Recalibrating Pre-COSTAR FOS Data

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Abstract

A description of the methods by which pre-COSTAR FOS data may be recalibrated using the photometric corrections and calibrations of Lindler and Bohlin (1994) is presented. Recalibration is accomplished through the use of the IRAF/STSDAS task calfos (version 2.0), which includes corrections for deviations in OTA focus, changes in sensitivity over time, and new inverse sensitivity data based on the switch from the IUE absolute flux scale in the UV to a model atmosphere flux distribution for G191B2B.

I. Introduction

Lindler and Bohlin (1994; LB94) have redetermined the pre-COSTAR absolute photometric calibration for the Faint Object Spectrograph, superceding the calibrations of Neill, Bohlin, and Hartig (1992; NBH) which were used in the routine pipeline processing of cycle 1-3 FOS data since 1 April 1992. The fundamental differences in the NBH calibration and the superceding work of LB94 are the corrections for changing sensitivity over time, the correction for the deviation of OTA focus from the baseline, and the switch from the IUE flux scale in the UV to a scale defined by a pure hydrogen model atmosphere flux distribution for the standard star G191B2B (see LB94 for details).

The LB94 calibrations approach an internal photometric precision of 1% in the high dispersion gratings, which implies a photometric accuracy for an individual stellar observations that is limited by the photon statistics, pointing accuracy, OTA breathing, and aperture size of the particular spectrum. Thus, the accuracy of absolute fluxes measured in any FOS science observation will be limited by the uncertainties in the observation itself, rather than by any deficiencies in the calibration algorithm.

Pre-COSTAR FOS data can be reproessed to take advantage of the LB94 calibration using the task calfos that resides in the hst_calib_fos package of the IRAF/STSDAS system. The LB94 calibrations are only available in versions 2.0 and higher of the calfos task. If you have an earlier version you can obtain a more recent one from STScI by contacting the STSDAS support HotSeat by phone at 410-516-5100 or by e-mail to “hotseat@stsci.edu”.

Section 2 of this report describes the new calibration methods and how they differ from the previous method. Section 3 contains instructions for preparing and reproprocessing existing
II. The New Calibration Methods

FOS data that were processed with calfos using the NBH calibrations were converted from observed count rates to absolute fluxes by simply multiplying by the IVS curve that was appropriate for the detector, disperser, and aperture used in the observation. The appropriate IVS data were selected by setting the values of the IV1HFILE and IV2HFILE header keywords in the raw science data image (the "d0h" file) to the names of the reference files that contained the necessary IVS data. Non-polarimetry data obtained through a single aperture used a single IVS file, specified by the IV1HFILE keyword. Polarimetry data and data obtained through paired apertures used two IVS files, one for each polarimetry pass direction or aperture position, specified by the IV1HFILE and IV2HFILE keywords.

The LB94 calibrations, on the other hand, utilize a single IVS curve for each detector and grating combination that was derived from observations obtained through the 4.3 arc-second square (A-1) aperture. Data obtained through all entrance apertures—for a given detector/disperser combination—use this one IVS curve to convert count rates to absolute fluxes, but also undergo an additional correction that accounts for the differences in aperture throughputs relative to the A-1. Under this new scheme paired aperture observations also use only a single IVS curve for calibration. Any differences between the lower and upper apertures of the pair are accounted for in the aperture throughput correction step.

The processing flow within calfos is as follows. All processing steps up to the point of the existing flux calibration—including count to countrate conversion, GIMP correction, paired-pulse correction, background subtraction, scattered light subtraction, flat fielding, and wavelength calculations—remain the same. The first of the new calibration steps is the correction for aperture throughput relative to the A-1 aperture, upon which the IVS is based. This processing step is controlled by the new raw image header keyword APR_CORR and uses a new calibration reference table specified by the raw image header keyword CCSB. The CCSB table contains polynomial coefficients describing the throughput as a function of wavelength for each aperture relative to the A-1 aperture. The spectral data are corrected by dividing the net count rates by the values determined from the CCSB table.

The APR_CORR step also includes the correction for changes in aperture throughput as a function of OTA focus. The focus history of the OTA is stored in a calibration reference table specified by the new header keyword CCSA. The CCSA table contains the deviation (in microns) from the nominal focus position, which is the focus setting of the OTA on 18 October 1991, as a function of Modified Julian Date (MJD). Relative aperture throughputs as a function of OTA focus are contained in the reference table specified by the new CCSA header keyword. This table contains values of throughput relative to the throughput at nominal focus as a function of wavelength and focus for each detector and aperture combination. The correction is applied by linearly interpolating within the CCSA table data to determine the focus position corresponding to the date of the observation, and then using bi-linear interpolation within the CCSC table data to determine the relative throughput for the focus
position and wavelength of each spectral data point. Each data point is then divided by the relative throughput value.

The next step in the new calibration process is the application of the IVS curve to convert the data from units of countrates to absolute fluxes. In order to avoid confusion with the IVS reference files used by the old process the LB94 IVS reference files are specified by the new header keyword AISHFILE (Average Inverse Sensitivity Header FILE) and, similarly, the switch controlling this step has been given the new header keyword name ATS\_CORR (the old process was controlled by the FLX\_CORR keyword). Furthermore, the new AIS reference files use a file name extension of “r8h”, instead of the the “r2h” extension used by the old IVS files.

The final step in the new calibration process is the correction of the absolute fluxes for changes in instrumental sensitivity over time. This step is controlled by the new header keyword TIM\_CORR and uses a reference table specified by the new keyword CCSD. The CCSD table contains correction factors as a function of wavelength and MJD for each detector/disperser combination. Corrections for each spectral data point are determined by using bi-linear interpolation to determine the appropriate correction for the date of the observation and the wavelength of the data point.

III. Recalibrating Your Data

In order to recalibrate your pre-COSTAR FOS data sets it is necessary to first add the eight new keywords to your raw image header files. A summary of the required new keywords is shown in Table 1. Table 1 also includes the names of the relevant reference tables that you must have in order to apply the new flux calibration steps. The four reference tables—CCSA, CCSB, CCSC, and CCSD—contain information for all detector/grating/aperture combinations and therefore only one table is required to process any observation. There are fourteen different AIS reference files; one for each supported detector/grating combination. A complete list of the AIS reference files is given in Table 2.

The keywords and their values may be added to the raw image headers individually using, for example, the IRAF task hedit, or they can all be added at once using the special task addnewkeys which is available in the STSDAS package hst\_calib\_fos. The addnewkeys task will read the values of the detector and fgwa\_id keywords in the raw data files and automatically select the appropriate value for the AISHFILE keyword.

If you do not have the reference tables or files on your computer system, you can obtain them via anonymous ftp from STScI on node “ftp.stsci.edu”. See the Appendix for step-by-step instructions on obtaining and installing the files.

Now all that is left to do is to reprocess the raw data sets using the calfos program. Note that calfos versions 2.0 and higher are backwards compatible with the old flux calibration methods, i.e. you can process data sets that do not contain the new header keywords or you can set the APR\_CORR, AIS\_CORR, and TIM\_CORR keywords to “OMIT” and set the FLX\_CORR keyword to “PERFORM”, in which case the old flux calibration method will be applied to the data. The software will not allow both methods to be applied. If any one
of the APR_CORR, AIS_CORR, or TIM_CORR keywords is set to "PERFORM" they will take precedence and FLX_CORR will automatically be skipped.

Furthermore, the APR_CORR (aperture correction) step is a prerequisite for the AIS_CORR (flux calibration) step because the countrate data must first be scaled to the throughput of the AIS reference aperture (usually the A-1) before the inverse sensitivity function can be applied. Therefore both APR_CORR and AIS_CORR must be set to "PERFORM" in order to obtain an accurate absolute calibration. If either one is set to "OMIT", the other will also be omitted by calfos.

The following is a sample of the processing log that will be printed by calfos when applying the new flux calibration methods to a data set. Messages from the early (unchanged) processing steps have been omitted for brevity.

*** CALFOS - Version 2.0 : STSDAS - Version 1.3.2 ***
YOAN0504T Begin CALFOS for input file rootname: y0an0504t
YOAN0504T output file rootname: y0an0504t
YOAN0504T Data quality initialization done using ...
YOAN0504T ...
YOAN0504T Aperture throughput coefficients from ytab$e9f1430ny.cyb
YOAN0504T LOWER aperture:
YOAN0504T  wmin = 1588.0  wmax = 2317.0
YOAN0504T  c0 = 0.544160E-01  c1 = 0.201469E-03  c2 = -0.383119E-07
YOAN0504T UPPER aperture:
YOAN0504T  wmin = 1588.0  wmax = 2317.0
YOAN0504T  c0 = 0.544160E-01  c1 = 0.201469E-03  c2 = -0.383119E-07
YOAN0504T Focus history from ytab$e8c13579y.cya
YOAN0504T Focus error for MJD 48122.382 = -2.8549  microns
YOAN0504T Focus corrections from ytab$e8c13588y.cyc
YOAN0504T Mean aperture throughput focus correction = 0.99078
YOAN0504T Conversion to abs. flux units using yref$e9f1319my.r8h
YOAN0504T Sensitivity time corrections from ytab$e8c1357ky.cyd
YOAN0504T Reference file PEDIGREE information:
YOAN0504T AISFILE=yref$e9f1319my.r8h  AIS_CORR=COMPLETE
YOAN0504T INFLIGHT
YOAN0504T Average Pre-Costar A-1 inverse sensitivity
YOAN0504T Reduction completed for input file y0an0504t

This is a paired aperture observation, therefore there are two sets of aperture throughput coefficients (although in this case they are identical). The three coefficients describe the second-order polynomial function that is applied to the countrate data to place it on an absolute scale equivalent to the A-1 aperture, upon which the IVS is based. The relative throughput for some apertures is defined by separate functions over different portions of the wavelength range of the grating. The renormalized countrate data have also been corrected for a change in OTA focus of about 3 microns from the nominal position. The countrate data have then been converted to absolute flux units using the average inverse sensitivity
curve in reference file e9f1319my.r8h and also corrected for changes in instrumental sensitivity appropriate for the date of the observation using information from the reference table e8c1357ky.cyd.

References
Appendix

The FOS calibration reference files and tables can be retrieved via anonymous ftp from node “ftp.stsci.edu” (IP address 130.167.1.125). The reference tables are located in directory /cdfs/ytab and the reference files are in directory /cdfs/yref. The tables and files are stored on this node in Sun binary format. Therefore if your host computer is a VAX/VMS system you will need to convert the files after you have retrieved them. Use the STSDAS tasks tconvert to convert tables and sun2vax to convert files (images). After you have retrieved and converted the files, place them in the directories on your system that are referenced by the STSDAS ytab and yref environment variables.

The exact steps for retrieval are as follows:

1) ftp ftp.stsci.edu (to connect to stsci)
2) anonymous (login as anonymous)
3) your e-mail address (just for information)
4) bin (set transfer mode to binary)
5) cd /cdfs/ytab (change to the tables directory)
6) get e8c13579y.cya (get a table)
7) cd /cdfs/yref (change to the images directory)
8) get e9f13201y.r8h (get an AIS image)
9) bye (to exit from ftp)
### Table 1
New Header Keywords

<table>
<thead>
<tr>
<th>Keyword</th>
<th>Value</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>APR_CORR</td>
<td>PERFORM</td>
<td>Aperture throughput correction switch</td>
</tr>
<tr>
<td>AIS_CORR</td>
<td>PERFORM</td>
<td>Flux calibration switch</td>
</tr>
<tr>
<td>TIM_CORR</td>
<td>PERFORM</td>
<td>Time change in sensitivity switch</td>
</tr>
<tr>
<td>CCSA</td>
<td>ytab$e8c13579y.cya</td>
<td>CCSA reference table name</td>
</tr>
<tr>
<td>CCSB</td>
<td>ytab$e9f1430ny.cyb</td>
<td>CCSB reference table name</td>
</tr>
<tr>
<td>CCSC</td>
<td>ytab$e8c13588y.cyc</td>
<td>CCSC reference table name</td>
</tr>
<tr>
<td>CCSD</td>
<td>ytab$e8c1357ky.cyd</td>
<td>CCSD reference table name</td>
</tr>
<tr>
<td>AISHFILE</td>
<td>(see Table 2)</td>
<td>AIS reference file name</td>
</tr>
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</table>

### Table 2
AIS Reference Files

<table>
<thead>
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<th>Detector</th>
<th>Grating</th>
<th>AISHFILE</th>
<th>Detector</th>
<th>Grating</th>
<th>AISHFILE</th>
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<td>BLUE</td>
<td>H13</td>
<td>yref$e9f13201y.r8h</td>
</tr>
<tr>
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<td>yref$e9f1319my.r8h</td>
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<td>H19</td>
<td>yref$e9f13202y.r8h</td>
</tr>
<tr>
<td>AMBER</td>
<td>H27</td>
<td>yref$e9f1319ny.r8h</td>
<td>BLUE</td>
<td>H27</td>
<td>yref$e9f13203y.r8h</td>
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<tr>
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<td>H40</td>
<td>yref$e9f13204y.r8h</td>
</tr>
<tr>
<td>AMBER</td>
<td>H57</td>
<td>yref$e9f1319qy.r8h</td>
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<td>H57</td>
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<td>AMBER</td>
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<td>H78</td>
<td>(not supported)</td>
</tr>
<tr>
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<td>yref$e9f13205y.r8h</td>
</tr>
<tr>
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<td>yref$e9f1319ty.r8h</td>
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<td>L65</td>
<td>(not supported)</td>
</tr>
<tr>
<td>AMBER</td>
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<td>PRI</td>
<td>yref$e9f13206y.r8h</td>
</tr>
</tbody>
</table>