FOS INSTRUMENT AND CALIBRATION STATUS: 1993 – 1995

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Abstract. The Faint Object Spectrograph (FOS) is operating well and all its instrumental modes are functional. There has been an enhancement for the pipeline calibration that accounts for scattered light correction, temporal changes in the instrument sensitivity and focus changes. These calibration changes can be applied to pre-COSTAR data post-facto. The calibration changes to the CALFOS software will be available for post-COSTAR data in September 1995, and will be incorporated into the HST calibration pipeline.

In addition to changes to the calibration procedure, new modes of operation that have been added to enhance target acquisition capabilities. The "FOS assisted GHRS target acquisition" technique has been developed primarily to allow guest observers (GOs) acquire faint targets and obtain GHRS spectroscopy. The "reuse-target-offset acquisition" capability was developed to so that a program could have more efficient target acquisitions if there was more than one visit to the same target.

Key words: FOS – Status – Calibration

1. FOS Calibration Status

1.1 Dead Diodes

Occasionally, one of the 512 diodes on either of the FOS detectors becomes noisy or ceases to collect data. When such a diode is discovered, the diode is monitored to determine its behavior. If the diode is dead or the noisy behavior persists, the diode is disabled and diode number is added to a list of dead diodes, with a particular effective date. Presently, several diodes are 'under scrutiny,' but no new additions have been made to the dead diode tables (DDT) since December 1993. Currently, 26 FOS/BL and 15 FOS/RD diodes are disabled. The latest DDTs are given in a paper by Christensen and Martin, in these proceedings.

Since the DDTs are only updated periodically, it is possible that some data can be processed through the CALFOS calibration pipeline without correction for newly discovered dead diodes. An uncorrected dead diode produces a characteristic signature in the data, which can be corrected. For details consult the FOS section of the HST Data Handbook. The latest version of the DDTs are available via the FOS home page on the world wide web (WWW). These should be consulted to insure that data have been processed with the most appropriate dead diode reference file.

Summary Dead or noisy diodes may not be corrected for in some FOS datasets. All observers and archive users should consult the latest version of the DDTs to ensure that data have been processed with the most appropriate dead diode reference file.

1.2 Background Subtraction

The FOS spectral background is particle-induced. A background correction for all FOS gratings is now included in the CALFOS calibration pipeline. Note that FOS spectra suffer also from grating scatter and require a scattered light correction. Please see the subsection below on scattered light for details.

In the last calibration workshop, Rosa (1993) had reported a discrepancy of ~30% between the observed particle induced background and the predicted pipeline background. We have a substantial baseline of new dark (background) measurements that have been investigated by Hayes (see his paper in these proceedings). The analysis indicates that the measured background count rates are 0.004 ±0.003 cts/s/diode for FOS/BL and 0.009 ±0.004 cts/s/diode for FOS/RD. For more details on geomagnetic latitude and longitude dependence please refer to the above mentioned paper in these proceedings. These background count rates indicate that observations of faint objects are affected.

Summary All FOS observations have a particle-induced background subtraction applied to them.

1.3 Flat Fields

The FOS flat fields correct for the diode-to-diode variations on the scale of 10 pixels or less. Spectral flat fields are produced for all usable FOS detector/aperture/disperser combinations. A more complete discussion of flat fields is given in this volume in a paper by Keyes.

All post-COSTAR flat fields have been derived using the superflat technique. For details of this technique refer to the Instrument Science Report CAL/FOS-088. Additional variations of the superflat technique that describe the currently installed post-COSTAR flat fields are given in Instrument Science Report CAL/FOS-143. Typical post-COSTAR flat fields display deviations of 1-2% about a mean value of unity, but some substantial (10 - 50%) deviations also occur. Additional spatial variations do occur. Details of this investigation will be discussed in a future Instrument Science Report. Temporal variations of the FOS/RD G190H, G270H, and G160L flat fields have been observed. Flat field deviations as a function of distance perpendicular to the dispersion direction are under investigation. A discussion of this is provided by Keyes in this volume.

Currently, no flat field corrections are applied in the pipeline for *any* paired aperture data. There will be corrections applied in the pipeline at a later date. However, flat field corrections will not be applied to the 0.1-pair and barred apertures. All post-COSTAR single aperture high dispersion data obtained prior to 13 July 1994 need to be re-calibrated because pre-COSTAR flat fields were used in the pipeline calibration. All post-COSTAR single aperture low dispersion data taken prior to 10 June 1995 need to be re-calibrated.

Summary All post-COSTAR flat fields have been delivered. No flat field corrections will be applied to the 0.1-pair and barred apertures. Currently, no flat field corrections are applied in the pipeline for any paired aperture data. All post-COSTAR single aperture high dispersion data prior to 13 July 1994, and all post-COSTAR single aperture low dispersion data taken prior to 10 June 1995 need to be re-calibrated. Some spatial variations have been observed in post-COSTAR flat fields for the FOS/BL G160L grating, and an appropriate UPPER aperture is recommended for such observations to minimize the effect of the flat field feature. Temporal variations have been observed for the FOS/RD G190H, G270H and G160L flat fields.

1.4 Absolute Photometry

The FOS inverse sensitivity reference files are used to apply the absolute photometric calibration for an observation. These reference files are produced for all usable FOS detectors/aperture/disperser combinations. A detailed discussion of FOS absolute photometry is given in this volume by Bohlin.

All post-COSTAR inverse sensitivity files have been delivered. For details of the post-COSTAR FOS photometry, refer to the Instrument Science Report CAL/FOS-144. The FOS/RD G190H and G270H grating data show temporal changes in the post-COSTAR period. All other detector/disperser combinations have been stable at the 2% level during the post-COSTAR era.

In the CALFOS pipeline, no absolute photometry corrections are applied to the 0.1-pair and barred apertures. All Cycle 4 data prior to 21 March 1994 need to be re-calibrated because unity reference files were used in the pipeline calibration.

Pre-COSTAR photometry was strongly dependent upon the combined effects of Optical Telescope Assembly (OTA) focus changes and time-dependent degradation of the FOS sensitivity. The pipeline calibration now includes corrections for these effects. Thus, properly re-calibrated pre-COSTAR data will improve the photometric accuracy of these data. Standard pipeline calibrations will include corrections for the influence of time dependence for the post-COSTAR data from September 1995. The calibration changes are discussed in detail in the Instrument Science Report CAL/FOS-129 as the Average Inverse Sensitivity (AIS) method. Additional information is also available in the Instrument Science Reports CAL/FOS-126 and CAL/FOS-144. All data obtained prior to 1 September 1995 need to be re-calibrated using the new AIS calibration technique. The corrections due to re-calibration using the AIS system will vary depending on the aperture and grating.

Summary All post-COSTAR inverse sensitivity files have been delivered. No absolute photometry corrections are applied to the 0.1-pair and barred apertures. All Cycle 4 data prior to 21 March 1994 need to be re-calibrated. Further, all data prior to 1 September 1995 need to be re-calibrated using the new AIS calibration system. The FOS/RD G190H and G270H grating inverse sensitivities show temporal changes in the post-COSTAR period. All other detector/disperser combinations have been stable at the 2% level during the post-COSTAR era. The CALFOS pipeline calibration now includes corrections for focus changes and time-dependent degradation of the FOS sensitivity.

1.5 Wavelength Calibration

All FOS wavelengths are vacuum wavelengths.

Because of the different paths followed by light from the internal calibration lamps and an external target, wavelength offsets between the two paths have to be determined. The wavelength offsets between the internal calibration lamps and a known external point source are currently based on observations of the dwarf emission line star AU Mic. On the red side, the mean offset between internal and external sources is $+0.176\pm0.105$ diodes. On the blue side, the mean offset is -0.102 ± 0.100 diodes. These offsets are included in the pipeline reduction wavelength calibration. More details on internal wavelength calibration are given in the paper by Dahlem in this volume.

An independent technique to determine the wavelength offset for the FOS/BL G130H grating is to use the geo-coronal Lyα. An analysis using this method (see paper by Koratkar and Evans in these proceedings) indicates that the offset is $+0.358\pm0.165$ diodes for the FOS blue detector.

Wavelength calibration is affected also by the filter-grating-wheel repeatability. The 1σ filter-grating-wheel repeatability is of the order of 0.1 diodes, but deviations as large as 0.36 diodes are observed (see paper by Koratkar and Martin in this volume). The relative uncertainty of the FOS wavelength calibration can also be estimated from the position of the geo-coronal Lyα. Results of this analysis (see paper by Koratkar and Evans in this volume) are consistent with those determined from the filter-grating-wheel repeatability test.

Summary The wavelength calibration used in the CALFOS pipeline has not been changed since science verification. The mean offset between internal and external sources is $+0.176\pm0.105$ diodes for the red detector and -0.102 ± 0.100 diodes for the blue detector. The repeatability of the wavelength calibration of the order of 0.1 diodes, but deviations as large as 0.36 diodes are observed.

1.6 Scattered Light

Scattered light observed in the FOS data is produced by the diffraction patterns of the FOS gratings, the entrance apertures, and the micro-roughness of the gratings (extensive work discussed in the Instrument Science Report CAL/FOS-114). There is a routine pipeline calibration correction that is applied *only* for *gratings that have regions of zero sensitivity to dispersed light.* The applied correction is *wavelength independent.* For details of the correction please see the Instrument Science Report CAL/FOS-103. Note that the scattered light correction is *in addition* to the background subtraction. Since the scattered light characteristics of the FOS are well understood, a scattered light model is now available for use as a post-observation parametric analysis tool to estimate the amount of scattered light affecting a given observation.

Summary A wavelength-independent scattered light correction is applied in the CALFOS pipeline for observations obtained using some gratings. A more complete scattered light model is available for use as a post-observation parametric analysis tool.

1.7 Sky Lines

The lines of geo-coronal Lyα λ1216 and OI λ1304 appear regularly in FOS spectra, with a width determined by the size of the aperture. Occasionally, the sky lines of OI at λ1356 and of OII at λ2470 can also be seen when observing on the daylight side of the orbit. Second order Lyα sometimes appears at λ2432.

1.8 Polarimetry

FOS polarimetry with the G190H and G270H gratings after the introduction of COSTAR is possible. The instrumental polarization introduced by the COSTAR reflections is $<$2% and is wavelength dependent. More details on accuracies can be found in the paper by Allen in this volume.

1.9 Aperture Location

The absolute V2,V3 locations of the $1.0''$ apertures are known to $0.3''$. The internal accuracy of the aperture locations is $\sim 0.05''$, but the absolute accuracy of $0.3''$ is limited by the Fine Guidance Sensor (FGS) to FGS alignment. The positions of other single 'small apertures' (smaller than the $1.0''$ aperture) relative to the $1.0''$ apertures are known to $\sim 0.02''$. The relative positions of all other apertures are known to $0.15''$. For details see the Instrument Science Reports CAL/FOS-137 and CAL/FOS-138.

1.10 Aperture Areas

The $1.0''$ aperture dimensions in the FOS X and Y coordinate frame have been measured by doing X and Y scans. For details see the Instrument Science Report CAL/FOS-140.

The photometric areas for a limited number of apertures have been measured from observations of centered targets for the pre-COSTAR epoch and post-COSTAR measurements. For details see the Instrument Science Report CAL/FOS-136.

2. New Target Acquisition Capabilities

2.1 FOS assisted GHRS target acquisition

Due to the presence of COSTAR the FOS and GHRS aperture locations are now separated by a small enough distance on the sky that targets can sometimes be offset from one instrument to the other using the same guide stars. This technique of target acquisition is called an FOS or GHRS assisted target acquisition.

The standard FOS-assisted GHRS target acquisition uses the FOS blue detector to acquire the target and then offsets the target into the GHRS large science aperture (LSA). The separation of the GHRS and FOS red detector apertures is large enough ($> 2.5'$). This distance is large enough that only under very special situations will it be possible to find guide stars which are within the field of view of the FGSs from the beginning to the end of an operation involving both the FOS red detector and the GHRS, which is a requirement of this target acquisition strategy. Therefore, FOS-assisted target acquisitions from the FOS red detector may actually be possible only in very few cases. One can reverse the target acquisition strategy and use the GHRS to acquire a target for an FOS/BLue-side science observation.

A FOS-assisted GHRS target acquisition strategy is recommended especially for observations that are best performed using the GHRS and for which the target cannot be acquired with the GHRS (even with Side 2). Similarly, a GHRS-assisted FOS target acquisition is recommended if the observations are best performed using the FOS and for which the target cannot be acquired at all with the FOS. Various considerations indicate that a GHRS assisted FOS target acquisition is recommended only for the $1.0''$ aperture and the $4.3''$ aperture. See the FOS Instrument Handbook version 6.0 for details of this acquisition capability.

An assisted target acquisition is a restricted resource since the number of available guide stars will be limited, as the two instruments *must* be used in the same observation set/visit.

A real gain in overhead times for an FOS-assisted GHRS target acquisition is achieved only if a binary search acquisition can be used. If a peak-up has to be used, the observer must decide if a 2-stage peak-up acquisition is sufficient. Otherwise the FOS target acquisition overhead is similar to the GHRS overhead if a Side-1 acquisition is possible. Of course, if a 3-stage peak-up acquisition is the only way to acquire a particular target, then there is no choice but to use that strategy.

2.2 Reuse-Target-Offset

If an FOS observing program requires more than one visit to a target within 3-4 weeks, and the target acquisition sequence is time consuming, then the reuse-target-offset procedure can be used. This procedure requires that the same guide star positions in the FGS field-of-view be used for the repeat visits. For this target acquisition procedure the first return visit must be at least 4 days after the initial acquisition. Furthermore, the procedure can be used only if the target acquisition scenario for the first visit is a peak-up acquisition. It is recommended that in subsequent return visits, a single-stage peak-up be performed to improve the pointing accuracy. See the FOS Instrument Handbook version 6.0 for the details of this acquisition capability.

3. FOS Cycle 5 Calibration Plan

After the deployment of COSTAR, an extensive calibration program was carried out during SMOV and Cycle 4, and the performance of the post-COSTAR FOS has been characterized in detail. A summary of the Cycle 4 calibration, as completed through November 1994, is presented in Instrument Science Report CAL/FOS-130. Instrument Science Report CAL/FOS-135 provides further calibration information.

In Cycle 5, we expect to maintain the routine calibration for the FOS. Our calibration program is divided into two parts:

(1) a set of monitoring tests which aim to verify the stability of the instrument

performance, and to monitor those aspects of the FOS performance that are known to show time variation, and

(2) a set of specific tests designed to maximize the instrumental performance, and to characterize those aspects of the FOS performance that have been specially requested by Cycle 5 GOs. See the FOS Instrument Handbook version 6.0 and the Instrument Science Report CAL/FOS-135 for the details of the Cycle 5 calibration program.

4. FOS WWW Page

The FOS Web page can be accessed via the following URL:

http://www.stsci.edu/ftp/instrument_news/FOS/topfos.html

Instrument related documentation, including many Instrument Science Reports, are now available on the Web. Anything new and/or important can be found under the "Advisories" button. All of the currently recommended reference files for any observation date are listed under the "Calibration Products" button. A list of FOS team contacts and their specialties are can be accessed through these pages.

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