Astronomical Data Analysis Software and Systems X
ASP Conference Series, Vol. 238, 2001
F. R. Harnden Jr., F. A. Primini, and H. E. Payne, eds.

HST NICMOS Residual Bias Removal Techniques

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

Abstract. *HST* NICMOS detectors suffer from temporal bias drifts, which lead to incomplete bias subtraction during image calibration. The residual bias signal is spatially constant, so that application of flatfield images during calibration gives rise to an imprint of the flatfield structure. In images of sparse fields the flatfield imprint is easily identifiable and removable through the use of iterative techniques to minimize the imprint. Fields with complicated source structure, however, require more sophisticated approaches, utilizing spatial filtering techniques to isolate and separate source and residual bias signals.

1. Introduction

The Hubble Space Telescope (*HST*) Near Infrared Camera and Multi-Object Spectrometer (NICMOS) uses detectors that are read out non-destructively. An image is formed by subtracting readouts at the beginning of an exposure from those at the end. It is often the case that many readouts are taken throughout the duration of an individual exposure. The initial readout serves as a record of the initial state of the detector pixels and is analogous to a bias image. However, systematic bias signals can only be completely removed from subsequent readouts if the bias is stable during the exposure.

The NICMOS detectors suffer from temporal bias drifts, which are thought to be due to temperature instablilites. Subtraction of the initial or bias readout from all subsequent readouts of an exposure can often leave a residual bias signal. Furthermore, each quadrant of the NICMOS detectors is readout by a separate amplifier, so that the amount of residual bias can vary from quadrant to quadrant within an image. Within a given quadrant the residual bias is usually spatially constant, such that subsequent division by a flatfield image leaves an imprint of the flatfield structure. The existence of this imprint sets an upper-limit to the achievable sensitivity and signal-to-noise ratio. In addition, the detector bias can vary non-linearly during the multiple readouts of an exposure, which causes source signals to appear to accumulate non-linearly.

Several software tools have been developed, which use a variety of techniques to correct NICMOS data for these problems. The tasks run within the IRAF/STSDAS environment, are written in ANSI C, and use the IRAF CVOS interface to perform parameter and data I/O. These tasks are all available in the STSDAS `nicmos` package.

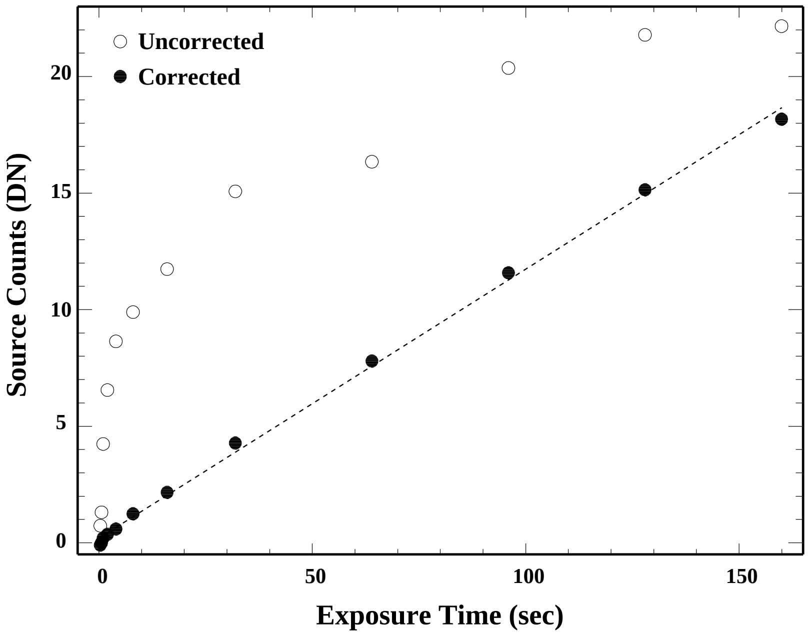

Figure 1. Application of `biaseq`.

2. The BIASEQ Task

The `biaseq` task is designed to correct for non-linear drifts in the bias level from readout to readout within an exposure. The basic approach is:

- Form a model or average image of the scene from a user-selectable subset of the exposure's readouts. Typically the later readouts are used, which usually have the longest exposure times and are the least affected by bias drifts. The image combination process uses a simple mean with min/max rejection to remove cosmic-ray hits and otherwise bad pixels.
- The averaged image is subtracted from each readout. Changes in bias between readouts are left as residual signal in the subtracted images.
- The median residual signal in each quadrant of each readout is subtracted from the readout, thus forcing the median signal to accumulate linearly with exposure time.

The subtraction of the average image before measuring the residual bias signal in each readout effectively removes signal from real sources and therefore makes this task insensitive to image source content. Figure 1 shows an example of the uncorrected (non-linear) and corrected accumulating counts for a source in an image. The dashed line is a linear fit to the corrected data.

While `biaseq` is able to force signals to accumulate linearly, an uncertainty in the overall slope of the signal vs. time relation remains present in the corrected data. This uncertainty is due to net *linear* drifts in bias between readouts that still need to be removed. This remaining bias signal manifests itself as a constant zeropoint offset in each quadrant of the corrected image. The tasks described next must be used to apply this final correction.

3. The PEDSKY Task

The `pedsky` task is designed to measure and remove any remaining net bias residual (often referred to as "pedestal") from the final image that is formed after combining the corrected readouts of an exposure. The task derives its name from the fact that it measures and removes both pedestal and sky background signals in an image. The sky signal is assumed to be constant across the entire image, while the pedestal level is measured and removed individually for each image quadrant.

The basic assumption in the `pedsky` algorithm is that signal that is near the sky background level is composed of the true sky, which is modulated by the spatially-varying quantum efficiency of the detector, plus the residual bias or pedestal signal, which is assumed to be constant in each quadrant. In mathematical terms, the task assumes for each pixel that contains only sky and pedestal

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

where I_{xy} is the total signal in the pixel at coordinates (x, y), sky is the sky background signal, Q_{xy} is the relative quantum effeciency (flatfield) value of pixel (x, y), and $bias$ is the bias or pedestal signal for the quadrant.

The `pedsky` task can solve this relation for sky and bias by one of several user-selectable methods. First, it can perform a direct least-squares solution to Equation 1 using the values for all pixels that are near the sky level. Second, it can solve Equation 1 by iteratively subtracting trial sky and bias values from the image, seeking the optimal combination that produces an image with the minimum remaining rms deviation in pixel values. Both of these methods essentially seek to minimize the expression

$$\sigma^2 = \sum_{xy} \left(I_{xy} - sky \times Q_{xy} - bias\right)^2, \tag{2}$$

where σ is the standard deviation of corrected pixel values. A third method allows the user to specify a known sky value, in which case the task subtracts that sky value and then only measures and removes the remaining bias signal from each quadrant. Figure 2 shows an example of the application of `pedsky` to an image. Note that the flatfield imprint has been removed, as well as the DC offsets between quadrants.

Because `pedsky` relies on the use of image pixels that only contain sky and bias signal, it can only work effectively on images that are sparsely populated with real sources. The `pedsub` task, described next, is designed to work with images of any source content.

4. The PEDSUB Task

The `pedsub` task is similar to `pedsky`, but it does not rely on being able to measure sky values in order to determine the residual bias. Like `pedsky`, it relies on the fact that the application of the flatfield to an uncorrected image leaves an imprint, which artificially increases the rms pixel spread. The task solves for the pedestal value in each quadrant by seeking to minimize the spread

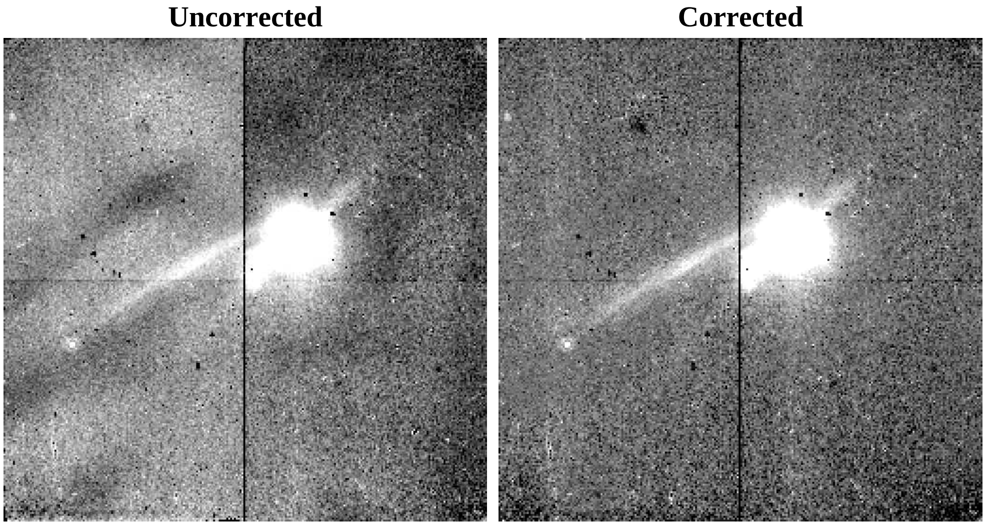

Figure 2. Application of `pedsky`.

in pedestal-subtracted pixel values. It assumes that the flatfielded signal in each pixel can be expressed as

$$C_{xy} = I_{xy} + bias \times Q_{xy}, \tag{3}$$

where C_{xy} is the calibrated value of pixel (x, y), I_{xy} is the intrinsic signal from sky and sources, *bias* is the residual bias signal in a given quadrant, and Q_{xy} is again the relative quantum efficiency (flatfield) value.

`Pedsub` loops over a range of trial pedestal values for each quadrant, generating a trial image that has the *bias* × *flatfield* values subtracted from each pixel, and then measuring the remaining spread in pixel values in the trial image. It iterates this process until the pixel spread is minimized.

Spatial filters can optionally be applied to each trial image in order to remove unwanted features or spatial frequencies that might artificially bias the pixel spread. A choice of filter types is available. A ring-median filter can be used to remove small sources, which when applied essentially confines the pixel spread computation to low Fourier frequencies. Alternatively, an unsharp mask filter option (median filtered image subtracted from the unfiltered image) can be used to remove low frequency information, such as signal from extended sources. This option confines the pixel spread computation to only high-frequency image information.

The availability of these options makes the `pedsub` task useful for images with almost any type of source content, while `pedsky` can often give incorrect results when applied to images with large amounts of source signal.

Acknowledgments. Many of the algorithms in these tasks were developed from concepts originally devised by Mark Dickinson and Roeland Van der Marel (STScI), and Brian McLeod (Harvard CfA).