Chapter 31

Calibrating and Recalibrating FOS Data

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This chapter describes how data are processed in the standard pipeline calibration. The software used in the STScI calibration pipeline is the same as the **calfos** task used to re-calibrate data. Here we will emphasize the calibration procedures themselves and defer discussions of errors and uncertainties to the next chapter.

31.1 Pipeline Calibration Overview

The basic steps of the calibration pipeline, calfos, are summarized in Figure 31.1 and Table 31.1.

Figure 31.1: Pipeline Processing by **calfos**

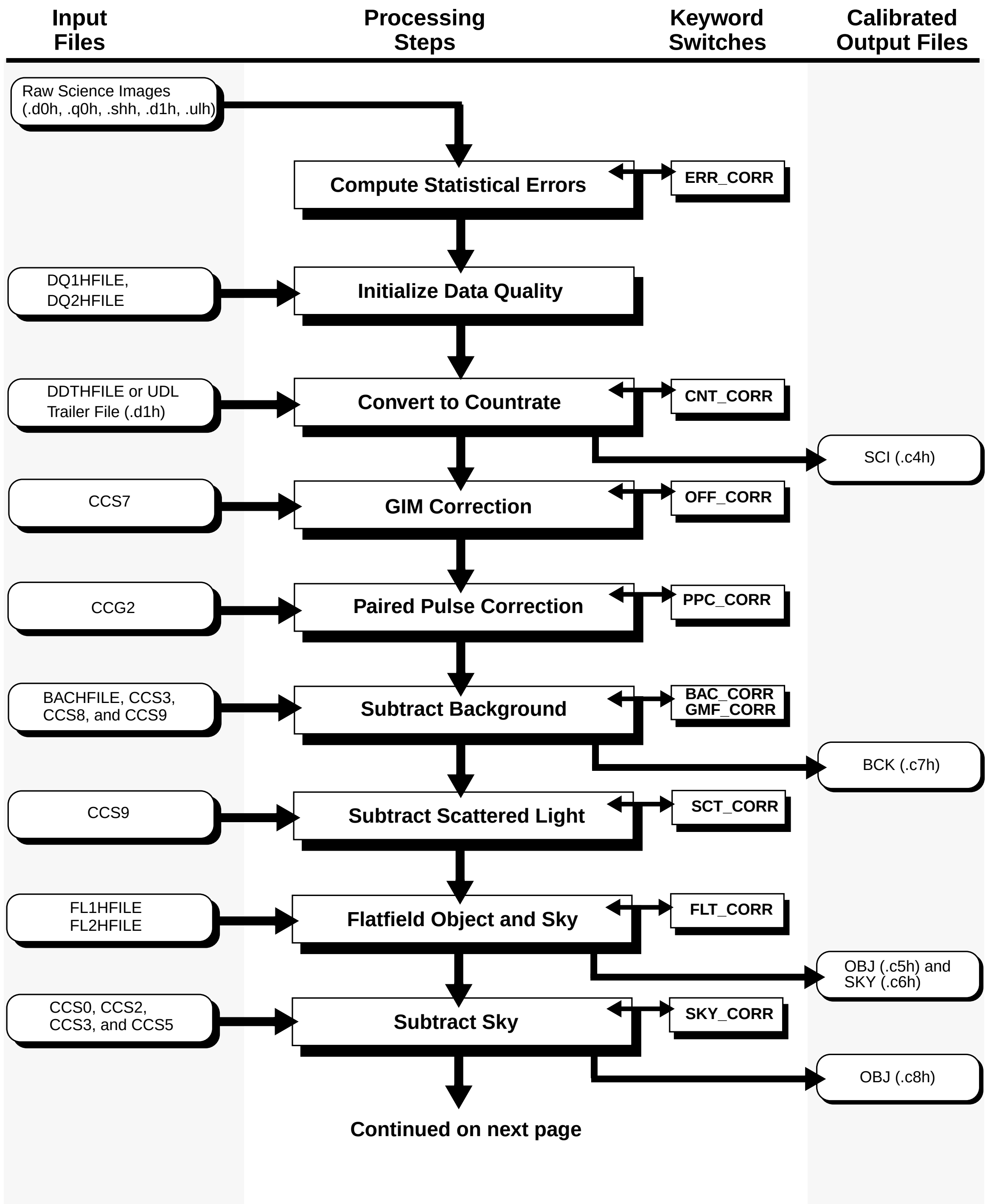

Figure 31.1: Pipeline Processing by calfos (Continued)

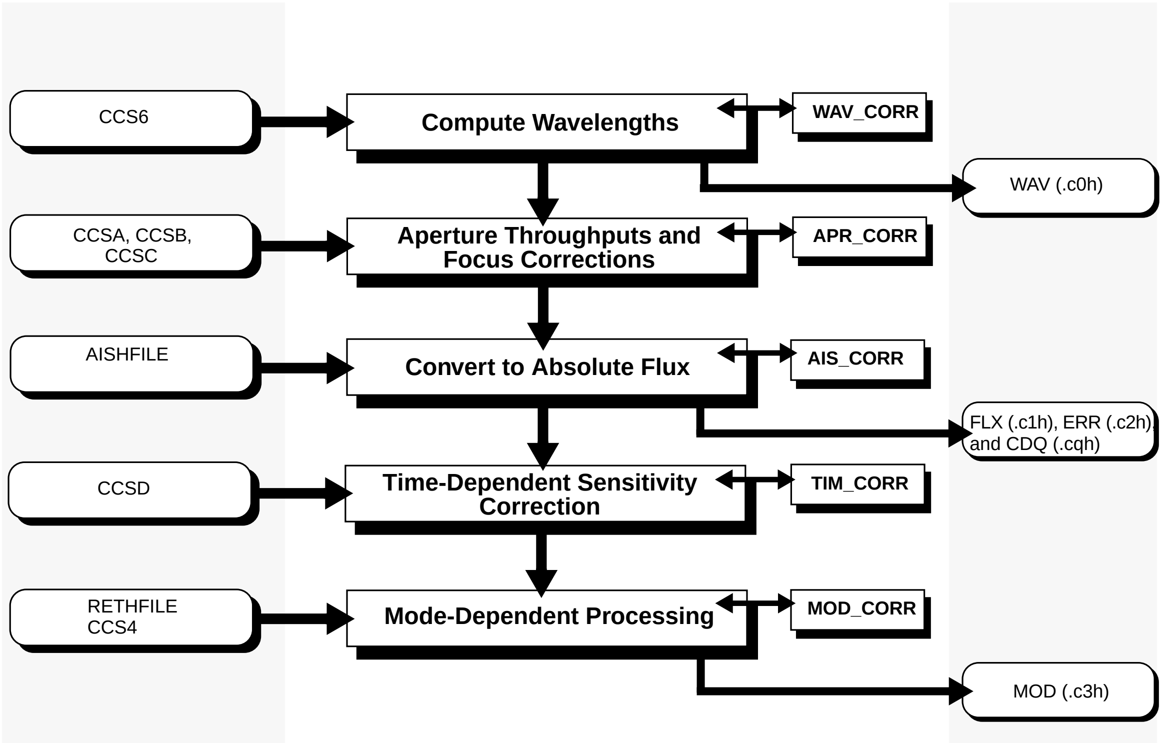

Table 31.1: Calibration Steps and Reference Files for FOS Pipeline Processing

Switch	Processing Step	Reference File or Table
ERR_CORR	Compute propagated error at each point in spectrum. Error file calibrated with science file and propagated statistical errors written to .c2h.	
CNT_CORR	Convert from raw counts to count rates by dividing each data point by exposure time and correcting for disabled diodes. Diode numbers are taken from ddthfile or from the unique data log.	`ddthfile`
OFF_CORR	Correct for image motion in the FOS X direction (dispersion) induced by magnetic field. Uses a model of the earth's magnetic field along with scale factors from table ccs7. This step should be applied for observations taken before April 5, 1993, after which the on-board GIM correction is used.	`ccs7`
PPC_CORR	Correct raw count rates for saturation in detector electronics using paired-pulse correction table (coccgr2).	`ccg2`
BAC_CORR	Correct for particle-induced background using default reference background (bachfile) if no background spectrum was obtained as part of the observation.	`bachfile`

Table 31.1: Calibration Steps and Reference Files for FOS Pipeline Processing (Continued)

Switch	Processing Step	Reference File or Table
GMF_CORR	If BAC_CORR is set to PERFORM, and the default background file (bachfile) is used, this file can be scaled to the expected mean count rate for the spacecraft geomagnetic position using the ccs8 reference table and subtracted from the count rate spectra by setting GMF_CORR to PERFORM. Scaled background is written to the .c7h file.	`ccs8`
SCT_CORR	Remove background scattered light. The scattered light is determined by calculating the mean value of diodes not illuminated by the selected grating. This mean is then subtracted from the observed spectrum. Un-illuminated diodes are found in the CCS9 reference table.	`ccs9`
FLT_CORR	Correct for diode to diode sensitivity variations by multiplying by the flatfield response file (fl1hfile). For paired aperture or spectropolarimetry observations, a second flatfield file is used.	`fl1hfile, fl2hfile`
SKY_CORR	If a sky spectrum was observed, the background is subtracted and the sky smoothed using a median and mean filter. Uses filter widths table (ccs3), aperture size table (ccs0), emission line positions (ccs2), and sky shift table (ccs5).	`ccs0, ccs2, ccs3, ccs5`
WAV_CORR	Compute vacuum wavelength scale for each object or sky spectrum using coefficients (ccs6).	`ccs6`
APR_CORR	Correct for relative aperture throughputs. Object data are normalized to the reference aperture used to derive the average inverse sensitivity used in AIS_CORR. This step is required if AIS_CORR is used. Additionally, object data are divided to correct for changes in aperture throughput due to changes in OTA focus.	`ccsa, ccsb, ccsc`
FLX_CORR	**POLARIMETRY ONLY**: Convert from count rate to absolute flux units by multiplying by inverse sensitivity curve. Uses inverse sensitivity file (iv1hfile) and, for paired aperture or spectropolarimetry, file (iv2hfile).	`iv1hfile, iv2hfile`
AIS_CORR	Convert from count rate to absolute flux units by multiplying by inverse sensitivity curves. This step replaces FLX_CORR and is different in that an average inverse sensitivity, determined from calibration of all epochs, is used. APR_CORR must be performed for this step to have meaning.	`aishfile`
TIM_CORR	Correct for changes in instrument sensitivity over time by dividing the object data by an appropriate correction factor.	`ccsd`
MOD_CORR	Perform ground software mode dependent corrections for time-resolved, rapid readout, or spectropolarimetry observations. For RAPID, write total flux and sum of statistical errors to groups 1 and 2 of .c3h file. For PERIOD mode, write pixel-by-pixel averages of all slices to groups 1 and 2 of .c3h file. For spectropolarimetry, data from individual waveplate positions is used to make Stokes parameters I, Q, U, and V and linear and circular polarization position angle spectra.	`ccs4, rethfile`

31.2 Input Files

calfos uses three different types of input files:

- Input data files: these are the observation data files, in Generic Edited Information Set (GEIS) format, i.e., a multi-group image.
- Reference files (GEIS format images).
- Reference tables (STSDAS tables).

31.2.1 Science Files Required by calfos

Table 31.2 lists the science files that are used as required input to **calfos**.

Table 31.2: Observation Input Files for calfos

File Extension	File Contents
`.shh` and `.shd`	Standard header packet
`.ulh` and `.uld`	Unique data log
`.d0h` and `.d0d`	Science data
`.q0h` and `.q0d`	Science data quality
`.x0h` and `.x0d`	Science header line
`.xqh` and `.xqd`	Science header line data quality
`.d1h` and `.d1d`	Science trailer line
`.q1h` and `.q1d`	Science trailer line data quality

31.2.2 Reference Files and Tables

Table 31.1 lists the types of calibration reference files that are used in the pipeline and the information these files contain. Although reference files can be generated for any combination of NXSTEPS, FCHNL (first channel), NCHNLS, and OVERSCAN, the routine calibration reference files have a length of 2064 pixels, corresponding to the standard keyword values:

- NXSTEPS = 4
- FCHNL = 0
- NCHNLS = 512
- OVERSCAN = 5

For other values of FCHNL, NCHNLS, and NXSTEPS **calfos** interpolates from or resamples the standard reference files. *Only* OVERSCAN = 5 *is supported by FOS calibration*. Highly accurate OVERSCAN=1 reference files can not be simply extracted from the standard reference files as different values of OVERSCAN produced contributions from different numbers of physical diodes to the observed pixels. All FOS calibration observations were made with OVERSCAN=5.

Table 31.3: Reference Tables and Files Required by calfos

Header Keyword	Data Base Relation	Filename Extension	File Contents
CCS0	cyccs0r	`.cy0`	Aperture areas
CCS1	cyccs1r	`.cy1`	Aperture positions
CCS2	cyccs2r	`.cy2`	Sky emission line positions
CCS3	cyccs3r	`.cy3`	Sky and background filter widths
CCS4	cyccs4r	`.cy4`	Polarimetry parameters
CCS5	cyccs5r	`.cy5`	Sky shift parameters
CCS6	cyccs6r	`.cy6`	Wavelength dispersion coefficients
CCS7	cyccs7r	`.cy7`	GIM correction scale factors
CCS8	cyccs8r	`.cy8`	Predicted background (count rate)
CCS9	cyccs9r	`.cy9`	Un-illuminated diodes for scattered light correction
CCSA	cyccsar	`.cya`	OTA focus positions for aperture throughputs
CCSB	cyccsbr	`.cyb`	Aperture throughput coefficients
CCSC	cyccscr	`.cyc`	Throughput corrections versus focus
CCSD	cyccsdr	`.cyd`	Instrument sensitivity throughput correction factors
CCG2	coccg2r	`.cmg`	Paired-pulse coefficients
BACHFILE	cybacr	`.r0h` & `.r0d`	Default background file (count rate)
FL*n*HFILE	cyfltr	`.r1h` & `.r1d`	Flatfield file
IV*n*HFILE	cyivsr	`.r2h` & `.r2d`	Inverse sensitivity file (ergs cm^{-2} $Å^{-1}$ $count^{-1}$ $diode^{-1}$)[a]
RETHFILE	cyretr	`.r3h` & `.r3d`	Retardation file for polarimetry data
DDTHFILE	cyddtr	`.r4h` & `.r4d`	Disabled diode file
DQ*n*HFILE	cyqinr	`.r5h` & `.r5d`	Data quality initialization file
AISHFILE	cyaisr	`.r8h` & `.r8d`	Average inverse sensitivity file

a. Note that all references to inverse sensitivity, IVS, in the version 6 *FOS Instrument Handbook* contain the per diode component of this definition implicitly. The meaning of IVS is identical in both this document and in the *FOS Instrument Handbook*.

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31.3 CDBS Reference Relations

The CDBS relations for the FOS reference files and reference tables are described below. Note that these are relations that point to the reference files and tables: they do not contain the data used. Multiple entries are allowed for each reference file or table type which are distinguished by effective (or USEAFTER) date.

- **cyccs0r:** This table is used to determine the aperture area for paired apertures. If STEP-PATT=OBJ-SKY (or STAR-SKY) is used, it is only for sky subtraction.
- **cyccs1r:** This table is used to determine which aperture (UPPER or LOWER) of a paired aperture was used for observing an object or sky spectrum.
- **cyccs2r:** Regions of the sky spectrum known to have emission lines. These regions are not smoothed before the sky is subtracted from the object spectrum.

The cyccs2r table values were never formally confirmed after science verification (SV). This had little or no practical impact as, only a few sky observations were taken, none of which were intended to aid the proposed science.

- **cyccs3r:** Filter widths used for smoothing the sky or background spectra.
- **cyccs4r:** Polarimetry information regarding waveplate pass direction angles, initial waveplate position angles, the pixel number at which the wavelength shift between the two pass directions is to be determined for computing the merged spectrum, and the phase and amplitude coefficients for correction of polarization angle ripple.
- **cyccs5r:** The shift in pixels to be applied to the sky spectrum before subtraction.
- **cyccs6r:** Dispersion coefficients to generate wavelength scales. There is one entry for each detector, disperser, aperture, and polarizer combination.
- **cyccs7r:** GIM correction scale factors used to scale the modeled shift of the spectrum due to the earth's magnetic field.
- **cyccs8r:** Predicted background count rates as a function of geomagnetic position used to scale the background reference file.
- **cyccs9r**: Un-illuminated diode ranges for each detector and grating combination. Used to determine the background scattered light.
- **cyccsar**: List of OTA focus positions versus time. Used to correct for aperture sensitivity dependent on focus position.

- **cyccsbr**: As a function of detector and disperser combination, coefficients to normalize aperture throughputs to the reference aperture used to determine the average inverse sensitivity calibration.
- **cyccscr**: Throughput corrections versus focus as a function of the combination of detector, disperser, and aperture.
- **cyccsdr**: As a function of detector and disperser combination, throughput correction factors to account for changes in instrument sensitivity over time.
- **coccg2r:** Paired pulse correction table used to correct for non-linear response of the diode electronics. Both detectors have the same correction constants, which are time independent. This table is shared with GHRS.
- **cybacr:** This relation is for the background reference files. For each detector there is one file that is used as a default background count rate in the event no background spectra were observed.
- **cyfltr:** This relation is for the flatfield reference files. These files are used to remove the small scale diode and photocathode non-uniformities. There are separate files for each detector, disperser, aperture, and polarizer combination.
- **cyivsr:** *(polarimetry only)* This relation is for inverse sensitivity reference files. These files are used to convert corrected count rates to absolute flux units. There are separate files for each detector, disperser, aperture and polarizer combination.

Figure 31.2: Pre-COSTAR Inverse Sensitivity Curves for Blue High Dispersion Gratings

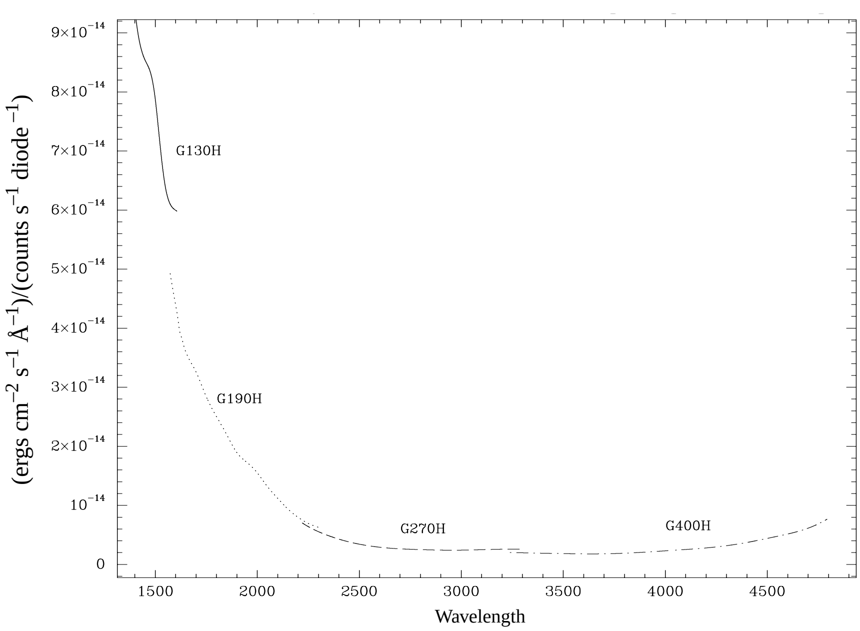


Figure 31.3: Pre-COSTAR Inverse Sensitivity Curves for Red High Dispersion Gratings

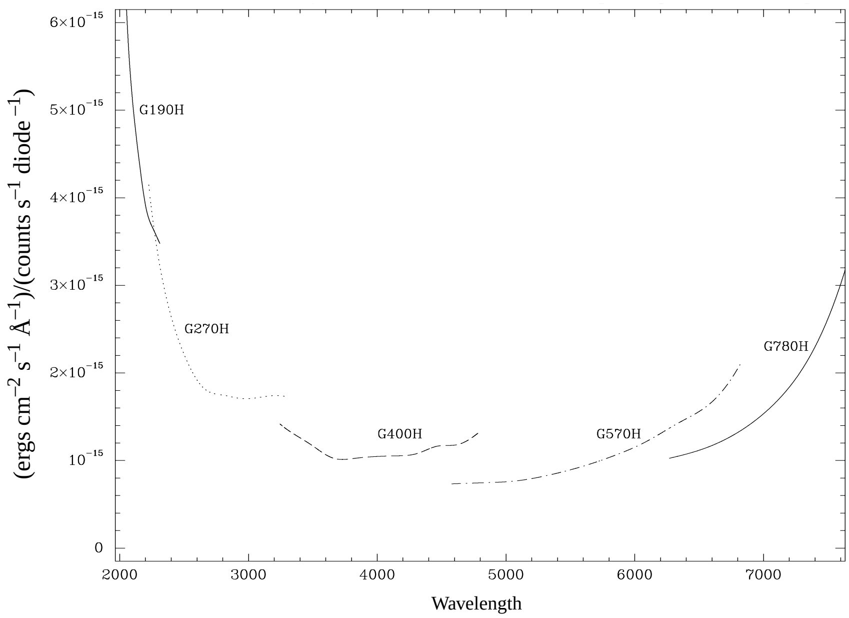


Figure 31.4: Post-COSTAR Sensitivity Curves for High Dispersion Gratings

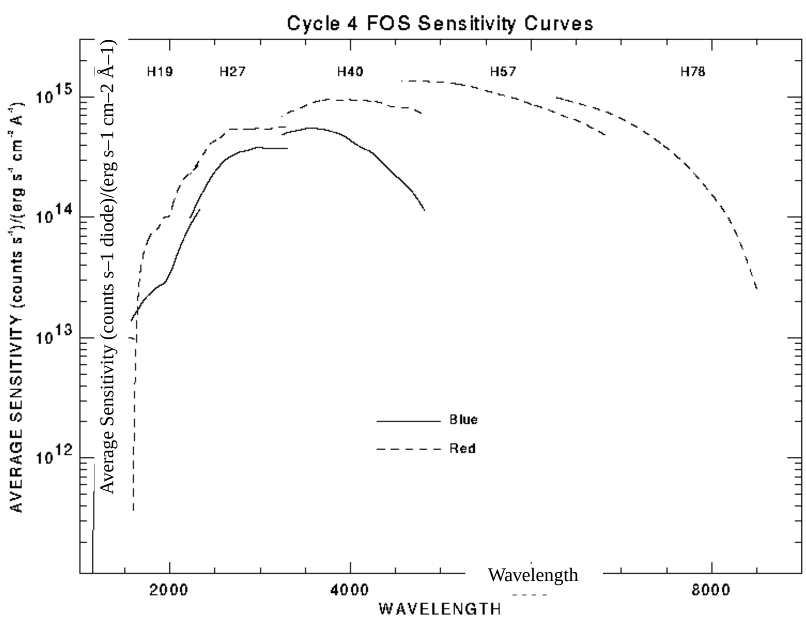
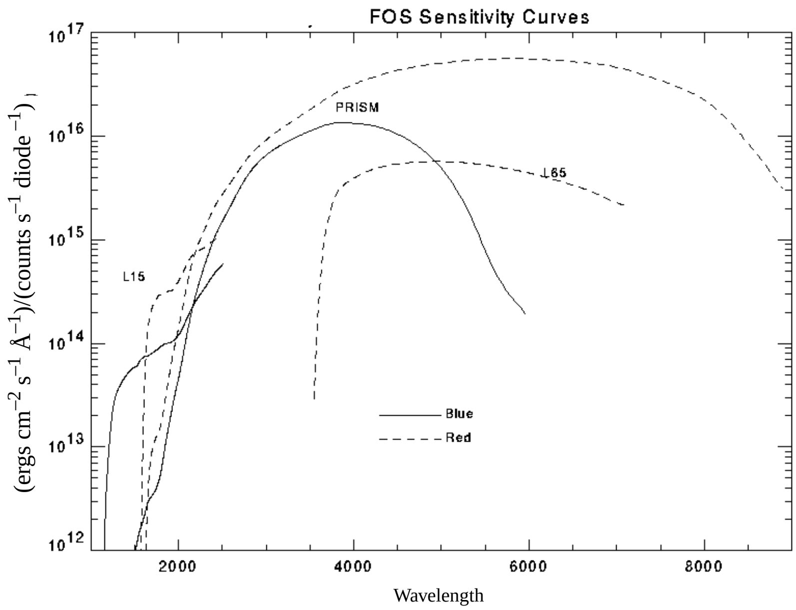


Figure 31.5: Post-COSTAR Sensitivity Curves for Low Dispersion Gratings



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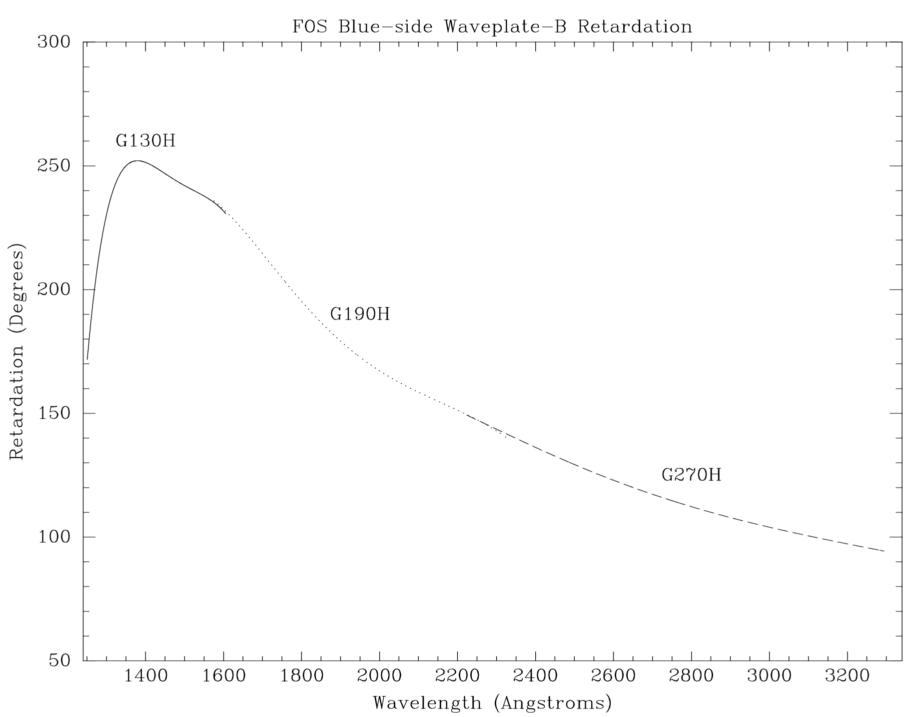
- **cyretr:** This relation is for retardation reference files used for spectropolarimetric data. The files are used to create the observation matrix *f*(*w*). There are separate files for each detector, disperser, and polarizer combination. The three available retardation files for the blue detector and waveplate B are plotted in Figure 31.6 with the appropriate disperser shown.

Figure 31.6: Retardation Reference Files



- **cyddtr:** This is the relation for the disabled diode files. The table is used only if the keyword DEFDDTBL = F in the `.d0h` file. The disabled diode information is also contained in the `.ulh` file. DEFDDTBL *must be set to* F *for proper re-calibration of any FOS data!* Over the operational lifetime of the FOS, 26 FOS/BL and 17 FOS/RD diodes were disabled. Note that the diodes listed in Tables 31.4 and 31.5 are numbered such that the first diode in the diode array is 0 and the last diode is 511. For use in IRAF and STSDAS, the diode number would be the diode number in the table + 1.

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Table 31.4: Blue Detector Disabled Diodes

DISABLED Dead Channels	DISABLED Noisy Channels		DISABLED Cross-Wired Channels	ENABLED But Occasionally Reported Noisy
49	31	268	47	8
101	73	398	55	138
223	144	415		139
284	201	427		209/210
292	218	451		381
409	225	465		421
441	235	472		426
471	241	497		
8	16		2	7

Table 31.5: Red Detector Disabled Diodes

DISABLED Dead Channels	DISABLED Noisy Channels	ENABLED But Occasionally Reported Noisy	
2	110	97	258/259
6	189	114/115	261
29	285	116	268
197	380	142	285
153	381	163	410
212	405	174	
289	409	181	
308	412	225	
486		243	
9	8	14	

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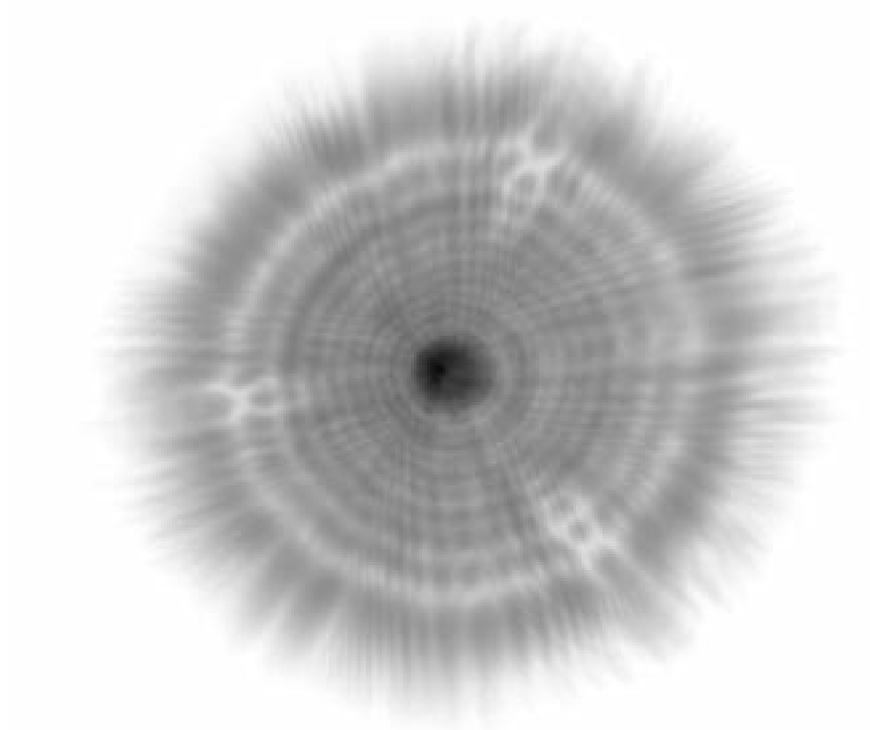
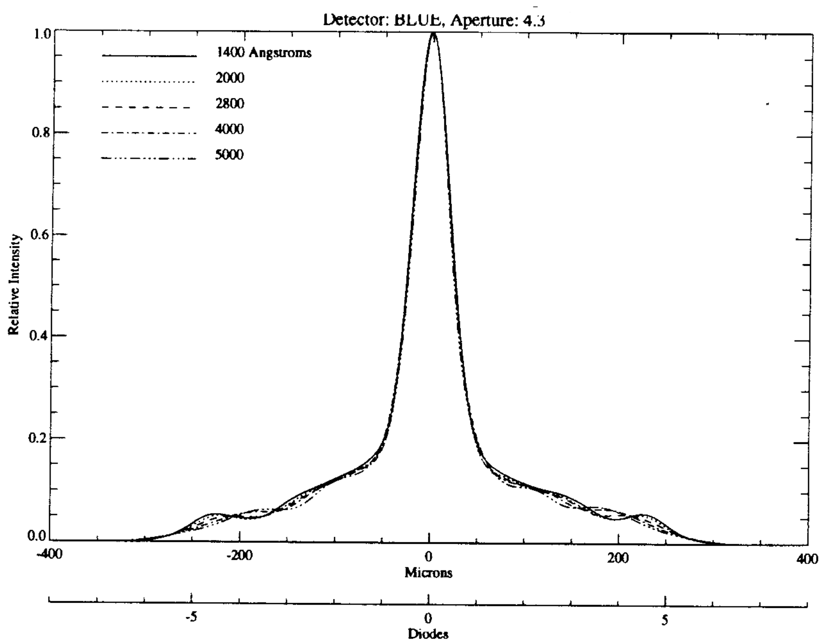
- **cyaisr**: This is the relation for the average inverse sensitivity reference files. These files are used to convert corrected count rates to absolute flux units. There is one file for each detector and disperser combination. Figures 31.2 and 31.3 show the pre-COSTAR inverse sensitivity for the most commonly used gratings for both detectors. The post-COSTAR sensitivity curves are plotted in Figures 31.4 and 31.5
- **cypsf:** This is the relation for the monochromatic pre-COSTAR point spread functions for the FOS, covering the wavelength range 1200–5400 Å for the blue side and 1600–8400 Å for the red side. These PSFs were modeled using the TIM software. In Figure 31.7, a sample blue side FOS PSF at 1400 Å is shown.

Figure 31.7: Example of a Pre-COSTAR Point Spread Function for the FOS



- **cylsf:** This is the relation for the monochromatic pre-COSTAR line spread functions for all of the non-occulting FOS apertures computed using the PSFs in cypsf. Figure 31.8 shows a sample monochromatic pre-COSTAR FOS LSF for the blue side `4.3` aperture. Pre-COSTAR LSFs are available at each PSF wavelength. Observation-derived LSFs are not stored in CDBS.

Figure 31.8: Example of a Pre-COSTAR Line Spread Function for the FOS



- **cyqinr:** This is the relation for the data quality initialization files. These files were intended to flag intermittent or noisy diodes, *but were never kept up to date* since dead diode quality flagging is handled in the **calfos** pipeline through the use of the DDTHFILE dead diode reference file.

31.4 Details of the FOS Pipeline Process

This section describes in detail the STScI pipeline calibration or re-calibration (**calfos**) procedures. Each step of the processing is selected by the values of keyword *switches* in the science data header file. All FOS observations undergo pipeline processing to some extent. Target acquisition and IMAGE mode data are processed only through step 6 (paired pulse correction) but are not GIM corrected. ACCUM data are processed through step 14 (absolute flux calibration) and RAPID, PERIOD, and POLARIMETRY data are processed through step 15 (special mode processing). The steps in the FOS calibration process are:

1. Read the raw data.
2. Calculate statistical errors (ERR_CORR).
3. Initialize data quality.
4. Convert to count rates including dead diode correction (CNT_CORR).
5. Perform GIM correction (OFF_CORR).
6. Do paired-pulse correction (PPC_CORR).

7. Subtract background (BAC_CORR).
8. Subtract scattered light (SCT_CORR).
9. Do flatfield correction (FLT_CORR).
10. Subtract sky (SKY_CORR).
11. Correct aperture throughput and focus effects (APR_CORR).
12. Compute wavelengths (WAV_CORR).
13. Correct time-dependent sensitivity variations (TIM_CORR).
14. Perform absolute calibration (FLX_CORR); superseded by AIS_CORR.
15. Do special mode processing (MOD_CORR) if RAPID, PERIOD, or spectropolarimetry.

These steps are described in detail in the following sections. A basic flowchart is provided in Figure 31.1.

Note: For *non*-polarimetry cases use *only* AIS_CORR; if both are set to PERFORM, AIS_CORR overrides FLX_CORR as a safeguard. For polarimetry use FLX_CORR; here it will override AIS_CORR should both be set to PERFORM.

31.4.1 Reading the Raw Data

The raw data, stored in the `.d0h` file, are the starting point of the pipeline data reduction and calibration process. The raw science data are read from the `.d0h` file and the initial data quality information is read from the `.q0h` file. If science trailer (`.d1h`) and trailer data quality (`.q1h`) files exist, these are also read at this time.

31.4.2 Calculating Statistical Errors (ERR_CORR)

The noise in the raw data is photon (Poisson) noise and errors are estimated by simply calculating the square root of the raw counts per pixel. An error value of zero is assigned to filled data, i.e., pixels that have a data quality value of 800.[1] For all observing modes except polarimetry, an error value of zero is assigned to pixels that have zero raw counts. Polarimetry data that have zero raw counts are assigned an error value of one.

From this point on, the error data are processed in lock-step with the spectral data. Errors caused by sky and background subtraction, as well as those from flatfields and inverse sensitivity files, are not included in the error estimate. At the end of the processing, the calibrated error data will be written to the `.c2h` file.

1. Data quality values are described in Table 30.2.

31.4.3 Data Quality Initialization

The initial values of the data quality information are the data quality entries from the spacecraft as recorded in the `.q0h` file. This step of the processing adds values from the data quality reference files to the initial values in the `.q0h` file. The routine uses the data quality initialization reference file DQ1HFILE listed in the `.d0h` file. A second file, DQ2HFILE, is necessary for paired-aperture and spectropolarimetry observations. These reference files contain flags for intermittent noisy and dead channels (data quality values 170 and 160, respectively). The data quality values are carried along throughout the remaining processing steps where subsequent routines add values corresponding to other problem conditions. *Only the highest (most severe) data quality value is retained for each pixel*. At the end of the processing the final data quality values are written to the `.cqh` file.

The noisy and dead channels in the data quality files were often out of date, but the dead diode table (DDTHFILE) contains the most accurate list of dead and disabled diodes. Noisy diodes are not flagged in routine processing. Normally, after three reports of noisy activity an offending diode was disabled. As a result, diodes that had fewer than three reports as noisy are not flagged in the data quality file.

31.4.4 Conversion to Count Rates (CNT_CORR)

At this step, the raw counts per pixel are converted to count rates by dividing by the exposure time of each pixel. Filled data (data quality = 800) are set to zero. *A correction for disabled diodes is also included at this point.* If the keyword DEFDDTBL in the `.d0h` file is set to TRUE, the list of disabled diodes is read from the unique data log (`.ulh`) file. Otherwise the list is read from the disabled diode reference file, DDTHFILE, named in the `.d0h` file. In pipeline calibration the DDTHFILE was more commonly used for the disabled diode information.

For re-calibration purposes, DEFDDTBL *should always be set to* FALSE *so that the FOS closeout calibration dead diode tables are used for the proper dead diode correction*.

The actual process by which the correction for dead diodes is accomplished is as follows. First, recall that because of the use of the OVERSCAN function, each pixel in the observed spectrum actually contains contributions from several neighboring diodes (see “Data Acquisition Fundamentals” on page 29-15). Therefore, if one or more particular diodes out of the group that *contributed to* a given output pixel is dead or disabled, there will still be some amount of signal due to the contribution of the remaining live diodes in the group. We can correct the observed signal in that pixel back to the level it would have had if all diodes were live; to do this, we divide by the relative fraction of live diodes. The corrected pixel value is zero if all the diodes that contribute to that pixel are dead or disabled, otherwise, the value is given by the equation:

$$corr = obs\frac{total}{(total - dead)}$$

Where:

- *corr* – is the corrected pixel value.
- *obs* – is the observed pixel value.
- *total* – is the total number (live + dead) of diodes.
- *dead* – is the number of dead or disabled diodes.

This correction to the signal is applied at the same time the raw data are divided by exposure time. If the fraction of dead diodes for a given pixel exceeds 50%, then a data quality value of 50 is assigned. If all of the diodes for a given pixel are dead, both the data and error values are set to zero and a data quality value of 400 is assigned.

The count rate spectral data are written to the `.c4h` file at this point. Note that the S/N and the computed statistical errors in a given pixel are appropriate to the actually observed, not the corrected, count rate.

31.4.5 GIM Correction (OFF_CORR)

Data obtained prior to April 5, 1993, do not have an onboard geomagnetic-induced image motion (GIM) correction applied, and therefore require a correction for GIM in the pipeline calibration. Note that there are some observations obtained after April 5, 1993, that do *not* have onboard GIM correction, because the application of the onboard GIM correction depended on when the proposal was completely processed for scheduling on the spacecraft. Reference to keywords YFGIMPEN and YFGIMPER, respectively, indicate whether onboard GIM correction was enabled and whether any error occurred in its implementation. The GIM correction is determined by scaling a model of the strength of the geomagnetic field at the location of the spacecraft. The model scale factors are read from the CCS7 reference table. The correction is applied to the spectral data, the error data, and the data quality values.

A unique correction is determined for each data group based on the orbital position of the spacecraft at the mid-point of the observation time for each group. While the correction is calculated to sub-pixel accuracy, it is applied as an integer value and is therefore accurate only to the nearest integral pixel. This is done to avoid resampling the data in the calibration process. Furthermore, the pipeline correction (OFF_CORR) is applied only in the *x*-direction (i.e., the dispersion direction).

The correction is applied by simply shifting pixel values from one array location to another. As a typical example, if the amount of the correction for a particular data group is calculated to be +2.38 pixels, the data point originally at pixel location 1 is shifted to pixel 3, pixel 2 shifted to pixel 4, pixel 3 to pixel 5, and so on. Pixel locations at the ends of the array that are left vacant by this process (e.g., pixels 1 and 2 in the example above) are set to a value of zero and are assigned a data quality value of 700.

Special handling is required for data obtained in ACCUM mode since each data frame contains the sum of all frames up to that point. In order to apply a unique correction to each frame, data taken in ACCUM mode are first *unraveled* into separate frames. Each frame is then corrected individually, and the corrected frames are recombined.

The *pipeline processing* GIM correction (OFF_CORR) is not applied to target acquisition data, image mode data, and polarimetry data. The correction can be applied to IMAGE mode *spectral* data by setting header keyword OFF_CORR to PERFORM prior to running **calfos**.

The *onboard* GIM correction is applied on a much finer grid than integral pixels and is made within the FOS so that data are recorded by the detector with the corrections already included. The onboard GIM correction is applied along both the direction of the diode array and in the perpendicular direction. In the *x*-direction the onboard GIM correction is applied in units of 1/32 of the width of the diodes and in the *y*-direction in units of 1/256 of the diode height.

The *onboard* GIM correction is calculated and applied every 30 seconds, and is applied to all observations except for ACQ/PEAK observations.

31.4.6 Paired Pulse Correction (PPC_CORR)

This step corrects the data for saturation in the detector electronics. The dead time constants q_0, q_1, and F are read from the reference table CCG2. The values of these dead time constants in the CCG2 table are $q_0 = 9.62\text{e-}6$ seconds, $q_1 = 1.826\text{e-}10\ \text{sec}^2$/counts, and F = 52,000 counts per second. These quantities were determined in laboratory measurements prior to launch and were never modified (*FOS ISR*s 25 and 45). The following equation is used to estimate the true count rate:

$$x = \frac{y}{(1 - yt)}$$

Where:

- x – is the true count rate.

- *y* – is the observed count rate.
- *t* – is q_0 for y less than or equal to F.
- *t* – is $q_0 + q_1 * (y-F)$ for y greater than F.

The values of these different saturation limits in the CCG2 table are as follows:

- Observed count rates greater than the saturation limit of 57,000 counts per second (and recorded in the **calfos** processing log) are set to zero and assigned a data quality value of 300.
- All observed count rates that are between this severe saturation limit and 10 counts/second are corrected, but those lying between the predefined limits of large (55,000 counts/second) and severe saturation (57,000 counts/second) are assigned a data quality value of 190.
- Those that lie between the limits of moderate (52,000 counts/second) and large (55,000 counts/second) saturation are assigned a data quality value of 130, and the paired pulse correction is applied.
- Count rates between the threshold value (10 counts/second) and 52,000 counts/second have the paired pulse correction applied.
- Data with count rates below this threshold value (10 counts/second) do not have any paired-pulse correction.

31.4.7 Background Subtraction (BAC_CORR)

This step subtracts the background (i.e., the particle-induced dark count) from object and sky (if present) spectra. If no background spectrum was obtained with the observation (the situation for nearly all FOS exposures), a default background reference file, BACHFILE, which is scaled to a mean expected count rate based on the geomagnetic position of the spacecraft at the time of the observation, is used. The scaling parameters are stored in the reference table CCS8. The scaled background reference spectrum is written to the `.c7h` file for later examination.

If an observed background was used (rarely the case), it is first repaired; bad points (i.e., points at which the data are flagged as lost or garbled in the telemetry process) are filled by linearly interpolating between *good neighbors*. Next, the background is smoothed with a median filter, followed by a mean filter. The median and mean filter widths are stored in reference table CCS3. No smoothing is done to the background reference file, if used, since the file is already a smoothed approximation to the background. Spectral data at pixel locations corresponding to repaired background data are assigned a data quality value of 120. Finally, the repaired background data are subtracted.

Although this is called background subtraction, it is really a *dark count* subtraction.

31.4.8 Scattered Light Correction (SCT_CORR)

Scattered light observed in FOS data is produced by the diffraction patterns of the FOS gratings, the entrance apertures, and the micro-roughness of the gratings.

The routine pipeline scattered light correction is applied only for those gratings that produce spectra in which the detector had regions of zero sensitivity to dispersed light or that did not fully illuminate all the science diodes (Table 31.6). The values listed in the table apply to spectra with FCHNL=0, NCHNLS=512, NXSTEPS=4, and OVERSCAN=5, i.e., the default FOS observing mode. For the listed combinations, these *dark* diodes can be used to estimate the scattered light illuminating all of the diodes. For the valid combinations, the average count rate for these diodes is determined and subtracted from the whole data array, including the *dark* pixels. If the dark pixels were excluded from readout by the use of a restructured wavelength range, no scattered light correction is made.

The correction applied in this way is only a wavelength-independent first-order approximation. The **calfos** task reports (via the standard output) whether it performs this step, along with the subtracted value. Group parameter SCT_VAL gives the value subtracted from each group. This information is also provided in the paper products and, if you have a dataset from the pipeline, is in the trailer file.

For details of the correction please see *FOS ISR* 103. Note that the scattered light correction is in addition to the background subtraction. Effectively, *the scattered light correction serves to remove residual background, as well*.

Table 31.6: Regions Used for Scattered Light Subtraction

Detector	Grating	Minimum Pixel Number	Maximum Pixel Number	Total Pixels
Blue	G130H	31	130	100
Blue	G160L	901	1200	300
Blue	Prism	1861	2060	200
Red	G190H	2041	2060	20
Red	G780H	11	150	140
Red	G160L	601	900	300
Red	G650L	1101	1200	100
Red	Prism	1	900	900

Since the scattered light characteristics of the FOS are now well understood, a scattered light model is available at STScI. It is available for use as a post-observation parametric analysis tool (**bspec**) in STSDAS to estimate the amount of scattered light affecting a given observation (see *FOS ISR* 127). The amount of scattered light depends on the spectral energy distribution across the whole detector wavelength range of the object being observed and on the sensitivity of the detector. For cool objects the number of scattered light photons can dominate the dispersed spectrum in the UV. Thus, in order to model the scattered light in the FOS appropriately, the red part of the source spectrum has to be *very well* known. For an atlas of predicted scattered light as a function of object type and FOS disperser and additional guidelines for modeling FOS grating scatter with **bspec**, see *FOS ISR* 151.

31.4.9 Flatfield Correction (FLT_CORR)

This step removes the diode-to-diode sensitivity variations and fine structure (typically on size scales of ten diodes or less) from the object, error, and sky spectra by multiplying each by the inverse flatfield response as stored in the FL1HFILE reference file. A second flatfield file, FL2HFILE, is required for paired aperture or spectropolarimetry observations. No new data quality values are assigned in this step.

Different locations on the FOS photocathodes displayed quite different flatfield characteristics so that FOS flats were aperture-dependent. Additionally, FOS flatfields for some dispersers were quite time-variable. Care must be taken to use the correct flatfield reference file for the date and aperture of observation.

31.4.10 Sky Subtraction (SKY_CORR)

If the sky was observed, the flatfielded sky spectrum is repaired in the same fashion as described above for an observed background spectrum. The spectrum is then smoothed once with a median filter and twice with a mean filter, except in regions of known emission lines, which are masked out. The CCS2 reference table contains the pairs of starting and ending pixel positions for masking the sky emission lines. The sky spectrum is then scaled by the ratio of the object and sky aperture areas, and then shifted in pixel space (to the nearest integer pixel) so that the wavelength scales of the object and sky spectra match. The sky spectrum is then subtracted from the object spectra and the resulting sky-subtracted object spectrum is written to the `.c8h` file. Pixel locations in the sky-subtracted object spectrum that correspond to repaired locations in the sky spectrum are assigned a data quality value of 120.

This routine requires table CCS3 containing the filter widths, the aperture size table CCS0, the emission line position table CCS2, and the sky shift table CCS5.

For OBJ-SKY (or STAR-SKY) observations, half the integration time is spent on the sky. The only science observations made of the sky were taken by mistake and were not required for proposal science. Additionally, the CCS2 table values were never confirmed.

Note that—especially for extended objects—paired aperture observations could be obtained in the so-called “OBJ-OBJ” mode, in which no sky subtractions were performed (see “Paired Aperture Calibration Anomaly” on page 31-25).

31.4.11 Computing the Wavelength Scale (WAV_CORR)

A *vacuum* wavelength scale at *all* wavelengths is computed for each object or sky spectrum. Wavelengths are computed using dispersion coefficients corresponding to each grating and aperture combination stored in reference table CCS6. *Corrections for telescope motion or motion of the Earth are not made in the standard pipeline calibration.* The computed wavelength array is written to the `.c0h` file.

For the gratings the wavelengths are computed as follows:

$$\lambda(\text{Å}) = \sum_{p=0}^{3} l(p) \times x^p$$

For the prism, wavelengths are computed as:

$$\lambda(\text{Å}) = \sum_{p=0}^{4} \frac{l(p)}{(x - x_0)^p}$$

Where:

- $l(p)$ – are the dispersion coefficients in table CCS6.
- x – is the position (in diode units) in the object spectrum, where the first diode is indexed as 0.
- x_0 – is a scalar parameter also found in table CCS6.

Note that the above equations determine the wavelength at each diode. This must be converted to pixels using NXSTEPS. For example, if NXSTEPS=4, the values for x are given as 0, 0.25, 0.5, 0.75, 1, etc., for pixels 1, 2, 3, 4, 5, etc.

For multigroup data, as in either rapid-readout or spectropolarimetry mode, there are separate wavelength calculations for each group. These wavelengths may be identical or slightly offset, depending on the observation mode.

31.4.12 Aperture Throughput Correction (APR_CORR)

This calibration step consists of two parts: normalizing throughputs to a reference aperture and correcting throughputs for focus changes. Both steps are relevant only if the average inverse sensitivity files are used, see AIS_CORR in the next sub-section.

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Each aperture affected the throughput of light onto the photocathode. To prepare the object data for absolute flux calibration, the object data must be normalized to the throughput as would be seen through a pre-determined reference aperture (the `4.3` aperture is always used). The normalization is calibrated as a second-order polynomial and is a function of wavelength. The polynomial is evaluated over the object wavelength range and divided into the object data. The coefficients are found in the CCSB reference table.

Once the object data has been normalized, the throughput is compensated for variations in sensitivity due to focus changes. The CCSA table contains a list of dates and focus values. The sensitivity variation is modeled as a function of wavelength and focus, the coefficients of which are found in the CCSC table. This model is evaluated and divided into the object data. (Although post-COSTAR focus-dependent corrections are unity, this step still must be performed for proper calibration).

31.4.13 Absolute Flux Calibration (AIS_CORR and FLX_CORR)

This step multiplies object (and error) spectra by the appropriate inverse sensitivity vector to convert from count rates per pixel to absolute flux units (erg s^{-1} cm^{-2} $Å^{-1}$). Two different methods of performing this calibration were used. The pipeline used the so-called FLX_CORR method from the time of HST launch to March 19, 1996. The pipeline processing method, for *non-polarimetric* observations, was changed to the AIS_CORR method on March 19, 1996. AIS_CORR calibration files are available for all FOS observing epochs and AIS_CORR is *the only recommended* method for the flux calibration (or re-calibration) of non-polarimetric FOS observations. On the other hand, spectropolarimetric measures will continue to be processed via the FLX_CORR method.

AIS_CORR: This step is functionally no different than FLX_CORR except for the way in which absolute flux is calibrated. The absolute flux calibration is based on data from all calibration observation epochs. An average sensitivity function for the entire pre- or post-COSTAR period for the `4.3` reference aperture is contained in the AISHFILE reference file for each combination of detector and disperser. As necessary, TIM_CORR factors (see following sub-section) correct the sensitivity to the date of observation and APR_CORR factors (see preceding sub-section) correct for the throughput of the aperture employed. The calibrated spectral data are written to the `.c1h` file, and the calibrated error data are written to the `.c2h` file. The final data quality values are written to the `.cqh` file.

FLX_CORR: Now used for spectropolarimetry flux calibration only. The inverse sensitivity data are read from the IV1HFILE reference file. A second inverse sensitivity file, IV2HFILE, is required for paired-aperture or spectropolarimetry observations. Individual reference files are required for every combination of detector, disperser, and aperture. Time-dependencies are, in principle, tracked via multiple reference files with different USEAFTER dates.

For both flux calibration methods, points where the inverse sensitivity is zero (i.e., not defined) are flagged with a data quality value of 200. The calibrated spectral data are written to the `.c1h` file, and the calibrated error data are written to the `.c2h` file. The final data quality values are written to the `.cqh` file.

31.4.14 Time Correction (TIM_CORR)

This step corrects the absolute flux for variations in sensitivity of the instrument over time and is an important component of the AIS_CORR flux calibration. The correction factor is a function of time and wavelength. The factor is calculated by linear interpolation for the observation time and wavelength coverage. The factor is divided into the object absolute flux. The coefficients are found in table CCSD. TIM_CORR is used only with AIS_CORR calibration.

This is the final step of processing for ACCUM mode observations.

31.4.15 Special Mode Processing (MOD_CORR)

Data acquired in the rapid-readout, time-resolved, or spectropolarimetry modes receive specialized processing in this step. All data resulting from this additional processing are stored in the `.c3h` file. See the discussions of output data products for each of these modes on pages 30-40, 30-42, and 30-46.

RAPID Mode: For RAPID mode, the total flux, integrated over all pixels, for each readout is computed. The sum of the statistical errors in quadrature for each frame is also propagated. The following equations are used in the computation.

$$sum(F) = \left(\sum_{x=1}^{NDAT} f(x, F)\right)\left(\frac{NDAT}{good}\right)$$

$$errsum(F) = \sqrt{\left(\sum_{x=1}^{NDAT} ef^2(x, F)\right) \times \left(\frac{NDAT}{good}\right)}$$

Where:

- *f(x,F)* – is the flux in pixel *x* and readout *F*.
- *ef(x,F)* – is the associated error in the flux for pixel *x* and readout *F*.
- *sum(F)* – is the total flux for readout *F*.
- *errsum(F)* – is the associated error in the total flux for the readout *F*.
- *NDAT* – is the total number of pixels in the readout *F*.
- *good* – is total number of good pixels, i.e., pixels with data quality less than 200.

The output `.c3h` file contains two data groups, where the number of pixels in each group is equal to the number of original data frames. Group 1 contains the total flux for each frame, where pixel 1 is the sum for frame 1, pixel 2 the sum for frame 2, etc. Group 2 of the `.c3h` file contains the corresponding propagated errors.

POLARIMETRY Mode: For the POLARIMETRY mode, the data from individual waveplate positions are combined to calculate the Stokes I, Q, U, and V parameters, as well as the linear and circular polarizations and polarization position angle spectra (for details of calculating the Stokes parameters see *FOS ISR* 078). Four sets of Stokes parameter and polarization spectra are computed. The first two sets are for each of the separate pass directions, the third for the combined pass direction data, and the fourth for the combined data corrected for interference and instrumental orientation.

PERIOD Mode: For PERIOD mode, the pixel-by-pixel average of all slices (NSLICES separate memory locations) and the differences from the average for each slice of the last frame are computed. The following equations are used in the computation:

$$average(x) = \left(\frac{\sum_{L=1}^{NSLICES} f(x,L)}{good(x)} \right)$$

$$errave(x) = \frac{\sqrt{\left(\sum_{L=0}^{NSLICES-1} (ef(x,l))^2 \right)}}{good(x)}$$

$$diff(x,L) = f(x,L) - average(x)$$

$$errdiff(x,L) = \sqrt{(ef(x,L)^2 + errave(x)^2)}$$

Where

- NSLICES – is the number of slices.
- *f(x,L)* – is the flux in slice *L* at pixel *x.*
- *ef(x,L)* – is the error associated with the flux in slice *L* at pixel *x.*
- *average(x)* – is the average flux of all slices at the pixel *x.*
- *errave(x)* – is the error associated with the average flux at pixel *x.*
- *good(x)* – is the total number of good values, i.e., data quality <200, accumulated at pixel *x.*
- *diff(x,L)* – is the flux difference at pixel *x* between slice *L* and the average.
- *errdiff(x,L)* – is the error associated with the flux difference.

The first two data groups of the output `.c3h` file contain the average flux and the associated errors, respectively. Each subsequent pair of data groups contains the difference from the average and the corresponding total error for each slice.

31.5 Paired Aperture Calibration Anomaly

Any HST data taken with a paired aperture prior to January 1, 1995 may need manual editing of certain `.d0` header fields prior to recalibration with **calfos**.

Several programs used both the upper and lower portions of a paired aperture with Exposure Logsheet (or RPS2) entries of STEP-PATT=STAR-SKY, OBJ-OBJ, or OBJ-SKY in order to sample different portions of extended objects in alternating 10-second dwells throughout an exposure. The diagnosis of this problem is slightly complicated, but in the following, please realize that whenever "chopping" between apertures was invoked, the data recorded through each aperture segment were always recorded separately so that correct calibration of the data from each aperture segment is possible after the manual header update.

Prior to January 1, 1995 important keywords in the headers of all FOS paired aperture exposures for STEP-PATT not equal to SINGLE were constructed on the assumption that SKY was sampled in one aperture segment. This occurred even if STEP-PATT=OBJ-OBJ had been specified in the logsheet. Additionally, prior to February 1, 1994 the only way to obtain spectra with both segments of the paired apertures in this alternating fashion was to specify the potentially misleading STEP-PATT=STAR-SKY. Naturally, **calfos** calibrates these exposures as if sky subtraction is intended and the final `.c1` file contains the difference between nominal default star and sky apertures.

The simplest approach to correcting this problem is to change the YSTEPn keywords (i.e., YSTEP1, YSTEP2, etc) from "SKY" to "OBJ." Values of "NUL" or "BCK" should not be changed. Modern versions of **calfos** (revised after January 1, 1995) will process these updated data correctly and produce separate calibrated spectra for the two aperture segments.

As a general rule, no sky subtraction observations were *intended* by any observer in the FOS science program after SV ended (January 1, 1992). On a very few occasions OBJ-SKY observations were obtained through implementation error when only OBJ (i.e., STEP-PATT=SINGLE) was intended. Particularly for extended targets, you should broadly assume that any SKY observation, whether explicitly requested in the logsheet STEP-PATT or not, may contain additional spectra from nearby regions of an extended source and should be recalibrated only after header update.

31.6 Recalibrating FOS Data: A Checklist

You will use the IRAF/STSDAS task **calfos**. to recalibrate your FOS spectra. This task sequentially performs each step described in the preceding section.

Here is a checklist of things that you should routinely do to re-calibrate any FOS exposure:

1. ***Add new or updated keywords:*** The first thing to do is make sure that your data have all the required keywords in their headers. The STSDAS task **addnewkeys** will update the headers of your `.d0h` files accordingly. This task insures that the AIS flux calibration method keywords are in the header and also adds the scattered light correction keyword to older pre-COSTAR files. Note that a default set of reference filenames is used for the new calibration switch keywords - you must update these as part of the next point on this checklist.
2. ***Get correct reference file names:*** Next you must determine which are the correct reference files to use. You can determine the correct reference files and tables to use for re-calibration of any exposure by using the StarView FOS calibration reference file screen (see section 1.3 for a complete description of this procedure). Alternatively, the FOS WWW Reference File Guides provide a listing of recommended FOS reference files as a function of observing epoch for each type of reference file or table.
3. ***Update header files***: In order to recalibrate FOS data using updated calibration files, you need to edit the header of the original science data, `.d0h`, with the task **chcalpar** and replace the names of the original calibration files with those of the new ones. If required, you should also update the values of YSTEPn for paired aperture exposures as described in section 31.5
4. ***Set DEFDDTBL to "F" (false)***: As noted earlier, some header files may have had the Default Dead Diode Table keyword set to TRUE in order to use the `.udl` file to specify the list of dead diodes for original pipeline processing. Since a complete history of dead diode occurrence dates is now available, only the DDTHFILE should now be used to identify dead diodes. Under no circumstances should DEFDDTBL be set to "T". Naturally, it is also a good idea to make sure that all other calibration switches are set properly at this point.
5. ***Run the calfos calibration routine***: **calfos** will create new calibrated output files with the same suffixes as the originally delivered data, namely `.cnh` and `.cnd` (n=0...8).

If you are concerned about any aspect of the appearance of your calibrated data, you should compare the final data with flatfield (and other) reference files used in the data reduction process to make sure that spurious features were not introduced through improper data handling in the pipeline or in your recalibration.

31.7 Post-Calibration Output Files

The several types of calibrated output files produced by **calfos** are listed in Table 31.7. More detailed descriptions of each type of file are provided in Chapter 30.

Table 31.7: Output Calibrated FOS Data Files

Filename Extension	File Contents
`.c0h` and `.c0d`	Calibrated wavelengths
`.c1h` and `.c1d`	Calibrated fluxes
`.c2h` and `.c2d`	Calibrated statistical error
`.c3h` and `.c3d`	Special mode data
`.cqh` and `.cqd`	Calibrated data quality
`.c4h` and `.c4d`	Count rate object and sky spectra
`.c5h` and `.c5d`	Flatfielded object count rate spectrum
`.c6h` and `.c6d`	Flatfielded sky count rate spectrum
`.c7h` and `.c7d`	Background count rate spectrum
`.c8h` and `.c8d`	Flatfielded and sky subtracted object count rate spectrum

If the reference files and reference tables used in the pipeline processing do not reflect the actual instrument performance, calibration errors can occur, which can lead to artificial features in the calibrated science data. In the next chapter, we address a variety of sources of error in FOS calibration and assess limiting accuracies in the STScI instrument calibration.

Figure 31.9: Partial Sample Post-COSTAR FOS .c1h Header

```
GCOUNT  =                   77 /
        / FOS DATA DESCRIPTOR KEYWORDS
INSTRUME= 'FOS               ' / instrument in use
ROOTNAME= 'Y3JK0709T         ' / rootname of the observation set
FILETYPE= 'FLX     '           / file type
BUNIT   = 'ERGS/CM**2/S/A'     / brightness units

        / CALIBRATION FLAGS AND INDICATORS
GRNDMODE= 'RAPID-READOUT     ' / ground software mode
DETECTOR= 'BLUE              ' / detector in use: amber, blue
APER_ID = 'B-2               ' / aperture id
POLAR_ID= 'C                 ' / polarizer id
POLANG  =                  0.0 / initial angular position of polarizer
FGWA_ID = 'H13               ' / FGWA id
FCHNL   =                    0 / first channel
NCHNLS  =                  512 / number of channels
OVERSCAN=                    5 / overscan number
NXSTEPS =                    4 / number of x steps
YFGIMPEN=                    T / onboard GIMP correction enabled (T/F)
YFGIMPER= 'NO                ' / error in onboard GIMP correction (YES/NO)

        / CALIBRATION REFERENCE FILES AND TABLES
DEFDDTBL=                    F / UDL disabled diode table used
BACHFILE= 'yref$b3m1128my.r0h' / background reference header file
FL1HFILE= 'yref$e7813577y.r1h' / first flat-field header file
FL2HFILE= 'N/A               ' / second flat-field header file
IV1HFILE= 'yref$e3h14503y.r2h' / first inverse sensitivity header file
IV2HFILE= 'N/A               ' / second inverse sensitivity header file
AISHFILE= 'yref$fac08361y.r8h' / average inverse sensitivity header file
RETHFILE= 'N/A               ' / waveplate retardation header file
DDTHFILE= 'yref$d9h1244ay.r4h' / disabled diode table header file
DQ1HFILE= 'yref$b2f1306ry.r5h' / first data quality initialization header file
DQ2HFILE= 'N/A               ' / second data quality initialization header file
CCG2    = 'mtab$a3d1145ly.cmg' / paired pulse correction parameters table
CCS0    = 'ytab$a3d1145dy.cy0' / aperture parameters
CCS1    = 'ytab$aaj0732ay.cy1' / aperture position parameters
CCS2    = 'ytab$a3d1145fy.cy2' / sky emission line regions
CCS3    = 'ytab$a3d1145gy.cy3' / bkg and sky filter widths
CCS4    = 'ytab$e5v13262y.cy4' / polarimetry parameters
CCS5    = 'ytab$a3d1145jy.cy5' / sky shifts
CCS6    = 'ytab$e5v11576y.cy6' / wavelength coefficients
CCS7    = 'ytab$ba910502y.cy7' / GIMP correction scale factors
CCS8    = 'ytab$ba31407ly.cy8' / predicted background count rates
CCS9    = 'ytab$e3i09491y.cy9' / scattered light parameters
CCSA    = 'ytab$fad1554cy.cya' / OTA focus history
CCSB    = 'ytab$g1512585y.cyb' / relative aperture throughput coeff
CCSC    = 'ytab$fad1554hy.cyc' / aperture throughput vs OTA focus
CCSD    = 'ytab$fad1554ky.cyd' / time changes in sensitivity

        / CALIBRATION SWITCHES
CNT_CORR= 'COMPLETE'           / count to count rate conversion
OFF_CORR= 'OMIT              ' / GIMP correction
PPC_CORR= 'COMPLETE'           / paired pulse correction
BAC_CORR= 'COMPLETE'           / background subtraction
GMF_CORR= 'COMPLETE'           / scale reference background
SCT_CORR= 'COMPLETE'           / scattered light correction
FLT_CORR= 'COMPLETE'           / flat fielding
SKY_CORR= 'SKIPPED '           / sky subtraction
WAV_CORR= 'COMPLETE'           / wavelength scale generation
FLX_CORR= 'OMIT              ' / flux scale generation
APR_CORR= 'COMPLETE'           / aperture throughput corrections
AIS_CORR= 'COMPLETE'           / AIS flux scale generation
TIM_CORR= 'COMPLETE'           / time changes in sensitivity correction
ERR_CORR= 'COMPLETE'           / propagated error computation
MOD_CORR= 'PERFORM           ' / ground software mode dependent reductions

HISTORY   FL1HFILE=yref$e7813577y.r1h       FLT_CORR=COMPLETE
HISTORY   INFLIGHT  01/03/1994
HISTORY   Based on SMOV Superflats: proposal 4776
HISTORY   AISHFILE=yref$fac08361y.r8h       AIS_CORR=COMPLETE
HISTORY   INFLIGHT 01/02/1994 - 15/07/1995
HISTORY   1st delivery: post-costar ais time+aperture dependent flux cal
END
```

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31.8 User Calibrations

Some users may wish to create their own calibration reference files or tables for certain parts of the pipeline calibration. IRAF/STSDAS tools exist to generate certain types of user reference files. In nearly all cases, however, some manual editing of reference file headers may be necessary after producing the new calibration data.

- ***Wavelengths**:* IRAF/STADAS tasks **hst_calib.fos.y_calib.linefind** and **.hst_calib.fos.y_calib.dispfity** are required. **linefind** is used to find the positions in a WAVE spectrum of candidate comparison lines from a template list of lines. (The FOS comparison line template lists may be found in the Calibration Tools section of the FOS WWW page.) The identified lines are then fit in **dispfity** with an appropriate polynomial (order 3 for all FOS grating spectra). See the STSDAS help files for detailed information on these tasks. The results of the fit must be entered into an STSDAS table to be used with pipeline calibration. Be careful to insure that sufficient lines are used to characterize the fits throughout the spectrum. Remember that due to the design of the spectrograph an internal to external wavelength system offset exists between internal calibration arc spectra and external astronomical source spectra and that this offset must be included in any new wavelength calibration (see Chapter 32 for further discussion of internal to external offsets, filter-grating wheel offsets, and other instrumental characteristics affecting wavelength accuracies). Also, please refer to *FOS ISRs* 149 and 156 and references therein.
- ***Flatfields**:* IRAF/STADAS task **stadas.hst_calib.fos.y_calib.flatfield** can be used to generate new FOS flatfields. In general, a spectrum of an object with few lines is used. Continuum levels are marked interactively throughout the spectrum and a spline is fit through these points. The original data is then divided by the spline to produce a unity-normalized flatfield, which can be inverted for use as a **calfos** inverse flatfield. The output of **flatfield** can be highly subjective in some cases. FOS IDT-developed software exists for more objective generation of FOS flatfields, but its description is beyond the scope of this manual (see *FOS ISRs* 135 and 157 for recent comprehensive discussions of FOS team flatfield generation techniques.
- ***Sensitivity Functions**:* Tasks **stsdas.hst_calib.fos.y_calib.absseny** and **absfity** are used to generate FOS inverse sensitivity functions (IVS files for use with FLX_CORR only). Unfortunately, all AIS reference files and tables were generated using IDL software written by the FOS team. No STSDAS tasks exist to generate these reference materials. The methods involved are discussed in FOS ISRs 144 and 158.
- ***Background**:* Refer to *FOS ISR* 146 and the references contained therein for a discussion of FOS background modeling techniques. The task **y_calib.parthity** is required for this calibration.