Faint Object Spectrograph

Instrument Handbook

The STScI FOS Group

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Version 6.0

June 1995

This is version 6.0 of the Instrument Handbook for the Faint Object Spectrograph (FOS) of the *Hubble Space Telescope*.

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Date of issue is June 1, 1995.
Date of last revision was May 10, 1995.

This FOS Instrument Handbook supersedes all previous versions. If a conflict exists between this document and another, the document with the latest date of issue should be accepted.

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To get to the FOS home page on the World Wide Web use this URL:

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

FOS Instrument Handbook Revision History

Version	Date of Issue	Authors
1.0	1985 October	H.C. Ford
1.1	1990 May	H.C. Ford and G.F. Hartig
2.0	1992 April	A.L. Kinney
4.0	1993 February	A.L. Kinney
5.0	1994 May	A.L. Kinney
6.0	1995 June	C.D. Keyes

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Table of Contents

List of Figures

List of Tables

INTRODUCTION

This Handbook describes The Faint Object Spectrograph (FOS) and its use for Cycle 6 of the Hubble Space Telescope General Observer program. Many presentations have been updated from previous versions, especially those pertaining to target acquisition, brightness limits, and instrumental sensitivities needed for exposure and S/N calculations. This Handbook draws upon discussions from earlier versions of the Handbook, notably the Version 1.0 FOS Instrument Handbook (Ford 1985), the Supplement to the Version 1.0 Instrument Handbook (Hartig 1989), and the Version 5.0 Handbook (Kinney, 1994). *Only the current document should be used for Cycle 6*. The detectors are described in detail by Harms *et al* (1979) and Harms (1982).

This version of the FOS Instrument Handbook is for the post-COSTAR refurbished telescope. The change in focal length introduced by the addition of COSTAR affects the aperture sizes as projected on the sky. However, the pre-COSTAR aperture designations used in the Remote Proposal Submission System, version 2 (RPS2) and in the Project Data Base (PDB) have not been changed. Apertures are referred to throughout this document by their size followed in parentheses by their RPS2 exposure level designation (`in Courier typeface`). Indeed, all RPS2 designations, which are used for proposal preparation, will be denoted in Courier typeface in this Handbook. For example, the largest circular aperture is referred to as the 0.9″ (`1.0`) aperture, while the smallest paired apertures are referred to as the 0.09″ paired (`0.1-PAIR`) apertures.

Chapters 1 and 2 provide the essential information required for filling out Phase I (and much of Phase II) proposals. Chapter 3 contains information on current FOS calibration status and instrument performance.

Chapter 1 describes basic FOS instrument capabilities and presents a complete discussion of the spectroscopic and spectropolarimetric data taking modes. Section 1.0.1 provides an important discussion of unique FOS observing capabilities that will no longer be available after the FOS is removed from HST during the Second Servicing Mission now scheduled for February, 1997 (*under the current schedule Cycle 6 represents the last opportunity to propose to use the FOS*). An overview of instrument capability is presented in section 1.1 and summarized in Table 1-2. The spectral resolution is given in section 1.2 as a function of grating and aperture. FOS instrumental sensitivities and aperture throughputs are presented in section 1.3 along with illustrations of exposure time and expected count rate calculations. The limits for the brightest objects that can be observed with FOS are listed in Tables 1-10 and 1-11 and section 1.4. The fundamentals of spectroscopic data-taking with the FOS are presented in section 1.5, along with examples of RPS2 inputs and practical considerations for the standard data taking mode (`ACCUM`) and the high time-resolution mode (`RAPID`). Polarimetry is discussed in section 1.6. The FOS noise and dynamic range are covered in section 1.7.

In Chapter 2 we present a complete discussion of FOS target acquisition modes and strategies. Examples and tips are given for using the most important FOS target acquisition modes (for example, `ACQ/BINARY` and `ACQ/PEAK`).

TIP: *Phase I proposers should carefully consider the impact of FOS target acquisition requirements on their observing requests. No routine adjustments can be made in Phase II for inadequately specified target acquisitions, i.e., the number of orbits awarded by the TAC will not be increased to accommodate FOS target acquisition.*

Chapter 3 describes the current calibration status and instrument performance for the FOS. (Appendix I gives the text of the Cycle 5 FOS Calibration Plan - the Cycle 6 plan will be qualitatively similar.)

Chapter 4 describes how to simulate FOS spectra with the “synphot” package, which runs in the ST Science Data Analysis System (STSDAS) under IRAF. This simulator allows input of a large variety of spectra, and incorporates the current calibration files for the FOS.

Appendix A provides many details of FOS data taking and lists the FOS observing parameters in the nomenclature of RPS2 as well as in the nomenclature of FOS output data headers. Appendix A also gives the equations for calculating the start time of any time-resolved exposure. Appendix B lists the current dead diode tables. Appendix C, by M. Rosa, gives a method to estimate the scattered light contribution for a number of spectral types. Appendix D supplies line lists and spectra of the comparison lamps for wavelength calibration. Appendix E is a compendium of all FOS Instrument Science Reports (ISRs), including science verification reports. Appendix F is a sample RPS2 FOS proposal including exposure level examples for various FOS modes. Appendix G gives maps of the 3.7″ x 1.3″ (`4.3`) aperture flat field structure for all dispersers except the prisms. Appendix H compares the ultraviolet throughput of the FOS with that of the low dispersion mode of the GHRS. As noted above, Appendix I is a description of the Cycle 5 FOS Calibration Plan.

The members of the STScI FOS Group, our telephone numbers, and our e-mail addresses are listed on the inside front cover of this Handbook. We urge you to contact us at any phase of your HST program from pre-Phase I through post-observation analysis. Also, the Science Support Division (SSD) at STScI has established a Helpline (telephone: (410) 338-1082; e-mail: *help@stsci.edu*) for you to contact if you need help with any aspect of your program. A compendium of FOS instrument news and related documentation, including any recent advisories concerning instrument performance or calibration status, is available on-line via the FOS World Wide Web (WWW) Homepage (*http://www.stsci.edu/ftp/instrument_news/FOS/topfos.html*). The FOS Homepage may also be reached via the Instruments button on the STScI WWW Homepage (*http://www.stsci.edu/top.html*). Postscript copies of recent ISRs can be downloaded via the FOS WWW Homepage and paper copies may be obtained by e-mail request to *help@stsci.edu*.

1. THE INSTRUMENT

1.0.1 Cycle 6: The Last Opportunity to Use the Unique Capabilities of the FOS.

The FOS and the GHRS are scheduled to be removed from HST during the Second Servicing Mission in February, 1997. These two instruments will be replaced by the Space Telescope Imaging Spectrograph (STIS). Although STIS will in many respects offer much improved capabilities, some types of observing programs may be better accomplished with the FOS. Important areas of consideration in this regard are:

1. Ultraviolet spectropolarimetry: STIS offers no polarimetric capability. See section 1.6 for a discussion of post-COSTAR FOS spectropolarimetric capabilities.

2. High count rates in the ultraviolet: FOS can accurately measure raw count rates as high as 50,000 per second per resolution element. The STIS ultraviolet detectors are limited to approximately 50 counts per second per pixel; observations of bright sources will require either small apertures, which may compromise photometric accuracy, or limitation of spectral coverage per exposure.

1.1 General Description of Instrument Capabilities

The Faint Object Spectrograph has two Digicon detectors with independent optical paths. The Digicons operate by accelerating photoelectrons emitted by the transmissive photocathode onto a linear array of 512 diodes. The individual diodes are 0.31″ wide along the dispersion direction and 1.29″ tall perpendicular to the dispersion direction. The detectors are sensitive over the wavelength range from 1150Å to 5400Å (`FOS/BL`) and from 1620Å to 8500Å (`FOS/RD`). The quantum efficiencies of the two detectors are shown in Figure 1-1. The optical diagram for the FOS is given in Figure 1-2.

The general characteristics of `FOS/BL` and `FOS/RD` are given in Table 1-2. Appendix H provides a comparison of the relative instrumental sensitivities of the FOS and GHRS Side 1.

TIP: *For the G130H spectral region the GHRS Side 1 G140L is normally more efficient than FOS/BL, especially when re-binned to FOS resolution. See Appendix H.*

Dispersers are available with both high spectral resolution (1 to 6Å diode^{-1}, $\lambda/\Delta\lambda \approx 1300$) and low spectral resolution (6 to 25Å diode^{-1}, $\lambda/\Delta\lambda \approx 250$). The actual spectral resolution depends on the point spread function of HST, the dispersion of the grating, the aperture used, and whether the target is physically extended. The brightest objects observable with FOS depend strongly upon the type of object and the combination of detector, spectral element, and aperture to be used; see Tables 1-10 and 1-11 for brightness limits for each detector and grating as a function of spectral type. Particle-induced FOS detector background is normally the dominant consideration in determining limits on faint sources that can be observed by FOS (see section 1.7).

The mapping of the photocathode to the diode array is affected by the changing geomagnetic environment on orbit. An onboard real-time correction (the geomagnetic-image-motion, or GIM, correction) is applied routinely in all data-taking modes except `ACQ/PEAK`.

The instrument has the ability to take spectra with high time resolution (≥ 0.03 seconds, `RAPID` mode) and the ability to bin spectra in a periodic fashion (`PERIOD` mode). Although FOS originally had ultraviolet polarimetric capabilities with the FOS/BL G130H grating, the post-COSTAR environment allows polarimetry only for $\lambda \geq 1650$Å; that is only with gratings G190H, G270H, and G400H and both FOS/BL and FOS/RD.

There is a large aperture for acquiring targets using on-board software (3.7″ x 3.7″, designation 4.3). Since the diode array extends only 1.3″ in the Y-direction, this largest aperture has an effective collecting area of 3.7″ x 1.3″. Other apertures include several circular apertures with sizes 0.86″ (1.0), 0.43″ (0.5), and 0.26″ (0.3); and paired square apertures with sizes 0.86″ (1.0-PAIR), 0.43″ (0.5-PAIR), 0.21″ (0.25-PAIR), and 0.09″ (0.1-PAIR), for isolating spatially resolved features and for measuring sky. In addition, a slit and several barred apertures are available (see Figure 1-3 and Table 1-4).

FOS/BL sensitivity decreased by about 10% from launch until 1994.0, but has been stable since that time to the present. A dip in FOS/BL instrumental sensitivity to approximately 50% of pre-COSTAR levels centered at 2000Å (which extends with an approximate Gaussian full width from 1600Å to 2400Å) appeared immediately post-servicing. The FOS/RD sensitivity is now generally stable to within 5%, but was observed to decrease rapidly in Cycles 1 and 2 in a highly wavelength dependent fashion between 1800Å and 2100Å, affecting gratings G190H, G160L, and to a lesser degree G270H. The flat fields for these 3 gratings changed little between early 1992 and mid-1994. Flat fields have been obtained in either the large 3.7″ x 1.3″ aperture (4.3) or the 0.9″ (1.0) aperture for the G190H, G160L, and the G270H gratings approximately quarterly beginning March, 1994 in order to monitor this effect. The sensitivity of both the blue and the red detectors is to be monitored approximately every 2 months in cycle 5. Please refer to Chapter 3 for a more complete characterization of the calibration status of the FOS.

1.2 Spectral Resolution

The spectral resolution depends on the point spread function of the telescope, the dispersion of the grating, the diode width, the spacecraft jitter, the aperture, and whether the target is extended or is a point source. Table 1-3 lists the dispersers, their wavelengths, and their dispersions (Kriss, Blair, and Davidsen 1991). All available FOS apertures are listed in Table 1-4 with their designations as given in HST headers, their sizes, and shapes. Figure 1-3 shows the FOS entrance apertures overlaid upon each other together with the diode array. The positions of the apertures are known accurately and are highly repeatable.

FOS line widths (FWHM) are given as a function of aperture in Table 1-5 in units of diodes for a point source at 3400Å and for a uniform, extended source. The FWHM does not vary strongly as a function of wavelength.

- **Example:** Observing a point source using FOS/RD with the G270H grating in the 3.7″ x 1.3″ aperture (4.3) gives a

$$\mathrm{FWHM} = 0.96 \text{ diode} \times 2.05 \text{ Å diode}^{-1},$$

$$\mathrm{FWHM} = 1.97 \text{ Å}.$$

The same observation with the 0.26″ (0.3) aperture would have a

$$\mathrm{FWHM} = 0.92 \text{ diode} \times 2.05 \text{ Å diode}^{-1},$$

$$\mathrm{FWHM} = 1.89 \text{ Å}.$$

1.3 Exposure Time Calculations

Tables 1-6 and 1-7 list actual FOS *inverse* instrumental sensitivities, S_λ, for the 3.7″ x 1.3″ (`4.3`) aperture as a function of wavelength for all detector/disperser combinations. Table 1-8 gives aperture throughputs, T_λ, relative to the 3.7″ x 1.3″ (`4.3`) aperture for all FOS apertures. The expected count rate (see TIP below) at a given wavelength can be calculated by dividing the anticipated flux at that wavelength expressed in erg cm^{-2} s^{-1} $Å^{-1}$ by the *inverse* sensitivity from the tables and then multiplying by the aperture throughput from Table 1-8.

- **Example Exposure Time Calculation:**. The count rate for a point source with flux of $F_\lambda = 3.5 \times 10^{-15}$ erg cm^{-2} s^{-1} $Å^{-1}$ at 3600Å using the `FOS/RD` detector, in the 0.9″ (`1.0`) aperture, with the G400H grating, is given by

$$N_\lambda = (F_\lambda / S_\lambda)\, T_\lambda.$$

where λ = 3600Å, $S_\lambda = 1.087 \times 10^{-15}$ erg cm^{-2} $Å^{-1}$$count^{-1}$ (from Table 1-7), $F_\lambda = 3.5 \times 10^{-15}$ erg cm^{-2} s^{-1} $Å^{-1}$, and aperture throughput $T_\lambda = 0.94$ (from Table 1-8), so that

$$N_\lambda = 3.0 \text{ counts } s^{-1} \text{ diode}^{-1}.$$

TIP: *There can be some confusion about the effective exposure per PIXEL in output FOS spectra. As is explained in section 1.5 below, FOS data are normally acquired in one of three* `SUB-STEP` *modes* (`=1,2,` or `4`). *Most commonly, FOS data are sampled with* `SUB-STEP=4` *which normally assures satisfaction of the Nyquist sampling theorem. That is, the data are sampled at a spacing corresponding to one-fourth of the sampling element (diode width). This yields the often counter-intuitive situation that output FOS data products contain PIXELS whose effective exposure is 1./*`SUB-STEP` *of the exposure time specified at the RPS2 exposure level. Essentially, the RPS2 exposure time will be the exposure time per resolution element (or diode) in the output data.*

For example, a 1000-second `ACCUM` *mode* `SUB-STEP=4` *exposure produces 4 pixels per resolution element each of whose effective exposure is 250 seconds.*

The exposure time for a desired signal-to-noise ratio per resolution element is then given by

$$t = (SNR)^2 / N_\lambda,$$

which in our example above for SNR = 20 per DIODE, yields t = 400/3.0 counts sec^{-1} $diode^{-1}$= 133 seconds.

For a source with a count rate comparable to the dark count rate, d, this equation becomes

$$t = (SNR^2 / N_\lambda)\ (1+N_\lambda / d) / (N_\lambda / d).$$

- **Example using V magnitude and spectral type (see Table 1-9).** As a comparison, count rates for objects of representative spectral type with V=15.0 are given in Table 1-9 at the wavelengths corresponding to the peak response of each grating. The example given above corresponds to an object with power law $F_\nu \propto \nu^{-2}$, V=15.0, observed in the 0.9″ (`1.0`) aperture, the G400H grating, and `FOS/RD` detector.

1.4 Brightness Limits

The photocathodes can be damaged if illuminated by sources that are too bright. The danger thresholds for the detectors have been translated into a limit of total counts detected by all 512 diodes per 60 seconds - the overlight limit. If the overlight limit is exceeded in a 60-second interval, the FOS automatically safes - *i.e.* the FOS shuts its aperture door, places all wheels at their rest position, and stops operation. The overlight protection limit is 1.2×10^8 counts per minute summed over the 512 diodes for the gratings and 3×10^6 counts per minute for the mirror. The visual magnitudes for unreddened stars of representative spectral types corresponding to this limiting count rate are given in Tables 1-10 and 1-11 for all spectral elements.

1.5 Fundamentals of Data Acquisition

1.5.1 Sub-stepping

FOS data are usually acquired in one of three `SUB-STEP` modes (`=1,2,` or `4`). Normally, `SUB-STEP` should be ≥ 2, but 1 can be tolerated in certain special cases. The following describes details for `SUB-STEP=4`, so-called “quarter-stepping,” which is the default and most commonly used mode.

FOS data are acquired in a nested manner, with the innermost loop being livetime, LT, plus deadtime, DT, (see Appendix A for a full description of data taking). The next loop sub-steps the diode array along the dispersion direction (X-direction), normally by one-quarter of the diode width (12.5 microns, or 0.076″) and so on for four quarter-steps. To minimize the impact of dead diodes, this loop of data-taking is then continued by sub-stepping in steps of one-quarter of the diode width, but over the adjacent diode. This over-scanning procedure is repeated until spectra are obtained over 5 contiguous diodes, or for a total of 20 quarter-steps. The process is repeated until *each diode (not pixel - see below)* has been exposed for the duration specified in the RPS2 exposure level.

A typical data taking sequence would divide the exposure time into twenty equal time bins, and first perform the sequence of (livetime + deadtime) stepped four times. Each of these first four `SUB-STEP`s is placed in a separate memory location onboard, thereby producing initially 2048 pixels or wavelength-bins of data (512 diodes × 4 quarter-steps). This sequence is continued by stepping the spectrum onto the next diode for four more quarter-steps (so-called over-scanning). Again 2048 wavelength bins are produced, but four of the second set were not in the first. The wavelength bins are correctly co-added in memory so that we now have 2052 pixels. This process is continued for three more over-scan steps, finally yielding a total of 2064 pixels in the resultant spectrum. *Note that at the end of the exposure none of the pixels has been exposed for the duration specified in the RPS2 exposure level. The typical pixel in the output spectrum will have been exposed for one-fourth of the RPS2-specified exposure time.*

TIP: *Although overscanning can be turned off via the RPS2 exposure level parameter* `COMB=NO`*, we do not recommend this option because then no corrections for the impact of dead diodes can be made.*

1.5.2 ACCUM

FOS observations longer than a few minutes are automatically time-resolved. Spectra taken in a standard manner in ACCUM mode are read out at regular intervals. The red side (FOS/RD) is read out at ≤ 2 minute intervals, while the blue side (FOS/BL) is read out at ≤ 4 minute intervals. The standard output data for ACCUM mode preserve the time resolution in "multi-group" format. Each group of data has associated group parameters with information that can be used to calculate the start time of the interval, plus a spectrum for each interval (2 minutes for FOS/RD, 4 minutes for FOS/BL) of the observation. Each consecutive spectrum (group) is made up of the sum of all previous intervals of data. The last group of the data set contains the spectrum from the full exposure time of the observation. For details on output data formats, see Part VI of the *HST Data Handbook* (ed. Baum 1994).

ACCUM with default SUB-STEP=4 is the standard data-taking mode for FOS.

TIP: *Remember that for* SUB-STEP=4 *an exposure time of 1000 seconds entered in the RPS2 exposure level corresponds to 250 seconds exposure for each quarter-stepped pixel in the actual spectrum.*

The sample RPS2 FOS proposal in Appendix F contains an example of an ACCUM mode exposure in Visit 01.

1.5.3 RAPID

For observations needing higher time resolution, RAPID mode reads out FOS data at a rate set by the observer with the parameter READ-TIME, which is equal to the sum of livetime, LT, plus deadtime, DT, plus the time to read out the diode array, ROT. READ-TIME is, normally, the length of time between the start of one exposure in a RAPID series and the start of the next exposure in the series. The observer should be aware that the percentage of READ-TIME spent actually accumulating data in RAPID can be very small depending on how the parameters are set. Figure 1-4, from Welsh *et al* (1994), shows the duty cycle, or ratio of time spent accumulating data (LT) to READ-TIME, as a function of READ-TIME. Given the two values of telemetry rate (32,000 bits/sec, and 365,000 bits/sec) and the three common values of SUB-STEP (4, 2, and 1), there are six duty cycle curves in Figure 1-4.

TIP: *The FOS will switch from low telemetry rate to high when the duty cycle drops below 80%. The* READ-TIME*s at which this transition occurs are given as the minimum* READ-TIME*s for the low telemetry rate in Table 1-1. Switching to the high telemetry rate normally limits the total amount of data-taking to 18 minutes per orbit due to onboard tape recorder capacity. The telemetry rate can be forced to remain at the low rate in special circumstances. Normally, the parameters should be set to maximize duty cycle, while maintaining the resolution and wavelength coverage necessary for the scientific objectives.*

The minimum value of READ-TIME is dependent upon the SUB-STEP, the overscanning, the number of diodes being read out, and the telemetry rate. For the most common case of SUB-STEP=4, OVERSCAN=5 (COMB=YES), and all 512 diodes used, the minimum READ-TIME is 6.18 seconds for the low telemetry rate and 0.708 seconds for the high rate (see Table 1-1 below). The shortest possible READ-TIME of 0.033 seconds requires SUB-STEP=1, no overscanning (COMB=NO), the high telemetry rate, and limiting data-taking to 50 diodes.

The minimum values of READ-TIME to read-out all 512 diodes with allowed values of SUB-STEP and normal (default) OVERSCAN=5 (COMB=YES) are given in Table 1-1.

As a further complication, in certain cases the start times of individual measures of a RAPID observing sequence may be separated by an interval substantially shorter and less predictable than READ-TIME. This special shortened interval can occur for values of the READ-TIME less than the *recommended* minimum READ-TIMEs for the low telemetry rate given in Table 1-1 below. Each *default* minimum READ-TIME, which corresponds to an 80% duty cycle, is shorter than the corresponding *recommended* minimum value. Contact an Instrument Scientist if you are contemplating using a low telemetry rate READ-TIME shorter than the recommended values.

Table 1-1: Minimum RAPID mode READ-TIME and read-out (ROT) times

Telemetry rate		SUB-STEP=1		SUB-STEP=2		SUB-STEP=4	
		READ-TIME	ROT	READ-TIME	ROT	READ-TIME	ROT
low	default minimum	1.55	0.309	3.09	0.617	6.18	1.234
	recommended minimum	1.86		3.70		7.40	
high		0.177	0.027	0.354	0.054	0.708	0.108

RAPID data are also delivered in group format with a header present at the beginning of the data. Each group then contains group parameters with FOS-related information followed by the spectrum for one time segment; that is, each exposure in a RAPID time series is stored in a separate group. (Of particular interest among the output group parameters is FPKTTIME, which can be used to derive the start time for each individual exposure, as given in Appendix A.)

1.5.3.1 Practical Considerations and Suggestions: RAPID

Again, the default SUB-STEP=4 is the standard data-taking mode for RAPID mode. Normally, SUB-STEP=2, or 1, is used with RAPID mode only when read-out time management is required.

The sample RPS2 FOS proposal in Appendix F contains an example of a RAPID mode exposure in Visit 02.

In RAPID mode, when a wavelength range is specified, that range will be used whether or not there is room in memory for a larger region. Therefore, *specifying a wavelength range is NOT a good idea unless absolutely necessary*, because it restricts the wavelength region that is read out. The full wavelength region is often useful. For example, the background can be determined directly from the diode array for gratings G130H, G160L, G190H, G650L, G780H, and PRISM. The diodes below the lowest wavelength, given in Table 1-3, can be used to average the actual background rate. The zero order, which provides a measure of broad band photometry, can also be monitored for G160L if all diodes are read out. If the observer needs *only* a specific wavelength range to be read out, then that range should be specified with the keyword WAVELENGTH at the exposure level in RPS2. Otherwise, the largest possible wavelength range that is compatible with the requested READ-TIME will be observed automatically.

Additional suggestions for RAPID mode (mostly drawn from Welsh *et al*, 1994):

- If the sampling rate (READ-TIME) must be set *a priori*, the total exposure time specified in RPS2 must be an integral multiple of READ-TIME. If not, READ-TIME will be altered to make this true.
- NON INT must be specified if a continuous data set is required. Otherwise, Earth occultations will not be prohibited in the exposure series.
- Due to jitter of the spacecraft, one should use the largest aperture possible.
- Avoid READ-TIMEs that are very near to the transition between high and low telemetry rates (see Figure 1-4). Small roundoff errors can have a drastic effect.
- Indeed, if timing is critical, avoid READ-TIMEs ≤ minimum *recommended* READ-TIME given in Table 1-1. Contact an Instrument Scientist in this case.

1.5.4 PERIOD

For objects that have a well known period, FOS data can be taken in PERIOD mode in such a way that the period is divided into BINS where each bin has a duration of Δt = period/BINS. The period of the object is specified by the parameter CYCLE-TIME. The spectrum taken during the first segment of the period, Δt_1, is added into the first memory location. The spectrum taken during the second segment, Δt_2, is added to a contiguous memory location, and so on. The number of segments that a period can be divided into depends on the amount of data each spectrum contains, which depends on the number of SUB-STEPs, whether or not the data are overscanned, and how large a wavelength region is to be read out. If the full range of diodes is read out, and the default observing parameters are used, 5 BINS of data can be stored. PERIOD mode output data contain a single group with a standard header followed by the spectra stored sequentially where there are BINS spectra.

The data size, which cannot exceed 12,288 pixels, is given for PERIOD by

$$\text{Data size} = (\text{NCHNLS} + \text{OVERSCAN} - 1) \times \text{SUB-STEP} \times \text{BINS},$$

where BINS applies to PERIOD mode only. BINS is the number of time-segments into which the periodic data are divided and overscan will be either 5 (normally) or 1. If the observer needs a larger number of BINS than 5, the wavelength range can be decreased, or the sub-stepping can be decreased to 2 or 1. (See Table 1-3 for relation between the number of diodes, (NCHNLS) and wavelength dispersion.)

1.5.5 Practical Considerations and Suggestions: General

TIP: *The FOS filter-grating wheel is turned in only one direction. In order to minimize overheads during spectral element changes (about 10 seconds per grating wheel position or about 100 seconds for a complete grating wheel revolution) use the following order:*
G130H, G400H, G160L, G650L, PRISM, G780H, MIRROR, G270H, G190H, G570H, G130H,..

TIP: *Observations requiring precise wavelength accuracy should always be scheduled consecutively with an internal WAVECAL exposure with no motion of the filter-grating wheel between the exposures (see section 3.2 and Visit 03 of the sample RPS2 FOS program in Appendix F).*

TIP: *Observations requiring high S/N (i.e., ≥30) should be centered with the same precision as FOS calibration flat field exposures (≤0.04″) since small size-scale photocathode granularity differences could compromise high S/N objectives. See Visit 03 of the sample FOS RPS2 proposal in Appendix F for an example of an* `ACQ/PEAK` *sequence to achieve this accuracy.*

1.6 Polarimetry

The deployment of COSTAR resulted in two extra reflections for light entering the FOS. These extra reflections introduce wavelength-dependent instrumental polarization of the order of 2%. The net effect is that FOS polarization measures are now feasible only at wavelengths longward of 1650 Å. Routine FOS polarimetric calibration will be supported only for gratings G190H and G270H for both `FOS/BL` and `FOS/RD`. For highest quality polarimetric measures we recommend usage of the 0.9″ (`1.0`) aperture only. Indeed, only the 0.9″ (`1.0`) aperture will be calibrated in the Cycle 5 (and presumably Cycle 6) calibration plan. Please refer to section 3.6 for a discussion of the FOS polarimetric calibration uncertainties. Naturally, the highest levels of polarimetric accuracy are achievable only for bright sources. Refinement of the Cycle 4 polarization calibration status will not be complete until after this Handbook goes to press - please refer to the FOS WWW Homepage ADVISORIES section for further updates on polarization accuracies and uncertainties.

A Wollaston prism plus rotating waveplate can be introduced into the light beam to produce twin dispersed images of the aperture, with opposite senses of polarization, at the detector (Allen and Angel 1982). Although there are two waveplates available, only waveplate "B" is currently recommended for use, and only in the G190H and the G270H gratings.

The sensitivity of the polarizer depends upon its throughput efficiency. The detector can observe only one of the two spectra produced by the polarizer at one time, so that another factor of two loss in practical throughput occurs. The polarizer count rate is related to the ordinary FOS count rate (as calculated in section 1.3) by

$$\text{Count rate(pol)} = \text{Count rate(FOS)} \times \eta_{thr} \times 0.5,$$

where η_{thr} which ranges between approximately 60% and 80% for G190H and G270H spectral regions is found in Figure 1-5.

Uncertainties in the percentage of linear polarization may be estimated from the following expression (adapted from Allen and Smith, 1992):

$$\sigma_{pol} \approx \{ 1600. / C_{pol} \}^{0.5} \times 4.16\%$$

The number of counts, C_{pol}, to be used in evaluating this expression is the total number of counts summed over all polarizer rotation angles and pass directions within a pixel bin of size appropriate to the science.

1.6.1 Practical Considerations and Suggestions: Spectropolarimetry

The use of the optional parameter `POLSCAN` is demonstrated in Visit 01 of the sample RPS2 FOS proposal in Appendix F.

A typical `POLSCAN` sequence might consist of pairs of sub-exposures (one for each of the two pass directions) at each of 4, 8, or 16 separate polarizer rotation angles. *All of these sub-exposures must fit within a single target visibility period.* Obviously, a very severe constraint is thereby placed on the duration of exposure at any individual polarizer position. The exposure time that is entered in the RPS2 exposure level should be the total exposure time for a complete single-visibility `POLSCAN` sequence. Additional complete `POLSCAN` sequences can be executed in subsequent orbits as separate RPS2 exposures in order to increase S/N.

TIP: `POLSCAN` *observational overheads are quite large. We urge all prospective polarimetry observers to contact an FOS Instrument Scientist to discuss these considerations.*

Polarimetry Summary:

- use “B” waveplate only
- use only G190H, G270H, and G400H with either `FOS/BL` or `FOS/RD`
- recommend use of only 0.9″ (`1.0`) aperture
- refer to FOS WWW Homepage ADVISORIES section after 1 June 1995 for updates on polarization accuracies and uncertainties.

1.7 FOS Noise and Dynamic Range

The minimum detectable source levels are set by instrumental background, while the maximum accurately measurable source levels are determined by the response times of the FOS electronics.

When the FOS is operating outside of the South Atlantic Anomaly, the average dark count rate is roughly 0.01 counts s^{-1} $diode^{-1}$ for the red detector and 0.007 counts s^{-1} $diode^{-1}$ for the blue detector (Rosenblatt *et al* 1992). However, Rosenblatt *et al* note that the background count rate varies with geomagnetic latitude so that higher rates are observed at higher latitudes.

At the present time the FOS Group is nearing completion of an extensive re-analysis of the FOS background count rate. Preliminary analysis indicates that the Rosenblatt *et al* dark rates systematically underestimate the actual dark counts by ≈ 30%. *Only faint source observations that will not be corrected routinely for scattered light will be affected by this discrepancy.* Please refer to the FOS WWW Homepage ADVISORIES section after 1 June 1995 for updates on the FOS background calibration.

The instrumental sensitivities in Tables 1-6 and 1-7 can be used to evaluate the F_λ for which the measured count rate would equal the detector background.

- **Example:** For an object observed at 2600Å with G270H and the 0.9″ (`1.0`) aperture, what incident flux will produce a count rate comparable to detector dark for both detectors?

$$F_\lambda = (N_\lambda S_\lambda) / T_\lambda,$$

where $N_\lambda = 0.01$ counts s^{-1} diode^{-1} (`FOS/RD` dark); $S_\lambda = 2.044 \times 10^{-15}$ (from Table 1-7); and $T_\lambda = 0.92$ (interpolated from Table 1-8) yield that

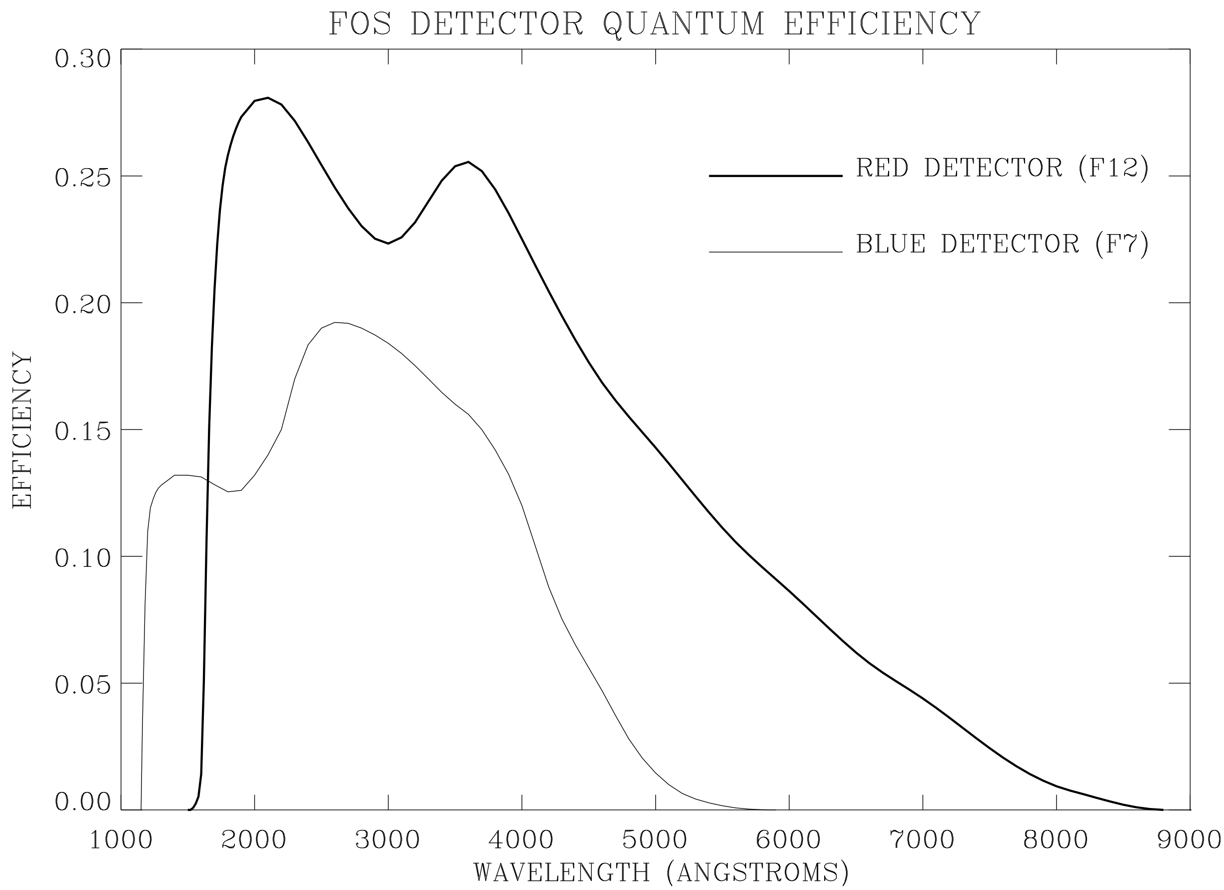
$F_\lambda = 2.2 \times 10^{-17}$ erg cm^{-2} s^{-1} Å^{-1} produces a count rate equivalent to `FOS/RD` dark.

Similarly, for `FOS/BL` : $N_\lambda = 0.007$ counts s^{-1} diode^{-1} (`FOS/BL` dark); $S_\lambda = 3.463 \times 10^{-15}$ (from Table 1-6); and $T_\lambda = 0.92$ (interpolated from Table 1-8) yield that

$F_\lambda = 2.6 \times 10^{-17}$ erg cm^{-2} s^{-1} Å^{-1} produces a count rate equivalent to `FOS/BL` dark.

At the other extreme, for *incident* count rates higher than about 100,000 counts s^{-1} diode^{-1} (that is, for raw *observed* count rates higher than about 50,000 counts s^{-1} diode^{-1}), the observed output count rate does not have an accurate relation with the true input count rate. Figure 1-6 shows a determination of the relation between true count rate and observed count rate as measured by Lindler and Bohlin (1986, for `FOS/RD` only). A correction, the so-called paired pulse correction, is applied in the pipeline processing to account for this detector non-linearity at high count rates. For observed count rates above 50,000 counts s^{-1} diode^{-1}, the correction exceeds a factor of two and its accuracy decreases drastically. By the time a true count rate of 200,000 counts s^{-1} diode^{-1} is reached, the error in the correction to the true rate is of order 50%.

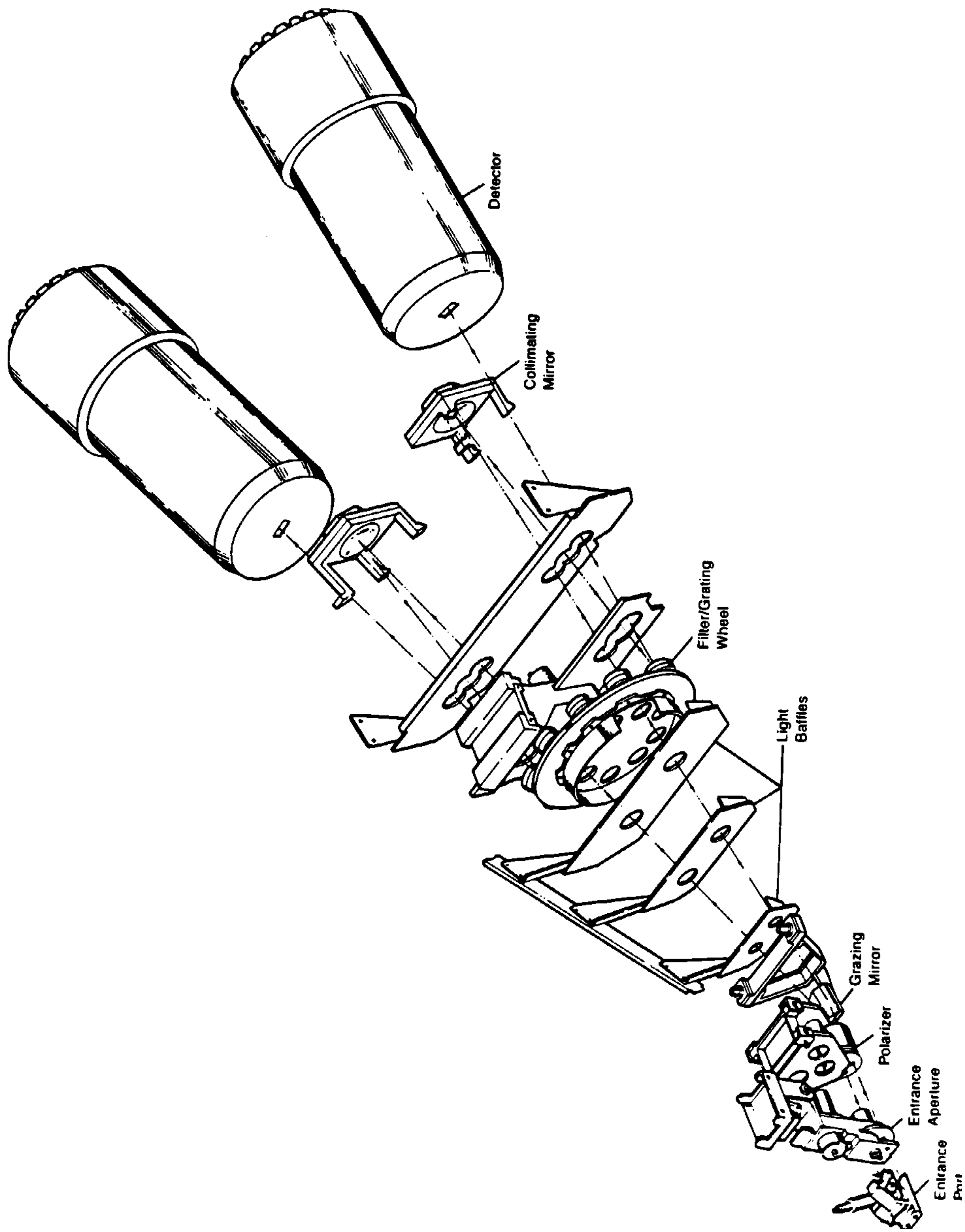
Figure 1-1: Quantum efficiency of the FOS Flight detectors.



The `FOS/BL` detector has a bialkali photocathode (Na_2KSb) deposited on a magnesium fluoride window to cover the wavelength range 1150 Å < λ < 5500 Å.

The trialkali, $Na_2KSb(Cs)$, photocathode of the `FOS/RD` detector is deposited on fused silica to provide an extension of sensitivity to the red covering 1700 Å < λ < 8500 Å.

Figure 1-2: A schematic optical diagram of the FOS.



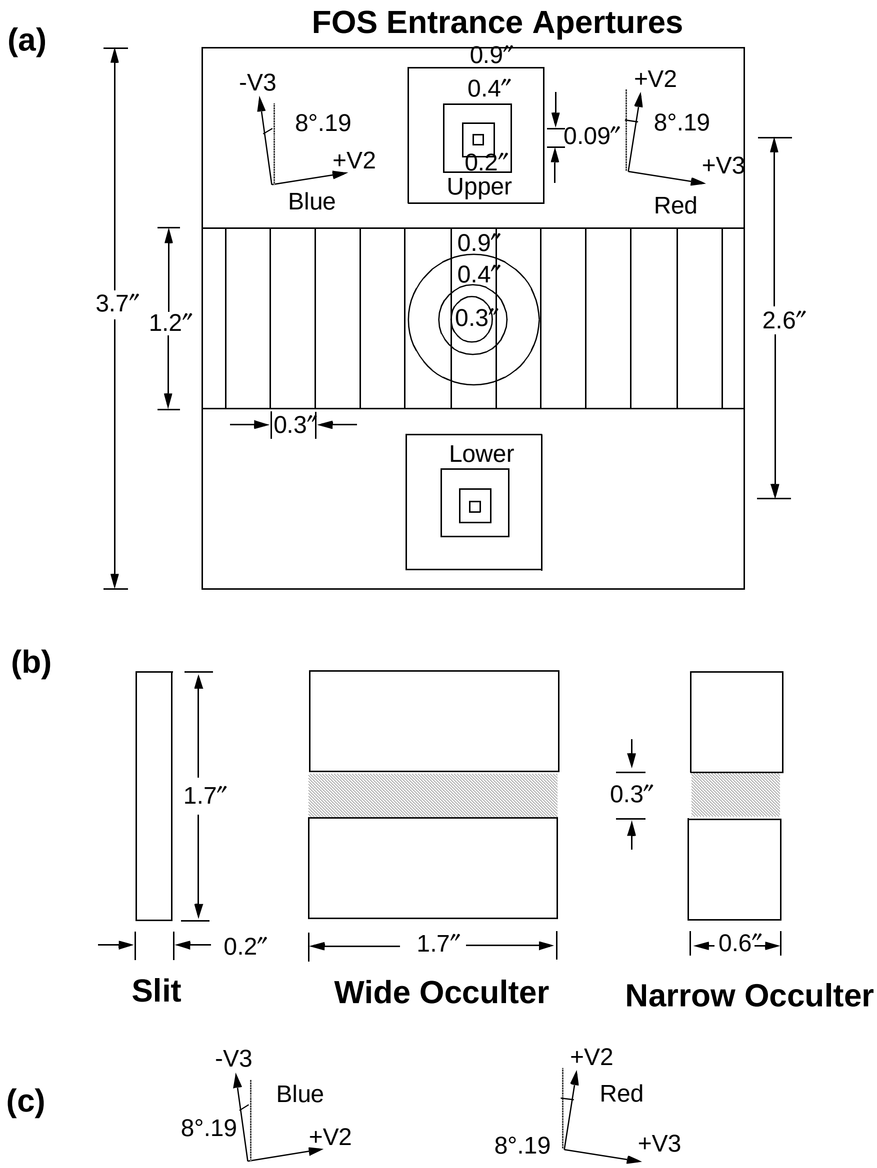
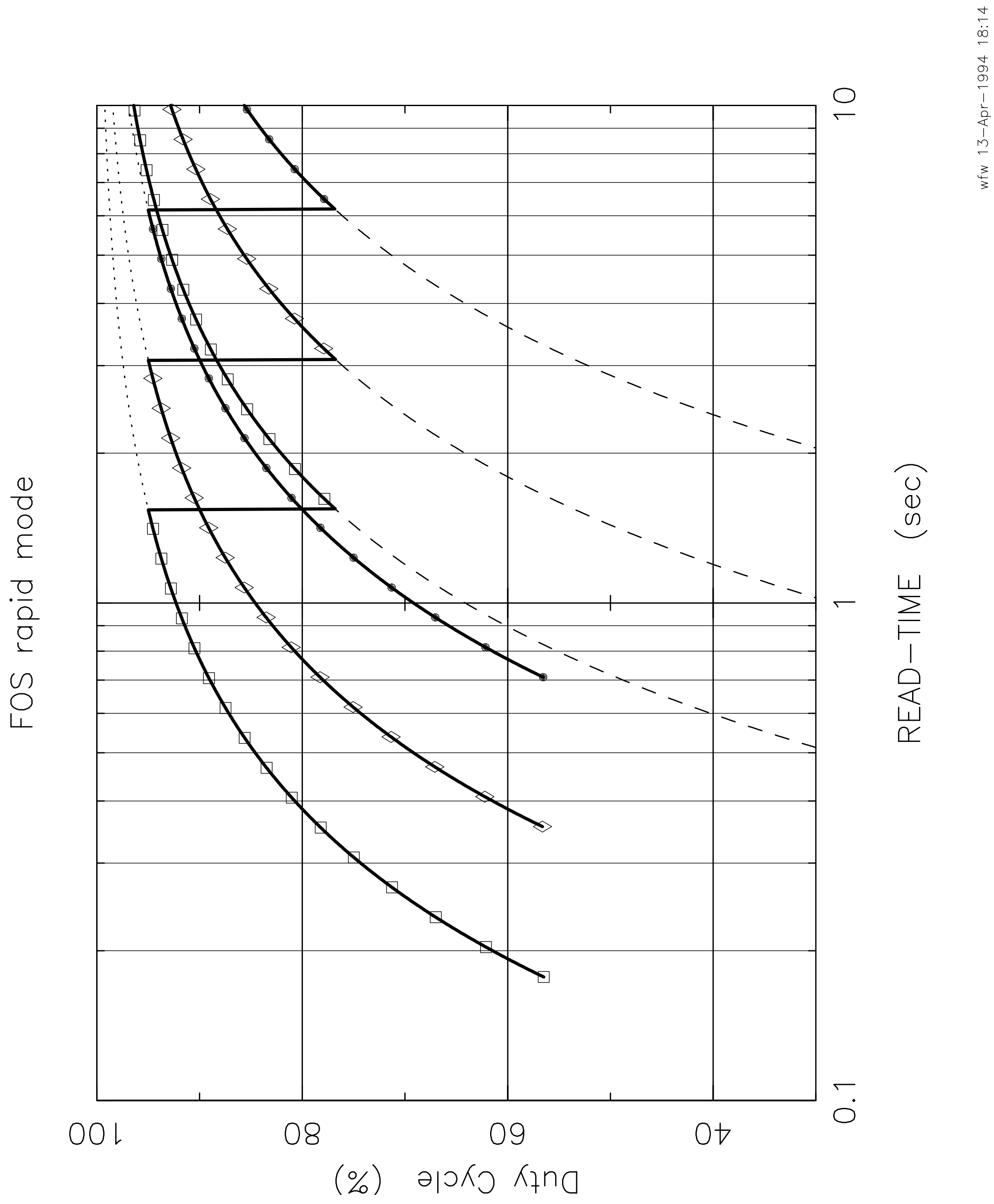


Figure 1-3: A Schematic of the FOS Apertures projected onto the sky.
The upper panel (a) shows the array of 0.31″ × 1.29″ diodes projected across the center of the 3.66″ × 3.71″ target acquisition aperture. The target acquisition aperture and the single circular apertures position to a common center. The pairs of square apertures position to common centers with respect to the target acquisition aperture as shown in the figure. Either the upper aperture (the "A" aperture, which is furthest from the HST optical axis) or the lower aperture (the "B" aperture, which is closest to the HST optical axis) in a pair can be selected by an appropriate y-deflection in the Digicon detectors. The lower panel (b) shows three more slits that position to the center of the target acquisition aperture. The bottom of the figure (c) shows the orientation of the direction perpendicular to the dispersion (shown as a dashed line) relative to the HST V2, V3 axes. The FOS x-axis is parallel to the diode array and positive to the left; the y-axis is perpendicular to the diode array and positive toward the upper aperture. The angle between the `FOS/BL` and the `FOS/RD` slit orientation is 73.6 degrees.

Figure 1-4: Duty Cycle versus `READ-TME` for `RAPID` mode observation.



Percentage of time spent accumulating data in `RAPID` mode as a function of `READ-TIME`, telemetry rate, and `SUB-STEP`. The squares mark the `SUB-STEP`=1 case, the diamonds denote the `SUB-STEP`=2 case, and `SUB-STEP`=4 is indicated by filled dots. The upper three curves, all dotted, are for the high telemetry rate and the three dashed curves are for the low (32kHz rate). The thick curves correspond to the default telemetry rate. In all cases OVERSCAN=5 and NCHNLS=512.

Figure 1-5: FOS waveplate retardation (left) and polarimeter transmission (Allen and Angel, 1982).

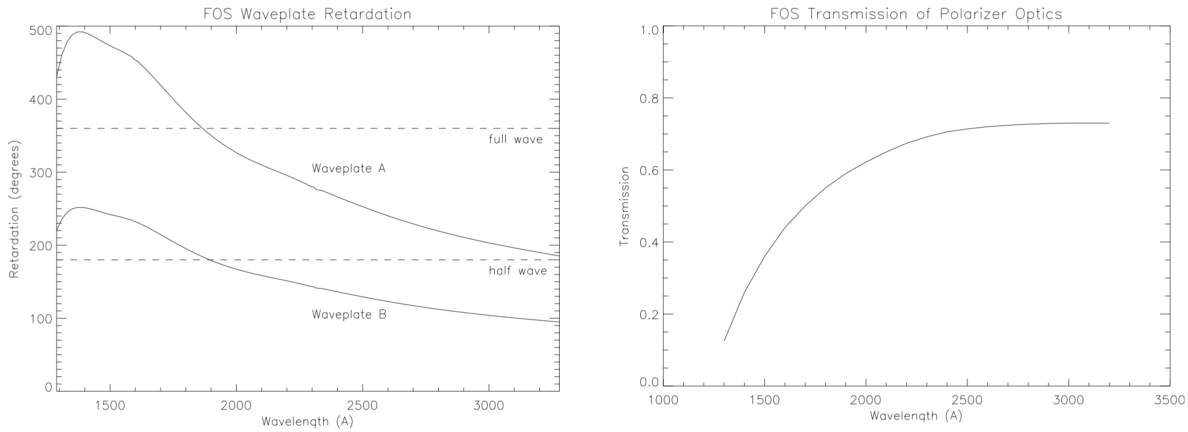


Figure 1-6: Measured count rate versus true count rate (Lindler and Bohlin 1986). The lower curve is a plot of the upper curve expanded by 10 in the x-direction.

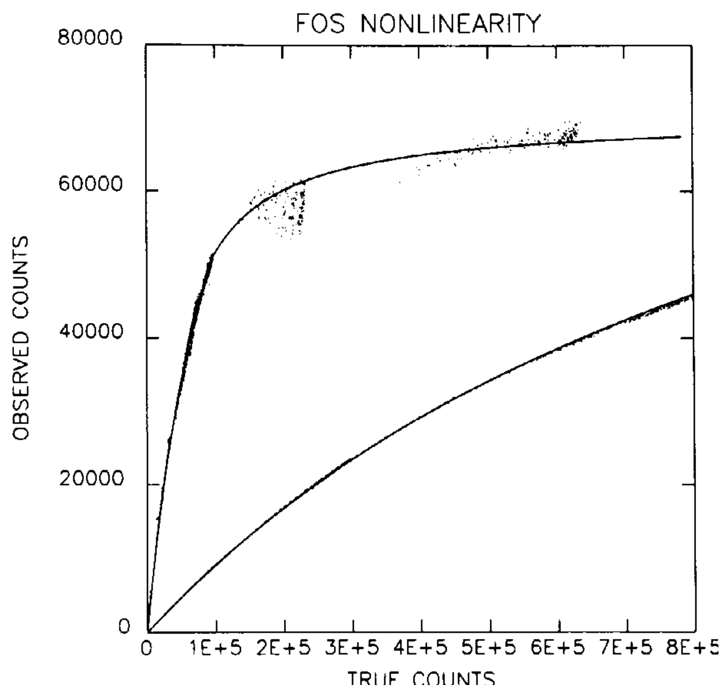


Table 1-2: FOS Instrument Capabilities

Wavelength coverage[1]	FOS/BL: 1150Å to 5400Å in several grating settings. FOS/RD: 1620Å to 8500Å in several grating settings.
Spectral resolution	High: $\lambda/\Delta\lambda \approx 1300$. Low: $\lambda/\Delta\lambda \approx 250$.
Time resolution	$\Delta t \geq 0.033$ seconds.
Acquisition aperture	3.7″ x 3.7″ (4.3).
Science apertures[2]	Largest: 3.7″ x 1.3″ (4.3). Smallest: 0.09″ square paired (0.1-PAIR).
Brightest stars observable[3]	V≈ 9 for B0V, V≈7 for G2V.
Dark count rate	FOS/BL: 0.007 counts s^{-1} $diode^{-1}$ FOS/RD: 0.010 counts s^{-1} $diode^{-1}$
Example exposure times 0.9″ (1.0) aperture[4]	$F_{1300}=2.5 \times 10^{-13}$, SNR=20/(1.0Å), t=260s. $F_{2800}=1.3 \times 10^{-13}$, SNR=20/(2.0Å), t=10s (FOS/BL). $F_{2800}=1.3 \times 10^{-13}$, SNR=20/(2.0Å), t=6.6s (FOS/RD).

[1] See Table 1-3 for grating dispersions and wavelength coverage.

[2] See Table 1-4 for available apertures.

[3] See Tables 1-10 and 1-11 for brightest objects observable, which are strongly dependent on spectral type and grating.

[4] See Section 1.3 for exposure time calculations, and Table 1-8 for count rates for objects with a variety of spectral types. The example given here is per diode for 3C273

Table 1-3: FOS Dispersers

Grating	Diode No. at Low λ	Low λ (Å)	Diode No. at High λ	High λ (Å)	Δλ (Å-Diode^{-1})	Blocking Filter
			Blue Digicon			
G130H	53	1140[a]	516[b]	1606	1.00	--
G190H	1	1573	516	2330[c]	1.47	--
G270H	1	2221	516	3301	2.09	$Si0_2$
G400H	1	3240	516	4822	3.07	WG 305
G570H	1	4574	516	6872[d]	4.45	WG 375
G160L	319	1140[a]	516	2508[c]	6.87	--
G650L	295	3540	373	9022[d]	25.11	WG 375
PRISM[e]	333	1500[f]	29	6000[d]	--	--
			Red Digicon[i]			
G190H	503	1590[g]	1	2312	-1.45	--
G270H	516	2222	1	3277	-2.05	SiO_2
G400H	516	3235	1	4781	-3.00	WG 305
G570H	516	4569	1	6818	-4.37	WG 375
G780H	516	6270	126	8500[h]	-5.72	OG 530
G160L	124	1571[g]	1	2424	-6.64	--
G650L	211	3540	67	7075	-25.44	WG 375
PRISM[e]	237	1850	497	8950[h]	--	--

a. The blue Digicon MgF_2 faceplate absorbs light shortward of 1140 Å.
b. The photocathode electron image typically is deflected across 5 diodes, effectively adding 4 diodes to the length of the diode array.
c. The second order overlaps the first order longward of 2300 Å, but its contribution is at a few percent.
d. Quantum efficiency of the blue tube is very low longward of 5500 Å.
e. PRISM wavelength direction is reversed with respect to gratings of the same detector.
f. The sapphire prism absorbs some light shortward of 1650 Å.
g. The red Digicon fused silica faceplate strongly absorbs some light shortward of 1650Å.
h. Quantum efficiency of the red detector is very low longward of 8500 Å.
i. Dispersion direction is reversed for `FOS/RD` relative to `FOS/BL`

Table 1-4: FOS Apertures

Designation (Header Designation)	Number	Shape	Size (″)	Separation (″)	Special Purpose
0.3 (B-2)	Single	Round	0.26 dia	NA	Spectroscopy
0.5 (B-1)	Single	Round	0.43 dia	NA	Spectroscopy
1.0 (B-3)	Single	Round	0.86 dia	NA	Spectroscopy and Spectropolarimetry
0.1-PAIR (A-4)	Pair	Square	0.09	2.57	Object and Sky
0.25-PAIR (A-3)	Pair	Square	0.21	2.57	Object and Sky
0.5-PAIR (A-2)	Pair	Square	0.43	2.57	Object and Sky
1.0-PAIR (C-1)	Pair	Square	0.86	2.57	Extended Objects
0.25X2.0 (C-2)	Single	Rectangular	0.21 x 1.71	NA	High Spectral Resolution
0.7X2.0-BAR (C-4)	Single	Rectangular	0.60 x 1.71	NA	Surrounding Nebulosity
2.0-BAR (C-3)	Single	Square	1.71	NA	Surrounding Nebulosity
BLANK (B-4)	NA	NA	NA	NA	Dark and Particle Events
4.3 (A-1)	Single	Square	3.66 x 3.71	NA	Target Acquisition and Spectroscopy
FAILSAFE	Pair	Square	0.43 and 3.7	NA	Target Acquisition and Spectroscopy

The first dimension given for rectangular apertures is along the X or dispersion direction and the second dimension is perpendicular to the dispersion direction. The two apertures with the suffix designation "BAR" are bisected by an occulting bar which is 0.26″ wide in the direction perpendicular to dispersion.

Table 1-5: FOS Line Widths (FWHM) as a Function of Aperture Size

Designation	Size (″)	Aperture Filled with Uniform Source G130H (Blue) FWHM	Aperture Filled with Uniform Source G570H (Red) FWHM	Point Source at 3400Å FWHM
0.3	0.26(circular)	1.00 ± .01	0.95 ± .02	0.92
0.5	0.43(circular)	1.27 ± .04	1.20 ± .01	0.93
1.0	0.86(circular)	2.29 ± .02	2.23 ± .01	0.96
0.1-PAIR	0.09(square)	0.97 ± .03	0.92 ± .02	0.91
0.25-PAIR	0.21(square)	0.98 ± .01	0.96 ± .01	0.92
0.5-PAIR	0.43(square)	1.30 ± .04	1.34 ± .02	0.94
1.0-PAIR	0.86(square)	2.65 ± .02	2.71 ± .02	0.96
0.25X2.0	0.21 X 1.71(slit)	0.99 ± .01	0.96 ± .01	0.92
0.7X2.0-BAR	0.60 X 1.71	1.83 ± .02	1.90 ± .01	1.26
2.0-BAR	1.71	5.28 ± .07	5.43 ± .04	1.34
4.3	3.66 X 3.71	12.2 ± 0.1	12.2 ± 0.1	0.96

The FWHM are given in units of diodes. A diode is 0.31″ wide and 1.29″ high.

Table 1-6: S_λ, FOS/BL Inverse Sensitivity (erg-cm^{-2}-Å^{-1}-count^{-1}) : 3.7″ x 1.3″ (4.3) aperture

Wavelength	G130H	G190H	G270H	G400H	G160L	PRISM
1200	5.010E-13				1.250E-13	
1250	1.911E-13				4.200E-14	
1300	1.467E-13				2.935E-14	
1350	1.305E-13				2.233E-14	
1400	1.164E-13				2.093E-14	
1450	1.077E-13				1.732E-14	
1500	1.041E-13				1.888E-14	1.085E-12
1550	9.774E-14				1.665E-14	6.667E-13
1600	1.024E-13	6.627E-14			1.373E-14	4.804E-13
1650		5.509E-14			1.254E-14	3.467E-13
1700		4.901E-14			1.207E-14	2.738E-13
1750		4.397E-14			1.143E-14	2.391E-13
1800		4.108E-14			1.059E-14	1.689E-13
1850		3.831E-14			9.770E-15	9.628E-14
1900		3.601E-14			9.453E-15	5.263E-14
1950		3.446E-14			9.515E-15	3.520E-14
2000		2.969E-14			8.762E-15	2.129E-14
2050		2.451E-14			7.011E-15	1.372E-14
2100		1.876E-14			5.513E-15	7.731E-15
2150		1.556E-14			4.598E-15	4.934E-15
2200		1.258E-14			3.927E-15	3.062E-15
2250		1.070E-14	9.207E-15		3.365E-15	2.526E-15
2300		9.392E-15	7.784E-15		2.893E-15	1.741E-15
2350			7.067E-15		2.514E-15	1.261E-15
2400			5.645E-15		2.186E-15	1.017E-15
2450			4.850E-15		1.928E-15	8.319E-16
2500			4.243E-15		1.742E-15	6.960E-16
2550			3.796E-15			5.645E-16
2600			3.463E-15			4.559E-16
2650			3.238E-15			3.738E-16
2700			3.090E-15			3.091E-16
2750			2.998E-15			2.668E-16
2800			2.928E-15			2.326E-16
2850			2.850E-15			2.070E-16
2900			2.770E-15			1.852E-16
2950			2.717E-15			1.690E-16
3000			2.717E-15			1.562E-16

Table 1-6: S_λ, FOS/BL Inverse Sensitivity (erg-cm^{-2}-Å^{-1}-count^{-1}) : 3.7″ x 1.3″ (4.3) aperture

Wavelength	G130H	G190H	G270H	G400H	G160L	PRISM
3050			2.740E-15			1.451E-16
3100			2.751E-15			1.352E-16
3150			2.761E-15			1.276E-16
3200			2.763E-15			1.210E-16
3250			2.726E-15	2.076E-15		1.141E-16
3300			2.673E-15	2.004E-15		1.070E-16
3350				1.955E-15		1.019E-16
3400				1.918E-15		9.692E-17
3450				1.879E-15		9.165E-17
3500				1.846E-15		8.756E-17
3550				1.821E-15		8.283E-17
3600				1.804E-15		7.938E-17
3650				1.796E-15		7.634E-17
3700				1.804E-15		7.446E-17
3750				1.832E-15		7.255E-17
3800				1.887E-15		7.163E-17
3850				1.967E-15		7.107E-17
3900				2.066E-15		7.108E-17
3950				2.177E-15		7.145E-17
4000				2.296E-15		7.213E-17
4050				2.419E-15		7.310E-17
4100				2.543E-15		7.392E-17
4150				2.672E-15		7.546E-17
4200				2.809E-15		7.673E-17
4250				2.971E-15		7.907E-17
4300				3.183E-15		8.097E-17
4350				3.474E-15		8.321E-17
4400				3.815E-15		8.585E-17
4450				4.157E-15		8.897E-17
4500				4.475E-15		9.268E-17
4550				4.801E-15		9.713E-17
4600				5.210E-15		1.025E-16
4650				5.732E-15		1.090E-16
4700				6.364E-15		1.169E-16
4750				7.144E-15		1.268E-16
4800				8.121E-15		1.327E-16

Table 1-7: S_λ, FOS/RD Inverse Sensitivity (erg-cm^{-2}-Å^{-1}-count^{-1}) : 3.7″ x 1.3″ (4.3) aperture

λ	G190H	G270H	G400H	G570H	G780H	G160L	G650L	PRISM
1600	9.841E-13					6.418E-14		1.085E-12
1650	4.246E-14					7.447E-15		3.131E-13
1700	2.100E-14					4.472E-15		1.025E-13
1750	1.606E-14					3.642E-15		8.171E-14
1800	1.326E-14					3.201E-15		5.898E-14
1850	1.315E-14					3.296E-15		3.774E-14
1900	1.122E-14					3.315E-15		1.866E-14
1950	1.047E-14					3.068E-15		1.274E-14
2000	9.849E-15					2.638E-15		7.700E-15
2050	7.245E-15					2.123E-15		4.431E-15
2100	5.733E-15					1.702E-15		2.699E-15
2150	4.902E-15					1.457E-15		1.814E-15
2200	4.403E-15					1.352E-15		1.309E-15
2250	4.132E-15	4.134E-15				1.248E-15		9.984E-16
2300	3.764E-15	3.670E-15				1.214E-15		7.907E-16
2350		3.227E-15				1.128E-15		6.435E-16
2400		2.820E-15				1.039E-15		5.269E-16
2450		2.508E-15						4.358E-16
2500		2.322E-15						3.710E-16
2550		2.187E-15						3.184E-16
2600		2.044E-15						2.742E-16
2650		1.915E-15						2.353E-16
2700		1.846E-15						2.068E-16
2750		1.849E-15						1.821E-16
2800		1.879E-15						1.624E-16
2850		1.889E-15						1.463E-16
2900		1.876E-15						1.317E-16
2950		1.860E-15						1.202E-16
3000		1.861E-15						1.107E-16
3050		1.868E-15						1.020E-16
3100		1.862E-15						9.420E-17
3150		1.852E-15						8.807E-17
3200		1.836E-15						8.200E-17
3250		1.802E-15	1.456E-15					7.689E-17
3300			1.376E-15					7.274E-17
3350			1.318E-15					6.832E-17

Table 1-7: S_λ, FOS/RD Inverse Sensitivity (erg-cm^{-2}-Å^{-1}-count^{-1}) : 3.7″ x 1.3″ (4.3) aperture

λ	G190H	G270H	G400H	G570H	G780H	G160L	G650L	PRISM
3400			1.272E-15					6.457E-17
3450			1.226E-15					6.030E-17
3500			1.178E-15					5.620E-17
3550			1.132E-15				1.835E-14	5.195E-17
3600			1.087E-15				3.221E-15	4.824E-17
3650			1.049E-15				1.043E-15	4.476E-17
3700			1.022E-15				6.275E-16	4.165E-17
3750			1.012E-15				4.405E-16	3.898E-17
3800			1.022E-15				3.511E-16	3.700E-17
3850			1.040E-15				3.043E-16	3.533E-17
3900			1.051E-15				2.787E-16	3.380E-17
3950			1.050E-15				2.617E-16	3.261E-17
4000			1.046E-15				2.490E-16	3.141E-17
4050			1.050E-15				2.381E-16	3.021E-17
4100			1.058E-15				2.274E-16	2.905E-17
4150			1.065E-15				2.190E-16	2.800E-17
4200			1.069E-15				2.116E-16	2.702E-17
4250			1.078E-15				2.051E-16	2.609E-17
4300			1.101E-15				1.994E-16	2.519E-17
4350			1.134E-15				1.945E-16	2.433E-17
4400			1.164E-15				1.902E-16	2.369E-17
4450			1.179E-15				1.865E-16	2.300E-17
4500			1.186E-15				1.831E-16	2.240E-17
4550			1.193E-15				1.807E-16	2.192E-17
4600			1.206E-15	7.290E-16			1.788E-16	2.149E-17
4650			1.227E-15	7.296E-16			1.773E-16	2.106E-17
4700			1.258E-15	7.303E-16			1.762E-16	2.080E-17
4750			1.297E-15	7.315E-16			1.754E-16	2.045E-17
4800				7.330E-16			1.751E-16	2.018E-17
4850				7.351E-16			1.750E-16	1.993E-17
4900				7.380E-16			1.751E-16	1.969E-17
4950				7.419E-16			1.755E-16	1.947E-17
5000				7.467E-16			1.761E-16	1.926E-17
5100				7.613E-16			1.780E-16	1.883E-17
5200				7.829E-16			1.805E-16	1.847E-17
5300				8.117E-16			1.837E-16	1.811E-17
5400				8.478E-16			1.877E-16	1.782E-17

Table 1-7: S_λ, FOS/RD Inverse Sensitivity (erg-cm^{-2}-Å^{-1}-count^{-1}) : 3.7″ x 1.3″ (4.3) aperture

λ	G190H	G270H	G400H	G570H	G780H	G160L	G650L	PRISM
5500				8.890E-16			1.927E-16	1.758E-17
5550				9.104E-16			1.954E-16	1.748E-17
5600				9.309E-16			1.983E-16	1.738E-17
5700				9.730E-16			2.048E-16	1.725E-17
5800				1.020E-15			2.127E-16	1.716E-17
5900				1.079E-15			2.212E-16	1.712E-17
6000				1.150E-15			2.308E-16	1.713E-17
6100				1.227E-15			2.417E-16	1.720E-17
6200				1.304E-15			2.548E-16	1.728E-17
6300				1.383E-15	1.029E-15		2.688E-16	1.743E-17
6400				1.469E-15	1.076E-15		2.848E-16	1.760E-17
6500				1.568E-15	1.126E-15		3.042E-16	1.787E-17
6600				1.692E-15	1.182E-15		3.253E-16	1.822E-17
6700				1.852E-15	1.244E-15		3.497E-16	1.858E-17
6800				2.055E-15	1.320E-15		3.782E-16	1.892E-17
6900					1.416E-15		4.142E-16	1.953E-17
7000					1.538E-15		4.550E-16	2.002E-17
7100					1.690E-15		4.913E-16	2.080E-17
7200					1.878E-15			2.161E-17
7300					2.106E-15			2.248E-17
7400					2.377E-15			2.369E-17
7500					2.713E-15			2.510E-17
7600					3.134E-15			2.689E-17
7700					3.667E-15			2.879E-17
7800					4.358E-15			3.131E-17
7900					5.271E-15			3.438E-17
8000					6.519E-15			3.828E-17
8100					8.322E-15			4.274E-17
8200					1.095E-14			4.850E-17
8300					1.501E-14			5.668E-17
8400					2.199E-14			6.602E-17
8500					3.795E-14			7.926E-17
8600								9.352E-17
8700								1.229E-16
8800								1.523E-16

Table 1-8: T_{λ}, Point Source Post-COSTAR FOS Aperture Throughputs (rel. 4.3 = 1)

	1500	2250	3400	5000	7500
1.0	0.89	0.91	0.94	0.96	0.97
0.5	.76	.81	.90	.91	.90
0.3	.67	.72	.80	.86	.83
0.25X2.0	.72	.76	.84	.89	.86
1.0-PAIR	.92	.92	.95	.97	.97
0.5-PAIR	.76	.83	.92	.92	.91
0.25-PAIR	.61	.71	.77	.81	.79
0.1-PAIR	.54	.64	.64	.58	.47
2.0-BAR	.13	.10	.09	.08	.10
.7X2.0-BAR	.10	.08	.08	.07	.07

Fraction of light transmitted by the apertures as a function of wavelength, relative to the throughput of the 3.7″ x 1.3″ (4.3) aperture, after deployment of COSTAR for a perfectly centered point source, based upon STScI modeling with the TIM code. These values should be used in exposure time calculations. Note: actual 0.1-PAIR throughputs will be strongly dependent on target centering and in practice may be up to 50% smaller than the values given in this table.

Listed immediately below are the theoretical *absolute* throughputs of the 3.7″ x 1.3″ (4.3) aperture. These values are provided for use in some calculations involving extended sources and so that the theoretical absolute throughputs of all apertures may be calculated if desired.

	1500	2250	3400	5000	7500
4.3	0.940	0.962	0.974	0.975	0.971

Table 1-9: Expected counts-sec^{-1}-diode^{-1} at specified wavelengths for V=15 unreddened objects in the 3.7″ x 1.3″ (4.3) aperture

Type	B-V	G130H	G190H	G270H	G400H	G570H	G780H	G160L	G650L	PRISM
FOS/BL										
λ		1600	2300	2650	3250	4600	---	2400	4000	4000
07V	-0.32	1.6	6.1	13.	11.	2.5	---	24.	20.	190.
B0V	-0.30	1.3	5.0	11.	10.	2.3	---	19.	20.	175.
A6V	+0.17	---	0.15	0.6	1.3	1.7	---	0.5	10.	95
G2V	+0.63	---	---	0.15	0.9	1.3	---	---	5.5	42
α[1]=1	---	0.11	0.8	2.2	2.8	1.4	---	3.5	8.0	68
α[1]=2	---	---	0.34	1.1	1.7	1.1	---	1.8	5.7	47
FOS/RD										
λ		---	2300	2650	3600	4600	6300	2400	4400	4000
07V	-0.32	---	15.	22.	14.	10.	2.0	49.	44.	370.
B0V	-0.30	---	11.	18.	14.	9.7	1.9	40.	42.	350.
A6V	+0.17	---	0.38	0.9	3.4	7.0	2.2	1.0	27.	210.
G2V	+0.63	---	---	0.25	1.5	5.1	2.9	---	20.	170.
α[1]=1	---	---	2.1	3.7	4.7	6.0	3.0	6.7	22.	195.
α[1]=2	---	---	0.9	1.8	3.0	4.9	3.4	3.0	19.	187.

[1] Where $F_\nu \propto \nu^{-\alpha}$.

Table 1-10: FOS/RD Brightness Limits[1]

Type	B-V	G190H	G270H	G400H	G570H	G780H	G160L	G650L	PRISM	MIRROR
07V	-0.32	8.7	9.4	8.8	7.7	5.5	10.3	8.2	10.3	14.8
B0V	-0.30	8.5	9.1	8.8	7.7	5.5	10.1	8.1	10.2	14.6
B1.5V	-0.25	8.2	9.0	8.6	7.7	5.5	10.0	8.1	10.1	14.5
B3V	-0.20	7.5	8.3	8.4	7.7	5.5	9.5	8.1	9.7	14.0
B6V	-0.15	7.3	8.2	8.3	7.6	5.5	9.3	8.0	9.6	13.8
B8V	-0.11	6.5	7.5	8.3	7.6	5.5	9.0	8.0	9.3	13.5
A1V	+0.01	5.3	6.6	7.9	7.6	5.6	8.6	7.9	8.9	13.1
A2V	+0.05	5.1	6.4	7.9	7.6	5.6	8.5	7.9	8.8	13.0
A6V	+0.17	4.5	6.1	7.8	7.6	5.6	8.4	7.8	8.7	12.9
A7V	+0.20	4.4	6.0	7.7	7.6	5.7	8.3	7.8	8.7	12.8
A9V	+0.28	4.0	5.8	7.6	7.6	5.8	8.2	7.7	8.6	12.7
F0V	+0.30	3.8	5.7	7.6	7.5	5.8	8.2	7.7	8.6	12.7
F5V	+0.44	3.2	5.7	7.4	7.5	5.9	8.1	7.6	8.6	12.6
F7V	+0.48	2.5	5.2	7.3	7.5	5.9	8.0	7.6	8.4	12.5
F8V	+0.52	2.3	5.0	7.2	7.5	5.9	8.0	7.6	8.4	12.5
G2V	+0.63	2.0	4.9	7.2	7.5	6.0	7.9	7.6	8.4	12.4
G6V	+0.70	---	4.8	7.1	7.6	6.0	7.9	7.5	8.4	12.4
K0V	+0.81	---	4.0	6.9	7.6	6.0	7.8	7.5	8.3	12.3
K0III	+1.00	---	3.2	6.5	7.5	6.1	7.7	7.5	8.2	12.2
K5V	+1.15	---	3.2	6.2	7.5	6.2	7.6	7.4	8.1	12.1
K4III	+1.39	---	2.0	5.9	7.4	6.3	7.5	7.3	8.0	12.0
M2I	+1.71	---	---	5.4	7.3	6.3	7.3	7.2	7.8	11.8
$\alpha^2=1$	---	6.3	7.5	7.8	7.7	6.2	8.8	7.8	9.1	13.3
$\alpha^2=2$	---	5.2	6.7	7.4	7.6	6.5	8.4	7.7	8.8	12.9
$\alpha^2=-2$	-0.46	9.6	9.9	9.0	7.8	5.6	0.9	8.2	10.6	15.4
50,000°	---	9.0	9.5	8.8	7.7	5.5	10.4	8.2	10.3	14.9

[1] The FOS can be damaged if illuminated by sources that are too bright. If illuminated by targets brighter than the V magnitude limits given here, the instrument will go into safe mode, shutting its aperture door and stopping operations. Table is for objects observed in the 3.7″ (4.3) aperture.
[2] Where $F_\nu \propto \nu^{-\alpha}$.

Table 1-11: FOS/BL Brightness Limits[1]

Type	B-V	G130H	G190H	G270H	G400H	G570H	G160L	G650L	PRISM	MIRROR
07V	-0.32	6.6	7.6	8.8	8.0	5.0	9.8	6.5	9.5	14.3
B0V	-0.30	6.4	7.4	8.6	7.9	5.0	9.7	6.4	9.3	14.2
B1.5V	-0.25	6.0	7.1	8.5	7.8	4.9	9.5	6.3	9.2	14.0
B3V	-0.20	5.2	6.4	7.8	7.5	4.9	8.9	6.3	8.7	13.4
B6V	-0.15	4.8	6.3	7.7	7.4	4.9	8.7	6.1	8.6	13.2
B8V	-0.11	3.9	5.4	7.0	7.3	4.9	8.2	6.2	8.2	12.7
A1V	+0.01	2.0	4.3	6.0	6.9	4.8	7.5	6.0	7.7	12.0
A2V	+0.05	---	4.1	5.9	6.9	4.8	7.4	6.0	7.6	11.9
A6V	+0.17	---	3.5	5.6	6.8	4.7	7.2	5.8	7.5	11.7
A7V	+0.20	---	3.5	5.6	6.7	4.7	7.2	5.8	7.4	11.7
A9V	+0.28	---	2.8	5.4	6.6	4.7	7.1	5.7	7.3	11.6
F0V	+0.30	---	2.6	5.3	6.5	4.6	7.0	5.6	7.2	11.5
F5V	+0.44	---	2.1	5.3	6.4	4.6	6.9	5.5	7.1	11.4
F7V	+0.48	---	---	4.9	6.3	4.5	6.7	5.4	6.9	11.2
F8V	+0.52	---	---	4.7	6.2	4.5	6.6	5.3	6.8	11.1
G2V	+0.63	---	---	4.6	6.2	4.5	6.5	5.3	6.8	11.0
G6V	+0.70	---	---	4.5	6.0	4.4	6.4	5.2	6.7	10.9
K0V	+0.81	---	---	3.7	5.8	4.4	6.1	5.1	6.4	10.6
K0III	+1.00	---	---	2.8	5.4	4.3	5.7	4.8	6.0	10.2
K5V	+1.15	---	---	2.8	5.0	4.2	5.4	4.6	5.7	9.9
K4III	+1.39	---	---	---	4.7	4.0	5.0	4.3	5.3	9.5
M2I	+1.71	---	---	---	4.2	3.8	4.6	4.0	4.9	9.1
α^2=1	---	3.6	5.2	6.9	6.9	4.6	8.0	5.7	8.0	12.5
α^2=2	---	2.4	4.2	6.2	6.5	4.5	7.4	5.4	7.5	11.9
α^2=-2	-0.46	8.0	8.5	9.2	8.2	5.0	10.6	6.6	9.8	15.1
50,000°	---	6.9	7.9	8.9	8.0	5.0	10.0	6.4	9.5	14.5

[1] The FOS can be damaged if illuminated by sources that are too bright. If illuminated by targets brighter than the V magnitude limits given here, the instrument will go into safe mode, shutting its aperture door and stopping operations. Table is for objects observed in the 3.7″ (4.3) aperture.
[2] Where $F_\nu \propto \nu^{-\alpha}$.

2. TARGET ACQUISITION

In this chapter we describe in detail the various methods of FOS target acquisition and provide examples and tips for using the most important target acquisition modes. We discuss how basic science requirements (photometric accuracy, wavelength accuracy, desired S/N) affect the choice of target acquisition strategy and we provide guidelines for choosing between the various methods of FOS target acquisition. We also give in a convenient tabular format the parameters required by RPS2 for the specification of the most commonly used FOS acquisitions.

TIP: *The importance of exercising care and consideration in FOS target acquisition can not be overestimated. The most common problems encountered with FOS proposals have to do with target acquisition. Paramount among these are failure to obtain sufficient pointing accuracy to achieve the desired science objectives, and insufficient allocation of orbit time to the target acquisition sequence.*

2.1 Background for FOS Target Acquisition

HST pointing is quite accurate and reliable. For target positions given in the Guide Star Catalog reference frame, about 70% of all blind pointings are within 1″ of FOS aperture center. The FOS acquisition aperture is 3.7″ x 3.7″ square (`4.3`). Given the foregoing, in order to have a 95% chance of placing a target in this aperture, the target *must* have an RMS positional error with respect to the guide stars of less than 1.0″. After the initial blind pointing, however, an *onboard target acquisition* is still necessary with the FOS to properly center the target in any science aperture.

TIP: *ALL FOS target positions MUST be specified in the Guide Star Catalog reference frame.*

Three (non-interactive) onboard acquisition modes (`ACQ/BINARY`, `ACQ/PEAK`, and `ACQ/FIRMWARE`) and the interactive acquisition mode (set with the Special Requirement `INT ACQ`) are described below. During an onboard acquisition, the FOS performs the acquisition, calculates the small offset required to center the target in a science aperture, and makes the offset. In contrast, during an interactive acquisition there must be a real-time contact with HST, and the observer normally must be present at the ST ScI to interpret the resultant image. Because of the probability of confusion when looking at an FOS white light picture, we believe that in nearly all cases a WFPC2- assisted target acquisition will be a better scientific choice than an interactive FOS acquisition. However, special mode `ACQ` provides an important means of verifying, after the fact, where the FOS aperture was positioned on the target during a science exposure. An Instrument Scientist should be consulted if you are considering an interactive acquisition.

2.2 Overview of FOS Target Acquisition Strategies

FOS target acquisitions can be divided into three broad categories: 1) those that utilize `ACQ/BINARY`, at least for the first stage of acquisition; 2) those that require `ACQ/PEAK`; and 3) those that require consultation. The applicability of one or more of these categories to a particular acquisition is determined by many characteristics of the target (e.g., variability, brightness distribution, geometry, target environment) and importantly, *by the pointing accuracy required for the science.*

TIP: *Observations requiring precise wavelength accuracy should be centered as accurately as possible in the science aperture. Normally such observations require pointing accuracies of order 0.04″.*

TIP: *Observations requiring S/N ≥30 require high precision measures of the photocathode granularity (flat field). As a result, such observations require pointing accuracies of order 0.04″*

`ACQ/BINARY` can be used (at least for the first stage of acquisition) for all single, not very bright, not highly variable (up to ± 1 magnitude) objects (*e.g.*, stars, some QSOs, extragalactic planetary nebulae that are not extended, and not highly variable AGN with dominant point-like nuclei in the 2000-5000Å range).

`ACQ/PEAK` is used for any required later stages of acquisitions commencing with `ACQ/BINARY`, for acquisitions of objects too bright for the FOS MIRROR (see Tables 1-10 and 1-11 for FOS brightness limits), for variable objects, for AGN without dominant point source nuclei in the 2000-5000 Å range, or for *any observations requiring precise centering (see above for a discussion of the pointing requirements of observations that need high S/N or wavelength accuracy).*

Contact an Instrument Scientist or the Help Hotseat, *help@stsci.edu*, for the following types of situations:

(a) extended targets(≥0.2″),
(b) crowded fields (≥ 2 objects separated by ≤1.3″),
(c) slit, barred, or 0.09″(`0.1-PAIR`) aperture observations,
(d) objects fainter than V=19,
(e) objects with emission lines, but little continuum,
(f) peculiar geometry as in gravitational lenses,
(g) objects with E(B-V) > 0.1, or
(h) acquisitions using offset stars and slews of more than 30″.

Table 2-1 presents a summary of each individual pattern (or step) that is commonly used in FOS acquisition sequences. Table 2-2 presents commonly recommended sequences as a function of science aperture and desired pointing accuracy. Note that, for strategies commencing with `ACQ/BINARY`, different sequences are employed for `FOS/RD` and `FOS/BL` detectors since `ACQ/BINARY` pointing accuracies are quite different for the two detectors, but sequences commencing with `ACQ/PEAK` are independent of detector. *Further, the* `ACQ/BINARY` *pointing accuracies are one-sigma values, whereas* `ACQ/PEAK` *values derive directly from pattern geometry and, in the limit of very high S/N, are upper limits to the pointing uncertainty.* The instrumental overheads for each step and complete sequence are also provided in the tables.

Following the tables are more detailed descriptions of each type of FOS target acquisition as well as discussions of special strategies that can make observing more efficient, such as FOS "side-switching," FOS-assisted GHRS target acquisition, GHRS-assisted FOS target acquisition, and the new "reuse_target_offset" procedure).

Software that can guide the user through the details of conventional FOS acquisitions is also currently under development. This "TA Tool" will provide recommendations for acquisition strategy and exposure time based upon user-supplied information concerning required pointing accuracy, target type, and target brightness. The tool will be run from the FOS WWW Homepage. Please refer to the ADVISORIES section of the FOS Homepage after 1 June 1995 for further information.

Table 2-1: FOS Target Acquisition Pattern Pointing Accuracies and Overheads

Aperture	Pattern Name	Search-size-X	Search-size-Y	Step-size-X (arcsec)	Step-size-Y (arcsec)	Pointing Accuracy (arcsec)	Overhead (minutes)
4.3	A	1	3	-	1.23	-	7
1.0	B1	6	2	0.61	0.61	0.43	12
0.5	C1	3	3	0.29	0.29	0.21	10
0.3	D1	5	5	0.17	0.17	0.12	17
	D2	5	5	0.11	0.11	0.08	17
	D3	5	5	0.052	0.052	0.04	17
	E1	4	4	0.17	0.17	0.12	14
	E2	4	4	0.11	0.11	0.08	14
	E3	4	4	0.052	0.052	0.04	14
	F1	3	3	0.17	0.17	0.12	10
	F2	3	3	0.11	0.11	0.08	10
1.0-PAIR	B2	6	2	0.61	0.61	0.43	12
0.5-PAIR	C2	3	3	0.29	0.29	0.21	10
0.25-PAIR	P1	5	5	0.17	0.17	0.12	17
	P2	5	5	0.11	0.11	0.08	17
	P3	5	5	0.052	0.052	0.04	17
	P4	4	4	0.11	0.11	0.08	14
2.0-BAR	BD1	1	11	-	0.052	0.03	11
0.7-BAR	BD2	1	11	-	0.052	0.03	11
SLIT	S	9	1	0.057	-	0.03	10
ACQ/BIN RED	Z	-	-	-	-	0.12 (1-sigma)	9
ACQ/BIN BLUE	Z	-	-	-	-	0.08 (1-sigma)	9

Table 2-2: Commonly Recommended Target Acquisition Sequences and Their Overheads

Science Observation Aperture	Required Pointing Accuracy (arcsec)	Sequences Starting with `ACQ/BINARY`				Sequences Starting with `ACQ/PEAK` (both detectors)	Over -head
		RED Detector	Over -head	BLUE Detector	Over -head		
4.3	>0.1	Z	9	Z	9	A+B1+C1	29
	0.12	Z+E1	23	Z+F1	19	A+B1+C1+F1	39
	0.08	Z+D2	26	Z+E2	23	A+B1+C1+E2	43
	0.04	Z+C1+F1+D3[a,b]	46	Z+C1+F1+D3[a,b]	46	A+B1+C1+F1+D3[a]	56
1.0	>0.1	Z	9	Z	9	A+B1+C1	29
	0.12	Z+E1	23	Z+F1	19	A+B1+C1+F1	39
	0.08	Z+D2	26	Z+E2	23	A+B1+C1+E2	43
	0.04	Z+C1+F1+D3[a,b]	46	Z+C1+F1+D3[a,b]	46	A+B1+C1+F1+D3[a]	56
0.5	0.12	Z+E1	23	Z+F1	19	A+B1+C1+F1	39
	0.08	Z+D2	26	Z+E2	23	A+B1+C1+E2	43
	0.04	Z+C1+F1+D3[a,b]	46	Z+C1+F1+D3[a,b]	46	A+B1+C1+F1+D3[a]	56
0.3	0.08	Z+D2	26	Z+E2	23	A+B1+C1+E2	43
	0.04	Z+C1+F1+D3[a,b]	46	Z+C1+F1+D3[a,b]	46	A+B1+C1+F1+D3[a]	56
1.0-PAIR	>0.1	Z	9	Z	9	A+B2+C2	29
	0.12	Z+E1	23	Z+F1	19	A+B2+P1	36
	0.08	Z+P2	26	Z+P4	23	A+B2+C2+P4	43
	0.04	Z+P1+P3	43	Z+P1+P3	43	A+B2+P1+P3	53
0.5-PAIR	0.12	Z+E1	23	Z+F	19	A+B2+P1	36
	0.08	Z+P2	26	Z+P4	23	A+B2+C2+P4	43
	0.04	Z+P1+P3	43	Z+P1+P3	43	A+B2+P1+P3	53
0.25-PAIR	0.08	Z+C2+P4	33	Z+C2+P4	33	A+B2+C2+P4	43
	0.04	Z+P1+P3	43	Z+P1+P3	43	A+B2+P1+P3	53
0.1-PAIR, 2.0-BAR, 0.7-BAR, SLIT	CONTACT INSTRUMENT SCIENTIST						

[a] Occasionally, C1+F1 may be replaced with D1 for more efficient orbit packing.

[b] Z+D2+D3 can have smaller overheads, but does not always yield more efficient orbit packing.

2.2.1 ACQ/BINARY

ACQ/BINARY is the method of choice for targets with well known energy distributions, but *should not be used for variable sources, sources of unknown color, or sources extended by much more than 1 diode, or 0.3″*. The method has a restricted dynamic range of brightness. Specifically, target brightness uncertainty should be less than 1.0 magnitude for the use of ACQ/BINARY. Objects of poorly known color should be acquired with ACQ/PEAK.

During an ACQ/BINARY, the camera mirror images the FOS focal plane onto the photocathode. Acquisition of the target is performed not by moving the telescope, but by deflecting the photoelectrons from the image of the target acquisition aperture on the photocathode until the target has been placed on the Y-edge of the Digicon diode array. ACQ/BINARY finds first the number of stars in the 3.7″ x 3.7″ (4.3) acquisition aperture by integrating at three different positions in the Y-direction. The program finds the target in one of the three strips, measures its count rate, and locates the target in the X-direction. The algorithm then positions the target on a Y-edge of the diode array by deflecting the image across the diode array through a geometrically decreasing sequence of up to eight more Y-deflections until the observed count rate from the star is half that of when the object is positioned fully on the diode array. If the binary search algorithm fails to converge on a position with half the counts of the original target, the telescope slews to the last step of the binary search pattern, *i.e.*, to the X-position of the target and the last Y-deflection. RPS2-specified ACQ/BINARY times allow for a maximum of 11 sub-exposures, that is, the actual exposure time onboard for each sub-exposure is 1/11 the RPS2 exposure time. ACQ/BINARY is the preferred acquisition mode for points sources and is the mode that uses the least instrumental overhead.

For ACQ/BIN to succeed there should be about 400 counts observed in the so-called "peak pixel" (pixel for which the diode is perfectly centered over the point source target). If the number of counts in the peak is significantly larger than 400, the tolerances for when the target is on the edge of the diode array become very small since they are based on $\sqrt{N}$ statistics. ACQ/BINARY 1 σ centering uncertainty is 0.08″ for FOS/BL and 0.12″ for FOS/RD. Therefore, science observations in apertures smaller than the 0.9″ (1.0) aperture following an ACQ/BINARY require at least one additional stage of ACQ/PEAK.

A target must lie within the range of counts specified by the optional parameters BRIGHT and FAINT. We recommend that BRIGHT and FAINT normally be set to allow for targets 30 times brighter and approximately 13 times fainter than expected, that is, BRIGHT=132000 (*e.g.*, 400 x 30 x 11 possible sub-exposures) and FAINT=330. See section 2.2.11 for more details.

Although ACQ/BINARY is designed to obtain the Nth brightest star in a crowded field by setting the optional parameter NTHSTAR, acquisitions in crowded fields have not been attempted. The default value is NTHSTAR=1. Please consult an Instrument Scientist prior to utilization of the NTHSTAR capability as subtleties abound in this procedure.

An example of an ACQ/BINARY is given in Visit 01 of the sample FOS RPS2 proposal in Appendix F.

2.2.2 ACQ/PEAK

During ACQ/PEAK the telescope slews and integrates at a series of positions on the sky with a science aperture in place. At the end of the slew sequence (with the default optional parameter TYPE=UP) the telescope is returned to the position with the most counts, *i.e.*, no positional interpolation is performed. In the case of an ACQ/PEAK into a barred aperture, or when using the optional parameter TYPE=DOWN, the telescope is returned to the position with the fewest counts. ACQ/PEAK is a relatively inefficient procedure because a minimum of approximately 30 seconds per dwell is required for the telescope to perform the required small angle maneuvers. Tables 2-1 and 2-2 list the recommended combinations of peak-ups for acquisition of targets according to the size of the science aperture and desired telescope pointing accuracy. These tables also give the overhead times involved in each stage of an ACQ/PEAK. Overheads for many FOS peak-up patterns will be reduced relative to previous cycles by as much as 25% with new spacecraft commanding that will be effective 1 July 1995. Tables 2-1 and 2-2 and RPS2 include these new overheads.

- **Example:** A peak-up into the 0.26″ (0.3) aperture for science observations that require pointing accuracy of 0.08″ (typically for observations requiring S/N < 30 and photometric accuracies no better than 5%) would utilize sequence A+B1+C1+E2 from Tables 2-1 and 2-2; that is, a 1X3 peak-up into the 3.7″ x 3.7″ (4.3), followed by a 6X2 peak-up into the 0.9″ (1.0) aperture, followed by a 3X3 peak-up into the 0.43″ (0.5) aperture, and lastly a 4X4 peak-up into the 0.26″ (0.3) aperture. The overhead time required for this four-stage peak-up is 43 minutes. See Visit 02 of the sample FOS RPS proposal in Appendix F for the RPS2 coding for this example.

An additional example of an ACQ/PEAK is given in Visit 03 of the sample FOS RPS2 proposal in Appendix F.

This mode is used for objects too bright to acquire with the camera mirror in place, for objects too variable to acquire with ACQ/BINARY, for centering targets in the smallest apertures, and for positioning bright point sources on the bars of the occulting apertures in order to observe any surrounding nebulosity. For bright object acquisitions, the science grating is put in place before the acquisition.

TIP: *FOS* ACQ/PEAK *is now available for moving targets.*

TIP: *Specification of a wavelength range for* ACQ/PEAK *limits the amount of data actually read-out and evaluated onboard. This may be very useful in certain circumstances, however please do NOT simply specify wavelength ranges routinely as you may lose data you really need.*

Target acquisitions requiring high pointing precision (pointing accuracy ≤0.08″), *e.g.*, to acquire objects into the smallest FOS apertures, specifically the 0.26″ (0.3), 0.2″ (0.25-PAIR), 0.09″ (0.1-PAIR), and 0.2″X 1.7″ slit (0.25X2.0), should use a so-called "critical" ACQ/PEAK exposure in the last stage of the acquisition. The "critical" ACQ/PEAK exposure must produce a high number of counts (≈ 10000) in order to discriminate the precise pointing in the center of these smallest apertures. Normal non-critical ACQ/PEAK stages require shorter exposure times (typically to produce ≈ 1000 counts) and spacing between dwells of order half the aperture size. See Tables 2-4 and 2-5 and section 2.2.11 below for exposure times.

Of course, count rates must not exceed the safety limits for the mirror or the grating selected (see Tables 1-10 and 1-11).

2.2.3 SPECIAL CASES: FOS Side-Switch Acquisitions

Once a target has been acquired into a science aperture and observed with one detector, a slew can be performed to place the target directly into an aperture for the other detector in order to allow science observations to continue without a complete new Guide Star acquisition. Such "side-switch" slews are accurate enough to center objects directly in *the 0.9″* (`1.0`) *and larger apertures*. (Please consult the ADVISORIES section of the FOS WWW Homepage after 1 July 1995, as an aperture location calibration currently in progress *may* relax this requirement somewhat.) Science observations with the "new" detector and any aperture smaller than the 0.9″ (`1.0`), require at least one stage of `ACQ/PEAK` to re-center the target. The *current* recommendation is to use a stage of peakup identical to the last stage used in the initial acquisition.

TIP: *Approximately 50-55 minutes are required for the transition between detectors. However, if exposures are arranged to fill the last orbit before the side-switch, much of this time can be "hidden" in target occultation and the subsequent guide star re-acquisition period. NOTE: There is a 2-3 minute shorter transition between* `FOS/BL`*-to-*`FOS/RD` *than for* `FOS/RD`*-to-*`FOS/BL`. *In practice this difference rarely affects scheduling efficiency.*

TIP: *Contrary to statements in earlier versions of the FOS Instrument Handbook, there are no restrictions on side-switching other than normal observational constraints.*

2.2.4 SPECIAL CASES: FOS-assisted GHRS target acquisitions and GHRS-assisted FOS target acquisitions

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

The standard FOS-assisted GHRS target acquisition uses the `FOS/BL` detector to acquire the target and then offsets the target into the GHRS large science aperture (LSA). This is possible because the separation between the `FOS/BL` detector and the GHRS apertures is only 78.72″. Unfortunately, the separation of the GHRS and `FOS/RD` detector apertures is more than 2.5′. Since the same guide stars must be kept for the FOS- and the GHRS-part of the observations, the guide stars will move more than 2.5′ across the Fine Guidance Sensor (FGS) field-of-view during such an `FOS/RD` to GHRS maneuver. Only under very limited situations will it be possible to find guide stars which are within the Field of View of the FGS from the beginning to the end of an operation involving the `FOS/RD` detector and the GHRS. Therefore, we anticipate that most FOS-assisted target acquisitions will involve `FOS/BL` to GHRS transitions and that very few FOS-assisted target acquisitions from the `FOS/RD` detector will actually be possible.

Calibration observations using `ACQ/BIN` with the FOS followed by an offset into the GHRS LSA have shown that the target was placed to within 0.2″±0.1″ of the LSA center. Therefore, the accuracy of an assisted acquisition instrument-to-instrument slew is precise enough to allow direct GHRS science in the LSA without any further peakup.

An FOS-assisted target acquisition should be used if the observations are best done with the GHRS and the target cannot be acquired at all with the GHRS. FOS-assisted target acquisition is more commonly used if the target is in a brightness range such that it can barely be acquired with the GHRS. In this case, a GHRS acquisition will often have substantial overhead, either through a sideswitch or through a Side-1 acquisition with the maximum steptime. Thus, if the associated GHRS target acquisition overhead time is a significant (≥30%) fraction of the science time, then an FOS-assisted target acquisition is recommended.

One can reverse the above target acquisition strategy and use the GHRS to acquire a target for an FOS science observation, but, there are some difficulties with this procedure. A GHRS-assisted FOS target acquisition is recommended only if the observations are best done with the FOS and the target *cannot be acquired at all with the FOS*. Unfortunately, the magnitude of uncertainty in the position of the GHRS LSA aperture is large enough that a direct target acquisition into the FOS apertures smaller than 0.9″ (`1.0`) may not be efficient. Note that if observations with the small FOS apertures are required, the GHRS-assisted target acquisition into the 0.9″ (`1.0`) aperture has to be followed by a peak-up acquisition sequence. In such cases, the overhead time saved by using a GHRS-assisted target acquisition may not be substantial. Further, if the FOS science observations are predominantly using the `FOS/RD` detector, there may be great difficulty in obtaining guide stars, as noted above. Therefore, a GHRS-assisted FOS target acquisition is normally recommended only for the 0.9″ (`1.0`) and the 3.7″x1.3″ (`4.3`) apertures.

An assisted target acquisition is a restricted resource as the number of available guide stars will generally be small because two instruments are used in the same observation set. Typically, substantial savings in overhead time for an FOS-assisted target acquisition are achieved if a binary acquisition can be used. If a peak-up has to be used, the observer must decide if a 2-stage peak-up acquisition pointing accuracy is sufficient. Otherwise the FOS target acquisition overhead comes close to the GHRS overhead when 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 other choice but to use that strategy.

An example of an FOS-assisted GHRS acquisition is given in Visit 03 of the sample FOS RPS2 proposal in Appendix F.

TIP: *Observers considering the use of either FOS- or GHRS-assisted target acquisition should contact an FOS or GHRS Instrument Scientist to discuss technical feasibility and scheduling constraints.*

2.2.5 SPECIAL CASES: reuse_target_offset

If an FOS observing program requires more than one visit to an object within 3-4 weeks, then under certain circumstances the majority of a lengthy acquisition sequence need not be performed on visits after the first. If the same guide stars can be used at the same positions in the FGS field-of-view for the two visits, then the reuse_target_offset procedure may be invoked. A minimum of four days is required to guarantee receipt of the necessary telemetry at STScI and then uplink the offset to the spacecraft. Hence the first return visit can occur no earlier than four days after the initial visit. Additional return visits can execute immediately following the first return if necessary. This procedure may be used only for purely `ACQ/PEAK` target acquisition scenarios.

A routine `ACQ/PEAK` acquisition sequence is used for the first visit. Subsequent returns must use `SAME ORIENT` so that the same guide stars may be used in the same positions in the FGS field-of-view. Return pointings of this type are typically accurate to approximately 0.03″. Nonetheless, we recommend that one stage of peak-up (such as pattern E3 from Table 2-1) be performed on the return visits.

An example of a reuse_target_offset acquisition is provided in Visits 03 and 04 of the sample FOS RPS2 proposal in Appendix F.

TIP: *Reuse_target_offset can save nearly two orbits on each return visit for programs requiring precise pointing accuracy. Please consult an Instrument Scientist for further details.*

Reuse_target_offset Summary:

- ACQ/PEAK only
- return visits at SAME ORIENT within 3-4 weeks (intervals of up to about 40 days are possible, but have not been tested to date).
- the first return visit must be at least 4 days after the initial acquisition; subsequent returns may follow immediately.
- perform single stage of peakup on return visit.

2.2.6 INT ACQ

The mode ACQ, when used with the Special Requirement INT ACQ FOR, maps the acquisition aperture into 64 rasters and sends the image to the ground in real time. The apparent elongation of stars in the Y-direction caused by the shape of the diodes (0.31″ x 1.29″) is removed on the ground by multiplying the picture by an appropriate matrix. After the picture has been restored, the astronomer measures the position of the target on the image. The small offset required to move the target to the center of one of the science apertures is calculated and uplinked to the telescope. After the slew is performed the science observations begin. Centering accuracies for INT ACQ are the same as those for ACQ/BIN, specifically 1 σ centering uncertainty is 0.08″ for FOS/BL and 0.12″ for FOS/RD. As a result, science observations in apertures smaller than the 0.9″ (1.0) aperture following an INT ACQ require at least one additional stage of ACQ/PEAK.

TIP: *In order to produce the same effective exposure in the most densely exposed pixel as for* ACQ/BINARY *(400 counts), the* ACQ *exposure time must be 64/11 (roughly 6) times the* ACQ/BINARY *exposure time (64 rasters in* ACQ *versus maximum of 11 sub-exposures in* ACQ/BINARY*). Normally, we recommend at least 1000 counts in the most densely exposed pixel of an FOS image (requires 15 times the* ACQ/BINARY *exposure).*

A modified form of interactive acquisition, the dispersed-light interactive acquisition utilizing IMAGE mode, may be employed for acquisition of sources in which spectral features of known wavelength are prominent. This method has proven quite useful for planetary satellite acquisitions. Spacecraft overheads for this procedure are no different than the overheads for conventional INT ACQ. Contact an Instrument Scientist for more information on this procedure.

2.2.7 ACQ: Confirmatory

The special mode ACQ can also be used after any other type of acquisition to provide a picture which shows where HST is pointed in FOS detector coordinates. Visit 01 of the sample FOS RPS2 proposal in Appendix F contains an illustration of a confirmatory ACQ.

TIP: *Use the same exposure guidelines as for* INT ACQ.

2.2.8 ACQ/FIRMWARE

ACQ/FIRMWARE is an engineering mode that maps the camera-mirror image of the aperture in X and Y with small, selectable Y increments. The FOS microprocessor filters the aperture map and then finds the Y-positions of the peaks by fitting triangles through the data. Firmware is less efficient than ACQ/BIN, and fails if more than one object is found within the range of counts set by the observer (BRIGHT and FAINT). This mode is not generally recommended and an Instrument Scientist should be consulted prior to its use.

2.2.9 Early Acquisition Using WFPC2

TIP: *Since the duration of Cycle 6 may be as short as 6 months, the utility of WFPC2 early acquisition may be diminished for many programs.*

We recommend using an "early" WFPC2 assisted target acquisition when it is known *a priori* that an offset acquisition will be required, when there will be more than two stars in the 3.7″x1.3″ (4.3) acquisition aperture, or when there will be intensity variations across the acquisition aperture which are larger than a few percent of the mean background intensity. A WFPC2 image (made up of three chips of size 1.25′ on a side and a fourth chip 0.6′ on a side) of the field is taken several months in advance of the science observation. The positions of the target and an offset star are measured in the image and then (at least 2 months later) the positions are updated in the RPS2, the offset star is acquired with a normal FOS acquisition scenario, *e.g.*, ACQ/BIN or ACQ/PEAK, and finally the FOS aperture is offset onto the target. The same guide stars used for the WFPC2 early image will not be in the Fine Guidance Sensors (FGS) when the subsequent FOS observations are made. With new guide stars, the 1σ uncertainty in any position is about 0.3″. The 1σ uncertainty in the position of the telescope after a 1′ offset slew (due to the accuracy with which the WFPC2 rotation angle is known with respect to V2, V3) is of order 0.07″, and science pointing accuracy requirements must therefore be carefully considered.

TIP: *Offsets larger than 30″ should be discussed with an FOS Instrument Scientist as additional peak-ups may be necessary on the science target.*

The first step in a WFPC2-assisted target acquisition is to use a Special Requirement in the RPS2 exposure level to specify the exposure as an EARLY ACQ which must be taken at least two months before the FOS observations. The camera, exposure time, filter, and centering of the target in the image should be chosen such that the picture will show both the target and an isolated (no other star within 5″) offset star which is brighter than $m_V = 19$ and more than 1 magnitude brighter than the background (in magnitudes per square arcsecond). In order to insure that an appropriate offset star will be in the WFPC2 image, the centering of the target in the WFPC2 field should be chosen by measuring a plate or CCD image. The Target List for the FOS exposures should provide the offset star with nominal coordinates and with position given as TBD-EARLY. The Target List also should list the position of the offset star as RA-OFF, DEC-OFF, and FROM the target. Alternatively, the offsets can be given as XI-OFF and ETA-OFF, or R, PA.

TIP: *If* ACQ/BINARY *is likely to be used for acquisition of the offset star at the time of the FOS science observations, then we recommend that two exposures (for example, B and V) be obtained with WFPC2 or, if possible, ground-based colors be obtained for your candidate offset star. This will greatly improve the chances for success with the* ACQ/BINARY *methodology,* *which requires some knowledge of the spectral energy distribution of the target.*

After the WFPC2 exposure has been taken and the data have been received, the next steps are to choose an offset star, measure its color, right ascension, and declination, and measure the right ascension and declination of the target relative to the offset star. Naturally, all such coordinates must be in the Guide Star Catalog reference frame. Please contact your Program Coordinator or a WFPC2 Instrument Scientist for details on this procedure. Based on your choice of an offset star, the ST ScI will choose a pair of guide stars for the FOS observations which will stay in the FGS field-of-view during the move from the offset star to the target. The probability that a suitable pair of guide stars can be found increases and the positional uncertainty after the offset slew decreases as the separation of the offset star and the target decreases. So, choose the offset star as close as feasible to the target. The final step is to send the position of the offset star and the positional offsets to the ST ScI to update the RPS2 proposal information for your FOS observations

TIP: *Check the HST Archive for pre-existing non-proprietary WFPC or WFPC2 images of the target that may include an offset star.*

2.2.10 Acquisitions of Specific Types of Objects

The following section gives examples for acquiring different types of astronomical objects based on the strengths and weaknesses of the various target acquisition methods.

- **Example: Single Stars**

The FOS can be damaged if illuminated by sources that are too bright. The instrument will go into safe mode, shut its aperture door, and stop operations if illuminated through the 3.7″x1.3″ (`4.3`) aperture by targets brighter than the unreddened visual magnitudes given in Tables 1-10 (`FOS/RD`) and 1-11 (`FOS/BL`). The exact limits depend on the spectral type of the target and on the combination of spectral element and detector used as indicated in these tables.

Stars that are too bright for `ACQ/BINARY` (spectral element `MIRROR`) can be acquired by using `ACQ/PEAK` with one of the high dispersion gratings instead of the camera mirror. If the visual magnitude of a single star or point source is fainter than the `MIRROR` limits given in Tables 1-10 and 1-11, if the star does not vary by more than 1.0 magnitude, and if its colors are known, use `ACQ/BINARY` for the acquisition.

- **Example: Stars Projected on Bright Backgrounds**

`ACQ/BINARY` can successfully find a star projected on a *uniform background* provided the target acquisition integration time is long enough to give ≈ 400 peak counts from the star and the star is at least one magnitude brighter than the background surface brightness in magnitudes per square arcsecond. If star magnitude and the background magnitude differ by less than 1 magnitude, the star can still be acquired with `ACQ/BINARY`, though with increased risk of failure, by increasing the integration time. An Instrument Scientist should be consulted for such situations. Alternatively, the acquisition can be accomplished by using an early acquisition with WFPC2, followed two months later by an FOS acquisition and blind offset.

A different problem arises when the *background varies* across the acquisition aperture. Since the logic in the `ACQ/BINARY` program drives the star to the edge of the diode array by finding the position which gives half the maximum number of counts, any change in the background in the Y-direction will bias the derived Y-position of the star. We recommend ACQ/PEAK for such cases.

- **Example: Diffuse Sources and Complex Fields**

The FOS onboard acquisition methods were designed to acquire point sources. Consequently, diffuse sources and complex fields must be observed by first acquiring a star and then offsetting to the desired position in the source. The most accurate positioning of the FOS aperture on the source will be accomplished by using an early WFPC2-assisted target acquisition. In many programs, the interesting positions in the source will be chosen on the basis of WFPC2 images. If the imaging program is planned as described in the section on WFPC2-assisted target acquisitions, the science images can be used for the acquisition.

- **Example: Nebulosity Around Bright Point Sources**

The optimal FOS aperture position for a bright point source surrounded by nebulosity will depend on the distribution and brightness of the nebulosity relative to the point source. If high spatial resolution images show that the nebulosity has a scale length of a few tenths of an arcsecond and is relatively symmetrical around the source, then the signal-to-noise ratio may be maximized by placing the stellar source on the occulting bar of one of the occulting apertures and observing simultaneously the nebulosity on both sides of the occulting bar. A normal FOS acquisition strategy should be employed to first position the source near the center of the occulting aperture then peak-down in the Y-direction to position the stellar source on the occulting bar. Exposure times for the peak-down stage should be chosen that will produce approximately 50,000 counts for the unobscured source through the 0.9″(1.0) aperture. An Instrument Scientist should be consulted for any peak-down acquisitions.

If high-resolution images show that the nebulosity is rather asymmetrical, the best approach may be to observe the nebulosity with one of the small circular apertures. In that case the bright stellar source could be acquired with ACQ/BINARY, followed by an ACQ/PEAK, followed by an offset onto the nebulosity.

2.2.11 Acquisition Exposure Times

- **Example: ACQ/BINARY exposure times**

There should be about 400 counts in the peak of the Y-step that is centered on the star in an ACQ/BINARY exposure. The maximum number of Y-steps which can be taken during ACQ/BINARY is 11. Tables 2-4 and 2-5 summarize the total exposure time for an ACQ/BINARY, *i.e.*, the time per Y-step multiplied by 11, for various types of stars. *The exposure times in Tables 2-4 and 2-5, scaled to the magnitude of the target, are the times that should be entered in RPS2.* There is a minimum integration time of 0.66 sec that can be entered in RPS2 for an ACQ/BINARY exposure (see Table 2-3). If your expected ACQ/BINARY exposure time must be larger than that calculated from Table 2-4 or 2-5 to accommodate the minimum time, the values for the optional parameters BRIGHT and FAINT must be set to reflect the total number of counts expected.

$$\texttt{BRIGHT} = 132{,}000 \times 0.66 \text{ sec} \ / \ \text{TIME}_{\text{Table 2-4 or 2-5}}$$

$$\texttt{FAINT} = 330 \times 0.66 \text{ sec} \ / \ \text{TIME}_{\text{Table2-4 or 2-5}}$$

For example, for an FOS/RD ACQ/BINARY of an unreddened V=12.5 K0III star, 0.45 seconds is the exposure time derived from Table 2-4, but the minimum allowed exposure time is 0.66 seconds. The default values of BRIGHT and FAINT must then be multiplied by the factor 0.66/0.45 = 1.47, so that BRIGHT = 194000 and FAINT = 480.

- **Example: ACQ/PEAK Exposure Times**

The peak-up exposure times in Tables 2-4 and 2-5 are calculated to produce 1000 counts in the peak of the target image, which is the number of counts recommended for a non-critical ACQ/PEAK. We recommend a “critical” ACQ/PEAK into small apertures with exposures producing 10,000 total counts in order to achieve a centering error that corresponds to a signal loss of less than about 2% for the apertures smaller than 0.3″. For a critical peak-up, the values in Tables 2-4 and 2-5 relating to peak up must be multiplied by a factor of 10. Peak-down exposures should be designed so as to produce 50,000 counts for the unobscured target if it were observed through the 0.9″(1.0) aperture, so times in Tables 2-4 and 2-5 must be multiplied by 50 for peak-down stages of acquisition.

The times in Tables 2-4 and 2-5 do not include the overhead involved in the initial setup of parameters or the analysis time, since that overhead should not be included in the RPS2 specifications. The overhead times for ACQ/PEAK patterns are given in Tables 2-1 and 2-2. Note we have provided special strategies for peakups into the smaller apertures that are designed to efficiently pack orbits. In many cases these special strategies are different from those recommended in prior cycles.

TIP: *Since overhead dominates* ACQ/PEAK *exposures for short dwell times, do NOT specify less than 1 second for exposure time. The count levels given above are lower bounds and, UNLIKE the case with* ACQ/BINARY *pose no problem for the algorithm.*

- **Example: Very Faint Sources**

TIP: *Extrapolations of acquisition exposure times for sources fainter than V=19.5 should not be made from Tables 2-4 or 2-5 because of the influence of background noise. Consult an Instrument Scientist for such situations.*

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Table 2-3: Minimum Exposure Times to be Entered in RPS2 Exposure Level

ACQ/BINARY	0.66 sec
ACQ/FIRMWARE	0.96 sec
ACQ/PEAK	0.003 sec
ACQ	3.84 sec

Table 2-4: FOS/RD Acquisition Exposure Times[1,2,3]

Spectral Type	B-V	Peak/up G190H	Peak/up G270H	Peak/up G400H	Peak/up G570H	Peak/up G780H	Peak/up G650L	Peak/up PRISM	Peak/up MIRROR	ACQ/ BIN
07V	-0.32	0.2	0.1	0.2	0.5	3.8	0.3	0.1	0.1	0.39
B0V	-0.30	0.2	0.1	0.2	0.5	3.8	0.4	0.1	0.1	0.46
B1.5V	-0.25	0.3	0.1	0.3	0.5	3.8	0.4	0.1	0.1	0.53
B3V	-0.20	0.6	0.3	0.3	0.5	3.7	0.4	0.1	0.1	0.8
B6V	-0.15	0.7	0.3	0.3	0.5	3.9	0.5	0.1	0.1	1.0
B8V	-0.11	1.6	0.6	0.4	0.5	3.8	0.5	0.1	0.2	1.3
A1V	+0.01	4.5	1.4	0.5	0.5	3.7	0.5	0.2	0.2	2.0
A2V	+0.05	4.9	1.6	0.5	0.5	3.5	0.5	0.2	0.2	2.1
A6V	+0.17	9.3	2.2	0.5	0.5	3.3	0.5	0.2	0.2	2.4
A7V	+0.20	10	2.3	0.5	0.6	3.1	0.5	0.2	0.2	2.4
A9V	+0.28	16	2.6	0.6	0.6	3.1	0.6	0.2	0.3	2.7
F0V	+0.30	20	2.8	0.6	0.6	3.1	0.6	0.2	0.2	2.8
F5V	+0.44	44	3.0	0.6	0.6	2.7	0.6	0.3	0.2	3.0
F7V	+0.48	62	4.1	0.7	0.6	2.6	0.6	0.3	0.2	3.3
F8V	+0.52	72	5.0	0.7	0.6	2.6	0.6	0.3	0.3	3.4
G2V	+0.63	---	6.2	0.8	0.6	2.5	0.6	0.3	0.3	3.5
G6V	+0.70	---	6.3	0.9	0.6	2.5	0.7	0.3	0.3	3.7
K0V	+0.81	---	14	1.0	0.6	2.3	0.7	0.3	0.4	4.0
K0III	+1.00	---	32	1.5	0.6	2.2	0.7	0.4	0.4	4.5
K5V	+1.15	---	30	2.0	0.6	2.1	0.8	0.4	0.4	4.9
K4III	+1.39	---	---	2.8	0.7	1.9	0.8	0.5	0.5	5.4
M2I	+1.71	---	---	4.0	0.7	1.9	0.9	0.6	0.5	6.2
α=1	---	1.9	0.6	0.5	0.5	2.0	0.5	0.2	0.2	1.5
α=2	---	4.9	1.2	0.6	0.6	1.6	0.6	0.3	0.2	2.2
α=-2	-0.46	0.2	0.1	0.2	0.5	3.6	0.3	0.1	0.1	0.23
50,000	---	0.2	0.2	0.3	0.5	3.6	0.4	0.1	0.1	0.35

Table 2-5: FOS/BL Acquisition Exposure Times[1,2,3]

Spectral Type	B-V	Peak/up G130H	Peak/up G190H	Peak/up G270H	Peak/up G400H	Peak/up G570H	Peak/up G650L	Peak/up PRISM	Peak/up MIRROR	ACQ/ BIN
07V	-0.32	1.5	0.5	0.2	0.4	5.9	1.6	0.1	0.1	1.6
B0V	-0.30	1.7	0.6	0.2	0.3	6.1	1.6	0.1	0.1	1.8
B1.5V	-0.25	2.3	0.8	0.3	0.4	6.7	1.8	0.1	0.1	2.2
B3V	-0.20	5.0	1.6	0.5	0.6	6.2	1.9	0.2	0.2	3.6
B6V	-0.15	7.2	1.9	0.4	0.5	7.0	2.1	0.2	0.2	4.4
B8V	-0.11	17	4.2	0.9	0.6	7.0	2.1	0.3	0.2	6.8
A1V	+0.01	---	12	2.0	0.8	7.4	2.5	0.5	0.5	12.
A2V	+0.05	---	14	2.6	0.8	7.1	2.5	0.5	0.5	14.
A6V	+0.17	---	27	3.5	0.9	8.2	2.9	0.6	0.6	16.
A7V	+0.20	---	28	3.6	1.0	8.2	3.0	0.6	0.6	17.
A9V	+0.28	---	48	4.1	1.1	8.2	3.4	0.7	0.7	20.
F0V	+0.30	---	53	4.5	1.4	8.7	3.4	0.8	0.8	20.
F5V	+0.44	---	---.	5.0	1.6	9.0	4.0	0.8	0.8	24.
F7V	+0.48	---	---	6.2	1.8	9.2	4.3	0.9	0.9	28.
F8V	+0.52	---	---	7.7	2.0	9.2	4.4	1.1	1.1	30.
G2V	+0.63	---	---	8.5	2.1	9.2	4.6	1.2	1.2	32.
G6V	+0.70	---	---	8.8	2.2	9.4	5.2	1.3	1.3	36.
K0V	+0.81	---	---	19.	2.7	11.	5.8	1.7	1.7	44.
K0III	+1.00	---	---	39	3.9	11	7.3	2.5	2.5	66.
K5V	+1.15	---	---	42	5.7	13	9.0	3.1	3.1	88.
K4III	+1.39	---	---	---	7.9	16.	12	4.8	4.8	130.
M2I	+1.71	---	---	---	13	19.	16.	7.0	7.0	180.
$\alpha=1$	---	21.	5.0	1.0	1.0	8.6	3.2	0.4	0.4	8.4
$\alpha=2$	---	64.	123	1.9	1.4	9.6	4.2	0.6	0.6	15
$\alpha=-2$	-0.46	0.4	0.3	0.1	0.3	5.6	1.4	0.1	0.1	0.88
50,000	---	1.0	0.4	0.2	0.4	6.5	1.6	0.1	0.1	1.4

Notes to Tables 2-4 and 2-5

Note: Exposure time must be multiplied by $10^{0.4(V-15)}$.

[1] Optimal exposure times for ACQ/BINARY and ACQ/FIRMWARE are calculated to detect 400 peak counts in the peak pixel of the target.

[2] Last stage of ACQ/PEAK into the 0.26″ (0.3) aperture requires 10000 total counts.

[3] Exposure times for ACQ/PEAK into all apertures are calculated to detect 1000 total counts for non-critical acquisitions. For critical centering (≤ 0.08″), multiply the exposure times by a factor of 10. **Note that the exposure time for ACQ/PEAK must be multiplied by the inverse throughput of the aperture used (T_λ, see Table 2-6 below)**. Although the exact factor depends on the input spectrum, the approximate multiplicative factors given below are sufficient for most acquisition purposes.

Table 2-6: Average Aperture-Dependent Exposure Correction Factors (relative to 4.3=1)

Aperture	Inverse Throughput
1.0	1.1
0.5	1.2
0.3	1.25
0.25X2.0	1.2
1.0-PAIR	1.1
0.5-PAIR	1.2
0.25-PAIR	1.33
0.1-PAIR	~2.5

For the wavelength-dependence of aperture throughputs please refer to Table 1-8.

3. INSTRUMENT PERFORMANCE AND CALIBRATIONS

3.1 Current Calibration Status

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. In Cycle 5, we expect to maintain the routine calibration situation for the FOS. Our calibration program is divided into two parts: (1) a set of monitoring tests which aim to check the stability of the instrument performance, and (2) a set of specific tests designed to maximize the instrumental performance.

As a general guide to the FOS calibration programs in Table 3-1 we provide a list of the calibration tests which are being performed in Cycle 5. For each calibration program we give the proposal ID, title, accuracy goal, number of orbits required, and comments which may include scheduling information. For detailed information regarding the Cycle 5 calibration program see Appendix I.

The routine monitoring proposals are designed to monitor those aspects of the FOS performance that are known to show time variations. The focus test is conducted only once during the cycle because we know that the variations in the FOS focus are not large and do not affect the photometric accuracy of the data dramatically. The high voltage settings for the Digicons are also checked once a cycle. Since the FOS detectors are affected by external magnetic fields, the location of spectra on the photocathode and the FOS internal background observations will be conducted once every month. Similarly, the stability of the internal wavelength calibrations will be checked once every month. Some FOS detector/disperser combinations have shown temporal variations in their flat field structure during previous cycles. Several, though not all, flat fields will be monitored as frequently as every 2 months. The absolute photometric calibration of some spectral elements have shown modest temporal variations during Cycle 4; we will monitor these aspects of FOS sensitivity also once every 2 months.

The special calibration proposals are designed to characterize those aspects of the FOS performance which have been specially requested by Cycle 5 GOs.

The accuracies specified in Table 3-1 are the minimum goals of the Cycle 5 calibration program. The requirements for the success of the calibration program are slightly less stringent.

We expect that the Cycle 6 calibration plan will be similar to that of Cycle 5. We expect to monitor instrument modes that have been previously characterized. We do not anticipate the expansion of the calibration beyond the areas described in the Cycle 5 plan. If the calibration accuracies specified here are insufficient to meet science program requirements, then proposers should be prepared to provide extra calibration time in their programs to meet their specific calibration needs.

Table 3-1: Summary of FOS Cycle 5 Calibration Programs

ID	Proposal Title	Accuracy	Time (orbits) External	Time (orbits) Internal	Notes
Routine Monitoring Programs					
6163	Focus, X-pitch, Y-pitch test	N/A	4	0	Monitor the FOS focus; scheduled for mid-cycle
6165	Discriminator Test	N/A	0	12	every 3 months
6167	Dark Monitoring	5%	0	48	Monitor the background every month; always in occultation
6166 & 6236	Y-base Monitoring and	10 Y-bases	0	194	Check stability of the location of spectra on the photocathode; every month; always in occultation
	Internal Wavelengths	0.03 diodes			
6202	Spectral Flat Field Calibration	1%	22	0	Monitor flat fields; at least twice in cycle
6203	Photometric Calibration	3%	48	0	Monitor inverse sensitivity
Special Calibration Programs					
6206	Polarimetry Calibration	~0.5%	20	2	Characterize polarimetry mode; mid-cycle
6204	Internal External Offset and	0.1 diodes	21	0	Determine the wavelength calibration and characterize the nature of UV scattered light; mid-cycle
	Scattered Light Test	5%			
6205	Location of 1.0″ aperture and the FOS PSF	0.05″	12	0	Verify the stability of the FOS apertures and determine the FOS PSF; mid-cycle
TOTAL TIME (including all executions)			127	256	

3.2 Wavelength Calibration

Unlike the IUE, all FOS wavelengths are vacuum wavelengths both below 2000Å and above.

Wavelength offsets between the internal calibration lamp and a known external point source are currently based on observations of the dwarf emission line star AU Mic that have been corrected for geomagnetically induced image drift (Kriss, Blair, and Davidsen 1992). On the red side, the mean offset between internal and external sources is $+0.176 \pm 0.105$ diodes. On the blue side, the mean offset is -0.102 ± 0.100 diodes. These offsets *are included* in the pipeline reduction wavelength calibration. If the target is well-centered in the science aperture, velocity measurements based on single lines in FOS spectra have a limiting accuracy of roughly 20 km s^{-1} *if wavelength calibrations are obtained at the same time as the science observations and with no filter-grating wheel motion between the science and the wavelength exposures*. (See Appendix D for line lists and spectra of the comparison lamps for each detector/disperser combination.) If simultaneous wavelength calibrations are not obtained, the non-repeatability of order 0.35 diodes in the positioning of the filter-grating wheel will dominate the errors in the zero point of the wavelength scale (Hartig 1989). Visit 03 of the sample RPS2 FOS program in Appendix F presents an example of a science exposure and accompanying high-precision wavelength calibration.

Wavelength Calibration Summary:

- Filter-grating-wheel repeatability is of order 0.35 diodes.
- FOS wavelength accuracy limit approximately 20 km/sec.
- Precision wavelengths require centering ≤0.04″ and science and wavecal exposures must be observed consecutively, *i.e.*, with no move of filter-grating wheel in between. See example in Visit 03 of the sample RPS2 FOS program in Appendix F.

3.3 Absolute Photometry

The post-COSTAR absolute photometric calibrations have been performed by observing the standard stars G191B2B (WD0501+527), BD+28D4211, BD+75D325, HZ-44, GD153, GD71, HZ-43, and BD+33D2642 in the 3.7″ x 1.3″ (`4.3`) and the 0.9″ (`1.0`) apertures. Cycle 5 and 6 calibrations will be based primarily on BD+28D4211 and G191B2B. See Tables 3-2 and 3-3 for a summary of the detector/disperser/aperture combinations to be calibrated during Cycle 5.

Observations of these spectrophotometric standard stars have been used to produce inverse sensitivity functions for all usable FOS detector/disperser combinations and all apertures except the `0.1-PAIR`, `2.0-BAR`, and `0.7X2.0-BAR`. A highly precise target acquisition strategy (multi-stage `ACQ/PEAK` with pointing uncertainty of 0.04″) is used for these observations so that filter-grating wheel repeatability (0.10″ = 0.35 diodes) is the dominant source of uncertainty in photocathode sampling.

The standard star reference flux scale used for photometry is accurate to 1%. Limiting accuracies of FOS photometry are approximately 1.6% for `FOS/BL` and 2.0% for `FOS/RD` for well-centered targets (accuracy ≤0.04″) in the 3.7″ x 1.3″ (`4.3`) and 0.9″ (`1.0`) apertures. Modest temporal changes have been documented in the `FOS/RD` G190H and G270H sensitivity in the post-COSTAR period. The standard data reduction pipeline will include corrections for the influences of time dependence. As of May 1995 the sensitivities for all other detector/disperser combinations have been constant at the 2% level in the post-COSTAR epoch.

The dominant error in FOS photometry is due to the location of the target in the aperture (see chapter 16 of the *HST Data Handbook* for the sources of photometric error). Centering accuracies of ≤0.08″ are required for better than 5% photometric accuracies. Uncertainties in the instrumental magnetic deflection (the Y-base) required to direct photoelectrons from the photocathode to the diode array can affect the accuracy of photometry of extended sources observed through apertures comparable in size to the diodes (*i.e.*, 0.9″ (`1.0`) aperture and larger).

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. Nonetheless, limiting photometric accuracies similar to those quoted above are possible for properly re-calibrated pre-COSTAR data.

Absolute Photometry Calibration Summary:

- absolute reference system accuracy of 1%.
- observational accuracies strongly dependent upon telescope jitter, target centering, aperture used, and stability of requisite instrumental magnetic deflection (Y-base).
- limiting accuracies of approximately 1.6% (`FOS/BL`) and 2% (`FOS/RD`) require large apertures and precise centering (≤0.04″).

3.4 Flat Fields

Observations of two hot spectrophotometric standard stars (G191B2B and BD+28D4211) are used to produce spectral flat fields for all usable FOS detector/disperser combinations. A highly precise target acquisition strategy (multi-stage `ACQ/PEAK` with pointing uncertainty of 0.04″) is used for these observations so that filter-grating wheel repeatability (0.10″ = 0.35 diodes) is the dominant source of uncertainty in photocathode sampling. All post-COSTAR flat fields have been derived via the so-called superflat technique (described in Lindler *et al* CAL/FOS-088; flat field article by Keyes in HST Calibration Workshop, ed. Blades and Osmer (1994); and Part VI, Chapter 16 in the *HST Data Handbook*, ed. Baum (1994)).

Appendix G provides figures showing flat field structure for most usable FOS detector/disperser combinations derived from Cycle 4 3.7″ x 1.3″ (`4.3`) aperture superflat observations.

It must be emphasized that FOS flat field corrections are intended to remove photocathode granularity typically on the scale of 10 pixels or less. If high precision flat fields are required for scientific objectives, observers should attempt to attain the same pointing accuracy (described above) used for FOS flat field calibration observations so that the science target illuminates the same portion of the photocathode as was sampled by the calibration observations.

During Cycle 4 several observations have been made to attempt to quantify the change in flat field granularity structure as a function of target mis-centering perpendicular to dispersion. Most pixel ranges in typical flat fields display deviations of 1-2% about the mean value of unity or about a local running mean. However, some substantial (5-50% deviations from local mean) features do occur. Initial evidence indicates that photocathode granularity in these strong features can change by 25% on the scale of a diode height (1.29″). Should such a feature occur in the vicinity of an important spectral line and target centering be less accurate than that of the flat field calibration observation, then the observed flux could be affected by a potentially unknown amount. We note that there is such a prominent (30%) feature in the 1500-1550 Å range (affects C IV resonance doublet) of the `FOS/BL` G160L spectrum, which impacts all single apertures and all lower paired apertures, but is *not present in any* upper paired aperture G160L spectrum.

Normally one epoch of flat field measurement is made per cycle with the 0.9″ (`1.0`) aperture for each detector/disperser combination to be used. Additional individual detector/disperser/aperture combinations are calibrated depending upon use or known flat field variability. Please refer to Tables 3-2 and 3-3 for a summary of planned Cycle 5 calibrations.

In the pre-COSTAR era substantial temporal variation in FOS/RD G190H was observed. Between launch in April, 1990 and November, 1991 degradation of the 1800-2100 Å. region of the FOS/RD G190H and G160L flat fields proceeded at the approximate rate of 10% per year. The variation slowed in early 1992 and little change was noted in the pre-COSTAR era after November, 1992. Smaller changes also occurred on the same timescale at additional wavelengths for both gratings and in the FOS/RD G270H spectral region. Cycle 4 flat field observations have indicated the presence of some time-variability for these three spectral elements since March, 1994. *These gratings will continue to be monitored at approximate two month intervals during Cycle 5.*

Since time dependence has been observed in the red side flat fields, red side data taken after January 1992 should be flat fielded with the data most appropriate to the observation. On-line reference guides accessed through the FOS WWW Homepage refer the user to the appropriate flat field. Red side data taken between October 1990 and January 1992 will be difficult to flat field because of the lack of time-dependent flat fields available in that interval.

Flat Field Calibration Summary:

- must use precise target centering (≤0.04″) to achieve flat field accuracies appropriate for science goals of S/N≥30.
- deviations from STScI calibration flats as a function of distance perpendicular to dispersion not well calibrated at present. These deviations can be significant.

3.5 Sky Lines

The lines of geocoronal Lyα λ1216 and OI λ1304 appear regularly in FOS spectra, with a width determined by the size of the aperture (see Table 1-4). Occasionally, when observing on the daylight side of the orbit, the additional sky lines of OI λ1356 and of OII λ2470 can also be seen. Second order Lyα sometimes appears at λ2432.

3.6 Polarimetry

FOS/BL G130H polarimetry observation will not be feasible. Gratings G190H, G270H, and G400H will be usable with both FOS detectors. The 0.9″ (1.0) aperture should be used to obtain the highest polarimetric precision. Only the FOS/RD 0.9″ (1.0) aperture will be calibrated in Cycle 5. The instrumental polarization introduced by the COSTAR reflections is ≤2% and is wavelength dependent. Actual polarimetric accuracies depend on the measured signal, of course. For very bright sources, the Cycle 5 limiting linear polarization uncertainty goal is of the order of 0.2%. Our preliminary analysis of the Cycle 4 calibration indicates a linear polarization accuracy of approximately 0.7%, however. Naturally, for faint sources the accuracy is limited by the photon statistics obtained and by the intrinsic polarization of the object (see section 1.6). Please refer to the FOS WWW Homepage after 1 June 1995 for further updates on polarization accuracies and uncertainties.

3.7 Scattered Light

Extensive modeling of scattered light which has its origin in the diffraction patterns of the gratings, the entrance apertures, and the micro-roughness of the gratings has been performed by

M. Rosa (see Appendix C). Predictions from these models will be tested in Cycle 5 by comparison of FOS G130H and GHRS G140L observations of a single target. The Rosa modeling code is available at STScI for use as a post-observation parametric analysis tool. Please contact an Instrument Scientist for more information.

A routine wavelength-independent correction for scattered light plus uncorrected background (dark) is performed in the post-observation data reduction pipeline for those gratings, such as G130H, which have regions of zero sensitivity to dispersed light. Some gratings have no regions of zero sensitivity and therefore no pipeline correction is made in these cases.

3.8 Detector Background (Dark)

FOS background corrections applied in the standard pipeline reduction may be approximately 30% too small in some cases. Naturally, this affects only observations of faint sources. Approximate mean background count rates are 0.010 counts-sec^{-1}-diode^{-1} for `FOS/RD` and 0.007 counts-sec^{-1}-diode^{-1} for `FOS/BL`. The FOS team is presently analyzing all available background measures in order to derive corrected reference files and tables. New information will be posted in the ADVISORIES section of the FOS Homepage as appropriate. Background measures will continue to be made monthly throughout Cycles 5 and 6.

3.9 Dead Diodes

Occasionally, one of the 512 diodes on the red or the blue side becomes very noisy or ceases to collect data. Since launch 3 diodes on the blue side and 2 diodes on the red side have stopped functioning. In addition, several diodes on each side have become noisy and have been disabled. With the inclusion of the diodes known to be dead or troublesome from pre-launch there are currently 26 `FOS/BL` diodes disabled and 15 disabled for `FOS/RD`. See Appendix B for the current disabled diodes list (several diodes are "under scrutiny" at present, but no new additions to the list have been made since December 1993).

3.10 Additional Calibration Information

Although not needed for Phase I planning, additional information on instrument performance may be found in FOS Instrument Science Report CAL/FOS-130 (Keyes *et al*, 1994) which is a complete discussion and a synopsis of the Cycle 4 calibration status of the FOS through November, 1994. See also *Calibrating the Hubble Space Telescope: Proceedings of a Workshop*, ed. Blades and Osmer (1994) and Part VI of the *HST Data Handbook*, ed. Baum (1994). These and other calibration-related documents are accessible on-line from the FOS WWW Homepage (*http://www.stsci.edu/ftp/instrument_news/FOS/topfos.html*).

Table 3-2: FOS/BL Cycle 5 Calibration Chart

	G130H	G190H	G270H	G400H	G570H	G780H	G160L	G650L	PRISM
4.3	F S	F S	F S	F S			F S		F S
1.0	F S	F S	F S	F S			F S		S
0.5	S	S	S	S			S		
0.3	λ_e F S	λ_e F S	λ_e F S	λ_e F S	λ		λ F S	λ	λ
0.25x2.0									
1.0-PAIR									
0.5-PAIR									
0.25-PAIR	λ S	λ S	S	S	λ		λ F S		
0.1-PAIR			λ	λ				λ	λ
2.0-BAR									
0.7x2.0-BAR									

Table 3-3: FOS/RD Cycle 5 Calibration Chart

	G130H	G190H	G270H	G400H	G570H	G780H	G160L	G650L	PRISM
4.3		F S	F S	F S	F S	F S	F S	F S	F S
1.0		F S	F S	F S	F S	F S	F S	S	S
0.5		S	S	S	S	S	S	S	S
0.3		λ_e F S	λ_e F S	λ_e F S	λ_e F S	λ_e S	λ S	λ S	λ
0.25x2.0									
1.0-PAIR									
0.5-PAIR									
0.25-PAIR		λ F S	λ F S	S	F S	S	λ S	S	λ
0.1-PAIR				λ	λ F	λ		λ	
2.0-BAR									
0.7x2.0-BAR									

λ: internal source wavelength calibration ONLY

λ_e: external source and internal source wavelength calibration

F: flat field calibration

S: photometric (inverse sensitivity) calibration

4. SIMULATING FOS : SYNPHOT

We provide a software package that can be used to simulate FOS spectra for any input spectrum. This simulator is available in the Space Telescope Science Data Analysis System (STSDAS) package *synphot*. Details about the STSDAS synphot package can be found in the Synphot User's Guide, by H. Bushouse, Sep. 1993, STScI, and in Appendix D of the *HST Data Handbook* (1994, Baum). The synphot reference data, which are not part of standard STSDAS, must be retrieved and installed to run synphot.

- Logging on to STEIS: To log onto STEIS, type **ftp ftp.stsci.edu** or **ftp 130.167.1.2.** If prompted for Name, enter **anonymous**. Otherwise enter **user anonymous**. The password is your full e-mail address. You are now in a UNIX-FTP environment. Enter **get README** to transfer the instructions to your home account. Most information relevant to data reduction is located within the /instrument_news and the cdbs directories. (For detailed information on STEIS, see the HST Data Handbook, Part XI, Chapter B, ed. Baum 1994.)

Synphot can be used to "observe" an arbitrary input spectrum with any FOS configuration to produce a predicted spectrum of detector counts s^{-1} $diode^{-1}$. This can be done using one of several tasks in the synphot package, including *countrate*, *calcspec, and plspec*. The operation of each of these tasks involves specifying the desired FOS observing mode, the input spectrum, and the form of the output spectrum. The choice as to which task to use depends on the desired results. For producing spectra in units of counts s^{-1} $diode^{-1}$ the *countrate* task is the easiest to use and its input parameters are set up to mimic those found in FOS RPS2 exposure level usage.

For example, to reproduce a count rate spectrum for the FOS blue side with grating G190H and the 0.9″ (`1.0`) aperture, the parameters for the *countrate* task would be set as given in Table 4-1. Note the inclusion of the argument "costar" in the aperture parameter, which is necessary for the task to use the aperture throughput data that are appropriate for the PSF and plate scale provided by COSTAR. In this example the input spectrum is specified using the unit function, which produces a spectrum that has constant flux as a function of wavelength. The two arguments for the unit function specify the flux level and units (here, 1.0×10^{-14} ergs s^{-1} cm^{-2} $Å^{-1}$ or "flam").

The task evaluates the spectrum on a wavelength grid that is automatically selected to match the dispersion (Ångstroms $diode^{-1}$) of the chosen observing mode. The computed spectrum will be written to the STSDAS table "spectrum tab", which will contain two columns of wavelength and flux values, where the wavelengths will be in units of Ångstroms and the spectrum in units of counts $diode^{-1}$. With exptime=1, as in this example, the flux units are then essentially counts s^{-1} $diode^{-1}$. The spectral data in this table can be plotted using, for example, the STSDAS task *sgraph* (e.g. sgraph "spectrum.tab wavelength flux").

In addition to the unit function used in this example, synphot also has built-in blackbody and power-law functions that can be used to synthesize spectra of those forms. For example, in the countrate task you could set "synspec = bb(8000)" and "synmag = 14.5 V" to synthesize an 8000 K blackbody spectrum that is normalized to a V magnitude of 14.5. You could also specify "synspec = pl(3500,2)" and "synmag = 13.9 V" to obtain a power-law spectrum of the form F(ν) proportional to ν^{-2} (which has constant flux in wavelength space), normalized to a V magnitude of 13.9.

The userspec parameter can also be set to read spectral data from an existing table, such as data you may already have for a particular object. There are several spectral atlases available on STEIS that you can use as input to synphot. Current holdings include a library of HST standard star spectra, Kurucz model atmospheres, a spectrum synthesis atlas from G. Bruzual, the Bruzual-Persson-Gunn-Stryker spectral atlas which has wavelength coverage from the near-UV to the near-IR, and the optical stellar atlas from Jacoby, Hunter, and Christian (1985). See Appendix B of the Synphot User's Guide for information on how to obtain these data.

Table 4-1: Example parameters in Synphot countrate task to simulate an FOS observation of a flat-spectrum source with flux=1.0 x 10^{-14} ergs s^{-1} cm^{-2} $Å^{-1}$

Parameter	Setting	Definition
output	spectrum.tab	Output table name
instrument	fos	Science instrument
detector	blue	Detector used
spec_elem	g190h	Spectral elements used
aperture	1.0,costar	Aperture / field of view
cenwave	INDEF	Central wavelength (HRS only)
userspec	unit(1.e-14,flam)	User supplied input spectrum
synspec		Synthetic spectrum
synmag		Magnitude of synthetic spectrum
refwave	INDEF	Reference wavelength
reddening	0.	Interstellar reddening in E(B-V)
exptime	1.	Exposure time in seconds
verbose	yes	Print results to STDOUT?
count_tot	INDEF	Estimated total counts
count_ref	INDEF	Estimated counts at reference wavelength
refdata	----	Reference data

Acknowledgements

We especially appreciate the careful comments, criticisms, and proofreading of Ron Gilliland, Knox Long, Ian Evans, Ralph Bohlin, and Jack MacConnell. Also, we would like to thank Ralph Bohlin and Don Lindler for their counsel concerning absolute photometry with the FOS. Special thanks are due Ian Evans for many very fruitful discussions concerning the internal functioning of the FOS. We greatly appreciate the help of Mark Stevens who generated one of the complicated sensitivity tables. Last, but certainly not least, we wish to thank the many users of the FOS for their very helpful implicit and explicit suggestions for improving the utility of the FOS Handbook.

5. REFERENCES

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APPENDIX A : Taking Data with FOS

Two sets of nomenclature are used to describe the taking of FOS data - those used in the RPS2 exposure level to command observations, and those used in the FOS data headers. Table A-1 gives the translation between the two, together with defaults and definitions. This Appendix describes the manner in which FOS observations are constructed and also provides important information on the limitations of the calculation of observation start times.

FOS observations are performed in a nested manner, with the innermost nest being the livetime of the instrument plus the deadtime (LT + DT). Table A-1 lists the parameters in the order in which FOS observations are nested. In the most common mode of data-taking spectra are taken by sub-stepping the diode array along the dispersion in the X-direction, and then by performing the sub-stepping five times over adjacent diodes to minimize the impact of dead diodes. The sequence is then

$$(LT + DT) \times 4 \times 5.$$

The minimum livetime is 0.003 seconds. The minimum livetime plus deadtime is 0.030 seconds. Using the minimum livetime results in very inefficient observations, since data are being taken only 0.003/0.03 = 0.1 of the time.

The user has access only to those parameters that can be set in RPS2. For example, the user cannot set the livetime, but can set the product of livetime and INTS (`STEP-TIME` = LT × INTS). Likewise, the user cannot explicitly set the deadtime, but in `PERIOD` mode, the user can set the ratio of livetime to deadtime (`DATA-RATIO` = LT/DT).

For the most common mode, `ACCUM`, an FOS integration is constructed in the order (LT+DT), INTS, NXSTEP, OVERSCAN, YSTEPS, NPATT, and finally NREAD. The total *elapsed time* (time from start to finish of an observation in seconds) of an integration is then given by

$$\Delta t = (LT+DT) \times INTS \times NXSTEP \times OVERSCAN \times YSTEPS \times NPATT \times NREAD.$$

where NXSTEP = `SUB-STEP`, and YSTEPS = `Y-SIZE`, so the elapsed time for the observation for standard `ACCUM` mode is equal to

$$\Delta t = (LT + DT) \times INTS \times 4 \times 5 \times 1 \times NPATT \times NREAD.$$

The number of patterns, NPATT, is set after the setting of sub-step (NXSTEP), OVERSCAN, and YSTEP, to achieve the exposure time requested. When NPATT has reached the maximum to which it can be set (256), then INTS is incremented. Obviously, this must be done in an optimal way to ensure that the efficiency ($\propto$ LT/DT) remains high. The maximum value for INTS is also 256.

For a `RAPID` observation, an FOS integration is built up in a slightly different order; (LT+DT), INTS, NXSTEP, OVERSCAN, YSTEPS, NPATT, and finally NMCLEARS. The total elapsed time of the observation is

$$\Delta t = (LT+DT) \times INTS \times NXSTEP \times OVERSCAN \times YSTEPS \times NPATT \times NMCLEARS.$$

which is usually equal to

$$\Delta t = (LT + DT) \times INTS \times 4 \times 5 \times 1 \times NPATT \times NMCLEARS.$$

However, the sub-stepping, the overscan values, and the wavelength range can be lowered in `RAPID` to accommodate shorter time between the taking of spectra.

Alternatively, for `RAPID` mode one can also use the `READ-TIME` (the time from the start of one exposure in a `RAPID` series to the start of the next). For completeness, we include a description of how `READ-TIME` is constructed:

$$\texttt{READ-TIME} = (LT + DT) \times INTS \times \texttt{SUB-STEP} \times OVERSCAN \times YSTEPS \times NPATT + ROT$$

where `SUB-STEP` is usually set to 4, OVERSCAN may be 1 or 5 (normally 5), YSTEPS= `Y-SIZE` and is almost always set to 1, and where ROT refers to the Read-Out Time (the time to read-out the diode array). The Read-Out Time for FOS is dependent on the telemetry rate, and on the amount of data to be read out, which is dependent on the number of diodes being used (*i.e.*, the wavelength range being observed), as well as on the sub-stepping.

$$ROT = (15 / 14) \times (1024 / RATE) \times NSEG(WORDS) \times \texttt{SUB-STEP} \times YSTEPS .$$

where RATE is the telemetry rate, and NSEG(WORDS) is given by

$$NSEG = 1 \text{ if } WORDS < 51$$

$$NSEG = 1 + NINT\{0.499 + [(WORDS-50) / 61]\} \text{ if } WORDS>50$$

where WORDS = (NCHNLS + OVERSCAN - 1), NCHNLS is the number of diodes to be read out (with a maximum of 512 and a minimum of 46 for an OVERSCAN of 5), and NINT rounds to the nearest integer (NINT[.499]=0; NINT[0.5]=1). To achieve the fastest `READ-TIME`s, the RATE of reading data can be increased from the default telemetry rate of 32kHz to 365kHz, the wavelength region can be decreased, and sub-stepping set to 1. The amount of data being taken by FOS must be decreased to achieve the fastest `READ-TIME` because a smaller amount of data can be read out in a faster time. The relation between number of diodes read out and wavelength coverage can be derived from Table 1-3.

The observer should be aware of the fact that the percentage of time spent accumulating data in `RAPID` can be very small depending on how the parameters are set. Figure 1-4, taken from Welsh *et al* (1994), shows the duty cycle, or ratio of time spent accumulating data over `READ-TIME`, as a function of `READ-TIME`. Given the two values of telemetry rate (32,000, and 365,000) and the three possible values of `SUB-STEP` (4, 2, and 1), there are six duty cycle curves in Figure 1-4. The parameters should be set to maximize duty cycle, while maintaining the resolution and wavelength coverage necessary for the scientific objectives.

For a `PERIOD` mode observation, an FOS integration is built up of

$$\Delta t = (LT + DT) \times INTS \times NXSTEP \times OVERSCAN \times YSTEPS \times SLICES \times NPATT$$

where SLICES = `BINS`. As with `RAPID`, NXSTEP and OVERSCAN values can be lowered to result in a greater number of SLICES (`BINS`).

The equations above give the elapsed time of an observation, so, *in principle*, they can be used to calculate the actual start time of any observation, by subtracting them from the first packet time (FPKTTIME) which is given in the group parameter at the beginning of every group of "multi-group" data.

$$\text{Start Time} = \text{FPKTTIME} - \Delta t$$

Unfortunately, there is an uncertainty of 0.125 seconds in the accuracy of FPKTTIME due to limitations in the precision with which the onboard clock time is read out to the ground. If relative timings of individual exposures in a `RAPID` time series must be known more accurately than 0.125 seconds, we recommend the calculation of the start time of each individual group by successive addition of `READ-TIME` to the FPKTTIME-derived start time of the first group. (Of course the uncertainty of the precision of the first FPKTTIME will limit absolute timings, but relative timings will then be accurate.) As noted in section 1.5.3, if the `READ-TIME` is less than 1.2 times the default minimum values of `READ-TIME` given in Table 1-1, then `RAPID` mode timings become very complex and an FOS Instrument Scientist must be consulted in order to compute correct start times.

The start time of the entire observation is also given in the data header as EXPSTART. All times in the header, including the first packet time, and the start time, are given in units of Modified Julian Date, which is the Julian date minus 2400000.5. For example, the Modified Julian Date for 1996 is given by:

$$\text{MJD} = 50082.0 + \text{day of year} + \text{fraction of day from } 0^h \text{ UT.}$$

Note that a *Modified* Julian Date starts at midnight U.T. whereas the more traditionally employed Julian Date starts at noon U.T.

Table A-1: FOS Observing Parameters Listed in Order of Execution.

RPS2 Exposure Level	FOS Header	Default	Definition
---	LIVETIME	0.500 sec	(LT) Time FOS is integrating.
---	DEADTIME	0.010 sec	(DT) Overhead time.
---	INTS	---	Number of times to execute (LT+DT)
`SUB-STEP`	NXSTEP	4	Number of steps of size diode/NXSTEP in direction of dispersion.
`COMB`	OVERSCAN*	YES	Whether or not to execute x stepping to remove the effects of dead diodes. For `COMB`= YES, `MUL`=5. For `COMB`= NO, `MUL`=1.
`Y-SIZE`	YSTEPS	1	Number of steps perpendicular to dispersion.
`BINS`	SLICE	5	For `PERIOD` only, equal to 1 otherwise. Number of bins to divide one period into.
---	NPATT	---	Number of times to execute the pattern so as to achieve the exposure time.
---	NREAD	---	For `ACCUM` only, equal to 1 otherwise. For readouts short enough to correct for GIM
---	NMCLEARS	---	For `RAPID` only, equal to 1 otherwise. Number of times to clear data so as to read new data.
`STEP-TIME`	LT × INTS	0.5	Available in `RAPID` and `PERIOD`.
`DATA-RATIO`	LT / DT	Maximum	Available in `PERIOD` only.

* The FOS header value for OVERSCAN is equal to the value for `MUL`.

APPENDIX B : Dead Diode Tables

C. Taylor

Occasionally one of the 512 diodes on the red or the blue side becomes very noisy, or ceases to collect data. Since launch, the FOS has lost 3 diodes on the blue side and 2 diodes on the red side. In addition, several diodes on each side have become noisy and have been disabled. When a diode goes bad in orbit, there is a delay before that diode behavior is discovered, and another delay before that diode is disabled so that its effect is removed from the data. Tables B-1 and B-2 list the current (as of December 6, 1993) disabled diodes. Tables B-3 and B-4 list the history of the diodes that have been disabled, when they were discovered to be bad, and when they were disabled. The channels are numbered in this table from 0 to 511, while they are numbered in the STSDAS tasks from 1 to 512.

Table B-1: FOS DEAD AND NOISY CHANNEL SUMMARY[1]: FOS/BL

DISABLED Dead Channels	DISABLED Noisy Channels	DISABLED Cross-Wired Channels	ENABLED But Possibly Noisy
49	31	47	8
101	73	55	138
223	144		139
284	201		209/210
292	218		421
409	225		426
441	235		
471	241		
	268		
	398		
	415		
	427		
	451		
	465		
	472		
	497		
8	16	2	6

Total Blue Disabled: 26

[1] Diode numbering range is 0-511

Table B-2: FOS DEAD AND NOISY CHANNEL SUMMARY[1]: FOS/RD

DISABLED Dead Channels	DISABLED Noisy Channels	ENABLED But Possibly Noisy
2	110	153
6	189	142
29	285	174
197	380	258/259
212	381	261
308	405	410
486	409	
	412	
7	8	6

Total Red Disabled: 15

[1] Diode numbering range is 0-511.

Table B-3: FOS DEAD AND NOISY CHANNELS HISTORY[1]: FOS/BL

DISABLED Dead Channels	DATE Died	DATE Disabled
49	2/17/88	2/17/88
101	8/28/91	12/14/91
223	4/6/88	4/6/88
284	2/17/88	2/17/88
292	9/7/93	10/11/93
409	2/17/88	2/17/88
441	6/20/91	8/3/91
471	6/1/91	8/3/91

DISABLED Noisy Channels	DATE Noticed	DATE Disabled
31	3/11/88	11/1/90
73	Prelaunch	Prelaunch
144	3/17/93	5/3/93
201	Prelaunch	Prelaunch
218	Prelaunch	Prelaunch
225	Prelaunch, ?	5/18/90,(enabled 6/11/90),11/1/90
235	10/1/90	11/1/90
241	10/3/90	11/1/90
268	Prelaunch	Prelaunch
398	12/90	2/20/91
415	Prelaunch,10/92	Prelaunch,(enabled 2/20/91), 2/15/93
427	Prelaunch, 3/5/92	Prelaunch,(enabled 2/20/91),4/13/92
451	Prelaunch	Prelaunch
465	Prelaunch	Prelaunch
472	Prelaunch	Prelaunch
497	3/11/88	11/1/90
219	Prelaunch	Prelaunch,ENABLED 2/20/91

Table B-4: FOS DEAD AND NOISY CHANNELS HISTORY[1]: FOS/RD

DISABLED Dead Channels	DATE Died	DATE Disabled
2	Prelaunch	Prelaunch
6	Prelaunch	Prelaunch
29	10/27/91	1/7/92
197	12/90	2/20/91
212	Prelaunch	Prelaunch
308	10/12/93	
486	Prelaunch	Prelaunch

DISABLED Noisy Channels	DATE Noticed	DATE Disabled
110	7/16/90	9/14/90
189	9/91	12/14/91
285	Prelaunch	Prelaunch (formerly DEAD)
380	7/91	8/3/92
381	Prelaunch,5/93	Prelaunch,(enabled 8/27/90),10/11/93
405	Prelaunch	Prelaunch
409	Prelaunch	Prelaunch
412	11/91	10/11/93
235	Prelaunch	Prelaunch,ENABLED 8/27/90
261	Prelaunch	Prelaunch,ENABLED 8/27/90
344	Prelaunch	Prelaunch,ENABLED 8/27/90

[1] Diode numbering range is 0-511.

APPENDIX C : Grating Scatter

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C. 1. Dispersion and diffraction of light in the FOS

The FOS is a single pass spectrometer with blazed, ruled gratings. Both the blue and the red side detectors cover wide spectral ranges. Therefore, the FOS is subject to ‘‘scattered" light which has its origin primarily in the diffraction patterns of the gratings and the entrance apertures, as well as the micro roughness of gratings due to their ruled surfaces. These limitations are brought about by physical principles.

Additional scattering due to contamination of optical surfaces or unbaffled stray light worsens the situation. However, the analysis of laboratory and in-flight FOS data shows that the actual instrument performance is very close to the performance anticipated from ideal optical surfaces. Therefore, the contamination of observations by scattered light can be predicted with reasonable accuracy.

For illustration of the above arguments, let the target spectrum be the model atmosphere appropriate for the Sun (Kurucz 1993), observed in the FOS BLUE G190H mode through the 0.9″ (1.0) round aperture. The detector covers a range of ± 1.47 degrees of the diffracted angle, corresponding to the wavelength range 1573 Å to 2330 Å. The 3 panels of Figure C-1 cover the range -10 to +23 degrees in diffracted angles (0 Å to 7800 Å in first order). Figure C-1 shows, in logarithmic count rates (offset by +1 in the y direction),

- the ‘‘ideal" spectrum as observed by an unphysical instrument that relates wavelengths one-to-one to diffracted angles;
- the ‘‘grating" spectrum as dispersed by the blazed grating; orders visible on the graph are 0, 1 and 2;
- the ‘‘model observations", *i.e.*, the dispersed spectrum convolved with the additional scattering imposed by the finite size aperture, the ruled surface of the grating and a minute amount of dust on the optical surfaces.

The shapes of the zero order peaks in the lower panel of Figure C-1 reflect the actual line spread function (LSF). The far wings of this LSF carry light from the peak of the original distribution into domains where the target spectrum, filtered by the total throughput of all optical elements and the detector efficiency, produces very few intrinsic counts. In addition this LSF moves photons from the zero order peak into the adjacent parts of the 1st order seen by the detector--although the zero order peak itself is correctly baffled.

In Figure C-2 are shown the actual observed count rates for the star 16 Cyg B, very similar to the Sun, overlaid with the ‘‘ideal" and the ‘‘model" observations from Figure C-1. For a solar-like target spectrum, the scattered light component ranges between 0.999 and 0.01 of the observed signal in the BLUE G190H mode.

C. 2. Predicting the contamination

UV observations of intrinsically red spectra are subject to severe contamination. A rough idea of the contamination can be obtained from Table C-1, where the log of the count ratio (Scattered+Intrinsic/Intrinsic) is listed for a variety of target spectra and high dispersion FOS modes.

As a guide to the wavelength range where scattered light will dominate over the signal for a given target spectrum, one determines the signal count rate spectrum:

$$N_{\lambda} = F_{\lambda} * E_{\lambda}$$

where N_{λ} is the count rate per diode, F_{λ} is the incident spectrum, and E_{λ} is the efficiency as a function of wavelength for the spectral range (FOS mode) of interest, and for the adjacent modes (wavelength ranges) towards the red. Scattered light will dominate the signal in regions were N_{λ} falls off more rapidly than the LSF. The medium range (10-500 diode) wings of the LSF can be approximated by an inverse square function $(\text{diode-diode}_0)^{-2}$, the conversion from λ-space into diode-space is provided in Table 1-3 (FOS Dispersers).

In order to accurately predict the contamination by scattered light for a given grating/detector/aperture combination, an appropriate estimate of the intrinsic energy distribution of the target is required; and the properties of all optical components have to be taken into account in detail. Software to model the resultant count rate spectra will soon be made available in the IRAF/STSDAS FOS analysis package.

C. 3. Advice to proposers

- UV spectra shortward of 2500 Å of very red targets may be obtained almost free of scattered red light in the low resolution modes of the GHRS.
- Use the BLUE Digicon for very red targets (later than K3) for G190H observations to reduce the amount of far red scattered photons.
- Consult Table C-1 to find the wavelength range where the scattered light starts to dominate. Observations of continuum sources shortward of this range are absolutely useless, unless the intrinsic spectra flatten off. For example, the coronal emission in α Ori (M0Iab) can be traced in a G130H spectrum, but a quantitative assessment is impossible.
- Contaminated data with a ratio of scattered counts over intrinsic counts of up to 5 can likely be corrected **provided** the intrinsic target spectrum is known for longer wavelengths, **and provided** the exposure times are chosen such as to give enough S/N for the weak signal in the total of signal+scattered counts. It is also advisable to obtain a target spectrum at longer wavelengths, at least with the adjacent FOS range.

C.4. Appendix C. References

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Table C-1: Logarithmic ratios of count rates (Scattered+Intrinsic)/(Intrinsic)} for unreddened stars. FOS, blue detector

A0 V G130H		G5 V G190H		K3 III G270H	
λ	log[(S+I)/I)]}	λ	log[(S+I)/I)]	λ	log[(S+I)/I])
1170	0.98	1600	2.92	2250	1.49
1215	1.73	1700	1.00	2350	1.15
1250	0.18	1800	0.41	2500	0.52
1300	0.02	1900	0.19	2700	0.24
1400	0.01	2000	0.07	3000	0.02
1600	0.00	2300	0.01	3300	0.00

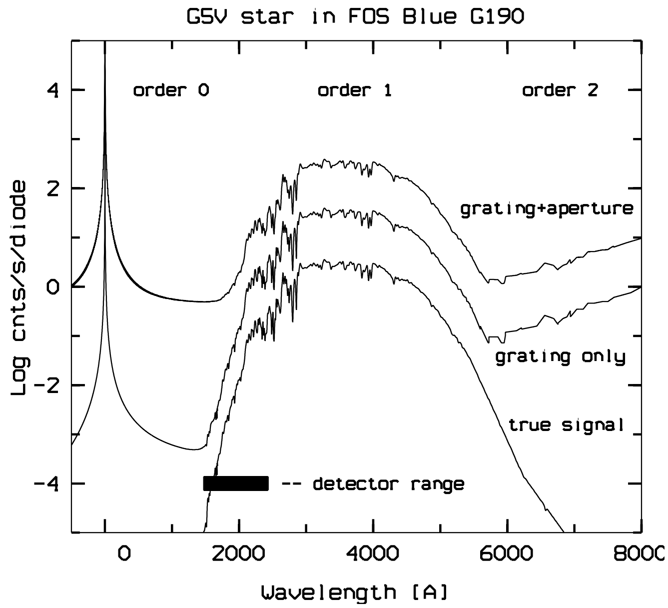

Figure C-1: FOS Blue G190H Count rate spectra for a G5 V model atmosphere in the detector plane. See text. Note that the real detector only covers the wavelength range marked by a thick bar.

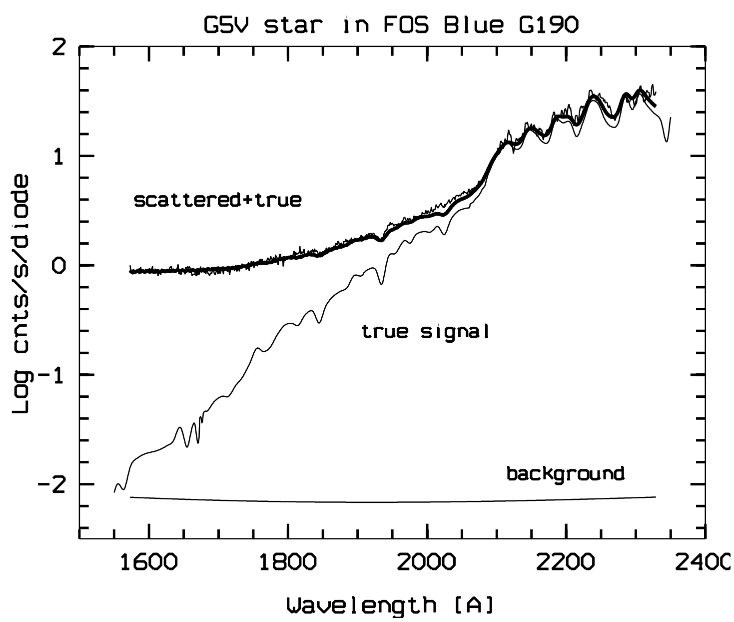

Figure C-2: FOS Blue G190H data for the G5 V star 16 Cyg B. The count rate spectrum due to intrinsic photons and the composite of intrinsic and scattered photons are overlaid.

Appendix D : FOS Wavelength Comparison Spectra

This appendix provides maps of the FOS Pt-Cr-Ne comparison spectrum for each FOS detector/disperser combination except the prism. The spectra are plotted as count-rates versus wavelength in Figures D-1 through D-14. Table D-1 contains a listing of the vacuum wavelength and element-of-origin for 159 potentially usable FOS comparison lines in the spectral range 1200-8800 Ångstroms. The wavelength of each of these lines is indicated by a diamond symbol in the figures. Please note that some of the lines marked on any particular plot may not be used in actual FOS dispersion-relation calibration computations.

Table D-1: Wavelength and Identification of FOS Comparison Lines

Vacuum Wavelength	Element	Vacuum Wavelength	Element	Vacuum Wavelength	Element
1238.852	Pt	1907.494	Ne	2390.262	Pt
1248.610	Pt	1911.710	Pt	2440.797	Pt
1271.793	Pt	1916.083	Ne	2487.919	Pt
1309.496	Pt	2037.089	Pt	2509.195	Pt
1327.432	??	2050.097	??	2603.913	Pt
1378.956	Pt	2076.139	Pt	2628.815	Pt
1382.046	Pt	2129.283	Pt	2640.132	Pt
1410.135	??	2144.922	Pt	2651.641	Pt
1482.826	Pt	2165.872	Pt	2703.205	Pt
1494.726	Pt	2175.352	Pt	2706.696	Pt
1509.272	Pt	2191.000	Pt	2734.770	Pt
1524.704	Pt	2235.610	Pt	2763.736	Ne
1530.199	??	2246.215	??	2772.490	Pt
1534.894	Pt	2263.363	Pt	2810.327	Cr
1554.929	Pt	2269.542	Pt	2876.693	Pt
1574.322	Pt	2275.083	Pt	2890.137	Cr
1581.399	??	2293.085	Pt	2894.720	Pt
1621.718	Pt	2311.668	Pt	2930.652	Pt
1688.358	Ne	2319.007	Pt	2956.594	Ne
1723.158	Pt	2340.894	Pt	2964.156	Ne
1867.100	Pt	2357.825	Pt	2987.111	Cr
1883.079	Pt	2378.002	Pt	2998.845	Pt
3022.460	Cr	3970.873	Cr	5946.479	Ne

Table D-1: Wavelength and Identification of FOS Comparison Lines

Vacuum Wavelength	Element	Vacuum Wavelength	Element	Vacuum Wavelength	Element
3089.126	??	3977.795	Cr	6031.672	Ne
3204.966	??	3985.026	Cr	6076.024	Ne
3219.139	Ne	3992.249	Cr	6097.851	Ne
3245.086	Ne	4127.875	Cr	6144.763	Ne
3298.689	Ne	4255.528	Cr	6165.298	Ne
3302.810	Pt	4276.013	Cr	6219.003	Ne
3310.732	Ne	4290.938	Cr	6268.226	Ne
3324.706	Ne	4345.731	Cr	6306.536	Ne
3379.250	Ne	4352.993	Cr	6336.184	Ne
3409.107	Pt	4372.508	Cr	6384.757	Ne
3418.880	Ne	4386.202	Cr	6404.022	Ne
3448.688	Ne	4581.334	Cr	6508.330	Ne
3473.564	Ne	4602.040	Cr	6534.688	Ne
3521.476	Ne	4627.477	Cr	6600.775	Ne
3543.912	Ne	4647.452	Cr	6680.127	Ne
3569.549	Ne	4653.463	Cr	6718.897	Ne
3594.575	Cr	4757.421	Cr	6931.385	Ne
3606.349	Cr	4923.655	Cr	7034.353	Ne
3634.705	Ne	5039.156	Ne	7175.920	Ne
3665.154	Ne	5081.797	Ne	7247.170	Ne
3695.251	Ne	5117.927	Ne	7440.953	Ne
3728.140	Ne	5299.666	Ne	7490.937	Ne
3744.954	Cr	5332.264	Ne	8084.688	Ne
3778.232	Ne	5402.063	Ne	8138.653	Ne
3819.774	Pt	5411.286	Cr	8302.612	Ne
3909.867	Cr	5658.231	Ne	8379.914	Ne
3920.270	Cr	5749.896	Ne	8420.745	Ne
3929.762	Cr	5806.062	Ne	8497.699	Ne
3942.616	Cr	5854.114	Ne	8656.766	Ne
3964.811	Cr	5883.522	Ne	8783.038	Ne

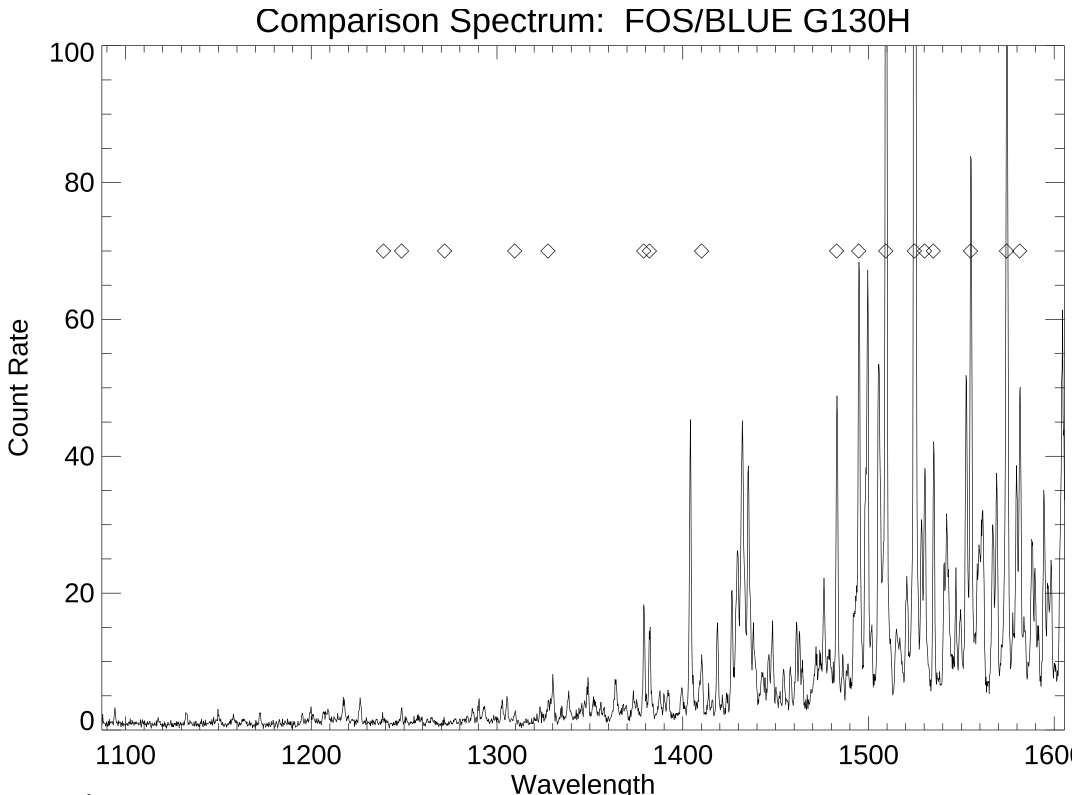

Figure D-1:

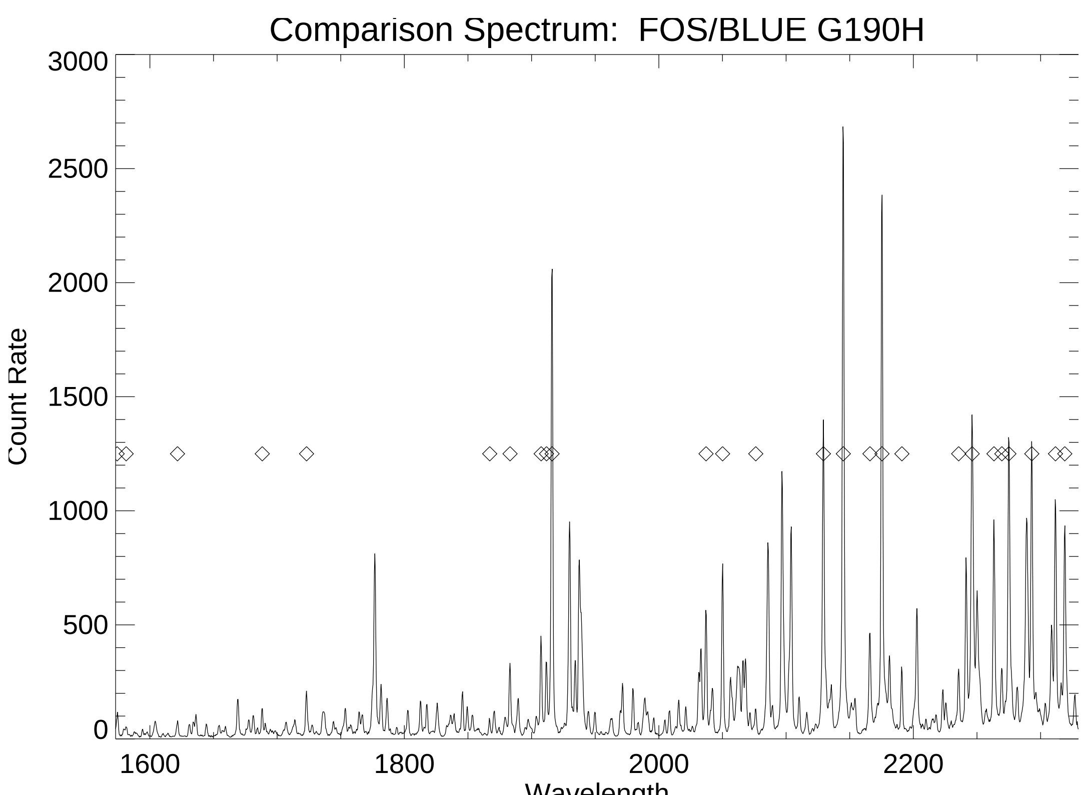

Figure D-2:

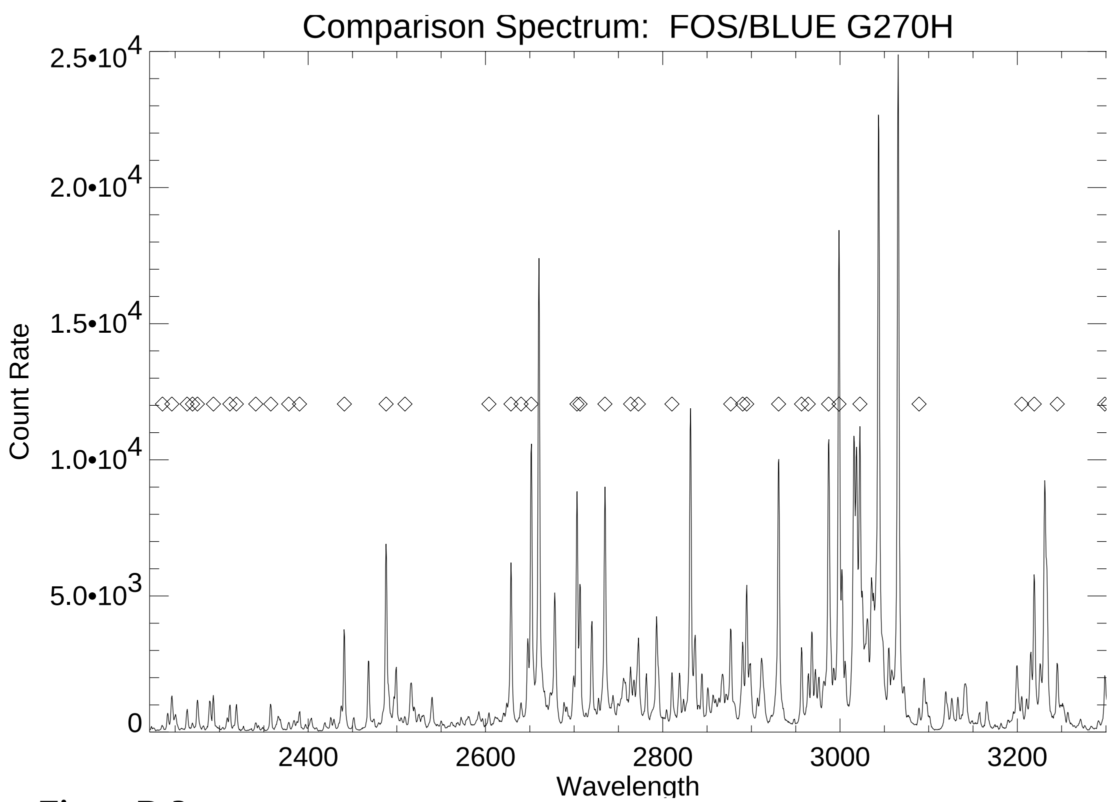

Figure D-3:

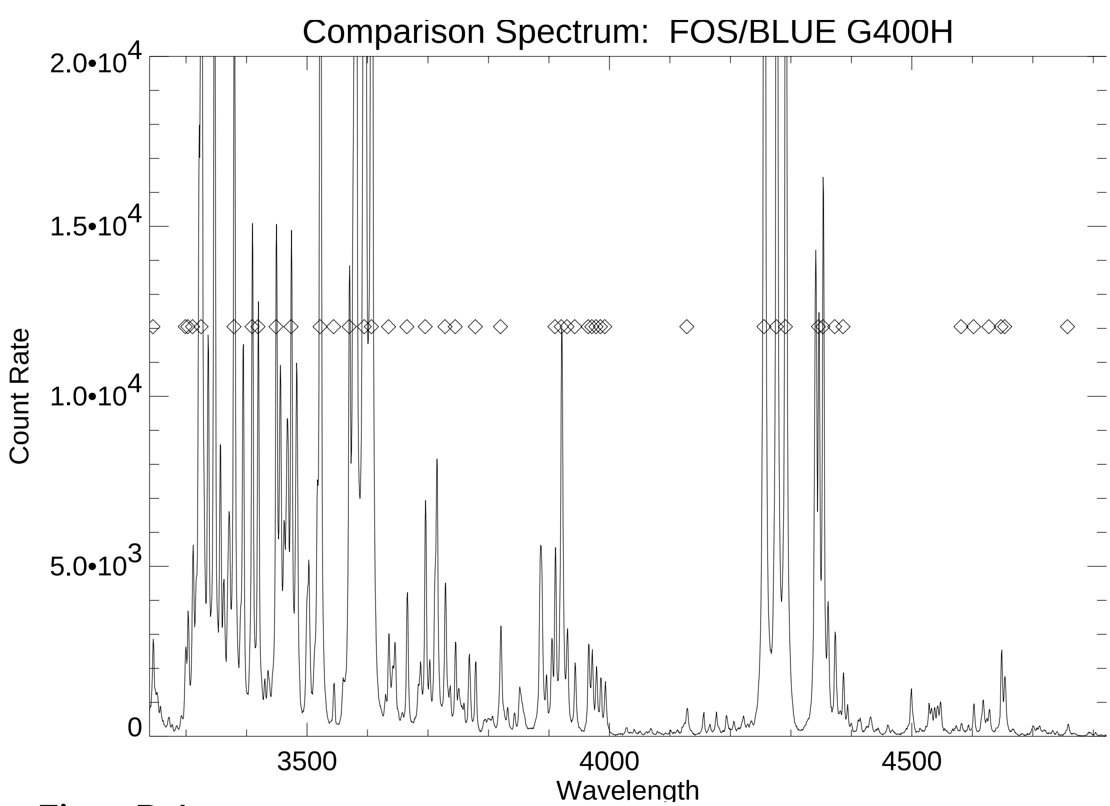

Figure D-4:

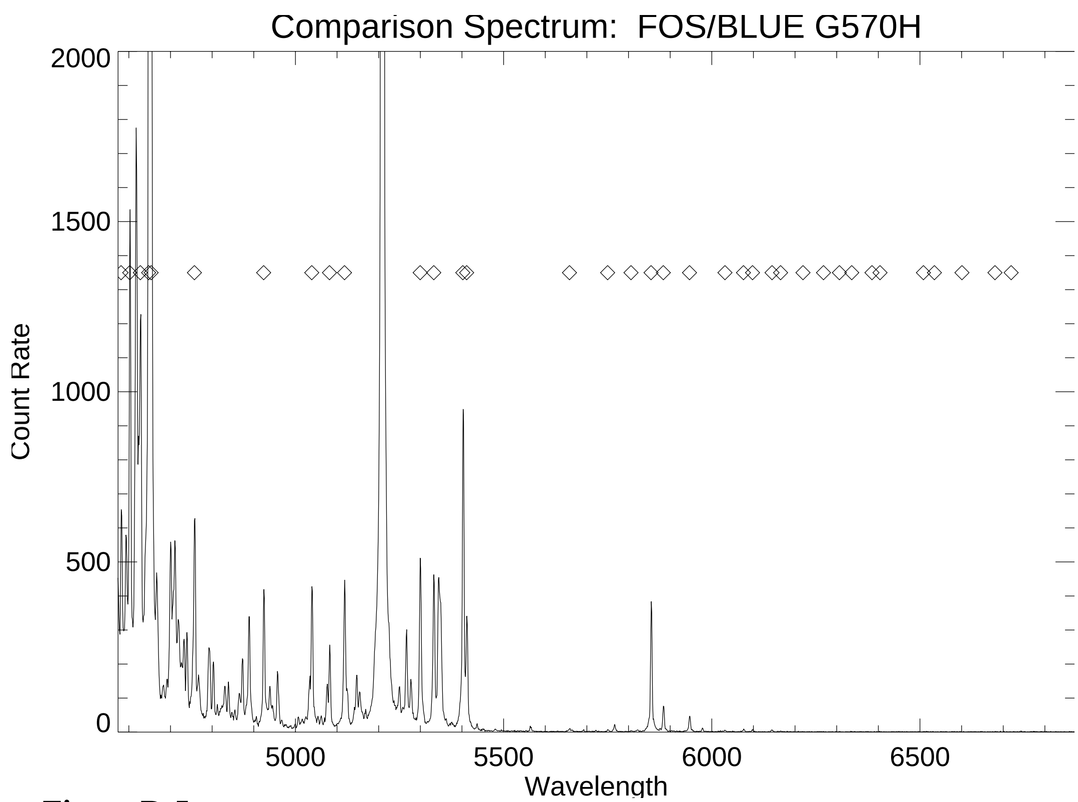

Figure D-5:

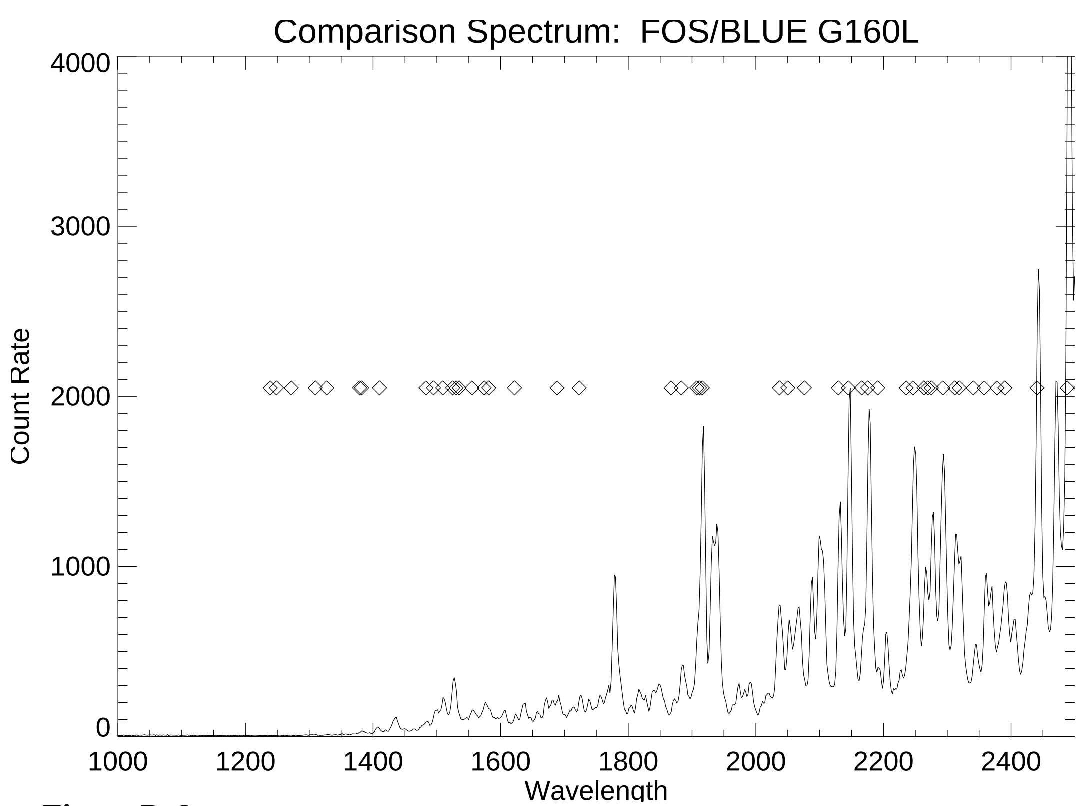

Figure D-6:

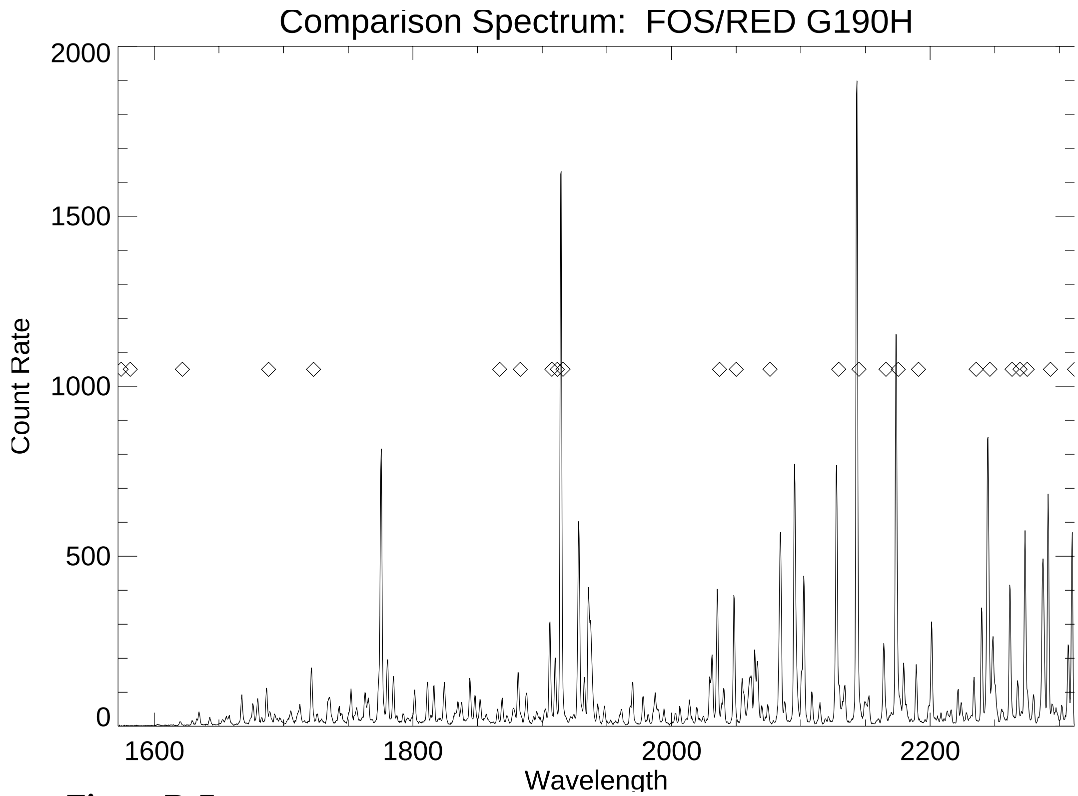

Figure D-7:

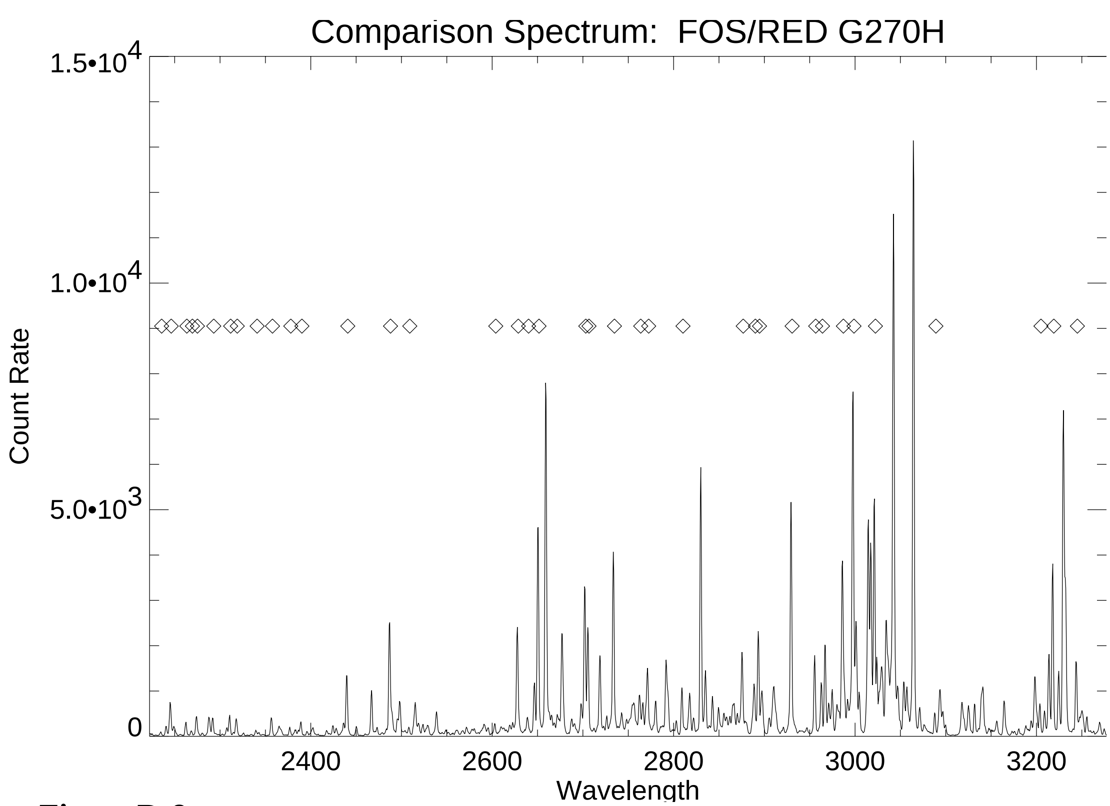

Figure D-8:

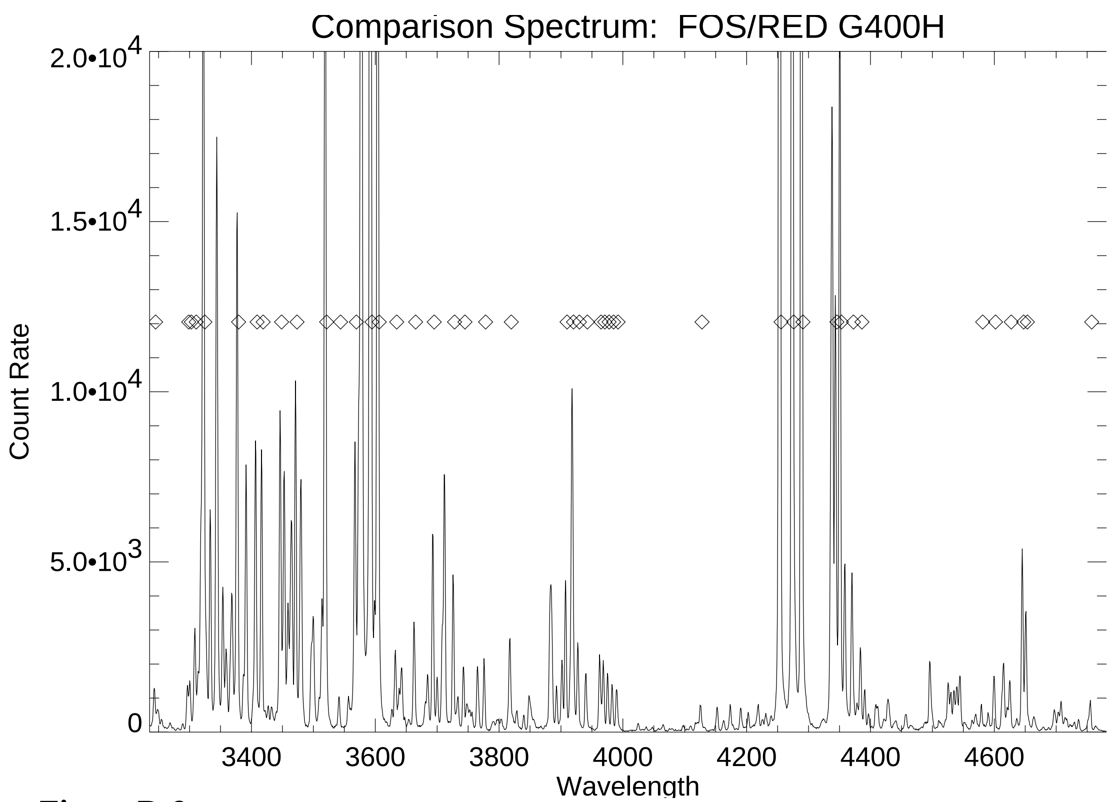

Figure D-9:

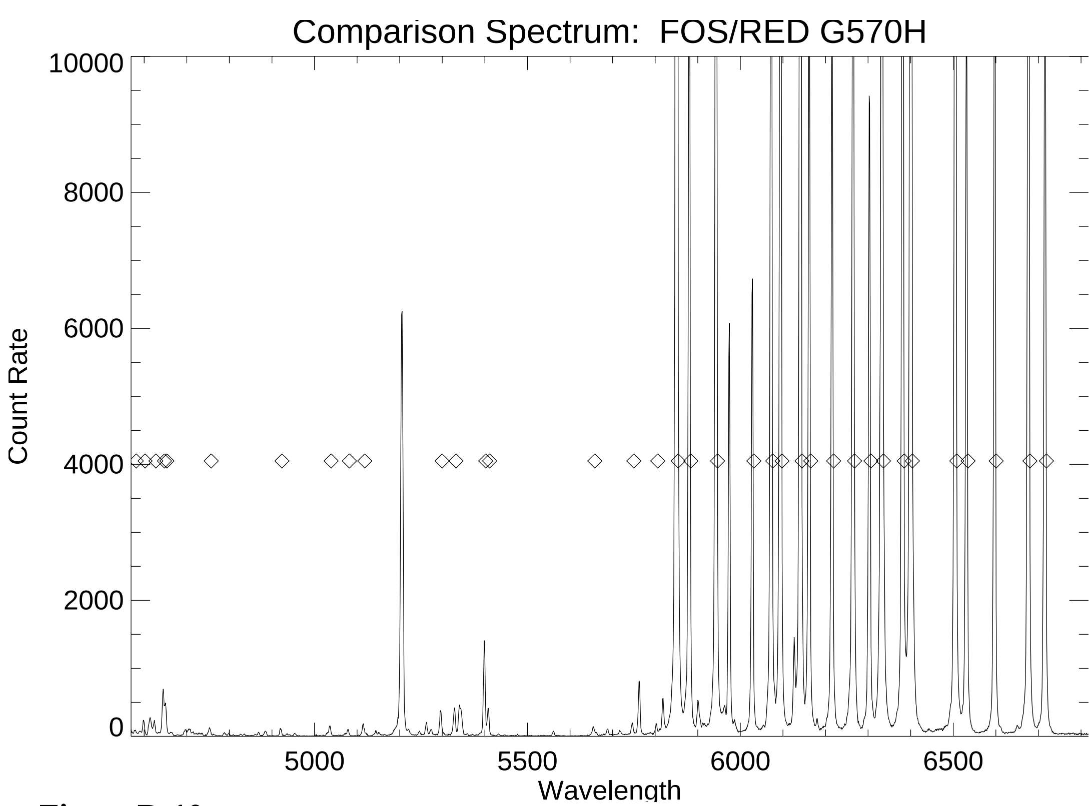

Figure D-10:

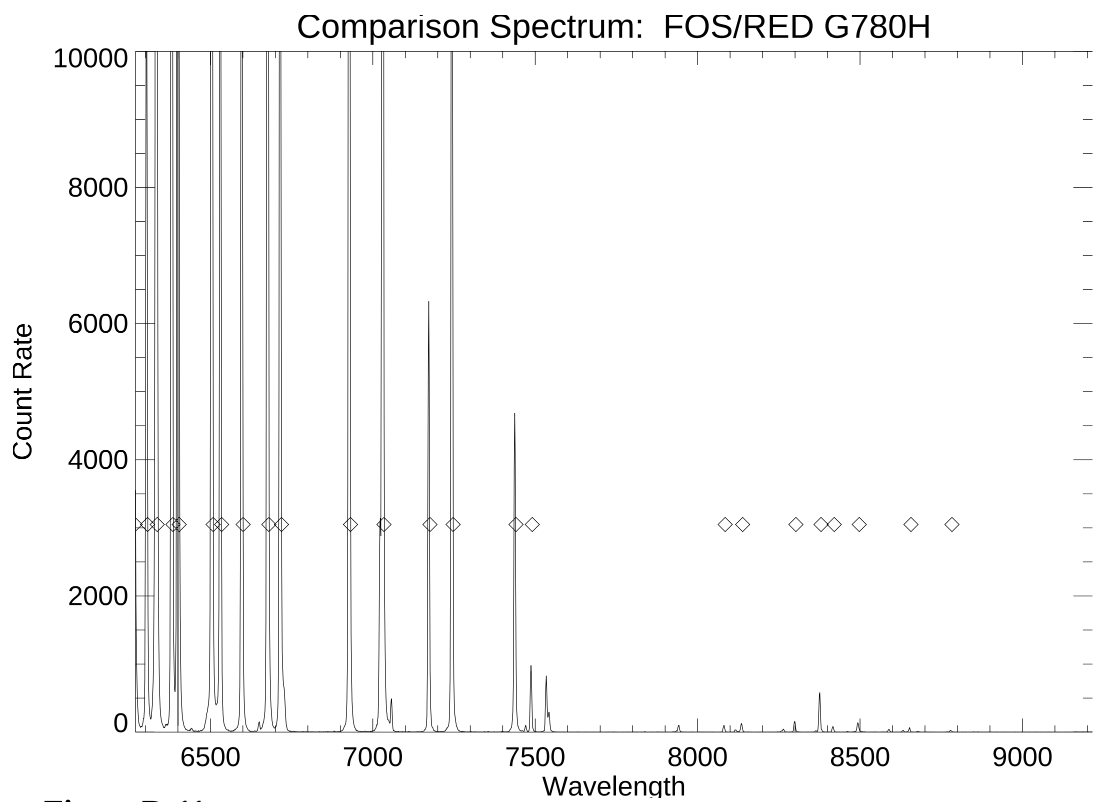

Figure D-11:

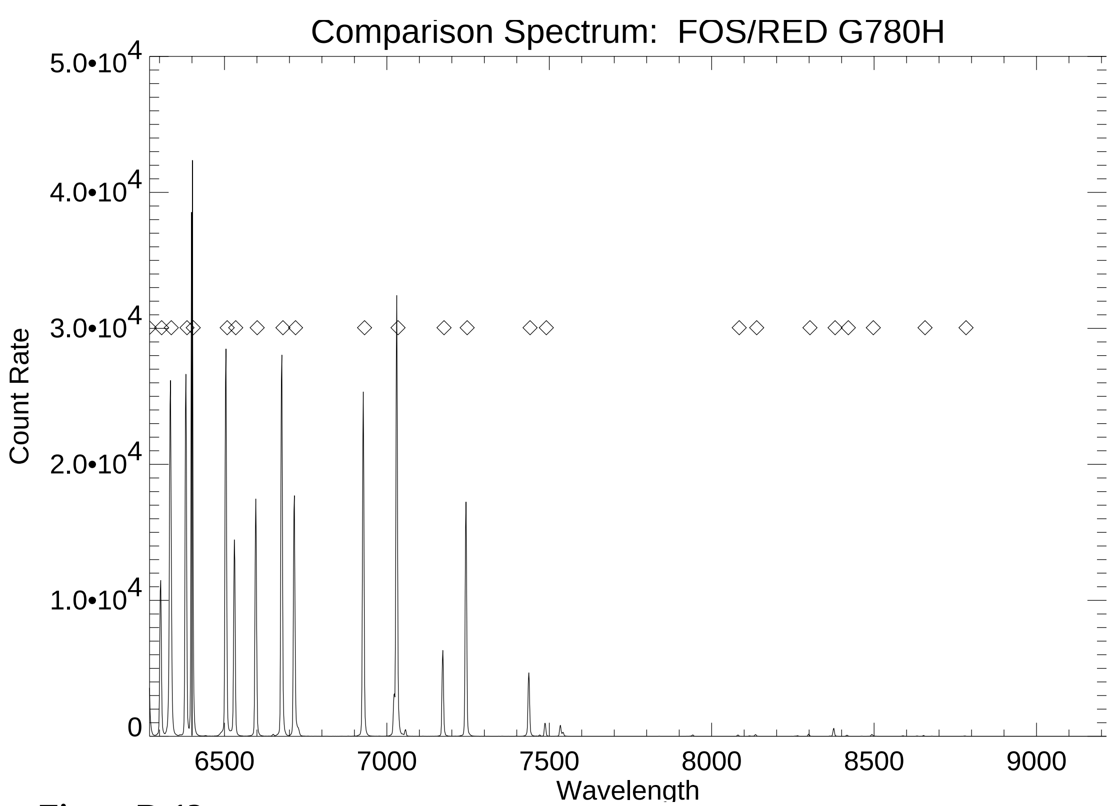

Figure D-12:

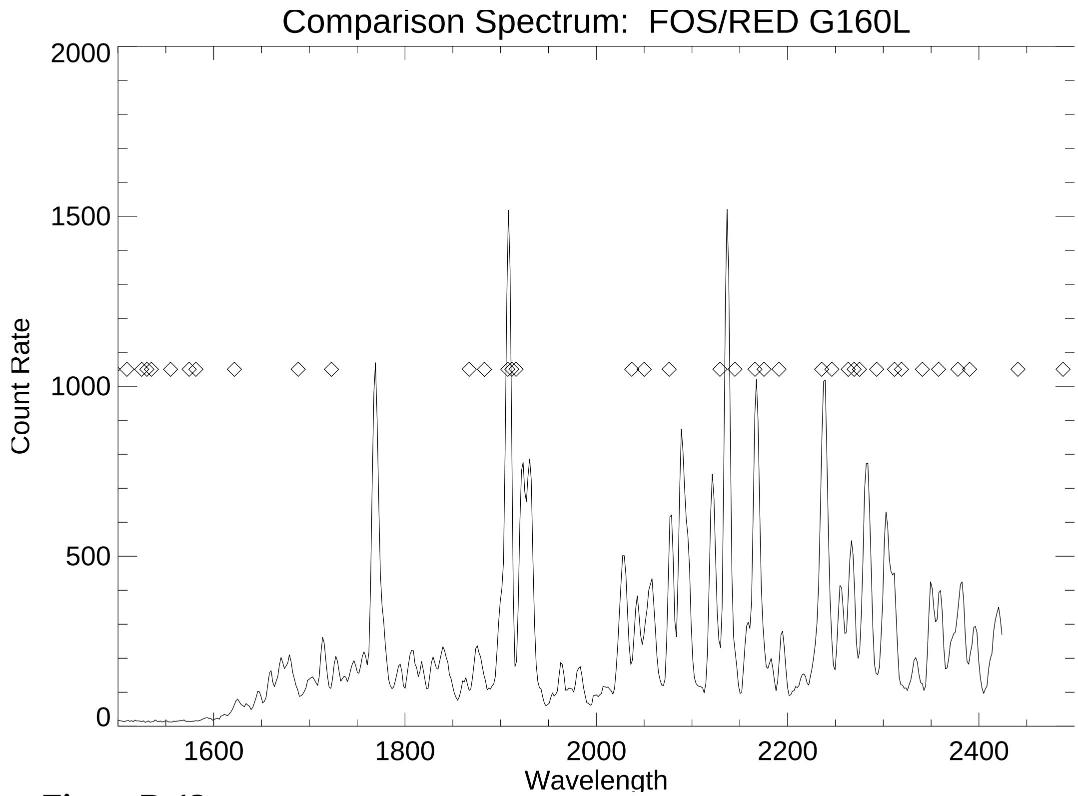

Figure D-13:

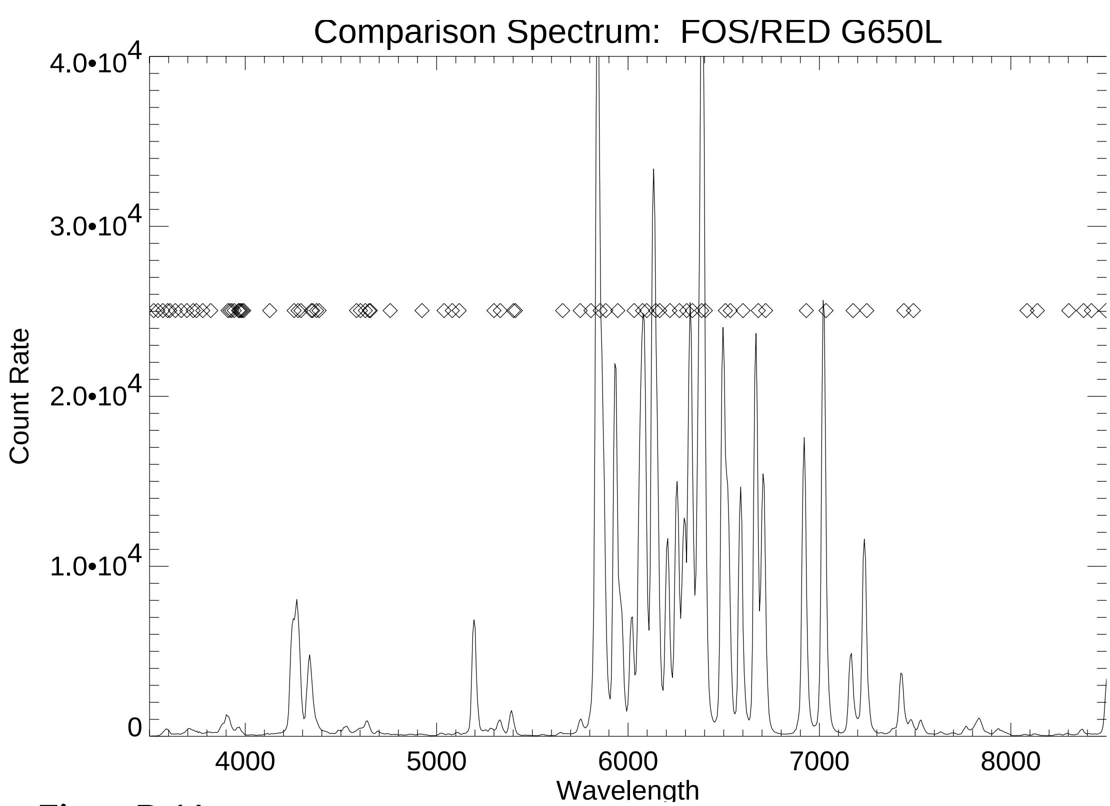

Figure D-14:

APPENDIX E : Faint Object Spectrograph Instrument Science Reports

CAL/FOS-series Instrument Science Reports as of 1 May 1995

134 - *Cycle 3 FOS Red Side Super-Flats*, D. Lindler, R. Bohlin, and C. Keyes, January 1995.
133 - *Location of FOS Spectra: Cycle 4*, A. Koratkar, C. Keyes, and S. Holfeltz, January 1995.
132 - *FOS Target Acquisition Strategies (SHORT VERSION for Cycle 5 Phase II Reference)*, C. D.(Tony) Keyes, A. P. Koratkar, and I. N. Evans, January 1995
131 - *Post-COSTAR FOS Aperture Wheel Repeatability Measurements*, M. Dahlem and A. Koratkar, December 1994.
130 - *Calibration Product Review for the Faint Object Spectrograph*, C. D. Keyes, A. P. Koratkar, and A. L. Kinney, November 1994.
129 - *Recalibrating Pre-COSTAR FOS Data*, H. A. Bushouse, November 1994.
128 - *Failure Analysis of the New FOS Peakup Algorithm*, J. Skapik and J. Fitch, September 1994.
127 - *The FOS Scattered Light Model Software*, M. R. Rosa, September 1994.
126 - *FOS Pre-COSTAR Target Pointing Anaylsis*, C. J. Taylor, August 1994.
125 - *Pre-COSTAR Photometric Calibration of the Faint Object Spectrograph*, D.J. Lindler and R.C. Bohlin, June 1994.
124 - *High Speed Spectroscopy using the FOS in Rapid Mode*, W. Welsh, D. Chance, C. Keyes, and M. Reinhart, May 1994.
123 - *SMOV Report V: FOS Plate Scale and Orientation*, A. Koratkar, T. Wheeler, I. Evans, O. Lupie, C. Taylor, C. Keyes, and A. Kinney, May 1994.
122 - *FOS Pre-COSTAR Blue Side: Target Acquistion Accuracy*, E. Vassiliadis, R. Bohlin, A. Koratkar, I Evans, April 1994.
121 - *SMOV Report IV: The Absolute Locations of the FOS 1.0 Apertures*, I. Evans, A. Koratkar, C. Taylor, and C. Keyes, May 1994.
120 – *FOS Aperture Transmissions for Point Sources*, R.C. Bohlin, February 1994.
119 – *The Faint Object Spectrograph Binary Search Target Acquisition Simulator BS4*, I Evans, February 1994.
118 – *SMOV Report III: FOS Baseline Sensitivity*, C. Keyes, A. Kinney, A. Koratkar, C. Taylor, January 1994.
117 – *SMOV Report II: FOS Coarse Alignment 4907*, A. Kinney, A. Koratkar, O. Lupie, C. Taylor, and C. Keyes.
116 – *SMOV Report I: Location of FOS Spectra*, A. Koratkar, C. Taylor, A. Kinney, and C. Keyes.
115 – *Scattered Light in the G130H and G190H Modes of the HST Faint Object Spectrograph*, T.R. Ayres, November 1993.
114 – *Scattered Light in the FOS: An Assessment Using Science Data*, M.R. Rosa, November 1993.
113 - *Reference Guide and Complete History of FOS Calibration ReferenceFiles and Tables* , C. J. Taylor and C. D. Keyes, August, 1994.
112 - *FOS Dead Diode Reference Files: A Quick Reference Guide to the Appropriate File for a Particular Date and Instrumental Configuration*, C, J. Taylor, August 1994.
111 - not completed.
110 – *Location of FOS Spectra: Cycle 3 Results*, A. Koratkar, December 1993.

109 – *FOS Calibration Plan for Cycle 4*, A. Koratkar, A. Kinney, C. Keyes, I. Evans, and C. Taylor, November 1993.
108 – *FOS Calibration Plan for SMOV*, A. Koratkar, C. Keyes, A. Kinney, I. Evans, and C. Taylor, November 1993.
107 – *Pre-COSTAR FOS Aperture Throughputs for Mis-centered Targets Derived from PSF Models*, I.N. Evans, November 1993.
106 – *Pre-COSTAR FOS Aperture Transmissions for Point Sources and Surface Brightness of Diffuse Sources*, R.C. Bohlin, October 1993.
105 – *Pre-COSTAR FOS Aperture Throughputs from Models*, I.N. Evans, September 1993.
104 – *Pre-COSTAR FOS Point Spread Functions and Line Spread Functions from Models*, I.N. Evans, September 1993.
103 – *Background Due to Scattered Light*, A.L. Kinney and R.C. Bohlin, September 1993.
102 – *FOS Aperture Throughput Variations Due to Focus Changes*, D.L. Lindler and R.C. Bohlin, August 1993.
101 – *Removal of Straylight in FOS Observations*, E. Kinney and R. Gilmozzi, June, 1994.
100 – C*ycle1/Cycle2 Discriminator Settings*, C.J. Taylor and A.L. Kinney, February 1994.
099 – *Serendipitous Background Monitoring of the Hubble Space Telescope's Faint Object Spectrograph*, J.E. Fitch and G. Schneider, August 1993.
098 – *Correction of the Geomagnetically-Induced Image Motion Problem on the Hubble Space Telescope's Faint Object Spectrograph*, J.E. Fitch, G.F. Hartig, E.A. Beaver and R.G. Hier, August 1993.
097 – *Light Loss in FOS as a Function of Pointing Error*, R.C. Bohlin, August 1993.
096 – *Location of FOS Spectra: Cycle 1 and Cycle 2 Results*, A. Koratkar and C. J. Taylor, August 1993.
095 – *Location of FOS Polarimetry*, Anuradha Koratkar and C.J. Taylor, June 1993.
094 – *FOS Calibration Plan for Cycle 3*, C. D. (Tony) Keyes and A. Koratkar, June 1993.
093 – *FOS Inverse Sensitivity Reference Files: A Quick Reference Guide to the Appropriate File for a Particular Date and Instrumental Configuration*, C.J. Taylor and C.D. (Tony) Keyes, June 1993.
092 – *The Post COSTAR Rotation Matrices for Calculating V2,V3 Offsets in Mode 2 FOS Target Acquisition*, A.P. Koratkar and O. Lupie.
091 – *A Rough Photometric Calibration for FOS, BLUE, G160L, ORDER0*, K. Horne and M. Eracleous, August 1993.
090 – *FOS Flat Field Reference Files: A Quick Reference Guide to the Appropriate File for a Particular Date and Instrumental Configuration*, C. Keyes and C. Taylor.
089 – not completed.
088 – *FOS Flats From Super Spectra*, D. Lindler, R. Bohlin, G. Hartig, and C. Keyes, March 1993.
087 – *FOS Blue Detector Plate Scale and Orientation*, A. Koratkar, May 1993.
086 – *Analysis of Photometric Standards following July 1992 FOS Over-light Safing Event*, C. J. Taylor and C.D. Keyes, December 1992.
085 – *FOS Aperture Throughput Variations with OTA Focus*, D. Lindler and R. Bohlin, August 1992.
084 – *Photometric Calibration of the Faint Object Spectrograph and Other HST Scientific Instruments*, R.C. Bohlin and J.D. Neill, July 1992.

083 – *Faint Object Spectrograph On-Orbit Sky Background Measurements*, R.W. Lyons, W. Baity, E.A. Beaver, R.D. Cohen, V.T. Junkkarinen, and J.B. Linsky, August 1992.
082 – *Lab Test Results of the FOS Detector Performance in a Variable External Magnetic Field*, E.A. Beaver and P. Foster, June 1992.
081 – *FOS Onboard Target Acquisition Tests,* S. Caganoff, Z. Tsvetanov, and L. Armus, April 1992.
080 – *FOS On-Orbit Background Measurements,* R. W. Lyons, J.B. Linsky, E.A. Beaver, W. A. Baity, and E. I. Rosenblatt, April 1992.
079 – *FOS Operation in the South Atlantic Anomaly*, W. A. Baity, E.A. Beaver, J.B. Linsky and R. W. Lyons, April 1992.
078 – *FOS Polarimetry Calibration [update of CAL/FOS 055]*, R.G. Allen and P.S. Smith, March 1992.
077 – *Photometric Calibration of the FOS,* J. D. Neill, R. C. Bohlin, and G. Hartig, June 1992.
076 – *Analysis of FOS On-Orbit Detector Background with Burst Noise Rejection*, E.A. Beaver and R. W. Lyons, April 1992.
075 – *FOS Spectral Flat Field Calibration (Science Verification Phase Data),* S.F. Anderson, February 1992.
074 – *On-Orbit Discriminator Settings for FOS*, R.D. Cohen, July 1992.
073 – *Scattered Light Characteristics of the HST FOS*, F. Bartko, G.S. Burks, G. A. Kriss, A.F. Davidsen, R.D. Cohen, V.T. Junkkarinen, and R. Lyons, April 1992.
072 – *Aperture Calibrations During Science Verification of the FOS*, L. Dressel and R. Harms, May 1992 (never completed).
071 – *An Analysis of FOS Background Dark Noise*, E.I. Rosenblatt, W.A. Baity, E.A. Beaver, R.D. Cohen, V.T. Junkkarinen, J.B. Linsky, and R. Lyons, April 1992.
070 – *Internal/External Offsets in the FOS Wavelength Calibration,* G.A. Kriss, W.P. Blair, and A.F. Davidsen, February 1992.
069 – *FOS Red Detector Flat-field and Sensitivity Degradation*, G. Hartig, November 1991.
068 – *FOS Red Detector Plate Scale and Orientation*, B. Bhattacharya and G. Hartig, November 1991.
067 – *In-Flight FOS Wavelength Calibration–Template Spectra*, G.A. Kriss, W.P. Blair, and A.F. Davidsen, February 1991.
066 – *Geomagnetic Image Deflection Problem in the Faint Object Spectrograph*, V.T. Junkkarinen, E.A. Beaver, R.D. Cohen, R. Hier, R. Lyons, and E. Rosenblatt, April 1992.
065 – *The Rotation Matrix for Calculating V2, V3 Offsets in Mode 2 FOS TA*, A.L. Kinney and G. Hartig, March 1990.
064 – *FOS Dead and Noisy Channel Update,* R. Cohen and E. Beaver, October 1989.
063 – *FOS Project Data Base Aperture Files*, A.L. Kinney and C. Cox, October 1989.
062 – *Long Term FOS Calibration Plan*, A.L. Kinney and G.F. Hartig, August 1989.
061 – *FOS Optical Focus and Resolution*, T. Ed Smith and G. Hartig, October 1989.
060 – *FOS Filter-Grating Wheel Repeatability: Dependence on Motor Selection*, G. Hartig, May 1989.
059 – *Scattered Light Perpendicular to the Dispersion in the FOS*, A. Uomoto, W.P. Blair and A.F. Davidsen, March 1989.
058 – *Scattered Red Light in the FOS,* W. P. Blair, A.F. Davidsen, and A. Uomoto, March 1989 (never completed).
057 – *Image Drift After HV Turn-on,* W. Baity and E. Beaver, February 1989.

056 – *FOS Internal/External Wavelength Offsets*, W.P. Blair, G. A. Kriss, and A.F. Davidsen, December 1988.
055 – *FOS Polarimetry,* R.G. Allen and P.S. Smith, November 1988 (never completed).
054 – *Revised FOS Wavelength Calibration,* G.A. Kriss, W.P. Blair, and A.F. Davidsen, November 1988.
053 – *Laboratory Calibration of FOS Throughput*, G. Hartig, January 1989.
052 – *Results of TA Related Tests,* A. Kinney, February 1989.
051 – *Dead and Noisy Diode Summary,* R. Cohen, April 1989.
050 – *FOS Discriminator Settings*, R. Cohen, E. Beaver, and D. Tudhope, May 1990.
049 – *FOS Filter Grating Wheel Repeatability (Revised),* G. Hartig, October 1988.
048 – *FOS Wavelength Calibration Exposures*, G. Hartig, October 1988.
047 – *FOS Exposure Limits*, G. Hartig, October 1988.
046 – *FOS Aperture Wheel Repeatability,* R. Harms and R. Downes, October 1988.
045 – *FOS Linearity Corrections (Revisited)*, D. Lindler and R. Bohlin, August 1988.
044 – *Limiting Accuracy of FOS Wavelengths Calibration,* R. Bohlin, M. Sirk, and G. Hartig, October 1987.
043 – *FOS Target Acquisition Cook Book*, A. Kinney and R. Antonucci, May 1988.
042 – *FOS Target Acquisition for Moving Targets*, A. Kinney, June 1987 (never completed).
041 – *Wavelength Offsets Among Internal Lamps and External Sources,* M. Sirk and R. Bohlin, April 1987.
040 – *Results of Target Acquisition Tests: Feb. 1987,* A. Kinney, March 1987.
039 – *FOS Entrance Aperture Transmittance for Point Sources*, G. Hartig, November 1986.
038 – *FOS Wavelength Scale Below the Calibration Lamp Cutoff at 1239A (Lab. Calibration Plan 13B)*, M. Sirk and R. Bohlin, October 1986.
037 – *Ambient QE Measurements of the FOS Red Side*, G. Hartig, October 1986.
036 – *TV Monitoring of the F8 Detector Red Sensitivity (Test SegmentMONTHLY)*, G. Hartig, August 1986.
035 – *Results of TA Tests at LMSC: Feb. 1986*, A. Kinney, August 1986.
034 – *FOS Throughput Optical Test Results*, G. Hartig, August 1986 (never completed).
033 – *Thermal Vac Measurements of the FOS Filter Grating Wheel Repeatability*, G. Hartig, August 1986.
032 – *An Automated Method for Computing Absolute Instrumental Sensitivity Curves for FOS: Results of Testing on IUE,* D. Lindler and R. Bohlin, August 1986.
031 – *Commanding FOS Target Acquisition*, T.M. Gasaway and A. Kinney, June 1986.
030 – *Limiting Magnitudes for FOS Target Acquisition*, A. Kinney, April 1986.
029 – *FOS Entrance Aperture Offsets (Calibration Plan 136),* M. Sirk and R. Bohlin, May 1986.
028 – *Exposure Times for FOS Wavelength Calibration—Apr. 1986*, M. Sirk and R. Bohlin, April 1986.
027 – *Firmware Target Acquisition*, A. Kinney, R.G. Hier, and H. Ford, June 1986.
026 – *FOS Wavelength Calibration - Jan 1986 (Laboratory Calibration Plan 13b),* M. Sirk and R.
025 – *FOS Linearity Corrections - Jan. 1986*, D. Lindler and R. Bohlin, January 1986.
024 – *Results of Binary Search Target Acquisition Tests of August, 1985*, A. Kinney and H. Ford, November 1985.
023 – *Mode 2 Target Acquisition: Binary Search Parameters, Oct. 1985,* A. Kinney and H. Ford, October 1985.

022 – *Locating Spectra on the FOS Digicons & The Photometric Consequences of Errors in Position, Oct. 1985*, J. Wheatley and R. Bohlin, October 1985 (never completed).
021 – *LMSC NSSC-1 Target Acquisition Tests of Feb. 1985*, D. Lindler, A. Kinney, and H. Ford, September 1985.
020 – *Scattered Light from Bright Emission Lines (Calibration Plan 12B),* M. Sirk and R. Bohlin, September 1985.
019 – *FOS Entrance Aperture Sizes (Calibration Plan 10B)*, D. Lindler and R. Bohlin, July 1985.
018 – *FOS Line Widths (FWHM) as a Function of Aperture Size*, A. Kinney and H. Ford, May 1985.
017 – *Improvements in Filter/Grating Wheel Repeatability*, G. Hartig, May 1985.
016 – *Absolute Photometric Calibration of the FOS*, G. Hartig, June 1985.
015 – *Scattered Light from Bright Emission Lines Preliminary Version (Calibration Plan 12B),* M. Sirk and R. Bohlin, March 1985.
014 – *Internal FOS PT-CR-Ne Calibration Lamps—Performance in the Far UV,* M. Sirk and R. Bohlin, March 1985.
013 – *Scattered Red Light—Preliminary Version (Calibration Plan 12A),* M. Sirk and R. Bohlin, January 1985.
012 – *FOS Filter Grating Wheel Repeatability (Calibration Plan 10D)*, G. Hartig, R. Bohlin, H. Ford, and R. Harms, December 1984.
011 – *Scattered Light Background Perpendicular to the Dispersion—Preliminary Version (Calibration #19)*, D. Lindler and R. Bohlin, January 1985.
010 – *High Voltage Settle (FOS Calibration #08)*, D. Lindler and R. Bohlin, December 1984.
009 – *FOS Firmware Target Acquisition*, H. Ford, June 1984.
008 – F*OS Aperture Repeatability & Filter–Grating Wheel Repeatability (Calibration Plan 10C & 10D)*, J. Wheatley, H. Ford, and R. Bohlin, March 1984.
007 – *FOS Scattered Light Measurements (Cal. Plan #128)*, J. Wheatley and R Bohlin, March 1984.
006 – *FOS Flat Field Calibration (FOS Calibration #15)*, D. Lindler and R. Bohlin, March 1984.
005 – *FOS-Scattered Red Light (Red Tube)*, J. Koornneef, January 1984.
004 – *FOS Wavelength Calibration*, J. Wheatley and R. Bohlin, December 1983.
003 – *Recent FOS Calibration at GSFC*, J. Wheatley and R. Bohlin, November 1983.
002 – *FOS Entrance Aperture Sizes*, J. Wheatley, R.C. Bohlin, and H. Ford, October 1983.
001 – *Lab. Calibration of the FOS: Absolute Sensitivity (First Results for the Blue Side)*, J. Koornneef, R. Bohlin and R. Harms, August 1983.

SCS-series (Standard Calibration Source) Instrument Science Reports

002 – *Preliminary Comparison of the HST and White Dwarf Absolute Flux Scales*, R. Bohlin, December 1993.
001 – *Updates to HST Standard Star Fluxes*, R. Bohlin and D. Lindler, July 1992.

APPENDIX F : Sample RPS2 Proposal for FOS Observations

In this Appendix we present the RPS2 code for a sample FOS observing proposal. This proposal contains four visits:

- Visit 01 : An `ACQ/BIN` will be performed. It will serve both as an onboard acquisition for FOS observations and as an FOS-assisted target acquisition for GHRS observations that follow the FOS exposures. The FOS observations consist of a confirming `ACQ` image, a standard `ACCUM` spectroscopy exposure, and a polarimetry observation. The GHRS exposures that follow are a WAVECAL and a standard Side 1 `ACCUM` in the spectral region where GHRS sensitivity is superior to that of FOS. Note: all FOS observations are with `FOS/BL`.
- Visit 02 : A four-stage `ACQ/PEAK` peak-up sequence to provide pointing accuracy of 0.08″ will be performed. The last stage of this sequence has a “critical” exposure designed to obtain 10,000 counts. The acquisition is followed by a `RAPID` mode exposure that will produce a time-series with 20-second intervals between successive samplings. This `READ-TIME` is sufficiently long that the low telemetry rate will be used.
- Visit 03 : Visits 03 and 04 are designed to execute within 4-15 days of each other. Both require very high pointing accuracy (0.04″) as the intended science will strive for high S/N. Visit 03 will contain the standard 5-stage high-precision `ACQ/PEAK` strategy, however, Visit 04 will use reuse_target_offset in order to save at least one orbit in the target acquisition and, on the assumption of a limited TAC allocation, make the second visit possible. The last stage of the peak-up sequence is again a “critical” exposure designed to obtain 10,000 counts. The acquisition is followed by `NON-INT ACCUM` mode WAVE and science exposures to insure no motion of the filter-grating wheel and hence to obtain a high-precision wavelength calibration.
- Visit 04 : This return visit will be between 4 and 15 days after Visit 03 (note that 4 days is the minimum separation between the first visit and ANY subsequent visit that uses a reuse_target_offset acquisition). A confirming 4x4 peak-up stage is performed to re-center the target and science immediately follows.

The sample RPS2 for this FOS observing proposal follows:

```
Proposal_Information

   Title:           FOS CYCLE 6: TEST PROPOSAL TO ILLUSTRATE EXAMPLES FOR RPS2
   Proposal_Category:   CAL/FOS
   Scientific_Category:
   Cycle:               6

Investigators

   PI_name:             CHRISTENSEN,JENNIFER
   PI_Institution:      STSCI
   CoI_Name:            KEYES
   CoI_Institution:     STSCI
   Contact:
```

```
 Abstract:               This proposal illustrates how to enter different types
                                     of exposures into RPS2.  You will
                                     find examples of: an ACQ/BIN acquisition,
                                     a confirmatory ACQ image, a four-stage
                                     ACQ/PEAK peak-up, an ACCUM mode exposure,
                                     a RAPID mode observation, a POLSCAN
                                     polarimetry observation, an FOS-assisted
                                     acquisition (and science) preceding GHRS
                                     science, a high-precision five-stage
                                     ACQ/PEAK peak-up acquisition, and a
                                     reuse_target_offset follow-up visit.

Questions

   Observing_Description:

   Real_Time_Justification:

   Calibration_Justification:
                                     This is to help you
   Additional_Comments:
                                     Good luck.
Fixed_Targets

   Target_Number:       1
   Target_Name:         NGC188-255
   Alternate_Names:     GSC-3788900057
   Description:         STAR
   Position:            RA=00H 44M 21.171S +/- 0.01S,
                                     DEC=+85D 26' 29.10" +/- 0.1",
                                     PLATE-ID=ZZZZ
   Equinox:             J2000
   Flux:             V = 13.42 +/- 0.1
                                     B-V = 0.19 +/- 0.1
   Comments:

Visits

Visit_Number:           01
Visit_Requirements:     BETWEEN 7-Oct-1996 AND 15-Oct-1996
On_Hold_Comments:

   Exposure_number:     10
   Target_Name:         NGC188-255
   Config:              FOS/BL
   Opmode:              ACQ/BINARY
   Aperture:            4.3
   Sp_Element:          MIRROR
   Wavelength:
   Optional_Parameters: BRIGHT=132000
   Number_of_iterations:1
   Time_Per_Exposure:   3.6S
   Special_Requirements:ONBOARD ACQ FOR 30-70
   Comments: ACQ FOLLOWED BY BOTH FOS AND GHRS EXPOSURES
```

```
Exposure_number:     30
Target_Name:         NGC188-255
Config:              FOS/BL
Opmode:              ACQ
Aperture:            4.3
Sp_Element:          MIRROR
Wavelength:
Optional_Parameters:
Number_of_iterations:1
Time_Per_Exposure:   64S
Special_Requirements:
Comments: CONFIRMING ACQ IMAGE

Exposure_number:     40
Target_Name:         NGC188-255
Config:              FOS/BL
Opmode:              ACCUM
Aperture:            1.0
Sp_Element:          G190H
Wavelength:
Optional_Parameters:
Number_of_iterations:1
Time_Per_Exposure:   10M
Special_Requirements:MAX DUR 200%
Comments:

Exposure_number:     50
Target_Name:         NGC188-255
Config:              FOS/BL
Opmode:              ACCUM
Aperture:            1.0
Sp_Element:          G270H
Wavelength:
Optional_Parameters: POLSCAN=8B
Number_of_iterations:1
Time_Per_Exposure:   10M
Special_Requirements:MAX DUR 200%
Comments:POLARIMETRY OBSERVATION NEXT WE GO TO GHRS

Exposure_Number:     60
Target_Name:         WAVE
Config:              HRS
Opmode:              ACCUM
Aperture:            SC2
Sp_Element:          G140L
Wavelength:          1300
Optional_Parameters:
Number_of_Iterations:1
Time_Per_Exposure:   60S
Special_Requirements:
Comments:INITIAL GHRS WAVECAL OBSERVATION FOLLOWING FOS-ASSIST
```

```
   Exposure_Number:     70
   Target_Name:         NGC188-255
   Config:              HRS
   Opmode:              ACCUM
   Aperture:            2.0
   Sp_Element:          G140L
   Wavelength:          1300
   Optional_Parameters:
   Number_of_Iterations:1
   Time_Per_Exposure:   60S
   Special_Requirements:
   Comments:GHRS SCIENCE OBSERVATION END OF VISIT

Visit_Number:           02
Visit_Requirements:
On_Hold_Comments:

   Exposure_number:     10
   Target_Name:         NGC188-255
   Config:              FOS/BL
   Opmode:              ACQ/PEAK
   Aperture:            4.3
   Sp_Element:          G270H
   Wavelength:
   Optional_Parameters: SCAN-STEP-Y=1.204, SEARCH-SIZE-Y=3, SEARCH-SIZE-X=1
   Number_of_iterations:1
   Time_Per_Exposure:   1S
   Special_Requirements:ONBOARD ACQ FOR 20
   Comments: STAGE 1 OF 4 STAGE PEAKUP WITH POINTING ACCURACY OF 0.08 ARCSEC

   Exposure_number:     20
   Target_Name:         NGC188-255
   Config:              FOS/BL
   Opmode:              ACQ/PEAK
   Aperture:            1.0
   Sp_Element:          G270H
   Wavelength:
   Optional_Parameters: SCAN-STEP-Y=0.602,SCAN-STEP-X=0.602,SEARCH-SIZE-
Y=2,SEARCH-SIZE-X=6
   Number_of_iterations:1
   Time_Per_Exposure:   2S
   Special_Requirements:ONBOARD ACQ FOR 30
   Comments: STAGE 2 OF 4 STAGE PEAKUP
```

```
   Exposure_number:     30
   Target_Name:         NGC188-255
   Config:              FOS/BL
   Opmode:              ACQ/PEAK
   Aperture:            0.5
   Sp_Element:          G270H
   Wavelength:
   Optional_Parameters:
SCAN-STEP-Y=0.3,SCAN-STEP-X=0.3,SEARCH-SIZE-Y=3,SEARCH-SIZE-X=3
   Number_of_iterations:1
   Time_Per_Exposure:   2S
   Special_Requirements:ONBOARD ACQ FOR 40
   Comments:  STAGE 3 OF 4 STAGE PEAKUP

   Exposure_number:     40
   Target_Name:         NGC188-255
   Config:              FOS/BL
   Opmode:              ACQ/PEAK
   Aperture:            0.3
   Sp_Element:          G270H
   Wavelength:
   Optional_Parameters: SCAN-STEP-Y=0.11, SCAN-STEP-X=0.11, SEARCH-SIZE-Y=4,
SEARCH-SIZE-X=4
   Time_Per_Exposure:   13S
   Special_Requirements:ONBOARD ACQ FOR 60
   Comments: CRITICAL STAGE 4 OF 4-STAGE ACQ/PEAK FOR POINTING ACC 0.08 ARCSEC

   Exposure_number:     60
   Target_Name:         NGC188-255
   Config:              FOS/BL
   Opmode:              RAPID
   Aperture:            0.3
   Sp_Element:          G270H
   Wavelength:
   Optional_Parameters: READ-TIME=20
   Number_of_iterations:1
   Time_Per_Exposure:   20M
   Special_Requirements:
   Comments: RAPID MODE EXP; WILL USE LOW TELEMETRY RATE
```

```
Visit_Number:            03
Visit_Requirements:      BETWEEN 1-Jul-1996 AND 7-Jul-1996
On_Hold_Comments:

   Exposure_number:      10
   Target_Name:          NGC188-255
   Config:               FOS/RD
   Opmode:               ACQ/PEAK
   Aperture:             4.3
   Sp_Element:           G270H
   Wavelength:
   Optional_Parameters: SCAN-STEP-Y=1.204, SEARCH-SIZE-Y=3, SEARCH-SIZE-X=1
   Number_of_iterations:1
   Time_Per_Exposure:   1S
   Special_Requirements:ONBOARD ACQ FOR 20
   Comments: STAGE 1 OF 5-STAGE PEAKUP FOR POINTING ACCURACY 0.04 ARCSEC FOR
HIGH S/N

   Exposure_number:      20
   Target_Name:          NGC188-255
   Config:               FOS/RD
   Opmode:               ACQ/PEAK
   Aperture:             1.0
   Sp_Element:           G270H
   Wavelength:
   Optional_Parameters: SCAN-STEP-Y=0.602,SCAN-STEP-X=0.602,SEARCH-SIZE-
Y=2,SEARCH-SIZE-X=6
   Number_of_iterations:1
   Time_Per_Exposure:   1S
   Special_Requirements:ONBOARD ACQ FOR 30
   Comments:    STAGE 2 OF 5-STAGE PEAKUP

   Exposure_number:      30
   Target_Name:          NGC188-255
   Config:               FOS/RD
   Opmode:               ACQ/PEAK
   Aperture:             0.5
   Sp_Element:           G270H
   Wavelength:
   Optional_Parameters:
SCAN-STEP-Y=0.3,SCAN-STEP-X=0.3,SEARCH-SIZE-Y=3,SEARCH-SIZE-X=3
   Number_of_iterations:1
   Time_Per_Exposure:   1S
   Special_Requirements:ONBOARD ACQ FOR 40
   Comments:    STAGE 3 OF 5-STAGE PEAKUP
```

```
   Exposure_number:     40
   Target_Name:         NGC188-255
   Config:              FOS/RD
   Opmode:              ACQ/PEAK
   Aperture:            0.3
   Sp_Element:          G270H
   Wavelength:
   Optional_Parameters: SCAN-STEP-Y=0.17, SCAN-STEP-X=0.17, SEARCH-SIZE-Y=3,
SEARCH-SIZE-X=3
   Time_Per_Exposure:   2S
   Special_Requirements:ONBOARD ACQ FOR 50
   Comments:    STAGE 4 OF 5-STAGE PEAKUP

   Exposure_number:     50
   Target_Name:         NGC188-255
   Config:              FOS/RD
   Opmode:              ACQ/PEAK
   Aperture:            0.3
   Sp_Element:          G270H
   Wavelength:
   Optional_Parameters: SCAN-STEP-Y=0.052, SCAN-STEP-X=0.052, SEARCH-SIZE-Y=5,
SEARCH-SIZE-X=5
   Time_Per_Exposure:   10S
   Special_Requirements:ONBOARD ACQ FOR 60-70
   Comments: CRITICAL STAGE 5 OF 5-STAGE PEAK-UP; GET 10,000 COUNTS

   Exposure_number:     60
   Target_Name:         WAVE
   Config:              FOS/RD
   Opmode:              ACCUM
   Aperture:            0.3
   Sp_Element:          G270H
   Wavelength:
   Optional_Parameters:
   Number_of_iterations:1
   Time_Per_Exposure:   DEF
   Special_Requirements:SEQ 60-70 NON-INT
   Comments: WAVECAL FOR HIGH PRECISION WAVELENGTHS; DO NOT MOVE FILTER-
GRATING WHEEL BETWEEN EXPOSURES 60 AND 70

   Exposure_number:     70
   Target_Name:         NGC188-255
   Config:              FOS/RD
   Opmode:              ACCUM
   Aperture:            0.3
   Sp_Element:          G270H
   Wavelength:
   Optional_Parameters:
   Number_of_iterations:1
   Time_Per_Exposure:   1300S
   Special_Requirements:
   Comments:
```

```
Visit_Number:            04
Visit_Requirements:      BETWEEN 11-Jul-1996 AND 15-Jul-1996
On_Hold_Comments: RE-USE TARGET OFFSET FROM VISIT 3

   Exposure_number:      10
   Target_Name:          NGC188-255
   Config:               FOS/RD
   Opmode:               ACQ/PEAK
   Aperture:             0.3
   Sp_Element:           G270H
   Wavelength:
  Optional_Parameters: SCAN-STEP-Y=0.052, SCAN-STEP-X=0.052, SEARCH-SIZE-Y=4,
SEARCH-SIZE-X=4
   Time_Per_Exposure:    10S
   Special_Requirements:ONBOARD ACQ FOR 20
   Comments: CONFIRMING PEAK-UP AFTER REUSE_TARGET_OFFSET ACQ

   Exposure_number:      20
   Target_Name:          NGC188-255
   Config:               FOS/RD
   Opmode:               ACCUM
   Aperture:             0.3
   Sp_Element:           G270H
   Wavelength:
   Optional_Parameters:
   Number_of_iterations:1
   Time_Per_Exposure:    1300S
   Special_Requirements:
   Comments: SCIENCE AFTER REUSE_TARGET_OFFSET ACQ



Data_Distribution

   Medium:               8MM
   Blocking_Factor:      10
   Ship_To:              PI_Address
   Ship_Via:             UPS
   Recipient_Email:
```

Appendix G : Post-COSTAR FOS Inverse Flat Fields

This appendix provides plots of the 3.7″ x 1.3″ (`4.3`) aperture flat field granularity structure for all FOS detector/disperser combinations except the prisms. These plots are of the *inverse* flat field, which is applied as a multiplicative operator in routine PODPS pipeline processing. The inverse flats shown are the first post-COSTAR flat field reference files and are based upon standard star “superflat” observations obtained in early March, 1994.

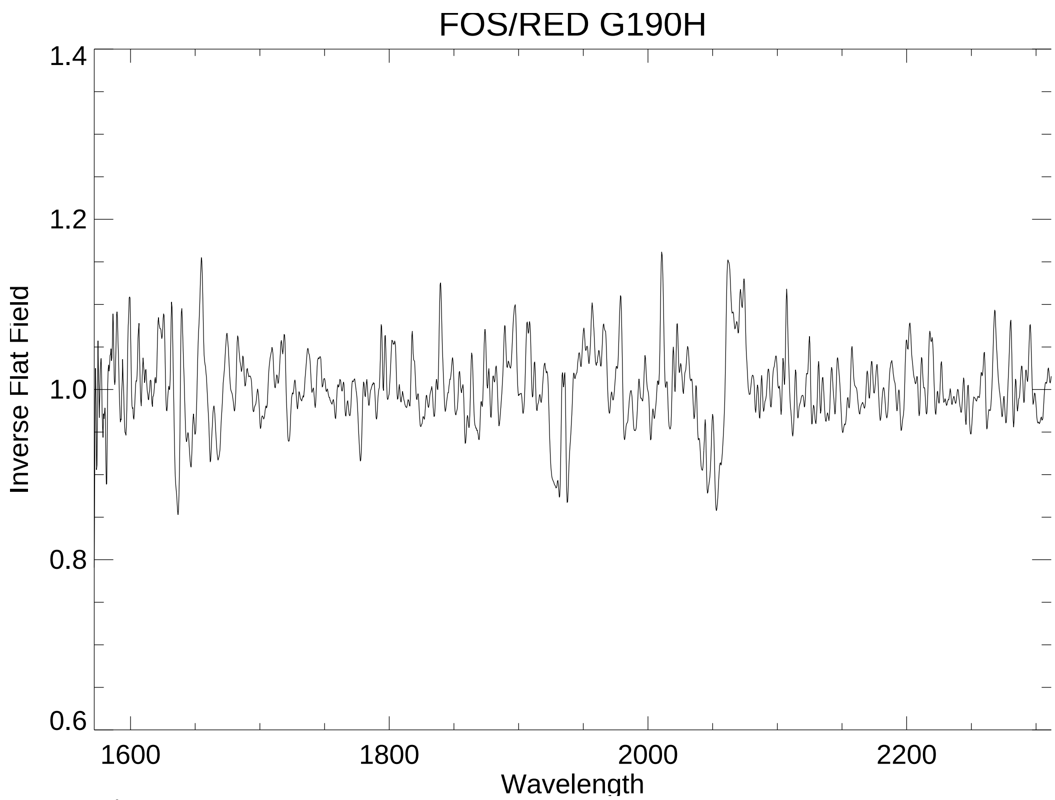

Figure G-1:

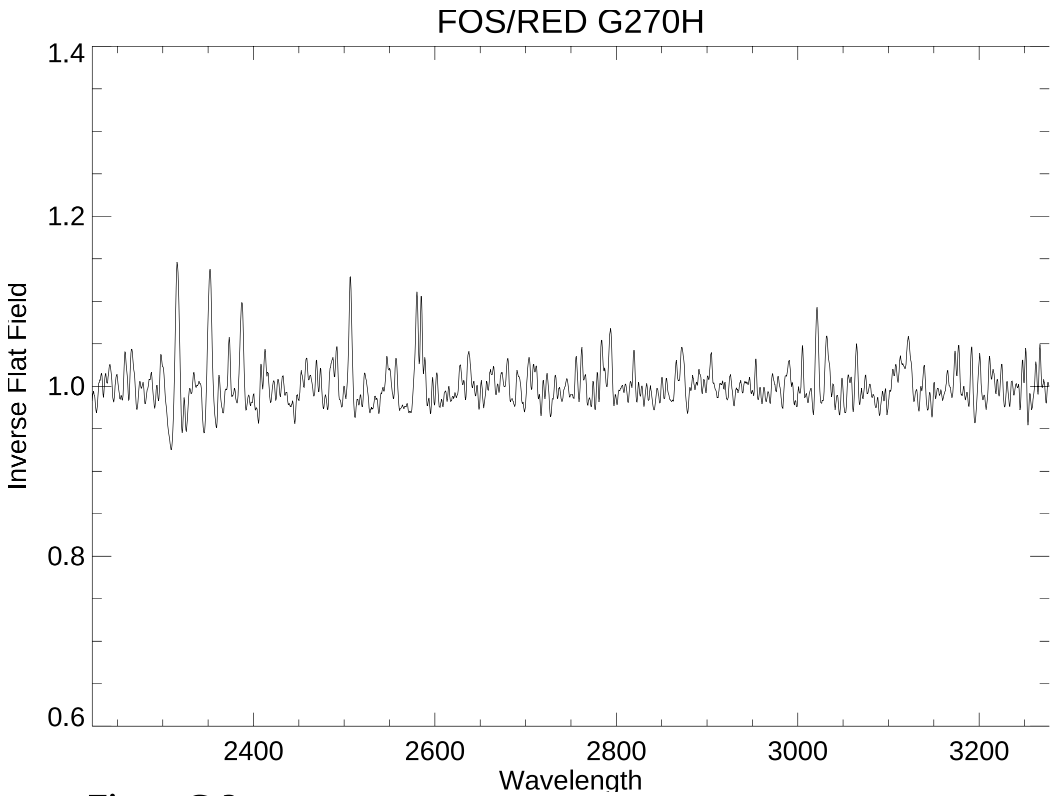

Figure G-2:

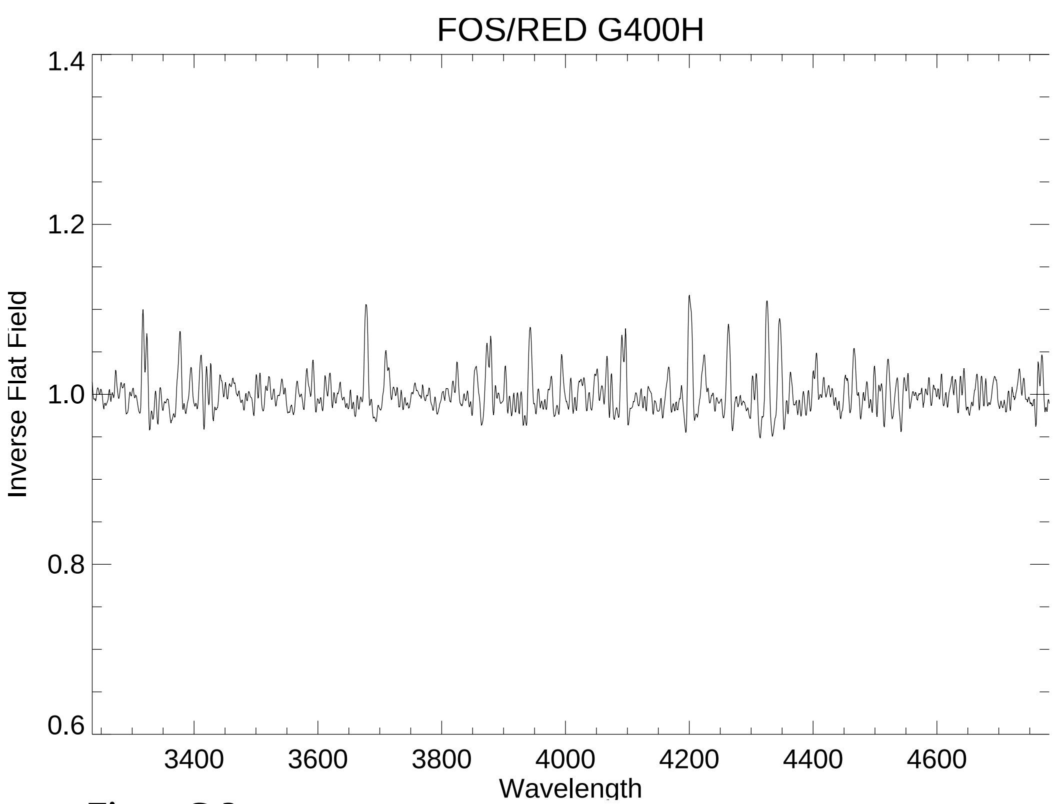

Figure G-3:

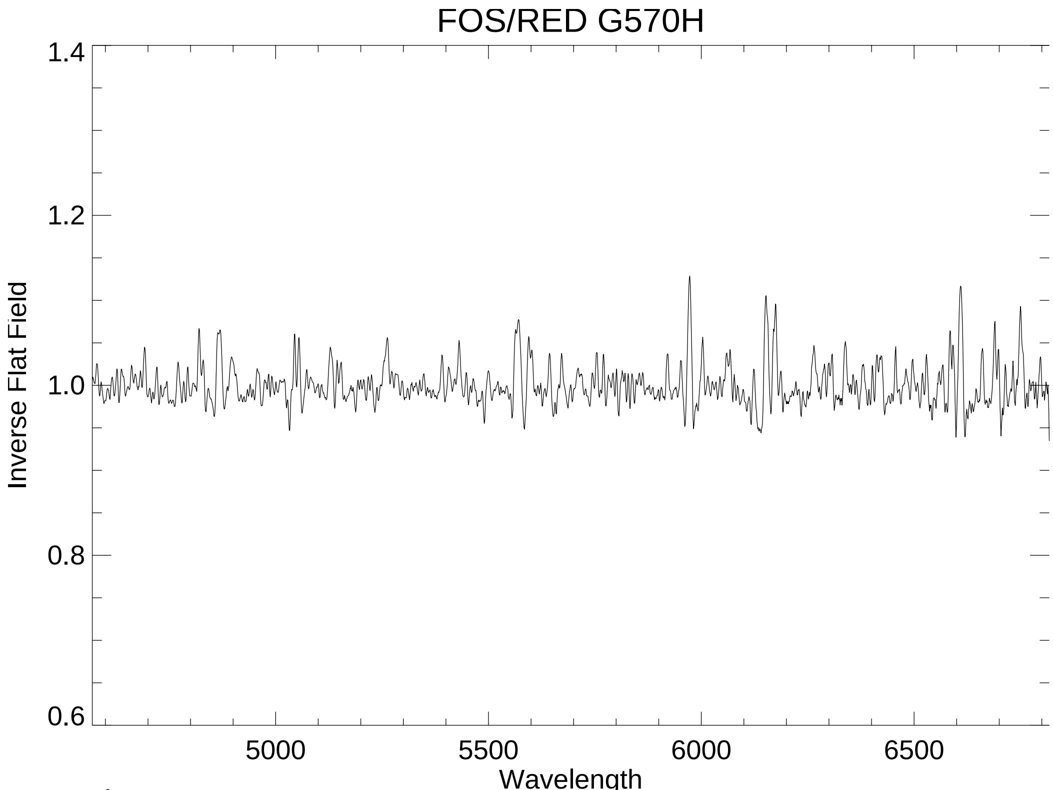

Figure G-4:

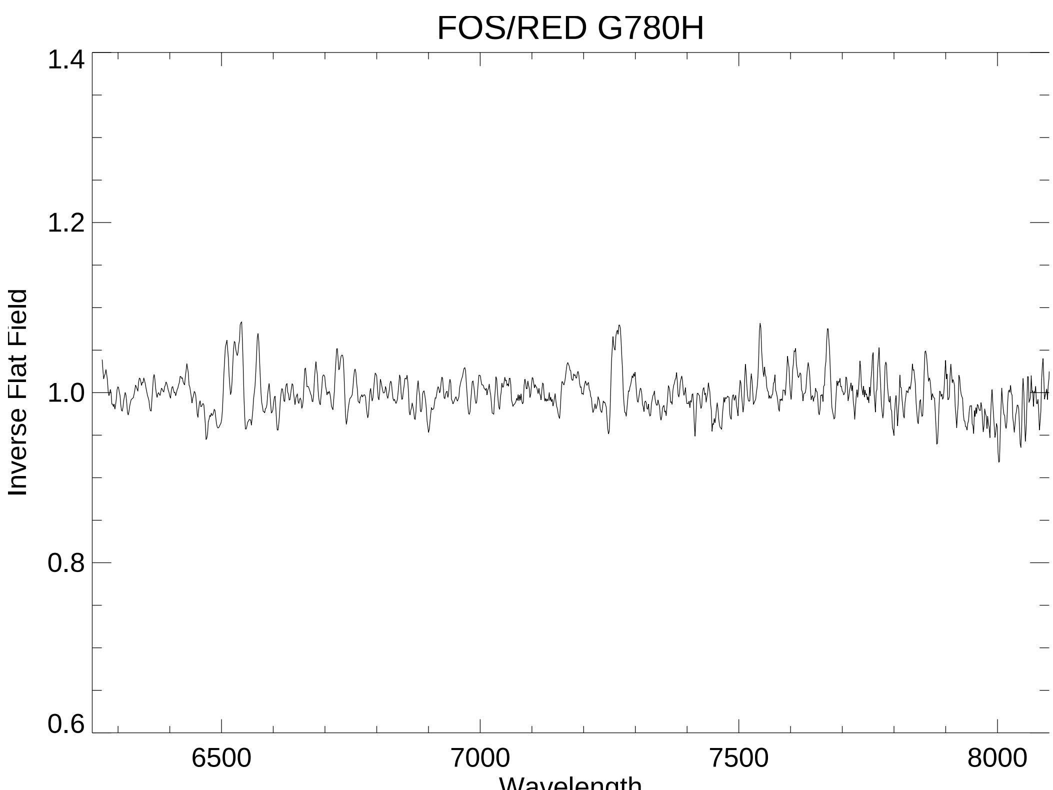

Figure G-5:

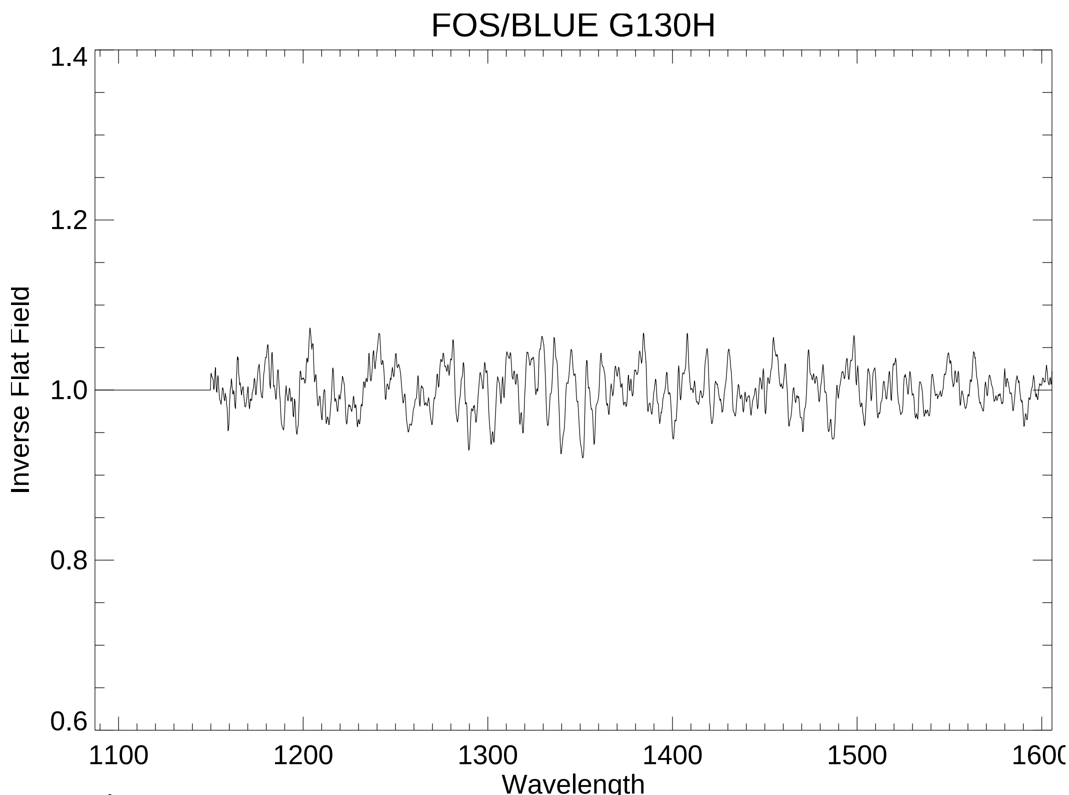

Figure G-6:

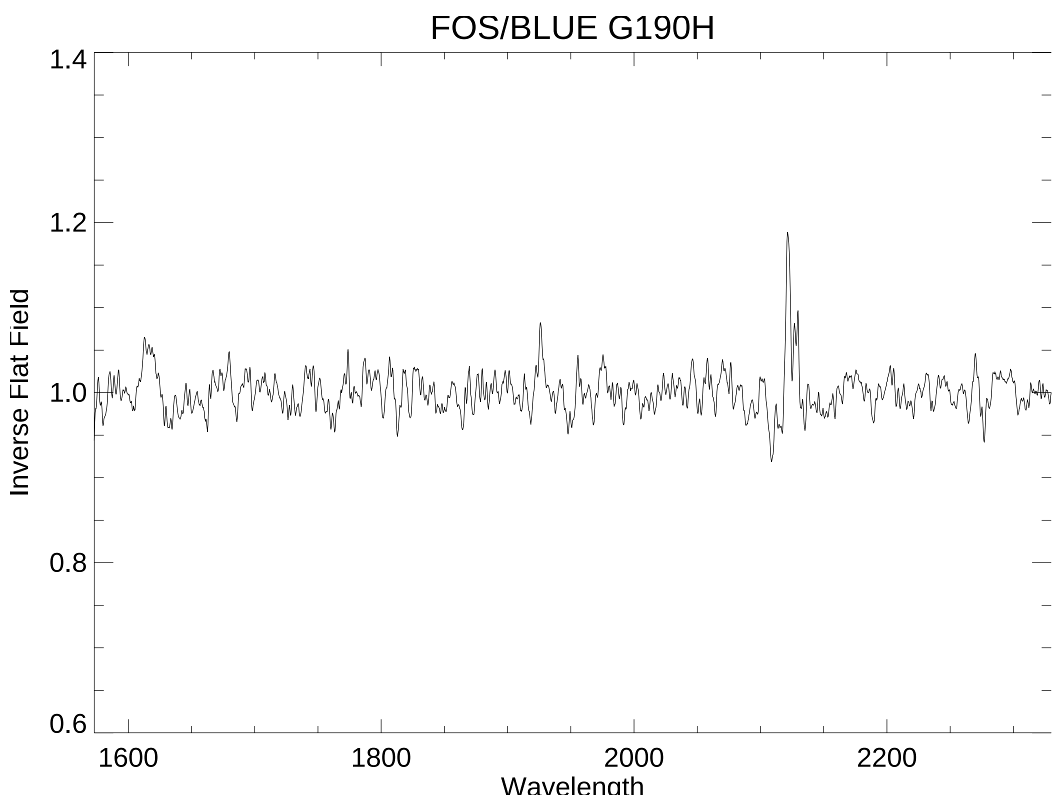

Figure G-7:

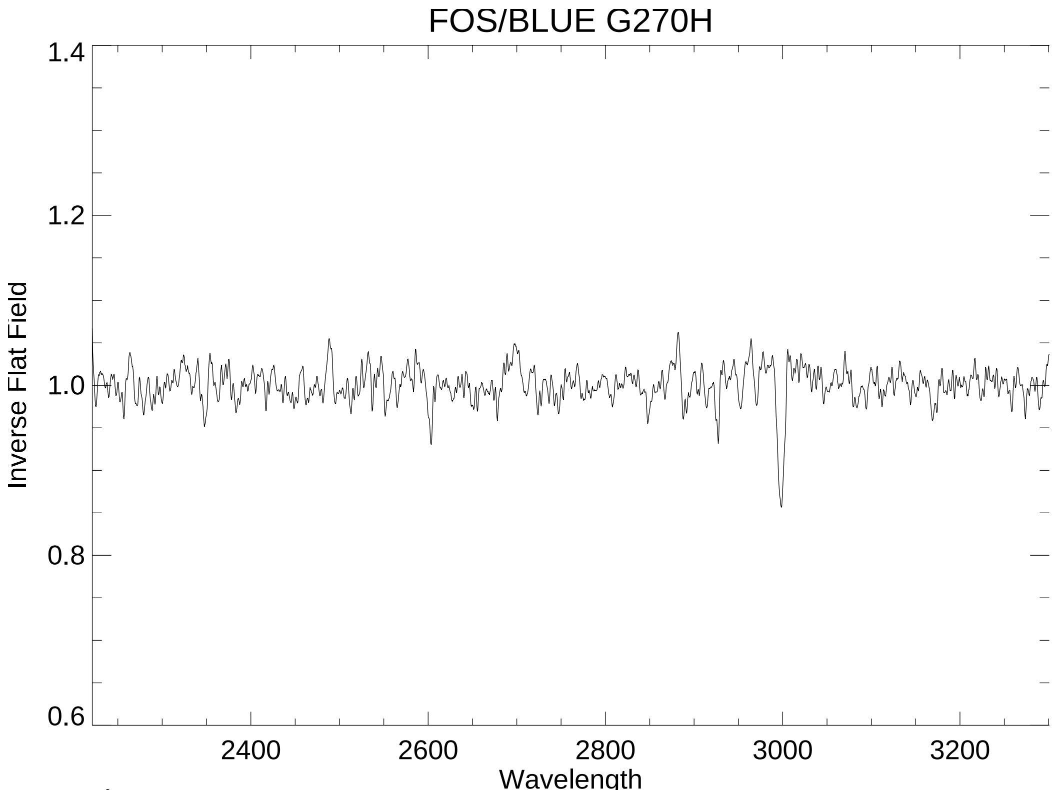

Figure G-8:

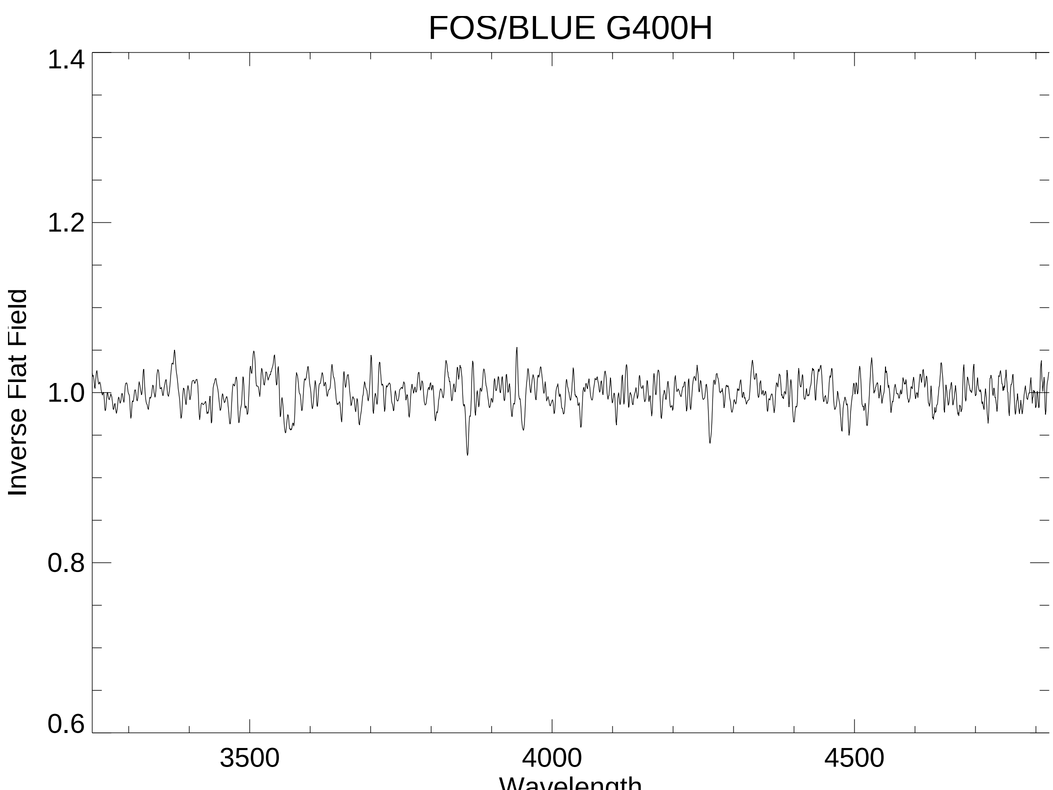

Figure G-9:

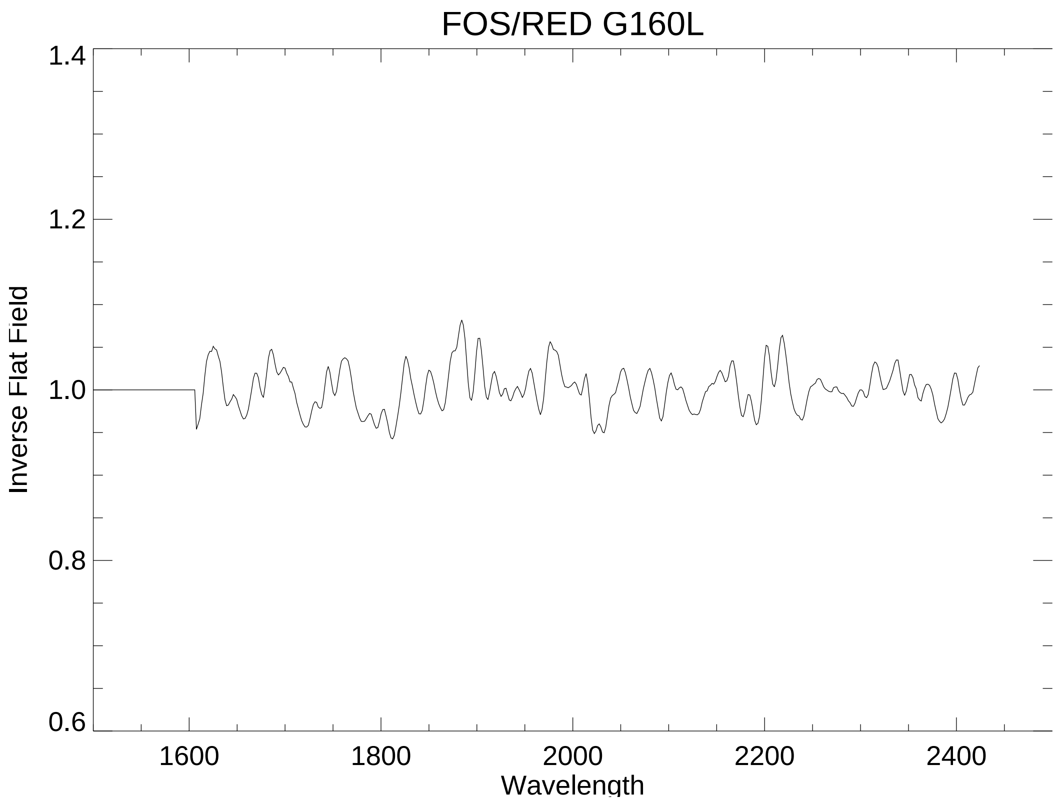

Figure G-10:

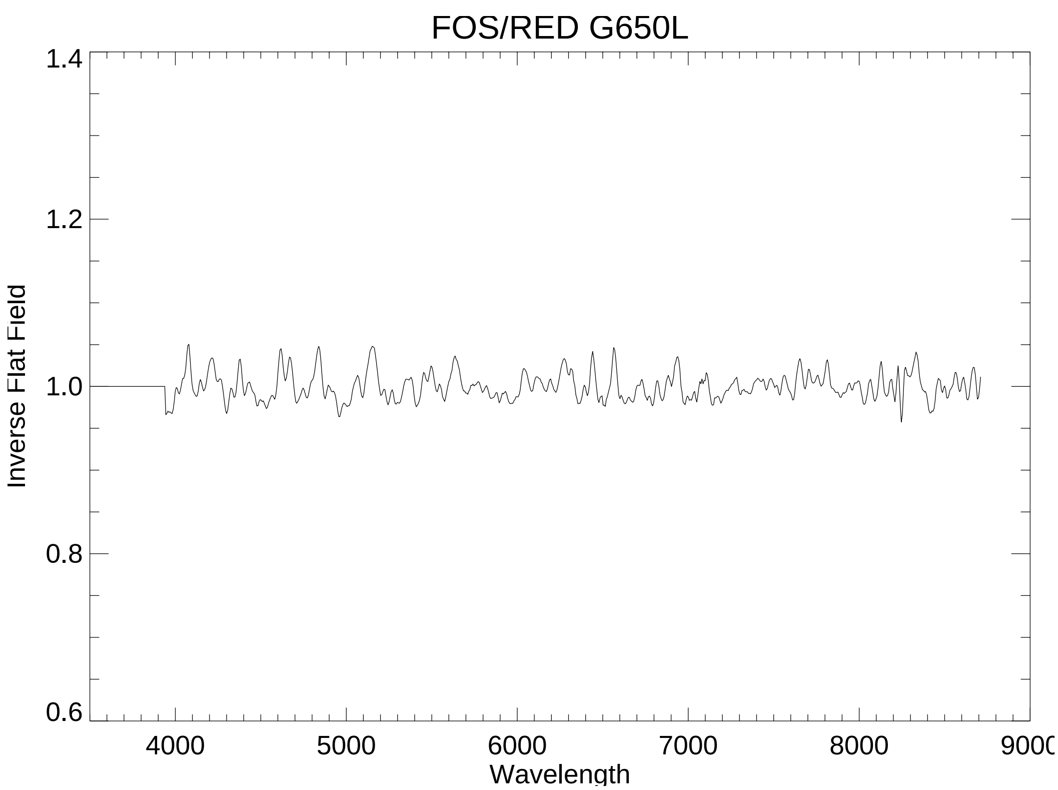

Figure G-11:

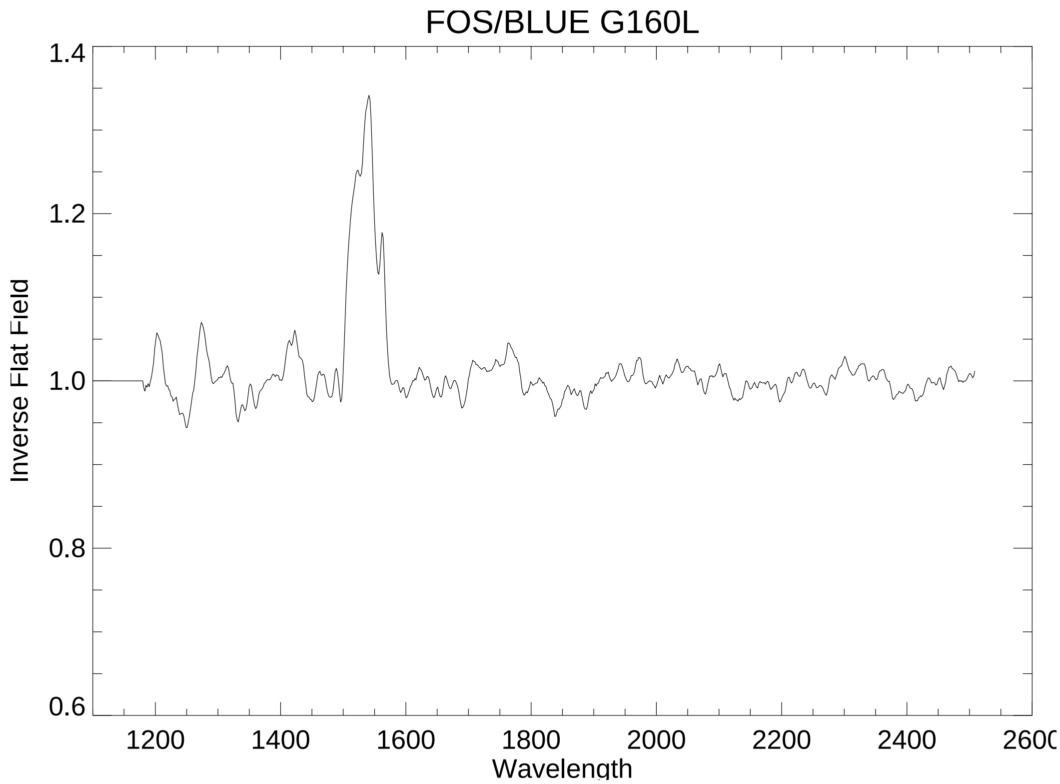
FOS/BLUE G160L
1.4
1.2
1.0
0.8
0.6
Inverse Flat Field
1200
1400
1600
1800
2000
2200
2400
Wavelength

Figure G-12:

APPENDIX H: Comparison of Post-COSTAR FOS and GHRS Side 1 Sensitivities

Table H-1: Comparison of Post-COSTAR FOS and GHRS Side 1 Sensitivities

Wavelength	GHRS G140L[a]	FOS/BL G130H[b]	FOS/BL G190H[b]	GHRS/FOS[c]	GHRS/FOS[d] (FOS-res)
1200	8.23×10^{12}	2.00×10^{12}	-	4.1	6.8
1250	15.2×10^{12}	5.24×10^{12}	-	2.9	4.8
1300	16.8×10^{12}	6.82×10^{12}	-	2.5	4.2
1350	16.6×10^{12}	7.66×10^{12}	-	2.2	3.7
1400	14.6×10^{12}	8.59×10^{12}	-	1.7	2.8
1450	11.4×10^{12}	9.29×10^{12}	-	1.2	2.0
1500	8.93×10^{12}	9.61×10^{12}	-	0.93	1.6
1550	6.70×10^{12}	10.2×10^{12}	-	0.65	1.1
1600	4.39×10^{12}	9.77×10^{12}	15.1×10^{12}	0.45 / 0.29[e]	0.75 / 0.5[e]
1650	4.00×10^{12}	-	18.2×10^{12}	0.22	0.37
1700	3.20×10^{12}	-	20.4×10^{12}	0.16	0.27
1750	2.07×10^{12}	-	22.7×10^{12}	0.09	0.15
1800	1.08×10^{12}	-	24.3×10^{12}	0.04	0.07
1850	0.40×10^{12}	-	26.1×10^{12}	0.02	0.03
1900	0.01×10^{12}	-	27.8×10^{12}	0.004	0.01

a.) Sensitivity for the LSA (2.0″ square)

b.) Sensitivity for the 3.7″x1.3″ (4.3) aperture

c.) Ratio of sensitivities

d.) Ratio of sensitivities with GHRS re-binned to FOS resolution

e.) GHRS / G130H ratio followed by GHRS / G190H ratio

APPENDIX I : FOS Calibration Plan for Cycle 5

May 1995

This appendix presents a detailed description of each program in the 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 FOS post-COSTAR has been characterized in detail. In Cycle 5, most of the calibration program is developed to produce an updated measure of the Cycle 4 calibration observations. Thus in Cycle 5, we expect to maintain the routine calibration situation for the FOS. Our calibration program is divided into two parts: (1) a set of monitoring tests which aim to check the stability of the instrument performance and (2) a set of specific tests designed to maximize the instrumental performance.

A summary description of each program is given that includes proposal number, primary targets (if any), detectors, apertures and spectral elements used. A description of target acquisition techniques if required is also given. Also provided are the scientific justification, a description of the observations and the calibration accuracies expected.

Proposal ID 6163: FOS Cycle 5: Focus, X-pitch, Y-pitch

Purpose: The observations in this proposal will be used to verify the focus, X-pitch, Y-pitch during the cycle, since the FOS focus is sensitive to external magnetic fields.

Description: A good instrumental focus is the first stage of the data acquisition process and thus impacts all FOS observations. The FOS focus will be determined by obtaining spectra with the 0.1-PAIR aperture, G190H, and the Pt-Ne lamp at various voltages until the maximum voltage is 23.86 kV (blue detector) or 22.8 kV (red detector). Once an optimal HV setting for the focus is determined and updates made to the PDB, a series of spectra at three different X-Bases will be made to determine the corresponding X-Pitch. Additionally, measurements with the TALEDs through the 0.1-PAIR aperture will be used to determine the Y-Pitch. This program may result in an instruction flow change to the detector high voltage setting, the X-pitch value, and the Y-pitch value. The focus will be checked once in a given cycle.

Primary External Targets: N/A

Target Acquisition Technique: N/A

Detectors: Blue and Red

Apertures: 0.1-PAIR-B

Dispersers: G190H

Fraction of GO/GTO Programs Supported: 100%

Resources:

Duration (orbits): 4 orbits of non-prime time

Special Requirements: These observations MUST occur during non-SAA impacted orbits.

Accuracy: The observations are to verify that the FOS focus has not changed. Thus this proposal aims to maintain the present FOS focus. Small changes in the FOS focus do not affect the photometric quality of the data dramatically.

Accuracy Requirement: Maintain the present FOS focus

Products: The analysis of the data obtained may lead to an Instructional Management Database (IMDB) update which will occur within two weeks of the observations. There are no reference files to be delivered.

Proposal ID 6165: FOS Cycle 5: Discriminator Test

Purpose: The observations in this proposal will be used to verify the stability of the discriminator settings.

Description: If the diodes are not maintained at their optimal high voltage settings, the resultant data tends to look like a noisy diode and compromises the observations. Thus, this test is conducted to verify the discriminator settings for each FOS diode. Noise and gain are known to be temperature sensitive, and it is therefore likely that some fraction of the channels will experience some change in their optimal discriminator settings on orbit. Hence, the stability of these settings has to be verified. This internal test must be run once per cycle. The FOS high voltage will be brought to approximately one-half the nominal operating voltage followed by a 60S wait to allow the high voltage to stabilize. Then observations will be obtained of the INTFLAT lamp.

Primary External Targets: N/A

Target Acquisition Technique: N/A

Detectors: Blue and Red

Apertures: N/A

Dispersers: N/A

Fraction of GO/GTO Programs Supported: 100%

Resources:

Duration (orbits): 12 orbits of non-prime time

Special Requirements: The detector high voltage will be set to a non-nominal value. Overlight protection will have to be disabled.

Accuracy: The observations are to verify the FOS discriminator settings.

Accuracy Requirement: Maintain/verify the discriminator settings

Products: The analysis of the data obtained will lead to an IMDB update which will occur within two months of the observations. There are no reference files to be delivered.

Proposal ID 6166 and 6236: FOS Cycle 5: Location of Spectra and Wavelength Calibration

Purpose: The observations in this proposal will monitor both the Y location of spectra and the wavelength scale for all reasonable aperture/disperser/detector combinations. This proposal has the highest priority because our ability to acquire spectra and minimize photometric calibration errors depends on our knowledge of Y-base values.

Description: In this cycle the two separate monitoring programs (Part 1: location of spectra, and Part 2: internal wavelength calibration) have been combined to minimize the number of on/off cyclings of the internal calibration lamps and to facilitate scheduling of the program as interleavers executed in Earth occultation.

Part 1: The primary objective of the first part of this proposal is to determine and monitor the Y-base measurements corresponding to the Y location of spectra for each aperture/disperser/detector combination every month using the 0.3″ aperture, and the internal Pt-Ne lamps and TALEDs. The observations will map the face of the photocathode using 24 y-steps and 1 x-step. Although the ideal technique is to obtain Y-base maps for each aperture/disperser/detector combination, the amount of time to perform such measurements is prohibitive. Hence, Y-base maps will be obtained to determine the locations of spectra and the coarse aperture location for the 0.3” aperture for all grating settings in both the FOS detectors. Y-bases for all the other apertures will be measured once with the G190H or G400H to determine the location of spectra for the single and paired apertures and both detectors. The small number of observations should suffice and the difference in the location of the spectra should be solely due to the single versus the paired apertures. This test has to be conducted once every month because previous cycles have shown that the locations of the spectra have drifted with time.

Part 2: The second part of this proposal is to monitor the stability of the FOS wavelength scale. ACCUM mode measurements of the Pt-Ne lamp will be obtained with both FOS detectors for all standard gratings with the 0.3″ circular and either the 0.1″ or 0.25″ paired apertures. The observations taken through the smallest circular (0.3″) aperture will be used to determine accurate wavelength scales for all disperser/detector combinations. The WAVECAL lamp has a fairly constant output, so that these data are a secondary monitor of any changes in the FOS internal sensitivity.

The visits in this program have been structured into groups no longer than approximately 25 minutes to facilitate scheduling as interleavers in occultation. It is necessary to conduct this program many times during the cycle since we know from previous cycles that the location of the spectra has drifted with time, and to check the stability of the FOS wavelength scale. The complete program can be scheduled as an interleaver observation and should be repeated every month for a total of 194 occultation periods. Due to the restrictions in RPS2 the program had to be divided into two separate proposals one for the FOS red detector (6166) and one for the FOS blue detector (6236).

Primary Targets: N/A

Target Acquisition Technique: N/A

Detectors: Blue and Red

Apertures:

Part 1: 0.3″ circular, 1.0″ circular, 0.5″ circular, 1.0-PAIR, 0.5-PAIR, 0.25-PAIR, 0.1-PAIR, 0.25″×2.0″ SLIT, 2.0-BAR and 0.25×2.0-BAR

Part 2: 0.3” circular, 0.1-PAIR or 0.25-PAIR

Dispersers:

Part 1: G130H, G190H, G270H, G400H, G570H, G160L, G650L, PRISM (Blue side and 0.3″ circular)

G190H, G270H, G400H, G570H, G780H, G160L, G650L, PRISM (Red side and 0.3″ circular)

G190H (Blue side, and 1.0″ circular, 0.5″ circular, 1.0-PAIR, 0.5-PAIR, 0.25-PAIR, 0.1-PAIR, 0.25″×2.0″ SLIT, 2.0-BAR and 0.25×2.0-BAR apertures)

G400H (Red side, and 1.0″ circular, 0.5″ circular, 1.0-PAIR, 0.5-PAIR, 0.25-PAIR, 0.1-PAIR, 0.25″×2.0″ SLIT, 2.0-BAR and 0.25×2.0-BAR apertures)

Part 2: G130H, G190H, G270H, G400H, G570H, G160L, G650L, PRISM (Blue side and 0.3″ circular)

G190H, G270H, G400H, G570H, G780H, G160L, G650L, PRISM (Red side and 0.3″ circular)

G270H, G400H, G650L, PRISM (Blue side, 0.1-PAIR)

G130H, G190H, G570H, G160L (Blue side, 0.25-PAIR)

G400H, G570H, G780H, G650L (Red side, 0.1-PAIR)

G190H, G270H, G160L, PRISM (Red side, 0.25-PAIR)

Fraction of GO/GTO Programs Supported: 100%

Resources:

Duration (orbits): 194 occultation orbits

Special Requirements: None

Accuracy:

Part 1: The Y-location of the spectra on the photocathode affect both the Binary acquisition strategy and the FOS photometric accuracy. The scatter in the location of the blueside spectra seem to be time dependent and the 1σ accuracy we hope to achieve is ± 10 YBASE units. The scatter in the location of spectra on the redside spectra is random and the 1σ accuracy we hope to achieve is ± 20 YBASE units. These accuracies will allow a 1σ binary acquisition accuracy of 0.08″ for the FOS Blue detector and 0.12″ for the FOS Red detector. The photometric accuracy in the 4.3″ and the 1.0″ apertures is affected the most because the size of the aperture is ≥ to the size of the diode array and all the photons in the point spread function are not collected. Further, this is not a simple matter of losing a percentage of light, but the effect is also wavelength dependent. On average an YBASE uncertainty of 20 YBASES leads to ≤ 3% photometric uncertainty in the 1.0″ aperture. The loss could be larger for extended objects.

Part 2: The dominant error in the wavelength accuracy for a typical FOS spectrum is due to the filter grating wheel non-repeatability of the order of 0.35 diodes. The FOS spectra have a limiting accuracy of 0.03 diodes if there is no motion of the filter grating wheel.

Accuracy Requirement: ± 10 YBASE units for Blueside, ± 20 YBASE units for Redside, 0.1 diodes

Accuracy Goal: ± 10 YBASE units, 0.03 diodes

Products: The analysis of the data obtained will lead to a PDB update for the location of spectra. The PDB updates will be made at least twice during the cycle and more often if required. There are no reference files to be delivered for the location of spectra part of the proposal. The analysis of the internal wavelength calibration will lead to an update of the RSDP. There are wavelength calibration reference files (CCS6) to be delivered.

Proposal ID 6167: FOS Cycle 5: Dark Monitoring

Purpose: The observations in this proposal will be used to measure the internal background as seen by the FOS, as a function of position on the sky, the South Atlantic Anomaly (SAA), and electromagnetic interference (EMI) sources.

Description: In this program measurements of the instrumental background (dark) will be obtained as internal observations with the FOS in the standard IMAGE mode. The observations will also be used to verify the dark count model used in the calibration pipeline. These data will also allow us to verify the instrumental noise, the derived limiting magnitude, and enable us to determine which channels should be disabled. This test will be conducted every month for a total of twelve different epochs during Cycle 5.

The observations in this program consist of eight sets of four exposures per epoch. An individual set of exposures is specified to be grouped WITHIN 4 DAYS; all observations in such a set should be scheduled on the same calendar, if possible. The visits in this program have been structured into groups no longer than approximately 30 minutes to facilitate scheduling as interleavers in occultation. The complete program can be scheduled as an interleaver observation and should be repeated every month for a total of 48 occultation periods.

Primary External Targets: N/A

Target Acquisition Technique: N/A

Detectors: Blue and Red

Apertures: N/A

Dispersers: N/A

Fraction of GO/GTO Programs Supported: 100%

Resources:

Duration (orbits): 48 occultation orbits

Special Requirements: The observations in this program consist of eight sets of four exposures per epoch. An individual set of exposures is specified to be grouped WITHIN 4 DAYS; all observations in such a set should be scheduled on the same calendar, if possible.

Accuracy: The FOS is affected by the geo-magnetic field and thus the instrumental background needs to be properly quantified. The error due to an incorrect background file is insignificant in the case of strong sources (number of source counts ≥ number of background counts), but causes substantial errors in the derived flux and spectral shape of weaker sources (number of source counts < number of background counts).

Accuracy Requirement: 10%

Accuracy Goal: 5%

Products: The analysis of the data obtained will lead to an RSDP update which will occur within 3 months of the final observations. There are background reference files (CCS8, BACHFILE) to be delivered.

Proposal ID 6202: FOS Cycle 5: Spectral Flat Field Calibration

Purpose: The observations in this proposal will be used to monitor some of the FOS detector/disperser combinations that have shown temporal variations in their flat field structure during previous cycles.

Description: Some FOS detector/disperser combinations have shown temporal variations in their flat field and need to be monitored to achieve good FOS data calibration accuracy. This set of observations will produce additional flat field calibrations appropriate to the Cycle 5 time period. At two epochs during Cycle 5, high S/N spectra will be obtained for G191B2B, which has a relatively featureless spectrum and which has been the primary target for earlier flat field observations. On each epoch observations are made through the 1.0″ aperture and either the 4.3″ or 0.3″ aperture with all usable detector/disperser combinations. These observations also double as inverse sensitivity measurements and must be scheduled in the designated time period. On four other occasions three red side spectral elements will be monitored with 1.0 aperture in the companion proposal 6203. This proposal will provide a contemporaneous flat field for the PODPS pipeline calibration of Cycle 5 data.

Primary External Targets: G191-B2B

Target Acquisition Technique: ACQ/PEAK for a pointing accuracy of 0.04”

Detectors: Blue and Red

Apertures: 4.3″, 1.0″ circular, 0.3″ circular, 0.25-PAIR, and 0.1-PAIR

Dispersers: G130H, G190H, G270H, G400H, G160L, PRISM (Blue)
G190H, G270H, G400H, G570H, G780H, G160L, G650L, PRISM (Red)

Fraction of GO/GTO Programs Supported: 100%

Resources:

Duration (orbits): 22 external orbits

Special Requirements: It is imperative that these observations be scheduled in the requested time frame, in order to coordinate with all other FOS flat field and IVS observations.

Accuracy: FOS superflats show that there are not many strong features (greater than 5% deviation from unity). The typical flat field deviations are of the order of 1-2% about the mean value of unity. The flat field corrections are only intended to remove photocathode granularity typically on the scale of 10 pixels or less. Higher precision requires simultaneous flat field calibration observations, so that the science target illuminates the same portion of the photocathode as the calibration observations. There is some time dependence which needs to be quantified.

Accuracy Requirement: 2%

Accuracy Goal: 1%

Products: The analysis of the data obtained will lead to an RSDP update which will occur within 3 months after the final observations. There are flat field reference files (FLnHFILE) to be delivered.

Proposal ID 6203: FOS Cycle 5: Photometric Monitor

Purpose: The observations in this proposal will be used to determine the absolute photometric calibration of both FOS detectors, and to determine the aperture throughputs. Many of the observations in this program also provide simultaneous flat fields.

Description: These measurements will determine the full photometric re-calibration of the FOS for Cycle 5 and determine the stability of the instrument. A measurement of the absolute sensitivity of both FOS detectors will be performed using a UV standard star. All the highest priority gratings (6 blue detector and 8 red detector-grating combinations) will be used with the 4.3″ and 1.0″ apertures. To assure registration of the spectrum on the diode array, the stars will be observed at 3 Y-bases with an 15-20 micron separation. Most of the spectra will be obtained in the 4.3″ and 1.0″ aperture, however, one star (BD+28D4211) also will be observed with all usable dispersers through the 4.3″, 0.5″, 0.3″ and 0.25-PAIR apertures to calibrate aperture throughputs. Measurement of aperture throughput ratios will be made for both detectors with all usable spectral elements for the single apertures expected to be most commonly used in Cycle 5. A multi-stage peakup on the standard star should provide excellent centering in the small apertures (0.04″ accuracy).

Primary External Targets: BD+28D4211, G191-B2B

Target Acquisition Technique: ACQ/PEAK for a pointing accuracy of 0.04”

Detectors: Blue and Red

Apertures: 4.3″ square, 1.0″ circular, 0.5″ circular, 0.3″ circular, and 0.25-PAIR

Dispersers: G130H, G190H, G270H, G400H, G160L, PRISM (Blue side)
G190H, G270H, G400H, G570H, G780H, G160L, G650L, PRISM (Red side)

Fraction of GO/GTO Programs Supported: 100%

Resources:

Duration (orbits): 48 external orbits

Special Requirements: None

Accuracy: The dominant error in the photometry is due to miscentering of the target and the aperture size. The other sources of error are (1) decline in the FOS sensitivity, (2) flat fields, (3) change in telescope focus, (4) location of spectra, (5) thermal breathing, (6) jitter, (7) GIMP, and (8) calibration system offsets. The internal repeatability of the FOS is 1-2%. The photometric calibration of a typical FOS spectrum is accurate to ~5-10% for the large apertures depending on the many factors given above and progressively worse for the smaller apertures.

Accuracy Requirement: 5% for the large apertures and 15% for the small apertures

Accuracy Goal: 3% for the large apertures

Products: The analysis of the data obtained will lead to an RSDP update within 3 months of the final observations. Inverse sensitivity reference files (IVnHFILE) will be delivered.

Proposal ID 6204: FOS Cycle 5: Wavelength Calibration: Internal/External Offsets and Scattered Light

Purpose: The observations in this program will be used to determine the wavelength offsets between the internal and external light sources and to determine the scattered light properties of the FOS. The two tests (calculation of offsets and scattered light) have been put together to save expensive target acquisition time and make the total calibration program more time efficient. The observations will simultaneously compare the FOS and GHRS wavelength scales.

Description:

Part 1: The observations in the first part of this proposal will determine the FOS wavelength scale for all commonly used disperser/detector combinations. In this test, we will obtain spectra of external and internal wavelength calibration sources, and compare the resulting channel versus wavelength relationships to search for any offset between the two. The external objects, as well as the internal Pt-Ne lamp, will be observed through one aperture, the 0.3 aperture in the standard FOS ACCUM mode. The primary velocity target, NGC 6833, has insufficient lines in the G130H spectral region, so the second target (HD 207757) is required for this grating. Both sources are observed with sufficient RED and BLUE spectral elements in order to place all observations on the same velocity system. Internal sources make up a small fraction of the exposure time and must be acquired at the same time as the external sources, so they can NOT be scheduled as parallel observations. Derived wavelength offsets can be applied to the polynomial fit of pixel number versus wavelength determined from the lines in the internal Pt/Cr-Ne lamp.

Part 2: This part of the test will determine the impact of light from wavelengths longer than 3000 Å scattered off the FOS UV gratings. HD 207757 will be observed with the FOS UV gratings, and will be compared with HRS Side 1 observations. Since HRS Side 1 is insensitive to wavelengths longward of approximately 2000 Å, any additional light detected in the FOS observations is attributable to longer-wavelength continuum light scattered off the FOS gratings. The object will also be observed throughout the visible with FOS/BL to provide a direct instrumental comparison between total detected long-wavelength counts and scattered long-wavelength counts. This will allow us to test our scattered light simulator in STSDAS. The observations with GHRS will allow us to compare the FOS and GHRS wavelength scales.

Primary External Targets: NGC 6833 and HD207757

Target Acquisition Technique: ACQ/PEAK for a pointing accuracy of 0.04″, ACQ with GHRS

Detectors: Blue and Red FOS detectors and the GHRS side 1

Apertures: 0.3″ circular, 4.3″ square and 1.0″ circular for the FOS and the GHRS 2.0″

Dispersers: G130H, G190H, G270H, G400H, G570H (Blue side, 0.3″ circular)

G190H, G270H, G400H, G570H, G780H (Red side, 0.3″ circular)

G140L (GHRS)

Fraction of GO/GTO Programs Supported: 100% of the programs will be affected by the wavelength calibration part of the proposal, while ~60% by the scattered light part of the proposal.

Resources:

Duration (orbits): 21 external orbits

Special Requirements: For the wavelength calibration part of the proposal, the internal sources make up a small fraction of the exposure time and must be acquired at the same time as the external sources, so they can NOT be scheduled as parallel observations.

In the time between the individual exposure pieces for the scattered light test, the FOS filter grating wheel MUST NOT be moved. This includes the homing of the instrument that would occur if a non-FOS observation is inserted in the time between the pieces. This restriction also applies to the internal WAVE observations - the filter grating wheel MUST NOT be moved between the external and internal observations. Internal Pt/Cr-Ne lamp observations must immediately follow each external observation.

Accuracy:

Part 1: The wavelength calibration accuracy is affected by the errors in the zero point of the wavelength scale. These offsets can be calculated to ±0.2 diodes for the FOS. In a typical FOS observation, which is not accompanied by a wavelength calibration, the wavelength error is dominated by the non-repeatability of the filter-grating wheel. The error is of the order of 0.35 diodes. For an FOS observation accompanied by a wavelength calibration and obtained with no filter-grating wheel motion, the wavelength accuracy is roughly 0.1 diodes.

Part 2: The scattered light in the FOS is due to grating scatter and is a major source of error for red objects which are observed in the UV gratings. A full correction for scattered light requires an understanding of the spectral energy distribution of the target across the FOS wavelength sensitivity range. A model prediction exists and needs to be verified.

Accuracy Requirement: 0.2 diodes for wavelength calibration,

Accuracy Goal: 0.1 diodes for wavelength calibrations

Products: Wavelength offsets found between internal and external sources will need to be incorporated into the dispersion coefficients used by the PODPS pipeline. The analysis of the wavelength calibration data will thus lead to an RSDP update which will occur within 2 months after the final observations. There are wavelength calibration reference files (CCS6) to be delivered. The scattered light part of the proposal will not lead to any database update, and therefore there are no reference files to be delivered. The analysis will lead to testing of the present scattered light model.

Proposal ID 6205: FOS Cycle 5: Location of the 1.0″ aperture and the FOS PSF

Purpose: The observations in this proposal will be used to determine the location of the FOS 1.0″ circular aperture, the PSF in the FOS focal plane, and to determine the amount of light scattered by a nearby bright object into the FOS 1.0″ aperture.

Description: This proposal has a high priority because the stability in the location of the apertures will be checked by comparing with Cycle 4 observations of the location of the 1.0″ aperture, since this technique provides the most precise (V2,V3) locations. Further the observations can also be simultaneously used to determine the amount of light scattered into the FOS 1.0″ aperture by a nearby target, which is important for a number of proposals that are and will be using the FOS to observe faint sources close to very bright targets. The location of the 1.0″ aperture and the amount of light scattered into the 1.0″ aperture will be determined by performing a raster step and dwell sequence in the FOS aperture along two perpendicular directions in the aperture to find the maximum throughput for the aperture out to 5″. This test has to be conducted for both the RED and BLUE detectors. This test will be conducted once during Cycle 5.

Primary External Targets: STAR-073628-594316 (CVZ)

Target Acquisition Technique: ACQ/BINARY followed by ACQ/PEAK (accuracy ≤ 0.08″)

Detectors: Blue and Red

Apertures: 1.0″ circular

Dispersers: N/A

Fraction of GO/GTO Programs Supported: 100%

Resources:

Duration (orbits): 12 external orbits

Special Requirements: All observations in this program MUST occur in non-SAA impacted orbits.

Accuracy:

Accuracy Requirement: 0.1″

Accuracy Goal: 0.05″

Products: The analysis of the data obtained may lead to an PDB update which will occur within 3 months of the final observations. There are no reference files to be delivered.

Proposal ID 6206 FOS Cycle 5: FOS Polarimetry Calibration

Purpose: The observations in this proposal will be used to determine the spectrophotometric calibration of the FOS for polarimetry using the UV gratings for the red detector, and determine the stability of the spectropolarimetric modes relative to Cycle 4 observations.

Description: The polarimetric calibrations are needed to establish a number of parameters that will be needed to determine the polarimetric capabilities of the FOS. This goal will be achieved by determining the locations of the polarization spectra, the transmission of the polarizer, the angles of the Wollaston prisms and wave plates in celestial coordinates, and the instrumental polarization. Since a number of parameters have to be determined in a sequence the proposal has been divided into three parts for ease.

Part 1: Measurements of the internal Pt-Ne lamps will be used to locate the two oppositely polarized spectra that occur with the polarimeter. The positions of the split spectra will be compared to those of spectra taken without the polarimeter. The data will be used to determine a wavelength scale for the most commonly used modes of the polarimeter.

Part 2: The instrumental polarization, flat-field corrections, and throughput of the polarimeter will be measured by observing the polarimetric and photometric standard BD+28D4211. Observations with the polarimeter will be taken at two roll angles separated by 45 degrees.

Part 3: The angles of the Wollaston and wave plates will be measured in celestial coordinates by observing the polarized standard BD+64D106 at two roll angles 45 degrees apart.

Primary External Targets: BD+28D4211 and BD+64D106

Target Acquisition Technique: ACQ/PEAK for a pointing accuracy of 0.04″

Detectors: Red

Apertures: 1.0″ circular

Dispersers: G190H, G270H, G400H

Fraction of GO/GTO Programs Supported: ~5%

Resources:

Duration (orbits): 20 external orbits and 2 non-prime orbits

Special Requirements: The observations in Part 1 must precede those in Parts 2 and 3. At least two to three weeks should be allowed after the data from Part 1 are in hand before scheduling Parts 2 and 3. Observations in Part 1 can be done in parallel with another instrument prime. It is preferable for Part 2 to occur before Part 3, but it is not essential. Note that for the Y-base maps with the polarizer, the map is normally centered on the Y-base for the lower of the two polarization spectra. We have therefore broken the maps into two segments, one to be centered on the lower spectrum, and one to be centered on the upper. The lower will use the default Y-value, while the upper should be +750 Y-units from the lower. Polarimetric observations need to be taken as a single sequence of observations. Changes in background, position angle of the spacecraft, and other variables can all adversely affect the results. This test is stray light sensitive.

Accuracy: The instrumental polarization due to COSTAR is ≤2% and is wavelength-dependent.

The calibration goal is to achieve rms polarimetric uncertainties of ≤0.2% for the bright polarimetric standard used.

Accuracy Requirement: ~0.5%

Accuracy Goal: ≥0.2%

Products: The analysis of the data obtained will lead to an RSDP update which will occur within 4 months of the final observations. There are polarimetry reference files (CCS4, RETHFILE) to be delivered.