FOC Status and Calibration

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Abstract

We describe the status of the Faint Object Camera, at the end of Cycle 3, before the refurbishment mission. We assess accuracies and limitations of the instrument calibrations performed up to Cycle 3, and their role in understanding the quality of the data produced by the automatic processing pipeline (RSDP).

I. Calibration Status

F/96 Relay

The f/96 camera has been performing nominally since launch. In the past three years, a number of instrument calibrations have been carried out to characterize its response. The following list provides a summary of the fundamental quantities which have been calibrated, and their current accuracies. These accuracies will be reviewed in detail later, in the context of the pipeline data reduction.

The Absolute Sensitivity for the f/96 relay has been calibrated between 1200 Å and 5500 Å to an accuracy of 15 percent.

Detector Background: detector background rates have been typically found at ~ 6×10^{-4} counts s^{-1} $pixel^{-1}$. Fluctuations in the detector background up to count rates 5 times the reported value may, however, be present in the data if taken in proximity of the South Atlantic Anomaly.

Flat Fields: smoothed full flat fields have been determined at 1300, 4800, 5600, and 6600 Å to an accuracy of ~3 percent. Pixel-to-pixel errors may be much larger due to blemishes.

Plate Scale & Distortion: the plate scale has been determined to an accuracy of ~0.3 percent. The following formats (all centered) have been geometrically calibrated: 512*z*x1024, 512*z*x512, 512x1024, 512x512, 256x256, 128x128. The geometric calibration has an accuracy of ~1 pixel rms.

Objective Prisms: the FUV prism has been wavelength calibrated to ~3 pixels (~30Å at 1500Å) and with larger wavelength uncertainties towards the red. The

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photometric response is determined to an accuracy of ~10 percent. The NUV prism is wavelength calibrated to within ~5 pixels (~100Å at 2500Å), with the photometric response only being known to within 20 percent.

Polarizers: the absolute orientation of the polarizer filters is known to better than 10 percent.

Pointing Accuracy: the center of the aperture has been determined to within 0.2 arcsec. General targeting errors have been found to have an uncertainty of ±0.75 arcsec (1 sigma).

F/48 Relay

On September 17, 1992, the high voltage supply for the image intensifier of the f/48 relay switched off immediately after powering up. The last images taken showed high background values, probably the result of a corona breakdown due to delamination of the potting. A subsequent attempt to switch the f/48 HV succeeded a few months later, but another failure occurred in early 1993. Since then, the f/48 has remained in HOLD mode with the camera tube being powered up every 30 days. The calibration program for the f/48 has not been completed as expected, due to the described problem, and this is reflected by the low accuracies associated to some of the following quantities:

Absolute Sensitivity: estimations of the f/48 sensitivity have been made with an accuracy of ~15 percent for the 1800 – 3000 Å range and ~25 percent for the 1300 – 1600 Å range.

Detector Background: typical detector background rates of 1.5×10^{-3} counts s^{-1} $pixel^{-1}$ with localized increases in the background having count rates which vary from 2×10^{-3} to 1×10^{-2} counts s^{-1} $pixel^{-1}$.

Flat Fields: smoothed full flat fields have been determined at 3745Å to an accuracy of ~5 percent.

Plate Scale & Distortion: the plate scale has been determined to within 0.2 percent. The geometric distortion has shown time-dependent changes and the following formats have been calibrated for these time-dependent variations: 128×128, 256×256, 512×512, 512z×512, 512z×1024, 256z×1024.

An attempt to switch-on the f/48 will be made after the Servicing Mission and prior to COSTAR deployment. Upon successful HV switch-on, a calibration proposal will be executed to obtain absolute sensitivity measurements for the f/48 relay. If this attempt is successful, another switch-on will be planned late for Cycle 4 which will utilize the long-slit spectrographic facility of the f/48 relay.

II. FOC Data: the calibration steps

All the data taken with the FOC are automatically processed and calibrated by the Routine Science Data Processing system (RSDP). The following steps are performed:

Dezooming of zoomed images. If the image was taken in zoomed mode, the first step is to split the data values along the sample direction. If the zoomed image contained n rectangular pixels [50 x 25 microns] in the sample direction, now the dezoomed image contains 2n square pixels [25 x 25 microns], each with half the flux of the original rectangular pixel.

Absolute Sensitivity correction, affects header parameters only. A constant is computed which can be used to convert the data values in the .C1D file to absolute fluxes. This constant is saved in the .C1H header file as the value of the PHOTFLAM keyword. Multiplying the data values in the calibrated image by this number and dividing the result by the actual exposure time converts the values to flux density F_λ in units of ergs cm^{-2} s^{-1} $Å^{-1}$.

Geometric distortion correction involves data interpolation with conservation of flux. Optical and detector distortions are determined by comparing the position of the grid of 17 x 17 reseaux marks (etched onto the first of the bi-alkali photocathodes of the intensifier tube) in the image, with a reference grid of the appropriate spacing.

Relative calibration or flat field correction, removes instrumental sensitivity variations using a UNI (Uniform Detective Efficiency) reference file, which is the reciprocal of a flat field. The suitable UNI reference file is selected on the basis of the observation wavelength. The UNI files have been derived from heavily smoothed flat fields, and do not flatten small scale features such as scratches and reseaux marks.

For spectrographic (long-slit) observations, the geometric correction is different and the flat field correction includes spectrographic relative and absolute calibrations with flux and wavelength calibrations affecting both data and headers.

III. Calibration Accuracies

Absolute Sensitivity:

Several sources of errors can influence the overall accuracy of the absolute response of the Faint Object Camera.

- Errors in the spectrophotometric standards: the published error estimates for the UV spectrophotometric standards range from 3 percent at longer wavelengths to 10-15 percent at shorter wavelengths.

- Errors in the assumptions for the PSF. Since the in-orbit calibrations used large aperture photometry, i.e., an aperture large enough to encompass the aberrated halo, there should be very little sensitivity to details of the PSF or changes in the PSF. This source of error should contribute less than 1 percent error to the derived efficiencies.

- Errors in the assumed filter transmission curves. The filter transmission curves were carefully measured on the ground, but some subsequent degradation or change in performance might have occurred since launch. Filter redleak may contribute to errors in the determination of the absolute sensitivity.

- Format dependencies. A variation of sensitivity with video format has been noted. In particular, differences have been found in the relative response of the more common f/96 formats with respect to the 512 x 512 imaging format.

- Variability of f/96 DQE. The UV throughput of the FOC has been regularly monitored as part of an observatory program. The only evidence for change has been an ~5 percent decline in the sensitivity over 3 years through the F140M filter. This decline is attributed to the filter rather than the *HST* mirrors, because GHRS sensitivity measurements over a similar baseline and wavelength are stable. The visible range has not shown any evidence for change in sensitivity.

- Source spectrum. The value of PHOTFLAM presumes that F_λ is constant across the effective bandpass. Situations where that is not true can lead to large errors, especially when the wideband filters are being used or where redleak plays a significant part. If there is any doubt as to whether there are significant color effects, the observer is advised to use SYNPHOT or FOCSIM to check their absolute fluxes.

Geometric Correction

Stability is the main concern in assessing the accuracy of the geometric correction calibration.

F/96. This relay has experienced a very slow, steady change since launch. This is a simple shift (~3 pixels) and rotation (~0.2 degrees), neither of which significantly affect astrometric measurements. New calibration files were produced in February 1993 for the most commonly used formats.

F/48. In January 1992, the geometric distortion behavior of the f/48 relay, (which had never been quite as stable as the f/96), began suddenly to show large, erratic variations in its distortion characteristics. Although there is no clear connection, these erratic changes continued up until September 1992 when the f/48 camera failed.

Noise Fringe Pattern (*Fingerprints*). A feature can be seen when geometrically corrected images are displayed with high contrast close to the background. When this is done, relatively low-frequency *fringes* appear in the image with scalelengths of between 40 and 100 pixels. This effect is a product of the geometric correction procedure and caused by re-binning the data while conserving flux. It is a modulation of the noise characteristics of the data, the mean intensities in the image are not affected.

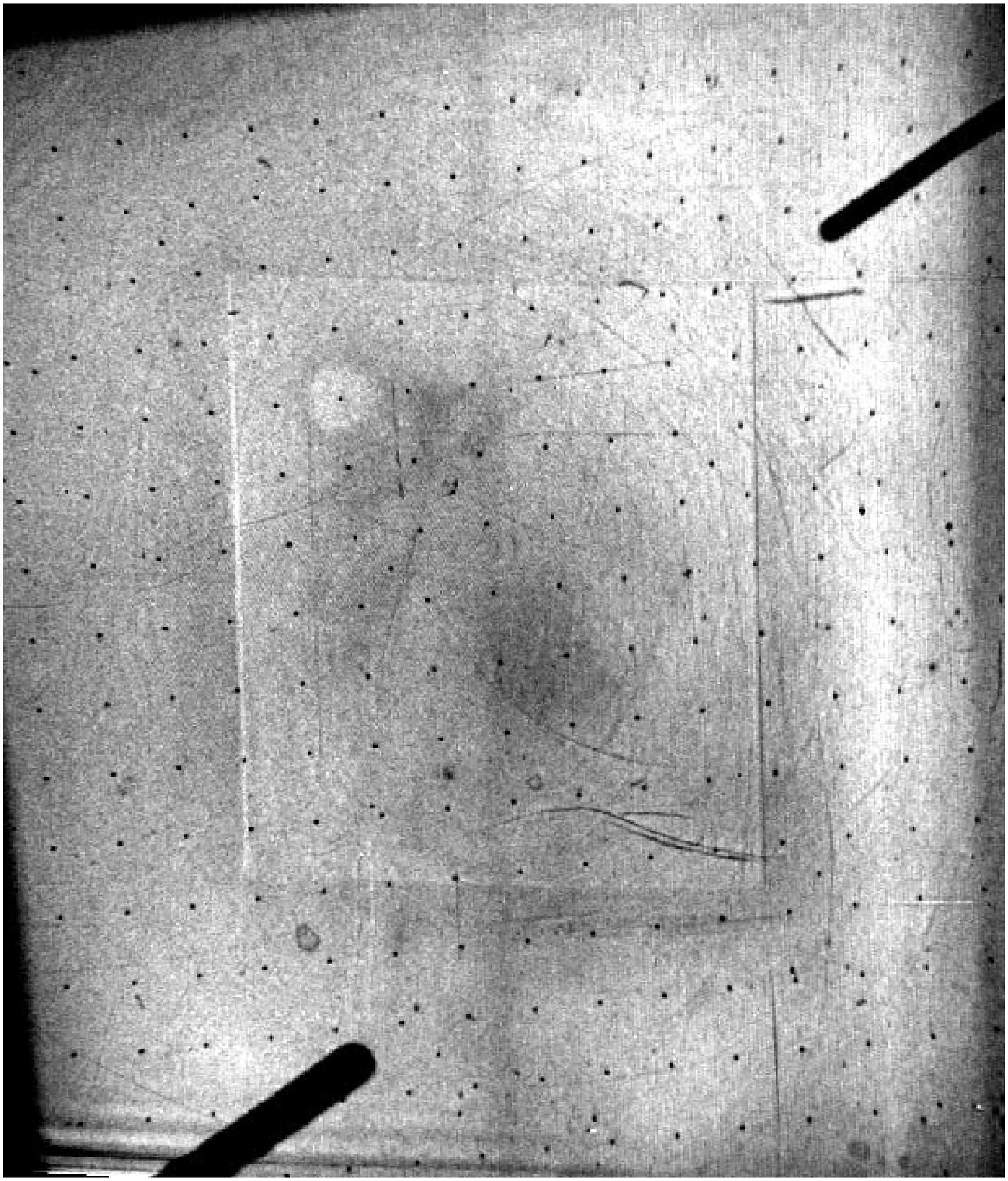

Figure 1: F/96 external UV flat field image.

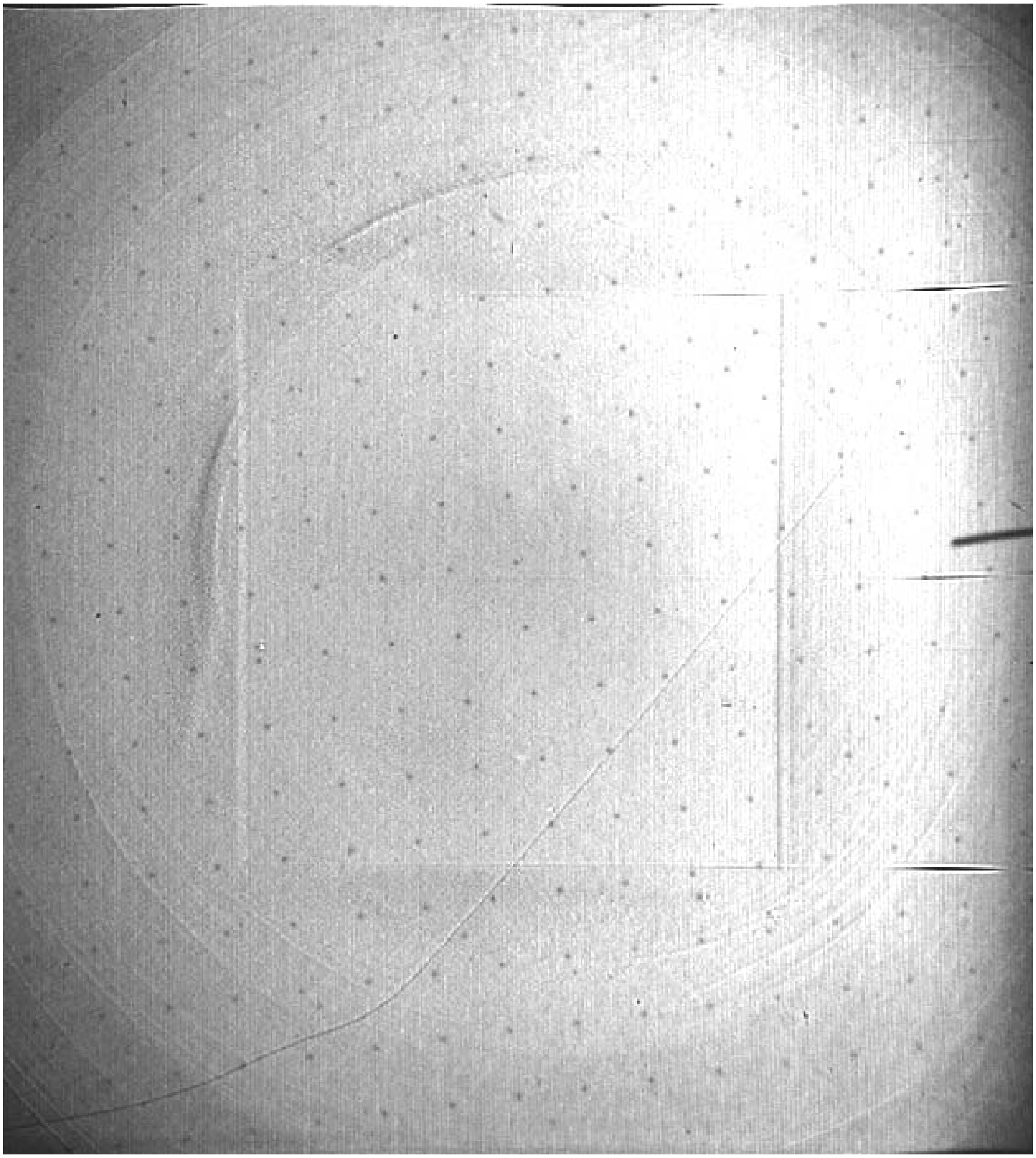

Figure 2: F/48 external UV flat-field image.

Flat Fields

Figures 1 and 2 show relatively high signal-to-noise full format flat fields obtained in the UV for the f/96 and f/48 relays, respectively. The figures display many of the features that are typically present in a flat field, and are not corrected by the pipeline which uses as calibration very smoothed FOC flats.

Border Effects: can be external (f/96 occulting fingers, upper and lower left corners of the f/96 image, lower right corner for the f/48 image) or internal (bad rows at the top and bottom of the raw images, leftmost columns of the raw images, and a number of columns at the beginning of the scan line).

Video and Digitizing Defects:

- fly back of the read beam of the television camera, especially noticeable in small formats.
- noise glitches on the scan coil driver caused by changes in the most significant bits of the line counter, show up as horizontal features at lines 256, 512 and 768.
- Both relays show the center 512 x 512 outlined by a sharp change in sensitivity. The effect is due to burn-in of the heavily used standard camera format.

Reseau Marks, Scratches and Blemishes: as the pipeline flat field correction is heavily smoothed, none of these effects will be flat fielded out.

Large Scale Variations: it is estimated that the f/96 large scale response is accurate to less than 3 percent over most the photocathode, at the wavelength it was obtained, excluding edges and corners.

Time Variability: a minor amount of time variability has been observed in the flat field response. It is largest just after HV turn-on, where changes of 1-2 percent are seen when compared to the response seen after an hour observation. The changes for the f/48 are twice as large.

Note added in Proof:

The f/48 detector was successfully switched on in the interim period between the maintenance and repair mission, and the deployment of the COSTAR corrective optics, to run a DQE proposal. Unfortunately, this good news was muted by the appearance of a rapidly increasing background level which seriously compromised the data quality and threatens the future usefulness of this detector (the background level had reached saturation levels for the larger formats). Nevertheless, it was still possible to do some analysis of the data to get estimates of the DQE of this relay. The general conclusion reached is that the DQE of f/48 appears to be on average about 60 percent of that predicted over most of the useful bandpass. No evidence was seen for any large discrepancies with the F150W and F130LP filters in the sensitivity for f/48.