The detection and removal of large-scale background structures in NICMOS observations

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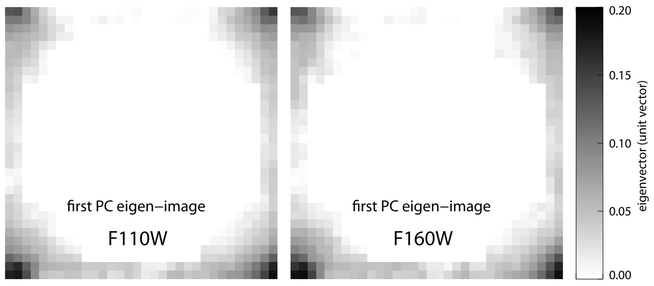
MOTIVATION

After applying the standard corrections for well-studied NICMOS anomalies, significant large-scale spatial background structures still remain, making precision study of faint sources difficult. We present novel methods for deriving model images of the observed background structures and for removing them from individual calibrated images. We also present a technique for recovering flux from the erratic middle column.

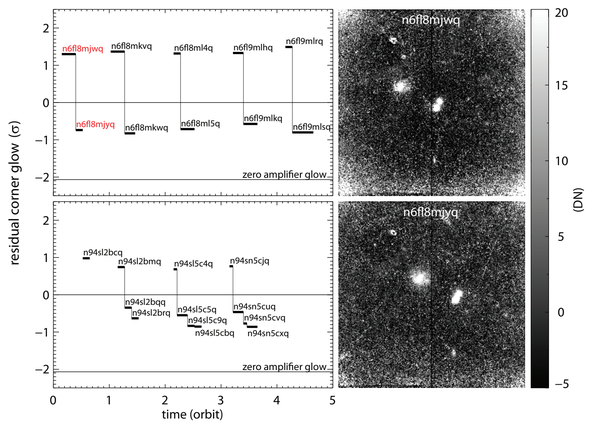
TIME DEPENDENCE OF RESIDUAL CORNER GLOW

The most obvious background is the corner structure which resembles amplifier glow and linear dark current, here loosely termed "residual corner glow." The first PC shows that this corner glow constitutes the largest variation in the data.

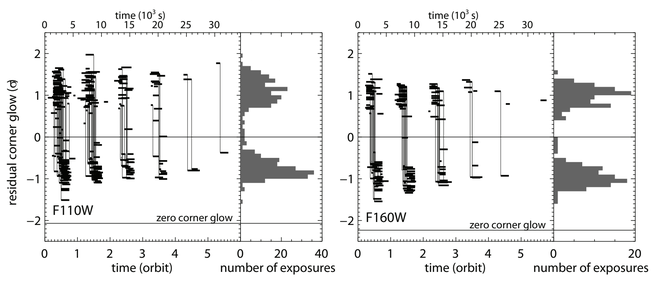


Projections of individual exposures onto the first PC reveal that the intensity is time dependent:

- starts high,
- decays exponentially,
- resets every orbit,
- never goes to zero.



The uniformity of the time dependence and the long exposure time allow the images to be segregated into two groups of approximately constant corner glow. We can then use a simple two-component model to represent the background structure.



MODELING BACKGROUND STRUCTURES

$$t(I+s) = stF + G + tI_0$$

$$t(I+s) = t(I_0+s)F + G$$

s: sky level
t: exptime

images

I : calibrated science image
I_0: desired zero-background image

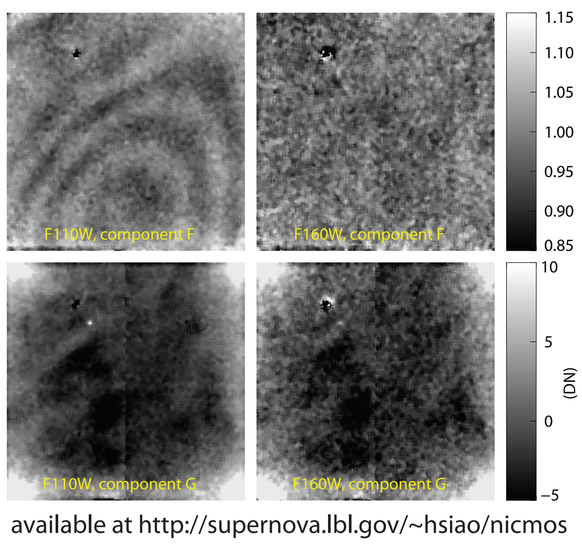
model components

component F: scales with sky level
component G: constant

Model components can be extracted using algebraic manipulations of stacked images:

$$F = \frac{\overline{t(I+s) - \overline{t(I+s)}}}{st - \overline{st}}$$

$$G = \overline{t(I+s) - stF}$$



available at http://supernova.lbl.gov/~hsiao/nicmos

component F

- fringe pattern detected in F110W, but not F160W
- resembles neither dark nor flat

component G

- corners resemble linear dark current and amplifier glow
- center resembles bright earth persistence (Riess & Bergeron 2008, NICMOS ISR 2008-01)

DATA

- NICMOS NIC2 follow-up of distant supernovae
- between June, 2002 and August, 2008, post-NCS
- 385 exposures in F110W, 188 exposures in F160W
- CALNICA pipeline, PEDSKY, SAACLEAN, NIC_REM_PERSIST

PRINCIPAL COMPONENT ANALYSIS

PCA is a powerful statistical technique which reduces the dimensionality and identifies patterns in a set of multi-dimensional data. An n-dimensional data set f_i can be written as the sum of its orthogonal principal components (PCs) ξ_j. The PCs describe the variations around the mean μ, with the first PC pointing in the direction of maximum variance in the n-dimensional data space. Here, we use PCA to characterize the intensity of the corner glow and to reconstruct the middle columns.

$$|f_i\rangle = |\mu\rangle + \sum_{j=1}^{n} p_{ij}|\xi_j\rangle$$

RECONSTRUCTING MIDDLE ROWS AND COLUMNS

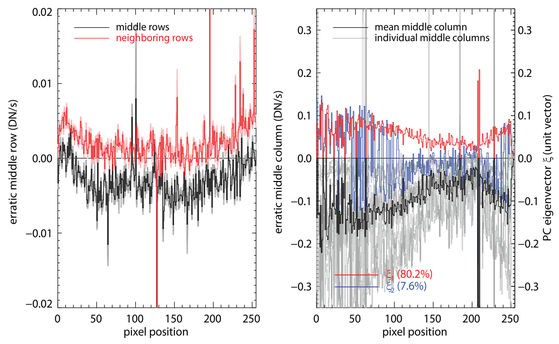
middle rows

- can be corrected with a constant offset
- have same noise statistics as neighbors
- corner glow structure is preserved

middle columns

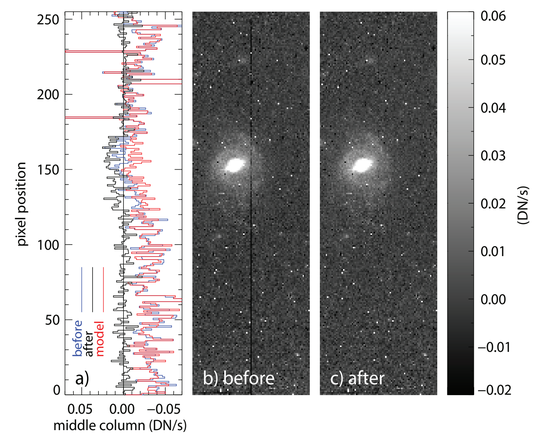
- PC1 describes the large variation in shape
- PC2 describes the modulating signal

which produces the larger-than-normal noise levels



PCA reconstruction of middle column

The algorithm of "expectation maximum (EM) PCA" with missing data (Roweis 1998, Neural Information) is adopted. Individual middle columns are reconstructed using projections of the source-masked columns onto the first few PCs.



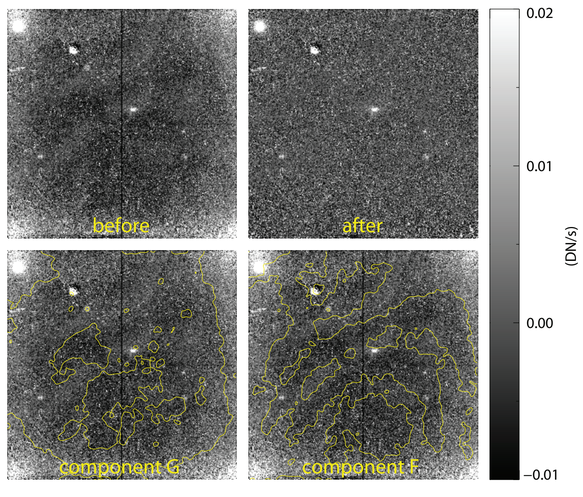
RESULTS AND IMPROVEMENTS

We fit the model components to individual source-masked images using three free parameters:

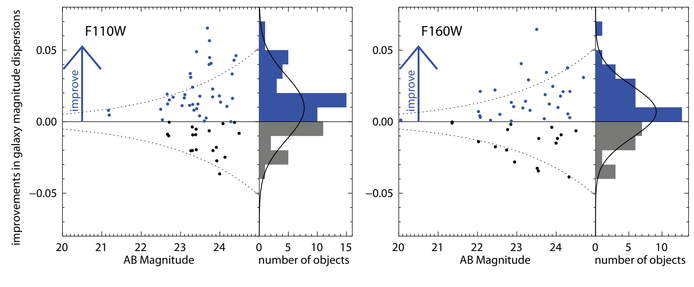
- a fiducial sky value
- a fiducial exposure time
- a constant offset

$$I_0 = I - \left[s(F-1) + \frac{G}{t}\right]$$

$$I_0 = \frac{1}{F}\left(I - \left[s(F-1) + \frac{G}{t}\right]\right)$$



Background-removed images show a clear advantage in cosmetic appearance. Quantitative tests using distant galaxies also show that removing the background structures, with the methods described here, yield on average a 20% reduction in magnitude dispersions.



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