FOC Cycle 4 Calibration Program: Observations and Results

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ABSTRACT

We summarize here the results of the Cycle 4 Calibration program

1. Introduction

The Cycle 4 Calibration Plan included 13 proposals, of which 10 external and 3 internal, which were all executed in the timeframe 11 Jan 1994 - 6 Jun 1995 except proposal 5520 which was withdrawn, as it was not deemed necessary anymore. In Table 1, we provide, for each proposal, the identification number, the title and the allocated time, both primary (p) and internal (i).

Table 1: FOC Cycle 4 Calibration Program Summary

ID	Proposal Title	Time (hrs)	Calibration Accuracy	
			Goal	Achieved
5517	FOC Absolute Sensitivity	12.86(p)	15-20%	10%
5518	FOC Point Source Non-Linearity- Cycle 4	5.93(p), 1.09(i)	20%	10%
5519	FOC F/96 Detector Focussing - Cycle 4	2.37(p)	10% sharp	<10% sharp
5520	FOC Optical Focus - Cycle 4	7.50(p)	10%	W/D
5521	FOC Geometric Correction and Plate Scale - Cycle 4	3.94(p), 1.45 (i)	0.3% p.s. 0.3 pix	0.3% 0.3 pix
5522	Polarization Calibration	5.02(p)	5%	5%
5523	Post-COSTAR FOC/96 Fine Aperture Location	4.99(p), 0.96(i)	0.5”	0.2”
5524	FOC Prism Wavelength Calibration - Cycle 4	2.06(p)	10%	10%
5525	FOC Neutral Density Filter Transmission	1.33(i)	10%	5%
5526	FOC UV Throughput Monitoring - Cycle 4	8.72(p)	5%	5%(3σ)
5527	FOC Post-COSTAR Relative DQE Calibration	6.11(p)	3%	5%[a]
5670	FOC Internal Relative Calibrations	12.70(i)	3%	In progress
5762	FOC Point Spread Function Monitoring		0.8μ	1-2μ
	Total	59.50(p), 17.53(i)		

a. Part of the original data was lost. This data will be re-taken and re-analysed in Cycle 6.

2. The Objectives of the Calibration Programs and the description of the Observations.

For each calibration program, we will provide a brief description of the scientific objectives and a description of the observations. In addition, for each calibration program, we will state the accuracy we hoped to achieve.

Proposal 5517: Absolute Sensitivity (F/96)

There is a SMOV DQE proposal that measures the F/96 DQE using 8 filters. This Cycle 4 proposal fills in the gaps in wavelength coverage left by the SMOV proposal while also checking those filters requested by GOs and GTOs. The filters checked are: F120M, F130LP, F140W, F152M, F165W, F175W, F190M, F220W, F253M, F275W, F278M, F320W, F342W, F346M, F372M, F430W, F480LP, F410M, F501N, F502M, and F550M.

This proposal, in using these filters, not only helps determine the DQE for the FOC+COSTAR, but it also determines the transmission characteristics of some wide-band filters and prisms. In addition to determining the DQE of the FOC+COSTAR, some requested wide-band filters will be used with the prisms to obtain the transmission characteristics of the filters, specifically looking for redleak. This requires the use of a second target, BD+75D325, to check the redleak for F320W as requested by a GO, while the F175W(GO requested this), F275W, F140W, and F130LP filters use HZ4. With the increased importance of the ND filters, the F2ND, F4ND, and F6ND will be checked with a F210M filter, while the F1ND filter is checked with the F501N and F210M filters. Furthermore, the F210M filter is used to check the format dependence of the 512zX1024, 512X512, 256X1024, 256X256 and 128X128 formats.

and updates our understanding of the format dependence nature of the FOC responsivity. Furthermore, images are taken to check that the ND filters respond as predicted; a crucial factor with the COSTAR-corrected PSFs.

Goal accuracy of the calibration:15 - 20 %.

Proposal 5518: Point Source Linearity

The point source linearity characteristics of the FOC are strongly dependenton the sharpness of the core of the PSF. After COSTAR, the PSF core size was different from that of the pre-COSTAR PSF due to two competing factors: the plate scale change from 0.022"/pixel to 0.014"/pixel, and the physical core size change (smaller), due to the core now being the diffraction-limited image from the whole HST primary. Furthermore, quantitative photometric work using FOC data is severely hampered because of the non-linear response of the detector. Because of the non-linearity, countrates must be kept down below a few tenths of a count per pixel (depending on format) in order to keep photometric uncertainties reasonable.For this reason it was necessary to re-measure the point-source linearity behaviour of the FOC F/96 detector using observations of a crowded field taken with different amounts of neutral density filters.

Observations of a crowded field (NGC5139) were taken with the F430W fileter and every ND combination from 2ND up to 7ND in the 512zx512 format and then with the F430W filter and neutral density filter combinations from 1ND to 7ND in the 512x512 format. This insured that at every ND filter combination, there would a a selection of stars which had a linear count rate that could be used to check for the effects of non-linearity on photometry and on the FWHM or sharpness of the PSF.

Proposal 5519: Detector Focus

The objective of this proposal was to verify the F/96 intensifier first stage focus. A standard HST calibration target field (NGC 104) was imaged at 7 different focus settings.The best focus had to be determined by assessment of FWHM of stars in each image.

Goal accuracy of the calibration: 10 %

Proposal 5520: Optical Focus

The objective of this test was to determine the optimum settings of the FOC refocusing mechanism, using a standard HST calibration target field (NGC 104). Two filters of different thickness were going to be used.

Goal accuracy of the calibration: 10 %.

This program was withdrawn during Cycle 4.

Proposal 5521: Geometric Correction and Plate Scale(F/96)

The aim of these observations was to update, if necessary, the platescale of the FOC f/96 Camera and to provide geometric corrections for all of the supported FOC f/96 imaging formats. The platescale would have been assessed by comparing this observation of the centre of 47-Tuc with an identical field which was obtained and calibrated as part of the Cycle 2 monitoring proposal (4231). After standard Geometric Correction of the largest imaging format, (512x1024 zoomed), all smaller formats will be corrected for the effects of geometric distortion by calculating a transform which causes the stars in the images to align with their positions in the large format. Using this method we increase the number of points used in determining geometric correction transform (since the central 512x512 format has >500 stars, compared to only ~75 reseau marks), and by default, con- strain the platescale to be the same in all formats.We also test the suitability of the same field for visible frames that have double the stars of the UV frames for use in cycle 5 as a reference.

The proposal consists of the following images of NGC104:

- 4 full format exposures taken with the F346M filter (each with a different set of neutral density filters),
- 3 full format exposures taken with the F470M filter (again each with different combination of neutral density fields),
- an INTFLAT,
- 5 full format F220W images each taken at a different POS TARG,
- 4 F220W images each using a one of the supported imaging formats (256x256, 128x128, 512x512, and 256x1024),
- then 2 F220W full format images taken with different ND filters.

The first two sets of observations will provide information on the suitability of the field in the visible, and allow a comparison with previously calibrated images for the determination of the plate scale. The images taken at different POS TARG positions and

using the different imaging formats will provide the necessary information for determining the geometric corrections.

Goal accuracy of the calibration: 0.3 % on the plate scale and 0.3 pixel RMS error for the geometric corrections.

Proposal 5522 : Polarization Calibration (F/96)

The characteristics of the Faint Object Camera with regard to polarization had to be recalibrated after the deployment of COSTAR because of the two additional oblique reflections. Exposures of the bipolar nebula Lick H-Alpha 233 with filter F430W were planned to check whether the reflections off the COSTAR mirrors has any observable effect on the polarization. One 1000-second target-acquisition exposure plus a 1500-second exposure through each of the three polarizers were required. Additional 600-second exposures of the unpolarized target NGC 5272 (M 3) using filters F410M plus F1ND were also proposed to determine the unpolarized transmission coefficients.

Goal accuracy of the calibration: 5%.

Proposal 5523: Post-COSTAR Fine Aperture Alignment (F/96)

Aim of this proposal was to fine tune the determination of the center of the F/96 FoV in the V2V3 system performed in SMOV. The target was an astrometric standard in the cluster NGC 188, which was to be placed at the center of the FoV.

Goal accuracy of the calibration: 0.5''.

Proposal 5524: Objective Prisms Wavelength Calibration

The aim of this proposal is to verify the wavelength calibrations obtained using pre-COSTAR observations and compare the photometric response between a line source and a continuum source (observed with the prisms as part of the DQE proposal). This will be accomplished by observing a source known from IUE spectra to contain a large number of emission lines in the UV and compare the resulting computed wavelengths for the lines that are detected with the IUE spectra. This will allow for refinement of the dispersion curve which was previously determined from only a very few lines. This level of calibration would then allow for reduction of objective prism observations and subsequent scientific comparison of FOC results with ground-based and IUE spectra which should which should be free of systematic errors.

Goal accuracy of the calibration: 10% spectrophotometry.

Proposal 5525: Filter PhotometricCalibration (F/96)

The aim of this proposal was to determine the transmission of the three most commonly used neutral density filters, the 1ND, 2ND and 4ND filters. The blue LED will be provide

a known source count rate INTFLAT image to be attenuated by the neutral density filters for comparison with the expected transmissions. These results will be compared with those from the DQE proposal and other calibration observations of point sources as part of a comprehensive check of these particular ND filters.

5526: FOC UV Throughput Monitoring

A subset of the DQE proposal (5517) was going to be repeated four times in Cycle 4, approximately every 3 months, to monitor possible changes in sensitivity. Frequency would have been increased if results had shown a drastic variability. The monitoring subset would have investigated the wavelength range 1200 - 2000, using the filters F120M, F140M, F170M, F210M, and F231M.

5527: FOC Post-COSTAR Relative DQE Calibration

The relative pixel-to-pixel response at UV wavelengths of the FOC over the entire field of view will be measured using a selected region of the Orion Nebula for the purposes of flat field illumination. This observation is a follow on to the 3160 FOC SV proposal which observed a region of the Orion Nebula for the purposes of determining full format flat fields. This proposal will use the F/96 full format (512zx1024) with the F220W filter instead (previous F/96 proposals have used the F140W filter). The flat field will be obtained by observing a relatively uniform region of the nebula with 10 overlapping exposures for F/96. Previous exposures of the region show that although it is smooth, it is not uniform. The overlapping exposures will be used to determine the variation in surface brightness of the nebula across the field of view and therefore allow the determination of the actual flat field response of the FOC.

Goal accuracy of the calibration: 3%.

5670: FOC Internal Relative Calibrations

The LED exposures of this program will map the relative DQE over the face of the individual detectors at the pixel level. The data will be used to update "master" DQE files in CDBS for use by the RSDP pipeline processing. A format-dependent variation in sensitivity has been noticed, so a series of exposures taken at the same LED intensity setting but in different formats will be used to measure this effect as well. Finally, pattern noise appears to disappear at low count rates, therefore a series of exposures will be included to determine the count rate threshold.

Goal accuracy of the calibration: 3%.

Proposal 5762: PSF (F/96)

This proposal will image a UV standard star in the F/96 mode in order to monitor the point-spread function of the HST-COSTAR-FOC channel. Data will be taken every 5-7 weeks, following a planned COSTAR DOB move to ensure that the FOC keeps pace with desorption. The COSTAR DOB and COSTAR FOC lines can be used as generic SUs to plug in whenever such adjustments are needed (e.g. to compensate for secondary mirror moves).

Goal accuracy of the calibration: 0.8μ secondary mirror motion.

3. Results

5517: FOC Absolute Sensitivity

Images of a spectrophotometric standard star were taken through the different filters. The FOC absolute flux was re-normalized to an aperture size of 1.0" radius. The ratio between the measured DQE and the predicted DQE was found to be a linear function of wavelength. The old FOC DQE curve was multiplied by the linear function to derive the new DQE curve, which was installed in CDBS in 10/94. The accuracy goal was met.

Documentation:

FOC-085 Results of the Cycle 4 FOC DQE Program (R. Jedrzejewski, 15 Jan 1996)

STATUS: closed.

5518: FOC Point-Source Nonlinearity

FOC images of a crowded field were taken with varying levels of neutral density filters. Data have been used to complete the data reduction for the geometric correction calibration, and are been used to perform the calibration of the Neutral Density Filters transmission curves. The FOC point source nonlinearity has not been fully characterized yet.

STATUS: in progress.

5519: FOC F/96 Detector Focus

The first-stage voltage was varied, while images of a crowded field were taken. The PSF quality was found to be optimum at the current default HV setting. No update was deemed necessary.

STATUS: closed.

5520: FOC Optical Focus

This program was withdrawn during Cycle 4, and, therefore, was never executed.

STATUS: closed.

5521/5750: FOC Geometric Correction & Plate Scale

Images of a crowded field were taken with small spatial offsets to provide mapping of the FOC geometric distortion with a much higher sampling than is provided by the FOC reseau marks. Part of program 5521 was executed incorrectly, and was repeated as program 5750.

The new geometric correction files were delivered to CDBS on 18 Sept 1995.

Documentation:

FOC-086 Deriving the Geometric Correction from Crowded Fields (P. Greenfield, Feb 1995)

FOC-087 The New f/96 Geometric Correction Models (P. Greenfield, Sept 1995)

FOC-088 A Description of the Software Used to Derive the Geometric Correction (P. Greenfield, Sept 1995)

STATUS: closed.

5522: FOC Polarization Calibration

This proposal was divided into parts: first, the imaging of a polarized (scattered) extended source through each of the 3 polarizers, and second, the imaging of an unpolarized source (we chose a crowded field to maximize the accuracy). The former exposures have allowed some checking of the angle between the polarizer axes and the image axes, while the latter exposures have allowed measurement of the instrumental polarization. The analysis of the Cycle 4 data has been performed and the proposed accuracies have been met. This program has a natural extension in Cycle 5.

Documentation:

FOC-089 Polarizer Throughputs and Image Shifts (P. Hodge, 21 July 1995)

STATUS: closed.

5523: Post-COSTAR fFOC/96 Fine Aperture Location

The program has been successfully carried out, by imaging an astrometric field using astrometric guidestars. The data analysis, which includes a study of the relative position of the astrometric target and of the astrometric guide stars in the V2V3 plane has shown that the FOC aperture location is stable, and determined with an accuracy of 0.2”. In this case, the accuracy goals have been exceeded.

Documentation:

FOC- 091 FOC/96 Cycle 4 Aperture Location (W. Hack & A. Nota, DRAFT)

STATUS: closed.

5524/5740: FOC Prism Wavelength Calibration

Prism exposures of an emission-line point source have refined the wavelength calibration for the FOC prisms. The initial execution failed due to the target being out of the field of view. A repeat was proposed, including an interactive acquisition. The proposal was re-written as Proposal 5740 to use an INT ACQ to insure proper target acquisition. Good S/N data was obtained for both prisms resulting in the determination of a new set of dispersion curves for the f/96 NUVOP and FUVOP. These dispersion curves meet the calibration accuracy goals in the 1600-4000Å range for the NUVOP and in the 1200-3000Å range for the FUVOP. The analysis software was significantly improved in the calibration process and the dispersion curves were distributed with IRAF and through the FOC WWW pages.

Documentation:

FOC-092 FOC Objective Prisms: Calibrations and Software (W. Hack)

STATUS: closed.

5525: FOC Neutral Density Filter Transmission

Comparison of images of stars with varying neutral density filters inserted gives a calibration of the ND filter transmission. Some analysis has already been performed, but the results of the various methods for measuring ND transmission have been so far inconsistent. Further analysis is being pursued using images taken as part of the non-linearity proposal.

STATUS: in progress.

5526: FOC UV Throughput Monitoring

Images of a spectrophotometric standard star have been taken every 3 months. Analysis has shown no significant trends of UV sensitivity with time at wavelengths of 1200Å, 1400Å, 1700Å and 2100Å. This program is being continued in Cycle 5.

Documentation:

FOC-090 Results of the Cycle 4 FOC UV Throughput Monitoring (R. Jedrzejewski, Jan 1996)

STATUS: closed

5527: FOC Post-COSTAR Relative DQE Calibration

In this program images of an external target are dithered to provide flatfield information. For the first execution, the small-angle maneuvers were not executed due to a scheduling error. The program was successfully repeated late in the Cycle, resulting in a delay in the analysis of this data.

STATUS: in progress.

5670: FOC Internal FOC Relative Calibrations

The LED images from this program were obtained and used to verify the format dependent sensitivity effects of the FOC in conjunction with the analysis of the DQE images (from proposal 5517). Analysis of these images for determination of flat-fields and pattern noise effects have been delayed until the external observations were available, since the two sets of images compliment each other.

STATUS: in progress.

5762: FOC Point-Spread Function Monitoring

This program was added when it was realized that the FOC is particularly sensitive to small focus errors. The 6-monthly schedule for OTA desorption corrections would make FOC images unacceptably poor at the extrema. The COSTAR DOB is moved every 3 months to keep the FOC focus closer and images taken afterwards to confirm the effectiveness of the move. This program continues in Cycle 5.

STATUS: closed.

4. Summary

The calibrations planned for Cycle 4 focussed primarily on characterizing a new instrument, an instrument whose characteristics were significantly altered with the installation of COSTAR. This comprehensive plan covered nearly all areas of FOC operations and successfully obtained all the necessary data. The calibration analysis has been completed on all but 3 characterstics: flat-fielding, neutral density filter characteristics, and non-linearity effects on the PSF. The remainder of the calibrations have resulted in the updating of critical calibration files as necessary, and the documentation of the new characteristics through ISRs and the WWW pages. Overall, the Cycle 4 calibration plan could be considered nearly complete, with the foundation set for the monitoring activities of future cycles.