Faint Object Spectrograph Calibration Pipeline

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Overview of FOS Data Acquisition

The Faint Object Spectrograph (FOS) has two Digicon detectors, one of which is included on the blue side (FOS/BL) and one of which is included on the red side (FOS/RD also called AMBER). The light path in the FOS is such that the light from the target is dispersed from the filter-grating wheel by a concave grating, or a camera mirror plus a prism. This dispersed light is then imaged onto the transmissive photocathode in the Digicon detector. The photocathode is a two dimensional detector which extends from +2048 y-base units to −2047 ybase units (256 y-base units is approximately the height of the diode array). Each disperser produces a spectrum at a different location on the photocathode. The locations of the red (dashed line) and blue (solid line) dispersed spectra are shown in Figure 1. The photoelectrons from the region of the photocathode where the image is expected are then accelerated to a linear array of 512 diodes. The extent of the region on the photocathode that is recorded by the diode array is equal to the height of the diode array or 256 y-base units. The FOS diode array is scanned in a pattern which determines the data acquisition mode. The different modes for the FOS are:

Spectrophotometry (ACCUM mode);
Spectropolarimetry;
Time Resolved Spectrophotometry (PERIOD mode); and
Rapid Readout (RAPID mode).

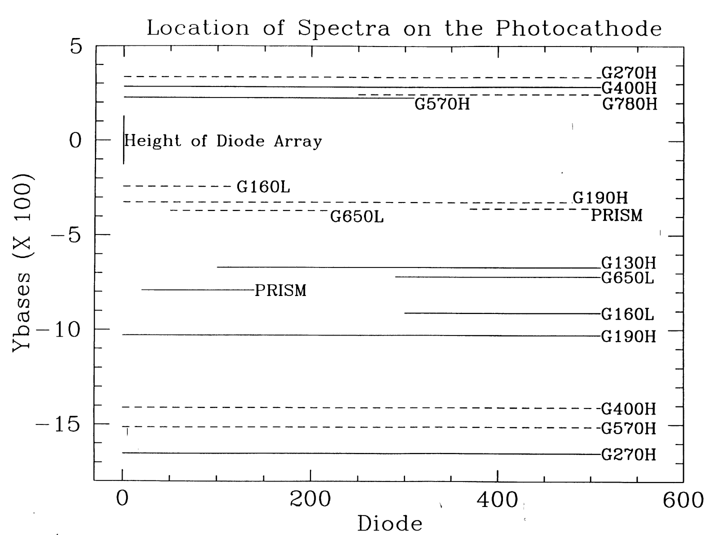

Figure 1

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Spectrophotometry

For the standard ACCUM mode the FOS microprocessor intergrates data for an interval of time (usually 512 ms), and after integration the data from the diode array are stored in memory . The spectrum is then magnetically deflected a fraction of a diode width in the dispersion direction and the diode array is scanned once more and the data are stored in new memory locations. This deflecting of the spectrum across the diode array is called sub-stepping and the number of sub-steps taken to acquire the data are called NXSTEPS in the data header files. For the standard ACCUM mode the default value is NXSTEPS=4. The data acquired with each of the 4 sub-steps go into new memory locations which correspond to the number of pixels in the observation. Next, to average out the response of the different diodes, including the disabled diodes, the data are overscanned, i.e. the spectrum is deflected across a range of diodes. The overscan parameter (OVERSCAN in the header files) has a default value of 5. Therefore, each pixel in the spectrum, except for the pixels at the edges, has contributions from 5 diodes if OVERSCAN=5. Although the number of diodes in the diode array are only 512, the number of pixels in an ACCUM mode observation is given by the equation

$$number\ of\ pixels\ =\ (number\ of\ diodes + (OVERSCAN - 1)) \times NXSTEPS.$$

For the default value of 4 for the sub-stepping, the exposure time per pixel for most of the pixels is the total exposure time of the observation divided by 4. The ACCUM mode spectra with total exposure time lasting more than a few minutes to a few hours are read out at regular intervals to the ground or to the onboard tape recorders. The frequent readouts are to protect against catastrophic losses of data. Since the data are read out at regular intervals, all observations longer than a few minutes (readout time is ≤ 2 minutes for the red detector and ≤ 4 minutes for the blue detector) are time resolved. Each readout is stored in the data files as follows: The first readout is stored as group 1, the next readout is added (accumulated) to the previous readout and stored as group 2, and so on. The last group contains the spectrum from the full exposure time of the observation. The number of groups per observation depends on the length of the exposure and the detector used.

Spectropolarimetry

The polarimetry data consists of a number of exposures (POLSCAN= 16, 8 or 4) with the waveplate set at different angles and taken consecutively (data must be within one orbit). The Wollaston prism splits the light beam into two spectra corresponding to the orthogonal directions of polarization. Hence, each exposure consists of the two orthogonal spectra at a given waveplate angle, which are alternately deflected to the diode array and recorded as two pass directions and stored as a single group in the raw data file. The first spectrum corresponds to the first pass direction (ordinary ray), and the second to the second pass direction (extraordinary ray). The number of groups in the raw data file corresponds to the number of waveplate positions used in the observation. Note that the number of pixels in each group is twice the number of pixels in a spectrum because two spectra are appended together , one for each pass direction. Once again the number of pixels in the spectrum depends on the values of

NXSTEPS and OVERSCAN used (see ACCUM mode for details). The group contents of the raw (.d0h) data file are:

Table 1

Group #	Contents
1	Polscan 1: pass direction 1 and pass direction 2
2	Polscan 2: pass direction 1 and pass direction 2
3	Polscan 3: pass direction 1 and pass direction 2
...	...
15	Polscan 15: pass direction 1 and pass direction 2
16	Polscan 16: pass direction 1 and pass direction 2

The number of POLSCAN positions (and therefore the total number of groups in the raw data file) may be 4, 8, or 16 depending on the number of polscans requested.

Time Resolved Spectrophotometry (PERIOD mode)

This mode is normally used for objects with known periodicity in the 50 ms to 100 sec range. T o maintain the phase information of these observations, the known period (CYCLE-TIME) of the object is divided into BINS or SLICES, where each bin has a duration time = CYCLE-TIME/BINS. The spectra acquired in this mode are stored in the different bins which correspond to the phase to form a pattern. The information obtained in each period is added correctly to the pattern so that the phase information is maintained (so long as the period is known accurately). The raw (.d0h) data file for time-resolved mode contains a single data group which is made up of all the individual spectral slices (or bins) stored sequentially . For example, if an observation used 374 detector channels, with NXSTEPS=1, OVERSCAN=5, and SLICES=32, the .d0h file would contain one data group having a total length of $(374 + 4) \times 1 \times 32 = 12096$ pixels.

Rapid Readout (RAPID mode)

In this mode, the data are acquired as in the normal ACCUM mode, but the spectra are read out at much shorter intervals than the nominal 4 minutes (blue detector) or 2 minutes (red detector). The raw data is stored as groups such that there is one group per readout of the detector .

Calibration of FOS data in PODPS using CALFOS

In this section we describe the FOS pipeline calibration (CALFOS) procedures. This processing uses the raw GEIS files containing counts per pixel as input files and produces the calibrated files (GEIS format) containing absolute fluxes and wavelengths as output files. Each step of the processing is selected by the values of keyword “switches” in the science data header (.d0h file). Prior to calibration these keywords contain a value of either OMIT or PERFORM. After processing by CALFOS, switches originally set to PERFORM are reset to COMPLETE. Some processing steps require additional data in the form of reference tables and files. The file names of these reference data are also stored in keywords in the .d0h file. Each calibration step and the relevant input/output data and reference files are described in detail below . The keyword switch name associated with each step is given in parentheses in the headings.

Each FOS observation consists of up to three parts: an optional science header line, the science data lines, and an optional reject array contained in the science trailer file. The three data types are stored in separate files, with the science data for each readout being stored in a separate group. An exception to this rule is when the science data are produced by the FOS Firmware target acquisition. In this case, each readout has two groups; one for the raw data and one for the filtered data. Every file generated for an observation has its associated data quality file.

CALFOS requires a set of observation files (see Table 2) as input files for any observation. These files are in the GEIS format. The number of observation files used as input depends on the type of observation. CALFOS further requires a set of reference files and a set of reference tables (see Table 3). The reference files are in the GEIS format and the reference tables are in the STSDAS table format. The actual number of reference files and tables used in the calibration again depends on the calibration steps performed. The reference files and tables are typically referred to by the name of the CDBS reference relation that holds their names. The extensions of the reference files are of the form .cyX, .rXh and .rXd where X represents a value from 0 to 8. CALFOS produces a set of GEIS format files containing the calibrated data and results from some intermediate processing steps (see Table 4). Once again the number of files produced depends on the type of observation. The calibrated data file headers are copies of the science data headers with the appropriate header keyword values updated during calibration. See table 5 for an overview of the data quality flags.

Table 2: The FOS raw data files

File extension	File contents
.shh & .shd	standard header packet
.ulh & .uld	unique data log
.d0h & .d0d	science data
.q0h & .q0d	science data quality
.x0h & .x0d	science header line
.xqh & .xqd	science header line data quality
.d1h & .d1d	science trailer line
.q1h & .q1d	science trailer line data quality

Table 3: The Reference Tables and Images

Header Keyword	Data Base Relation	Filename Extension	File Contents
DQnHFILE	cyqinr	.r5h & .r5d	data quality initialization file
DDTHFILE	cyddtr	.r4h & .r4d	disabled diode file
CCS7	cyccs7r	.cy7	GIMP correction scale factors
CCG2	cccg2r	.c02	paired-pulse coefficients
CCS1	cyccs1r	.cy1	aperture positions
CCS3	cyccs3r	.cy3	sky and background filter widths
CCS8	cyccs8r	.cy8	predicted background (count rate)
BACHFILE	cybacr	.r0h & .r0d	default background file (count rate)
FLnHFILE	cyfltr	.r1h & .r1d	flat field file (count rate)
CCS0	cyccs0r	.cy0	aperture sizes
CCS2	cyccs2r	.cy2	sky emission line positions
CCS5	cyccs5r	.cy5	sky shift parameters
CCS6	cyccs6r	.cy6	wavelength dispersion coefficients
IVnHFILE	cyinsr	.r2h & .r2d	inverse sensitivity file (count rate)
CCS4	cyccs4r	.cy4	polarimetry parameters
RETHFILE	cyretr	.r3h & .r3d	retardation file for polarimetry data

Table 4: The Calibrated Data Files Produced by CALFOS

Filename Extension	File Contents
.c0h & .c0d	calibrated wavelengths
.c1h & .c1d	calibrated fluxes
.cqh & .cqd	output data quality
.c2h & .c2d	propagated statistical error
.c3h & .c3d	special mode data
.c4h & .c4d	count rate
.c5h & .c5d	flat fielded object spectrum
.c6h & .c6d	flat fielded sky spectrum
.c7h & .c7d	background spectrum
.c8h & .c8d	flat field sky subtracted object spectrum

Table 5: The Data Quality Flags

Flag value	Description
Category 1: bad data where data value is set to 0	
800	filled data
700	filled data due to GIMP correction
400	disabled channel
300	severe saturation (uncertainty > 50%)
200	invalid inverse sensitivity
Category 2: uncertain data, where the error calculation does not account for uncertainty	.
190	high saturation (uncertainty > 20%)
170	intermittent noisy diode
160	intermittent dead diode
130	moderate saturation (uncertainty > 5%)
120	sky or background fixed or extrapolated
100	Reed Solomon decoding error
Category 3: uncertain data, where the error calculation does account for uncertainty	.
50	sampling < 50% nominal
Category 4: Good data	
0	good data

Overview of the FOS Pipeline Processing

In this section I describe the FOS pipeline calibration (CALFOS) procedures. Each step of the processing is selected by the values of keyword "switches" in the science data header file. The keyword switch name associated with each step is given in parentheses in the headings. The input files and the output files used by CALFOS are indicated in the following overview by the extension of the header file, while the data is read from, or written by CALFOS to the corresponding data file.

Step 1: Reading the raw data

The raw data, stored in the .d0h file, are the starting point of the pipeline data reduction/calibration procedures. 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.

Step 2: Calculation of statistical errors (ERR_CORR).

The dominant noise in the raw data is photon (Poisson) noise. Hence, 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. 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 step with the spectral data, except that errors caused by sky and background subtraction are ignored. At the end of processing the calibrated error data will be written to the .c2h file.

Step 3: Data quality initialization.

The starting point of the data quality information is the data quality values 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 will add values corresponding to other problem conditions. Only the highest (most severe) data quality value is retained for each pixel. At the end of processing the final data quality values will be written to the .cqh file.

Step 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 the pixel. Both the spectral data and the errors are divided by the exposure time. Filled data (data quality = 800) are set to zero. A correction for disabled diodes is also included at this point. If the keyword DEFDDTTBL 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. The DDTHFILE is more commonly used for the disabled diode information.

The actual process by which the correction for dead diodes is accomplished is as follows. First, recall that due to the use of the OVERSCAN function each pixel in the observed spectrum actually contains contributions from several neighboring diodes. Therefore if one or more particular diodes out of the group that “fed” 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. Therefore we can correct the observed signal and its associated error in that pixel back to the level it would have had if all diodes were live. This correction (to the signal and its error) 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 percent, then a data quality value of 50 is assigned to it. 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.

Step 5: GIMP correction (OFF_CORR).

Data obtained prior to 5 April 1993 do not have an onboard GIMP correction and as such require a correction for GIMP in the pipeline calibration. It should be noted here that there are some observations obtained after 5 April 1993, that do not have onboard GIMP correction. The GIMP correction is determined by scaling a default model based upon the strength of the magnetic 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 so as to avoid resampling the data. Furthermore, the correction is applied only in the direction of the diode array . The correction is applied by simply shifting data values from one array location to another . For example, if the amount of the correction for a particular data group is calculated to be +2.38 pixels, data 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.

The pipeline GIMP correction is applied for all FOS data acquisition modes except polarimetry unless the switch is turned on. 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 is first "unraveled" into separate frames, each frame is corrected individually , and then the corrected frames are recombined.

The onboard GIMP correction is applied on a finer grid and in both the direction of the diode array and in the perpendicular direction. The onboard GIMP correction is calculated and applied every 30 seconds.

Step 6: Paired pulse correction (PPC_CORR).

This step corrects the data for saturation in the detector electronics. The dead time constants are read from the reference table CCG2. Observed count rates greater than the saturation limit stored in CCG2 (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 below this severe saturation limit are corrected, but those lying between the predefined limits of large and severe saturation are assigned a data quality value of 190, and those that lie between the limits of moderate and large saturation are assigned a data quality value of 130.

Step 7: Background subtraction (BAC_CORR).

This step subtracts the background from object and sky (if present) spectra. If no background spectrum was obtained with the observation, a default reference background, BACHFILE, is used. The default reference background may be scaled to a mean expected count rate based on the geomagnetic position of the spacecraft at the time of the observation. The scaling parameters are stored in reference table CCS8. The scaled reference background spectra are written to the .c7h file for later examination. No smoothing is done to the reference file background, if used, since it is already a smoothed approximation to the background.

If an observed background is used, it is first repaired; bad points (i.e. points at which the data is 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, followed by a mean filter before subtraction. The median and mean filter widths are stored in reference table CCS3. Spectral data at pixel locations corresponding to repaired background data are assigned a data quality value of 120.

Step 8: Flatfield correction (FL T_CORR).

This step removes the diode-to-diode sensitivity variations and fine structure from the object, error , and sky spectra by multiplying each by the flat field response as stored in the FL1HFILE reference file. A second flat field file, FL2HFILE, is required for paired aperture or spectropolarimetry observations. No new data quality values are assigned in this step.

Step 9: Sky subtraction (SKY_CORR).

If the sky was observed, the flat fielded sky spectrum is repaired in the same fashion as described above for the observed background spectrum. It is then smoothed once with a median filter and twice with a mean filter , except in known regions of emission lines. The sky spectrum is then scaled by the ratio of the object and sky aperture areas, and then shifted 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.

Step 10: Compute wavelength scale (W AV_CORR).

A vacuum wavelength scale is computed for each object or sky spectrum. Wavelengths are computed using dispersion coefficients corresponding to each grating/aperture combination stored in table CCS6. The computed wavelength array is written to the .c0h file.

Step 11: Absolute calibration (FLX_CORR).

This step multiplies object (and error) spectra by the appropriate inverse sensitivity vector in order to convert from count rates to absolute flux units (ergs/s/cm^2/Å). 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. 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.

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

Step 12: 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.

For the RAPID mode, the total flux, integrated over all pixels, for each readout is computed. The sum of the statistical errors for each frame is also propagated, in quadrature. The .c3h file contains two data groups, here the number of pixels in each group is equal to the number of readouts (groups) in the original data. The value of each pixel is the sum of all pixels from the original readout (i.e. pixel 1 contains the sum of all pixel values from readout 1, pixel 2 is the sum of all pixels from readout 2, etc.). Group 1 of the .c3h file contains the summed flux values, while group 2 contains the corresponding statistical error values (summed in quadrature).

For the TIME RESOLVED mode, the pixel-by-pixel average of all slices and the differences from the average for each slice of the last frame are computed. The first two data groups of the output .c3h file contain the average flux and average errors, respectively. Each subsequent pair of data groups contains the difference from the average and the corresponding total error for each slice.

For example, if an observation used 374 detector channels, with nxsteps=1, overscan=5, and slices=32, the calibrated flux, wavelength, error, and data quality files will have the data from the individual slices (bins) broken out into separate groups. For the example above, the .c0h, .c1h, .c2h, and .cqh files would have 32 groups of 378 (number of diodes+(OVERSCAN-1)) pixels. The .c3h file is organized as follows:

Table 6

Group #	Contents
1	average of all 32 flux spectra from the .c1h file
2	average of all 32 error spectra from the .c2h file
3	spectrum 1 minus average
4	combined spectrum 1 and average errors
5	spectrum 2 minus average
6	combined spectrum 2 and average errors
...	...
65	spectrum 32 minus average
66	combined spectrum 32 and average errors

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. Four sets of Stokes parameter and polarization spectra are computed. The first two 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.

The group organization of the .c0h, .c1h, .c2h, and .cqh files is as follows:

Table 7

Group #	Group contents depending on the calibration file
1	Polscan 1, Pass direction 1: wavelength, flux, error or data quality
2	Polscan 1, Pass direction 2: wavelength, flux, error or data quality
3	Polscan 2, Pass direction 1: wavelength, flux, error or data quality
4	Polscan 2, Pass direction 2: wavelength, flux, error or data quality
...	...
31	Polscan 16, Pass direction 1: wavelength, flux, error or data quality
32	Polscan 16, Pass direction 2: wavelength, flux, error or data quality

The .c3h file is a data set with 56 groups containing the reduced polarimetry data. The data set is organized into four sets of 14 groups, where groups 1-14 contain the data for pass direction 1, groups 15-28 for pass direction 2, groups 29-42 contain the merged data from both pass directions 1 and 2, and groups 43-56 contain the merged data corrected for interference and instrument orientation. The organization of the

.c3h file is as follows:

Table 8

Group # Pass Direction 1	Group # Pass Direction 2	Group # Pass Direction 1&2	Group # Pass Direction 1&2 corrected	contents
1	15	29	43	Stokes I
2	16	30	44	Stokes Q
3	17	31	45	Stokes U
4	18	32	46	Stokes V
5	19	33	47	Stokes I error
6	20	34	48	Stokes Q error
7	21	35	49	Stokes U error
8	22	36	50	Stokes V error
9	23	37	51	Linear polarization
10	24	38	52	Circular polarization
11	25	39	53	polarization position
12	26	40	54	Linear polarization error
13	27	41	55	Circular polarization error
14	28	42	56	polarization position error

Note that for the first set of 14 groups the wavelengths are given by those for the first pass direction (i.e. group 1 of the .c0h file), while for the second set (groups 15-28) they are given by the wavelengths for the second pass direction (i.e. group 2 of the .c0h file). For the merged data in the third and fourth sets (groups 29-56), the wavelengths are given by the first pass direction.

FOS pipeline calibration flowchart:

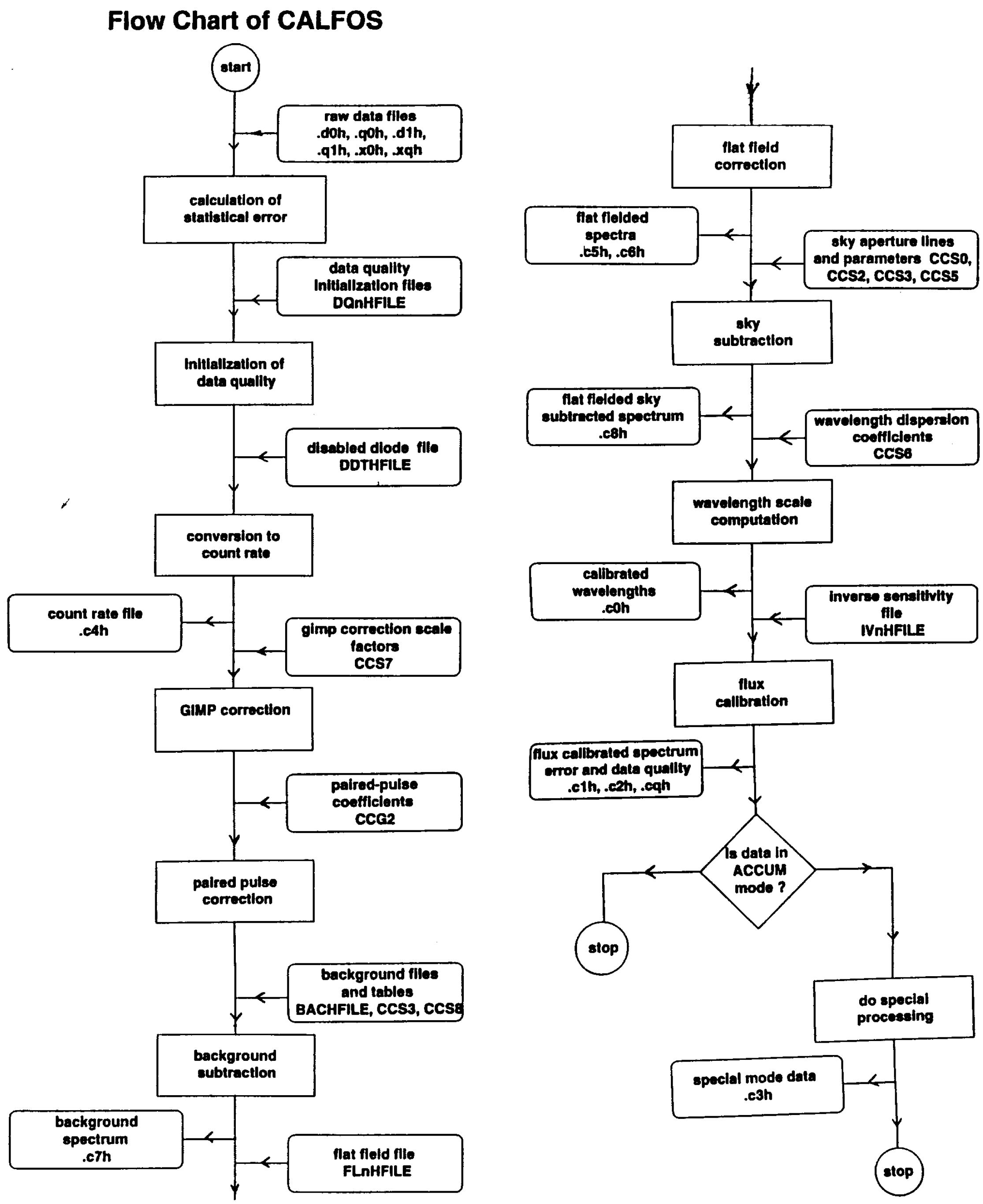
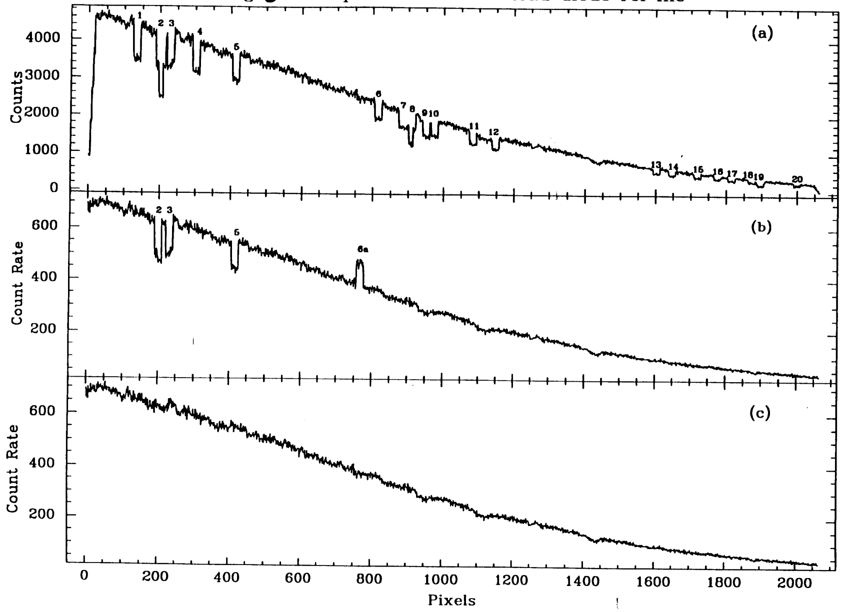


Figure 2

Fig. 3 Example of incorrect dead diode ref file



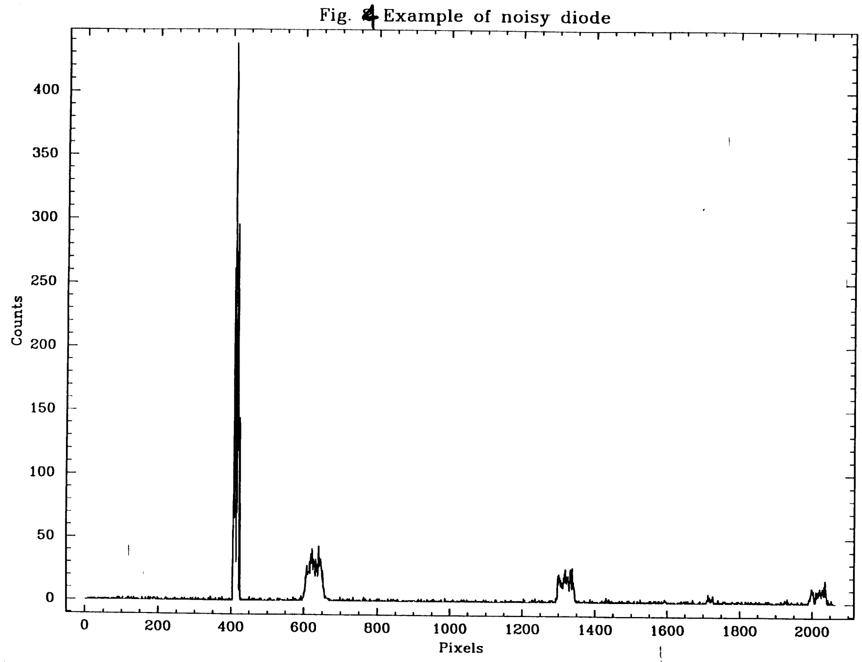
Expected errors from the pipeline calibration procedure

In principal the .c0h and .c1h files can be used for analysis with no further reduction. But sometimes there are limitations to the data. These limitations could be due to uncertainties in the calibration because of the usage of incorrect reference files or due to uncertainties in the calibration procedure itself. Some common examples of how to recognize errors due to bad reference files, and correct for them are provided.

Effect of an incorrect dead diode reference file

During the pipeline reduction CALFOS uses the dead diode reference files to correctly calculate the count rate for each pixel. The count rate calculation per pixel requires information regarding how many diodes contributed towards the counts. If an incorrect dead or disabled diode reference file is used, CALFOS does not have an accurate information of the diodes that were used for the onboard integration. This leads to serious errors in the count rates and hence in the subsequent calibration steps. The effect of incorrect dead diode correction (see Figure 3) has a very distinct signature, which looks like an "absorption feature" with sharp edges, extending over a fixed number of pixels (usually 20). Further , the dead diode "absorption feature" typically does not go to zero counts because more than 1 diode contributes towards the counts in a given pixel. In Figure 3, panel (a) shows the raw counts and the dead diodes labeled 1-20. Panel (b) shows the calibrated data from the pipeline processing from the .c1h file. Some of the dead diodes are correctly removed in the pipeline calibration while some of them are not. This occurred because an incorrect dead diode reference file was used in the processing of the data. Panel (c) shows the calibrated .c1h file AFTER the correct dead diode reference file has been used in the calibration.

Fig. 4 Example of noisy diode



To correct for the effects of a bad calibration, first determine the correct dead diode reference file. Next compare the reference files delivered by this tool with the reference files in the header . Correct the header information and recalibrate using CALFOS.

Effect of a noisy diode

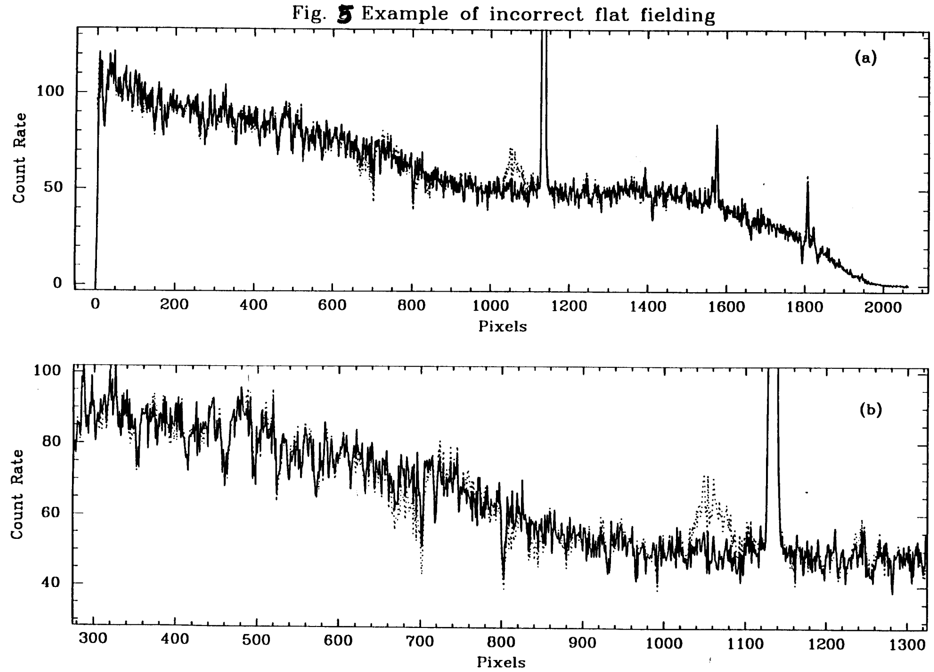
The effect of a noisy diode is typically an "emission feature" extending over 20 pixels (number of pixels = substep*overscan). Figure 4 shows pixels 400–420 of an observation which are affected by a noisy diode. This effect cannot be removed by recalibrating the data. The pixels affected by the noisy diode have to be edited manually .

Effect of an incorrect flat field reference file

Figure 5 shows the effect of an incorrect flat field reference file used in the pipeline calibration. An incorrect flat field file introduces small "emission-like" or "absorption-like" features in the spectrum because of the incorrect removal of diode-to-diode sensitivity variations. The dotted lines in panels (a) show the count rate in the .c1h file when an incorrect flat field reference file is used in the pipeline processing. The solid line is the calibrated data using the correct flat field. Panel (3) shows the 1000 pixels region from 300-1300 where the effect is most pronounced. For the red detector and the G190H filter the largest variation is near pixels 600 and 1050.

To correct for the effects of a bad calibration (if any), first determine the "correct" flat field reference file. Next compare the reference files delivered by this tool with the reference files in the header . If the difference between the two files is smaller than

Fig. 5 Example of incorrect flat fielding



the level of accuracy required for the analysis there is no need to recalibrate the data, otherwise the data needs to be recalibrated. Correct the header information and recalibrate using CALFOS.

Acknowledgment

I would like to thank Howard Bushouse for unraveling the CALFOS code and Tony Keyes for helpful comments.