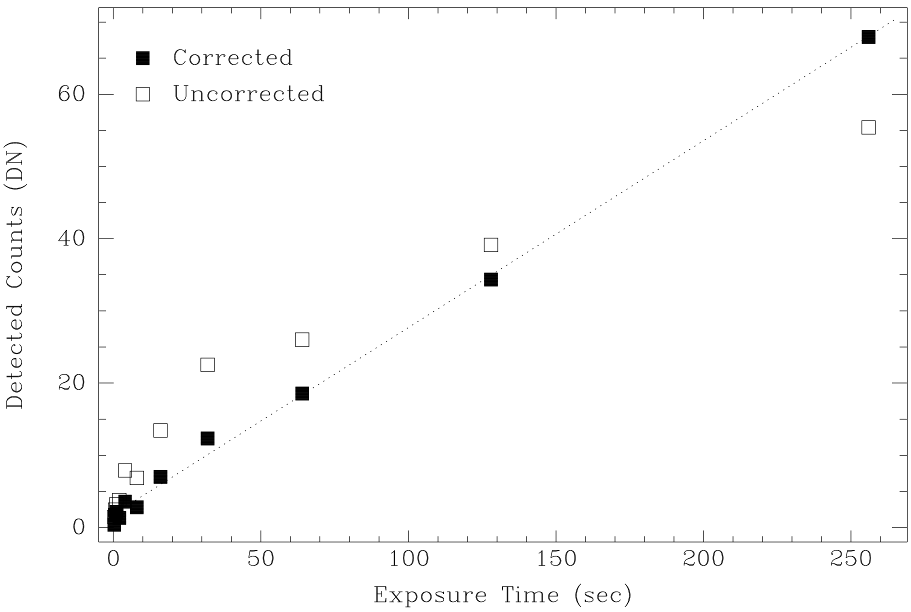

Figure 1. Accumulating signal from a source before and after correction with the `biaseq` task. The dotted line is a linear least-squares fit to the corrected data.

4. The `pedsky` Task

After combining the corrected readouts of a Multiaccum exposure sequence, there may still be a net linear bias term present in the combined image. This residual bias is often referred to as a "pedestal" signal. The `pedsky` task is designed to measure and remove this signal from a single, combined image. It accomplishes this by assuming that the total signal in a pixel that does *not* contain contributions from an astronomical source can be expressed as

$$I_{xy} = sky \times Q_{xy} + bias \tag{1}$$

where I_{xy} is the signal in pixel xy, sky is the background signal, Q_{xy} is the relative quantum efficiency of pixel xy (i.e. the flat field value), and $bias$ is the residual bias signal. It then seeks to minimize the variance in pixel values within each image quadrant that results from multiplying an inadequately removed bias signal by the flat field image. This is done by minimizing the relation

$$s^2 = \Sigma(I_{xy} - sky \times Q_{xy} - bias)^2 \tag{2}$$

where s^2 is the pixel-to-pixel variance over a detector quadrant. Values for the residual bias signal are determined independently for each detector quadrant, while the sky signal is determined globally for the entire image. The resulting sky and bias signals are then subtracted from the image. Figure 2 shows an example of an image with and without the `biaseq` and `pedsky` corrections.

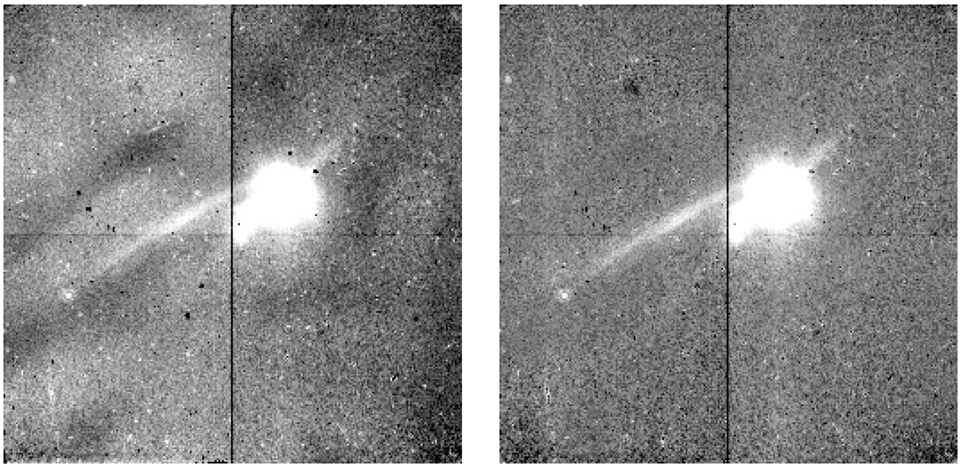

Figure 2. NICMOS image without (left) and with (right) corrections by the `biaseq` and `pedsky` tasks. The broad variations in background signal level in the uncorrected image are due to the flat field imprint.

5. Future Enhancements

All of the tasks discussed here have been initially written as IRAF `cl` scripts, using other standard IRAF/STSDAS image arithmetic tasks to accomplish their work. Several of these are currently being converted to native IRAF tasks, written in the C language. The main benefit of this is to increase the speed of the existing algorithms. Also, during the process of rewriting the tasks, new and more flexible algorithms are being added to the tasks, thus increasing their utility.

Most importantly, the `pedsky` task, as currently implemented, relies on the presence of blank sky regions within images to perform it's corrections. Therefore this task is not applicable to images of crowded fields or very extended targets. Algorithms to measure the residual bias in these types of images have been developed and will be made available as IRAF tasks in the STSDAS `nicmos` package. These algorithms utilize user-selectable spatial filtering techniques to measure the residual flat field pattern in an image depending on the source content of the image. While the `pedsky` task essentially measures the flat field residual on all spatial scales, the filtering algorithms can be tuned to confine these measurements to small spatial scales only, where the natural pixel-to-pixel variations in signal due to source structures are greatly reduced or eliminated.

More information about the NICMOS "pedestal" problem and correction techniques can be found in the NICMOS chapters of the HST Data Handbook[1] and in the STScI NICMOS Data Anomalies[2] web pages. Information specific to the techniques for extended source or crowded-field images can be found here[3].

---

[1] `http://www.stsci.edu/documents/data-handbook.html`

[2] `http://www.stsci.edu/instruments/nicmos/anom_pedestal.html`

[3] `http://sol.stsci.edu/~marel/software/pedestal.html`