Faint Object Spectrograph Flat Fielding

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I. Introduction

The FOS flat field calibration continues to follow the philosophy outlined in the SV-epoch report (Anderson, 1992). The calibration is intended to account for significant sensitivity changes (granularity) which occur on scales of approximately 1 diode. This includes true diode-to-diode variations; however, variations over a few diodes and, in a few cases, larger-scale variations (~10 diodes) which have sharp derivatives (e.g., a moderately broad "feature" with steep sides) must be included in the FOS flat field calibration. Smooth variations over scales of 10 or more diodes are intended to be accounted for in the absolute photometry (inverse sensitivity or so-called IVS) calibration.

Flat field files used in RSDP/PODPS processing of FOS data are stored as reference files of the form *rootname.r1h* and *rootname.r1d* in the Calibration Database System (CDBS). These files are actually unity-normalized inverse flat fields. FOS observations to be corrected are multiplied by the flat (rather than divided by it) and the flat has been normalized to have a mean value of ~1. These flat fields are applied after observations have been converted to count-rates, paired-pulse and GIM corrected, and background-subtracted (if applicable). The flat fields discussed herein are NOT appropriate for FOS spectropolarimetry mode.

II. How FOS Flats are Made

Since observations will sample the photocathode based upon the target acquisition pointing accuracy, we now utilize PEAKUP sequences that provide aperture centering of ≤ 0.03 arcsec. Further, with the aberrated PSF there are aperture-dependent differences in the flat field structure, most notably between the 4.3 arcsec aperture and the slit apertures. Therefore, since November 1992 all FOS flat field observations have been made with both the 4.3 and the slit.

FOS flat fields are generated, in principle, by dividing count-rate observations of a relatively featureless star by a pixel-to-pixel representation of the intrinsic stellar count-rate spectrum, so that the resultant quotient is, ideally, a measure only of the instrumental granularity. Two separate procedures have been employed to obtain the intrinsic count-rate spectrum used in flat field analysis; these are the so-called *traditional* and *superflat* methods.

The traditional method, which is used in the STSDAS FLATFIELD task, fits a continuum to each set of stellar count-rate observations with a cubic spline routine.

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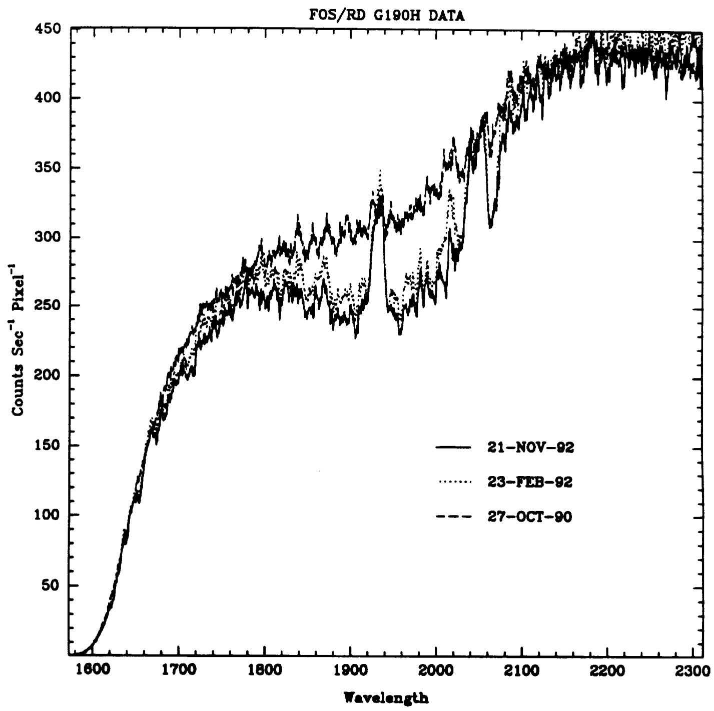

Figure 1: Comparison of representative FOS/RED G190H observed count-rate spectra obtained between October 1990 and November 1992. Note growth of both broad and narrow features, particularly in 1800–2100Å region.

Spectral lines and obvious photocathode blemishes can be masked out of the continuum fitting procedure. The count-rate observations are then divided by this continuum fit (regions in the vicinity of stellar lines are set to unity) to produce a flat field whose mean value is close to 1. This method depends upon subjective positioning of the spline nodes and subjective acceptance of the quality of the continuum fit. In the case of some complex FOS flat fields (e.g., FOS/RED G190H), this procedure can produce substantial continuum and flat field uncertainties of 5-10 percent.

As a direct consequence of the subjective and potentially non-reproducible nature of the traditional method, the superflat procedure was devised by Lindler et al 1993. A relatively featureless star is acquired with precise target centering (pointing accuracy ≤ 0.03 arcsec). Observations are obtained with the target centered in the 4.3 aperture and at each of at least six other positions offset by differing amounts parallel to dispersion. Note that any feature that is found at the same pixel in each of the spectra must be a real flat field feature and that any feature that "moves" must be a line in the stellar spectrum. Cross-correlation of the seven spectra yields two results:

1) an accurate and objective representation of the stellar count-rate spectrum at instrumental resolution, the so-called *super-spectrum* and

2) the pixel-by-pixel array of photocathode granularity, the flat field.

An additional benefit of the method is that future (or past) observations of the same

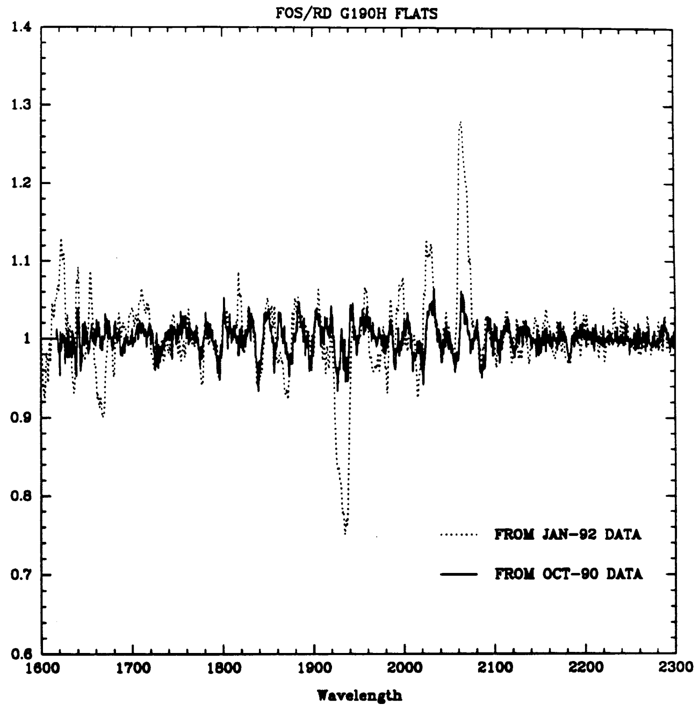

Figure 2: FOS/RED G190H inverse flat fields derived from observations obtained in October 1990 and January 1992.

star made with the same pointing accuracy and instrumental configuration can be compared with the super-spectrum to yield accurate flat fields appropriate to those epochs.

Two sets of FOS/BLUE flat field reference files have been delivered to CDBS to date. One set is based upon traditional analysis and the other is based upon superflat analysis. The superflat set is recommended for all observations after 1 January 1992. For a more complete discussion see Lindler et al (1993) and Keyes and Taylor (1993).

All FOS/RED flat field reference files delivered to CDBS for use in PODPS to date are based upon traditional analysis, however, FOS/RED superflat observations were obtained in late October, 1993. Pending successful analysis of these data, new, higher-quality flat fields will be possible not only for Cycle 3, but for many earlier epochs, as well. STEIS will be updated and a general announcement to the GO community will be made when these new flats are available.

For clarity we note again that the flat field reference files delivered to CDBS and used in PODPS reduction of FOS observations are, for historical reasons, *inverse* flat fields.

III. FOS Flat Fields - A Brief History

Table I lists month and year, detector, and brief explanatory information for all FOS flat field observations. A more detailed synopsis of each observing program may be found in Anderson (1992), Lindler et al (1993), and Keyes and Taylor (1993).

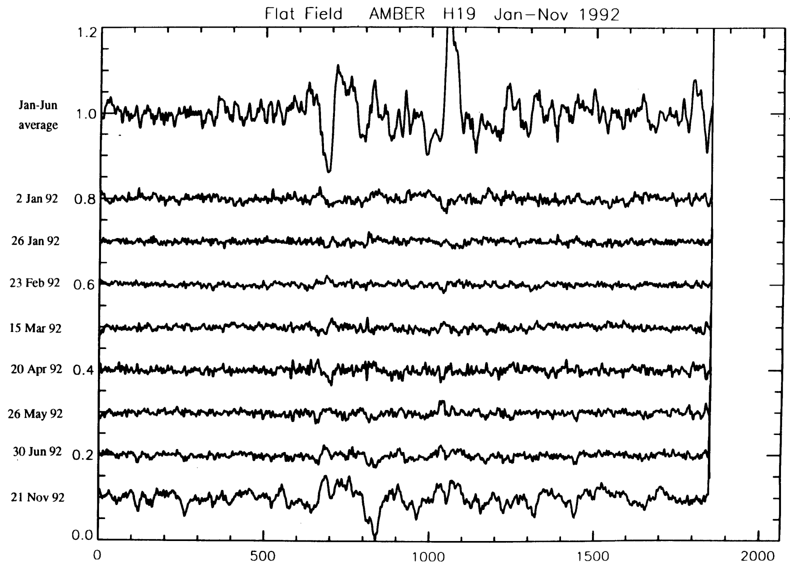

Figure 3: Comparison of inverse flat fields derived from all FOS/RED G190H monitoring observations between January and November, 1992. The average inverse flat field based upon all observations obtained between January and June, 1992 is shown at the top of the illustration. All other curves are residuals from this average at observational epochs indicated. Note mostly random deviations for January through April and the particularly large change that occurred between June and November.

Substantial flat field variations of more than 10 percent have occurred for three FOS/RED spectral elements, G160L, G190H, and G270H (see Figures 1 and 2). These changes were noted as early as mid-1991 (Hartig, 1991) and resulted in a continuing program of monitoring these three spectral elements at regular intervals. Several flat field reference files have been delivered in order to characterize the changes in flat field structure as a function of time. This required the institution of "time-tagged" flat field reference files, e.g., the addition of an effective date for each file denoted by the header keyword USEAFTER.

FOS/RED flat field monitor observations commenced in January 1992. Between early January and mid-June, 1992 observations were made every four weeks with the 4.3 aperture and the G190H, G160L, and G270H spectral elements. The initial January observations were quite different from the most recent previous flats, which had been taken in June 1991. However, only random change attributable to pointing uncertainties occurred in the remaining six sets of observations taken through June, 1992. No monitor observations were then made until November, 1992 when both 4.3 and slit apertures were used. Substantial differences are apparent between the June and November spectra (see Figure 3 for comparison of January through November G190H 4.3 aperture flats). Additionally, slit aperture flat field features appear somewhat narrower and deeper than their 4.3 aperture counterparts. For more information concerning comparison of slit and 4.3 aperture flat fields see the presentation by B. Jannuzi and G. Hartig later in this volume.

FOS/RED monitoring has continued at approximate three month intervals since November, 1992 with no more significant flat field structure change.

The flat field structure for the FOS/BLUE and the remaining FOS/RED spectral elements has been more quiescent. However, as indicated in section II, the introduction of the superflat methodology for the determination of FOS flat fields has resulted in more than one set of USEAFTER dates for FOS/BLUE, as well.

There have been multiple deliveries of flat field reference files since February, 1992. Some have been required to characterize the flat field changes, others have simply corrected errors in earlier versions, and some provide for the first time flats taken with the slit. Since the flat field reference file delivery history is quite complicated with many superseded files in the calibration database, a reference guide (Keyes and Taylor, 1993) that lists the *currently recommended* best flat field reference file to use for any particular combination of detector/disperser/aperture for any observation time has been made. A continually updated electronic version of the relevant tables from this report is available on the Space Telescope Electronic Information System (STEIS) - (accessed via anonymous ftp to *stsci.edu*). The hardcopy version of this report also provides short descriptions of each of the major flat field programs and their limitations.

IV. Summary

FOS/RED G190H, G160L, and G270H flat fields have varied substantially since launch. FOS/BLUE flats have been updated due to the improved accuracy made possible by the superflat technique.

For FOS/RED the *HST* archive is completely re-processed with the currently recommended flat field reference files for the date of observation. Any GO/GTO working with proprietary FOS/RED data obtained earlier than February 15, 1993 should consult CAL/FOS-090 (Keyes and Taylor, 1993) or the current electronic version on STEIS and re-process their observation. For FOS/BLUE any archive or proprietary observation obtained earlier than May 1, 1993 may need re-processing – consult CAL/FOS-090 or the current electronic version on STEIS.

In order to obtain the highest accuracy in flattening FOS science observations, we recommend:

a) utilize the same high-precision pointing accuracy as used for flat field calibration observations to insure similar sampling of the photocathode ($\leq$ 0.03 arcsec),

b) use superflats, if available, and

c) compare the flat field reference file with 1) raw science data, 2) raw count-rate data used to produce the flat, and 3) raw count-rate data for other standards taken as nearly contemporaneously as possible with science data in order to assess the validity of suspicious features in the science data.

References

Anderson, S.F., 1992, Instrument Science Report CAL/FOS-075.
Hartig, G., 1991, Instrument Science Report CAL/FOS-069.
Keyes, C. and Taylor, C., 1993, Instrument Science Report CAL/FOS-090.
Lindler, D., Bohlin, R., Hartig, G., and Keyes, C., 1993, Instrument Science Report CAL/FOS-088.

Table I: FOS Flat Field Observation Time Line

	Date	FOS/BLUE	FOS/RED
1990	Oct		traditional G191B2B
	Nov		
	Dec		
1991	Jan	traditional G191B2B	
	Feb		
	Mar		
	Apr		
	May		
	Jun	traditional KPD0005	traditional KPD0005
	Jul		
	Aug		
	Sep		
	Oct		
	Nov		
	Dec		
1992	Jan		traditional monitor G191B2B x 2
	Feb		traditional monitor G191B2B
	Mar	superflat G191B2B	traditional monitor G191B2B
	Apr		traditional monitor BD+28
	May		traditional monitor BD+28
	Jun	superflat BD+28	traditional monitor; superflat BD+28
	Jul		
	Aug		
	Sep		
	Oct		
	Nov		traditional monitor BD+28 (4.3/slit)
	Dec		
1993	Jan		
	Feb		traditional monitor BD+28 (4.3/slit)
	Mar		
	Apr	trad. G191B2B (4.3/slit) FAILED	traditional G191B2B (4.3/slit)
	May		
	Jun		
	Jul		
	Aug		traditional monitor BD+28 (4.3/slit)
	Sep		
	Oct		superflat G191B2B
	Nov	traditional G191B2B (4.3/slit)	trad. G191B2B (4.3/slit) FAILED