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To: Distribution

From: N. R. Izenberg

Subject: Pupil Ghost for CONTOUR imagers

References: (1) N. R. Izenberg, Master Calibration Record Parts 1-4

Summary

The CRISP (and to a lesser extent CFI) pupil ghosts presented major roadblocks in ultimate determination of CONTOUR Imager flatfields. Substantial progress had been made into remediating the problem by the time of CONTOUR's loss, but final flatfield was never achieved. This report shows the level of remediation achieved for the CRISP pupil ghost. This report is taken from Howard Taylor's presentation of ghost remediation from April 2002.

Introduction

CONTOUR's CFI and CRISP Imager are the two CCD-camera instruments on the CONTOUR spacecraft. Each imager has a 10-filter filter wheel in between the telescope optics and the CCD. Nine of the filters are "spectral" and one is a "clear" or wide-bandpass filter. Accurate knowledge of CCD linearity is required to determine the useful range dynamic range of the instruments for planning flight observations.

To support these analyses, a series of "flatfield" images were collected during the calibration of the instruments. Broad-spectrum, diffuse light was generated in the APL Optical Calibration Facility (OCF) using the facility's integrating sphere. These flatfields were to determine base imager response to a field filling uniform source. The revealed a substantial ghost image due to focused reflections from elements of the imager optics (Figure 1). The CRISP ghost is an additive artifact for scene filling images, with ghost signal over 5% of raw image signal. Late calibration included a series of tests to characterize the imager ghosts and attempt to remove them during post-processing.

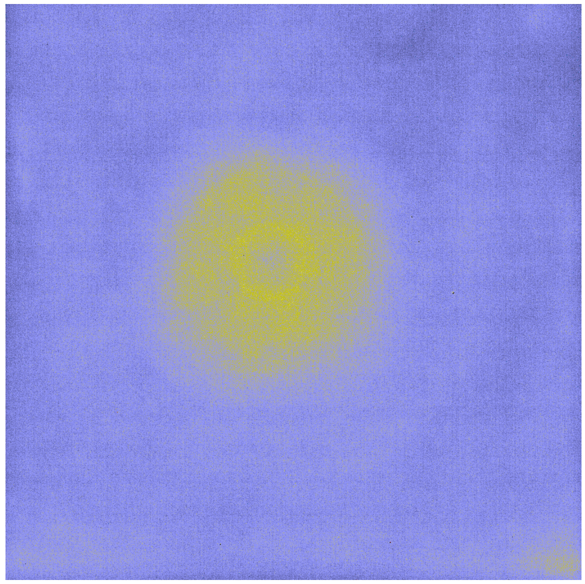

Figure 1. CRISP Imager ghost in false color linear scale. Yellow colors show additive ghost over blue flatfield image of the integrating sphere.

Test Conditions

The test setup for ghost removal determinations utilized the OCF collimator fed by a bright, broadband lamp. A grid of images was acquired for each imager filter, with the source in the same position (controlled by a motion stage) while the filters cycled through. Images were taken in pairs with light levels differing by a factor of 1000 using ND filters (Figures 2 and 3). The large ghost image is in fact a co-adding and smearing together of many reflected, near in-focus images of the imager pupil (including the spider mount) Fig. 3's over exposed image shows the contribution of light from one small area to the overall ghost.

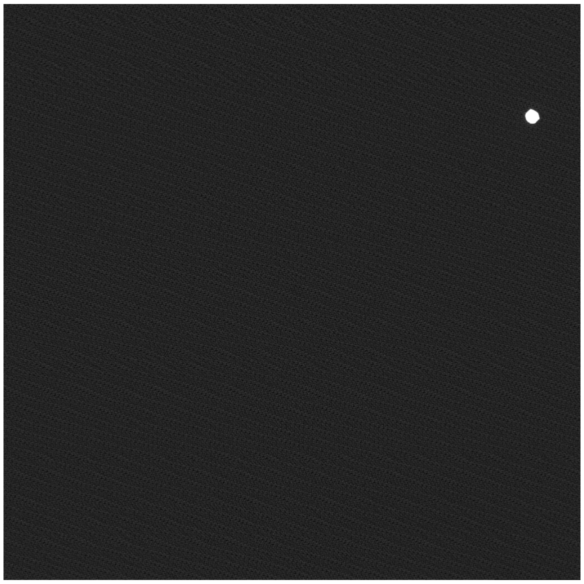

Figure 2. ND3 image of ~20 pixel point source

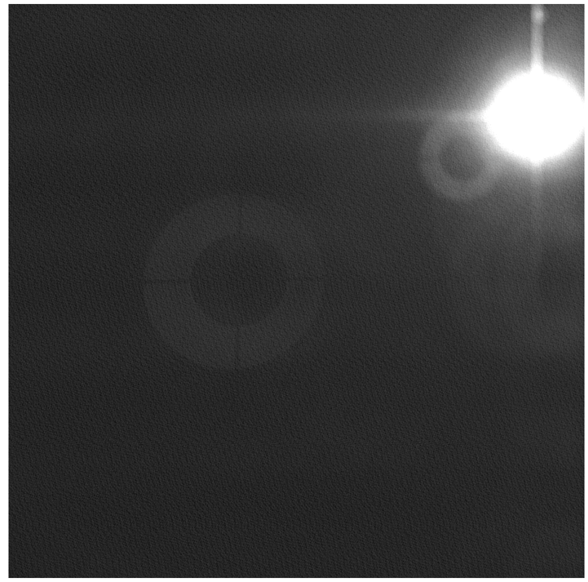

Figure 3. ND0 image of the same point source with ghost pupils visible.

A 12x12 grid of “spot image” pairs (Figure 4) and a diagonal scan of 50 spot image pairs (Figure 5). were taken to sample the imager ghost response across the field of view

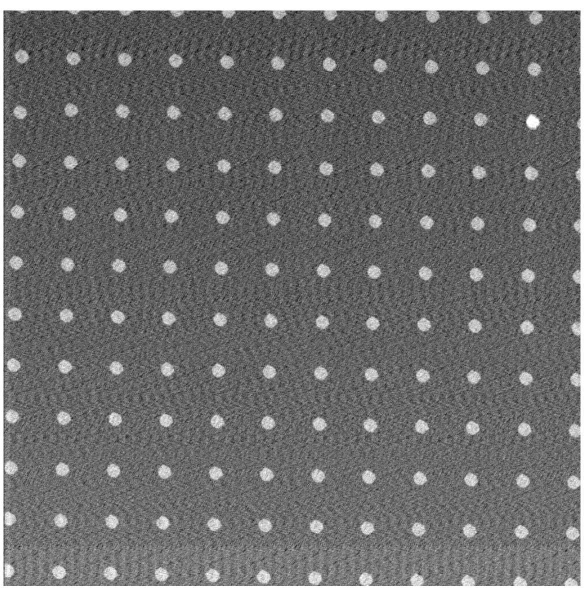

Figure 5. 12x12 grid of “spot” images

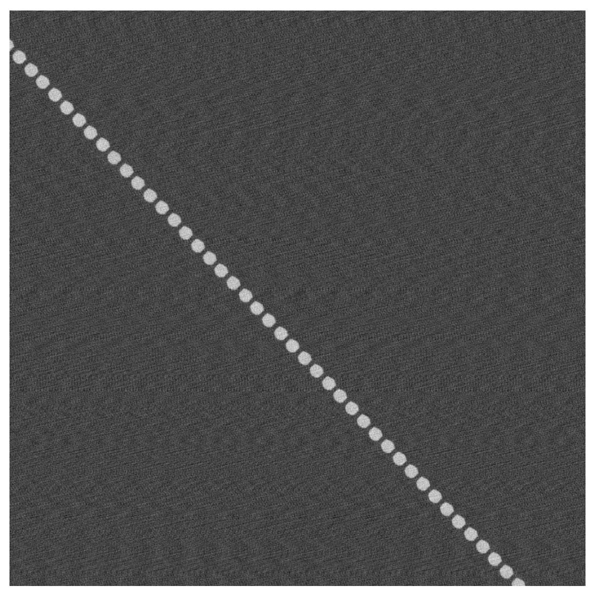

Figure 6. Diagonal scan of “spot” images.

The Dataset for CRISP was taken during the calibration tests CIBM1_ISL, CIBM2_ISL, CIBM3_ISL, CIBM7_ISL, CIBM9_ISL, and CIBM9_ISL. CFI scans used a smaller 8x8 grid and different sources for short and long wavelength filters in four tests:

CFCCC_IGS, CFCCC_IGL, CFCCC_IDS, CFCCC_IDL. Calibration observations are documented in the Master Calibration Record (MCR, Ref. 1).

Analysis and Results

The general approach to ghost pupil remediation was to divide the CCD area into a series of cells, iterateively estimate the ghost image at each cell, then remove a portion of the ghost at each cell.

Step 1: Estimate the extended source point spread function (Figure 7).

$H_i = F_i + G_i \quad (1 \le i \le 144$ grid cells)

H = observed laboratory data (ND0, ND3, dark images)

F = Fat point source plus associated point spread function

G = Ghost

Step 2: Generate the ghost response at each of the 144 grid cells (Figure 8).

$G_i = H_i - F_i$

Step 3: Incremental subtraction of ghost response at each cell (Figure 9).

residual[0] = desmear (dark_subtraction (observation_image))

For ***i***=1,144

$$\alpha[i] = \frac{\sum energy(cell(residual[i-1]))}{\sum energy(cell(H[i-1]))}$$

$$residual[i] = residual[i-1] - \alpha[i] * G[i]$$

Example results from this approach are shown in Figure 10, reflecting a roughly 75% correction of the pupil ghost.

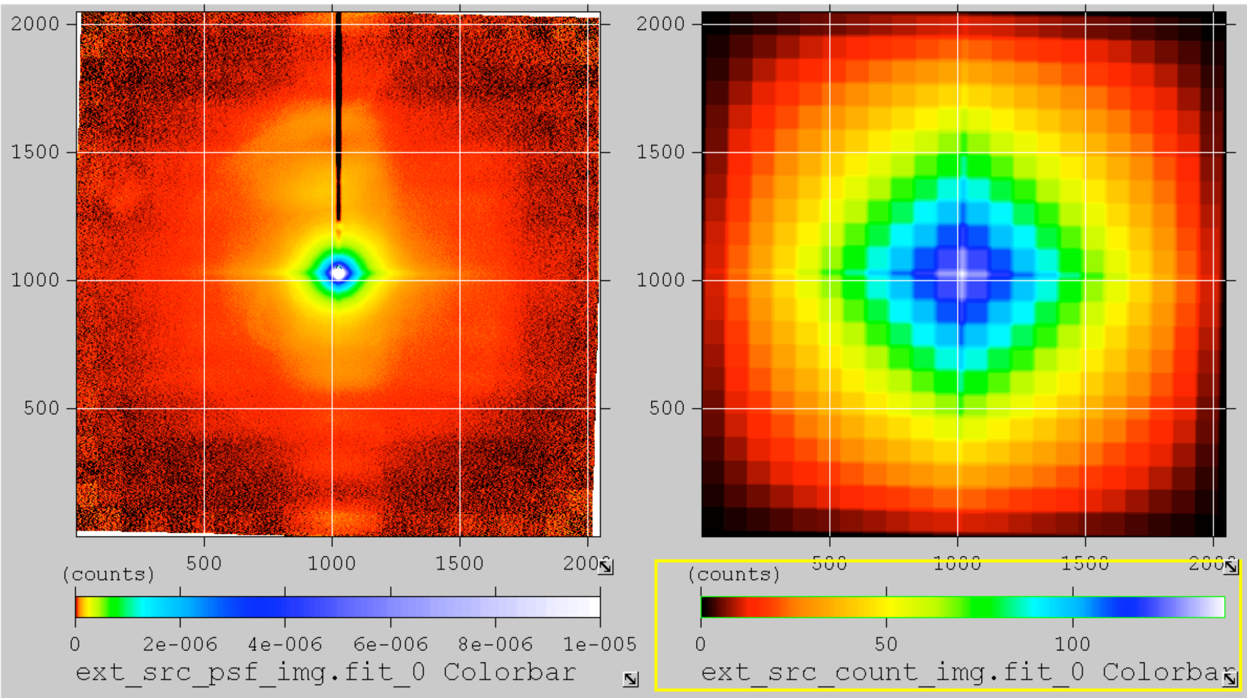

Figure 7. Estimated extended source Point Spread Function from Step 1.

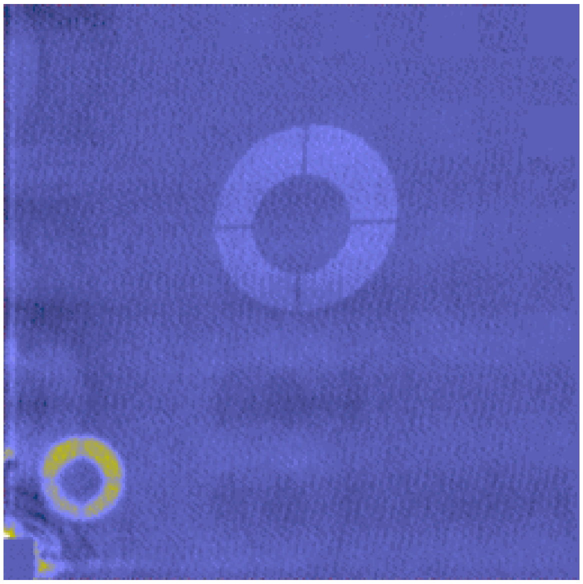

Figure 8, Synthesized ghost cube image from Step 2.

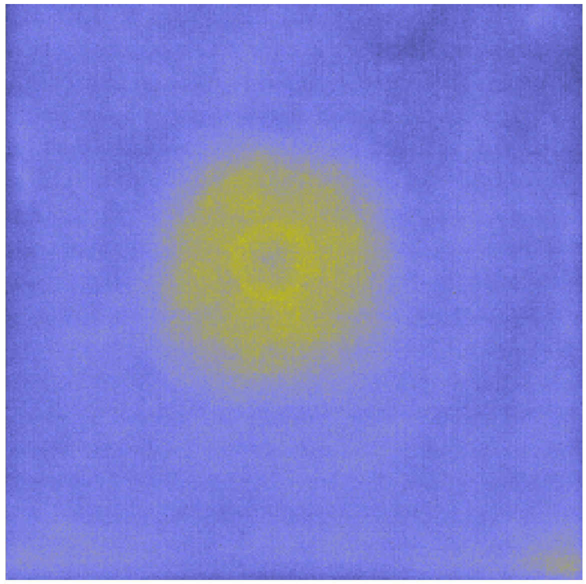

Figure 9. Ghost removal from flatfield image. IN this case DN range of the image is 1700-1955 DN, Ghost is up to 80 DN above background.

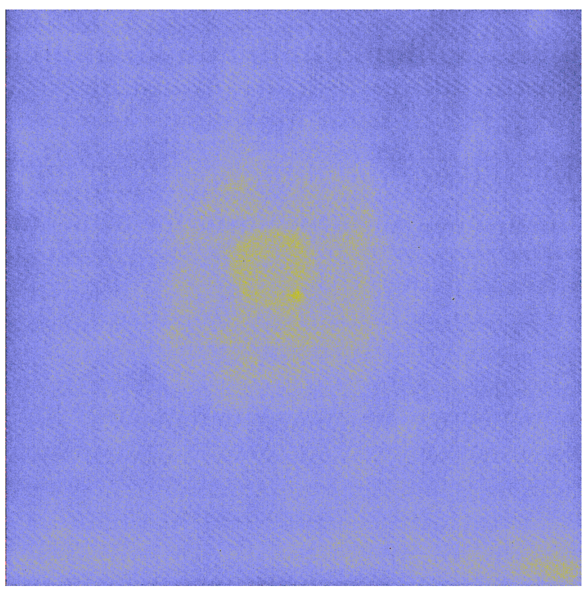

Figure 10. Results of ghost removal. Ghost signal is reduced by ~75%.

Discussion and Conclusion

This method shows promise and represents a viable solution to removal of the

CRISP pupil ghost. Results of correcting a single integrating sphere observation shows correction of ~75%. An improved method to produce Synthesized Ghost Cube will produce better correction. Comparison of pupil-ghost-removed sphere images from differing filters should be directly comparable as flatfield estimate.

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