

# GHRIS Data Structures and Data Assessment

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This chapter presumes that you have selected and retrieved some GHRIS observations from the Hubble Data Archive. We will describe the contents of the delivered data and how to assess those data. To more fully understand archival observations it sometimes helps to look at the Phase II proposal for the program that first requested them. We use some examples of actual GHRIS programs to illustrate how Phase II proposals were turned into observations and data products. Complete explanations are provided later for reference.

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## 35.1 Contents of Delivered Data

Most HST data are retrieved over the Internet, but it is still possible to get a tape. In either case, you will receive various FITS files containing science data and other information. StarView gives you the option of obtaining sets of uncalibrated, calibrated<sup>1</sup>, data quality, observation log, and used and best reference files.

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1. As we noted in the previous chapter, we urge you to recalibrate all GHRIS observations in order to take advantage of the latest and best calibrations and knowledge of the instrument. However, it can be helpful to look at the calibrated observations to judge the quality of the data and their suitability for your needs.

In this section we provide a description of the information stored in each file. The STSDAS routine for unpacking your data is **strfits**. The resulting files will have default suffixes, as described in Table 35.1 below.

The suffixes for the headers of the raw science data images you will have after running **strfits** are listed in the first column in Table 35.1; they are the output of the Routine Science Data Processing (RSDP) pipeline generic conversion process and are discussed in more detail below. You generally need all of these files in order to calibrate GHRs data.

The third column in Table 35.1 lists the header suffixes for the calibrated data created by running **calhrs**, as well as some additional engineering files available from the Archive. The RSDP pipeline usually runs **calhrs** on all GHRs data when it is taken, but due to updates to reference images and tables, we strongly recommend that you recalibrate the data.

**Table 35.1:** File Name Suffixes

Suffix	File Contents	Suffix	File Contents
.d0h	Raw science data	.c0h	Calibrated wavelength solution
.q0h	Data quality for raw science image	.c1h	Calibrated science data (fluxes)
.d1h	Return-to-Brightest & SSA ACQ/PEAKUP	.c2h	Propagated statistical error
.q1h	Data quality for RTB & SSA ACQ/PEAKUP	.c3h	Calibrated special diodes
.x0h	Extracted engineering data	.c4h	Special diodes data quality
.xqh	Data quality for extracted engineering data	.c5h	Background
.shh	Standard Header Packet	.cqh	Calibrated science data quality
.ulh	Unique Data Log	.jit, .jih	Jitter files (post- and pre-COSTAR)
.trl	Trailer file	.pdq or .ocx	PODPS data quality files

## 35.1.1 Uncalibrated Raw Data

### Science Data (.d0h and .q0h)

The science data (.d0h image) contains the single-precision floating point values representing the number of detected counts accumulated for each diode, just as it comes from the spacecraft. Depending on the stepping pattern (STEPPATT) used for the observation, there may be only one, or up to six groups of science data per exposure. The default STEPPATTs are listed in Table 35.3 and the implications are discussed more in “File Sizes” on page 35-5. The science data are read out from the 500 science diodes (see the *GHRs Instrument Handbook*).

The data quality image (.q0h) associated with the science data records whether there is “fill” data due to technical problems with the observation or due to problems in transmitting the data from the telescope. The .q0h file contains

zeroes where the data are good, and ones for Reed-Solomon errors (related to data transmission) and 16 for fill data (see “Calibration Quality Files” on page 37-22 for a more complete explanation).

### **Return-To-Brightest and Small Science Aperture ACQ/PEAKUP (.d1h and .q1h)**

Most acquisitions of point sources since mid-1993 used the return-to-brightest algorithm, in which the aperture (LSA or SSA) was rastered in a 3 x 3 or 5 x 5 pattern, and the pointing with the most counts was returned to for peakup and observation. The return-to-brightest (RTB) target acquisition record is in the .d1h image and also in the trailer file (.tr1). This image contains the total counts at each dwell point in the spiral search performed by the RTB acquisition algorithm.

SSA ACQ/PEAKUPs use the same algorithm as RTB target acquisitions. Therefore they will also have a .d1h file whose header file contains information on which dwell point (MAPFND) contained the largest flux (FLUXFND).

The data quality image (.q1h) associated with the RTB data records whether there is fill data due to technical problems with the observation or due to problems in transmitting the data from the telescope.

### **Extracted Engineering Data (.x0h)**

For ACCUM and RAPID mode observations, the extracted engineering data image (.x0h) consists of 24 pixels which contain the values of the twelve special diodes (i.e., focus, background monitor, and radiation monitor diodes; see the *GHRIS Instrument Handbook*) in the detector and twelve pixels of engineering trailer and flight software data relevant to each pattern execution (see Table 35.2). The data quality file (.xqh) records whether any of the data represent fill due to technical problems with the observation or telescope during the observation. These data are sometimes used for determining the background count rate.

### **Standard Header Packet (.shh)**

The standard header packet (SHP, image suffix .shh) contains the telemetry values from the engineering data and some GHRIS-unique data. The engineering data includes temperatures, currents, and voltages at various points in the instrument. The header packet also contains information used in the operation of the spacecraft, such as target name, position, and velocity of the telescope, the right ascension and declination of the target, Sun, and Moon, and other proposal information used in the observation which was provided in the Phase II part of the proposal. There is one group of .shh data per pattern used in the observation. Various items from the SHP are used in various steps of the reduction process.

### **Unique Data Log (.ulh)**

The unique data log (UDL, image suffix .ulh) contains the command values (i.e., the Observation Control Table) used to control the aperture, detector, carousel, Digicon deflections, observing modes, and flux measurements as well as some observation data produced by the flight software. There are two groups of .ulh data per pattern per observation. For images and standard ACCUM mode, a leading and following UDL are readout that bracket the observation.

### Trailer File (.trl)

The trailer file (suffix `.trl`) contains many messages generated by the conversion of the data from what is on-board the spacecraft into STSDAS images. These messages include information on missing or filled packets, RTB information for some acquisitions, and the informational messages produced by `calhrs` as it is used to calibrate the data.

## 35.1.2 Calibrated Data

### Calibrated Wavelength Solution (.c0h)

The calibrated wavelength solution (`.c0h`) image contains the wavelengths in Angstroms for each corresponding pixel in the `.c1h` file. The dimensions and number of groups is the same as the `.c1h` file. This file is produced when `ADC_CORR` is set to `PERFORM`.

### Calibrated Science Data (.c1h)

The calibrated science data (`.c1h`) image contains the calibrated science data, and is always produced by `calhrs`. The number of groups and dimensions of the spectra depends on the stepping pattern used (`STEPPATT`, see Table 35.3 and “File Sizes” on page 35-5) in the observation and also which calibration steps are performed. The contents can range from being an exact copy of the raw science data (found in the `.d0h` image) to a fully flux-calibrated spectrum.

### Propagated Statistical Error (.c2h)

The propagated statistical error (`.c2h`) image contains the propagated statistical error associated with the `.c1h` science data. The number of groups and dimensions of this file will be the same as the `.c1h` image. The units of the error will also be the same as the final units of the science data.

### Calibrated Special Diodes (.c3h)

This twelve-pixel image contains the calibration of the special diodes whose raw values correspond to the first twelve pixels in the `.x0h` file (see Table 35.2).

### Special Diode Data Quality (.c4h)

The special diode data quality (`.c4h`) image contains the data quality flags for the special diodes. See Table 37.5 for data quality flags.

### Background (.c5h)

The background (`.c5h`) image contains the actual subtracted background. The units of the background will be either in counts or count rate, depending on the setting of the `EXP_CORR` switch. This file is produced when a background correction is performed. You have several options for calculating the background rate; these are described in “Calibration Steps Explained” on page 36-2.

### Calibrated Science Data Quality (.cqh)

The calibrated science data quality (`.cqh`) image contains the data quality flags associated with each pixel in the calibrated science data image. The flags are num-

bers; the higher the value, the worse the data in the corresponding pixel. See Table 37.5 for calibrated data quality flags.

**Table 35.2:** Special Diodes

Diode Array Index	.c3h or .x0h Pixel #	Description
1	1	Upper left background (corner) diode
2	2	Lower left background (corner) diode
3	3	Left high-energy diode
4	4	Middle focus (disabled) diode
5	5	Upper left focus diode
6	6	Lower left focus diode
507	7	Upper right focus diode
508	8	Lower right focus diode
509	9	Middle focus diode
510	10	Right high-energy diode
511	11	Upper right background (corner) diode
512	12	Lower right background (corner) diode

### 35.1.3 File Sizes

As mentioned above, the size (number of pixels and number of groups) of your raw science file (.d0h) will depend on the substepping strategy used in the original observations, and that is determined by the setting of the STEPPATT keyword. The default STEPPATTs are listed in Table 35.3. Quarter-stepping, i.e., four output pixels per diode, was ordinarily done with science observations in order to achieve full resolution, but the default background measurement strategy may differ depending on the grating and order being observed. The different STEPPATTs you may encounter with GHRS data are listed in Table 35.3.

A typical raw science file (.d0h) will have a STEPPATT=5 and, like other data from STEPPATTs with quarter-stepping and two interorder background bins, will contain six 500-pixel groups per exposure. The first four groups (or bins) are the science data (each bin shifted by 1/4 diode) and the next two are interorder background measurements, one above the spectrum, one below. Mathematically, the number of raw science groups can be represented by the following formula;

$$\text{number}(\text{.d0h groups}) = (\text{spectrum} + \text{background bins}) * (\text{RPTOBS} + 1) * \text{fpsplits}$$

- The number of spectrum and background bins are determined by the STEPPATT, see Table 35.3.
- RPTOBS and STEPPATT are available in the header.

- *fpsplits* = 1 (FP\_SPLIT=DEF) or 2 (FP\_SPLIT=TWO or DSTWO) or 4 (FP\_SPLIT=FOUR or DSFOUR).

The .q0h, .x0h, .xqh, and consequently, .c3h and .c4h files will have the same number of groups as the .d0h file. Patterns which use the corner diodes for background measurements may still create measured background bins in the raw data, although they are not used by **calhrs**.

**Table 35.3:** Stepping Pattern Properties for the GHRs

STEP-PATT number	Bins Measured		Spectrum/Background Ratio	Diodes used for Background	On-target Efficiency	Appropriate Gratings	Minimum Exposure Time (sec) <sup>a</sup>
	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 <sup>b</sup>	4	2	8	science	0.94	first-order	27.2
6	2	2	8	science	0.89	echelle	14.4
7 <sup>c</sup>	4	2	8	science	0.94	echelle	27.2
8	2	2	8	corner	0.89	echelle	14.4
9 <sup>d</sup>	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

a. Calculated using COMB=4, STEP-TIME=0.2, and FP-SPLIT=NO. Scale these values by 4, for example, if using FP-SPLIT=STD.

b. Default STEPPATT for first-order gratings.

c. Default STEPPATT for Ech-A orders < 51 and Ech-B orders < 31.

d. Default STEPPATT for Ech-A orders ≥ 51 and Ech-B orders ≥ 31.

The size (number of pixels and number of groups) of your calibrated output flux file (.c0h, .c1h, .c2h, .c5h, .cqh) will depend on the switch settings and the substepping strategy used in the original observations. In a typical observation, the four groups of science data are merged (see the MER\_CORR description in “Calibration Steps Explained” on page 36-2) and the combined background groups subtracted from that merged spectrum (see the BCK\_CORR description in “Calibration Steps Explained” on page 36-2) to create one 2000-pixel group of calibrated science data per exposure. (Half-stepped data would create a 1000-pixel

calibrated exposure.) Unmerged data, such as RAPID-mode, remain in groups of 500 pixels. Mathematically, the number of calibrated flux file groups is:

$$\text{number (.c1h groups)} = (\text{RPTOBS} + 1) * \text{fpsplits}$$

RAPID-mode data are slightly different and will have a number of raw groups equal to three plus the exposure time divided by the sample (or step) time:

$$\text{number (raw RAPIDs)} = 3 + (\text{EXPTIME} / \text{STEPTIME}).$$

The number of calibrated data will be three less than that because the first two and last groups of raw RAPID data are hysteresis and are thrown away.

The pipeline calibration does not combine RAPID, FP-SPLITS, or repeat exposures.

### 35.1.4 Observation Log Files

As of February 1995, the observation log files (.jih) and jitter files (.jit), which are provided by the Observatory Monitoring System (OMS), were routinely available. These can give valuable information, such as telescope performance during the observation and the position of the target within the aperture. A so-called *jitter ball* is a routine portion of all GHRs paper products for which jitter files exist. This plot shows the motions of the FGSs needed to keep the target centered, recorded every six seconds throughout the exposure. See Appendix C in Volume I of this handbook for a description of these files and additional quantities available in the jitter files.

### 35.1.5 PODPS Data Quality

OPUS (formerly OSS and PODPS) staff performed a quick data quality assessment of the target acquisitions and the science observations. This assessment was performed to identify any target acquisition failures, guide star acquisition failures, other spacecraft anomalies, or instrumental problems. This assessment was recorded in the data quality keywords contained in the PDQ (Procedural Data Quality) file. The PDQ files are archived to data class PDQ and can be retrieved from the HST Archive using StarView. OCX files (Observation Support System (OSS) Observer Comment files) contain information about the success or failure of target acquisitions and science observations. Before April 17, 1992, OCX files were not always archived separately, and, in some cases, were prepended to the RSDP pipeline history file, the .tr1 trailer file. After February 1995, OCX files were produced only to document real-time activity (interactive target acquisition) in support of an observation. After October 1996, OCX files may contain information about observation execution problems.

Please note that the PDQ files and their comments should not be overinterpreted. These remarks were based on a quick visual examination of the data and the experience of the OPUS staff. The technical remarks are usually sound, but some comments about the “quality” of the observations can arise from an incomplete knowledge of the science goals of the original proposer. Unless the object was significantly miscentered, for example, the achieved signal-to-noise is proba-

bly close to what was expected, even if it may appear low in a single exposure. To assess whether or not a low flux is meaningful, you should examine the jitter file or other records of spacecraft performance, or simply look at the total number of counts achieved.

### 35.1.6 Reference Files

The Archive will also give you the opportunity to retrieve the “used” or “best” reference files that go along with the data you are retrieving from the Archive. The “used” reference files are those listed in the calibration reference file keywords, and are those actually applied to the observations to produce the calibrated files in the Archive. The “best” reference files are meant to reflect accumulated experience on GHRS calibration and performance and so are recommended. For more information, please see “Recalibrating GHRS Data” on page 36-13.

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## 35.2 Header Keywords

The header files provide all the information needed to calibrate GHRS data. The headers are divided into groups of keywords that deal with specific types of information (i.e., observing information, engineering information, and processing and calibration information). Table 35.4 lists a few of the important GHRS header keywords.

An HST observation is composed of packets of information sent down to the ground, and each observation packet has an embedded packet format code to identify the packet as SHP, UDL, or science. Each science packet has a packet format code (PKTFMT) that identifies the type of science. The default GHRS calibration switches are set by the PKTFMT keyword value, specified by the type of observation (Target ACQuisition, IMAGE, ACCUM, or RAPID mode). The default calibration switches have been selected to achieve the best possible calibration. The PKTFMT values are set when the observations are scheduled. They are used to determine the values of the science header keywords. This information is stated here for completeness.

The GHRS calibration steps are listed and described in “Recalibrating GHRS Data” on page 36-13.

**Table 35.4:** Important GHRS Header Keywords

Keyword	Description and Values
GCOUNT	Number of data groups
FILETYPE	shp, udl, ext, sci, img, wav, flx
NBINS	Number of substep bins in this pattern
RPTOBS	Expected number of observation repeats
STEPPATT	Step pattern sequence
FP_SPLIT	FP-SPLIT (NO, TWO, FOUR, DSTWO, DSFOUR)
COMB_ADD	Comb-addition (NO, TWO, FOUR, DSTWO, DSFOUR)
FINCODE	Observation termination code
OBSMODE	Observation mode (ACCUM, RAPID, SPYBAL, DEFCAL, ACQ,)
DETECTOR	Detector in use (1 or 2)
GRATING	Grating, echelle, or mirror in use
APERTURE	Aperture name
DATE	Date this file was written (dd/mm/yy)
KZDEPLOY	COSTAR deployed for the HRS (T or F)
APER_FOV	Aperture field of view (arcsec), N/A for cal
FGSLOCK	Commanded FGS lock (FINE, COARSE, GYROS, UNKNO)
DATE-OBS	UT date of start of observation (dd/mm/yy)
TIME-OBS	UT time of start of observation (hh:mm:ss)
EXPTIME	Exposure duration (seconds)—calculated

## 35.3 Paper Products

The term “paper products” refers to the package of text and graphical information that can be generated, for example, for a visit’s worth of GHRS data<sup>2</sup>. The GHRS paper products have been automatically generated as part of the RSDP pipeline process since September, 1996. Also, a task can now be run on any HST data by using **pp\_dads** which is in the **hst\_calib.paperprod** package. Refer to the help file for information on how to run this task. It is often useful to inspect the paper products to obtain a quick overview of data you have retrieved from the Archive.

2. A *visit* is the sequence of observations obtained on a single target during one continuous use of HST.

The GHRIS paper products produce title pages for an observation and a one-page summary for each rootname (excluding DEFCALs, which are deflection calibrations) in an observation. The page is divided into quadrants: summaries of the observation, the calibration, the image statistics, and OMS (or jitter) data. Quadrants may contain different information depending on the type of file being displayed.

An example of GHRIS paper products is shown below for reference to these remarks (see Figure 35.1 through Figure 35.4). We have not included the title page to save space, but we show an LSA acquisition and an SSA peakup so that you can see an example of both.

### 35.3.1 Title Pages

The first page produced by **pp\_dads** is a page which lists the proposal number and the name of the Principal Investigator. The next page(s) contains a list of targets for the observations and a list of the observations, similar to the exposure logsheet.

### 35.3.2 The Observation Summary

A separate sheet is produced for each individual exposure. The Observation Summary in the upper left quadrant contains information from keywords which characterize an exposure, such as the proposal ID, instrument, target and its location, grating, observation mode, exposure time, wavelength information, etc. The information for target acquisitions or images will be slightly different from science observations. For instance, target acquisitions will list the settings of the return-to-brightest indicator (RTBRIGHT) or the bright and faint limits, the size of the spiral search (SRCHSIZE), the highest flux in an RTB acquisition (FLUXFND), and the total flux on the eight target acquisition diodes at the end of the acquisition (ZFLUXM). At the bottom of the quadrant, the number of groups for the image displayed in the quadrant below (Image Statistics Summary) is listed.

### 35.3.3 The Calibration Summary

The Calibration Summary (upper right quadrant) will be blank for target acquisitions and images. For data that are calibrated, it will contain a list of the calibration images and tables, on the right; and a list of all the calibration switch settings, on the left. Two new additions (SAAHFILE and CCRE) to the headers, if added during any eventual reprocessing, may not show up in this section, since they were added after the paper products task was created. This quadrant also contains the “instrument: rootname” label for the observation being summarized on this sheet.

**Figure 35.1: Target and Observation List**

**Visit: 01** **Proposal: 06900** **GHR**

*Target List*

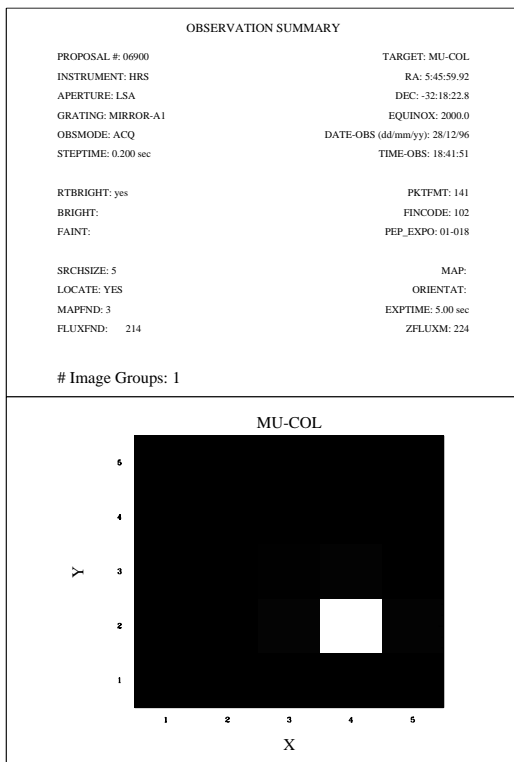
Target Name	R.A. (J2000)	Dec. (J2000)	Description
MU-COL	5:45:59.92	-32:18:22.8	CALIBRATION,PHOTOMETRIC,

*Observation List*

Logsheet Line#	Rootname	Target Name	Config	Observation Mode	Aperture	Spectral Element	Wavelength (central)	Exposure (sec)	Quality Flags Obs	Proc
1.018	Z3JN0102T	MU-COL	HRS	ACQ	LSA	MIRROR-A1	(N/A)	5.0		
1.100	Z3JN0114T	MU-COL	HRS	ACQ/PEAKUP	SSA	MIRROR-A1	(N/A)	25.0		
2.060	Z3JN020MT	MU-COL	HRS	ACCUM	LSA	ECH-B	1703	230.4		

Quality flags: ○ = OK ● = Not OK Blank = Unknown or file missing

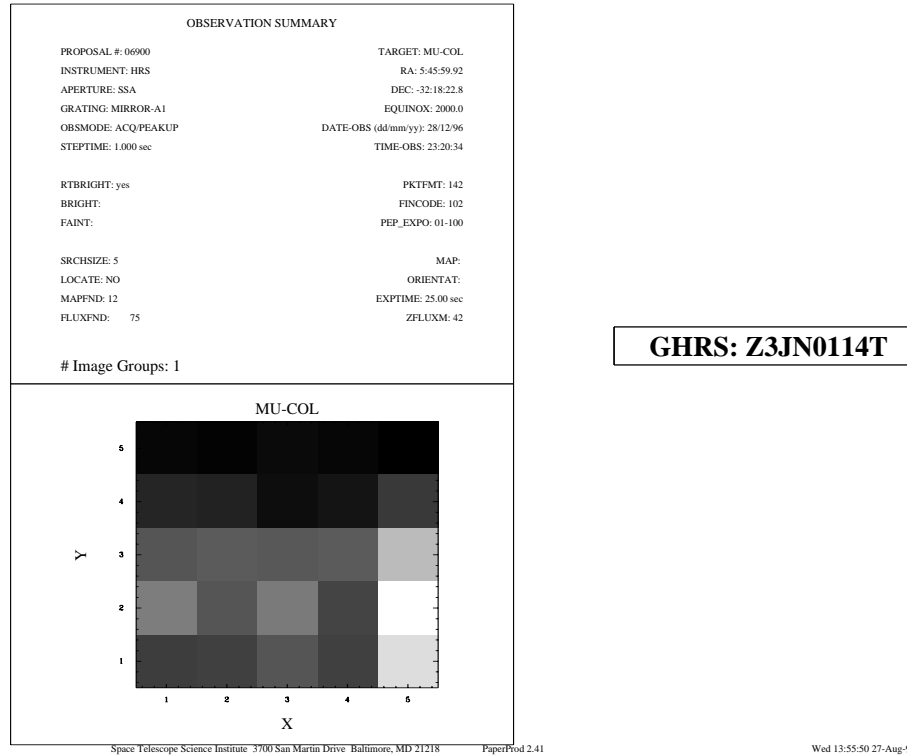
**Figure 35.2: Observation Summary—LSA Acquisition**



**GHR: Z3JN0102T**

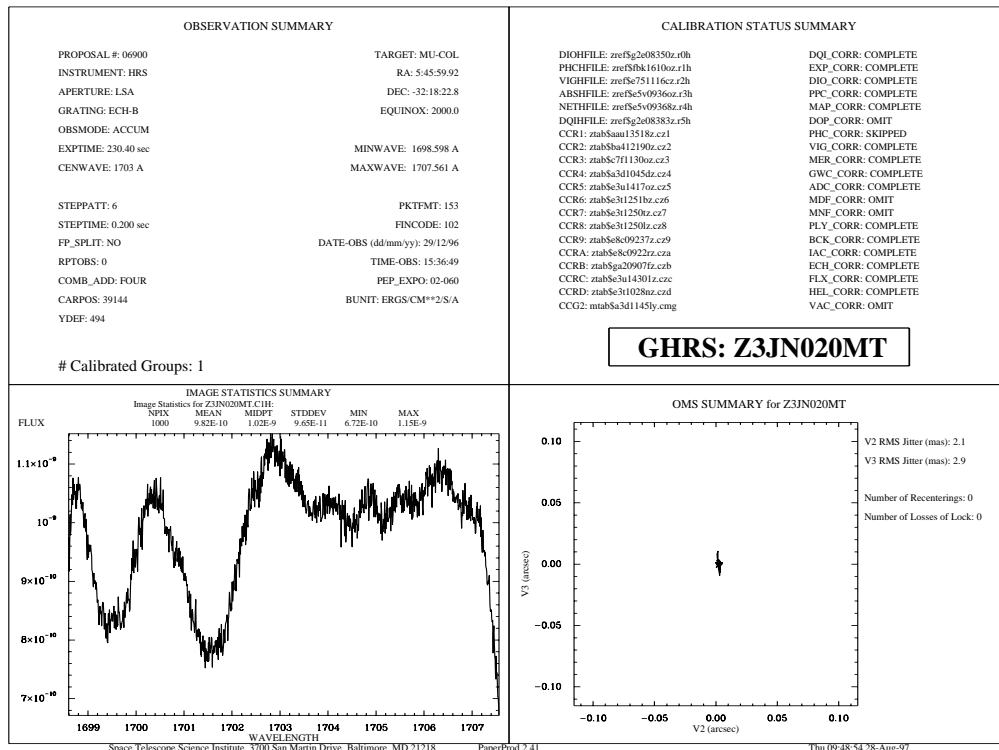
**GHR / 35**

Figure 35.3: Observation Summary—SSA Peakup



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Figure 35.4: Observation, Calibration, Image, and OMS Summaries



### 35.3.4 The Image Statistics Summary

The first thing you will notice in the Image Statistics Summary (lower left quadrant) for calibrated data is the plot of flux versus wavelength. Most data are coadded for this plot; the number of groups corresponding to the output display is printed at the bottom of the Observation Summary quadrant. At the top of the plot, image statistics for this observation are found, including the number of pixels, mean and mid-point (similar to a median; see the **imstat** help file), standard deviation, minimum and maximum. For RTB target acquisitions and SSA ACQ/PEAKUPs, there is a greyscale representation of the spiral search. Images will also be displayed in this quadrant.

### 35.3.5 The OMS Summary

The lower right corner contains the OMS (Observatory Monitoring System) Summary. Here you will find, if the information is available, the jitter plot (jitter ball) which shows the movement of the HST in V2 and V3 coordinates measured in arcseconds off center. The plot is made to be about the size of the Small Science Aperture (SSA), i.e., 0.25 arcsec on each side, unless the observation is a target acquisition in which case the full resolution of the spiral search is shown (3 x 3 or 5 x 5). Also listed is a summary of the rms jitter in V2 and V3 in milliarcsec, in addition to the number of recenterings and losses of lock during the observation. More information about OMS engineering data is available in Appendix C of Volume I of this handbook.

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## 35.4 Assessing GHRs Data

To help you assess GHRs data we will walk through actual proposals containing examples of many of the observing modes available. A short description of a program being used in the science assessment example is provided and a description and picture of the exposure logsheet, followed by assessment descriptions for the different observing modes represented in the example program.

Every observation in the Archive resulted from a detailed Phase II proposal created by the original observer. It is not usually necessary to examine the Phase II proposal to make sense of the data, but it is sometimes helpful to understand the structure of the observations.

### 35.4.1 An Example: R136a in the LMC

Program 5297 was executed in the spring of 1994 as an Early Release Observation (ERO), following the 1993 servicing mission. During that mission, COSTAR mirrors were deployed so that the full optical quality of HST could be realized by the GHRs. Also, a repair kit was installed that allowed Side 1 of the GHRs to be used once again (Side 1 capabilities were lost in 1991 due to the failure of a low-voltage power supply).

Program 5297 was designed to take advantage of and demonstrate these capabilities by obtaining low-resolution spectra of closely-spaced hot stars in a young cluster (R136a) in the Large Magellanic Cloud (LMC). Two of the stars to be observed were only about 0.12 arcsec apart, less than the size of the GHRS Small Science Aperture (SSA), which is 0.22 arcsec square. Thus precise positioning was needed. To achieve this, the telescope was first to acquire and center on the brightest object in the R136a field. That object was itself the convolution of two stars, so that some allowance had to be made for the apparent centroid of what was acquired. This was done using information from a WF/PC-1 image of R136a obtained before the servicing mission. Once centered on R136a1, the SSA could then be moved with high relative precision, but to ensure understanding of what was observed, IMAGES were taken at each position.

### 35.4.2 The Exposure Logsheet

An abridged version of the Phase II Proposal for 5297 is shown in Figure 35.5. The first portion of the figure is the Target List and the bottom half is the Exposure Logsheet. Here are some notes to go with individual lines of the Exposure Logsheet:

**Line 1:** R136a1 was acquired with the Large Science Aperture (LSA). The LSA is denoted as “2.0” but has a true size of 1.74 arcsec square with the COSTAR mirrors in place. SEARCH-SIZE=5 is specified to ensure a good acquisition by providing a wider search area. (The default SEARCH-SIZE=3 was adequate in nearly all cases, but the crowding of this field led to using a more liberal value.) The specified exposure time of 25 seconds implied a STEP-TIME of 1.0 second; STEP-TIME is the dwell per point in the spiral search pattern. MIRROR-N2 was used because these stars were faint. Using MIRROR-N1 would have been preferable if these stars were bright enough because then it would have been unnecessary to switch from using detector D2 on Side 2 (implied by MIRROR-N2) to detector D1 on Side 1 (implied by using Spectral Element G140L on line 20). Switching from one Side of the GHRS to the other took about 40 minutes because of the need to let the electronics stabilize. However, MIRROR-N1 reflected light only from about 1200 to 1700 Å, and the STEP-TIME needed to acquire these stars would have exceeded the maximum permitted value of 12.75 seconds. Note the comment explaining how the exposure time was estimated and the Special Requirements that tie this acquisition to the subsequent exposures. Acquisitions are explained in detail in the *GHRS Instrument Handbook*. The comment about BRIGHT=RETURN means that the onboard acquisition algorithm will determine which dwell point had the most counts and will center the LSA at that point.

Figure 35.5: Exposure Logsheets for Program 5297

PROPOSAL FOR HUBBLE SPACE TELESCOPE OBSERVATIONS ID 5297  
 1.Proposal Title: FIRST SPECTRA OF O STARS IN R136A

TARGET LIST a) Fixed Targets ID = 5297 [ 3 ]

1	2	3	4	5	6	7	8
Tar No	Target Name	Target Description	Target Position	Coord Equinox	Radial Vel.	Acqui Prblm	FLX REF Flux data
1	R136a1	B,103,D,203	RA = 05H 38M 42.438S +/- 0.1S, DEC = -69D 06' 02.294" +/- 0.5"	2000		1 2	V=12.77 B-V=+0.43
Comments: V,B-V from Malumuth & Heap (1993)							
2	R136a2	B,103,D,203	RA = 05H 38M 42.4576S +/- 0.1S, DEC = -69D 06' 02.242" +/- 0.5"	2000		1 2	V=13.38 B-V=+0.43
Comments: WN star in R136a; coordinates and V,B-V from Malumuth & Heap (1993)							
5	R136a5	B,105,D,203	RA = 05H 38M 42.4785S +/- 0.1S, DEC = -69D 06' 02.096" +/- 0.5"	2000		1 2	V=13.73 B-V=+0.12
Comments: O star in R136a; coordinates and V,B-V from Malumuth & Heap (1993)							

EXPOSURE LOGSHEET ID = 5297 [ 4 ]

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Line Number	Seq Name	Target Name	Inst Config	Oper. Mode	Aper. or FOV	Spectral Element	Central Waveln.	Optional Parameters	Num Exp	Time	S/N	Flx	Pr	Special Requirements	
1		R136a1	HRS	ACQ	2.0	MIRROR-N2		SEARCH-SIZE=5	1	25S			1	1	CYCLE 4/1-101 ONBOARD ACQ FOR 2-3 SEQ 1-101 NO GAP
Comments: Time=(128*Nmap +SS2)*StepT =(0 +5x5)*1.0S = 25S GHRs HDBR/Flg 7.3 gives N1 c/4=2500 for V=13.0, (B-V)o=-.3, E(B-V)=.4															
2		R136a1	HRS	ACQ/PEAKUP	2.0	MIRROR-N2			1	102S			1	1	CYCLE 4
Comments: Time=Papt*StepT =102 * 1S															
3		R136a1	HRS	ACQ/PEAKUP	0.25	MIRROR-N2		SEARCH-SIZE=5	1	25S			1	1	ONBOARD ACQ FOR 4-52
Comments: Time=SSIZE*2 * StepT =25 * 1S BRIGTH=RETURN assumed															
4		R136a1	HRS	IMAGE	0.25	MIRROR-N2		NX=13 NY=13 DELTA-X=1 DELTA-Y=1	1	169S			1	1	
Comments: Time=13*13*1S=169S															
5		R136a2	HRS	IMAGE	0.25	MIRROR-N2		NX=13 NY=13 DELTA-X=1 DELTA-Y=1	1	169S			1	1	
Comments: Time=13*13*1S=169S															
20		R136a2	HRS	ACCUM	0.25	GI40L	1300	STEP-PATT=3 FP-SPLIT=NO	1	10M				1	
21		R136a2	HRS	ACCUM	0.25	GI40L	1610	STEP-PATT=3 FP-SPLIT=NO	4	10M				1	
50		R136a5	HRS	ACCUM	0.25	GI40L	1610	STEP-PATT=3 FP-SPLIT=FOUR	4	30M				1	
Comments: total texp=120M															
51		R136a5	HRS	ACCUM	0.25	GI40L	1300	STEP-PATT=3 FP-SPLIT=FOUR	1	30M				1	
Comments: total texp=30M															
52		WAVE	HRS	ACCUM	SC2	GI40L	1300	STEP-PATT=3 FP-SPLIT=NO	1	25.6S				1	
Comments: WAVECAL FOR SPECTRA															
99		R136a5	HRS	IMAGE	0.25	MIRROR-N2		NX=13 NY=13 DELTA-X=1 DELTA-Y=1	1	169S			1	1	
Comments: Time=13*13*1S=169S															
100		R136a5	HRS	IMAGE	2.0	MIRROR-N2		NX=22 NY=22 DELTA-X=2 DELTA-Y=2	1	968S			1	1	
Comments: Time=22*22*2S=968S															
101		R136a5	HRS	ACQ	2.0	MIRROR-N2		SEARCH-SIZE=3 LOCKE=NO MAP=ALL-POINTS	1	1161S			1	1	
Comments: Time=(128*Nmap +SS2)*StepT =(128*9 +3X3)*1.0S=1161S															

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- **Line 2:** Here the object R136a1 was centered in the LSA. The exposure time of 102 seconds implied a STEP-TIME of 1.0 seconds, as for the initial acquisition. As we noted, what is called “R136a1” is not a single object but is a convolution of R136a1 with R136a2 because of the finite resolution of HST and the size of the LSA. An estimate of the centroid of a1+a2 was made from a pre-COSTAR WF/PC-1 image.
- **Line 3:** Here R136a1 was centered in the SSA, with SEARCH-SIZE=5 and an implied STEP-TIME of 1.0 second. The true post-COSTAR size of the SSA is 0.22 arcsec square. As for line 1, the acquisition algorithm automat-

ically determined which dwell point had the most counts and moved the SSA to that point. (The SSA ACQ/PEAKUP algorithm is the same as the LSA BRIGHT=RETURN acquisition algorithm.)

- **Line 4:** An IMAGE of R136a1 in the SSA was obtained. The values of NX, NY, DELTA-X, and DELTA-Y were chosen to fully cover the SSA with the minimum spacing between points. The time spent at each point was 1.0 seconds, as implied by the 169 second total exposure time.
- **Line 5:** This is the same as line 4 except that the object was R136a2. This implies that the telescope has been moved 0.052 arcsec north and 0.105 arcsec east, for a net motion of 0.117 arcsec, about half the size of the SSA. An IMAGE was taken to confirm the positioning.
- **Line 20:** This line obtained a ten-minute exposure on R136a2 with grating G140L centered at 1300 Å. The STEP-PATT value chosen (3) was not the default value of 5, but was selected to maximize the time on target at the cost of some uncertainty in the background. Because the object was faint and low signal-to-noise was anticipated, FP-SPLIT=NO has been chosen. Using a Side 1 spectrum element (G140L) implied a wait of about 40 minutes between lines 5 and 20 to allow one detector to be turned off and the other to be turned on and brought to a stable configuration.
- **Line 21:** Here a second spectrum centered at 1610 Å was obtained. Lines 20 and 21 together provided as much spectrum as G140L was capable of delivering.
- **Line 50:** Now the target was R136a5, implying a small motion of the telescope. The central wavelength was the same as for line 21 to eliminate a grating movement. A longer exposure of 30 minutes was needed for this fainter target. In this case the FP-SPLIT feature has been used.
- **Line 51:** Same as line 20, but for R136a5. Again, FP-SPLIT was used.
- **Line 52:** A wavelength calibration exposure obtained at the previous position for G140L.
- **Line 99:** An IMAGE of R136a5, analogous to line 5. As before, the use of MIRROR-N2 implied waiting about 40 minutes to switch Sides.
- **Line 100:** An IMAGE of R136a5 in the LSA with MIRROR-N2.
- **Line 101:** This “acquisition” at the end of the sequence of operations may seem odd, but what it achieved was a coarse image over a broader area (SEARCH-SIZE=3) than an IMAGE itself was capable of.

Each of these lines was an operation specified by the observer, and they corresponded closely to the operations performed by the instrument and the data files that were generated, as shown in Table 35.5. For example, each of the ACQUISITIONS, ACQ/PEAKUPS, and IMAGES resulted in a data file, but each is also preceded by a DEFCAL. This is a DEFLECTION CALIBRATION, in which an internal lamp illuminated an aperture (SC2) which the acquisition mirror then imaged onto the photocathode. Software on the spacecraft then determined where the actual image of the aperture was falling on the diodes so that the image could be properly centered. The image moved slightly due to thermal effects and the earth’s

magnetic field. These DEFCALs were essential for proper operation of the GHRS, but the information they contain is rarely of use to the observer.

You will note that many, but not all, of the ACCUMs were preceded by a SPYBAL exposure. SPYBAL stands for SPectrum Y BALance, and it, like a DEFCAL, was performed to ensure proper alignment of the spectrum on the science diodes. However, a SPYBAL was an actual spectrum recorded at a selected wavelength for each grating (chosen to provide a uniform distribution of comparison lines) and it was performed each time a different grating was used for the first time. In longer programs, SPYBALs will appear about every 90 minutes of alignment time as well, in order to compensate for thermal drifts and the like. An exposure was not interrupted to insert a SPYBAL, however. Also, in some

**Table 35.5:** Relationship Between Proposal Lines and Files for Program 5297

Exposure Logsheet Line #	OBSMODE	Aperture	Mirror or Grating	Targname	FP_SPLIT	Central Wavelength (Å)	ROOTNAME for output file
1	DEFCAL						z2bd0101t
	ACQ	LSA		R136a1			z2bd0102t
2	DEFCAL						z2bd0103t
	ACQ/PEAKUP	LSA		R136a1			z2bd0104t
3	DEFCAL						z2bd0105t
	ACQ/PEAKUP	SSA		R136a1			z2bd0106t
4	DEFCAL						z2bd0107t
	IMAGE	SSA	N2	R136a1			z2bd0108t
5	DEFCAL						z2bd0109t
	IMAGE	SSA	N2	R136a2			z2bd010at
20	SPYBAL	SC2	G140L	WAVE	NO	1414.899	z2bd010bt
	ACCUM	SSA	G140L	R136a2	NO	1304.579	z2bd010ct
21	ACCUM	SSA	G140L	R136a2	NO	1608.027	z2bd010dt
50	SPYBAL	SC2	G140L	WAVE	NO	1414.903	z2bd010et
	ACCUM	SSA	G140L	R136a5	FOUR	1598.548	z2bd010ft
51	SPYBAL	SC2	G140L	WAVE	NO	1414.728	z2bd010gt
	ACCUM	SSA	G140L	R136a5	FOUR	1294.922	z2bd010ht
52	ACCUM	SC2	G140L	WAVE	NO	1313.492	z2bd010it
99	DEFCAL						z2bd010jt
	IMAGE	SSA	N2	R136a5			z2bd010kt
100	DEFCAL						z2bd010lt
	IMAGE	SSA	N2	R136a5			z2bd010mt
101	DEFCAL						z2bd010nt
	ACQ	LSA	N2	R136a5			z2bd010ot

cases the PI suppressed SPYBALs in order to keep the carousel from moving during a sequence of observations.

Table 35.6 shows some of the different kinds of files generated in this program for the different operations that resulted from the Exposure Logsheet. The entries are Exposure Logsheet line numbers. The lines at the bottom of the table show what kinds of files are generated for the different kinds of operations. For example, all observations generate log files with suffixes .shh, .ulh, and .trl. The “\*” next to the acquisition files for lines 1 and 3 indicate that these observations also generate .dlh files and the corresponding .qlh data quality files. .dlh files are generated for Return-to-Brightest (RTB) acquisitions and SSA peakups (which use the RTB algorithm). Notice that LSA peakups do not generate .dlh files; nor would an LSA acquisition that does not use the RTB algorithm.

**Table 35.6:** Breakdown of Files by Proposal Line Number for Program 5297

Target	DEFCAL	ACQ	ACQ/PEAKUP	IMAGE (MAP)	SPYBAL	WAVECAL	ACCUM	FP-SPLIT
R136a1	1	1*						
	2		2					
	3		3*					
	4			4				
R136a2	5			5				
					20		20	
							21	
R136a5					50			50
					51			51
						52		
	99			99				
	100			100				
	101			101				
Header File Suffixes	Log files: .shh, .ulh, .trl.			All log files, plus raw data files: .d0h, .q0h, .x0h, .xqh	All log files, all raw data files, plus calibrated files: .c0h, .c1h, .c2h, .c3h, .c4h, .c5h, .cqh			

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## 35.5 Assessing GHRIS Acquisitions

There are no jitter files available for the example we just discussed, program 5297, and so in this section we show another case drawn from *GHRIS ISR 079*. We will return to program 5297 when we discuss the science assessments.

### 35.5.1 Understanding GHRIS Acquisitions

Most GHRIS targets were point sources (stars) and were acquired with the normal on-board target acquisition mode. Other types of targets were acquired either by blind offsetting from a nearby star, with an FOS acquisition, or offsetting from coordinates determined from a WFPC2 image. FOS acquisitions and WFPC2 offsets were discussed in the *GHRIS Instrument Handbook*. The LSA is larger than the GHRIS PSF, and using a blind offset to position a target into the LSA could introduce a wavelength shift in the data. Each OnBoard Acquisition is composed of up to eight steps, some of which are optional. The first and last steps always occur:

1. Initialization.
2. Deflection calibration (DEFICAL).
3. Target Search: 3 x 3 (or 5 x 5) spiral search.

Search stopped when within BRIGHT/FAINT limits or pointing returned to dwell scan position with most counts.

4. Locate: center the target in the LSA.
  - Y balance.
  - Coarse X balance.
  - Fine X balance.
5. Pickup in SSA.
6. Blind offset.
7. Post-offset pickup.
8. Final Flux measurement (ZFLUXM).

A DEFICAL is an internal calibration that used the calibration lamps to locate the spectrum on the photocathode. The location of the spectrum on the photocathode depended on thermal and geomagnetic factors. This spectrum was not saved, but the location of the spectrum on the photocathode was compared to coordinates stored in the onboard data base. An offset was determined and used by the onboard computer during the subsequent Search and Locate phases of the LSA ACQ. A DEFICAL observation only generated log files (.shp, .udl), not science data.

The target search phase slewed the telescope in a spiral search pattern. At each dwell point, the flux in the aperture was measured. All targets were first acquired using the LSA because the SSA is so small. (Note, however, that the SSA

ACQ/PEAKUP algorithm is the same as that used for the LSA Return-to-Brightest (RTB) target search.) The target is assumed to be somewhere within the LSA 3 x 3 (or 5 x 5) spiral search pattern. The separation between dwell points during the LSA search was 1.52 arcsec on the sky (for an SSA ACQ/PEAKUP 5 x 5 spiral search, the separation was 0.052 arcsec). Figure 35.6 displays normal LSA 3 x 3 and SSA 5 x 5 spiral search patterns (from OMS jitter files). The spiral searches are plotted in V2,V3 space.

Most LSA acquisitions from mid-1993 on specified the BRIGHT=RETURN (RTB) option. This feature automatically returned the spacecraft pointing to the dwell position with the highest total counts. Since a 32-bit onboard register was used to store and compare the measured counts, overflow was not a problem. Alternatively, BRIGHT and FAINT limits may have been specified for the spiral search. For this case, a 16-bit register was used to store the measured counts and wrapping of the counter could result if a diode exceeded about 65,000 counts. The spacecraft pointing stopped at the first dwell position that had a flux between the selected limits. If no dwell position was found to meet the requirements, the spacecraft pointing remained at the last position.

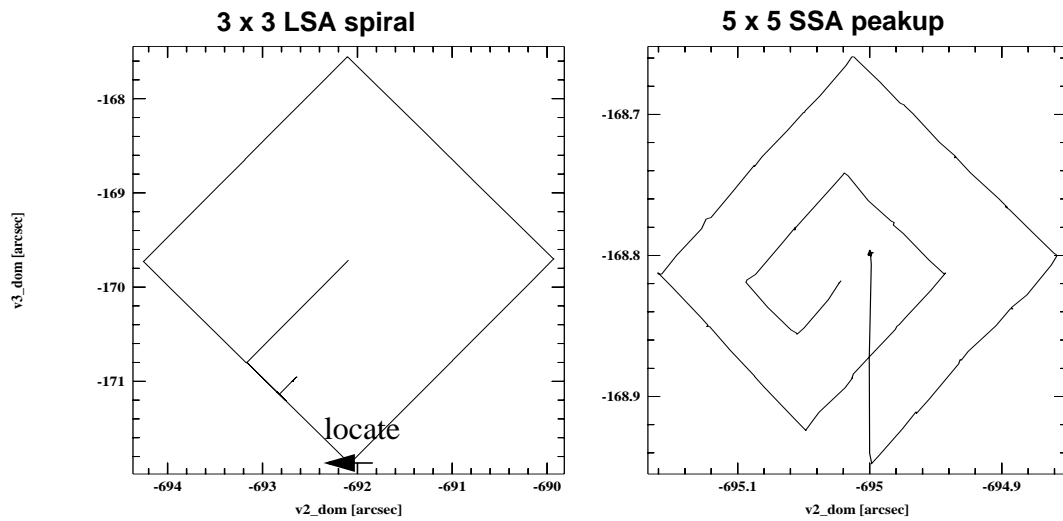
The locate phase consisted of  $y$  balance, coarse- $x$  balance, and fine- $x$  balance. This process determined the location of the target in the aperture, and commanded the telescope to slew to position the target in the center of the aperture. The  $y$  balance routine compared the counts in the upper and lower half of the aperture and used single step offsets to find the optimum centering of the target. The  $x$  balance algorithm computed a coarse offset to place the peak of the target on one of the two center acquisition diodes. The peak was then single stepped toward the other center diode until the peak count was sensed on the second diode. Offsets in  $y$  and  $x$  were computed and used to slew the telescope. Sometimes this phase helped pull targets into the aperture that were not well-centered by the search.

A small angle maneuver was performed to move the target to the SSA. The LSA shutter is closed when the SSA is used. An SSA ACQ/PEAKUP was used to perform the centering in the SSA. In practice, the SSA ACQ/PEAKUP is identical to the LSA RTB except the SSA was used and the Locate and balance phases are not performed. The pointing was returned to the dwell position with the most counts. For the SSA example in Figure 35.6, the target was found at the first dwell position. The offset in the return path to the first dwell position was due to a velocity aberration correction.

The flux was summed over the eight target acquisition diodes after the completion of the locate phase (and any additional peakups); this value was written into the keyword ZFLUXM, available in the Unique Data Log (.udl or .ulh) and the target acquisition science header, if one was generated. Executing the following IRAF command returns the flux value:

```
cl> hsel z2i10102t.ulh $I,zfluxm yes
z2i10102t.ulh 16092
```

**Figure 35.6:** Normal LSA 3 x 3 and SSA 5 x 5 Spiral Search Patterns (OMS Obs Logs)



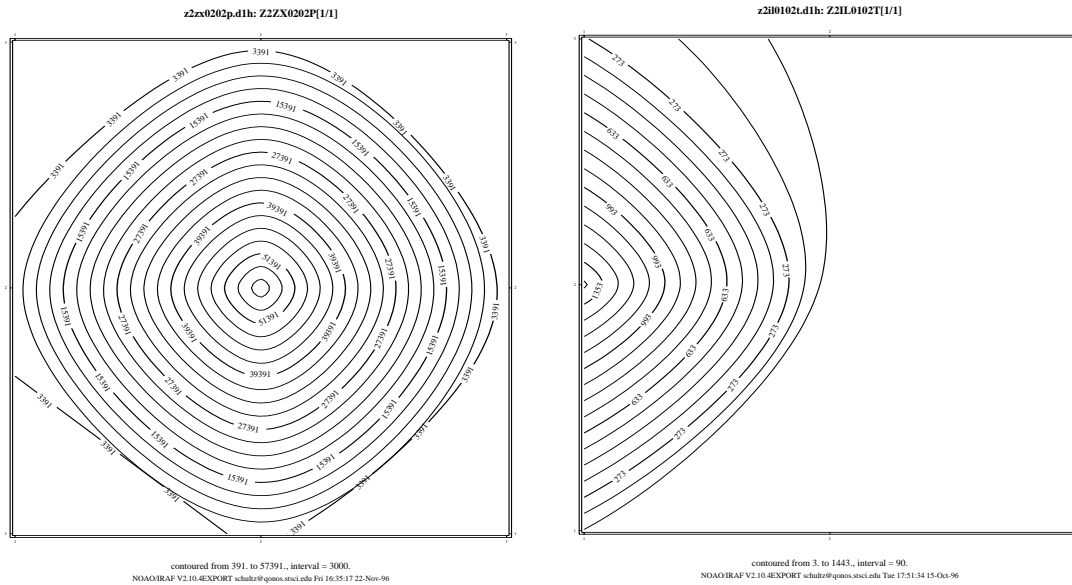
### 35.5.2 Return-to-Brightest

Not every GHRIS target acquisition method produces data to examine. After the acquisition, if specified in the proposal, IMAGES or MAPS will create science (.d0h) files. The Return-to-Brightest (RTB) acquisitions, implemented in 1993, record the flux at each dwell position. At first (April 27, 1993, SOGS Build 31.1) this information was dumped only to the trailer files (where the first dwell position is numbered 00) but eventually .d1h files were created to contain this data. See *GHRIS ISR 079* for more details.

Figure 35.7 shows examples of contour plots for two LSA ACQ .d1h/.d1d pseudo-images. The target was found at the first dwell position for the first example, while for the second example, the target was found at dwell position 6. For both examples, the spacecraft pointing was returned to the dwell position with the maximum flux.

During the spiral search, the telescope slews were parallel to the GHRIS  $x$  and  $y$  detector coordinates. The first slew in the sequence is in the positive  $x$  direction. The next slew is in the negative  $y$  direction, followed by a slew in the negative  $x$  direction. All subsequent slews are performed to complete the spiral pattern. Figure 35.6 displays the spiral search geometry and the corresponding detected counts at each dwell position for the two LSA ACQs presented in Figure 35.7. Figure 35.8 displays two examples of the SSA 5 x 5 spiral search. The upper search pattern found the target (a Cepheid binary star) at dwell position 1. The lower search pattern found the target (a B0-B2III-I star) on the edge of the spiral pattern at position 19. The spectra for this program were fine, indicating the target was found and subsequently moved to the center of the aperture.

**Figure 35.7:** LSA 3 x 3 Spiral Search Contour Plots



**Figure 35.8:** Examples of SSA 5 x 5 Spiral Search Patterns in Aperture Space (X and Y)

**Dwell Positions**

21	22	23	24	25
20	7	8	9	10
19	6	1	2	11
18	5	4	3	12
17	16	15	14	13
21	22	23	24	25
20	7	8	9	10
19	6	1	2	11
18	5	4	3	12
17	16	15	14	13

**Detected Counts**

481	956	1211	1095	643
1384	3312	3242	2746	803
2701	5246	5366	4974	1036
2707	4993	5104	4827	950
2311	4300	4391	4108	673
49	12	3	4	2
516	45	20	23	3
1202	146	22	7	4
1187	162	64	13	7
673	158	37	14	7

### 35.5.3 OMS Products and Guiding

The guide stars used for pointing control during an observation can be found in the Observatory Management System (OMS) observation log header and in the SHP (.shd/.shh) header file. The OMS data header file (.cmh or .jih) contains information about the observation. The header is divided into groups of keywords that deal with a particular topic (e.g., spacecraft data, background light, pointing

control data, line of sight jitter summary). A more complete description of OMS products can be found in Appendix C of Volume I.

There were three commanded guiding modes: FINE LOCK, FINE LOCK/GYRO, GYRO. If the acquisition of the second guide star failed, the spacecraft guidance could drop from FINE LOCK to FINE LOCK/GYRO or even to GYRO which could result in a target rolling out of an aperture. It must be noted that single guide star guiding is acceptable. A GHRs target could remain in the SSA even over multi-orbit exposures. The guiding at the time of the observation can be found in the OMS header keyword GUIDEACT.

```
cl> hsel z2i10102j.cmh $I guideact yes
z2i10102j.cmh      "FINE LOCK"
```

You can check the OMS header keywords to verify that the guiding mode was the one requested. Archive users should check the guiding mode to verify that no changes occurred during the observation. If you suspect that a target rolled out of the aperture during an exposure, you can check the counts in each group of the raw science data.

A “type 51” slew was used to track moving targets (planets, satellites, asteroids, comets). Observations were scheduled with FINE LOCK acquisition, i.e., with two or one guide star. Usually, a guide star pair stayed within the pickle during the entire set of observations (obset), but if two guide stars were not available, a single guide star may have been used. This assumes the drift was small or perhaps that the observer stated the roll was not important for the program. An option during scheduling was to drop from FGS control to GYRO control when the guide stars moved out of the pickle. Guide star handoffs (which are not a simple dropping of the guide stars to GYRO control) could affect the guiding and may be noticeable when the jitter ball (V3 vs. V2) is plotted.

On January 19, 1996, there was a failure in tape recorder #2. This recorder had been used for recording engineering data for subsequent playback to the ground. The failure was permanent, causing engineering data to be obtained only during real-time TDRSS availability (typically 80% or so during each orbit). Consequently, there are gaps in the engineering data and gaps in the OMS products.

### Displaying Spacecraft Motion

IRAF/STSDAS tools are available to read the OMS tables and graphically display the spacecraft motion during an observation. The package of tools to work with tables is called **ttools**. For most observers, the `.cmi` or `.jit` STSDAS table will contain all the information needed to determine if there was motion or jitter during an observation.

For example, plotting “v2\_dom” versus “v3\_dom” will generate a plot that looks like a ball of string, which is why it is sometimes called the *jitter ball*. The same plot for a target acquisition will display the spiral search and locate phase that occurred. See fifth page of paper product example.

```
st> sgraph "z2o40402j.cmi v2_dom v3_dom"
```

After entering the plotting command, the command will plot the data in the graphics window and auto scale using the minimum and maximum data values. The plot may be misleading due to the auto scaling of the axis units, so be careful.

## 35.5.4 Acquisition Anomalies

### Status Codes

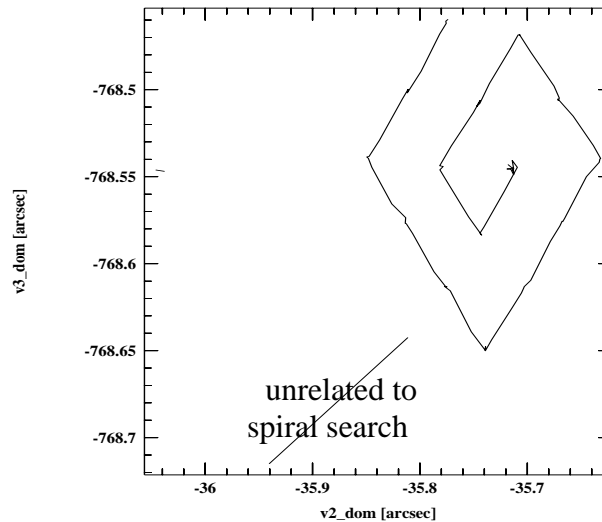
If a target was not in the aperture, the acquisition may have failed and generated an error message also known as a Status Buffer Message, or the acquisition software may have centered on noise or a background object. All of the flight software status messages have their corresponding numbers placed into the keyword FINCODE. The FINCODE value for each data group are stored in the UDL (.uld/.ulh) file. The STSDAS task **obsum** can be used to display the individual group FINCODE values. The FINCODE value of the last data group is extracted and written to the science header (.d0d/.d0h). FINCODE=102 is a normal end of an observation. Any other value of the keyword indicates a possible problem, see Table 37.7.

### The GHRIS Carrousel

All acquisition mirrors and gratings were mounted on a rotating carrousel. There were times when the carrousel failed to lock into position if a target acquisition took longer than expected to complete, due to carrousel movement. The subsequent observations may have been affected and exposure times shortened (FINCODE=106).

Figure 35.9 shows an example of a SSA ACQ/PEAKUP that started late and completed later than the expected time as specified by the SMS (Science Mission Specification). A guide star re-acquisition took longer to complete than normal and there were two loss of locks before the start of the SSA ACQ/PEAKUP 5 x 5 spiral search. The acquisition did not complete normally. The time window used by OMS to extract the telemetry was for the originally scheduled time. The OMS .jit table contains part of an unrelated slew as well as the start of the spiral search pattern. For this unique case, a request was sent to the STScI help desk (help@stsci.edu) for a new OMS observation log. The software engineers determined that the OMS software could not handle this special case, moving the start time of the observation to extract the spiral search pattern information. OMS software was to be modified to handle these special cases. Currently, the anomalous observation log is in the archive.

**Figure 35.9:** SSA ACQ/PEAKUP Started Late Due to Long Guide Star Re-acquisition



### False Fine Lock

A false lock, an anomaly that is not specific to GHRs, was simply a failure of an FGS (Fine Guidance Sensor) to lock onto the null point of the S-curve for the acquired guide star. Instead, it locked onto noise, onto a fake fine error signal at the edge of the FGS interference field of view, or onto a very weak S-curve. These sources of noise may be influenced by:

- Large noise in the FGS of faint stars.
- Star fainter than FGS magnitude limit due to magnitude error.
- Large star magnitude error of relatively bright star.
- Double star.
- Mask misalignment.

Figure 35.6 shows an example of a GHRs spiral search target acquisition while in a normal fine lock condition. The path indicates a very smooth travel during the slewing maneuver. Figure 35.10, on the other hand, exhibits a very ragged and irregular travel, a false fine lock.

The potential impacts of a false lock may include:

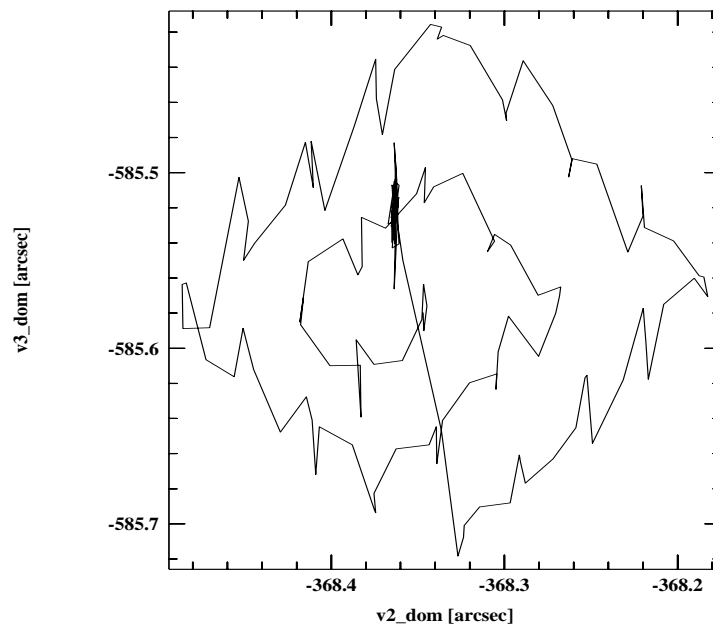
- Prolonged acquisitions.
- Loss of lock.
- Positioning errors.
- Loss of science in subsequent orbits.

It is also possible that a roll in the spacecraft could be introduced, causing the target to drift toward the edge of an aperture. Positioning errors, occurring as a result of an undetectable false lock, could result in a misinterpretation of the spacecraft attitude error. When corrected, the end result would be a real HST

pointing error, virtually impossible to identify without examining the data. However, such errors will not exceed 2.5 arcsec due to the maximum allowed drift. Loss of science in subsequent orbits could occur in cases where a re-acquisition results in a good, true lock following a false lock orbit. In a case such as this, it is entirely possible that the target would not be found in the aperture upon successful re-acquisition.

Prolonged acquisitions could delay subsequent science activities or result in the loss of science altogether. False locks, while possible, were not frequent. During 1995, false locks represented only 0.7% of the total number of acquisitions with HST. Unfortunately, however, most of the factors contributing to false locks were not preventable or fixable.

**Figure 35.10:** Example of False Fine Lock



### Loss of Lock

During a loss of lock, spacecraft motion can be large ( $>0.2$  arcsec). FGS control of the spacecraft is given up, and the FGSs execute a sequence of maneuvers to re-acquire the guide stars (sort of an on-the-spot guide star re-acquisition). During a loss of lock recovery, the spacecraft Take Data Flag (TDF) was set to “no.” The function of the TDF is to provide a simple reference for the science instruments to query about the stability of the spacecraft pointing. During a loss of lock, the GHRS stops acquiring data, but the LSA shutter does not close. (If an observation is taken in the SSA, the LSA shutter is already closed.) Once fine lock pointing control has been re-established, the TDF was set to “yes.”

A loss of lock did not necessarily result in the loss of science if the guide stars could be re-acquired and the observation completed before the next scheduled activity. However, this was unlikely for most GHRS observations and a delay usually forced an observation to time-out.

## Suspect Spoiler Guide Stars

The Guide Star Catalog (GSC) was created with entries down to 15th magnitude from digitized photographic Schmidt plates. Suitable guide stars were selected for each observation by the Guide Star Selection System (GSSS) to be used for fine pointing and guiding of HST. Most (>98%) guide star acquisitions and guiding were successful. The main source of problems was very close binary stars that were unresolved on the Schmidt plate, causing FGS fine lock failures. There were infrequent failures (1 to 3 a year) due to misclassification of an object in the GSC (blend of two stars or a faint circular galaxy).

A spoiler star could result in acquiring the wrong star with the FGS and the target would not be in the aperture due to this mispointing of HST. This could also result in a shift in the pointing following a guide star re-acquisition when the scheduled star was acquired. The target could roll in and out of the aperture resulting in changes in the counts between observations obtained during different orbits.

The differences between the predicted (PREDGSEP) and the actual (ACTGSSEP) measured separation between Guide Stars can be used to test for a spoiler star. For the following example, the science observation z2zx0207 started with the target in the aperture, was halted for earth occultation, and the observation completed on the following orbit. However, the guide star re-acquisition (REACQ) locked up on a spoiler star. The target was not centered in the aperture during the remaining exposure time. Observation z2zx0208 was noise. Observation z2zx0209 was halted for earth occultation and upon the REACQ, the target was moved into the aperture. For this observation, the first part of the exposure resulted in noise, while for the second orbit, the target was in the aperture.

```

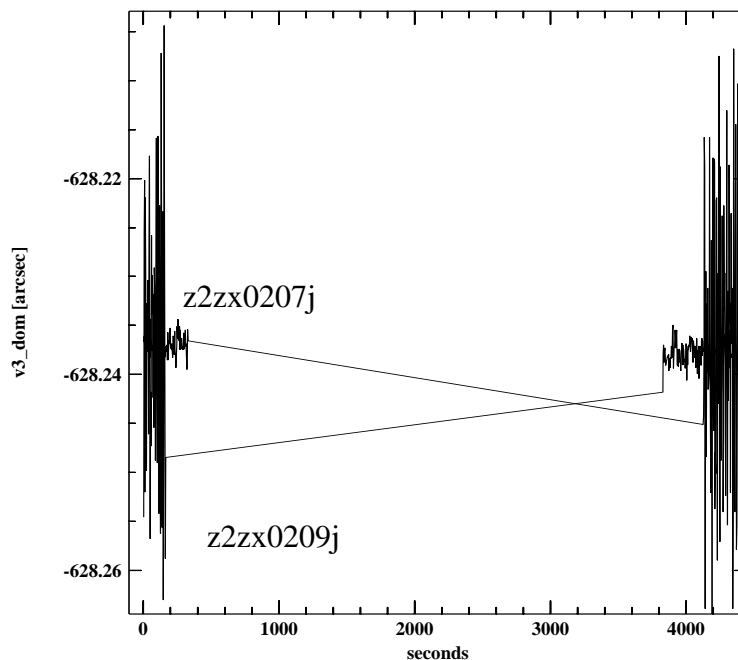
c1> hedit z2zx020*.jih PREDGSEP,ACTGSSEP .
z2zx0204j.jih,PREDGSEP = 1328.046 <-- SSA ACQ/PEAKUP
z2zx0204j.jih,ACTGSSEP = 1326.466
z2zx0205j.jih,PREDGSEP = / <-- SPYBAL
z2zx0205j.jih,ACTGSSEP = /
z2zx0206j.jih,PREDGSEP = / <-- WAVECAL
z2zx0206j.jih,ACTGSSEP = /

z2zx0207j.jih,PREDGSEP = 1328.046 <-- first science obs.
z2zx0207j.jih,ACTGSSEP = 1328.019 guide star REACQ
z2zx0208j.jih,PREDGSEP = 1328.046 wrong pointing
z2zx0208j.jih,ACTGSSEP = 1328.019
<-- guide star REACQ
z2zx0209j.jih,PREDGSEP = 1328.046 <-- correct pointing
z2zx0209j.jih,ACTGSSEP = 1326.475

z2zx020aj.jih,PREDGSEP = 1328.046 <-- no further problems

```

Figure 35.11 presents the overplotting of the pointing for each observation (v2\_dom versus seconds). This shows the change in HST pointing for this program. An HST Observation Problem Report (HOPR) was filed by the PI and the observations were repeated using different guide stars.

**Figure 35.11:** Jump in HST Pointing due to a Spoiler Guide Star

### Single FGS Mode

On February 12, 1993, FGS 2 was temporarily turned off. Some observations shortly thereafter were executed with guiding from a single FGS. Later, a guide star acquisition could fail, resulting in use of a single guide star. For GHRS this could become a problem if the observation was being done in the SSA because the star could roll out of the aperture, as seen by a decrease in counts in the data. At some point, it was decided that single FGS mode was perfectly all right for LSA observations because the amount of expected roll wouldn't take the star out of the LSA, but it was not to be done for SSA observations. If you see a large drop-off in counts with SSA data, one explanation could be use of a single FGS.

### Recentering Events

During a recentering event, pointing control of the telescope by the Fine Guidance Sensors was paused until the spacecraft motion excursions became small enough that FGS guiding could be resumed. Recenterings typically lasted a few seconds, the total spacecraft motion was less than 0.1 to 0.2 arcsec, and after the recentering was finished the pointing position should be the same as before the recentering (to within ~7 milliarcsec).

During a recentering event, the GHRS continued to acquire data. The PI (or archival researcher) is the only one who can determine whether or not a recentering event affected the target acquisition or data. Careful comparison of the time of recentering and the time during which the individual exposures were made can be obtained from the OMS Obs Log. Plotting the OMS "recenter" column versus "seconds" will indicate whether or not a recentering event occurred. The recentering event may have occurred during a time when data were being read out, in which case there is no problem. If the recentering was short compared to the exposure time of a given group of data, it probably had no effect on the data.

## 35.5.5 Images and Maps

### Location of Targets Within the SSA

The location of a single star within the Small Science Aperture cannot be determined with an SSA image.<sup>3</sup>

### Orientation

To determine the orientation of the GHR apertures on the sky, you need the value of the PA\_APER keyword in the SHP header (.shh). This number is the position angle of the +y axis of GHR measured from north through east. The +y axis is the direction from the LSA to the SSA. The +x axis is the direction of increasing wavelength.

The trick is to figure out how to display your image so that it has the same directional sense as Figure 34.1. The problem is that tasks typically display +y up and +x to the right but what is needed is +y down and +x to the right. In IRAF this would be something like:

```
cl> display test.hhh[*,-*].
```

Once you have this orientation then you apply the offset angle (PA\_APER) to get northeast lined up.

You should also know that RA\_APER1 and DECAPER1 are the predicted RA and Dec of the center of the aperture used, for the beginning of the observation. GHR PEAKUPs effectively re-zero the coordinate system so one would need to use the OBS logs (jitter files) to get the actual pointing.

---

## 35.6 Assessing GHR Science Data

### 35.6.1 Examining the ACCUMs

Here we return to our examination of program 5297. There are many, many data files for this program, but to start you would probably like to look at the reduced spectra, and then go back to understand how they got the way they are and how the calibrations might be improved.

The reduced wavelength and flux files have suffixes of .c0h and .c1h (for a complete explanation of file suffixes, see Table 35.1). GHR observations have separate files for wavelengths because they are on a non-linear scale; i.e., there is a distinct wavelength associated with each output data point, and those wavelengths are not necessarily evenly spaced. For a quick look, we need to use **fwplot**, a task in **stdas**. The **fwplot** task will display flux versus wavelength and it can find the right wavelength file automatically (unless you changed its name), so we use the following to examine the first group of a repeat observation containing R136a2:

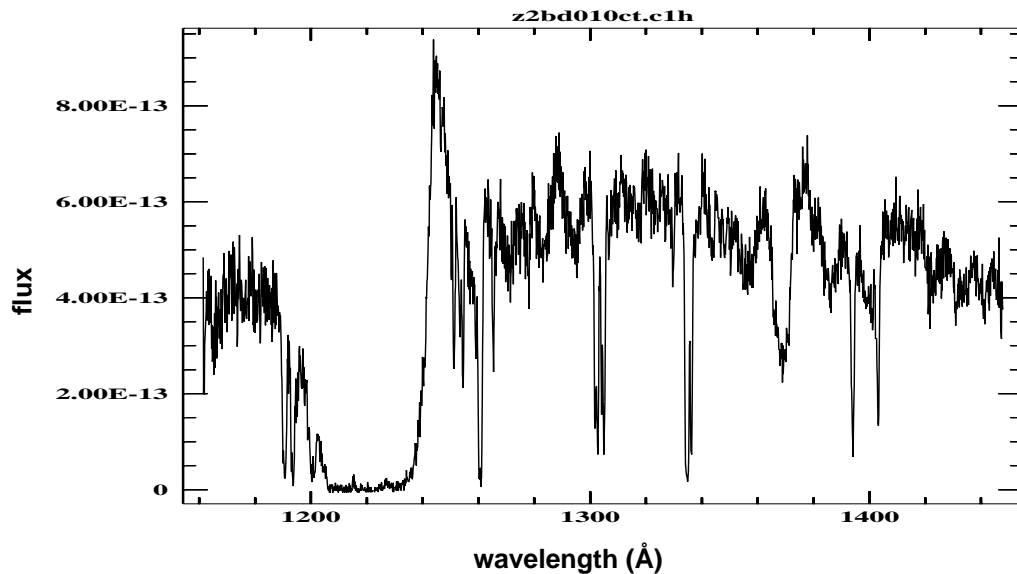
---

3. Malumuth, E., in *Calibrating HST: Post Servicing Mission*, 1995, pp. 227.- 241.

```
cl>fwplot z2bd010ct.c1h
```

This produces the plot shown in Figure 35.12. Plots of the other spectra can be obtained by changing the rootname. **fwplot** can also plot error bars and the like, which we will explain in a moment.

**Figure 35.12:** Flux vs. Wavelength for R136a2



Now that we have seen the spectrum, let's understand better why it looks the way it does. First let's look at counts versus pixel to get a sense of the quality of the observations. Since there are three repeats in this observation, we will look at all four of the corresponding groups of data. We must create a listing of the file names with the group numbers attached, so we use **grlist** and redirect the output to a file. Then we stack the spectra using **sgraph**.

```
cl> grlist z2bd010ct.d0h - > lis
cl> sgraph @lis st+
```

Note how few counts we have at the short-wavelength (left) end (Figure 35.14). We can see the effect of this in the reduced spectrum. If we use **fwplot** to plot a small part of the reduced spectrum with its errors (Figure 35.13) we get essentially the same information in a more compact form, and we can see that the errors are the statistical ones calculated from raw counts.

Figure 35.13: Reduced Spectrum of R136a2 with Error Bars

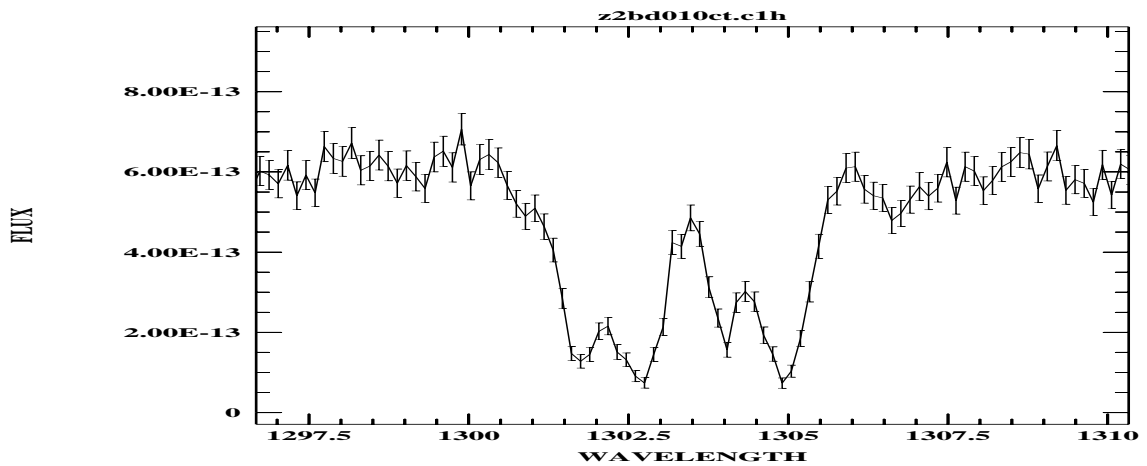
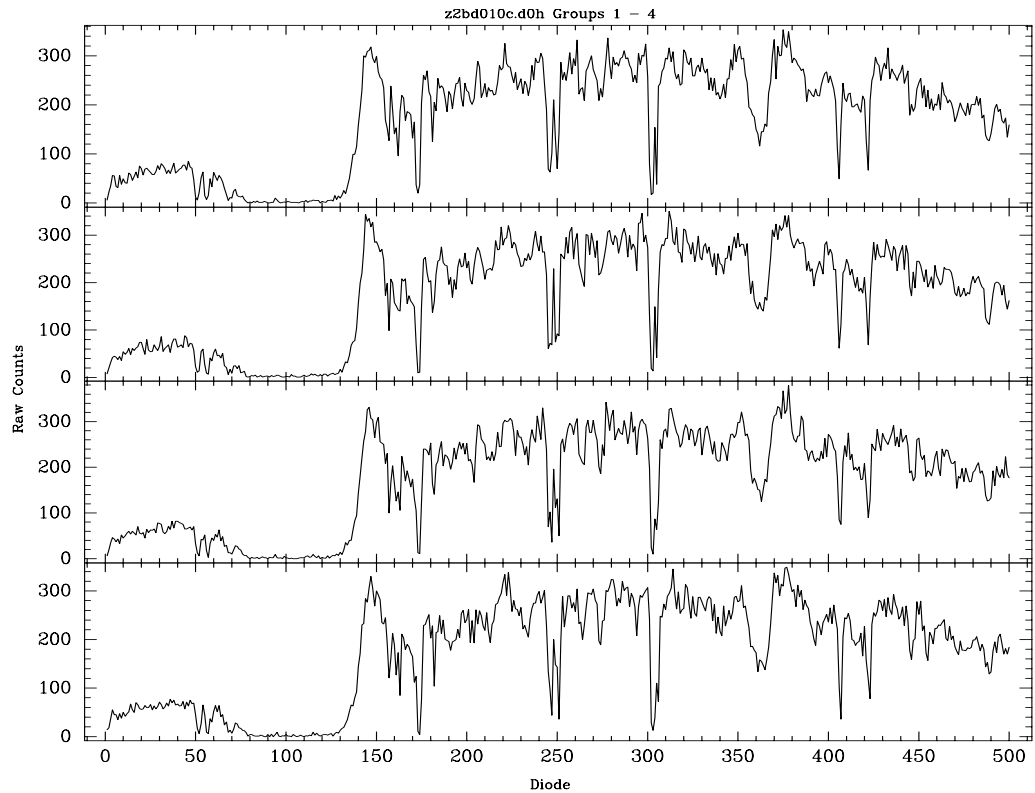
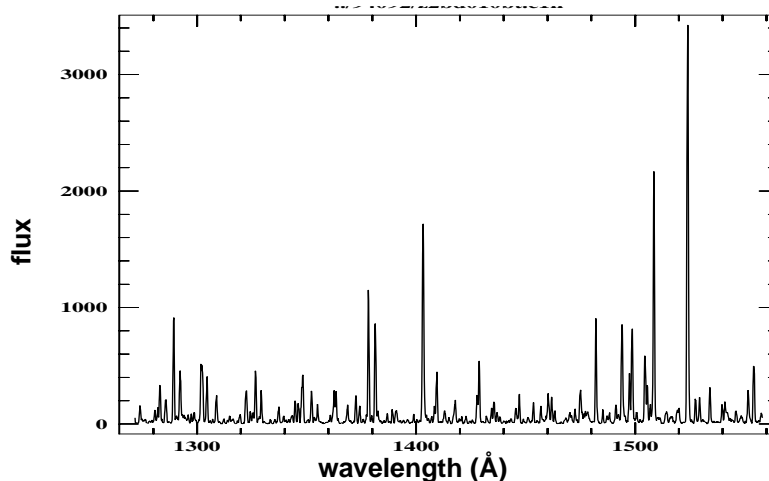


Figure 35.14: Raw Counts vs. Diode Number for Four Spectra in z2bd010c



The reduced spectrum in Figure 35.13 has a wavelength scale that is the default from the pipeline reduction system. There are two ways to improve on this, either by using a wavelength calibration exposure or by using a SPYBAL. For example, we can take the SPYBAL z2bd010bt and process it with **waveoff**. The SPYBAL exposure is shown in Figure 35.15, and the net result is that we compute a wavelength offset of  $0.708 \text{ \AA}$ . See the help file for **waveoff** for examples of how to use it.

**Figure 35.15:** SPYBAL Exposure z2bd010bt

### 35.6.2 Putting FP-SPLITS Back Together

Specifying FP-SPLIT=FOUR (or any value except “NO”) on the exposure logsheet resulted in small motions of the grating carousel between individual subexposures. This moved the source spectrum slightly on the diode array, making it possible to distinguish fixed-pattern noise from true spectrum features and to correct for that pattern.

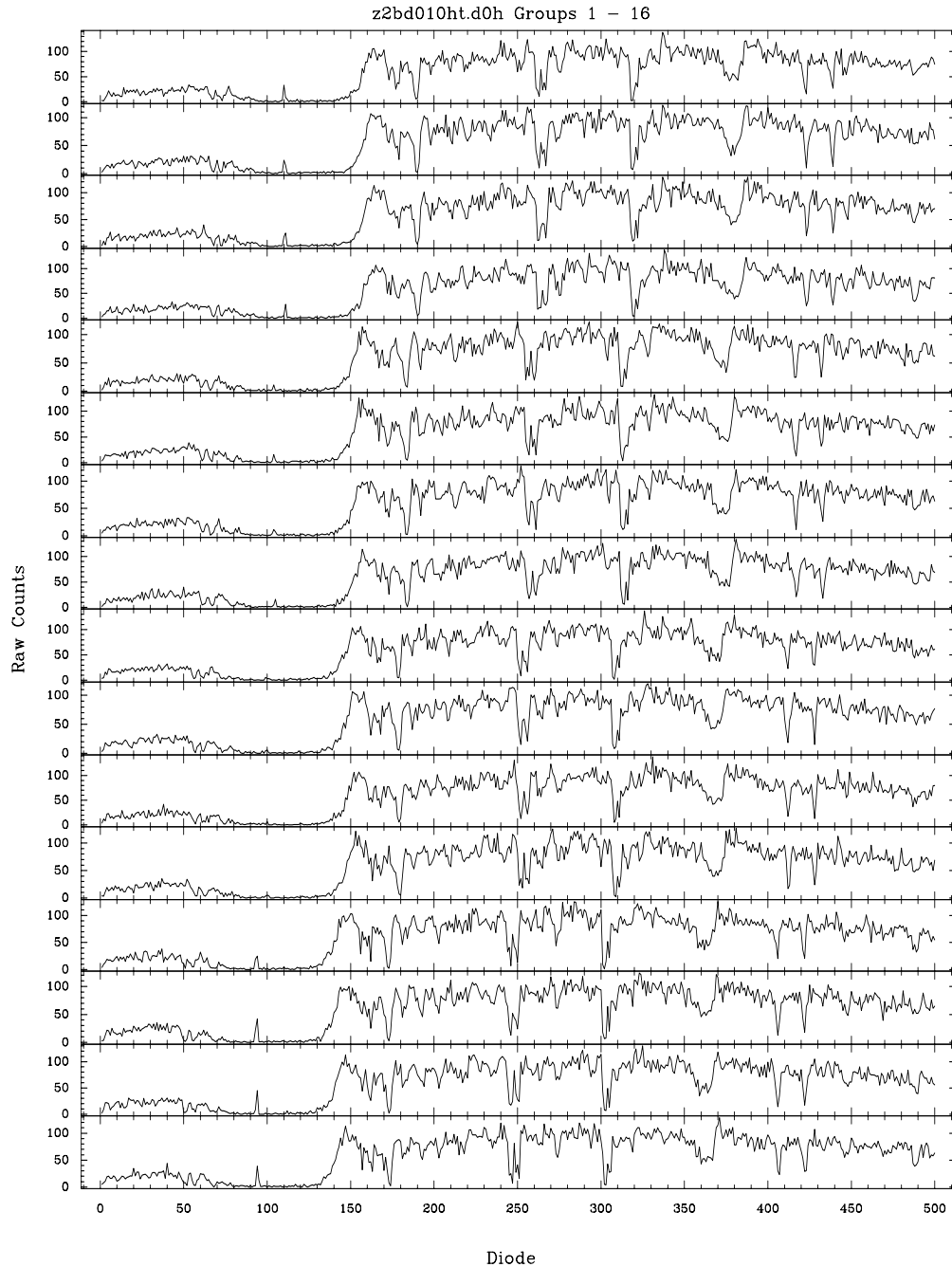
The most sophisticated use of FP-SPLITS involved iteration to determine a function representing the fixed-pattern noise. This could be augmented by obtaining spectra with larger discrete motions of the grating as well.<sup>4</sup> Here we describe the simplest use of FP-SPLITS for achieving more modest gains in signal-to-noise. This involves simply realigning the individual subexposures so that spectrum features line up, and then adding up the spectra.

The best way to align the subexposures is by cross-correlating them against the first exposure obtained. When there is not enough signal-to-noise for that, it is possible to determine the shift to apply from knowledge of instrument parameters, but the factors that limit the quality of the wavelength scale (see “Wavelength Data Quality” on page 37-26) make that method inferior to cross-correlation.

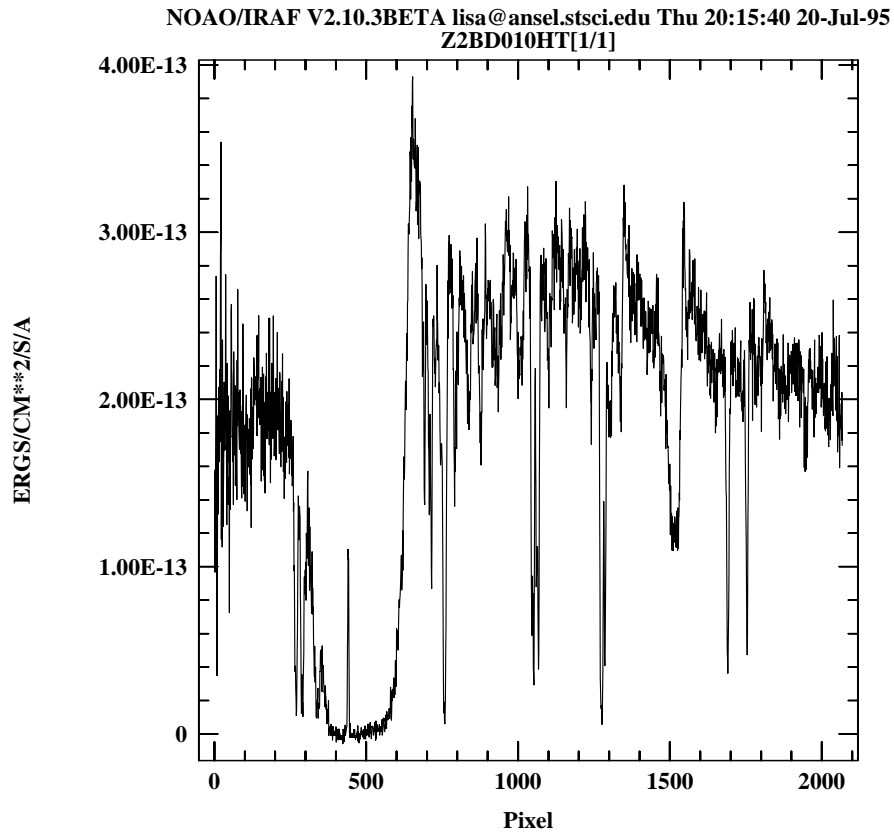
The cross-correlations to restore FP-SPLITS are done in **stsdas** with the **specalign** task. An example of raw data produced by an FP-SPLIT is shown in Figure 35.16.

---

4. See the discussion by Cardelli et al., 1993, *ApJ.*, 402, L17; Cardelli and Ebbets 1994, in *Calibrating Hubble Space Telescope*, J.C. Blades and A.J. Osmer eds., (Baltimore: STScI), 322.

**Figure 35.16:** Raw FP-SPLIT Observations for R136a5

Note that there are four groups of four (due to STEPPATT=3), with a shift in wavelength after every fourth spectrum (due to the FP-SPLIT setting). The result of shifting and adding all the subexposures for R136a5 is shown in Figure 35.17 using **sgraph** to show that there are more pixels in the combined spectrum than in the output of the pipeline software.

**Figure 35.17:** Summed Spectrum for R136a5

## 35.7 RAPID Mode (and a Little About Spatial Scans)

RAPID mode was used relatively rarely, but it had some unique capabilities. There are also some unique problems that arise in treating the resultant data.

Proposal 5745 was a calibration test designed to map out the central portion of the PSF as presented to the GHRs apertures by COSTAR. This particular test made use of a spatial scan to map out the PSF while collecting data in RAPID mode.

### 35.7.1 The Exposure Logsheet

An abridged version of the Phase II Proposal for 5745 is shown in Figure 35.18. Here are some notes to go with individual lines of the Exposure Logsheet:

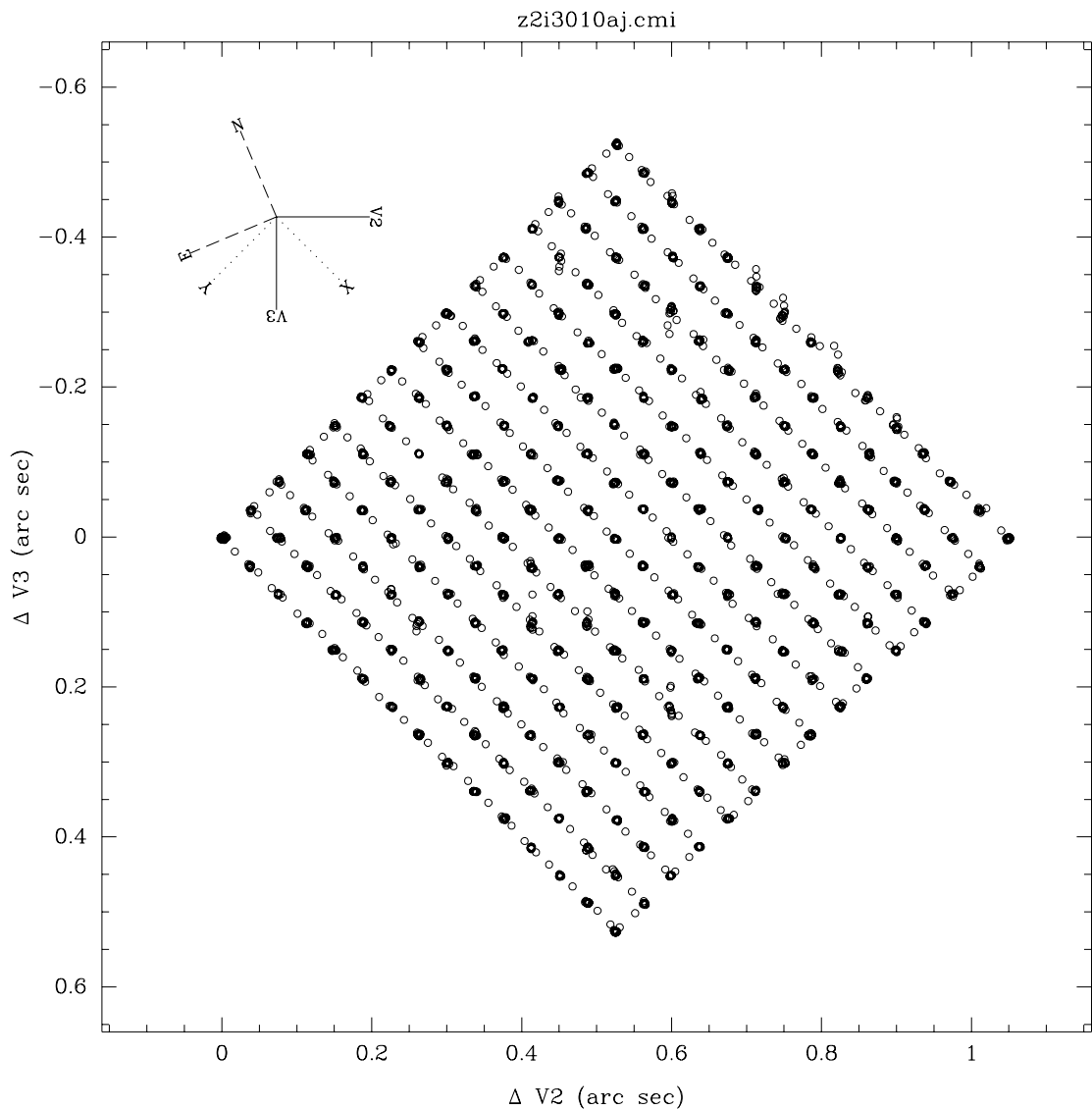
- **Line 10:** Sk-65°21 was acquired with an ONBOARD ACQ using MIRROR-N1.
- **Line 15:** A confirmation IMAGE was taken as a sanity check for this program. In general, an IMAGE was unnecessary.

Figure 35.18: Exposure Logsheet for Program 5745

EXPOSURE LOGSHEET														
Line Number	Seg Name	Target Name	Instr Config	Oper Mode	Aper or FOV	Spectral Element	Central Waveln.	Optional Parameters	Num Exp	Time	S/N	Fix Ref	Pr	Special Requirements
1														15
10	SK-65D21			ACQ	2.0	MIRROR-N1		SEARCH-SIZE=5 BRIGHT=RETURN	1	25S			1	ONBOARD ACQ FOR 15 -20 CYCLE 4 / 10-40
Comments : STEPTIME=1.0S EXPECT APPROX. 2800 COUNTS/S TARGET IS IN CVZ														
15	SK-65D21			IMAGE	2.0	MIRROR-N1		NX=16 NY=16 DELTA-X=4 DELTA-Y=4	1	256S			1	
Comments : STEPTIME=1.0S														
20	SK-65D21			ACQ/ PEAKUP	0.25	MIRROR-N1		SEARCH-SIZE=5	1	25S			1	ONBOARD ACQ FOR 25
Comments : STEPTIME=1.0S														
25	SK-65D21			ACQ/ PEAKUP	0.25	MIRROR-N1		SEARCH-SIZE=5	1	25S			1	ONBOARD ACQ FOR 40
Comments : STEPTIME=1.0S														
40	SK-65D21			RAPID	0.25	G140L	1400	SAMPLE-TIME=1.0	1	112.5M			1	SPATIAL SCAN SINGLE-EXP
Comments : 15X15 GRID WITH 0.053 ARC SEC SPACING EXPTIME AT EACH DWELL POINT=30S														
Scan Parameters Form Proposal ID: 5745 [ 5 ]														
Data ID: 1														
Exposure Logsheet Lines: 40														
FGS Scan: DWELL														
Scan width (arc-secs): 0.7420														
Number of lines: 15														
Scan Frame (CEL or S/C): S/C														
Dwell Only: dwell points/line: 15														
Scan length (arc-secs): 0.7420														
Scan rate (arc-sec/sec): 0.0000														
Length Offset (arc-sec): 0.3710														
Seconds per dwell: 30.00														
Angle between sides (degrees): 270.00														
PA of first scan line (degrees): 90.000														
Width Offset (arc-sec): 0.3710														

- The geometry of the spatial scan is shown in Figure 35.19. The **splot** display shows the relative orientations of the GHRIS  $x$ ,  $y$  and HST V2-V3 coordinate systems. Data points are delta distances in units of arcseconds.

**Figure 35.19:** Geometry of a Spatial Scan



- **Line 20:** Sk-65°21 was moved to the SSA using an ACQ/PEAKUP. The STEP-TIME was increased to compensate for the reduced throughput of the SSA relative to the LSA and to increase the signal-to-noise for the PEAKUP algorithm.
- **Line 25:** Another ACQ/PEAKUP. Again this is an exception rather than the rule for SSA ACQ/PEAKUPS (except when using MIRROR-A1).
- **Line 40:** This is the line where the spectra were obtained. A RAPID of 112.5 minute duration with a SAMPLE-TIME of 1.0 seconds was specified. We expected to get about 6750 individual spectra from this observation.

- **Spatial Scan:** The spatial scan specified a dwell scan that was 15 dwell points by 15 dwell points in extent. The spacing between dwell points was 0.053 arc seconds (about two deflection steps). The time spent at each dwell point was 30 seconds. Note that the total number of spectra was 30 one-second exposures, times 15 dwell points, times another 15 dwell points in the other direction, for a total of 6750.

## 35.7.2 Examining the RAPID Data

First let's look to see how many individual spectra we have:

```
cl> imhead ../data/z2i3010at.d0h,../data/z2i3010at.c1h 1-
../data/z2i3010at.d0h[1/9024][500][real]: Z2I3010AT[1/9024]
../data/z2i3010at.c1h[1/9021][500][real]: Z2I3010AT[1/9021]
```

The **imheader** task shows that we have many more spectra than expected. Further investigation turned up the fact that ten seconds was allocated for the slew from dwell point to dwell point. So we ended up having an extra ten seconds for each slew. Not all of these extra spectra are useful since the telescope was actually moving, but we ended up getting about 35 seconds per dwell point instead of the anticipated 30 seconds. The **imheader** output also shows that there are three less spectra in the calibrated output than in the raw data. Keep in mind that since there is no substepping or FP-SPLITS possible when using RAPID mode, that a single raw spectrum maps to a single calibrated spectrum. (Contrast this with a standard ACCUM with the default STEP-PATT: the raw data would contain six individual spectra—four substeps and two background spectra—which would be merged into a single calibrated spectrum.) In the case of RAPID mode, the first two readouts were generated during a hysteresis sequence that preceded every observation, and the last readout was produced by a final pass deflection made at the end of every observation. These readouts contain no useful science data and are not included in the calibrated data.

Manipulating a very large image can be difficult. For demonstration purposes, let's examine an arbitrary subsection of the original raw image in Figure 35.20. The **gcopy** task was used to extract a subset of groups from the original multi-group image. **gstat** computed the statistics for the new image.

Examining RAPID data as a two-dimensional image can be instructive. A simple way to convert the multi-group subset.hhh into a two-dimensional image is to use the **gftoxdim** task.

```
cl> gftoxdim subset.hhh subset_d2.hhh
```

The new image is now two-dimensional: the first dimension runs from diode 1 to 500 while the second dimension marks time.

```
cl> imhead subset_d2.hhh 1-
subset_2d.hhh[500,41][real]: SUBSET_2D[1/1]
cl> display subset_d2.hhh 1 z1=0 z2=40 zr- zs-
```

**Figure 35.20:** Manipulating a Large Image

```

cl> gcopy ../data/z2i3010at.d0h subset.hhh groups=4604-4644
../data/z2i3010at.d0h -> subset.hhh
cl> gstat subset.hhh groups=*
# Image Statistics for subset.hhh
# GROUP      NPIX      MEAN      MIDPT      STDDEV      MIN      MAX
  1          500     10.048    9.00849    5.7949      0.      28.
  2          500      9.68     9.87606    5.31584     0.      24.
  3          500      10.      9.12097    5.48161     0.      27.
  4          500     10.334    9.88548    5.68217     0.      27.
  5          500     10.174    9.94917    5.75412     0.      28.
  6          500     10.166    9.00516    5.83254     0.      28.
  7          500     10.014    9.06106    5.56919     0.      25.
  8          500     10.04     9.8603     5.64465     0.      29.
  9          500     9.792     9.00807    5.29384     0.      28.
 10         500     9.886     9.92473    5.40587     0.      26.
 11         500     9.818     8.99274    5.39881     0.      28.
 12         500     10.072    9.82091    5.79603     0.      27.
 13         500     10.092    9.89125    5.59913     0.      25.
 14         500     9.856     9.10092    5.50562     0.      29.
 15         500     10.004    9.05718    5.64195     0.      29.
 16         500     9.822     9.01055    5.71381     0.      35.
 17         500     9.952     9.88586    5.57313     0.      24.
 18         500     10.054    9.94277    5.68822     0.      30.
 19         500     9.856     9.01978    5.35805     0.      25.
 20         500     9.958     8.97168    5.75312     0.      28.
 21         500     9.916     8.98258    5.69824     0.      26.
 22         500     10.07     9.86902    5.49741     0.      23.
 23         500     9.834     9.90083    5.55231     0.      25.
 24         500     10.206    9.83871    5.75446     0.      32.
 25         500     10.122    9.00645    5.72859     0.      28.
 26         500     10.148    10.128     5.65137     0.      31.
 27         500     10.286    10.0233    5.7052      0.      28.
28 500      9.76     9.03122    5.41859     0.      25.
29         500     10.068    9.04799    5.69493     0.      25.
30         500     10.12     10.0108    5.52473     0.      28.
31         500     9.908     8.98854    5.53071     0.      26.
32         500     9.856     9.09568    5.40905     0.      29.
33         500     10.076    9.90533    5.61045     0.      25.
34         500     9.942     9.84996    5.42379     0.      27.
35         500     9.822     9.88937    5.39598     0.      25.
36         500     9.832     9.87903    5.58553     0.      25.
37         500     10.206    9.8606     5.54952     0.      27.
38         500     10.05     9.8626     5.61128     0.      26.
39         500     10.102    9.97581    5.49509     0.      25.
40         500     10.304    9.91161    5.80646     0.      27.
41         500     9.926     8.99917    5.49809     0.      32.

```

We can sum the two-dimensional image in each dimension for further inspection:

```

c1> blkavg subset_2d.hhh subset_sum_y.hhh b1=1 b2=41 option=sum
c1> blkavg subset_2d.hhh subset_sum_x.hhh b1=500 b2=1 option=sum
c1> imhead subset_sum_?.hhh l-
subset_sum_x.hhh[500,1][real]: SUBSET_SUM_X[1/1]
subset_sum_y.hhh[1,41][real]: SUBSET_SUM_Y[1/1]
    
```

Figure 35.21 shows plots of three images. At the top is a greyscale plot of the extracted two-dimensional image, in the middle is a plot of the sum of the 500 diodes as a function of time, and at the bottom is a summed plot of the spectra over time.

**Figure 35.21:** RAPID Data Displays

