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Goddard High Resolution

Spectrograph (GHRS)

Instrument Handbook

(for the post-COSTAR observatory)

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> This GHRS 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.

STScI Contacts for Assistance

Function	Contact Name	Title	Phone	e-mail
General instrument questions	David R.Soderblom	Lead GHRS Instrument Scientist	410-338-4543	*soderblom@stsci.edu*
	Stephen J. Hulbert	GHRS Instrument Scientist	410-338-4911	*hulbert@stsci.edu*
	Claus Leitherer	GHRS Instrument Scientist	410-338-4425	*leitherer@stsci.edu*
	Lisa Sherbert	Technical Assistant	410-338-5036	*lisa@stsci.edu*
Proposal-specific questions	User Support Branch	Technical Assistants		*usb@stsci.edu*

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This *Handbook* exists as a basic reference manual for the Goddard High Resolution Spectrograph (GHRS), and describes its properties and operation.

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Instrument Handbook for the Goddard High Resolution Spectrograph (GHRS)

Version 5.0
For the post-COSTAR observatory in Cycle 5 of the HST science mission
May, 1994

The STScI GHRS Team

D.R. Soderblom
S.J. Hulbert
C. Leitherer
L.E. Sherbert

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There are two reasons you may be referring to this *Handbook*. First, you may be considering using the GHRS to observe some celestial object, and you would like to know what the instrument can do and how long it might take. Better yet, your proposal to use the *Hubble Space Telescope* with the GHRS has been successful and you now need to supply all the details of your observations that are needed in Phase II of proposal processing.

Both tasks may seem daunting at first because any versatile instrument has many options. But for what most people want to do most of the time there are defaults that apply, and the GHRS is, in fact, a very easy-to-use device. Once you know that what you want to do falls within the bounds of conventional uses of the spectrograph, you can proceed with some confidence that your observations will be successfully obtained in the form you originally desired. Or you can at least get a sense that what you are proposing is truly unusual and may push the limits of the instrument.

This *Handbook* exists as a basic reference manual for the Goddard High Resolution Spectrograph (GHRS), and describes its properties and operation. This *Handbook* is revised and reissued approximately once each year. This version is written for observers wishing to propose to use the GHRS in *HST*'s Cycle 5, and it supersedes all previous versions of the *Instrument Handbook*. No *HST* document stands alone in providing complete information because each fills a particular need. The *Call for Proposals*, for example, describes the proposal submission process and provides a summary of the observatory and its instruments. The *Phase II Proposal Instructions* give detailed instructions for providing STScI with the specifications that translate your program into commands that *HST* executes. The instrument handbooks supplement both documents by providing the technical details of instrument performance and operation. The *HST Data Handbook* describes how software takes the raw data from the telescope and transforms it into a reduced and calibrated form for your further analysis and interpretation, and how you can duplicate those steps.

HST is now a fairly mature spacecraft and so we can predict what many observers will need. This *Handbook* is designed around the needs of the majority of users, so that essential information is concentrated in a few sections. Full details must also be given, of course, and they are provided in a reference section. We demonstrate the ease of use of the GHRS by providing examples for some of the different situations that a user might encounter. We have also tried to provide the information you need to decide when your observations deviate from the "normal" and involve special aspects.

No handbook of this kind can be complete and error-free until the instrument itself is obsolete. We have, of course, edited it thoroughly, but if significant revisions are called for they will be announced via STEIS[1], as with other *HST* news items. Do not be afraid to consult with us if you have questions; the means of contact are provided just after the title page.

As we said, this particular version of the *GHRS Instrument Handbook* is being written for Cycle 5 of the *HST* science program. That means that we are providing information on how the instrument works after the Servicing Mission installed COSTAR and a GHRS Repair Kit. COSTAR changed the image scale of *HST* at the entrance apertures

1. This and other terms are defined and described in a Glossary at the end of this *Handbook*.

of the GHRS; it also produces diffraction-limited images, but does not alter GHRS operations in any fundamental manner. In other words, COSTAR alters some of the parameters used in various calculations for pointing and throughput, but the instrument still operates in the same way.

The GHRS Repair Kit enabled the reactivation of Side 1 of the GHRS, once again permitting short-wavelength echelle spectra to be obtained, as well as spectra with the G140L and G140M gratings. At the time this is written Side 1 reactivation has been completed and a few observations have been made. They indicate that Side 1 is performing with essentially the same science capabilities that it had at the time of *HST*'s launch.

1.1 This Handbook

If you have looked through the Table of Contents, you will have seen that this *Handbook* is divided into four parts:

Part I is a summary in which this *Handbook* is described and suggestions are made on how to use this document and how it is related to other *HST*-related documents. Part I also describes how *HST* proposals are processed for review by the Telescope Allocation Committee (TAC) and how successful proposals get turned into commands that the spacecraft can execute; and it describes how the installation of COSTAR affects the GHRS and what the basic properties of the instrument are.

Part II elaborates on the writing of proposals to use the GHRS, both for Phase I and Phase II. The Phase I proposal is what the TAC sees, and it describes the observations to be made in broad terms. The most important technical decisions to be made regard the target acquisition strategy to adopt and the amount of exposure time to request. The Phase II proposal encompasses all the details that the planning and scheduling systems need to turn your program into commands for the spacecraft.

Part III is a reference section, and it includes the details that a *Handbook* should without cluttering the introductory explanations.

Part IV is a short glossary of GHRS terms and abbreviations and an index.

Data reduction and analysis are not covered in this *Handbook* because they are treated in detail in the *HST Data Handbook*, although we anticipate merging portions of that document into this in the future.

External references have been included where appropriate in order not to duplicate what is available elsewhere, but we have tried to include almost everything you need to know about the GHRS when writing a proposal. If you find that you need information that is not in here, please consult with us.

This document follows the usual STScI convention in which terms, words, and phrases which are to be entered by the user in a literal way on a form are shown in a typewriter font (e.g., `BRIGHT=RETURN`, `EARLY ACQ`).

1.2 Changes since the previous version

1.2.1 This Handbook

This version of the *GHRS Instrument Handbook* has been only modestly rewritten. It incorporates a few updates since version 4.0 that were issued electronically. Please bring errors to the attention of a GHRS Instrument Scientist (see back of title page). As before, wavelength units in this *Handbook* are in Ångstroms (Å), in keeping with astronomical tradition. A transition to SI units may take place in a future edition.

1.2.2 Side 1 Availability

At the time this is written, the capabilities of Side 1 of the GHRS have been fully restored, permitting one to obtain high-, medium-, or low-resolution spectra with a cesium iodide photocathode. We encourage you to consider its use. The low-resolution mode on Side 1 using grating G140L particularly makes the GHRS useful for observing faint objects in the far ultraviolet. The next two paragraphs discuss issues related to acquiring such targets.

1.2.3 Acquiring Extended Objects with the GHRS

An `EXTENDED` option for `ACQ/PEAKUP` was described in earlier versions of this *Handbook*. It will be tested in Cycle 4 and should be available for routine use in Cycle 5. It was written with the Gallilean satellites of Jupiter in mind, but should be applicable to other extended objects. See Section 4.1.5.4 on page 39 for more details.

We have also provided some guidance for users who may wish to observe extended objects so that acquisition count rates can be estimated; see Section 7.3 on page 76.

1.2.4 Acquiring Faint Objects with the GHRS or FOS

In some cases the G140L grating on Side 1 may provide an efficient means of obtaining a low-resolution spectrum of a source, but acquiring that object can be difficult or impossible with the GHRS' Side 1 because of the limited response of mirror N1 and the maximum permissible `STEP-TIME` of 12.75 seconds. There are two ways to overcome this problem:

- Acquire the object with Side 2 of the GHRS (mirror N2), then observe with Side 1. Using this technique will add about 40 minutes of overhead time involved in switching Sides, but often that can occur when the spacecraft is behind the earth anyway.
- Acquire the object with the Faint Object Spectrograph and then move it to the LSA of the GHRS. The positions of the COSTAR mirrors for the FOS and GHRS are quite close, so that the movement of an object from an FOS aperture to the LSA of the GHRS is only about 1 arcmin, a small enough motion to ensure that the object will fall within the LSA because one set of guide stars will suffice. This method should *not* be used for SSA observations.

At the time this is being written this method of cross-spectrograph acquisitions is being evaluated and tested. Please consult with us if you wish to consider using it. Also please note that the opposite sense will also work, namely acquiring a "bright" object with the GHRS in order to observe it with the FOS.

1.2.5 Noise Rejection for Very Faint Objects

A special commanding option called `FLYLIM` can be invoked to reject noise in the GHRS when the object observed is significantly fainter than the level of the background noise. Although only applicable in special situations, it can be very effective. Please see Section 8.6.3 on page 97.

1.2.6 The Proposal Process for Cycle 5

The basic methodology of proposal writing for *HST* has been changed. You should rely on the proposal instructions being issued with this *Handbook* for guidance if there are any conflicts, but the essential information needed (sequence of operations and exposure times) has not changed.

1.2.7 Updated Instrument Parameters

Because of the Servicing Mission, the GHRS is a brand-new instrument in many respects. We have undertaken to measure many basic instrumental quantities, such as sensitivities, *ab initio* so that observations obtained in Cycle 4 and beyond can be calibrated to the best possible level. Many of those observations were not been fully analyzed at the time this *Handbook* was last revised before issuance. The numeric values herein, particularly sensitivities, are therefore not "final" values that will be in place for data reduction, but they do reflect our knowledge of the post-Servicing Mission GHRS and will therefore lead to reliable exposure estimates. Updated information will be provided on STEIS as it becomes available.

1.2.8 GHRS Sensitivity

The sensitivity of the GHRS has turned out to be more wavelength-dependent than was anticipated prior to the Servicing Mission; see Section 8.1 on page 82. The reasons for this are not known, but users should use the measured sensitivity values in Section 8.2.3 on page 85 and Section 8.3.1 on page 87 when calculating exposure times and should definitely *not* scale exposures from older proposals.

1.2.9 GHRS Aperture Nomenclature

The plate scale at the entrance apertures of the GHRS is altered by COSTAR such that the angular scale per unit of physical length is reduced by a factor of 0.87. (COSTAR's mirrors also introduce anamorphic magnification, but its effect is so small – about 0.5% – that it is ignored here.) That means that the aperture sizes change in the following way:

Aperture	Nomenclature	Pre-COSTAR Size	New Size
Large Science Aperture (LSA)	`2.0`	2.00 arcsec	1.74 arcsec
Small Science Aperture (SSA)	`0.25`	0.25 arcsec	0.22 arcsec

Note that the names used to designate the apertures of the GHRS have not changed even though their angular sizes did. To lessen confusion somewhat, we will use "LSA" and "SSA" to refer to the large and small apertures, respectively, of the GHRS.

1.3 Where to find additional information, changes, errata, etc.

As we mentioned, the *Call for Proposals* provides an overview of *HST* capabilities and describes how a Phase I proposal is to be prepared. It goes hand-in-hand with the *Phase I Proposal Instructions* and documents for the Remote Proposal Submission System (RPSS). If your proposal is successful, you will need to submit a Phase II proposal that provides all the specific details we need to ensure that your observations are obtained in the form you intend. This *Handbook* provides much of the information you will need in Phase II, with the proposal procedures themselves in a *Phase II Proposal Instructions* book. There is also a separate document that describes how to process and reduce GHRS data. Contact the User Support Branch of STScI for further details. (Please note, incidentally, that the *Target Acquisition Handbook* is no longer produced because it is redundant.)

There is a separate document titled *HST Data Handbook* that describes how *HST* data are reduced by the "pipeline" system and how you can reproduce those steps to tailor the reduction to your needs. A copy may be obtained from the User Support Branch.

Do not use out-of-date documents as a source of information! If this *Handbook* does not contain the information you need, please consult us.

This *Instrument Handbook* is written to apply to the Goddard High Resolution Spectrograph as it will be configured and will operate in Cycle 5 of the *HST* science program. The installation of COSTAR has changed the dimensions of the apertures and other elements of GHRS as measured in arcsec projected on the sky. The new dimensions have been used throughout this document. This *Handbook* supersedes all previous versions, but if another document conflicts with this *Handbook*, you should use the one with the most recent date-of-issue.

You should also be aware of STEIS, the *Space Telescope Electronic Information Service*. STEIS provides an easy way to check for updates to existing documents and to get *HST*-related information and news. To use STEIS, *ftp* to *stsci.edu*, enter *anonymous* as the user and your last name as the password. Transfer the README file in the highest-level directory with a *get* command to get basic information. Various subdirectories provide details on specific subjects. For more information on STEIS, contact the User Support Branch. The xterm interface to *ftp* called *Mosaic* is an especially effective way to access STEIS.

You are always welcome to call us, the STScI GHRS team, to get information when you find yourself confused or at a loss. We prefer e-mail (to the addresses on the back of the title page), but you may contact us by telephone if you wish.

Finally, you will find some additional sources of information in Chapter 9.

Chapter 2

Instrument Summary — Why Use the GHRS?

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The Goddard High Resolution Spectrograph was built to obtain high-quality spectra of astronomical sources efficiently. The GHRS can also record images of the objects it observes, but that is mostly as an adjunct to its spectroscopic properties to confirm pointing.

2.1 Fundamental properties of the instrument

Here we provide a brief overview of the basic properties of the GHRS. Each of these aspects is described in more detail in the next two chapters. Chapters 6, 7, and 8 provide illustrations of the GHRS and tables of instrument parameters.

2.1.1 Entrance Apertures

The source to be observed may be centered in a Large Science Aperture (LSA) or a Small Science Aperture (SSA)[1]. Because of the installation of COSTAR, the LSA is 1.74 arcsec square and the SSA is 0.22 arcsec square, although they retain their pre-COSTAR names (`2.0` and `0.25`, respectively). The high-quality images that COSTAR produces mean that spectra with good spectroscopic resolution result when the LSA is used. The SSA has about 50 to 70% of the throughput of the LSA; using the LSA will degrade resolution by 10 to 20% compared to the SSA because of the wings to the instrumental profile.

The LSA has a shutter which automatically closes when an observation with the SSA is being performed, in order to reduce stray light.

2.1.2 Useful Wavelength Range

The GHRS can obtain spectra from about 1150 to 3200 Å. These limits are set by the magnesium fluoride coatings on *HST*'s optics and by the nature of the detectors. The additional two reflections introduced by COSTAR's mirrors significantly reduce throughput at the very shortest wavelengths (i.e., below Lyman-α) so that even very bright stars (e.g., μ Col) have failed to produce detectable flux below 1150 Å. It is possible to observe bright stars out to 3400 Å.

2.1.3 Available Resolving Powers

With Side 1, observations may be made from 1150 to 1800 Å at $\mathcal{R}$= 2,000, 25,000, and 80,000 (gratings G140L, G140M, and Ech-A, respectively). With Side 2, the options are $\mathcal{R}$= 25,000 from 1150 to 3200 Å (G160M, G200M, and G270M) and $\mathcal{R}$= 80,000 from 1680 to 3400 Å (Ech-B). For certain applications it can be advantageous to use grating G270M to wavelengths as low as 2100 Å because of its high efficiency.

1. We will use "LSA" and "SSA" to denote the two science apertures of the GHRS in this document in order to lessen ambiguity about their apparent size. Note that the official nomenclature of "`2.0`" and "`0.25`" does not change despite the fact that these two apertures are now 1.74 and 0.22 arcsec square respectively.

2.1.4 Photometric Precision and Accuracy

Routine calibrations on standard stars provide flux-calibrated spectra that are accurate to 10%[1]. Relative fluxes obtained at different wavelengths should be good to better than 5%. The repeatability of fluxes is even better, being better than 1%; i.e., it is possible to compare measures of the same wavelength in the same star at different times to within 1% for observations with the LSA.

Within a single bandpass (i.e., one grating setting), relative photometric precision is limited by photon statistics for S/N < 30 and by detector non-uniformities above that, provided that the detectors are being used within the linear portion of their response. With suitable observing strategies, it is possible to achieve relative S/N as high as 900 (Lambert et al. 1994)[2].

We have found that the photometric sensitivity of the GHRS has not changed with time to within 1% or less.

2.1.5 Time Resolution

Most observers use the GHRS to accumulate photons for the time needed to reach the signal-to-noise they desire. In ACCUM mode the exposures may be as short as 0.2 seconds, although use of standard procedures for improving S/N usually limits exposures to no shorter than about 15 seconds. The GHRS has a rapid readout mode (RAPID) that can obtain spectra as often as every 50 milliseconds, but that can only be done by sacrificing many features that are important for producing high-quality spectra.

2.1.6 Operational Complexity

The limited availability of memory on the *HST* spacecraft means that there exists a maximum number of operating commands that can be in place for a single set of observations. That can be a limit for use of the GHRS in certain cases, described later (Section 4.6 on page 47).

2.2 A Brief Description of the Instrument and Its Operation

The GHRS has the usual components of an astronomical spectrograph: entrance apertures, a collimator, dispersers, camera mirrors, and detectors. There are also a wavelength calibration lamp, flat field lamps, and mirrors to acquire and center objects in the observing apertures. The apertures were described above in basic terms, and are illustrated in Section 6.1 on page 56. The collimator and camera mirrors are unexceptional and need no further description here (see Section 6.2 on page 60 for details). The important elements are the dispersers and the detectors.

1. Starting in Cycle 4, the routine fluxes delivered by the pipeline data reduction system are no longer on the *IUE* system but instead have been adjusted to conform to models of the white dwarf G191B2B. This can produce systematic differences when comparing observations.

2. References are listed in Chapter 9.

The dispersers are mounted on a rotating carrousel, together with several plane mirrors used for acquisition. The first-order gratings are designated as G140L, G140M, G160M, G200M, and G270M, where "G" indicates a grating, the number indicates the blaze wavelength (in nm), and the "L" or "M" suffix denotes a "low" or "medium" resolution grating, respectively. The GHRS medium resolution first-order gratings are holographic in order to achieve very high efficiency within a limited wavelength region. G140L is a ruled grating. The first two first-order gratings, G140L and G140M, have their spectra imaged by mirror Cam-A onto detector D1, which is optimized for the shortest wavelengths. The other three gratings have their spectra imaged by Cam-B onto detector D2, which works best at wavelengths from about 1700 to 3200 Å, but which is also useful down to 1200 Å.

The carrousel also has an echelle grating. The higher orders are designated as mode Ech-A, and they are imaged onto D1 by the cross-disperser CD1. The lower orders are designated as mode Ech-B, and they are directed to D2 by CD2. Finally, mirrors N1 and A1 image the apertures onto detector D1, and mirrors N2 and A2 image onto D2. The "N" mirrors are "normal," i.e., unattenuated, while the "A" mirrors ("attenuated") reflect a smaller fraction of the light to the detectors, so as to enable the acquisition of bright stars. (To be precise, the mode designated as N1 actually uses the zero-order image produced by grating G140L.)

Use of the various gratings or mirrors in concert with the camera mirrors produces one of three kinds of image at the camera focus: 1) an image of the entrance aperture, which may be mapped to find and center the object of interest; 2) a single-order spectrum; or 3) a cross-dispersed, two-dimensional echelle spectrum.

The flux in these images is measured by Digicon detectors, and the portion of the image plane that is mapped onto the Digicon is determined by magnetic deflection coils. The detectors are the heart of the GHRS and they involve subtleties that must be understood if the instrument is to be used competently.

First, there are two Digicons: D1 and D2. D1 has a cesium iodide photocathode on a lithium fluoride window; that makes D1 effectively "solar-blind," i.e., the enormous flux of visible-light photons that dominate the spectrum of most stars will produce no signal with this detector, and only far-ultraviolet photons (1100 to 1800 Å) produce electrons that are accelerated by the 23 kV field onto the diodes. D2 has a cesium telluride photocathode on a magnesium fluoride window. Each Digicon has 512 diodes that accumulate counts from accelerated electrons. 500 of those are "science diodes," plus there are "corner diodes" and "focus diodes" (see Chapter 6).

Second, both photocathodes have granularity – irregularities in response – of about 0.5% (rms) that can limit the S/N achieved, and there are localized blemishes that produce irregularities of several percent. The Side 1 photocathode also exhibits "sleeking," which is slanted, scratch-like features that have an amplitude of 1 to 2% over regions as large as half the faceplate. The effects of these irregularities could in principle be removed by obtaining a flat field measurement at every position on the photocathode, but that is impractical. Instead, the observing strategy is to rotate the carrousel slightly between separate exposures and so use different portions of the photocathode. This procedure is called an `FP-SPLIT`, and with it each exposure is divided into two or four separate-but-equal parts, with the carrousel moving the spectrum about 5.2 diode widths each time in the direction of dispersion. These individual spectra can be combined together during the reduction phase.

Third, the diodes in the Digicons also have response irregularities, but these are very slight. The biggest effect is a systematic offset of about 1% in response of the odd-numbered diodes relative to the even-numbered ones. This effect can be almost entirely defeated by use of the default COMB addition procedure. COMB addition deflects the spectrum by an integral number of diodes between subexposures and has the additional benefit of working around dead diodes in the instrument that would otherwise leave image defects.

Fourth, the Digicons' diodes are only slightly smaller than the image of the SSA produced by the optics, and are larger than the point spread function (PSF) for *HST*. Thus the true resolution of the spectrum cannot be realized unless it is adequately sampled. That is done by making the magnetic field move the spectrum by fractions of the width of a diode, by either half- or quarter-diode widths, and then storing those as separate spectra in the onboard memory. These are merged into a single spectrum in the data reduction phase. The manner in which this is done is specified by the `STEP-PATT` parameter, described in more detail later. The choice of `STEP-PATT` also determines how the background around the spectrum is measured.

Defaults exist for these parameters and they have been set to yield the best quality of spectrum for the configuration to which they apply (except for `FP-SPLIT`, which must be invoked explicitly). Details on the defaults are provided later (Section 4.3 on page 43), but we strongly encourage you to use the defaults unless there are compelling reasons not to.

2.3 A Little About How *HST* and GHRS Work

Because of the difficulties of working with and communicating with a satellite in low-earth orbit, and in order to make *HST* more efficient, virtually all actions taken by the spacecraft are planned weeks in advance. Only a small fraction of *HST*'s time can be used for real-time actions that are at the discretion of the observer, and even then the realm of possible actions is very limited, being restricted to deciding which object in the field should be centered in the aperture before a subsequent observation is begun.

This need for detailed planning of *HST* observations lies at the heart of the apparent complexity of the use of the spacecraft and its instruments. At the same time, by carefully laying out every aspect of what you want done you will find yourself with a better understanding of what actually happens and more confidence that the desired results will be achieved.

All *HST* observations begin with an acquisition. An acquisition can be as simple as blindly pointing to particular celestial coordinates, although such a procedure is unlikely to succeed with the GHRS because its entrance apertures are small. For the GHRS, an acquisition usually means a pointing to precisely specified coordinates, small motions of the telescope in a spiral pattern to sample the region of sky in the vicinity of the coordinates, and then a peakup motion to center a star in the aperture after on-board software has determined its location. Variations include offsetting from the acquired star to another nearby object or moving the star to the small aperture. In rare cases it may be necessary to perform an interactive acquisition, in which the observer specifies the object in real time. An intermediate possibility is to take an image with one of *HST*'s cameras (or with the GHRS itself) in advance of the spectroscopic observation (by one to two months) and to then derive precise coordinates from that image (an early acquisition). For very faint objects, especially those to be observed with Side 1 of the GHRS, it is possible to acquire the object with the Faint Object Spectrograph before moving it to the LSA.

Once the star has been properly positioned in the appropriate aperture of the GHRS, science observations may begin. In some cases you may wish to use `IMAGE` mode, which can map the LSA at ultraviolet wavelengths, but in general this part means dispersing the light with one of the gratings and adding up the counts to form a spectrum. A `RAPID` mode also exists to record spectra that change on very short time scales. The GHRS has no independent microprocessor and so depends on the spacecraft's computer and memory for control of its operations. One implication of that dependence is that there is a maximum number of commands that can be stored at any one time. Since those commands are generally loaded into the spacecraft only a few times per day, that limitation restricts the total number of GHRS exposures that may be made in a 24 hour period. At the same time, image motion within the instrument that is induced by the earth's magnetic field (see Section 8.6.5 on page 98) is best dealt with by making individual exposures no longer than about 5 minutes, thereby increasing the total number of exposures you need to make to get a science observation. In some cases these requirements come into conflict and compromises must be made to accommodate science goals.

Some other relevant aspects of scheduling *HST* observations are:

- Objects in most regions of the sky "rise" and "set" and will be available for science observations for about half of an orbit (about 45 to 50 minutes). Longer exposures get spread over several orbits, with a reacquisition at the beginning of each orbit, but this occurs at no practical cost in science terms since the GHRS' detectors are photon counters. Some objects sometimes fall within *HST*'s Continuous Viewing Zones (CVZs), which enables them to be observed for long times at high efficiency; see the *Call for Proposals* for details on taking advantage of the CVZs.
- The orbit of *HST* passes through the South Atlantic Anomaly (SAA), which is a region in which the background count rate is very high. At present the scheduling software simply stops the counting of photons during times when the spacecraft is within the SAA.

2.4 GHRS Modes of Operation

GHRS has several operational modes for target acquisition and obtaining science data. See also Section 4.1 on page 35 for more discussion of acquisitions.

2.4.1 Target Acquisition Mode

2.4.1.1 Onboard Acquisitions

Most targets observed with the GHRS can be automatically acquired with an onboard acquisition (ONBOARD ACQ). An onboard target acquisition observation consists of distinct phases, which are executed in ascending numerical order. Phases 1 and 2 perform initialization and internal calibration functions, and need not concern the observer. The third phase is called Target Search. A series of small angle maneuvers, called a "spiral search," scans an area of the sky centered on the initial position. The flux coming through the Large Science Aperture (LSA) is measured at each dwell point in the search. If the `BRIGHT=RETURN` option has been chosen (and it is recommended), the telescope returns to that dwell point which had the greatest number of counts. If `BRIGHT` and `FAINT` limits have instead been specified, the flux is compared to these upper and lower limits at each step in the spiral, and if the measured value falls between these limits the target is assumed to be within the aperture and the search immediately stops. You may request that a field map be generated at the final dwell point by means of the `MAP` optional parameter. You should be aware, though, that approximately two minutes is required for each map, and that many pointings may be made during the search. (If you intend to analyze the maps in real time, the search phase must be done as an interactive acquisition.) If you wish to confirm the spacecraft's pointing, we recommend obtaining an `IMAGE` *after* the acquisition instead of using the `MAP` option – see Chapter 4.

The fourth phase is target locate (`ACQ/PEAKUP`). This process measures the precise location of the target within the aperture, and requests a small angle maneuver to move it to the center. The field map of the LSA may be made *before* the centering maneuver is performed by specifying `MAP=END-POINT`. If done *after* the centering (in `IMAGE` mode), the map can be helpful for confirming that the object was placed precisely in the center of the aperture[1]. The final phase of an acquisition is a flux measurement in which the flux entering the GHRS through the final target aperture is measured and inserted into the data. After centering, a second maneuver will automatically translate the object to the SSA if that is the aperture specified for the observation. An `ACQ/PEAKUP` with "`0.25`" as the specified aperture will also center the object in the SSA.

1. Please don't get the wrong impression. Getting an image of the aperture to confirm pointing is rarely necessary or useful and we mention it here mostly for completeness. If you are working in a crowded field, it might help to know exactly what was in the aperture after the fact.

For some kinds of difficult targets an onboard acquisition may not work. Possible causes might be:

- The error in the coordinates is greater than a few arcsec in either declination or right ascension, so that the target lies outside the largest area that the GHRS can search in its onboard procedure.
- The object is a moving target whose coordinates could not be predicted with ±5 arcsec accuracy when the proposal was written. Features in the atmosphere of a planet, and comets are possible examples.
- The object has a poorly known or unpredictably variable ultraviolet flux.
- The target has nearby neighbors of similar brightness – the onboard search process could center up on the wrong object.
- The object has a spatial extent greater than two arcsec. The automatic centering algorithms may not produce acceptable results on objects comparable in size or larger than the Large Science Aperture.
- The object is too faint to get adequate counts with the maximum permissible integration time of 12.75 seconds.

In many cases these problems can be worked around by using an onboard acquisition on a nearby star and then offsetting to the object of interest, or, perhaps, by using the FOS to acquire before slewing the target to the GHRS.

2.4.1.2 Early and Interactive Acquisitions

You may choose to obtain an early acquisition (`EARLY ACQ`) image with WFPC2, FOC, or GHRS itself. In some cases an acquisition image would be helpful, but the field of view of the WFPC2 is not needed. Stationary point sources in crowded but recognizable fields would be examples. The GHRS has its own "field map" capability which will produce an image of the sky as seen through the LSA. Each map is a square array of 16×16 pixels, covering 1.74×1.74 arcsec with 0.11 arcsec spatial resolution. A single field map requires a minimum of two minutes to take the data and send it to the ground, and much longer if each point in a spiral search is mapped or if a `STEP-TIME` longer than the default (0.2 sec) is used. One WFPC2 image requires from three to five minutes, but covers a much larger area of the sky. As a practical matter, if more than one field map would be needed, a WFPC2 image may be a more efficient choice. The FOC could also be an appropriate choice for ultraviolet-bright objects.

If an interactive acquisition (`INT ACQ`) is required, the observer must be present at STScI, prepared to inspect the image and identify the target in a timely fashion. Real-time observations are subject to many constraints and are difficult to schedule (they are occasionally impossible). Early acquisition should therefore be chosen in preference to interactive acquisition whenever possible. The *HST* (Phase I) Proposal Forms require justification of requests for real-time observation.

2.4.2 Science Data Acquisition Modes

There are several modes of science data acquisition, including Accumulation Mode, Rapid Readout Mode, and Image Mode. Each of these modes may be used in conjunction with any of the optical configurations described earlier.

Accumulation Mode

Accumulation Mode (ACCUM) is the normal way of obtaining a spectrum with the GHRS. The name refers to the fact that data can be accumulated in the onboard computer during a long exposure. All of the features of the flight software are available in this mode, making it the most powerful, flexible, and automatic way to use the GHRS. There are two types of benefits which one can expect by using the flight software in Accumulation Mode.

The first is the ability to make long duration observations with effective and automatic control of the process. The time varying Doppler shift caused by the orbital velocity of the spacecraft is compensated for automatically. The software constantly monitors a set of data quality criteria and can flag, reject, or reobserve individual integrations that fail the tests. Finally, the software can suspend the observation during scheduled or unexpected interruptions, such as occultation of the target by the Earth or passage through the South Atlantic Anomaly, and then resume when the interruption ends. The very low background count rate and absence of readout noise in the Digicons make exposures of hours duration feasible, though it is strongly suggested that these be broken into shorter segments to aid in scheduling and protect against catastrophic data loss in the event of an unexpected problem.

The second category of benefits results from the ability of the software to perform patterns of integrations at closely spaced positions on the photocathode, a process which is referred to as substepping. There are four purposes for this. At the beginning of an observation, the software executes a procedure called Spectrum Y Balance (SPYBAL) to find the optimum centering of the image on the diode array. This compensates for minor changes in the image location due to thermal or electrical drifts. The second use is to make multiple (2 or 4) samples per resolution element (1 diode width) to ensure that the digital data satisfy the Nyquist sampling criterion. This is *very* important when the ultimate spectral resolution of narrow features is required. Third, the background adjacent to the spectrum or in the echelle interorder region can be measured. Finally, comb addition allows the effect of small diode-to-diode sensitivity variations to be minimized and eliminates the holes in the data due to a few inoperative channels. When substepping is used to define the detailed sampling of the spectrum and background, the data obtained at each step are accumulated into one of up to seven distinct "bins" in the memory of the onboard computer.

This overview of the flight software features is not exhaustive, but summarizes those capabilities which are immediately relevant to the acquisition of spectra in accumulation mode. Several items, namely substepping and exposure control, require the observer to specify certain parameters. These will be described in more detail later in this *Handbook*.

Rapid Readout Mode (sometimes called Direct Downlink)

Rapid Readout Mode (RAPID) is intended to provide very fast time resolution without the overhead times associated with Accumulation Mode. The sample time can be between 50 ms and 12.75 seconds, in increments of 50 milliseconds (i.e., 1 to 255 times 50 ms). At the end of each integration the data are read out, either directly to the TDRSS satellite or to the spacecraft science data tape recorder. The flight software cannot execute all of its functions and still allow readouts every 50 ms. When the Rapid Readout Mode is entered, substepping, data quality checks and exposure control features are deactivated. The primary factor governing the choice between ACCUM and RAPID is time resolution. In accumulation mode, the time between exposures can be as short as about one minute. If higher time resolution is required, if the source is bright enough to give useful counts in a shorter integration, and if one is willing to sacrifice the flight software control, then direct downlink is a useful alternative. In RAPID mode, a SAMPLE-TIME of less than 0.33 sec requires the use of the 1 Mb data channel (see Section 4.4 on page 45). Such a high data rate stresses *HST*'s data-handling capabilities and means that only about 20 minutes of observations can be stored.

Image Mode

Images may be obtained in this mode by deflecting the image of the photocathode over the 0.11×0.11 arcsec focus diodes. The result is a map similar to that obtained during target acquisition, but without an acquisition being performed. Also, a MAP as part of an acquisition can cover more of the sky than the LSA subtends at one time by small movements of the telescope, whereas an IMAGE is limited to the 1.74 by 1.74 arcsec area of the LSA; see Section 4.2 on page 42.

WSCAN and OSCAN Modes

These are really modifications of the ACCUMulation mode designed for higher efficiency in multiple observations, and they may be requested during Phase II of the proposal process. WSCAN obtains a series of spectra within a given order, incrementing by a specified wavelength increment between each. The result is a spectrum spanning a broader wavelength range than is possible with a single exposure. OSCAN works with the echelle, and uses the magnetic deflection of the Digicon to obtain spectra over a range of echelle orders. The grating carrousel is not rotated, and spectra are obtained at equal values of $m\lambda$, where m is the echelle order. OSCAN is not ordinarily used for science observations.

Chapter 3

Phase I: What the TAC Sees

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A proposal for the *Hubble Space Telescope* is written in two phases. In Phase I, you are asked to provide the minimum information needed for the Telescope Allocation Committee and STScI to judge the scientific merit and technical feasibility of what you wish to do. If your proposal is successful, you will be asked in Phase II to provide the specific details and parameters that are needed to turn your proposal into a series of commands that the spacecraft can execute. At the time this *Handbook* is being written the procedures for submission of *HST* proposals are under review; consult the *Call for Proposals* for the procedures in effect. In particular, Cycle 5 proposals will ask for time in units of orbits instead of total spacecraft time and an orbit calculator has been constructed to allow for planning.

These instructions for completing a Phase I proposal are meant to work with the Cycle 5 *Call for Proposals* and *Phase I Proposal Instructions*.

3.1 Essential questions

The essential questions you must answer in filling out an *HST* proposal form are:

- Do I need real-time acquisition for my targets?
- How long will my exposures take?
- Are standard calibrations adequate for my needs?
- Does my science call for any special requirements?

All of these lead up to:

- What is the total number of orbits my program asks for?

The information you provide on the execution of observations is divided into Phase I and Phase II. Phase I proposal processing takes place before the TAC meets and at that time you are asked to provide only the information that they need to arrive at a decision on the scientific merit and feasibility of your proposal. The TAC needs to know, of course, how much telescope time your program is likely to need. Phase II takes place only after your proposal is successful and at that time you are required to specify all the details needed to transform your observational needs into spacecraft commands, and you must do so within the total spacecraft time that you have been allotted.

The distinction between Phase I and Phase II is somewhat arbitrary and in some cases the Phase I forms actually prevent you from supplying information (such as the entrance aperture to be used) that could be helpful in assessing the proposal. The intent is to make writing the Phase I proposal easier, but you may find that your proposal will be better if you understand fully the operation and use of the GHRS right from the start. We encourage you to think in terms of the Phase II requirements even when writing the Phase I proposal because in most cases that will not require much more work and you may be able to save some time later on. Thus there is information in this section that is only entered on the Phase II forms but which has been included here to provide a picture of how the instrument works.

3.2 Creating an Observation Scenario

3.2.1 The Simplest Case: One Spectrum for One Star

Let us assume that in answering the above questions you have decided that an onboard acquisition will suffice (more on that in a moment), that standard calibrations are adequate, and that you wish to obtain a single spectrum of a single star. By specifying the resolving power you desire for a particular wavelength, you have, in effect, chosen to observe with either Side 1 or Side 2 and with a particular grating (see Chapter 7). This simplest of observation scenarios then involves one acquisition sequence and one ACCUM observation. (An IMAGE mode observation may be specified in place of the ACCUM with no loss of generality. A WSCAN or OSCAN is just a minor variation on an ACCUM. See below for RAPIDs.)

The choice of Side 1 or Side 2 for obtaining the spectrum need not necessarily force you to that Side for the acquisition; for example, you might wish to observe a cool star with grating G140L on Side 1, but the far ultraviolet flux would be too low to acquire the object with mirror N1. In that case you can use mirror N2; it is permissible to mix Sides in a scenario, but there may be a cost in observing time for doing so (see Section 4.1.5.1 on page 38). Some difficult targets may be best acquired with the FOS before they are observed with the GHRS.

For this simple case this sequence of events can be compared to the *Phase I Proposal Instructions*:

- A guide star acquisition.
- The target acquisition with the GHRS.
- The ACCUM (or IMAGE).
- Some overhead time to read the observation.

3.2.2 Several Spectra for One Star

If more than one spectrum is desired for the star, the ACCUMs + overheads are repeated as necessary, bearing in mind the need to reacquire the star at the start of each orbit. The multiple spectra could be either an assortment of wavelengths or repeats at a single wavelength to follow an object in time or to improve signal-to-noise. In all cases overhead time must be added for each separate exposure:

- A guide star acquisition.
- The target acquisition with the GHRS.
- The first ACCUM or IMAGE.
- Some overhead time to read the observation.
- The second ACCUM or IMAGE, followed by an overhead allowance.
- The third ACCUM...

3.2.3 Spectra of Several Stars

This instance is just multiple versions of the previous case since changing stars requires a new visit, meaning a full guide star acquisition, acquisition of the object into the GHRS LSA, etc.

3.2.4 RAPID Mode Observations

RAPID mode observations can be planned just as for ACCUMs. The overhead time is added only once at the very end of the whole RAPID sequence.

3.2.5 Adding Calibrations

The only kind of calibration exposure that an observer will ordinarily need is one of the wavelength calibration lamp. An exposure of 30 to 60 seconds is adequate for almost all settings with the first-order gratings; otherwise the exposure is just another ACCUM. Note that for most applications the information contained in the SPYBAL that accompanies each first use of a grating is likely to suffice and a separate wavelength calibration is superfluous; see Section 4.5 on page 46.

3.3 Specifying Target Acquisition

For most situations, a standard onboard acquisition that automatically centers the brightest object in the field into the desired aperture is all that is needed. Such a procedure is especially appropriate for isolated point sources that are beyond our solar system and which have fairly predictable ultraviolet fluxes, i.e., most stars. In other cases, it is possible to use a variation on the automatic procedure to acquire other objects. For example, an extended object or some moving objects may be acquired by first automatically centering on a nearby pointlike source and then offsetting to the object of interest. Some potential problem cases are:

- very bright stars, which can saturate the detectors;
- moving targets, such as planets and their satellites;
- crowded fields, in which the automatic centering procedure might get confused;
- extended objects that do not have a sharply peaked source to center on;
- very faint objects for which few counts would be accumulated in the maximum permissible integration time (12.75 sec).
- objects that are so variable that their brightness relative to nearby objects may be unpredictable.

These situations may require an interactive (or real-time) acquisition, although an onboard acquisition may still work in many cases. In an interactive acquisition, the spacecraft obtains a picture of the target's field with one of the cameras (WFPC2 or FOC) or with the field mapping capability of the GHRS itself. This picture is relayed immediately to STScI where the observer is available to study the image and decide where the telescope should be pointed. Interactive acquisitions are obviously helpful in difficult situations, but the requirement for real-time contact between the ground and *HST*, together with the need to set aside a block of telescope time for the pointing decision to be made, makes interactive acquisitions consume much more spacecraft time than is needed for a standard onboard acquisition. Interactive acquisitions require special scheduling and so require greater-than-average work on the part of the planners of *HST*'s time. Real-time contact with *HST* is a limited resource (it cannot exceed 20% of the total time) which must be reserved for genuine need.

A variation on this procedure is to get the field image two months or so in advance of the time the spectrum will be obtained. This is called an early acquisition (EARLY ACQ) and it takes more time than an on-board acquisition but much less than an interactive acquisition and imposes no burden of real-time contact. The observer must be prepared to analyze the early acquisition image quickly (within a week or two) if the positions from it are to be incorporated into the telescope schedule.

If you wish to use either WFPC2 or FOC for early- or interactive acquisitions you must refer to documents specific to those instruments. Details on the use of the GHRS' imaging capability are provided in the next chapter.

3.3.1 Very Bright Stars

When is a star too bright for an onboard acquisition? In practice we are unaware of any real need to use interactive acquisition just because a star is very bright. GHRS acquisitions are done with ultraviolet light, so it is the UV flux of the star that matters. There are no stars too bright to acquire with the attenuated mirror A1, for example. Even with Side 2 it is not necessary to specify an interactive acquisition for a very bright star if the BRIGHT=RETURN option is used. Since the few very bright stars which could cause problems are always the brightest point sources in their immediate area, there is no apparent reason not to use BRIGHT=RETURN with an onboard acquisition.

3.3.2 Moving Targets

Sophisticated pointing at moving objects (i.e., objects within the solar system) often requires interactive acquisition to be sure the desired portion of the object's surface is centered in the observing aperture. There are cases where an on-board acquisition will suffice, especially if the object is small (essentially point-like) and has a well-determined orbit. An on-board acquisition can often work well even for a large moving object like Jupiter by first centering on a small object nearby whose relative position is well known (one of Jupiter's moons, for example), and then offsetting to the position of interest on the planetary disk. Solar system astronomers may wish to consult with a moving-target specialist at STScI before specifying the acquisition mode.

3.3.3 Crowded Fields

Work in crowded fields can usually be done by obtaining an early acquisition, so that you have an image to work from to specify the object to be observed, an image that has been obtained with *HST*'s full spatial resolution. The camera observation is usually best done at about the same wavelength that the spectroscopic observations will be made.

The Point Spread Function (PSF) of the GHRS has been restored by the COSTAR mirrors, making it possible to separately observe stars that are very close together. For example, in an Early Release Observation in April, 1994, two stars in R136a separated by only 0.25 arcsec were observed independently. One of these stars was only 0.1 arcsec from a brighter neighbor. This was done by centering on a bright object in the field and then offsetting to the targets of interest. We suggest that you consult with us if you wish to work in crowded fields. Also, see Section 8.6.1 on page 94.

3.3.4 Extended and Very Faint Objects

For most extended objects, it may be possible to offset from a nearby point source or at the least the pointing can be specified from an early acquisition image. Interactive acquisitions should be necessary only rarely. Another method is to acquire the object with the FOS and then offset to the GHRS' LSA.

In Cycle 5 observers can use a centering option designed expressly for extended objects, especially uniform ones like the Gallilean satellites of Jupiter. Chapter 4 contains more information on this option, known as `LOCATE = EXTENDED`.

3.3.5 Variable Objects

Objects whose ultraviolet brightness varied often caused acquisitions to fail when it was necessary to specify both `BRIGHT` and `FAINT` count limits. The advent of software that automatically finds the brightest object in the field (`BRIGHT=RETURN`) obviates that problem in most cases. A variable object in a crowded field might benefit from an early acquisition to determine precise coordinates, but an interactive acquisition should generally be unnecessary.

3.4 Calculating the Exposure Time

3.4.1 Sensitivity

The sensitivity of the GHRS and *HST* Optical Telescope Assembly (OTA), using the LSA, has been determined from observations of stars with known ultraviolet fluxes. The sensitivity is designated as S_λ, and has units of (counts diode^{-1} sec^{-1}) for each incident (erg cm^{-2} sec^{-1} Å). It varies as a function of wavelength for each grating. You must first estimate the intrinsic flux of your target and then multiply that by the appropriate value of S_λ to yield an estimate of the count rate to be expected for a particular grating configuration at the chosen wavelength. Sensitivity curves for the first-order gratings are provided in Section 8.2.3 on page 85 and for the echelles in Section 8.3.1 on page 87.

In the echelle configurations, the sensitivity varies with wavelength across each order. This behavior is characteristic of all echelle spectrographs, and is called the Blaze Function. The basic nature of the variation with wavelength is similar for all orders, and can be parameterized in terms of the product $m\lambda$, where m is the order number and λ is the wavelength (Å). The shape of the blaze function, normalized to a peak value of unity, and plotted as a function of $m\lambda$ is shown in Section 8.3.3 on page 91. The sensitivity at any wavelength in any order can be estimated by multiplying the peak response of that order by the relative response shown. The blaze function, relative to the center of an order, falls as low as 0.25 at the end of the free spectral range and its effect should not be omitted in exposure calculations.

3.4.2 Reddening

Corrections for ultraviolet extinction in the interstellar medium are included in Section 8.5 on page 93. These are standard values, and their applicability in specific situations is left to the judgment of the observer.

3.4.3 Background

There are several potential sources of background counts, including detector dark count, electrical interference or cross talk with devices either within the GHRS or the spacecraft, and effects caused by the charged particle radiation environment of the *HST* orbit. The intrinsic sources of dark count are very small. During "thermal vacuum" testing prior to launch the detector dark count rates were observed to be approximately 0.0004 counts per diode per second. On-orbit, the background is caused primarily by Cerenkov radiation bursts induced in the faceplate of the Digicon by cosmic rays. This causes the actual background to range from 4×10^{-3} to about four times that, depending on the orbital position of *HST*. For planning purposes these mean values suffice: 0.011 counts s^{-1} for D2 and 0.008 counts s^{-1} for D1. The counts appear to be randomly distributed in time, so that the "noise" in the dark count is the square root of the total counts accumulated during the observation. If one is observing very faint objects with low count rates the background can influence the signal to noise ratio of the data. Formulae for making quantitative estimates of S/N are given in Section 3.4.5.1 on page 29. At the present time there are no known sources of interference or cross talk which affect the detector count rates.

The GHRS is equipped with both hardware (automatic) and software capabilities to recognize and respond to cosmic ray and trapped particle events. You may invoke the software capability by specifying `CENSOR = YES` on an Exposure Logsheet line in Phase II. This causes rejection of individual `STEP-TIME` segments of data if they included a specified number of photons arriving within a short (8 μs) interval, as happens with cosmic rays. Any rejected integration is repeated, so there is no loss of total exposure time. You should only use this anticoincidence rejection on faint targets, since on bright targets the interval between actual photon events will be small and real counts would be rejected. We recommend using `CENSOR = YES` only for count rates less than about 0.1 counts per diode per second. The expected dark count reduction is a few tens of per cent (For more details on `CENSOR`, see Section 8.6.2 on page 95).

For extremely faint sources for which the expected count rate is well below the expected dark level, it is possible to use a special commanding option called `FLYLIM`. This option, if pertinent to your needs, should be explored with a GHRS Instrument Scientist. See also Section 8.6.3 on page 97.

An external source of background which can potentially be a problem during the acquisition (and sometimes the observation) of faint targets is geocoronal Lyman-α. This problem and what to do about it are discussed in Section 7.4.2 on page 80.

The final cause of background counts is passage through the dip in the Earth's Van Allen radiation belt called the South Atlantic Anomaly (SAA). SAA passage occurs on 7 of 16 daily orbits of *HST*. During the most central of these passages, dark count rates increase about two orders of magnitude, to about 1 count per diode per second. A contour around the SSA which corresponds to 0.02 cts/s/diode is known and no GHRS observations are scheduled when the *HST* is within this zone. At the time of this writing the SAA contours for the GHRS are being reviewed to allow for more efficient usage.

3.4.4 Scattered light

The presence of stray and scattered light in a spectrograph is an effect which can influence the planning and execution of an observation, as well as the reduction and interpretation of the data. None of the optical configurations which include first order gratings has any serious problem with scattered light. The high quality of the imaging optics and holographic diffraction gratings and the effectiveness of the baffles have successfully minimized the stray light. On-orbit measurements indicate that it amounts to less than 10^{-3} when using the SSA, and at most a few times 10^{-3} when using the LSA (these are in units of the peak intensity).

In the echelle configuration, both the echelle and the cross-dispersers are ruled gratings. This fact, plus the presence of light from sixteen orders simultaneously on the photocathode, results in a detectable level of background radiation. The irradiance on the photocathode due to scattered light (measured as count rate per unit area) amounts to a few percent of the signal in the order. Two factors complicate this effect. The first is a geometrical effect caused by the fact that the science diodes are 400 µm tall, while the image of the spectrum is only about 55 µm high. Thus about 1/8 of the diode is illuminated by the spectrum+background, while the rest is measuring background, meaning that a weak background irradiance is multiplied to the point that a significant fraction (anywhere from 2 to 50%) of the gross count rate on a diode may be due to background. The measured scattered light background can be calculated from information in Section 8.3.1 on page 87. It varies significantly with order number.

The second complication arises at the short wavelength ends of the echelle format. Below a wavelength of about 1800 Å with Echelle B (or 1250 Å with Echelle A), the spacing between orders is comparable to the length of the diodes, and it is difficult to make a clean measurement of a single order. The diode array has four large "corner diodes" which are long (1 mm) in the direction of the echelle's dispersion, but narrow (100 µm) in the cross-dispersion direction. These diodes may be used to sample the interorder background without the problem of contamination by in order light, but they do not provide any spatial resolution. The *HST* scheduling system will default to use of the corner diodes when that is appropriate. At a minimum, the time spent measuring the background should be about 10% of the time spent on the spectrum. If the goal is to achieve a very high signal to noise ratio in the net spectrum, it may be necessary to devote a greater fraction of time to the background measurement. Suggestions for estimating signal to noise ratios are made in the next section.

In order to reduce stray light, there is a shutter over the LSA which automatically closes whenever the SSA is being used for an observation. There is no shutter on the SSA. Thus a wavelength calibration exposure obtained with a bright star in the SSA will result in a combined spectrum of the two because the aperture for the wavelength calibration lamp (SC2) is displaced from the SSA in the same sense as the direction of dispersion. Usually you can subtract the stellar spectrum to recover the wavelength calibration.

More detailed quantitative information on background and scattered light in the GHRS is provided in Section 8.6.1 on page 94.

3.4.5 Signal-to-noise

There are several factors which influence the signal to noise, including statistical (Poisson) noise in the detected spectrum, dark count noise in the detector, scattered light in the spectrograph, diode to diode gain variations, and granularity in the photocathode sensitivity. For signal to noise ratios up to approximately 50, statistical fluctuations in the signal and background will dominate. Diode to diode variations are extremely small, and are accounted for in the routine calibration procedures. Cathode granularity will become important if signal to noise greater than 50 is required, and must be treated separately. For sources observed through the small aperture the sky background should not contribute significantly to the noise, except, perhaps, when observing at Lyman-α.

3.4.5.1 Photon Noise

The following equations may be used to estimate signal to noise ratio, depending on the relative importance of scattered light and dark count.

Case 1. Neither scattered light nor dark count are important.

Let:

s = signal strength (counts per diode per second) estimated by multiplying the stellar flux by the sensitivity at the desired wavelength.

t = duration of the observation in seconds. This total time will be divided among the separate substep bins.

n_s = the number of adjacent diodes that will be binned together to produce an effective resolution element. Usually $n_s = 1$. This is not the merging of substep bins, but the deliberate averaging to increase signal to noise at the expense of resolution.

Then

$$(S/N)^2 = sn_st$$

This formula would be appropriate for relatively bright objects observed with any first order grating, when substep pattern 1, 2, or 3 is used (see Section 8.4 on page 92).

Case 2. Dark count is important, scattered light is not.

Let:

d = dark count rate in counts per diode per second.

Then

$$(S/N)^2 = \left(\frac{s/d}{1+s/d}\right)sn_st$$

If the signal is less than about ten times the dark count rate, the factor in parentheses should be included in the estimate. This formula would be useful if STEP-PATT 5, for example, were used with a first order grating to measure a faint source (see Section 8.4 on page 92).

Case 3. Scattered light is important, dark count is not.

Let:

f = fraction of time spent measuring the spectrum. (See Section 8.4 on page 92)

b = scattered light as a fraction of the signal in the adjacent orders.

Then

$$(S/N)^2 \approx \frac{f}{1+b} s n_s t$$

This formula gives a good estimate of the performance for observations with the echelles when stepping patterns 6, 7, 8 or 9 are used. This formula assumes that the background bins are heavily smoothed. Most of the high frequency statistical noise in the background bins is thus suppressed.

Case 4. Both scattered light and dark count are important.

Let:

n_b = number of adjacent diodes to smooth the background bins over before subtracting. Experiments with ground-based data indicate that $n_b \approx 10$ gives the best results.

Then

$$(S/N)^2 = \frac{s^2 t}{s\left[\frac{1+b}{n_s f} + \frac{b}{n_b(1-f)}\right] + d\left[\frac{1}{n_s f} + \frac{1}{n_b(1-f)}\right]}$$

There are two ways to use these formulae. If you need a certain S/N to do the scientific analysis, use the appropriate equation to solve for the required exposure time t. Alternately, you can decide to devote a fixed length of time to the observation, and use the equations to estimate what S/N will be achieved.

3.4.5.2 Fixed Pattern Noise

The formulae just presented suggest that the signal to noise ratio increases in proportion to the square root of the exposure time. These relations only hold true until S/N ≈ 50 or so is reached. At higher signal levels the photocathode granularity described in Section 4.3 on page 43 will become the limiting factor. Observing standard stars to provide a precise "flat field" observation is too inefficient, and there is no onboard continuum lamp that illuminates the optics and detectors in exactly the same way as the stellar spectrum. The best practice is to use the `FP-SPLIT` option (Section 4.3.1 on page 43). Rather than merely averaging the four `FP-SPLIT` sub-exposures, the data analysis procedure solves for the two vectors representing photocathode granularity and the spectrum. S/N well in excess of 100 has been obtained this way on bright targets.

Achieving extremely high signal-to-noise (200 or more) is possible by obtaining a number of spectra, each with `FP-SPLIT` but at slightly different grating positions. See Lambert et al. (1994) for a discussion.

3.4.6 A Simple Example

Here is a very simple example to illustrate how an integration time may be computed. Suppose that the goal is to obtain a spectrum of a 13th magnitude B0 star at 1900 Å, with the G160M grating and with a signal-to-noise of 25 per diode in the continuum. In this case we will assume that this star has not been previously observed in the ultraviolet so that there is no *a priori* knowledge of the UV flux.

To be specific, take the star to have a spectral type of B0I, $V = 12.89$, and $(B-V) = 0.03$. The unreddened color for this spectral type is $(B-V)_0 = -0.24$, so that $E(B-V) = 0.27$. The total visual extinction is then $3.1 \times 0.27 = 0.84$, leading to a dereddened magnitude of $V_0 = 12.05$. The dereddened flux at 5500 Å is then $F_{5500} = 5.4 \times 10^{-14} \mathrm{erg\ s^{-1} cm^{-2} Å^{-1}}$.

What flux can we anticipate at 1900 Å? The model atmospheres of Kurucz (1979, ApJS, 40, 1) predict $F_{1900}/F_{5500} = 23$ for a star with $T_{eff} = 25000$ K. This leads to a flux of $F_{1900} = 1.2 \times 10^{-12} \mathrm{erg\ s^{-1} cm^{-2} Å^{-1}}$ at 1900 Å for the unreddened star. Reddening will diminish this by a factor of $10^{-0.4 \times A_{1900}}$, where the absorption at 1900 Å can be determined from the data in Section 8.5 on page 93; the result in this case is $A_{1900} = 2.26$. We therefore predict this star to have a flux at 1900 Å of $1.5 \times 10^{-13} \mathrm{erg\ s^{-1} cm^{-2} Å^{-1}}$.

The next step is to determine the detected count rate. For G160M at 1900 Å, the sensitivity is $S_\lambda = 5.2 \times 10^{11}$, in units of counts per second per diode per incident erg s^{-1} cm^{-2} $Å^{-1}$. This leads to an expected count rate of 7.8×10^{-2} counts s^{-1} diode^{-1}. An integration time of about 2.25 hours would lead to approximately 625 detected counts per diode, or the required signal-to-noise of 25. This neglects the effects of dark, which should be an order-of-magnitude below this count rate.

Chapter 4

Your Phase II Proposal

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CAUTION

The procedures for creating a Phase II proposal are being reviewed and revised as this is written. We strongly recommend that users check the Phase II documentation carefully. We also recommend checking on STEIS at that time for a revised version of this Instrument Handbook.

This chapter supplements the *Phase II Proposal Instructions* that will be issued for Cycle 5. You may also wish to consult *Phase II Instructions for the Solar System Target List* if your program is to observe solar system objects.

Most users of the GHRS will find that a simple sequence of commands will work most of the time to obtain the data they desire:

- ACQ in LSA with BRIGHT=RETURN.
- ACQ/PEAKUP to center star in LSA or SSA, whichever is appropriate to the science observations that follow.
- IMAGE, if you wish to verify target centering or to obtain an image of the object.
- Wavelength calibration exposure, if desired.
- ACCUMs at wavelengths of interest. NO GAP is recommended as a Special Requirement in order to ensure the PEAKUP operation is properly applied to the spectroscopic exposures.
- ACQ/PEAKUP in the SSA if the previous observation was in the LSA.
- ACCUMs for that different aperture, again with NO GAP.
- Repeat the above as needed for more stars.

Target acquisitions always take place with the LSA because the SSA is too small to enable a field to be mapped effectively. Additional ACCUMs may be specified after the first so as to obtain spectra at several wavelengths.

One task of the Instrument Scientists at STScI is to check the feasibility of successful proposals after the Phase II proposals have been submitted. **It is in your interest to help us with that by using standard and consistent formats for the Phase II proposals** because that can greatly reduce ambiguity about the intentions of the General Observer. We suggest the following:

- Follow the examples in the next chapter. The examples usually specify all the defaults for clarity, which is not strictly necessary, but, like comments in a computer program, can help to confirm that a procedure conforms to the intents of the observer.
- Although the submission software does not strictly require it, we ask that you give the commands in the order just listed: First the acquisition, then embellishments to the acquisition (PEAKUP, OFFSET, etc.), then an IMAGE and/or wavelength calibration exposure (if desired), and then the actual science observation (usually an ACCUM).

- Add plenty of comment lines (RPSS imposes a limit) to explain what you want to have happen so that we can see whether or not your proposal actually accomplishes that. In particular, please explain briefly how the exposure time was determined.

4.1 Acquisitions

Most objects observed with the GHRS are point sources (stars), and the majority of the remainder can be observed by first centering on a nearby point source and then offsetting to the object of interest. Point sources with accurate coordinates are very, very easy to acquire with the GHRS: just specify `ACQ` with `BRIGHT=RETURN` to have the instrument automatically center on the brightest object found within the LSA.

4.1.1 Initial Pointing

A blind pointing with *HST* is likely to place the object of interest within 2 arcsec of the center of the aperture. That accuracy is limited in part by the quality of coordinates provided by users and partly by errors in the positions of the FGSs relative to the GHRS apertures (see the *FOS Instrument Handbook* for a discussion of pointing errors). Using J2000 coordinates tied to the GSC reference frame can help to reduce the possibility of a failed acquisition. And don't forget to include proper motions if appropriate and to check the equinox and epoch of astrometric quantities.

4.1.2 Interactive Acquisitions

We discuss interactive acquisitions (`INT ACQ`) first in the hope of dissuading you from using that capability. An `INT ACQ` requires real-time contact between the ground and *HST*. Real-time contact is a limited and expensive resource that should only be used as a last resort. In almost all cases where an onboard acquisition will not work (because the object is in a crowded field, or is variable, or is a moving target), it is sufficient to use `EARLY ACQ` to get a WFPC2 or FOC image a few weeks in advance of the GHRS observation. The image can then be analyzed to pinpoint the source to be observed without requiring real-time contact. `INT ACQ` may be needed in a few instances where the object changes in its ultraviolet brightness unpredictably. We suggest that you consult with us before requesting `INT ACQ`.

If an interactive acquisition with the GHRS has been specified, a spiral search will be run after *HST* makes its initial pointing. A map of the LSA is made at each dwell point and each map is then downlinked to STScI in real time and may be viewed almost immediately in OSS. After the spiral is complete, the telescope remains at its final dwell point, awaiting instructions. The final 9 (or 25) maps are assembled into a mosaic and displayed for the observer to identify the target, either from a cursor position or from calculation of a centroid. The motion needed to center the specified position in the LSA is computed and uplinked to *HST*. The recentering of the target usually takes place about an orbit after the spiral search, and must be scheduled for a specific time. If you have so requested in your proposal, an image of the LSA will be made after the recentering so that you may confirm the position of the target (but additional interaction at that time is not normally possible).

4.1.3 Early Acquisitions

In an early acquisition (EARLY ACQ), an image of the field of interest is obtained several weeks (8 or more) in advance of the spectroscopic observation that the GHRS is to make. The image may be obtained with WFPC2, with the FOC (especially if an ultraviolet image is desired), or with the imaging capability of the GHRS itself. The GHRS is relatively slow at getting images, so if you wish to map an area much larger than about 2 × 2 arcsec we recommend that you consider WFPC2 or FOC. However, the GHRS has the capability of obtaining a monochromatic map (see Section 4.2.2 on page 43) in `IMAGE` mode, which can be useful in some situations. For any `EARLY ACQ`, be sure to note the relationship of the image to the spectroscopic observations as a Special Requirement (see the first example in the next chapter). Also, you should plan ahead so that the early acquisition image can be analyzed quickly and the positions measured sent back to STScI for incorporation into the telescope observing schedule.

4.1.4 Onboard Acquisitions

After the initial pointing, a GHRS onboard target acquisition begins with a spiral search centered on the field of view. The motions are made by the telescope, and at each point of the search either a single flux measurement (with 8 science diodes) or a map of the LSA is made. The default is a 3 × 3 pattern (`SEARCH-SIZE=3`) of maps in a square 4.6 arcsec on a side. Other options available are a 5 × 5 pattern (`SEARCH-SIZE=5`), 7.7 arcsec on a side, or a single integration (`SEARCH-SIZE=1`) that is 1.74 arcsec square (this latter option can be useful for obtaining a `MAP` after an object is centered). The telescope motions are made in the x and y coordinate system of the GHRS with a step-size of 1.53 arcsec, not the U2, U3 system of the telescope.

For stars with good coordinates, the default (3 × 3) acquisition strategy should suffice, but the 5 × 5 pattern usually costs little more in total time and guards against minor coordinate uncertainties (the time needed increases in proportion to $[\texttt{SEARCH-SIZE}]^2$, but the `STEP-TIME` for an acquisition is usually so low that the total time involved is small).

You should use ONBOARD ACQ whenever:

- The object is a point source, or
- The object can be reached by offsetting from a nearby object that meets the above description, or
- An extended object is small enough that `LOCATE=EXTENDED` will work (see Section 4.1.5.4 on page 39).

Also, the object to be centered should be the brightest object within the area searched (about 4.8 × 4.8 arcsec for a 3 × 3 search) but with allowance for about 3 arcsec uncertainty in positioning as well. In other words, you should ensure that your object is the brightest one that *HST* will find within a box whose total size is about 8 × 8 arcsec. Note that the flux is measured in the ultraviolet (see Section 7.4.1 on page 78).

The items you must specify for the ONBOARD ACQ are:

- The mirror to use. N2 and A2 should suffice for virtually all targets you might wish to observe. Mirrors N1 or A1 may also be used, especially for spectroscopic observations that utilize Side 1 (i.e., detector D1). Mirror N2 provides a flat reflectivity over a broad range of ultraviolet wavelengths (see Section 7.4.1 on page 78). Mirror A2 has a similar spectrum response but reflects much less light than N2, in order to acquire bright objects. Both detectors may be active at the same time, so it is permissible to specify mirror N2 for an acquisition to observe with Side 1; this may be desirable, for example, when observing cool stars. However, doing this may cost you observing time; see below.

- BRIGHT and FAINT flux limits so the instrument knows when the object has been found. However, in almost all cases it is better to use BRIGHT=RETURN, which is a feature that automatically centers the brightest object found. If BRIGHT=RETURN is specified, any FAINT limit given is ignored.
- The size of the spiral search pattern to execute (SEARCH-SIZE). The default is a 3×3 grid (which covers about 4.6 arcsec square), but you may also request a 5×5 search over a square 7.7 arcsec on a side.
- Whether or not to record a map of the field at the search points so that you can confirm the telescope's pointing after the fact. A MAP is usually unnecessary and so wastes spacecraft time. At most, a MAP=END-POINT should suffice. Note that such a MAP occurs after the return to the brightest point in the field but before the object is centered in the LSA by an ACQ/PEAKUP. To determine the position of an object in the LSA before spectroscopic observations are begun, we recommend obtaining an IMAGE on a separate Exposure Logsheet line. The MAP=ALL-POINTS option may *not* be used with an ONBOARD ACQ.
- The offset to apply once the object is centered (if appropriate).

4.1.4.1 Explicitly Specifying BRIGHT, FAINT, and STEP-TIME

Explicit BRIGHT and FAINT limits may be specified if you desire, although there is an increased risk of a failed acquisition unless you are fairly confident of those fluxes. Also, a few very bright stars cannot be acquired with Side 2 if an explicit BRIGHT value is given but they can be acquired automatically with BRIGHT=RETURN.

Details on computing BRIGHT and FAINT limits are given in Section 7.1 on page 68. Please note that although we discourage the use of explicit BRIGHT and FAINT values unless they are unavoidable, you still need to estimate the target acquisition count rate in order to ensure that you choose the acquisition mirror correctly and that the STEP-TIME is determined properly.

- Note that using BRIGHT=RETURN and explicitly specifying BRIGHT and FAINT limits result in fundamentally different acquisition procedures. If BRIGHT and FAINT are specified, the acquisition stops as soon as those conditions are met and the point at which that happened is moved to the center of the LSA. With BRIGHT=RETURN, the entire spiral search region is sampled and the brightest object in it determined before any movement is made to center on the target. Both procedures require the same amount of telescope time because the schedule must allow for the entire region to be sampled.

4.1.4.2 Peakups

After the initial acquisition, a peakup helps to precisely center the object in the aperture. Specifying a ACQ/PEAKUP before starting LSA observations will help to ensure the reliability of measured fluxes. A ACQ/PEAKUP before starting SSA observations is vital for achieving the best throughput with the small aperture.

In the past we recommended using a STEP-TIME value of 1.6 seconds for a ACQ/PEAKUP, but that is unnecessary for the post-Servicing Mission observatory. We recommend aiming to achieve 1,000 to 10,000 counts in the peak step, as for the acquisition, but levels as low as 100 will suffice for faint targets.

4.1.5 Special Onboard Strategies for Special Situations

4.1.5.1 Side 2 Acquisitions for Side 1 Science Observations

There are situations in which an object can be observed satisfactorily with Side 1 but for which the count rates for acquisition mirrors N1 or A1 are extremely low. One possibility is to increase the exposure time for the acquisition, but the maximum permitted STEP-TIME is 12.75 seconds. A better option may be to acquire with mirror N2. Both detectors, D1 and D2, may be active in the GHRS at the same time, but there is an overhead involved in making one primary and the other secondary; to go from Side 2 to Side 1, that time is approximately 40 minutes. Whether or not that is a "cost" or not to your program depends on specific details. It is often the case that an acquisition takes place over the first orbit, followed by science observations in later orbits. In that case, most or all of the 40 minutes can take place during the part of the orbit when the target is inaccessible. But for CVZ viewing the cost can be real.

4.1.5.2 Complex Targets

Given the centering algorithm for the GHRS, which we will now describe, you can usually predict the results of an onboard target acquisition. Stepping, in both the x and y directions, is done in 0.027 arcsec steps, and on a point source the centering is expected to be good to within two steps. If the target is extended enough that the fluxes in the areas which are compared do not change significantly when a step is made, the centering accuracy will be degraded. An example is the case in which there is more than one source of light within the LSA.

Consider, for instance, two stars which are separated by 1.0 arcsec and for which the second star is 1 magnitude fainter than the primary star. Exact results will depend on the position angle between the two stars. The x balancing algorithm begins by placing the brightest source on the fourth of the eight diodes that are used during an acquisition (the LSA is imaged onto eight diodes), and moving until the flux on diodes 4 and 5 is balanced. The second star would not affect this balance at all unless its light fell on one of the same diodes as the primary star. In that case it would affect centering by a fraction of a diode.

In the y direction the results are different. If the second star is "above" or "below" the primary, it will "pull" the centering in that direction. In the case described, an extra source of light 40% as bright as the primary would be present in the upper or lower half of the LSA. The flux-balancing algorithm would divide the primary image 70-30, rather than 50-50, with the image displaced towards the half of the LSA which did not contain the second star. In this case the centering error should be less than 0.1 arcsec. If the LSA acquisition were to be followed by a slew to the SSA, PEAKUP, and an observation, the primary object should be successfully centered and observed. More complicated images, or sources more similar in brightness may not be suitable for onboard acquisition. (Note that balancing in the *y* direction is done before the *x* direction is balanced.)

4.1.5.3 Acquiring Faint Targets with the GHRS or FOS

Sometimes a star may be just plain faint to the point where geocoronal Lyman-α interferes. Some guidance for when this may be a problem is provided in Section 7.4.2 on page 80. If it is, we recommend that you specify DARK TIME as a special requirement on the acquisition line on your Phase II form. Doing so constrains the scheduling of your proposal and is likely to result in greater resource charges to you, so DARK TIME should only be requested when it is necessary.

Another way to acquire very faint targets reliably is to use the Faint Object Spectrograph. This can be especially useful for acquiring extragalactic objects to observe with grating G140L because the acquisition mirrors for Side 1 of the GHRS reflect only far-ultraviolet light and because the maximum permissible integration time per dwell point is only 12.75 seconds. FOS-assisted acquisitions for the GHRS will be tested in Cycle 4, so we suggest that you consult us if you wish to explore this option.

4.1.5.4 Acquiring Extended Sources with the GHRS

There are three classes of extended sources we can consider:

- Objects larger than the LSA that have roughly uniform surface brightness.
- Objects smaller than the LSA with roughly uniform surface brightness.
- Objects with significant structure, some of which is on scales smaller than the LSA.

The first class might be typified by Jupiter, and such objects are impossible to acquire directly with the GHRS because there is no clear photometric "center" to align on. In such cases it is necessary to offset from a smaller object which can be centered.

The second class of objects includes the Gallilean satellites of Jupiter, and it is these for which the LOCATE=EXTENDED acquisition option was written. In a normal LOCATE, the object to be observed is moved in the *x* direction until the signal seen by the center two diodes (of the eight onto which the LSA is imaged) is balanced. LOCATE=EXTENDED in ACQUISITION mode balances the four left diodes against the four right-hand ones to roughly center an object. In ACQ/PEAKUP mode, the EXTENDED option allows you to specify that the balancing be done over the central four, six, or eight diodes (specified as EXTENDED=2, 3, or 4).

The third class of objects can be the most problematic, especially if the target is an extragalactic one at high latitude. In such cases there may be no nearby star from which you could offset, but the source itself often contains point-like sources that can be centered on; in these cases an early acquisition or a pre-existing image is invaluable. The problem is then one of predicting acquisition count rates; that is treated in Section 7.1 on page 68. You may also wish to consider an acquisition with the FOS, as described in the previous section.

4.1.5.5 Offsetting

Even if an ONBOARD ACQuisition will not work for your target, it may still be possible to acquire a nearby reference star and to then offset to your target. Such an offset will happen automatically if the coordinates given for an acquisition exposure are different from those given for the science exposure. You would normally use two or three lines on the Phase II Exposure Logsheet to achieve this: acquisition of a reference star, offset, peakup on the target (if desired), and a science observation. The first line would request an onboard acquisition of the reference star. It should specify `ONBOARD ACQ FOR` <line 2>. Line 2 should then be an `ACQ/PEAKUP`, and it should specify `ONBOARD ACQ FOR` <line 3>. The next line would specify an offset to move from the reference star to the target, and the final line should be your intended science observation.

You must, of course, include the reference star as one of the objects on your Target Logsheet. It should be designated *xxx*`-OFFSET`, where *xxx* is the name of the target object. If desired, you may give the position of your target by using `RA-OFF`, `DEC-OFF`, or `XI-OFF`, `ETA-OFF` and `FROM` relative to the offset star. See the Proposal Instructions for details and notes on proper units. On the Exposure Logsheet, the Target Name for lines 1 and 2 are *xxx*`-OFFSET`, and in the example above, the Target Name for line 3 is *xxx*.

To make a successful offset, the relative positions of the offset star and target must be very well known – about as well as 1/4 the size of the aperture. (e.g., rms errors of 0.05 arcsec for the SSA.) One way of obtaining such positions is by requesting an `EARLY ACQ`uisition WFPC2 image, and measuring relative positions from it (at least 2 months prior to the science observation). The offset positioning accuracy of the *HST* is expected to be very good (of the order of 0.03 to 0.05 arcsec for a 30 arcsec offset), and the accuracy of the placement will be primarily determined by the accuracy of your positions. An offset of more than 30 arcsec may require the telescope to acquire new guide stars, which would worsen the accuracy of the positioning.

4.1.6 MAPs

The GHRS has the ability to make a `MAP` of the LSA by raster scanning one or both of its small focus diodes over the aperture. You may, for example, want a map to confirm the pointing at the time your spectrum was taken. The default for `ONBOARD ACQ`uisitions is to make no map. If you ask for `MAP=END-POINT`, you will get a map after the spiral search has found your target, but before it has been centered (with `LOCATE`) in the LSA. If you want a map after the final centering, you can add a single Exposure Logsheet line in `IMAGE` mode. An `IMAGE` may also be obtained of the SSA, which can be a useful *a posteriori* means of determining what was observed in a crowded field. The `MAP=ALL-POINTS` option may *not* be used with an onboard acquisition.

4.1.7 Acquisition Parameters — A Summary

Step 1: Mode=`ACQ`

- Aperture is always LSA ("`2.0`").
- `MIRROR` is usually `N2` or `N1` unless object is too bright (then use `A2` or `A1`; see Section 7.1 on page 68). Mirrors A1 and N1 may also be used and it is permissible to acquire with one side (mirror `N2`, say) and observe with the other (grating G140L, perhaps), but with a possible cost in time.
- `SEARCH-SIZE=3` is the default and adequate almost all the time. Values of 1 or 5 may also be used.

- BRIGHT=RETURN is the default for finding the target and should be used unless you are forced not to. Do not specify FAINT unless you must specify an explicit BRIGHT limit. (FAINT is ignored if BRIGHT=RETURN is used.)
- LOCATE: Default is YES for an ONBOARD ACQ and NO for EARLY ACQ or INT ACQ. We recommend these defaults. Note that LOCATE=EXTENDED is now available. With an ONBOARD ACQ, LOCATE=NO may be used only if MAP=END-POINT is specified.
- MAP: The defaults provide for an image to be transmitted to the ground if INT ACQ or EARLY ACQ is specified. No image is generated by default for an ONBOARD ACQ; MAP=END-POINT will provide one with the target in the LSA, but it will not be centered. As we have pointed out, if you wish to determine the actual position of the object in the LSA before spectroscopic observations are begun, you should obtain an IMAGE as a separate Exposure Logsheet line and you should not specify a MAP at all. MAP=ALL-POINTS may not be used with an ONBOARD ACQ.
- The time per exposure can be calculated from

$$t_{exp} = (128 \times N_{MAP} + N_{SEARCH}) \times \text{STEP-TIME}$$

  where N_{SEARCH} = $(\text{SEARCH-SIZE})^2$ (i.e., 1, 9, or 25), and N_{MAP} is the number of dwell points mapped (=1 if MAP=END-POINT is chosen and $=N_{SEARCH}$ if MAP=ALL-POINTS. MAP=ALL-POINTS can only be used with INT ACQ and EARLY ACQ.). **Please note the value of STEP-TIME you want as a COMMENT on the Exposure Logsheet.**
- Special Requirements are INT ACQ, EARLY ACQ, or ONBOARD ACQ.

Step 2: Mode=ACQ/PEAKUP

- The aperture can be either the LSA ("2.0") or SSA ("0.25"); specify the one to be used for the science observations that immediately follow.
- Specify the MIRROR as for Mode=ACQ; i.e., N1, A1, N2, or A2 depending on target brightness.
- The time per exposure can be calculated from

$$t_{exp} = f_{Aperture} \times \text{STEP-TIME}$$

  where $f_{Aperture}$ = 102 if the LSA is used and = $(\text{SEARCH-SIZE})^2$ if the SSA is used. Note that the throughput of the SSA is half to 2/3 that of the LSA so that in general you should specify a STEP-TIME that is larger than the one you used for a PEAKUP in the LSA.
- We urge you to be precise and explicit about the way in which you specify an ACQ/PEAKUP and the order in which observations are to be made. The defaults that apply to ACQ and ACQ/PEAKUP modes will usually accomplish what you wish, but the way to be sure is to specify the details. Confusion can arise particularly when a program mixes LSA and SSA observations. We would recommend that you do an ACQ in the first line of the Exposure Logsheet, then on line 2 specify ACQ/PEAKUP and indicate the lines to which it applies (all of which should use the same aperture).

Also indicate a NO GAP Special Requirement for that group of lines. Then specify another ACQ/PEAKUP before starting observations in the other aperture, and again specify NO GAP to ensure that they are treated as a group.

4.2 Image Mode

The GHRS is, of course, primarily a spectrograph, but it includes useful imaging capabilities, especially because the detectors of the GHRS are blind to much of the visible light that dominates the flux of most stars. You may wish to request an IMAGE or MAP, for example, to confirm that the telescope had your object properly centered in the data-taking aperture before the exposure was taken.

Note the following in using the imaging capability:

- GHRS IMAGEs and MAPs are obtained with the focus diodes (see Section 6.3 on page 62) at the ends of the array of main science diodes. The focus diodes are smaller and square, making them more useful for focusing, but at the price of a lower count rate. The total count rate over the LSA is, of course, unchanged, and it is that which is predicted with the information in Section 7.1 on page 68. Multiply the count rate estimated for the regular diodes by approximately 0.3 to get the value appropriate to the focus diodes when they are centered on the star.
- A MAP is obtained as an integral part of an acquisition whereas an IMAGE is a separate observation that may or may not have anything to do with an acquisition. A MAP with SEARCH-SIZE=3 or 5 is made as the acquisition procedure causes the telescope to make small motions in a square spiral pattern, thereby enabling it to record a larger portion of the sky than the LSA itself subtends. An IMAGE can only record the light in the 1.74×1.74 arcsec region of the LSA. A single MAP (SEARCH-SIZE=1) is equivalent to an IMAGE. Note that MAP=ALL-POINTS may not be used with an ONBOARD ACQ.
- A standard IMAGE will have a pixel spacing of 0.109 arcsec and will cover the entire LSA aperture of 1.74×1.74 arcsec. You may also select pixel spacings of 0.055 or 0.027 arcsec, with proportionately smaller regions of the sky covered in a 16×16 (the default) IMAGE. You may also use IMAGE with the SSA.

4.2.1 Image Mode Parameters

- Either the LSA ("2.0") or SSA ("0.25") may be selected as the aperture. The SSA is so small that it is generally pointless to image it, although there may be special cases where IMAGE mode is of use, particularly for confirming pointing in a crowded field.
- A mirror is the usual choice as optical element. A grating may also be specified – see below.
- The number of pixels in the x and y directions can be chosen separately and can range from 1 to 512 pixels. However, a large number of pixels only oversamples the region of sky subtended by the LSA and does not make the IMAGE include a larger area. The parameters to specify are NX, NY, DELTA-X, and DELTA-Y, for which the defaults are 16, 16, 4, and 4, respectively. The product of NX and NY may not exceed 512. An image that is critically sampled in the x direction may be obtained by specifying NX=32, NY=16, DELTA-X=2, and DELTA-Y=4.

Only the N1 mirror intercepts the full beam diameter, meaning that images of the LSA with the other acquisition mirrors will not yield an accurate Point Spread Function (PSF).

- The PRECISION parameter may be specified as NORMAL (the default) or HIGH. PRECISION may only be specified if DELTA-Y=4. Using PRECISION=HIGH causes the image to be obtained with only one focus diode instead of two (thereby eliminating uncertainty over the relative response of the two), but the time per exposure you must list is the same in either case (but using PRECISION=NORMAL takes less actual time to execute and the differences in response of the diodes are known to be small).
- There are two focus diodes available to raster over the LSA. Thus the total time needed is the dwell time per pixel (0.2 seconds is the default) times the number of pixels in the x direction (default is NX=16) times the number of y pixels (default is NY=16), all divided by 2. The maximum permissible dwell time per pixel is 12.75 seconds. (Note that the *Phase II Proposal Instructions* for Cycle 4 required you to calculate the total time without dividing by the factor of two. The situation for Cycle 5 should be confirmed before a value is entered.)

4.2.2 The GHRS as a Slitless Spectrograph

In IMAGE mode you may specify a grating instead of a mirror as the spectrum element (note that this may *not* be done in Acquisition Mode). Doing so for a target that emits primarily in lines can yield the equivalent of using a slitless spectrograph over a very small portion of the sky (the 1.74 arcsec square region of the LSA). Thus the focus diodes would be swept over the image of the line to produce a picture that is resolved spatially in the y direction and spectroscopically in the x direction. This mode of use would be very slow if all you wanted was the spatial structure of a small object (the FOC would probably be better), but there might be interesting uses for obtaining spectrophotometrically pure, spatially resolved images in the ultraviolet. Please consult us if you wish to explore this option.

4.3 Accumulation Mode

4.3.1 Optimizing Data Quality

The previous chapter provided the information needed to estimate an exposure time to achieve a given level of signal-to-noise. We reiterate several factors having to do with the detectors that must be taken into account to achieve the best data quality. Note that it is not necessary to explicitly specify these parameters (except for FP-SPLIT) because the defaults that apply to each mode of operation will automatically invoke them. Moreover, you should not deviate from the defaults without good reason.

The Digicon detectors have faceplates with some granularity (uneven response). The diodes onto which the faceplate is imaged also have response irregularities and some of them have been turned off because of misbehavior. Both of these effects are relatively small but enough to prevent you from obtaining a spectrum with S/N much in excess of 50. They can also produce "glitches" that can mimic spectrum features. The FP-SPLIT parameter causes the carrousel to move slightly between each of the two or four separate subexposures. The COMB parameter suppresses diode-to-diode gain variations and allows one to work around the dead diodes. Both features should be used, especially since they cost little or nothing in exposure time and improve data quality.

The Digicon diodes also undersample the spectrum by about a factor of two. The parameter STEP-PATT causes electronic motions of the spectrum so as to sample the spectrum fully. It is possible to STEP-PATT at two samples per diode width, but we recommend using four samples per diode to yield optimum results, and again at no net cost. You can always rebin a quarter-stepped spectrum into a half-stepped one during your data analysis, but the process cannot make a quarter-stepped spectrum out of a half-stepped one. Deconvolution has worked best with quarter-stepped spectra (the default); see Gilliland et al. (1992). STEP-PATT also determines the way in which the background is measured (see Section 8.4 on page 92).

We also remind you to break up long exposures into subexposures that are no longer than about 5 minutes each, so as to defeat the effects of geomagnetically-induced image motion. Bear in mind that a 20 minute exposure, for example, specified with FP-SPLIT=4 will result in four 5-minute exposures.

4.3.2 Summary of Accumulation Mode Parameters

- Specify the aperture as "2.0" (LSA) or "0.25" (SSA). The object will automatically be moved to the correct aperture even if the acquisition was into the other. If a SSA spectroscopic observation follows an LSA spectroscopic observation, we recommend an ACQ/PEAKUP in the SSA with SEARCH-SIZE=5 before beginning an ACCUM.
- If wavelength accuracy is needed that exceeds the default (see Section 4.5 on page 46), then specify WAVE as the target with an aperture of SC2. Get a WAVE *before* the ACCUM to which it is to apply.
- Specify the grating to be used, either first-order or echelle. If you wish to force an echelle observation to be done in an order other than the default, you may do so by specifying the grating as, for example, ECH-B24, where 24 was the order chosen.
- STEP-PATT may be chosen as a number from 1 to 15, and specific pattern numbers go with specific spectrograph configurations. We recommend using the default that pertains to the setup you have chosen. The details of how the substepping is performed and the background measured are given in Section 8.4 on page 92.
- FP-SPLIT=STD is recommended. The default for FP-SPLIT is NO, which will *not* yield a spectrum with the best signal-to-noise.
- COMB=FOUR is the default value and is recommended for the best results.
- DOPPLER=DEF is recommended. This activates compensation for the velocity shifts of astronomical spectra over the course of an orbit but turns it off for internal exposures.
- STEP-TIME may be specified as a number from 0.2 to 12.75 seconds, in increments of 0.05 seconds. STEP-TIME specifies the length of the individual subspectra that are accumulated to form the final spectrum, and there is no good reason to not use the default of 0.2 sec.
- The CENSOR parameter may also be specified. The default is NO, which is appropriate in almost all cases. If CENSOR=YES is used, individual subspectra (of duration

STEP-TIME, which should be used at the default value of 0.2s) are examined onboard the spacecraft and are discarded if multiple counts have occurred within a 8 μs interval. This allows for the lowering of background noise in cases where the object being observed is very faint, i.e., less than about 0.1 counts per second per diode. Rejected exposures are repeated by the GHRS, leading to a longer total elapsed time for the observation, but only by about 2%. Since the observation must end at a specific time that is predetermined in the spacecraft schedule, using CENSOR involves a risk of losing all the data if too many subexposures are rejected. This is guarded against by adding some padding time in the observation planning process (that is done at STScI and does not affect the exposure time you estimate). See Section 8.6.2 on page 95 for more information on CENSOR.

- A special commanding option called FLYLIM can also be used to reject noise in cases where the object is substantially fainter than the background. Please consult with us if you wish to explore this possibility.
- If you have any doubts about the manner in which your program will be executed (which spectra first, whether a peakup is done, etc.), remove the ambiguity by explicitly indicating the nature and order of the exposures on the Exposure Logsheet.

4.3.3 WSCAN mode

Use of WSCAN can result in a spectrum covering a broader total bandpass than is possible with a single exposure. All the parameters listed above for an ACCUM exposure are available in WSCAN mode. The most important parameter to specify is WAVE-STEP, which is the spacing (in Ångstroms) between each subexposure. If WAVE-STEP=DEF is specified, the central wavelengths of the separate exposures will be equally spaced so as to cover the range of wavelengths that you specify, with at least 20% overlap from one subspectrum to the next.

You may also explicitly give a WAVE-STEP value. If λ_{min} is the central wavelength of the shortest-wavelength exposure, and λ_{max} is the central wavelength of the longest-wavelength exposure, then choose these values in concert with WAVE-STEP so as to yield an integral number of WAVE-STEPs between λ_{min} and λ_{max}.

4.3.4 OSCAN mode

This mode makes it possible to scan across echelle orders at a fixed value of $m\lambda$, where m is the order number and λ is the wavelength. It is rare that adjacent orders both have features of astrophysical interest and so this mode is primarily used for calibrations and not for science observations. If you do use this mode, all the parameters of an ACCUM observation are available.

4.4 Rapid Readout Mode

This mode is sometimes referred to as Direct Downlink. A normal ACCUM exposure is the best way to get a good spectrum because all the features of the spectrograph are available to you: automatic compensation for the motion of the spacecraft along the line-of-sight, rejection of high-noise subspectra with CENSOR, use of FP-SPLIT, COMB, and STEP-PATT to optimize data quality, and so on. However, there are times when ACCUM cannot obtain successive spectra as quickly as is needed to probe a particular phenomenon.

In those cases you can use RAPID mode. The data are read from the detector at the end of each short integration, either to the science tape recorder on *HST* or through TDRSS to the ground. Data obtained in RAPID mode require special handling by the observer to correct for some of the effects (especially doppler shifts) that are automatically compensated for in ACCUM mode.

As for an ACCUM, you should specify the science aperture and the spectral element. You may also choose to observe WAVE as target to get a wavelength calibration. The only other parameter you may specify is SAMPLE-TIME, which is the length of each separate exposure that is read to the ground. The default SAMPLE-TIME is also the minimum, 0.05 seconds. SAMPLE-TIME may be incremented in 0.05 second values up to a maximum of 12.75 seconds. Use of a very short SAMPLE-TIME and/or use of RAPID mode for extended periods can cause scheduling problems because of the very high data volumes that are generated. In particular, a SAMPLE-TIME of less than 0.33 sec records data at the 1 Mb rate and so can proceed for no more than about 20 minutes before filling the onboard tape recorder. A SAMPLE-TIME of 0.33 seconds or more, but less than 2.57 seconds, results in a 32k data rate, while a SAMPLE-TIME in excess of 2.57 seconds results in a 4k data rate. This latter low rate can be sustained almost indefinitely.

4.5 The Precision and Accuracy of Standard Calibrations

Our job of calibrating the GHRS on a routine basis ensures that you can rely on the wavelength scale and flux calibration that you are provided. The quality of the flux calibration is limited primarily by innate factors that are present in tying together different photometric systems. The GHRS has proved to be a reliable instrument whose response has not been seen to vary with time. Routine calibrations will deliver absolute fluxes accurate to 10% and photometrically precise to better than 1% with the LSA[1]. In other words, we monitor the sensitivity of the GHRS on a regular basis (approximately every four months) and have not seen changes in the count rates for the standard stars that exceed 1%, once the effects of telescope focus are taken into account. However, there are undoubtedly systematic effects present that preclude knowing absolute fluxes to better than 5 to 10%. The solid performance of the GHRS means that it is impossible to improve substantially on the flux-calibration by obtaining observations on your own. The GHRS dark count is so low for most objects as to be irrelevant (but see the discussion on CENSOR in Section 8.6.2 on page 95) and high signal-to-noise can be obtained without the need for flat-field exposures.

The one area in which you might wish to consider a special calibration is for the wavelength scale. However, even here the default wavelength scale provided by the pipeline

1. Starting in Cycle 4, the fluxes from the data reduction pipeline in the ultraviolet can differ systematically from earlier values by up to 1% because of the use of models of the white dwarf G191B2B as the fundamental standard.

data reduction system has been improved to take account of several systematic effects. As a result those wavelengths are good to better than 1 km s^{-1} for the first-order gratings, except at the shortest wavelengths (Ly-α). For Echelle-B, the rms scatter in fitted wavelengths is about 0.6 km s^{-1}. These values are uncertainties for the wavelength zero point of a spectrum; the dispersion of spectra differ negligibly from the routine values.

Our *specifications* for routine wavelength calibration are to have them good to only about one diode rms, estimated as follows:

- First, errors in carrousel positioning can amount to 0.2 diode.
- Second, if a wavelength calibration is not available for the precise carrousel position you select then it is necessary to interpolate in the dispersion constants, and that can lead to an error of 0.5 diode.
- Third, changing temperatures within the spectrograph can lead to wavelength shifts of about 0.5 diode over the course of an orbit.
- Finally, geomagnetically-induced image motion can lead to oscillations of up to 1 diode peak-to-peak amplitude over half an orbit.
- The net result is that about 1 1/4 diode accuracy is what is routinely expected.

Precision of about 0.2 diode can be achieved by requesting that an ACCUM with a TARGET of WAVE be made immediately *before* your science exposure. Nearly the same precision can be realized by using information in the SPYBAL exposures that are automatically taken at the start of a sequence of observations with a new grating. Also, you should specify NO GAP for the exposure lines to which the WAVE pertains. See Chapter 5 for an example. Bear in mind that the several separate exposures you list may not necessarily be obtained one right after the other (unless you so specify in Phase II), so that separate WAVE calibrations may be needed.

We also recommend breaking long exposures into subexposures that are no longer than about 5 minutes each. This is done to ensure that geomagnetically-induced image motion will not degrade the quality of your data. Any shifts in the different spectra of the same object can generally be determined by cross-correlating them during your data analysis.

4.6 Other Considerations

There are many factors that may influence how you specify the manner in which your observations should be obtained. Here we mention two that have arisen in particular instances. The first has to do with Targets of Opportunity (TOOs) and/or coordinated observations. The *Call for Proposals* should be consulted for information about proposing to observe Targets of Opportunity with *HST* and GHRS. Observations of TOOs often need to be coordinated with other satellites or ground-based observatories. The long lead times for planning *HST* observations, even for TOOs, are an impediment to that coordination. We encourage you to explain in detail exactly what is or is not required for the successful completion of your program.

Another problem that can occur arises when a science program specifies a large number of separate GHRS exposures. The problem is caused by the relatively small amount of memory available on *HST* in which to store GHRS commands. It is usually possible to break up such a program so that the separate exposures are not all together, but occasionally the science goals cannot allow that and some other compromise must be made. Roughly speaking, about 40 total spectra can be scheduled in a single block (a WSCAN with *n* set-points counts as *n* exposures and an FP-SPLIT counts as 2 or 4). Once that number is exceeded the remaining observations must be scheduled in a new block of time, and that means a new target acquisition will be needed, with the concomitant overhead time.

Chapter 5

Phase II Proposal Examples

We present in this chapter several examples of how to actually execute proposals to achieve what you want, since abstract instructions are, at best, difficult to follow. The examples are shown separately, partly for formatting reasons, since they require a sideways orientation of the page, and partly to assemble them in one place for easy reference.

We begin by showing how the first entry on the next page would look as input to RPSS. The remainder of this chapter shows how Phase II proposals look to us. In most of these examples, the various parameters have been explicitly listed for clarity, even though they often correspond to the defaults that would apply anyway.

We remind you that any if differences exist between this document and, say, the Phase II Proposal Instructions, the one with the most recent date of issue should be followed or you should consult us to resolve the discrepancy.

```
exposure_logsheet:

linenum:          1.0
targname:         MU-COL
config:           HRS
opmode:           ACQ
aperture          2.0
sp_element:       MIRROR-A2
num_exp:          1
time_per_exp:     10.75M
fluxnum_1:        1
priority:         1
param_1:          SEARCH-SIZE=5,
param_2:          MAP=ALL-POINTS
req_1:            CYCLE 5/ 1-2;
req_2:            EARLY ACQ FOR 2.0
comment_1:        STEP-TIME=0.2S;
comment_2:        EXPECT 21000 COUNTS IN STEP-TIME
!
linenum:          2.0
targname:         MU-COL
config:           HRS
opmode:           ACCUM
aperture:         2.0
sp_element:       ECH-B
num_exp:          1
time_per_exp:     4.8S
fluxnum_1:        1
priority:         1
param_1:          STEP-PATT=13
```

1. Example of an observation that specifies an early acquisition. Note that the TIME in column (11) is 0.2 sec (the STEP-TIME) times (128 x 25) + 25, in accord with the formula in Section 4.1.13 . Note also that the expected number of counts for the acquisition is mentioned.

1 LN NM	2 SEQ NAME	3 TARGET NAME	4 INSTR CONFIG	5 OPER. MODE	6 APER OR FOV	7 SPECTRAL ELEMENT	8 CENTRAL WAVELN	9 OPTIONAL PARAMETERS	10 NUM EXP	11 TIME	12 S/N	13 FLX REF	14 PR	15 SPECIAL REQUIREMENTS
1.0		MU-COL	HRS	ACQ	2.0	MIRROR-A2		SEARCH-SIZE=5, MAP=ALL-POINTS	1	10.75M		1	1	CYCLE 5/ 1-2; EARLY ACQ FOR 2.0
	COMMENTS: STEP-TIME=0.2S; EXPECT 21000 COUNTS IN STEP-TIME													
2.0		MU-COL	HRS	ACCUM	2.0	ECH-B	1600	STEP-PATT=13	1	4.8S		1	1	

2. The same observation as above specified as an interactive acquisition.

1 LN NM	2 SEQ NAME	3 TARGET NAME	4 INSTR CONFIG	5 OPER. MODE	6 APER OR FOV	7 SPECTRAL ELEMENT	8 CENTRAL WAVELN	9 OPTIONAL PARAMETERS	10 NUM EXP	11 TIME	12 S/N	13 FLX REF	14 PR	15 SPECIAL REQUIREMENTS
10.0 00		MU-COL	HRS	ACQ	2.0	MIRROR-A2		SEARCH-SIZE=5, MAP=ALL-POINT S	1	10.75M		1	1	CYCLE 5/ 10-20; INT ACQ FOR 20;
	COMMENTS: STEP-TIME=0.2S; EXPECT 21000 COUNTS IN STEP-TIME													
20.0 00		MU-COL	HRS	ACCUM	2.0	ECH-B	1600	STEP-PATT=13	1	4.8S		1	1	

3. A GHRS acquisition specified with explicit BRIGHT and FAINT limits.

1 LN NM	2 SEQ NAME	3 TARGET NAME	4 INSTR CONFIG	5 OPER. MODE	6 APER OR FOV	7 SPECTRAL ELEMENT	8 CENTRAL WAVELN	9 OPTIONAL PARAMETERS	10 NUM EXP	11 TIME	12 S/N	13 FLX REF	14 PR	15 SPECIAL REQUIREMENTS
100.000		BD28D4211	HRS	ACQ	2.0	MIRROR-A2		BRIGHT=65535, FAINT=700	1	9S		1	1	ONBOARD ACQ FOR 200;

COMMENTS: STEP_TIME=1.0S; EXPECT 1800 COUNTS IN STEP-TIME; FAINT SET TO APPROX. 40% OF EXPECTED COUNTS.

4. Example of an acquisition with an offset.

1 LN NM	2 SEQ NAME	3 TARGET NAME	4 INSTR CONFIG	5 OPER. MODE	6 APER OR FOV	7 SPECTRAL ELEMENT	8 CENTRAL WAVELN	9 OPTIONAL PARAMETERS	10 NUM EXP	11 TIME	12 S/N	13 FLX REF	14 PR	15 SPECIAL REQUIREMENTS
900.000		HII-POS1	HRS	ACQ	2.0	MIRROR-N2		BRIGHT=RETURN	1	1.8S		1	1	ONBOARD ACQ FOR 910
COMMENTS: STEP-TIME=0.2S														
910.000		HII-POS2	HRS	ACCUM	2.0	G160M	1500		1	272S	50	1	1	
COMMENTS: RA-OFF = +0.227S +/- 0.001S, DEC-OFF = +6.0" +/- 0.01", FROM HII-POS1														

5. A fairly typical GHRS observation, starting with an acquisition using BRIGHT=RETURN and proceeding to several spectroscopic exposures that use alternative variants of ACCUM specifications. Not all of these would be used in one program. Note the IMAGE (line 300) that is obtained to later confirm centering of the target in the LSA.

1 LN NM	2 SEQ NAME	3 TARGET NAME	4 INSTR CONFIG	5 OPER. MODE	6 APER OR FOV	7 SPECTRAL ELEMENT	8 CENTRAL WAVELN	9 OPTIONAL PARAMETERS	10 NUM EXP	11 TIME	12 S/N	13 FLX REF	14 PR	15 SPECIAL REQUIREMENTS
100.000		BD28D4211	HRS	ACQ	2.0	MIRROR-A2		BRIGHT=RETURN,	1	9S		1	1	ONBOARD ACQ FOR 200;
COMMENTS: STEP_TIME=1.0S; EXPECT 1800 COUNTS IN STEP-TIME.														
200.000		BD28D4211	HRS	ACQ/PEAKUP	2.0	MIRROR-A2			1	102S		1	1	ONBOARD ACQ FOR 300-800;
COMMENTS: STEP_TIME=1.0S														
300.000		BD28D4211	HRS	IMAGE	2.0	MIRROR-A2		NX=16, NY=16	1	256.0S		1	1	
COMMENTS: STEP-TIME=1.0S														
400.000		BD28D4211	HRS	ACCUM	2.0	G160M	1500	STEP-PATT=5, STEP-TIME=0.2, FP-SPLIT=NO, COMB=FOUR	1	217.6S	50	1	1	
COMMENTS: EXPOSURE TIME IS A INTEGRAL NUMBER OF MINIMUM EXPOSURE TIME (27.2S IN THIS CASE); S/N IS PER DIODE; STEP-PATT WILL RESULT IN 4 PIXELS/DIODE.														
450.000		BD28D4211	HRS	ACCUM	2.0	G160M	1500	STEP-PATT=5, STEP-TIME=0.2, FP-SPLIT=FOUR, COMB=FOUR	1	217.6S	50	1	1	
COMMENTS: FP-SPLIT WILL PRODUCE 4 SPECTRA EACH WITH 54.4S EXPOSURE TIME.														
475.000		BD28D4211	HRS	ACCUM	2.0	G160M	1500		10	217.6S	50	1	1	
COMMENTS: TOTAL EXPOSURE = 2176S--BREAK UP LONG EXPOSURE TO AVOID DRIFT DUE TO GIMP.														

6. A sequence of exposures that could be added to Example 5 if additional SSA observations were desired. The ACCUM, RAPID, and WSCAN lines illustrate a range of options. Note the ACQ/PEAKUP with the SSA (line 550) to move the star to that aperture. If line 550 were absent the star would still be moved to the SSA, but it would not be as well centered.

1 LN NM	2 SEQ NAME	3 TARGET NAME	4 INSTR CONFIG	5 OPER. MODE	6 APER OR FOV	7 SPECTRAL ELEMENT	8 CENTRAL WAVELN	9 OPTIONAL PARAMETERS	10 NUM EXP	11 TIME	12 S/N	13 FLX REF	14 PR	15 SPECIAL REQUIREMENTS
550.		BD28D4211	HRS	ACQ/PE AKUP	0.25	MIRROR- A2		SEARCH-SIZE=5	1	25S		1	1	ONBOARD ACQ FOR 600.00;
COMMENTS: STEP_TIME=1.0S														
575. 000		WAVE	HRS	ACCUM	SC2	G160M	1500		1	60S		1	1	CALIB FOR 525; SEQ 500-600 NO GAP
COMMENTS: STANDARD SPECTRAL CAL LAMP SPECTRUM.														
600. 000		BD28D4211	HRS	ACCUM	0.25	G160M	1500	STEP-PATT=5, S TEP-TIME=0.2, FP-SPLIT=NO, C OMB=FOUR	1	326.4S	50	1	1	
COMMENTS: THROUGHPUT OF SSA APPROX. 0.67 OF LSA AT 1500A.														
700. 000		BD28D4211	HRS	RAPID	0.25	G160M	1500	SAMPLE-TIME=1. 0	1	20M	25	1	1	
800. 000		BD28D4211	HRS	WSCAN	0.25	G160M	1400-1 610	WAVE-STEP=30.0	1	217.6S	50	1	1	
COMMENTS: WSCAN TO PRODUCE 7 SPECTRA W/ CENTRAL WAVELENGTHS: W1=1415.0,W2=1445,W3=1475,W4=1505, W5=1535,W6=1565,W7=1595.														

Chapter 6

Design and Construction of the GHRS

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6.2 Gratings and Optical Elements *60*

6.3 The Digicon Detectors *62*

6.1 The HST Focal Plane and the GHRS Apertures

We provide here a description of the instrument in largely pictorial terms. More illustrations and full technical descriptions of the GHRS may be found in the references (see Section 9.2 on page 104).

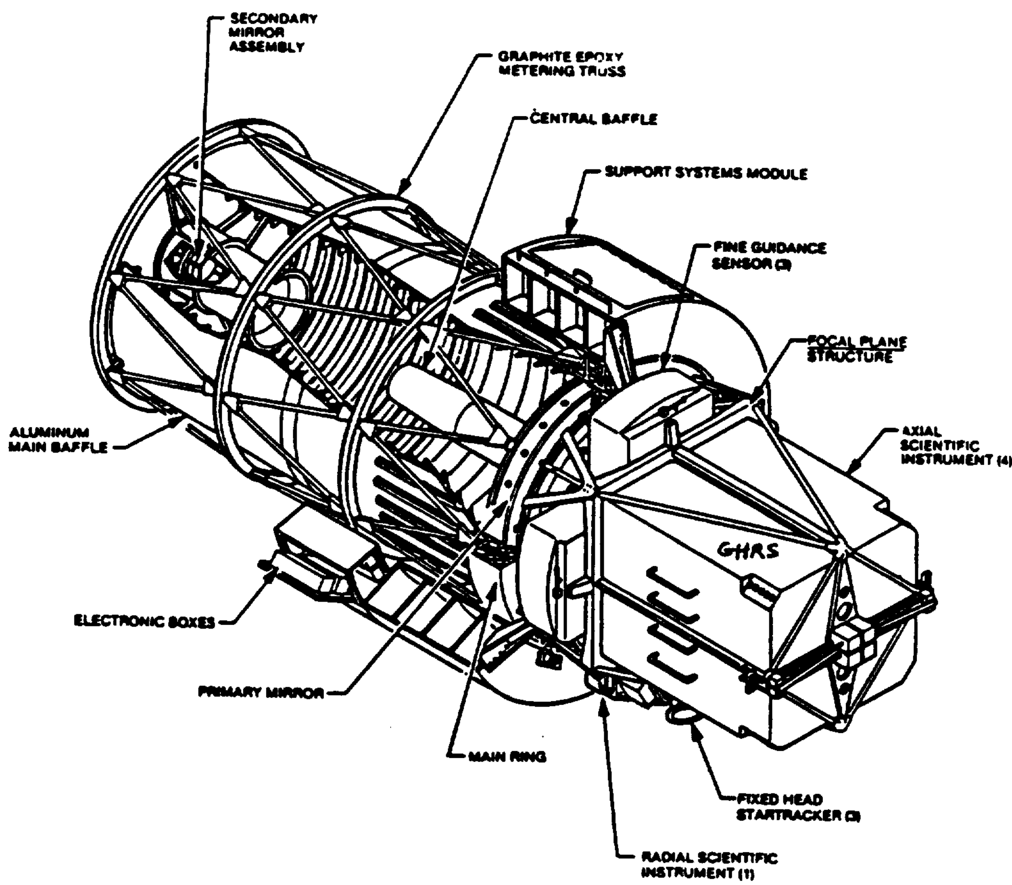

Figure 6-1. The Hubble Space Telescope and its components, with the locations of important operational elements shown.

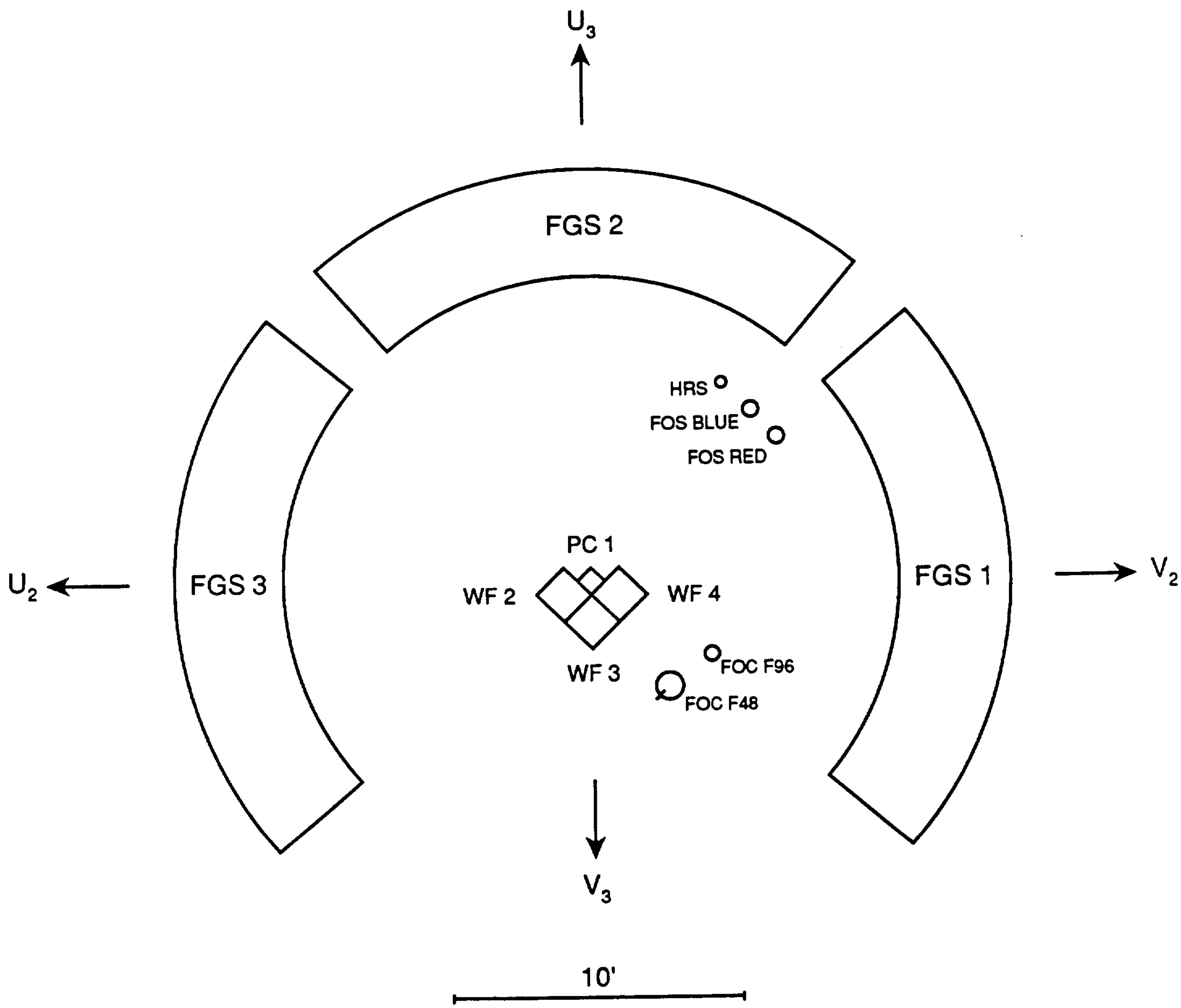

Figure 6-2. The focal plane of HST and the definitions of the V2, V3 and U2, U3 coordinate systems of the spacecraft.

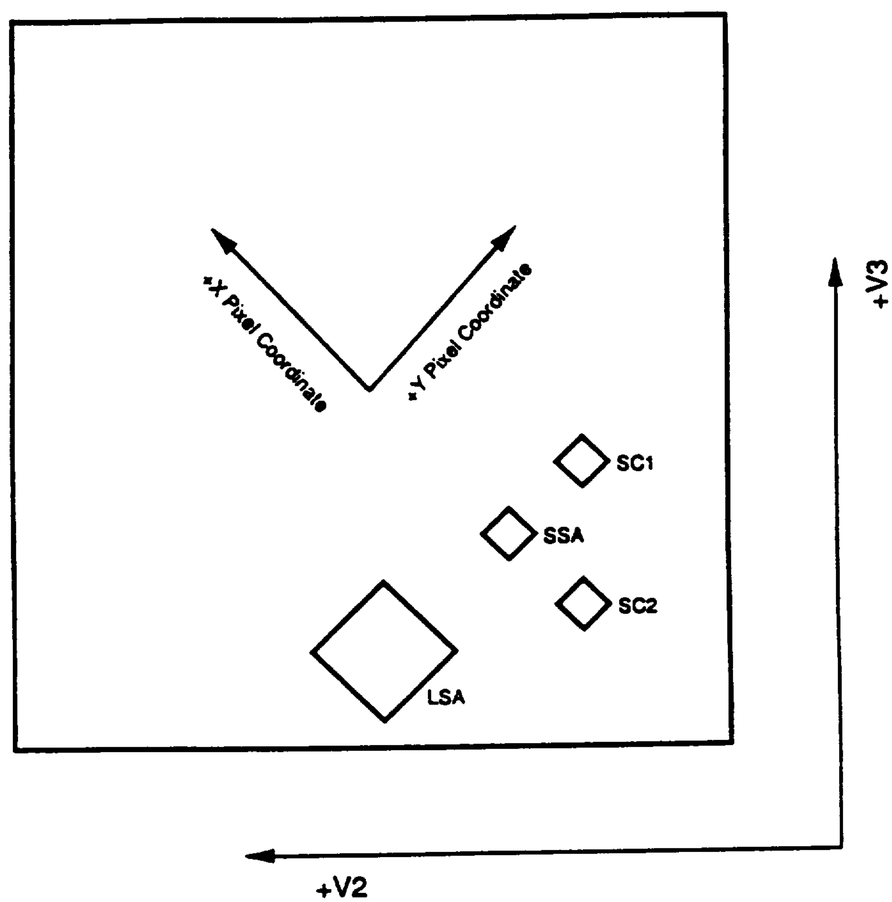

Figure 6-3. Locations of GHRS apertures relative to spacecraft axes. Note that the sense of the *x* and *y* motions are shown by the arrows, but that the zero point for each aperture (SSA and LSA) is located at its center. COSTAR does not, of course, change the layout of the entrance apertures, but it does alter the way that the sky is imaged onto the focal plane. The sense is easy to remember: the COSTAR mirrors invert the sense of the original image, which means that the signs of motions in both coordinates, V2 and V3, (or U2 and U3) are reversed.

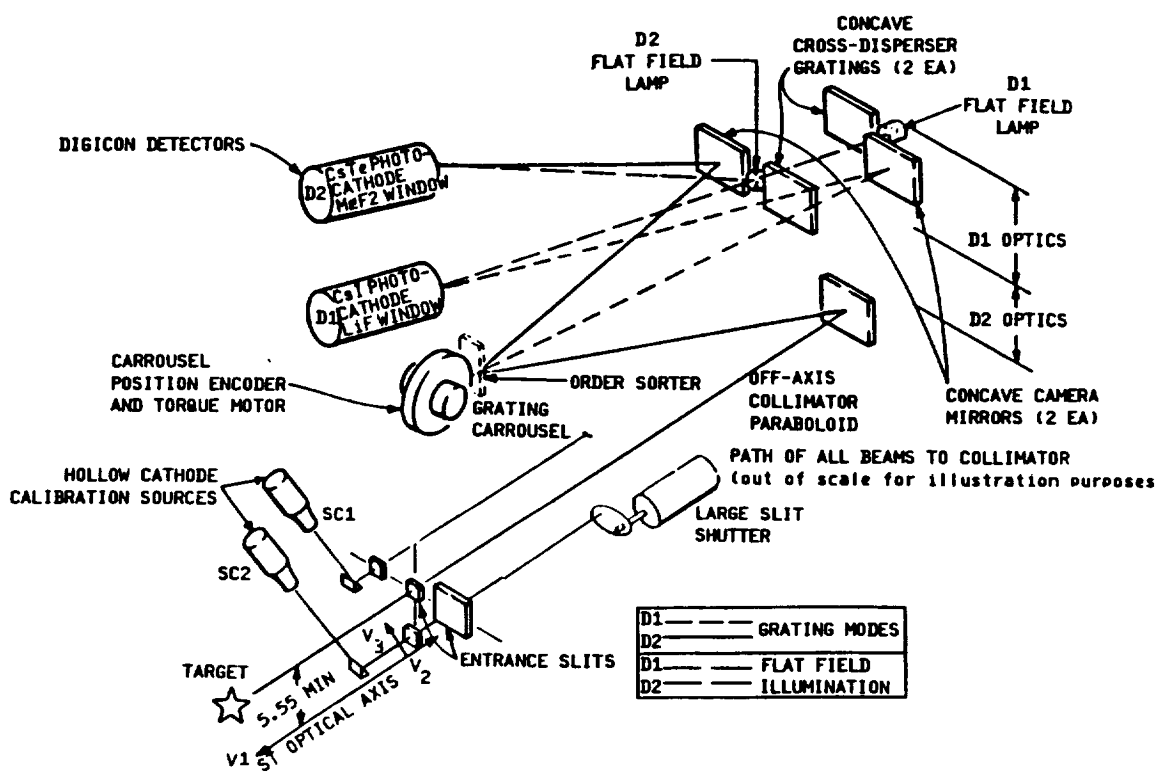

Figure 6-4. Optical schematic of the GHRS.

6.2 Gratings and Optical Elements

TABLE 6-1 Properties of GHRS Gratings

Name	Grooves per mm	Blaze Angle	Order of use	Angle of Incidence	Diffraction Angle	Deviation Angle	Detector
G140L	600	2.6	1	9.0 – 10.3	-5.3 – -4.0	14.25	D1
G140M	6000	23	1	26 – 38	11 – 24	14.25	D1
G160M	4960	19	1	21 – 33	14 – 27	6.25	D2
G200M	4320	26	1	23 – 34	17 – 28	6.25	D2
G270M	3600	28	1	27 – 38	20 – 32	6.25	D2
Ech-A	316	63.4	33 – 53	68 – 74	54 – 61	13.25	D1
Ech-B	316	63.4	17 – 33	63 – 72	58 – 66	5.75	D2
CD-A	194.6	0.75	1				D1
CD-B	85.7	0.54	1				D2

Note that the "CD" gratings are cross-dispersers for the echelles. CD-A has a focal length of 1460 mm and CD-B has a focal length of 1340 mm. Note also that the "M" gratings are holographic and that the blaze angle quoted formally is that which correctly predicts the center of the wavelength region the grating is optimized for. G140L is a ruled grating. "Ech-A" and "Ech-B" refer to two modes of operation that use the same echelle grating but different cross-dispersers and detectors.

TABLE 6-2 Properties of Other GHRS Optical Components

Name	Clear Aperture (mm)	Focal Length (mm)	Detector
LSA = "2.0"	0.559		D1, D2
SSA = "0.25"	0.067		D1, D2
Collimator	80	1850	D1, D2
Mirror N2[a]	80		D2
Mirror A2	20		D2
Mirror N1	80		D1
Mirror A1	20		D1
Cam-A	84	1425	D1
Cam-B	86	1350	D2
D1	22 × 28		
D2	22 × 28		

a. Mirror N2 is actually "D" shaped, being a circle with a small slice off one side. It is about 60 × 80 mm.

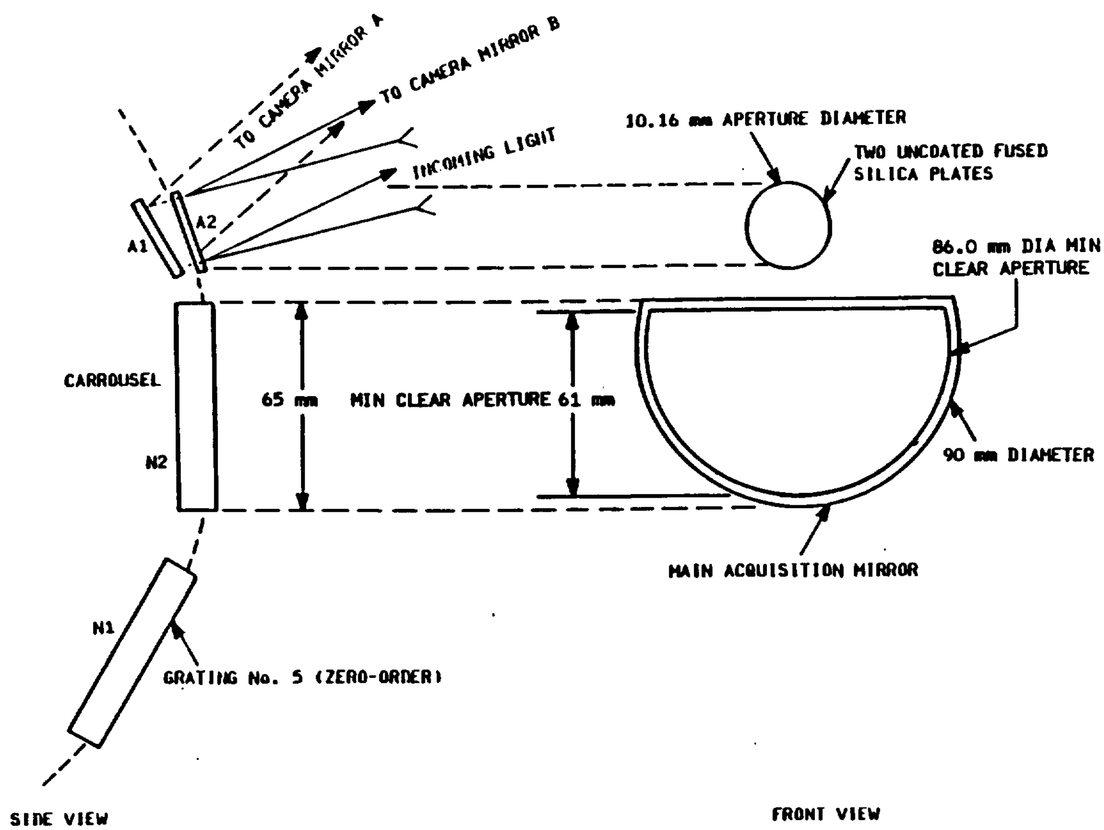

Figure 6-5. Schematic diagram of GHRS' acquisition optics. The "main acquisition mirror" is N2.

6.3 The Digicon Detectors

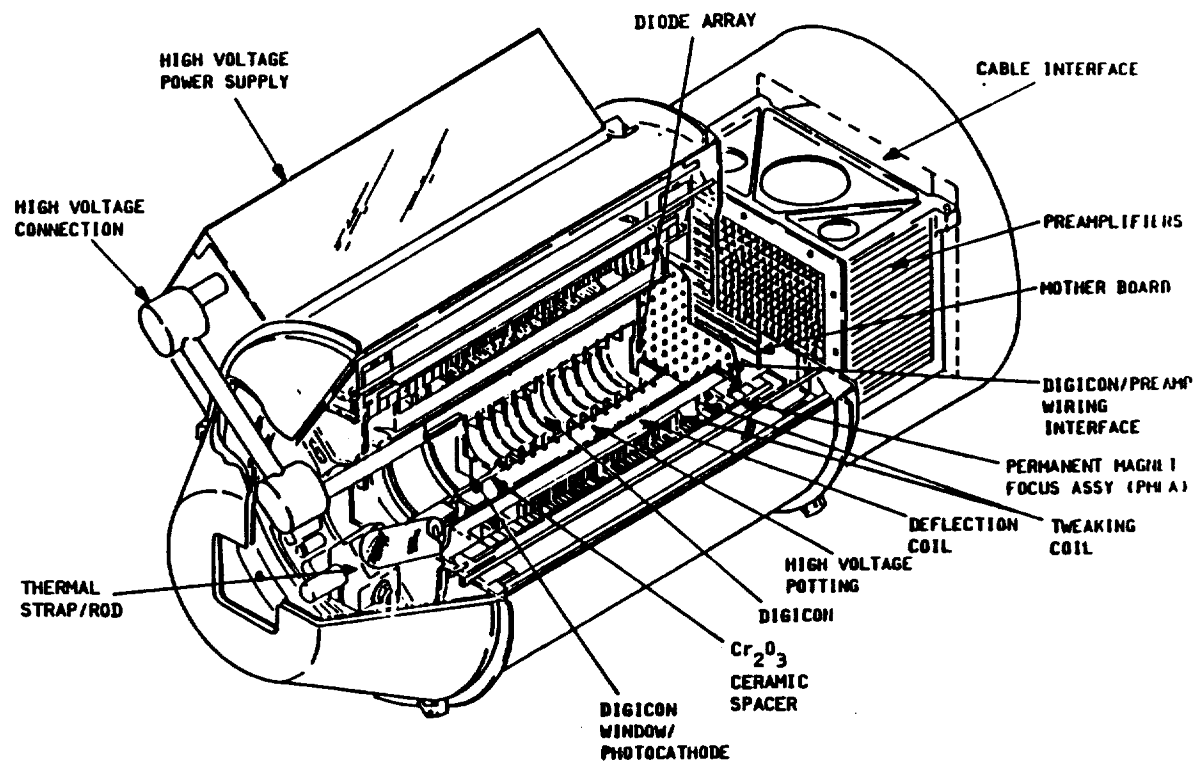

Figure 6-6. Cutaway view of a Digicon.

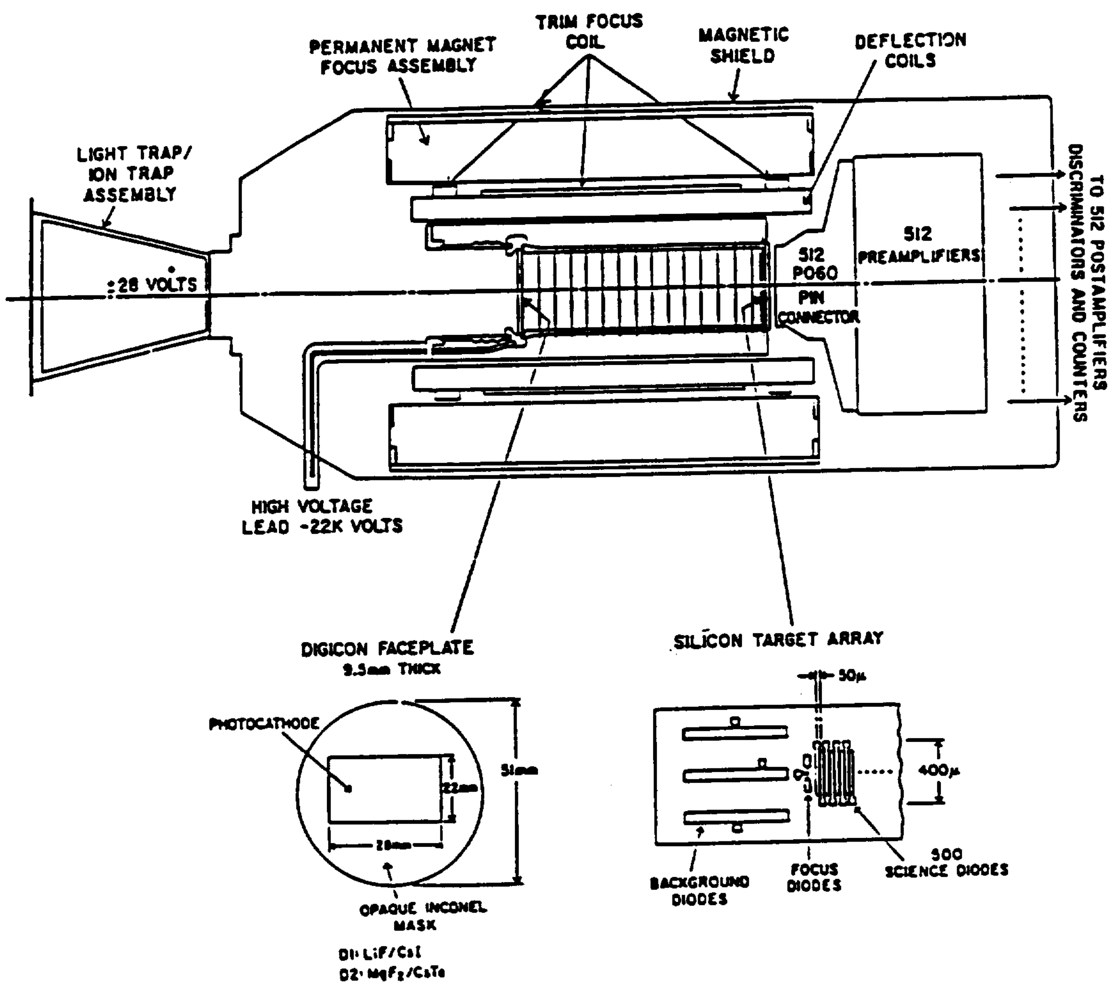

Figure 6-7. Cross-sectional view of a Digicon and views of its faceplate and diode arrays.

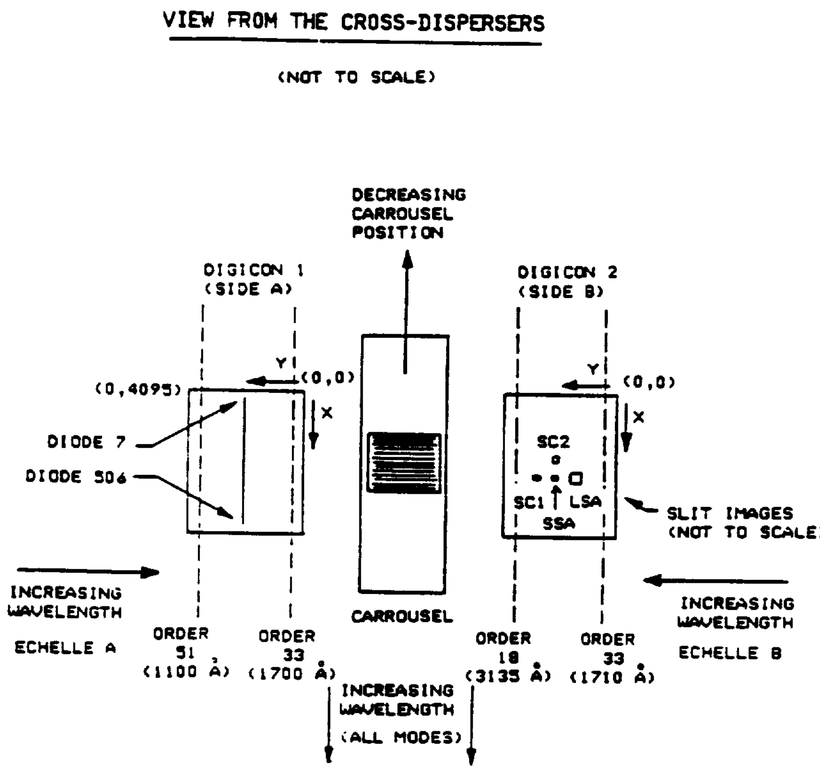

Figure 6-8. A view from the cross-dispersers toward the Digicon detectors to illustrate the senses of *x* and *y* motions and of increasing wavelength.

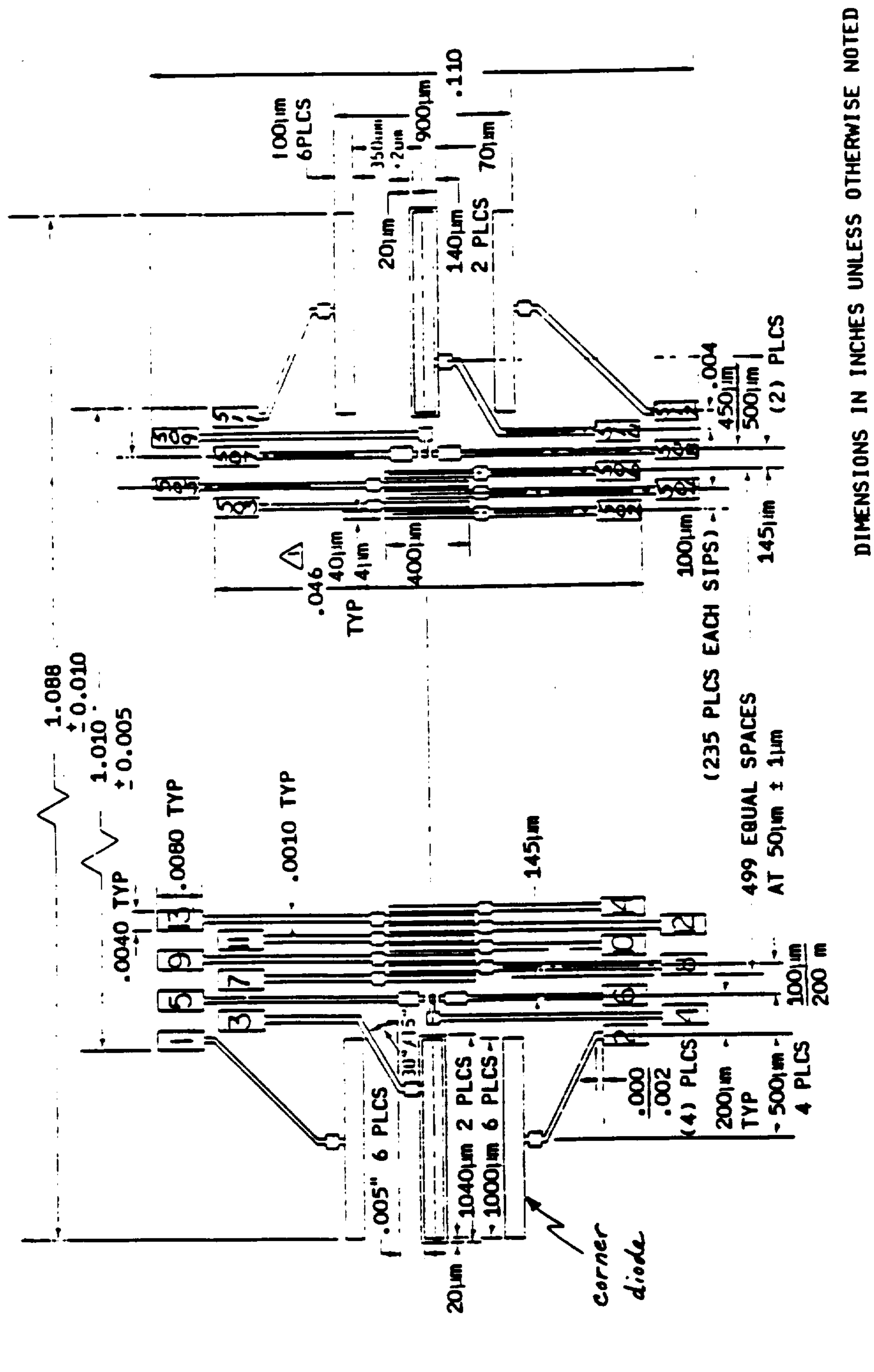

Figure 6-9. A detailed layout of the diodes in the Digicon detectors. Note the 6 large "corner diodes" and the 6 "focus diodes" (numbers 4, 5, and 6, for example).

Chapter 7

Target Acquisition Reference Information

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7.1 Predicting Target Acquisition Count Rates for Stars

We have calculated GHRS target acquisition count rates for the spectra of a subset of the 175 stars contained in the Bruzual-Persson-Gunn-Stryker (BPGS) Library of Stellar Spectra by using calcphot, a task in the synphot package in stsdas. GHRS target acquisition count rates for objects similar to those in the BPGS catalog can be predicted by following the procedures described here. Constraints on the value of STEP-TIME are discussed. Please note that the values tabulated are the total count rate for a star, and that the count rate for a particular diode will depend on that portion of the Point Spread Function that strikes it. That can influence the degree, for example, to which the paired-pulse correction applies. However, the acquisition procedure sums the counts over the eight science diodes upon which the LSA is imaged, so for most objects these values may be used straightforwardly.

Do not forget to reduce these values by a factor of 0.3 if the focus diodes are being used for an IMAGE; this is because of the reduced area of the focus diodes compared to using eight normal diodes for an acquisition. This factor applies to when a focus diode is centered on a point source.

The flux distributions in the BPGS catalog include ultraviolet wavelengths and can be used for planning GHRS target acquisitions. Each spectrum in the catalog was dereddened and scaled to $V_0 = 0.0$. The calcphot task in the synphot package of stsdas was used to convolve the catalog flux distributions with the effective areas of the acquisition mirrors. Table 7-1 on page 74 contains columns giving the BPGS catalog object name, spectral type, $(B-V)_0$, count rate for the acquisition mirror with no reddening, and scale factors (per unit magnitude) indicating the relative count rate observed at given amounts of reddening compared to the count rate with no reddening.

To use Table 7-1 to predict target acquisition count rates:

- Determine the *intrinsic* color, $(B - V)_0$, and magnitude, V_0, of your object as well as its color excess, $E(B - V)$.
- Find an entry in Table 7-1 that has similar spectral characteristics to your object (by spectral type or $(B - V)_0$ and note that luminosity class is important for the coolest stars). The table is sorted by increasing $(B - V)_0$. Make sure you pick from the column corresponding to the acquisition mirror that you plan to use.
- Scale the predicted count rate found in the previous step by the ratio of apparent brightness of your object to an object with $V_0 = 0.0$, i.e., multiply by $10^{-0.4 V_0}$.
- To obtain the scale factor by which the unreddened count rate will be reduced for an amount of reddening appropriate to your object, multiply the count rate from the previous step by this factor: $10^{\text{scale factor} \times E(B-V)}$
- The GHRS detectors are nonlinear at high count rates: this phenomenon is referred to as the "dead-time" or "paired-pulse" effect. Consequently, the predicted count rate from the previous step must be reduced to yield the actual count rate that GHRS will measure. Multiply the count rate you just determined by the "fraction detected" value determined from Figure 2 on page 71 to obtain the final predicted count rate.
- This final value is probably reliable to within a factor of two, which is adequate for acquisition purposes in almost all instances.

7.1.1 Alternate Method for Predicting Target Acquisition Count Rates

Figure 7-1 on page 70 shows mean predicted count rates as a function of $(B-V)_0$ color for the four acquisition mirrors. Also shown are the fits to the predicted count rates for various amounts of reddening. The label for each curve represents the color excess, $E(B-V)$, applied to the spectra.

You can estimate target acquisition count rates using the plots instead of Table 7-1:

- Determine the intrinsic color and magnitude of your object as well as its color excess.
- Read from the Figures (depending on the mirror used) the predicted count rate.
- Scale the predicted count rate by the ratio of apparent brightness of your object to an object with zero magnitude.
- Use Figure 2 on page 71 to correct for the "paired-pulse" effect.

7.1.2 Two Examples

First, suppose you want to observe μ Col, which has the following properties:

Name	Sp. Type.	V	B – V	E(B – V)
μ Columbae	O9V	5.16	–0.29	0.01

Using the table, you would see that HR 8023, an O6 star with $(B-V) = -0.313$ is the closest match, giving a predicted count rate for the A2 mirror of 1.3 x 10^7counts s^{-1} for a $V_0 = 0$ star. Multiplying this count rate by $10^{-0.4 \times 5.13}$ gives 1.2 x 10^5 counts s^{-1}. Reddening will decrease the counts slightly; calculation of the scale factor indicates that you should multiply by 0.93, giving a new count rate of 1.1 x 10^5 counts s^{-1}. The dead-time correction factor estimates that only 83% of those counts will be detected, so one would expect approximately 94000 counts s^{-1} with this star. In fact, when μ Col was observed early in Cycle 4, 19,600 counts were obtained in 0.2 seconds with the A2 mirror, which works out to 98,000 counts s^{-1}, which is within 5% of the calculated value.

Second, consider a very red star such as Aldebaran:

Name	Sp. Type.	V	B – V	E(B – V)
α Tauri	K5III	0.84	1.54	0.00

Using the table, you would see that BD–1°3113 has a similar spectral type (K5III) and color (1.61). The calculated count rate for mirror A2 is then 1.6×10^3 counts per second. The adjustment for apparent magnitude is $10^{-0.4 \times 0.84}$, which yields a count rate of 530 per second, or 210 in 0.2 seconds. Early in Cycle 4 a Tau was acquired with mirror A2 and the count rate seen was 246 in 0.2 seconds, within 15% of the predicted value.

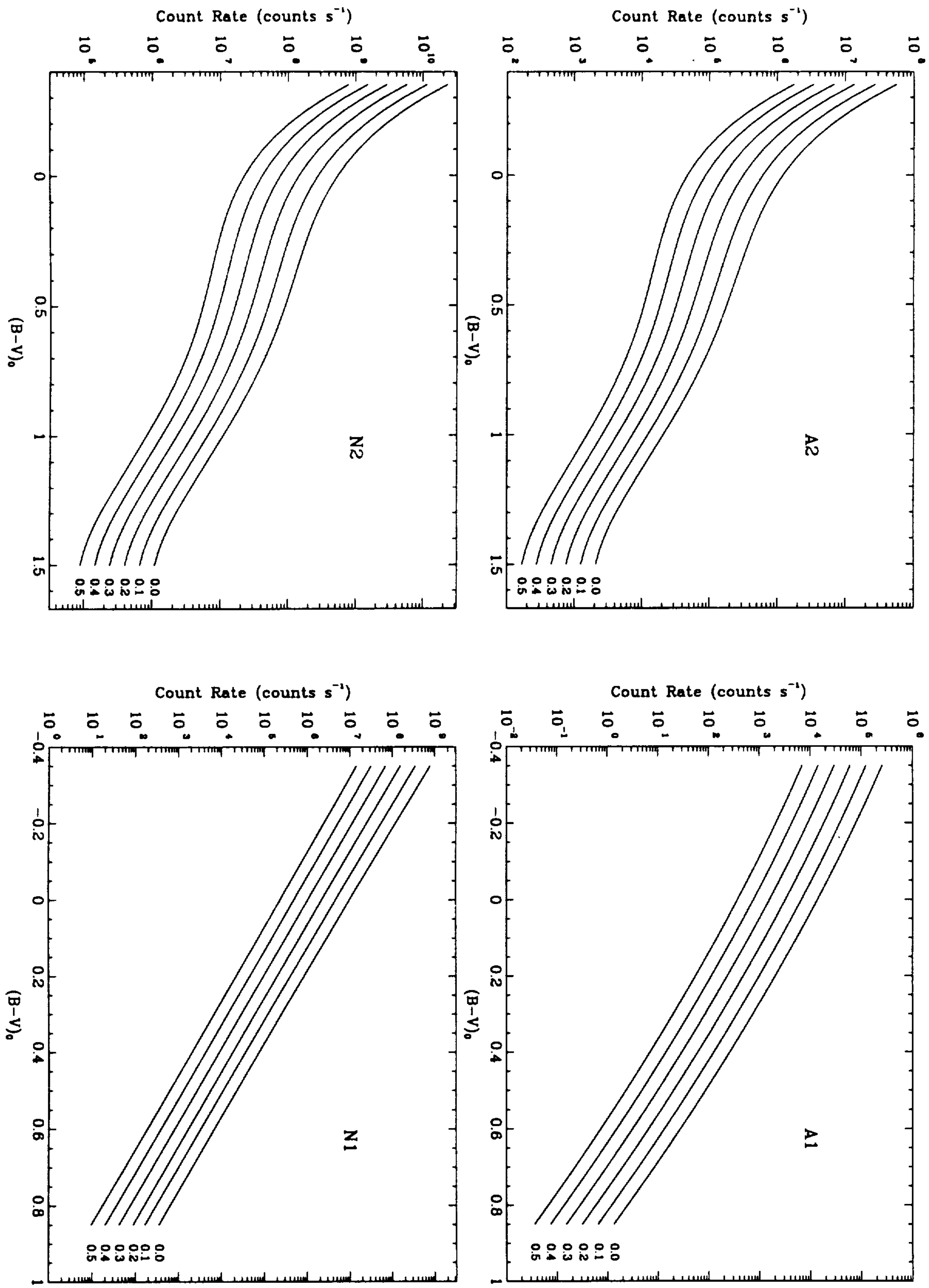

Figure 7-1. Mean target acquisition count rates for stars with the four mirrors of the GHRS. The numbers at the right indicate the appropriate *E(B − V)* for each curve.

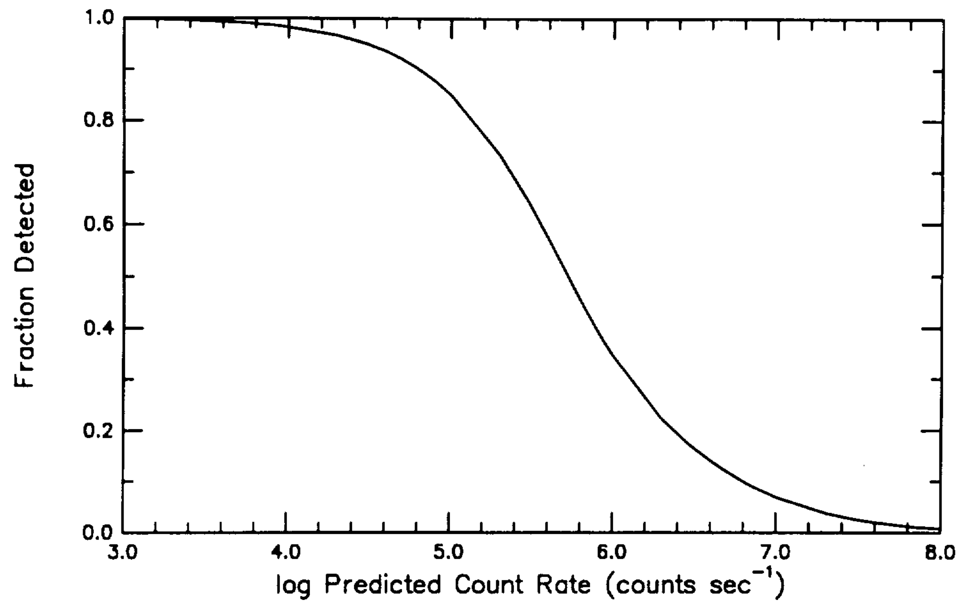

Figure 7-2. Fraction of counts detected as a function of the true count rate, i.e., before the paired pulse correction.

7.2 Constraints on the Value of the STEP-TIME Parameter

Once you have the predicted countrate, you then need to extract the piece of information required to plan your target acquisition: STEP-TIME. This is necessary to calculate the time per exposure that is entered on the proposal logsheet. The goal is to have GHRS see 10^3 to 10^4 counts at the peak dwell point of the spiral search for either an acquisition or a peakup. A minimum of 100 counts are needed to have a chance at a successful target acquisition. The STEP-TIME then is just the number of counts desired (10^3 to 10^5, but at least 100) divided by the predicted count rate. Remember, however, that the minimum STEP-TIME permitted is 0.2 seconds. Also bear in mind that the STEP-TIME may not exceed 12.75 seconds.

To avoid the possibility of a failed target acquisition, it is important that the combination of your target flux and the acquisition mirror used should not result in the eight science diodes used for the target acquisition seeing more than a total of about 65,000 counts (the number accommodated in a 16 bit register) in a given STEP-TIME. Counting more than 65,000 counts effectively causes the register to wrap back to zero and thus confounds the target acquisition algorithm. **This problem is avoided if BRIGHT=RETURN is specified** because a 32-bit on-board register is used. If a BRIGHT limit is explicitly given, the register that holds it is limited to 16 bits.

Figure 7-3 and Figure 7-4 are provided to allow for a visual check of potential problems arising from the choice of STEP-TIME. These Figures show the constraints placed on using a particular mirror and STEP-TIME. Figure 7-4 is analogous for the Side 1 mirrors.

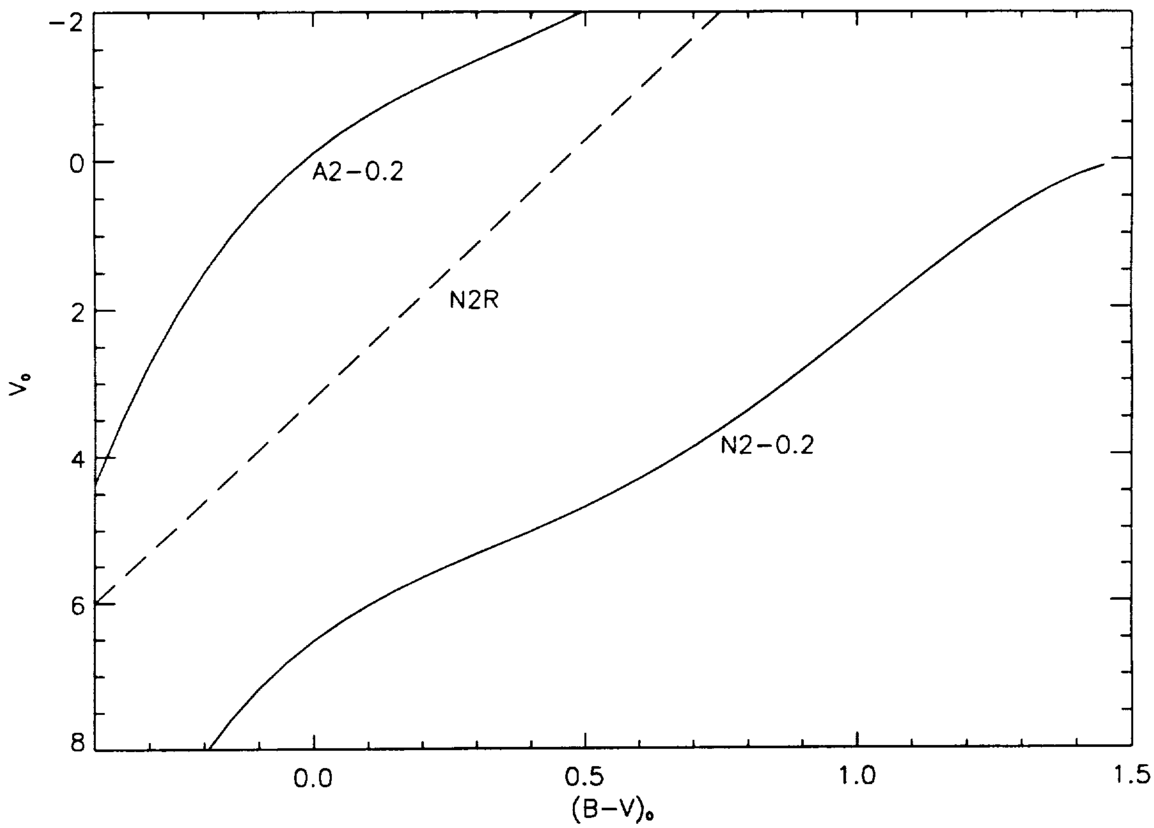

Figure 7-3. Target acquisition constraints for the Side 2 mirrors N2 and A2.

N2R:	Constraints and Restrictions Document (CARD) upper limit for use of Mirror-N2. Observing objects that are bluer and brighter than indicated by this line would result in degraded performance and possible damage to the instrument. Brighter and bluer objects should be acquired with mirrors A2 or A1.
N2-0.2:	GHRS will count 65,000 counts in 0.2 seconds with the N2 mirror for objects on this contour. To the left of this curve, more than 65,000 counts will be detected leading to a probable failure to acquire the object if a `BRIGHT` value is specified. However, use of `BRIGHT=RETURN` will result in a satisfactory acquisition.
A2-0.2:	GHRS will count 65,000 counts in 0.2 seconds with the A2 mirror for objects on this contour. To the left of this curve, more than 65,000 counts will be detected leading to a probable failure to acquire the object if a `BRIGHT` value is specified. However, use of `BRIGHT=RETURN` will result in a satisfactory acquisition.

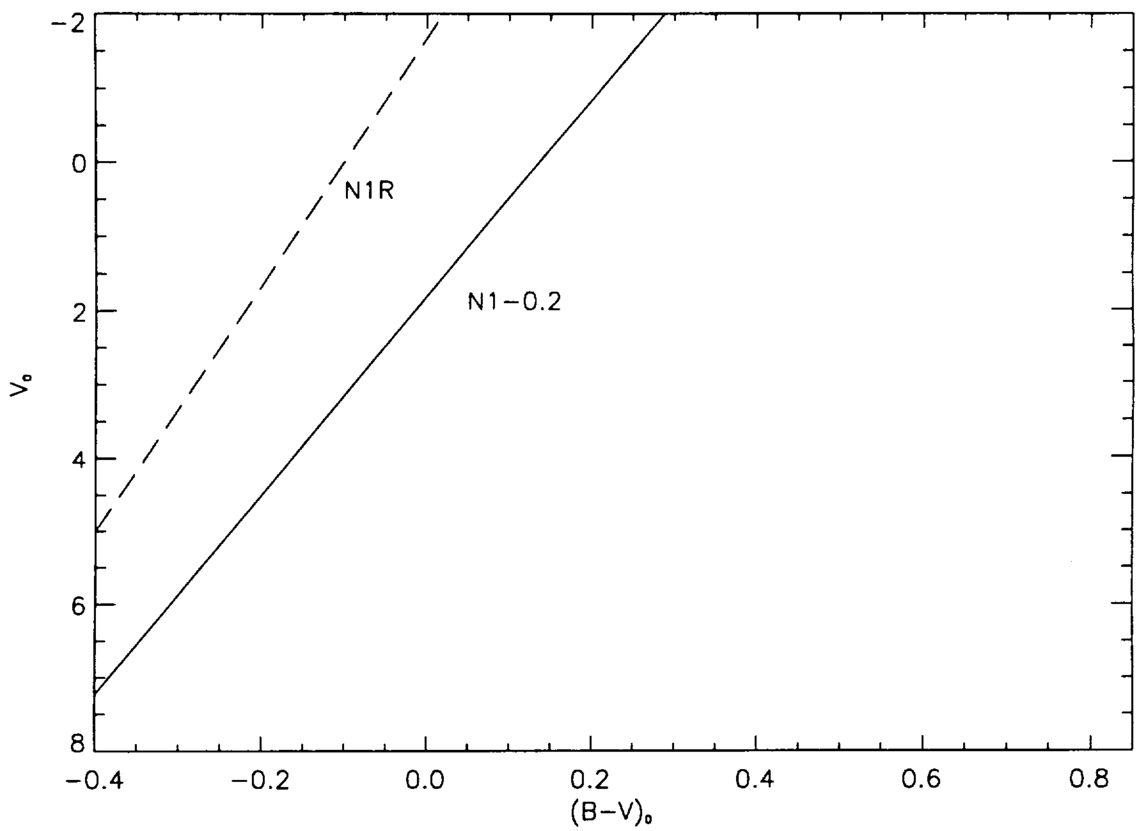

Figure 7-4. Target acquisition constraints for the Side 1 mirrors N1 and A1.

N1R:	Constraints and Restrictions Document (CARD) upper limit for use of Mirror-N1. Observing objects that are bluer and brighter than indicated by this line would result in degraded performance and possible damage to the instrument. Brighter and bluer objects should be acquired with mirrors A2 or A1.
N1-0.2:	GHRS will count 65,000 counts in 0.2 seconds with the N1 mirror for objects on this contour. To the left of this curve, more than 65,000 counts will be detected leading to a probable failure to acquire the object if a `BRIGHT` value is specified. However, use of `BRIGHT=RETURN` will result in a satisfactory acquisition.!
	Note that no constraints apply to the use of the A1 mirror, i.e., no objects are too bright.

TABLE 7-1 Predicted target acquisition count rates for stars, reduced to $V_0 = 0$.

Star Name	Spectral Type	$(B-V)_0$	count rate for mirror				reddening reduction factor[a]			
			N2	A2	N1	A1	N2	A2	N1	A1
9 Sgr	O5	-0.337	8.595E9	2.098E7	4.598E8	2.657E5	-3.034	-3.108	-3.428	-3.130
HR 8023	O6	-0.313	5.684E9	1.348E7	2.545E8	1.690E5	-2.955	-3.021	-3.382	-3.114
60 Cyg	B1V	-0.269	5.367E9	1.293E7	2.794E8	1.767E5	-3.002	-3.070	-3.393	-3.123
69 Cyg	B0IB	-0.234	4.192E9	9.901E6	1.869E8	1.209E5	-2.935	-3.003	-3.384	-3.110
ι Her	B3V	-0.203	2.764E9	6.529E6	1.232E8	7.970E4	-2.935	-3.003	-3.384	-3.110
HR 7467	B3III	-0.182	2.436E9	5.755E6	1.087E8	7.028E4	-2.936	-3.004	-3.384	-3.110
20 Aql	B3IV	-0.156	2.268E9	5.357E6	1.012E8	6.542E4	-2.936	-3.004	-3.384	-3.110
38 Oph	A1V	-0.139	1.776E9	4.108E6	6.421E7	4.582E4	-2.891	-2.953	-3.347	-3.101
HR 7346	B7III	-0.108	1.368E9	3.165E6	4.948E7	3.531E4	-2.892	-2.953	-3.347	-3.101
HD 189689	B9V	-0.081	1.008E9	2.303E6	2.763E7	2.306E4	-2.864	-2.921	-3.317	-3.097
59 Her	A3III	-0.045	5.948E8	1.363E6	1.700E7	1.407E4	-2.873	-2.932	-3.320	-3.099
11 Sge	B9IV	-0.027	5.745E8	1.293E6	1.168E7	1.182E4	-2.819	-2.873	-3.281	-3.088
69 Her	A2V	0.000	4.918E8	1.107E6	9.997E6	1.011E4	-2.819	-2.873	-3.281	-3.088
HR 8020	B8IA	0.027	1.063E9	2.386E6	1.940E7	2.154E4	-2.820	-2.872	-3.255	-3.089
78 Her	B9V	0.036	4.532E8	1.018E6	8.272E6	9.187E3	-2.820	-2.872	-3.255	-3.089
58 Aql	A0V	0.057	4.291E8	9.634E5	7.830E6	8.696E3	-2.820	-2.872	-3.255	-3.089
60 Her	A3IV	0.085	3.197E8	7.086E5	3.280E6	5.497E3	-2.758	-2.810	-3.217	-3.077
HR 6570	A7V	0.107	2.999E8	6.647E5	3.079E6	5.161E3	-2.759	-2.811	-3.217	-3.077
HD192285	A4IV	0.124	2.628E8	5.771E5	1.444E6	3.569E3	-2.719	-2.771	-3.184	-3.071
θ^1 Ser	A5V	0.143	2.669E8	5.862E5	1.466E6	3.623E3	-2.718	-2.770	-3.184	-3.071
KW 114		0.175	2.395E8	5.240E5	9.954E5	2.843E3	-2.703	-2.755	-3.168	-3.069
KW 154		0.219	2.050E8	4.439E5	4.497E5	1.636E3	-2.666	-2.715	-3.166	-3.063
χ Ser	F0IV	0.240	1.829E8	3.958E5	4.004E5	1.457E3	-2.665	-2.714	-3.166	-3.062
HD5132	F0IV	0.287	2.011E8	4.354E5	4.412E5	1.605E3	-2.666	-2.715	-3.166	-3.063
HD508	A9IV	0.305	1.718E8	3.720E5	3.771E5	1.372E3	-2.666	-2.716	-3.166	-3.063
ρ Cap	F2IV	0.339	1.125E8	2.322E5	2.619E4	1.014E2	-2.484	-2.517	-3.181	-3.023
KW 332		0.389	1.177E8	2.431E5	2.751E4	1.065E2	-2.486	-2.519	-3.181	-3.023
HD7331	F7IV	0.427	9.807E7	2.012E5	2.256E4	8.772E1	-2.451	-2.482	-3.179	-3.015
BD+63°13	F5IV	0.444	1.139E8	2.362E5	6.070E4	2.395E2	-2.488	-2.523	-3.171	-3.024
HD35296	F8V	0.489	1.089E8	2.259E5	5.804E4	2.290E2	-2.488	-2.523	-3.171	-3.024
vB 1		0.530	6.757E7	1.374E5	2.147E4	8.448E1	-2.407	-2.437	-3.175	-3.006
HD154760	G2V	0.586	6.393E7	1.285E5	3.115E3	1.151E1	-2.365	-2.386	-3.206	-2.998

TABLE 7-1 Predicted target acquisition count rates for stars, reduced to $V_0 = 0$. (Continued)

Star Name	Spectral Type	$(B-V)_0$	count rate for mirror				reddening reduction factor[a]			
			N2	A2	N1	A1	N2	A2	N1	A1
HD139777A	K0V	0.631	6.040E7	1.215E5	2.954E3	1.091E1	-2.367	-2.387	-3.206	-2.998
HR 6516	G6IV	0.651	5.167E7	1.039E5	2.518E3	9.301E0	-2.365	-2.386	-3.206	-2.998
HD136274	G8V	0.672	4.901E7	9.855E4	2.392E3	8.837E0	-2.366	-2.387	-3.206	-2.998
HD150205	G5V	0.700	4.650E7	9.352E4	2.275E3	8.404E0	-2.367	-2.388	-3.206	-2.998
31 Aql	G8IV	0.732	4.042E7	8.123E4	1.960E3	7.242E0	-2.364	-2.384	-3.206	-2.997
vB 21		0.766	3.890E7	7.818E4	1.887E3	6.972E0	-2.364	-2.385	-3.206	-2.997
BD–2°4018	G5IV	0.791	3.516E7	7.068E4	1.713E3	6.328E0	-2.365	-2.386	-3.206	-2.998
HD190571	G8V	0.816	1.587E7	3.086E4	1.165E1	4.76E-4	-2.233	-2.244	-3.719	-3.247
HD11004	G5IV	0.825	1.587E7	3.086E4	1.169E1	4.78E-4	-2.234	-2.244	-3.719	-3.247
HD56176	G7IV	0.857	1.510E7	2.937E4	1.109E1	4.54E-4	-2.233	-2.244	-3.719	-3.247
HD190470	K3V	0.895	1.237E7	2.403E4	8.968E0	3.67E-4	-2.230	-2.241	-3.719	-3.246
θ^1 Tau	G8III	0.904	1.950E7	3.862E4	2.639E1	2.67E-4	-2.306	-2.320	-3.750	-3.262
HD170527	G5IV	0.918	2.157E7	4.277E4	2.944E1	2.98E-4	-2.309	-2.323	-3.750	-3.263
HD191615	G8IV	0.947	1.596E7	3.159E4	2.136E1	2.16E-4	-2.303	-2.317	-3.750	-3.261
HD4744	G8IV	0.989	1.087E7	2.119E4	8.241E0	3.37E-4	-2.240	-2.250	-3.719	-3.248
91 Aqr	K0III	1.010	8.535E6	1.662E4	6.381E0	2.61E-4	-2.237	-2.247	-3.719	-3.247
HD95272	K0III	1.041	8.184E6	1.593E4	6.086E0	2.49E-4	-2.236	-2.246	-3.719	-3.247
ψ UMa	K1III	1.081	6.894E6	1.342E4	5.143E0	2.10E-4	-2.237	-2.247	-3.719	-3.247
BD+1°3131	K0III	1.143	4.403E6	8.511E3	7.928E0	2.54E-4	-2.210	-2.221	-3.718	-3.242
vB 173		1.202	6.753E6	1.337E4	2.396E1	7.80E-4	-2.296	-2.311	-3.721	-3.260
HD166780	K5III	1.323	2.059E6	3.986E3	3.791E0	1.21E-4	-2.214	-2.225	-3.718	-3.243
RZ Her	M6III	1.380	5.352E6	1.042E4	1.057E1	3.39E-4	-2.228	-2.239	-3.718	-3.246
HD116870	M0III	1.413	1.414E6	2.734E3	2.228E0	7.87E-5	-2.207	-2.218	-3.717	-3.241
M67 IV-202		1.463	1.170E6	2.263E3	1.857E0	6.56E-5	-2.208	-2.219	-3.717	-3.242
HD104216	M2III	1.523	1.423E6	2.795E3	4.603E0	1.50E-4	-2.271	-2.287	-3.721	-3.255
BD–1°3113	K5III	1.609	8.070E5	1.588E3	2.681E0	8.72E-5	-2.277	-2.293	-3.721	-3.256
HD142804	M1III	1.694	7.419E5	1.463E3	2.517E0	8.19E-5	-2.283	-2.299	-3.721	-3.258
Gl 15B	M6V	1.707	2.391E6	4.742E3	8.704E0	2.83E-4	-2.303	-2.318	-3.721	-3.262
Gl 65	M5V	1.768	1.075E7	2.122E4	3.642E1	1.18E-3	-2.284	-2.300	-3.721	-3.258
HD 151658	M2III	1.770	7.242E5	1.423E3	2.359E0	7.67E-5	-2.272	-2.288	-3.721	-3.255
R Leo		1.918	4.550E6	8.879E3	1.308E1	4.26E-4	-2.245	-2.260	-3.721	-3.250
WZ Cas	N	2.636	1.987E5	3.867E2	5.89E-1	1.92E-5	-2.246	-2.263	-3.721	-3.250
AW Cyg	N	3.790	1.951E5	3.796E2	5.70E-1	1.85E-5	-2.243	-2.260	-3.721	-3.249

a. use factor f to reduce count rate by $10^{f \times E(B-V)}$.

7.3 Acquisition Count Rates for Extended Objects

Chapter 4 mentions acquisition methodologies for extended objects, and, in particular, the use of the EXTENDED optional parameter. In this section we provide some guidance on predicting the count rates to be expected during an acquisition of an extended object, especially one beyond our own Galaxy. The renewed availability of Side 1 of the GHRS and its G140L grating make it possible to get high-quality spectra of faint objects efficiently.

Whenever possible, we recommend that faint objects be acquired by offsetting from a nearby and brighter point source. If accurate coordinates are used this method should be reliable. However, such objects are not always present next to targets of astrophysical interest. Also, obtaining a good astrometric position of an extended source can be prevented by its large saturated area on the photographic plates upon which the Guide Star Catalog is based. In these cases a direct target acquisition will need to be attempted, and it should succeed if the object provides enough ultraviolet photons. The procedure closely follows that for point sources just described:

- Find a star in Table 7-1 with a spectral energy distribution like that of your object, or consult the IUE Atlas of Star-Forming Galaxies, by Kinney et al. (1993, ApJS, 86, 5). This publication provides representative spectra of many classes of galaxies and compares their shapes to ones of stellar spectra (whence the "spectral types" listed).
- Estimate the flux that will fall within the LSA from either Table 7-1 or Table 7-2 on page 77, as appropriate.
- Calculate STEP-TIME in the same manner as for stars. If necessary, you may use mirror N2 on Side 2 for your acquisition, even if Side 1 is being used to observe, but doing so will add about 40 minutes of overhead time.
- If your object does not fall within these categories, please consult us.

TABLE 7-2 Predicted count rates for non-stellar objects

"Spectral Type"	count rate for mirror				reddening reduction factor[a]			
	N2	A2	N1	A1	N2	A2	N1	A1
o3_6v	8.843E9	2.116E7	3.990E8	2.726E5	-3.059	-3.112	-3.362	-3.134
o4_9i	8.047E9	1.934E7	3.731E8	2.427E5	-3.054	-3.109	-3.380	-3.133
o5_6iii	8.935E9	2.140E7	3.961E8	2.687E5	-3.068	-3.121	-3.364	-3.136
o7_b0v	7.407E9	1.771E7	3.282E8	2.065E5	-3.028	-3.086	-3.388	-3.129
o9_b0iv	6.413E9	1.533E7	2.931E8	1.784E5	-3.012	-3.072	-3.396	-3.125
b0_2i	4.314E9	1.005E7	1.372E8	9.530E4	-2.949	-3.005	-3.378	-3.113
b0_2iii	5.144E9	1.214E7	1.908E8	1.231E5	-2.994	-3.051	-3.388	-3.122
b2_4v	2.889E9	6.765E6	1.037E8	7.131E4	-2.964	-3.021	-3.364	-3.116
b2_5iv	2.754E9	6.444E6	9.673E7	6.712E4	-2.960	-3.017	-3.367	-3.115
b3_5i	1.694E9	3.836E6	3.581E7	3.042E4	-2.859	-2.910	-3.328	-3.095
b3_6iii	2.344E9	5.448E6	7.404E7	5.400E4	-2.943	-2.998	-3.353	-3.112
b5_8v	1.713E9	3.952E6	4.849E7	3.716E4	-2.922	-2.976	-3.337	-3.108
b6_9i	9.689E8	2.187E6	2.021E7	1.765E4	-2.831	-2.882	-3.313	-3.089
b7_9iii	8.700E8	1.975E6	1.845E7	1.663E4	-2.867	-2.918	-3.305	-3.098
b8_9iv	9.701E8	2.216E6	2.337E7	1.984E4	-2.889	-2.941	-3.316	-3.102
f2_7iv	1.007E8	2.108E5	2.968E4	1.206E2	-2.547	-2.580	-3.201	-3.043
f2_8i	4.536E7	9.480E4	1.403E4	5.634E1	-2.535	-2.569	-3.201	-3.041
f5_7v	1.079E8	2.254E5	1.782E4		-2.538	-2.571	-3.238	
f6iii	9.009E7	1.862E5	8.586E2		-2.499	-2.526	-3.830	
f8_9v	6.664E7	1.367E5	3.996E3		-2.460	-2.484	-3.245	
g0_2iv	4.451E7	9.041E4	3.614E2		-2.415	-2.434	-3.604	
g0_3i	1.971E7	4.015E4			-2.429	-2.444		
g0_5iii	3.349E7	6.822E4			-2.431	-2.450		
g0_5v	5.372E7	1.095E5			-2.428	-2.449		
g5_8i	4.802E6	9.721E3			-2.399	-2.414		
g5_8iv	2.123E7	4.242E4			-2.344	-2.354		
g5_k0iii	6.969E6	1.384E4			-2.320	-2.330		
g6_9v	2.588E7	5.189E4			-2.360	-2.372		
g8_k1iv	8.008E6	1.583E4			-2.297	-2.304		
k0_1v	1.307E7	2.606E4			-2.337	-2.348		
k0_2iii	5.918E6	1.165E4			-2.285	-2.290		
k1_3i	2.497E6	5.057E3			-2.397	-2.411		
k2_3v	9.035E6	1.800E4			-2.327	-2.336		
k2iii	2.092E6	4.107E3			-2.268	-2.273		
k3iii	1.157E6	2.266E3			-2.259	-2.264		
k4_5iii	5.490E5	1.085E3			-2.290	-2.296		
k5_m0v	2.607E6	5.167E3			-2.304	-2.311		
k5_m5i	9.714E5	1.976E3			-2.413	-2.426		
k7_m3iii	5.420E5	1.081E3			-2.323	-2.330		

a. use factor *f* to reduce count rate by $10^{f \times E(B-V)}$.

7.4 Other Acquisition Information

7.4.1 Effective Areas of the Acquisition Mirrors

Table 7-3 on page 79 lists the effective areas of the four acquisition mirrors (in cm^2) as a function of wavelength, to use to predict acquisition count rates. These values are those from the Science Verification Report for the GHRS, adjusted by the observed ratio of post- to pre-COSTAR sensitivities (see Section 8.1 on page 82). Note that A1 and N1 may only be used with detector D1 and A2 and N2 with detector D2.

Also note that the proper use of this table requires compensation for the different energies of photons of different wavelengths, hence the last column, which is in picoergs per photon.

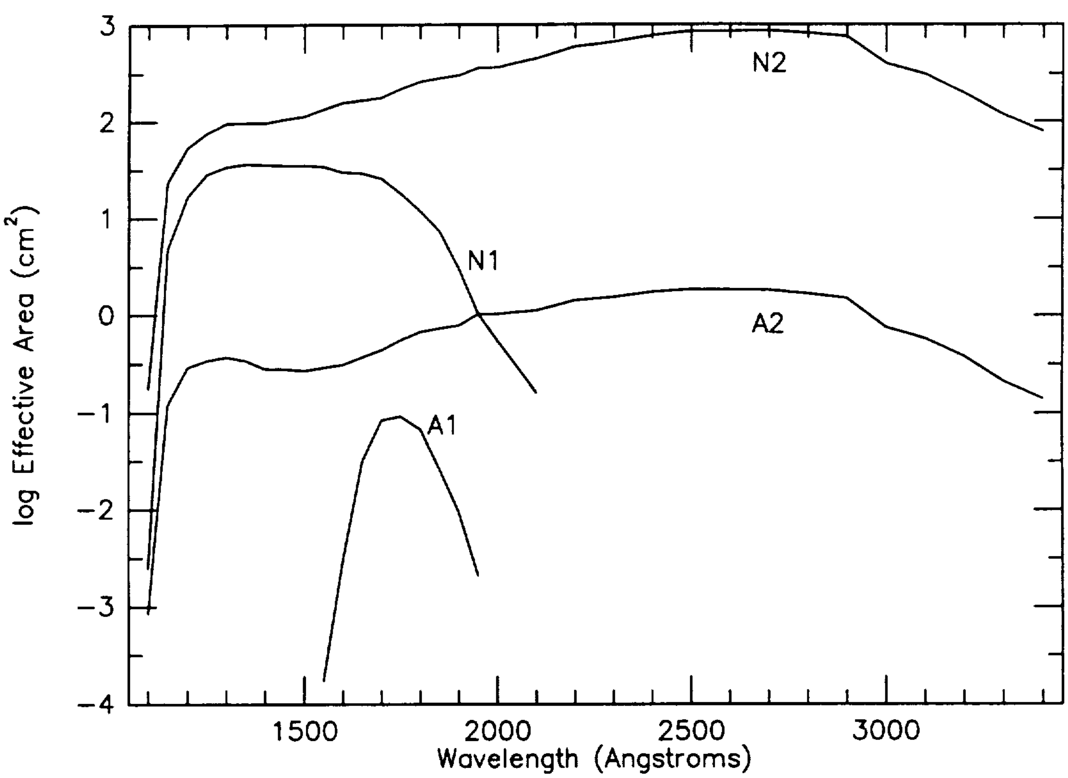

Figure 7-5. Relative sensitivities of the GHRS acquisition mirrors. The effective areas shown are from Table 7-3 on page 79.

TABLE 7-3. Effective areas of the four GHRS acquisition mirrors

Wavelength (Å)	Effective Area (cm^2)				perg photon^{-1}
	A1	N1	A2	N2	
1100		0.0025	0.00085	0.175	18.1
1150		4.89	0.12	23.36	17.3
1200		16.79	0.29	54.18	16.6
1250		28.54	0.34	76.50	15.9
1300		34.10	0.37	96.22	15.3
1350		36.64	0.34	97.03	14.7
1400		36.05	0.28	96.88	14.2
1450		35.35	0.28	105.46	13.7
1500		35.49	0.27	113.43	13.2
1550	0.000172	34.43	0.29	133.84	12.8
1600	0.00298	30.18	0.31	155.76	12.4
1650	0.0317	29.37	0.37	165.92	12.0
1700	0.0843	25.91	0.44	176.10	11.7
1750	0.0923	18.11	0.56	216.91	11.4
1800	0.0680	11.82	0.68	259.65	11.0
1850	0.0261	7.38	0.74	281.80	10.7
1900	0.0094	3.04	0.79	302.40	10.5
1950	0.0021	1.04	1.04	362.78	10.2
2000		0.55	1.04	363.32	9.93
2050		0.30	1.08	406.51	9.69
2100		0.16	1.13	449.71	9.46
2200			1.43	594.61	9.03
2300			1.55	663.74	8.64
2400			1.75	776.52	8.28
2500			1.87	847.76	7.95
2600			1.85	854.42	7.64
2700			1.83	866.65	7.36
2800			1.68	813.29	7.09
2900			1.50	754.81	6.85
3000			0.76	398.89	6.62
3100			0.58	309.31	6.41
3200			0.38	194.15	6.21
3300			0.21	116.67	6.02
3400			0.14	80.	5.84

7.4.2 Geocoronal Lyman-α Background

The acquisition mirror sensitivity curves illustrated above show that the mirrors still reflect well at the Lyman-α line at 1216 Å. Note that Ly-α is suppressed by mirror A1. Tests have shown that the count rate from geocoronal Lyman-α can be as high as 12 counts per second per diode. If you wish to acquire a faint target with the least Ly-α contamination, we suggest that you specify DARK TIME as a Special Requirement in Phase II.

Chapter 8

Reference Tables for Instrument Performance

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8.1 The Effect of COSTAR on the GHRS

Prior to the Servicing Mission, it was believed that the COSTAR mirrors would have little effect on the throughput of the GHRS. It was known that the magnesium fluoride coatings would severely attenuate light below 1150 Å, but at longer wavelengths we anticipated that the light lost from the extra two reflections would be compensated for by the improved throughput of the restored Point Spread Function.

The actual situation is more complex, as shown below. What is plotted is a mean relation that was fitted to observations of the same star that were made both before and after the Servicing Mission. The most prominent feature is the dip at 2000 Å. The high ratio at longer wavelengths is just due to the improved PSF, but the peak near 1300 Å is not understood.

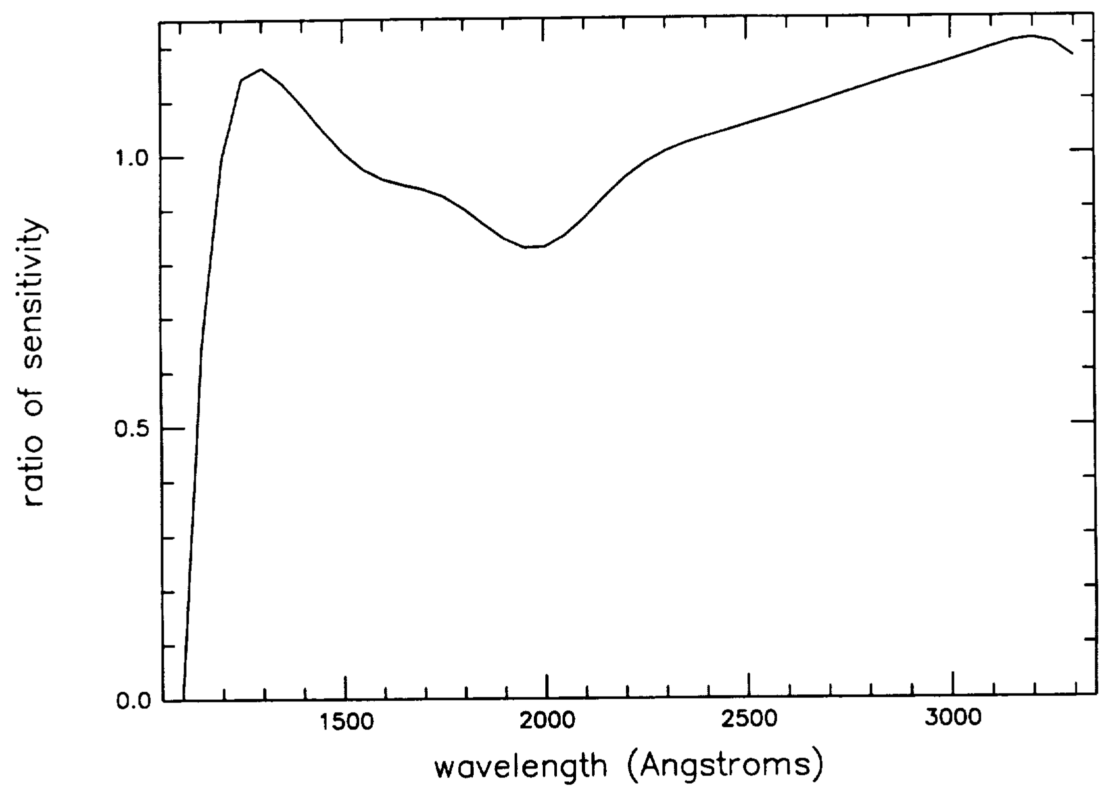

Figure 8-1. The observed ratio of counts for μ Col, made before the Servicing Mission (in Cycle 2) and after the deployment of the COSTAR mirrors.

8.2 Properties of the First-Order Gratings

8.2.1 Useful Wavelength Ranges

The following table summarizes the useful wavelength range for each of the first-order gratings of GHRS. More precise sensitivity values are enumerated below. Note that little or no flux below 1150 Å is reflected by the COSTAR mirrors because of their magnesium fluoride coatings.

TABLE 8-1

Useful wavelength ranges for first-order gratings.

Grating	Useful Range (Å)	Å per diode	Bandpass (Å)	Comment
G140L	1100 – 1900	0.572 – 0.573	286 – 287	
G140M	1100 – 1900	0.056 – 0.052	28 – 26	
G160M	1150 – 2300	0.072 – 0.066	36 – 33	2nd order overlap above 2300 Å
G200M	1600 – 2300	0.081 – 0.075	41 – 38	2nd order overlap above 2300 Å
G270M	2000 – 3300	0.096 – 0.087	48 – 44	2nd order overlap above 3300 Å

The last three gratings are used with detector D2, which admits some second-order light, hence the comments. For example, Lyman-α light (1216 Å) can appear at 2432 Å in second order. Except for this possibility of geocoronal contamination, many cool stars have very little short-wavelength flux, so that the best resolution can be achieved without undue extraneous light by observing in first order near the high-wavelength limit.

Note that the G270M grating has an order-sorting filter which eliminates light below about 1650 Å so that no cross-order contamination occurs below 3300 Å.

8.2.2 Resolving Power

The following figures illustrate the resolving power as measured for each of GHRS' gratings. In this case the resolving power was computed as $\mathcal{R} = \lambda/\Delta\lambda$, where $\Delta\lambda$ is the measured full-width-at-half-maximum (FWHM) of lines from an exposure of a spectrum calibration lamp. Tests have shown that the measured FWHM does not change significantly with wavelength (for the first-order gratings) or with $m\lambda$, the product of the wavelength and order number (for the echelle gratings). The nominal design specification for the GHRS was $\mathcal{R} = 20{,}000$ for the first-order gratings, but in fact one can exceed a resolving power of 25,000 at virtually all wavelengths. Similarly, the low-dispersion grating G140L has R in excess of 2,000 over most of its useful wavelength range. The true resolving powers for the echelle gratings are closer to 80,000 than the nominal 100,000.

By providing a sharper image of a point source, COSTAR restores the resolving power achieved with the LSA to within about 20% of that possible with the SSA. There is no effective change for the SSA, however.

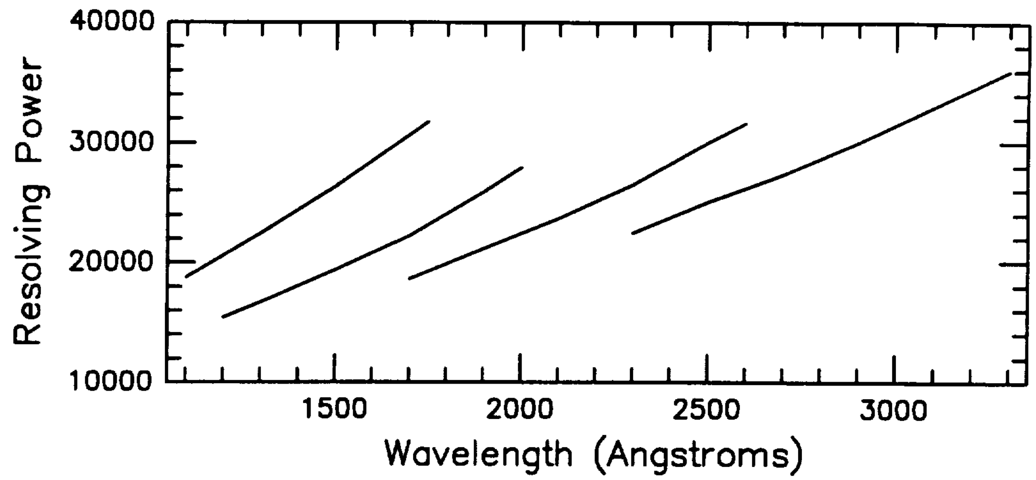

Figure 8-2. Spectrum resolving power as a function of wavelength for the GHRS medium-resolution (holographic) gratings. From left to right the curves are for G140M, G160M, G200M, and G270M, respectively.

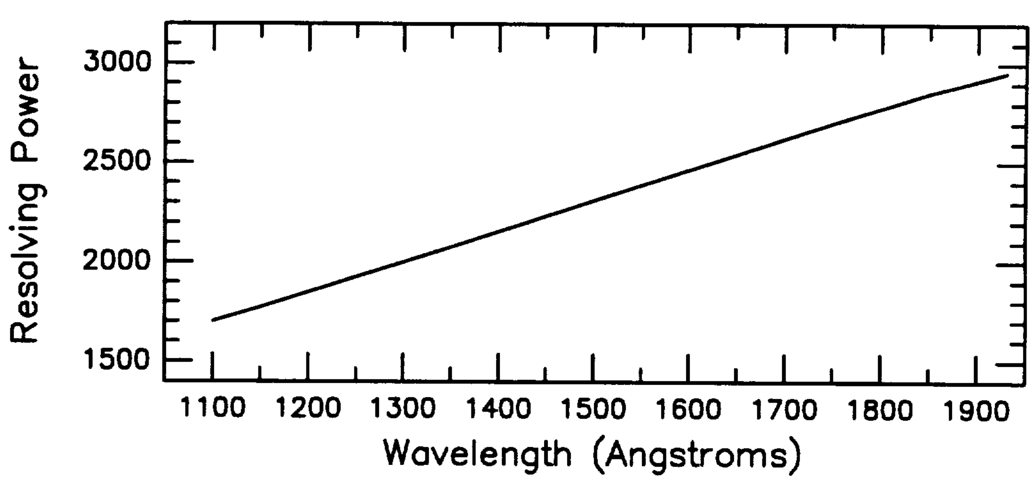

Figure 8-3. Resolving power for grating G140L.

8.2.3 Sensitivity Functions for the First-Order Gratings

Below are given sensitivities for the first-order gratings, using the Large Science Aperture, in units of 10^{11}(counts sec^{-1} diode^{-1}) per incident (erg cm^{-2} sec^{-1} Å^{-1}) . These values will be updated with precise numbers determined in Cycle 4 but what is listed here has been adjusted for the known effects of the COSTAR mirrors. SSA sensitivity is about 50 to 70% of these values, with the larger value applying at longer wavelengths.

TABLE 8-2

Sensitivities for first-order gratings.

	Grating				
Wavelength (Å)	**G140L**	**G140M**	**G160M**	**G200M**	**G270M**
1100	0.20	0.006			
1150	20.9	0.75	0.64		
1200	82.3	2.27	2.87		
1250	152.	4.95	5.77		
1300	168.	7.13	7.96		
1350	166.	5.89	7.33		
1400	146.	5.23	6.41		
1450	114.	4.74	6.08		
1500	89.3	3.41	4.34		
1550	67.0	2.34	4.87		
1600	43.9	1.36	5.17	4.48	
1650	40.0	1.14	4.89	4.63	
1700	32.0	0.88	4.74	5.56	
1750	20.7		4.80	6.53	
1800	10.8		4.78	7.42	
1850	4.03		5.02	8.21	
1900	1.09		5.20	8.61	
1950			5.20	8.40	3.64
2000			5.00	8.23	4.72
2050			4.75	8.57	6.72
2100			4.68	8.92	9.25
2150				9.18	12.31
2200				9.35	16.19
2250				9.02	20.87
2300				8.57	23.82
2350				8.14	23.98
2400				8.70	26.29
2450				9.24	32.34
2500				9.76	41.63

TABLE 8-2 (Continued)
Sensitivities for first-order gratings.

	Grating				
Wavelength (Å)	**G140L**	**G140M**	**G160M**	**G200M**	**G270M**
2550					49.06
2600					53.21
2650					54.37
2700					53.01
2750					50.28
2800					46.73
2850					42.44
2900					37.71
2950					32.19
3000					25.76
3050					19.46
3100					14.14
3150					10.07
3200					6.53
3250					3.83
3300					2.64

8.3 Properties of the Echelle Gratings

8.3.1 Wavelength Coverage, Bandpass, and Sensitivity

The following tables summarize basic properties of the two echelle gratings. The dispersion in each order has not been listed but does not change if it is computed in velocity units. At the center of each order, the dispersion is 3.0 km s^{-1} per diode, at the long-wavelength end of each order it is 2.9 km s^{-1} per diode, and at the short-wavelength end of each order it is 3.1 km s^{-1} per diode.

TABLE 8-3

Properties of Grating Echelle-A

Order	Central Wavelength (Å)	Order Coverage (Å)	Bandpass per exposure (Å)	Scattered Light[a]	S_λ[b]
51	1102	1091 – 1113	5.90 – 5.55		
50	1124	1113 – 1135	6.05 – 5.65		
49	1147	1135 – 1159	6.15 – 5.75	0.061	0.12
48	1171	1159 – 1183	6.25 – 5.90	0.058	0.27
47	1196	1183 – 1209	6.40 – 6.00	0.055	0.46
46	1222	1209 – 1235	6.55 – 6.10	0.052	0.8
45	1249	1235 – 1263	6.70 – 6.25	0.049	0.92
44	1277	1263 – 1292	6.85 – 6.40	0.046	1.15
43	1307	1292 – 1322	7.05 – 6.55	0.044	1.16
42	1338	1322 – 1354	7.20 – 6.70	0.041	1.34
41	1371	1354 – 1387	7.40 – 6.85	0.039	1.23
40	1405	1387 – 1423	7.55 – 7.00	0.037	1.47
39	1441	1423 – 1460	7.80 – 7.20	0.035	1.04
38	1479	1460 – 1498	8.00 – 7.40	0.034	0.91
37	1519	1498 – 1539	8.25 – 7.55	0.032	0.77
36	1561	1539 – 1583	8.45 – 7.75	0.031	0.64
35	1606	1583 – 1629	8.70 – 7.95	0.030	0.56
34	1653	1629 – 1677	8.95 – 8.20	0.030	0.44
33	1703	1677 – 1729	9.25 – 8.40	0.029	0.40

a. "*d*" coefficient of Cardelli, Ebbets, and Savage (1993; see Section 9.2 on page 102). These apply only to the SSA.

b. Sensitivity function at blaze peak, in units of 10^{11} (counts $diode^{-1}$ sec^{-1}) per incident (erg cm^{-2} sec^{-1} $Å^{-1}$).

TABLE 8-4

Properties of Grating Echelle-B

Order	Central Wavelength (Å)	Order Coverage (Å)	Bandpass per exposure (Å)	Scattered Light[a]	S_λ[b]
33	1703	1677 – 1729	9.3 – 8.4	0.045	0.35
32	1756	1729 – 1784	9.6 – 8.6	0.043	0.74
31	1813	1784 – 1842	9.9 – 8.9	0.041	1.06
30	1873	1842 – 1905	10.3 – 9.2	0.039	1.62
29	1938	1905 – 1971	10.7 – 9.5	0.037	2.26
28	2007	1971 – 2043	11.1 – 9.8	0.035	3.04
27	2082	2043 – 2120	11.5 – 10.1	0.033	4.29
26	2162	2120 – 2203	11.9 – 10.5	0.031	6.18
25	2248	2203 – 2293	12.4 – 10.9	0.030	8.59
24	2342	2293 – 2391	13.0 – 11.3	0.028	9.96
23	2444	2390 – 2497	13.6 – 11.7	0.026	11.2
22	2555	2497 – 2613	14.2 – 12.2	0.024	13.0
21	2676	2613 – 2740	14.9 – 12.7	0.022	13.4
20	2810	2740 – 2880	15.8 – 13.3	0.020	12.8
19	2958	2880 – 3036	16.7 – 13.9	0.018	9.57
18	3122	3036 – 3209	17.6 – 14.6	0.016	4.20

a. "*d*" coefficient of Cardelli, Ebbets, and Savage (1993; see Section 9.2 on page 102). These apply only to the SSA.

b. Sensitivity function at blaze peak, in units of 10^{11} (counts diode^{-1} sec^{-1}) per incident (erg cm^{-2} sec^{-1} Å^{-1}).

8.3.2 Echelle Wavelength Formats

The illustrations below provide a means of estimating where particular wavelengths fall within the echelle formats and where they lie relative to the blaze peak. Note that these layouts are purely schematic; the actual length of the free spectral range changes from order to order. The center of each order is at $m\lambda = 56200$.

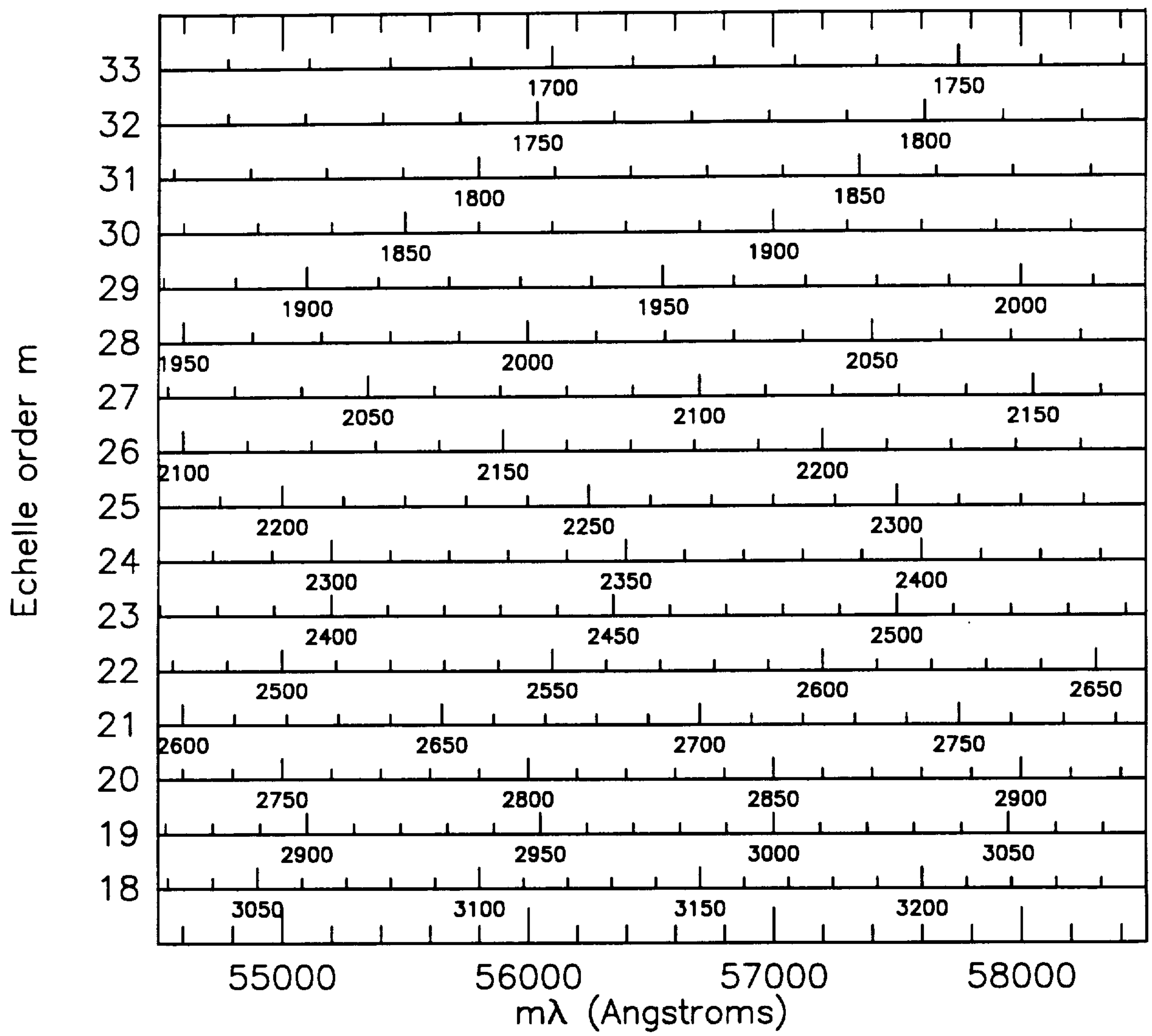

Figure 8-4. Schematic format of wavelengths for Echelle-B.

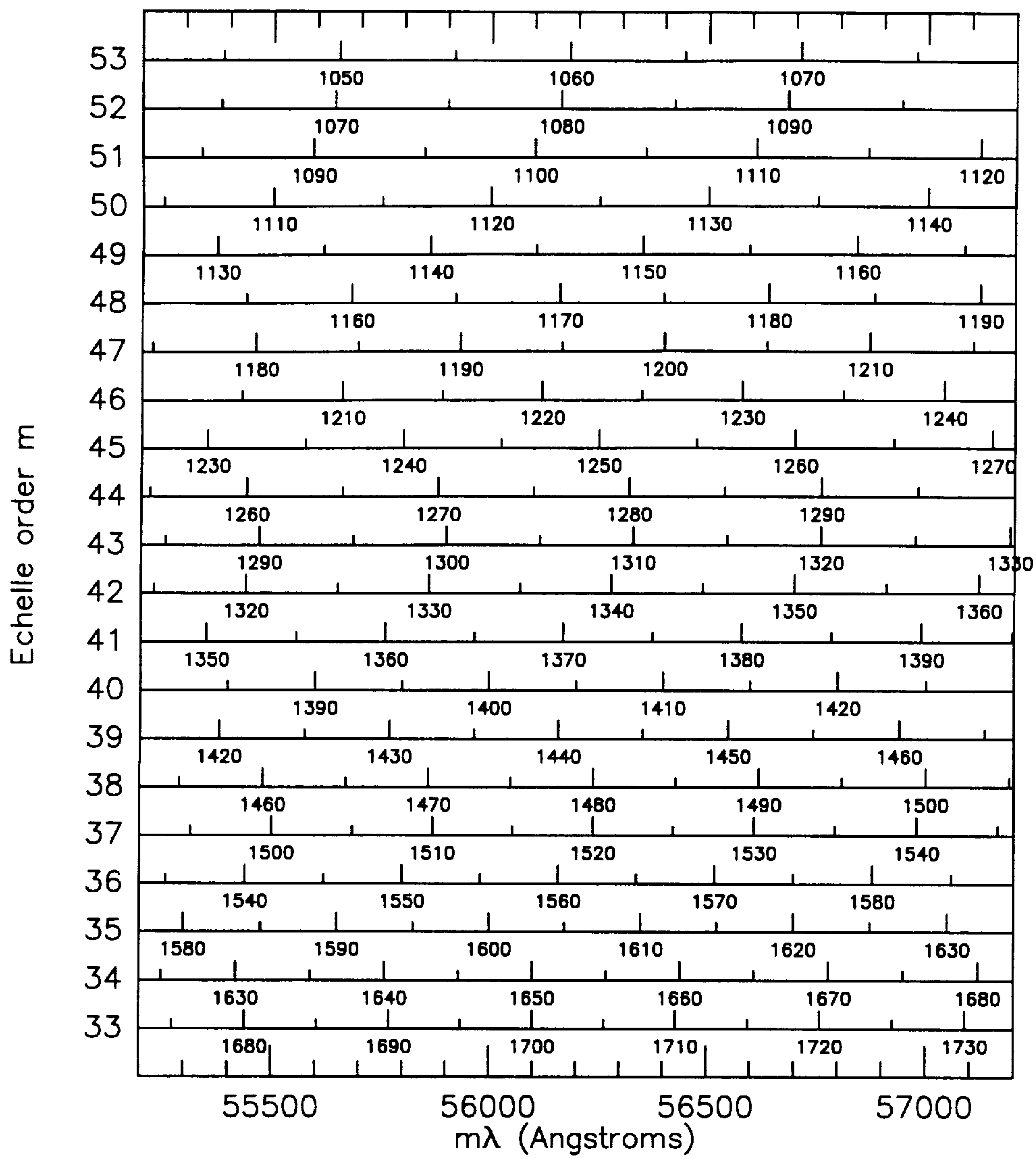

Figure 8-5. Schematic format of wavelengths for Echelle-A.

8.3.3 Echelle Blaze Function

The figure below shows the echelle blaze function (also known as the "Ripple Function") in the form of sensitivity relative to the peak of the blaze as the product of wavelength and order number.

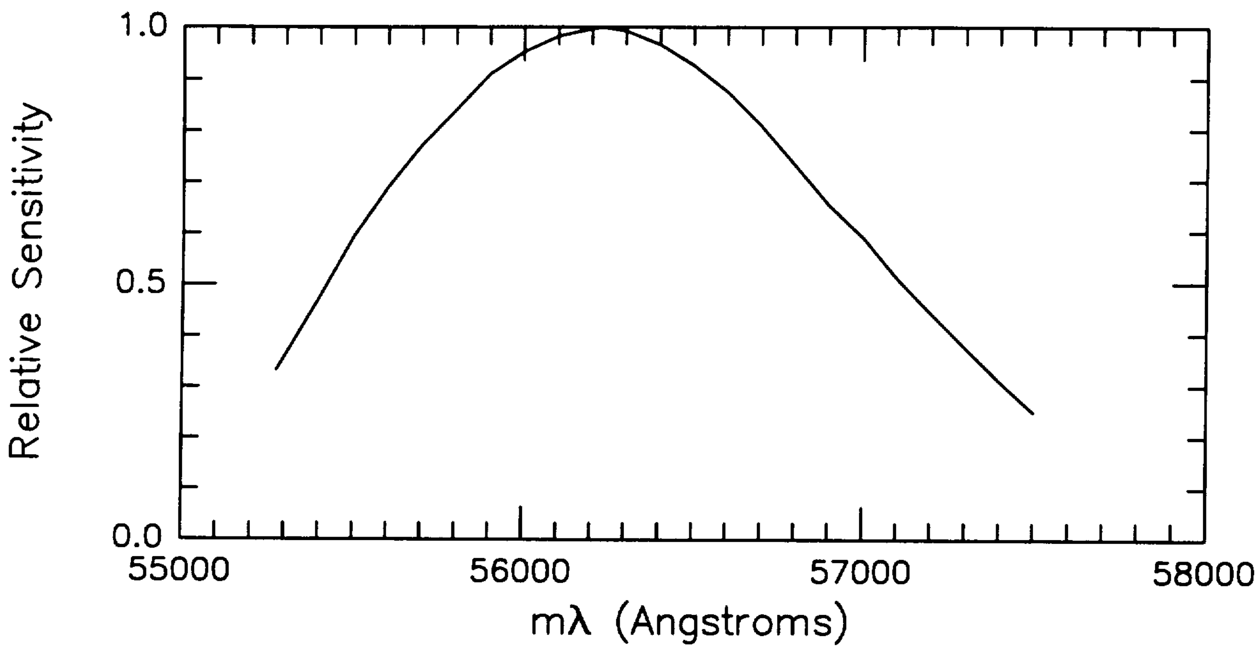

Figure 8-6. Normalized blaze function for the GHRS echelle gratings.

8.4 Standard Patterns for Substepping and Background Measurement

This table shows how each STEP-PATT pattern measures the background for a science exposure. Listed are the STEP-PATT number, the number of spectrum bins for which substepping occurs, the number of background bins measured, the diodes used to measure the background, the fraction of the total time spent measuring flux on the science diodes, the gratings for which the STEP-PATT is appropriate, and the shortest exposure that can be used for that pattern. The shortest exposure has been computed assuming COMB=4, which is the recommended value. These minimum exposures can be reduced by half if COMB=2 is used and by a factor of four for COMB=NO.

TABLE 8-5

STEP-PATT specifications

STEP-PATT number	Bins Measured		Spectrum/ Backgr Ratio	Diodes used for Background	On-target Efficiency	Appropriate Gratings	Minimum Exposure Time (sec)
	Spectrum	Background					
1	1	0	1		1.00	all	0.8
2	2	0	1		1.00	all	1.6
3	4	0	1		1.00	all	3.2
4	2	2	8	science	0.89	first-order	14.4
5	4	2	8	science	0.94	first-order	27.2
6	2	2	8	science	0.89	echelle	14.4
7	4	2	8	science	0.94	echelle	27.2
8	2	2	8	corner	0.89	echelle	14.4
9	4	2	8	corner	0.94	echelle	27.2
10	2	2	1	science	0.50	first-order	3.2
11	4	2	1	science	0.67	first-order	4.8
12	2	2	1	science	0.50	echelle	3.2
13	4	2	1	science	0.67	echelle	4.8
14	2	2	1	corner	0.50	echelle	3.2
15	4	2	1	corner	0.67	echelle	4.8

TABLE 8-6

Default STEP-PATT for science modes

Grating	Order	STEP-PATT
First-order	1	5
Ech-A	≥ 51	9
	< 51	7
Ech-B	≥ 31	9
	< 31	7

8.5 The Effects of Reddening in the Ultraviolet

TABLE 8-7

Average normalized ultraviolet extinction as a function of wavelength.

Wavelength (Å)	$A_\lambda/E(B\text{-}V)$	Wavelength (Å)	$A_\lambda/E(B\text{-}V)$
1100	11.70	2160	10.10
1200	10.20	2200	9.85
1300	9.19	2300	8.75
1400	8.54	2400	7.92
1500	8.29	2500	7.30
1600	8.03	2600	6.82
1700	7.85	2700	6.41
1800	7.90	2800	6.10
1900	8.38	2900	5.85
2000	9.05	3000	5.65
2100	9.90	3300	5.16

The table above lists extinction from interstellar reddening at ultraviolet wavelengths. More information on the effects of reddening may be found in the bibliography in Chapter 9. The above values are from Code et al. (1976). Seaton (1979) has provided convenient fits to ultraviolet extinction for $x = 1/\lambda$, with λ in microns:

x range	$X(x) = A_\lambda/E(B-V)$
$2.70 \le x \le 3.65$	$1.56 + 1.048x + 1.01/[(x-4.60)^2 + 0.280]$
$3.65 \le x \le 7.14$	$2.29 + 0.848x + 1.01/[(x-4.60)^2 + 0.280]$
$7.14 \le x \le 10$	$16.17 - 3.20x + 0.2975x^2$

8.6 Instrumental Properties

8.6.1 The Point Spread Function

The illustration below shows the PSF for the GHRS after the installation of the COSTAR mirrors, to allow for estimation of the degree of scattered light in the vicinity of a bright object. Note that this PSF is only one-dimensional, and was only measured on one side of the center of the aperture at that; in fact the true PSF has two-dimensional structure. The relative throughput of the SSA at the wavelength at which this measurement was done (1450 Å) is 0.55.

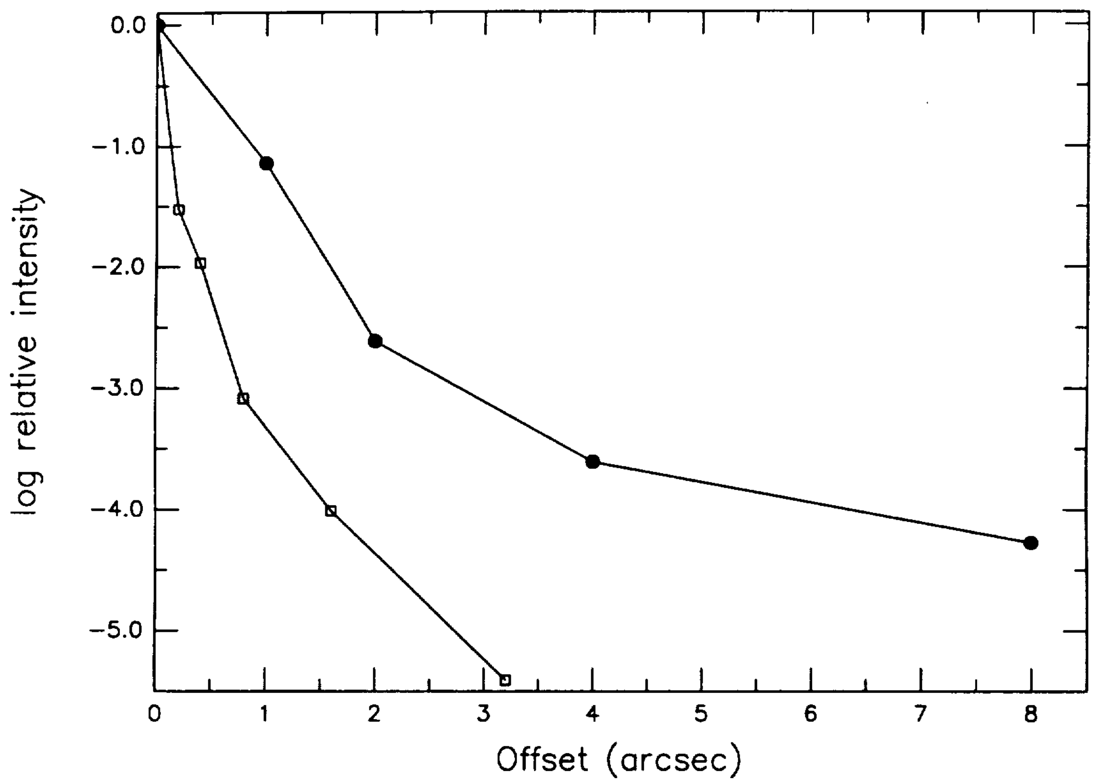

Figure 8-7. Normalized Point Spread Function for the GHRS. The upper curve is for the LSA and the lower for the SSA, both normalized to 1.0 at the origin.

8.6.2 Detector Dark Count and the CENSOR Option

Each Digicon diode has its own discriminator, and if they are properly set the dark count rate measured is very low. On-orbit measurement has shown that both GHRS detectors have a dark rate less than the design goal of 0.01 counts diode^{-1} sec^{-1} at low geomagnetic latitudes and that the dominant noise source is cosmic rays. During SAA passage, the noise increases to a maximum of about 1 count diode^{-1} sec^{-1}. The scheduling software for *HST* uses known contours of the SAA and does not accumulate counts when the spacecraft is within those contours.

Even outside the SAA, observations show that "dark" counts tend to come in bursts. Approximately 15% of dark counts are produced by events that occur within a time of 8 µs or less. The CENSOR feature in Accumulation Mode allows you to ignore integrations with such high dark rates. CENSOR works by summing all 512 channels of the Digicon every 8 µs, and if that sum exceeds a threshold a coincident event is recorded. The flight software maintains a record of how many coincidence events occurred within a given STEP-TIME and can reject and repeat a subexposure for which the coincidence sum exceeds a specified level. The coincidence circuit reacts only to strong events that trigger about 8 diodes simultaneously, so that only the high-amplitude tail of background events can be rejected, even if the specification is to reject any STEP-TIME with a non-zero coincidence sum. It is estimated that use of CENSOR can reduce the dark count rate by about 20%. Using CENSOR=YES is unlikely to degrade an observation (unless the object is bright enough to cause a consistently high count rate), but the benefit is also low: only about a 10% gain in S/N in favorable cases.

The dark count rate is highly uniform over the diodes, so that a mean dark count rate is an excellent representation of what happens at the detector.

Summary:

- The pre-flight noise specification was 0.01 counts diode^{-1} sec^{-1}. The average measured value is 0.005 for D1 and 0.008 for D2.
- The background is sensibly constant between –20 and +20° geomagnetic latitude.
- At ±40° geomagnetic latitude, the extrema of *HST*'s orbit, the rate is twice that at the geomagnetic equator. Typical average rates are 0.007 counts per diode per second for D1 and 0.011 for D2.
- The background rate is correlated with the cosmic ray and trapped particle flux. Calculations show that the dark noise can be accounted for by cosmic-ray-induced Cerenkov radiation in the faceplates of the Digicons.
- The background due to the direct penetration of cosmic rays into diodes is very low (0.0004 counts diode^{-1} sec^{-1}).

When using CENSOR:

- Use the default STEP-TIME of 0.2 sec.
- Do not use CENSOR if the expected count rate exceeds about 100 counts per second per diode because real photon events will be rejected. In a severe case, all the data could be lost.
- Using CENSOR can drop the noise level by about 20%. The nominal Side 2 dark count rate is 0.011 counts per second per diode, so CENSOR=YES can lower it to 0.0088.

C-2

- The following table shows the expected effects of using CENSOR. Rate is the target count rate per diode per second; the second column shows the standard S/N and the third column lists the S/N achieved with CENSOR=YES if the dark is 80% of its value without CENSOR. Signal-to-noise was calculated on a per diode basis for a nominal exposure time of 10,000 seconds (which is reduced to 9,800 if CENSOR is used because of the loss of 2% of the exposures).

  Note that for rates exceeding one per second the effective loss of exposure time (due to 2% of the exposures being rejected) more than offsets any reduction of the noise. At a rate of 0.1 CENSOR has essentially no effect on S/N but for lower rates CENSOR can help.

TABLE 8-8 Effects of CENSOR

Rate	Standard S/N	S/N with CENSOR=YES
100	999.94	989.91
10	316.05	312.91
1	99.45	98.56
0.1	30.02	30.01
0.01	6.90	7.22
0.005	3.95	4.21
0.001	0.91	1.00

8.6.3 Noise Rejection with FLYLIM

FLYLIM is a special commanding option for rejecting noise in cases where the source signal is much weaker than the noise level. The idea is that as *HST* circles the Earth it finds itself in different noise environments due to the changing magnetic field, and that influences the detected noise background. Also, the background noise occurs as discrete events from radiation in the space environment. If the source count level is well below the background noise, then spectra integrated over a sufficiently short interval that contain multiple counts are probably just noise, and should be rejected, whereas spectra with single counts are more likely to contain real information. The rejected spectra are discarded, which wastes observing time, but there is a net gain in signal-to-noise. A test-in-principle run in 1993 showed that the net background rate could be reduced to as low as 0.002 counts sec^{-1} $diode^{-1}$ for the Side 2 detector, which was a factor of four improvement over the mean dark rate. This gain was achieved at the cost of the loss of about 25% of the individual 0.2 second STEP-TIME integrations.

By "special commanding" we mean that FLYLIM is requested as a comment on the Phase II proposal, rather than as an optional parameter. The normal scheduling system cannot automatically invoke FLYLIM; manual intervention is necessary. A detailed description of FLYLIM cannot be provided here, but if users believe that FLYLIM may be of help in their science program they should note the following:

- The use of the FLYLIM parameter may not be assumed by the proposer but instead must be arranged in advance, i.e., before the Phase I proposal deadline, through consultation with a GHRS Instrument Scientist. The TAC will be made aware that FLYLIM may require additional resources to implement.
- If your program that uses FLYLIM is approved, we will attempt to execute it on a best efforts basis, but limited resources may prevent that.
- At the time this is written FLYLIM has not been fully tested and its use is at the observer's risk.

8.6.4 Count Rate Linearity

Deviations from linearity in the way in which the Digicons count photons at high rates were illustrated above in Figure 7-2 on page 71. The effective deadtime for the GHRS detectors has been measured to be 10.2 μs for detector D1. The same value has been assumed to hold for D2. Deviations from linearity are imperceptible below 10^3 and can be corrected to an accuracy of 1% up to a measured count rate of 20,000 (in units of counts $\text{diode}^{-1}\ s^{-1}$).

8.6.5 Image Stability

The images formed by the Digicons are vulnerable to the effects of the Earth's magnetic field. Over the course of a full orbit, the amplitude of the motion is about 50 microns per Gauss for D2 (about 15 microns peak-to-peak) and 10 microns per Gauss for D1. The 50 micron motion seen in D2 corresponds to the size of a diode. This geomagnetically-induced image motion ("GIMP"), together with thermal effects, is the underlying reason for breaking up long exposures into segments of no more than about 5 minutes each.

8.6.6 Wavelength Calibrations

The GHRS has two spectrum calibration lamps, although only lamp SC2 now operates. Lamp SC1 should not be specified under any circumstances. Both are platinum-neon hollow cathode lamps manufactured by Westinghouse, providing a rich array of emission lines throughout the ultraviolet region that the GHRS observes. The lines are bright enough so that a 30 second exposure will yield a good comparison spectrum at almost any wavelength, although longer times are needed at some echelle settings. The lamps are designated `SC1` and `SC2` and are selected by using `WAVE` as the target specification with `SC1` or `SC2` as the aperture. Each lamp, in fact, has its own aperture, offset from the two science apertures of the GHRS. SC2 forms its spectrum at the same y deflection as the SSA, but displaced in x (the direction of dispersion). SC1 is nearly aligned with the SSA in x but differs in y by about 130 deflection steps. The lamp apertures are each 67 microns square and they form Gaussian-shaped images with FWHM = 1.1 diode widths.

A wavelength calibration exposure made with the star in the SSA may be contaminated by the stellar spectrum. This is because the SSA has no shutter and the fact that the SC2 aperture is in line with the SSA. This contamination is rarely a serious problem, however, because it is possible to subtract the stellar component. Also, such exposures are usually used to only confirm the zero-point of the spectrum and not to obtain a full wavelength solution.

For a comprehensive listing of the platinum lines, see Reader et al. (1990).

8.6.6.1 Aperture Offsets

The light from the spectrum calibration lamps does not enter the spectrograph along the same path that starlight takes. This introduces a wavelength shift that must be corrected for in solving for the wavelength solution. The data reduction software incorporates corrections that were determined during pre-flight ground testing (new values are being measured in Cycle 4).

8.6.6.2 Thermal Effects

The image formed by the Digicons is also affected by the thermal environment within the GHRS, which in turn is influenced by whatever electronics happen to be on or off in the GHRS and the other instruments. The temperature inside the GHRS can be monitored and the image motion calibrated. This correction is also provided for in the data reduction software. However, this correction is applied only once to a given Exposure Logsheet line. We recommend that the exposure times for individual Exposure Logsheet lines be kept shorter than about one hour as long as you do not encounter problems with using too much on-board memory (see Section 4.6 on page 47).

8.6.6.3 Geomagnetic Effects

As for overall image stability, geomagnetic effects influence wavelength stability. Long exposures should be divided into units of about 5 minutes each, the time over which the wavelength scale does not change measurably.

Chapter 9

GHRS Bibliography

9.1 Ultraviolet Extinction *102*
9.2 GHRS-Related Technical Papers *102*
9.3 GHRS Scientific Papers *104*
9.4 Acknowledgments *109*

We have tried to make this *Handbook* a comprehensive guide to using the Goddard High Resolution Spectrograph, but some of the best information on the instrument and the uses to which it can be put can be found in the open literature. Here we provide three lists. The first provides additional information on interstellar reddening in the ultraviolet. The next is technically oriented, and gives papers that provide detailed information on specific aspects of the GHRS. The final list is of scientific papers that have used GHRS data.

9.1 Ultraviolet Extinction

"Ultraviolet Photometry from the Orbiting Astronomical Observatory. II. Interstellar Extinction."

Bless, R.C., and Savage, B.D. 1972, ApJ, 171, 293–308.

"Studies of Ultraviolet Interstellar Extinction with the Sky-survey Telescope of the TD-1 Satellite."

Nandy, K., Thompson, G.I., Jamar, C., Monfils, A., and Wilson, R. 1976, A&A, 51, 63–69.

"Empirical Effective Temperatures and Bolometric Corrections for Early-Type Stars."

Code, A.D., Davis, J., Bless, R.C., and Hanbury Brown, R. 1976, ApJ, 203, 417–434.

"Interstellar Extinction in the UV"

Seaton, M.J. 1979, MNRAS, 187, 73P–76P.

"Observed Properties of Interstellar Dust"

Savage, B.D., and Mathis, J.S. 1979, ARA&A, 17, 73–112.

9.2 GHRS-Related Technical Papers

"Ultraviolet High-Resolution Spectroscopy from the Space Telescope."

Ebbets, D.C., Brandt, J.C., and the HRS Investigation Definition Team 1983, PASP, 95, 543–549.

"Wavelengths and Intensities of a Platinum/Neon Hollow Cathode Lamp in the Region 1100–4000 Å"

Reader, J., Acquista, N., Sansonetti, C.J., and Sansonetti, J.E. 1990, ApJS, 72, 831–866.

"Status of the Goddard High Resolution Spectrograph in May 1991."

Ebbets, D.C., Brandt, J., Heap, S. 1991, in The First Year of *HST* Observations, edited by A.L. Kinney and J.C. Blades, p. 110-122, *"Scattered Light in the Echelle Modes of the Goddard High Resolution Spectrograph Aboard the* Hubble Space Telescope*. I. Analysis of Prelaunch Calibration Data."*

Cardelli, J.A., Ebbets, D.C., and Savage, B.D. 1990, 365, 789–802.

"Scattered Light in the Echelle Modes of the Goddard High Resolution Spectrograph Aboard the Hubble Space Telescope*. II. Analysis of Inflight Spectroscopic Observations."*

Cardelli, J.A., Ebbets, D.C., and Savage, B.D. 1993, ApJ, 413, 401–415.

"Resolution and Noise Properties of the Goddard High Resolution Spectrograph"

Gilliland, R.L., Morris, S.L., Weymann, R.J., Ebbets, D.C., and Lindler, D.J. 1992, PASP, 104, 367–382.

This last paper is especially recommended for its discussion of the deconvolution of the effects of the Point Spread Function (PSF) and Line Spread Function (LSF) of *HST* and the GHRS.

"Final Report of the Science Verification Program for the Goddard High Resolution Spectrograph for the Hubble Space Telescope"

Ebbets, D.C. 1992, prepared for NASA/Goddard Space Flight Center by Ball Aerospace Systems Group.

This is a technical document prepared by Ball to fulfill a contractual requirement. It provides a detailed description of the tests and calibrations performed during the Science Verification phase that occurred immediately after the launch of *HST*. We cite it here for completeness, but a General Observer should usually be able to get the information that he or she needs from this *Handbook* or by consulting us.

9.3 GHRS Scientific Papers

A number of GHRS-related papers are concentrated in three special volumes whose contents will not be itemized here:

- *The First Year of HST Observations*, 1991, edited by A.L. Kinney and J.C. Blades, and published by STScI.
- *Astrophysical Journal Letters*, volume 377, number 1, 1991.
- *Science with the Hubble Space Telescope*, 1992, edited by P. Benvenuti and E. Schreier, and published by ESO.

1992:

"The Abundance of Boron in Three Halo Stars"

Duncan, D.K., Lambert, D.L., and Lemke, M. 1992, ApJ, 401, 584–595.

"Ultraviolet Observations of the Gas Phase Abundances in the Diffuse Clouds Toward Zeta Ophiuchi at 3.5 Kilometers per Second Resolution"

Savage, B.D., Cardelli, J.A., and Sofia, U.J. 1992, ApJ, 401, 706–723.

"Fractionation of CO in the Diffuse Clouds Toward Zeta Ophiuchi"

Sheffer, Y., Federman, S.R., Lambert, D.L., and Cardelli, J.A. 1992, ApJ, 397, 482–491.

"Highly Ionized Atoms Toward HD 93521."

Spitzer, L., and Fitzpatrick, E.L. 1992, ApJ, 391, L41–L44.

"Ultraviolet and Optical Spectral Morphology of Melnick 42 and Radcliffe 136a in 30 Doradus"

Walborn, N.R., Ebbets, D.C., Parker, J.W., Nichols-Bohlin, J., and White, R.L. 1992, ApJ, 393, L13–L16.

"Detection of a Proton Beam During the Impulsive Phase of a Stellar Flare"

Woodgate, B.E., Robinson, R.D., Carpenter, K.G., Maran, S.P., and Shore, S.N. 1992, ApJ, 397, L95—L98.

1993:

"Interstellar Mg II and C IV Absorption Toward Mrk 205 by NGC 4319: An 'Optically-Thick' QSO Absorption System"

Bowen D.V., and Blades, J.C. ApJ, 403, L55–L58.

"Observations of 3C 273 with the Goddard High Resolution Spectrograph on the Hubble Space Telescope"

Brandt, J.C., et al. 1993, AJ, 105, 831–846.

"The Galactic Halo and Local Intergalactic Medium toward PKS 2155–304"

Bruweiler, F.C., Boggess, A., Norman, D.J., Grady, C.A., Urry, C.M., and Kondo, Y. 1993, ApJ, 409, 199–204.

"Ultraviolet Transitions of Low Condensation Temperature Heavy Elements and New Data for Interstellar Arsenic, Selenium, Tellurium, and Lead"

Cardelli, J.A., Federman, S.R., Lambert, D., and Theodosiou, C.E. 1993, ApJ, 416, L41–L44.

"Abundance of Interstellar Carbon Toward Zeta Ophiuchi"

Cardelli, J.A., Mathis, J.S., Ebbets, D.C., and Savage, B.D. 1993, ApJ, 403, L17–L20.

"Detection of Boron, Cobalt, and other Weak Interstellar Lines toward ζ Ophiuchi"

Federman, S.R., Sheffer, Lambert, D.L., and Gilliland, R.L. 1993, ApJ, 413, L51–L54.

"Quantitative Spectroscopy of K647 — the PNN of Ps1 in the Globular Cluster M15"

Heber, U., Dreizler, S., and Werner, K. 1993, Acta Astron., 43, 337–342.

"The Interstellar Abundances of Tin and Four Other Heavy Elements"

Hobbs, L.M., Welty, D.E., Morton, D.C., Spitzer, L., and York, D.G. 1993, ApJ, 411, 750–755.

"Time-Series Observations of O Stars. III. IUE and HST Spectroscopy of ζ Ophiuchi and Implications for the 'Photospheric Connection'"

Howarth, I.D. et al., 1993, ApJ, 417, 338–346.

"Hubble Space Telescope Spectra of the Phase-Modulated Wind in the SMC O+WR Binary R31"

Hutchings, J.B., Morris, S.C., and Bianchi, L. 1993, ApJ, 410, 803–807.

"Deceleration of Interstellar Hydrogen at the Heliospheric Interface"

Lallement, R., Bertaux, J.-L., and Clarke, J.T. 1993, Science, 260, 1095–1098.

Provides a good illustration of geocoronal Ly-α with the LSA and Echelle-A.

"High Resolution UV Stellar Spectroscopy with the HST/GHRS, Challenges and Opportunities for Atomic Physics"

Leckrone, D.S., Johansson, S., Wahlgren, G.M., and Adelman, S.J. 1993, Physica Scripta, T47, 149–156.

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Linsky, J.L., Brown, A., Gayley, K., Diplas, A., Savage, B.D., Ayres, T.R., Landsman, W., Shore, S.N., and Heap, S.R. 1993, ApJ, 402, 694–709.

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"A Search for Proton Beams During Flares on AU Microscopii"

Robinson, R.D., Carpenter, K.G., Woodgate, B.E., and Maran, S.P. 1993, ApJ, 414, 872–876.

"Observations of the Gaseous Galactic Halo Toward 3C273 with the Goddard High Resolution Spectrograph"

Savage, B.D., Lu, L., Weymann, R.J., and Morris, S.L. 1993, ApJ, 404, 124–143.

"Goddard High Resolution Spectrograph Observations of Narrow Discrete Stellar Wind Absorption Features in the Ultraviolet Spectrum of the O7.5III Star ζ Persei"

Shore, S.N., Altner, B., Bolton, C.T., Cardelli, J.A., and Ebbets, D.C. 1993, ApJ, 411, 864–868.

"The Early Ultraviolet Spectral Evolution of Nova Cygni 1992"

Shore, S.N., Sonneborn, G., Starrfield, S., Gonzalez-Riestra, R., and Ake, T.B. 1993, AJ, 106, 2408–2428.

"High-Resolution Ultraviolet Observations of the Interstellar Diffuse Clouds toward μ Columbae"

Sofia, U.J., Savage, B.D., and Cardelli, J.A. 1993, ApJ, 413, 251–267.

"Composition of Interstellar Clouds in the Disk and Halo. I. HD 93521"

Spitzer, L., and Fitzpatrick, E.L. 1993, ApJ,409, 299–318.

1994:

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Bowen, D.V., Roth, K.C., Blades, J.C., and Meyer, D.M. 1994, ApJ, 420, L71–L74.

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Cardelli, J.A., Sofia, U.J., Savage, B.D., Keenan, F.P., and Dufton, P.L. 1994, ApJ, 420, L29–L32.

"GHRS Observations of Cool, Low-Gravity Stars. I. The Far-Ultraviolet Spectrum of α Orionis (M2Iab)"

Carpenter, K.G., Robinson, R.D., Wahlgren, G.M., Linsky, J.L., and Brown, A. 1994, ApJ, in press.

"Composition of Interstellar Clouds in the Disk and Halo. II. γ^2 Velorum"

Fitzpatrick, E.L., and Spitzer, L. 1994, ApJ, in press.

"Search for CO Absorption Bands in IUE Far-Ultraviolet Spectra of Cool Stars"

Gessner, S.E., Carpenter, K.G., and Robinson, R.D. 1994, AJ, 107, 747–750.

"Comparison of New Experimental and Astrophysical f-values for Some Ru II Lines, Observed in HST Spectra of χ Lupi"

Johansson, S.G., et al. 1994, ApJ, 421, 809–815.

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Kunth, D., Lequeux, J., Sargent, W.L.W., and Viallefond, F. 1994, A&A, 282, 709–716.

"Interstellar Clouds toward Sirius and Local Cloud Ionization. I. GHRS Observations of Sirius A"

Lallement, R., Bertin, P., Ferlet, R., Vidal-Madjar, A., and Bertaux, J.L. 1994, A&A, in press.

"Interstellar Carbon Monoxide toward ζ Ophiuchi."

Lambert, D.L., Sheffer, Y., Gilliland, R.L., and Federman, S.R. 1994, ApJ, 420, 756–771.

An especially good discussion of how to achieve very high signal-to-noise with the GHRS.

"High Velocity Plasma in the Transition Region of Au Microscopii: Evidence for Magnetic Reconnection and saturated Heating During Quiescent and Flaring Conditions"

Linsky, J.L., and Wood, B.E. 1994, ApJ, in press.

"Probing the Galactic Disk and Halo. I. The NGC 3783 Sight Line"

Lu, L., Savage, B.D., and Sembach, K.R. 1994, ApJ, in press.

"Observing Stellar Coronae with the Goddard High Resolution Spectrograph. I. The dMe Star AU Microscopii"

Maran, S.P., Robinson, R.D., Shore, S.N., Brosius, J.W., Carpenter, K.G., Woodgate, B.E., Linsky, J.L., Brown, A., Byrne, P.B., Kundu, M.R., White, S., Brandt, J.C., Shine, R.A., and Walter, F.M. 1994, ApJ, 421, 800–808.

"Highly Ionized Gas Absorption in the Disk and Halo toward HD 167756 at 3.5 Kilometers per Second Resolution"

Savage, B.D., Sembach, K.R., and Cardelli, J.A., 1994, ApJ, 420, 183–196.

"Al III, Si IV, and C IV Absorption toward ζ Ophiuchi: Evidence for Photoionized and Collisionally Ionized Gas"

Sembach, K.R., Savage, B.D., and Jenkins, E.B. 1994, ApJ, 421, 585–599.

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Simon, T., Landsman, W.B., and Gilliland, R.L. 1994, ApJ, in press.

"The Abundant Elements in Interstellar Dust"

Sofia, U.J., Cardelli, J.A., and Savage, B.D. 1994, ApJ, in press.

"High-Resolution Spectra of Jupiter's Northern Auroral Ultraviolet Emission with the Hubble Space Telescope"

Trafton, L.M., Gerard, J.C., Munhoven, G., and Waite, J.H. 1994, ApJ, 421, 816–827.

"A Weak Diffuse Interstellar Band in the Far-Ultraviolet Spectrum of ζ Ophiuchi?"

Tripp, T.M., Cardelli, J.A., and Savage, B.D. 1994, AJ, 107, 645–650.

"G191–B2B: Accurate Abundances for Nitrogen, Silicon, and Iron from GHRS Observations"

Vidal-Madjar, A., et al. 1994, A&A, in press.

9.4 Acknowledgments

It is easier to write a document like this for an instrument that has already been operating for several years, so we owe a debt to Dennis Ebbets and Doug Duncan, who compiled earlier versions of this *Handbook* when much less was known. Others who have contributed to the success of the GHRS, especially in the technical areas that this document treats, include D. Lindler, E. Malumuth, S. Shore, G. Wahlgren (and others at Goddard Space Flight Center), and R. Gilliland and J. Skapik at STScI. The GHRS Investigation Definition Team (IDT) is also thanked for their help and for the quality of the instrument that they have provided to the astronomical community.

Glossary of Terms and Abbreviations

Here we provide definitions and explanations of technical terms and abbreviations used in the text. The usual abbreviations found in HST-related documents (e.g., WFPC2, FGS) are not repeated here.

Blaze Function

The efficiency of an echelle grating drops sharply as one moves away from blaze center. The shape of the response function is virtually the same for the different orders and this function is known as the Ripple Function (see Section 8.3.3 on page 91).

Corner diodes

The detector area of the Digicons is laid out into specific diodes, each of which acts as an independent detector. There are 500 science diodes, each of which is skinny but tall, four focus diodes (see below), and four corner diodes. The corner diodes are large rectangles (0.1 × 1 mm) of detector area above and below the science diodes and are used for measuring background.

Cycles

Proposals to use HST are solicited and reviewed on roughly an annual basis. However, because HST's properties changed fundamentally when COSTAR and WFPC2 were installed, Cycle 3 was defined to end at the time of the Servicing Mission. Cycle 4 began at the end of SMOV. Cycle 5 is due to begin in mid 1995.

CVZ

Continuous Viewing Zones. The inclined orbit of HST allows for uninterrupted observations of objects in some declination ranges at certain times. See the *Call for Proposals* for further information.

DEFCAL

Short for Deflection Calibration. All GHRS acquisitions begin with a DEFCAL, which measures the instantaneous location of the images on the onboard spectrum lamps and then compares that location to the nominal coordinates stored in the onboard database. The differences can range over several deflection steps in response to thermal and magnetic drifts. The offsets are applied to the database coordinates of the science apertures to provide an updated estimate of their location. In practice, only observations of lamp SC2 are used because of the loss of Side 1 and because using SC2 decreases the time interval between the DEFCAL and the target locate phase of the acquisition.

Focus diodes

See Chapter 7 to see how the diodes in the GHRS Digicons are configured. At both ends of the array of 500 science diodes are two focus diodes. The focus diodes are smaller than the science diodes and are square. The image of the LSA is deflected to the focus diodes to generate MAPs and IMAGEs. The focus diodes are 25 microns square.

GIMP

Geomagnetically-induced image motion problem. This problem underlies our recommendation to have no single exposure be longer than about 5 minutes in length. See Section 8.6.5 on page 98.

GSC

Guide Star Catalog, the list used to find stars upon which the Fine Guidance Sensors can lock to control the pointing of HST.

LSA

Large Science Aperture. This is a square opening at the front of the GHRS that is used to acquire stars and for some science observations. Its dimensions were 2.00 arcsec square before COSTAR is installed and 1.74 arcsec square afterwards. The name used for the LSA will continue to be "2.0".

OSS

Observation Support System, which is the facility located at STScI for real-time interaction between the ground and the *HST* spacecraft.

Phase I

A Phase I proposal for *HST* includes just the information need by the Telescope Allocation Committee (TAC) and STScI to judge scientific merit and technical feasibility. In addition to the scientific justification, you are asked to provide a list of the targets that you wish to observe and a brief description of the observations themselves. We recommend adding comments to provide a clearer explanation of what you intend, even if they are not required.

Phase II

The Phase II proposal is written once the Phase I proposal has been accepted for the HST science program. The Phase II proposal includes all the detailed specifications that are needed to turn your science program into the commands that the spacecraft will execute. As with Phase I, we recommend the liberal use of comments to help ensure that your goals will be achieved.

Ripple Function

See Blaze Function

SAA

South Atlantic Anomaly. A region lying over southeastern South America where the earth's radiation belts dip low, leading to high particle background rates for satellites in Low Earth Orbit. GHRS observations are suspended during passage through the SAA.

Side 1, Side 2

GHRS is split into two "sides," one for the short-wavelength detector (D1) and one for the long-wavelength detector (D2). The sides operate independently but depend on each other for communication with the spacecraft. The installation of the GHRS Repair Kit during the HST Servicing Mission has meant that all GHRS communications are now through Side 2. Moreover, Side 2 now solely controls the grating carrousel and LSA shutter.

SMOV

Servicing Mission Orbital Verification, the period of time immediately after the Servicing Mission in which the basic capabilities of the telescope and instruments are verified.

SPYBAL

SPectrum Y BALance. A `SPYBAL` consists of a quick observation of the spectrum calibration lamp SC2 at a standard wavelength setting to ensure that the spectrum is properly centered on the diodes in the cross-dispersion direction. The y position at this standard wavelength is compared to a stored value and the difference is applied to the observations made with the proposal configuration until another `SPYBAL` is done. A `SPYBAL` is normally done before each new use of a different spectrum element, such as a grating. The resultant spectrum is provided to the observer and can be used to improve the default wavelength calibration.

SSA

Small Science Aperture. The nominal (pre-COSTAR) size was 0.25 arcsec square, but after COSTAR it is 0.22 arcsec square. The name for this aperture will continue to be "`0.25`".

STEIS

Space Telescope Electronic Information Service. This service provides on-line news, information, and documents via anonymous ftp. To use it, *ftp* to *stsci.edu* (Internet node 130.167.1.2) and login with username *anonymous*, using your last name as password. Use *get* to transfer the README file in the entry directory; this will provide a general explanation of how to access STEIS information. For more details, consult the User Support Branch.

STEP-PATT

`STEP-PATT` is the pattern of operations undertaken in an `ACCUM`. A typical `STEP-PATT` defines the relative proportions of time spent accumulating on the science diodes versus time with the background diodes. See Section 8.4 on page 92.

STEP-TIME

STEP-TIME is the exposure time for the smallest unit of an exposure. For example, during an acquisition, `STEP-TIME` is the amount of time spent at each dwell point while executing a spiral search pattern. During an `ACCUM`, the detector integrates for a `STEP-TIME` before reading the diodes and adding their contents to the memory. A unit of `STEP-TIME` is spent executing each portion of a `STEP-PATT`, for example.

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