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Self-calibration for the SIRTF GOODS Legacy Project

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Abstract. Data analysis for the SIRTF GOODS Legacy Project must be able to achieve a level of calibration noise well below a part in 10,000. To achieve such a high level of fidelity, a form of self-calibration may be required in which the sky intensity and the instrumental effects are derived simultaneously. Two methods being investigated are a least squares approach based on the work of Fixsen and Arendt at GSFC, and an iterative method. Both methods have been applied to derive the sky, flat field, and offset from simulated data for instruments to be flown on SIRTF; the results will be discussed.

1. Introduction

The Great Observatories Origins Deep Survey (GOODS) incorporates a SIRTF Legacy project designed to study galaxy formation and evolution over a wide range of redshift and cosmic lookback time. Our current understanding is that the standard pipeline developed by the SIRTF Science Center may not achieve the levels of fidelity required for the analysis of the deepest GOODS data, which translate into a level of calibration noise well below a part in 10,000. Self-calibration may be required to achieve the necessary level of calibration.

2. Algorithms

Two algorithms have been used to simultaneously solve for the sky, gain, and offset for simulated sets of dithered images. These techniques are the Fixsen-Arendt least squares self-calibration code (Arendt et al. 2000) and an iterative code.

Fixsen-Arendt code:

- Written in IDL using C matrix routines; handles ideal case (integer pixel shifts, no geometric distortion), solves data=gain*sky+offset. Code incorporating geometric distortion is under development.
- When solving for sky and gain, achieves machine precision on noiseless data; for noisy data, solution within noise.
- Memory limitations become a problem when attempting to use all dither positions for GOODS.
- Additional instrumental effects are difficult to add to code, and the amount of memory and execution time required roughly triple with each effect.

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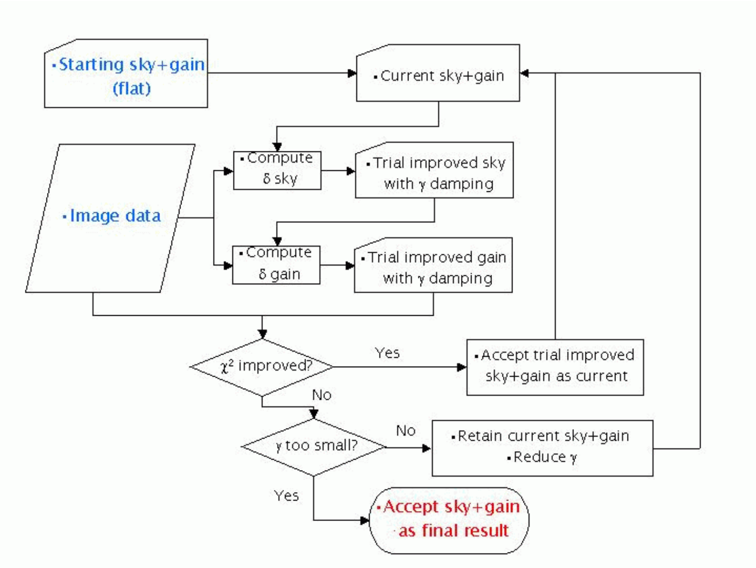

Figure 1. Iterative self-calibration method.

Iterative code:

- Written in IDL; handles ideal case (integer pixel shifts, no geometric distortion), solves for data=gain*sky+offset.
- Tests on simulated MIPS HDF-N campaign (1440 pointings) converge to shot-noise-limited sky in 2 hours (single-processor 440 MHz Sun Blade 1000)
- When solving for sky and gain, achieves machine precision on noiseless data; for noisy data, solution slightly different from Fixsen-Arendt solution, but within noise.
- Run times slightly better than the Fixsen-Arendt code.
- We are developing a version in which subpixel shifts and geometric distortion are included.
- Somewhat inefficient since there is no built-in independence between successive steps.

Compared to the Fixsen-Arendt technique, the iterative approach may scale more favorably with dataset size and complexity of the observing process (i.e., presence of instrumental artifacts), and is less memory intensive. In the iterative algorithm, the sky and gain are alternately updated, as shown in Figure 1.

3. Approach

In lieu of actual data, we've used SIRTF's MIPS instrument simulator[1] to generate truth images. The simulator generates images which include sky background,

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[1] Ranga-Ram Chary, private communication

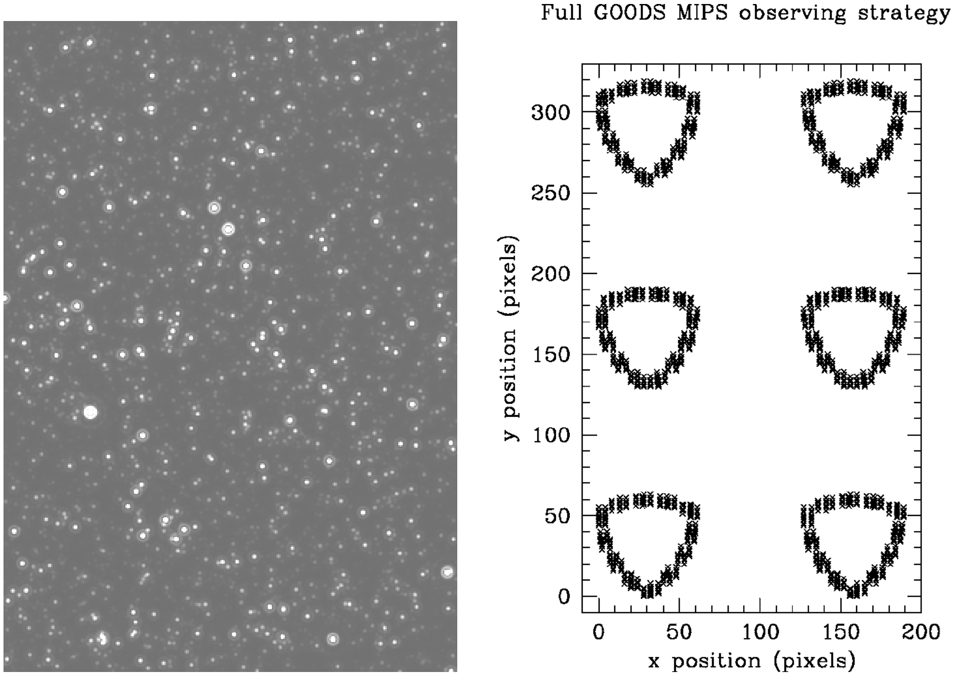

Figure 2. MIPS truth image, and full MIPS dither pattern

Poisson noise, readout noise, and dark current. The MIPS truth image (316×453 pixels) is shown in Figure 2; 94% of the pixels are greater than 0.01% above the background.

From a truth image, sets of individual images (128×128 pixels for MIPS) were generated from a table of integer dither positions. For a self-calibration run in which the sky and gain are to be derived, each individual image is multiplied by the input gain. (If the offset is also to be derived, it is also incorporated). The input gain image used has ±30% large-scale variation, and ±5% rms pixel-to-pixel variation.

4. Results

For the sky and gain runs, the goodness of fit was quantified by comparing the derived gain to the input gain. Tests were done by varying the dither pattern, varying the number of dither positions, and varying the tightness of the pattern. The full MIPS dither pattern of 1440 pointings (6 major pointings with 18 minor pointings each) is shown in Figure 2. Several dither patterns were compared for a subset of these observations.

With a poor dither pattern (4 sets of only 3 chosen positions from the 18-point Reuleaux pattern), the gain ratio shows vertical artifacts due to an insufficient number of x-positions. With a better dither pattern (4 sets of 7 chosen positions from the 18-point Reuleaux pattern), there are no visible artifacts in the gain ratio.

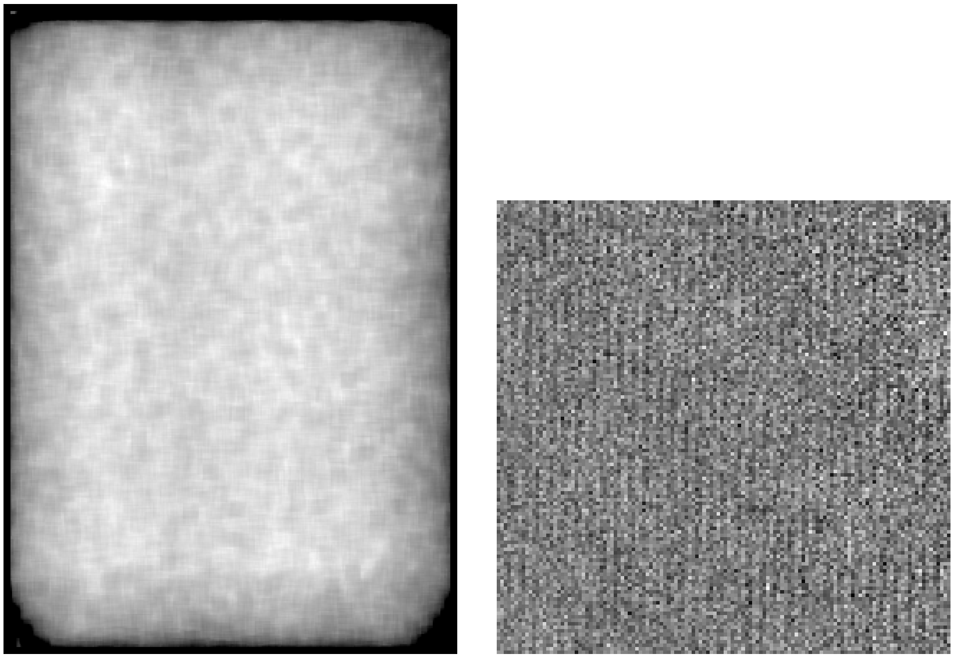

Figure 3. Sky noise (rms=1.5E-4) and gain ratio (rms=6.4E-5)

Using the full MIPS dither pattern shown in Figure 2, the derived sky and gain have no unexpected features. The sky is reproduced with the expected noise level, and is within a few percent of the combined shot and read noise. The derived sky noise and the gain ratio for this case are shown in Figure 3.

5. Discussion

Our tests indicate that for reasonable dithering strategies, the results of the derived sky and gain are close to shot-noise-limited sensitivity. If there are too few dither positions, periodic artifacts are introduced into the derived quantities at approximately the 1-sigma level. If the dither pattern is too tight, the large-scale variation in the gain is not constrained.

The iterative method offers flexibility to incorporate additional instrumental effects which may occur in the actual data. We are currently modifying the routine to accommodate subpixel dither positions and geometric distortion.

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References

Arendt, R. G., Fixsen, D. J., & Moseley, S. H. 2000, ApJ, 536, 500