

# GIS CALIBRATION PROCEDURES

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# Chapter 1

## INTRODUCTION

This document is intended to fill a gap in the CDS documentation. The calibration procedures for the Grazing Incidence Spectrometer (GIS) are complicated, and have in the past been performed with some consistency, but without proper documentation.

In October 2005, Nearly ten years after start of CDS operations, I was hired to investigate the GIS calibration, as questions had been raised regarding its pointing, a clear degradation in the performance of the GIS 1 detector, and the quality of the latest calibration of 2003, which was based on the known characteristics of Microchannel Plate (MCP) aging and observed line widths and intensities in the major spectral lines.

The development of the GIS was done by a team of young graduates and their work has been published, including in their Theses. Of particular interest is the thesis work by Alice Breeveld, who describes the detector and ground testing of GIS performance. Her thesis also gives the mathematical formulas used in developing the GIS software. The final formulas used in the operational code I can only find described in some solarsoft GIS routines, and I intend to write them down in this document.

The developers of GIS had to make some hard decisions due to limited processing capability, limiting electronics capability, and limited telemetry being available. Their solution was to allow several modes for the GIS:

1. The operational mode, where data are aggregated into bins according to a certain, potentially adjustable, set of parameters, called a 'GSET'.
2. A 'raw' data mode where samples of the data are sent down in real-time telemetry. Uplink commanding capability is required for this mode, and the data are not calibrated.

3. A 'filament' mode, where a tungsten filament illuminates the detectors for obtaining a flat-field.

The concept of the instrument operation was that the gset used for the operational mode could be determined in a calibration exercise in the raw data mode, and that the detector degradation can be monitored using the filament mode.

After launch several problems developed. The first had to do with the assumption that the spectrum could be wholly contained in a mapping structure that can be visualized in the form of a spiral in a 2-dimensional data plane, as specified by the GSET. Some of the spectral lines did 'ghost' across spiral arms and thus contributed counts to other parts of the spectrum. The second problem was that the amount of ghosting varied over time, as a function of the decreasing sensitivity of the detector in spectral lines. The third problem was, that the filament exposures illuminated the detector wholly, but from a different incident angle than the EUV photons from the grating. Moreover, the EUV image of the slit on the detector does not illuminate the same area as the filaments: it is only 16 mm instead of 25mm. Over time the reliability of the filaments for providing a flat field was put into question. Precise details of that are not available to me, so I cannot comment on it. A final blow was that in June 1998 during loss of control of the spacecraft, the CDS instrument became heated to over 100 degrees. After the attitude recovery, new raw data were not obtained until the latter part of 1999, meaning that the GIS was operating for a year on the faith that there had not been any ill aftereffects of the SoHO loss. In fact, there were, affecting pointing and detector response, as were discussed in Kuin and Del Zanna (2006a, 2006b), and in this manual.

## Chapter 2

# HISTORY

As far as I can reconstruct, the initial commissioning of the GIS in 1996 was the first period where ample raw data were obtained. A number of GSETs were derived for operational use, and depending on the to be expected count rates, different GSETs are loaded. Thus there are different GSETs for each slit and for each region (CH, QS, AR). Then a period followed where work was done to identify ghosts, and spectral lines.

During the first few months the gain showed much change. After the commissioning period in 1996 and the end of 1997 the GSETs were not changed, and an inspection of QS spectra shows that the count rates decrease in the stronger lines. That is partly due to long term gain depression (LTGD), a decrease in response of the MCPs used in GIS, but also partly due to an increasing number of counts in some lines going into ghosts. An adjustment was made to the GSETS in 1998, after which ghosting was reduced close to the value at commissioning. After the SOHO loss, and until new gsets were prepared late in 1999, some lines show above average intensities, and some below average, suggesting that the gsets were bad for that period. It is likely that the voltages over the detectors were too low, and also the gain of the electronics had changed sufficiently to cause additional ghosting in unexpected parts of the spectrum. The GSETs introduced in 1999 fixed that problem, and apart from a continued gain loss in some strong lines, and a continued broadening of the lines over time, the spectral line intensities were back in line with those of pre-SoHO loss. Subsequently, some raw data were taken in 2001, and 2003, and only minor adjustments to the GSETs were made. In this respect the GIS has shown to be a very stable instrument. In 2004 some changes to the spectra are occurring, but they are subtle, and I cannot easily describe them. From early 2005 to March 2006, the voltages had become too low in detector 1 to get a proper detector response, i.e., many of the weaker events were lost and the positional ac-

curacy of the detector was affected as seen in a large broadening of the lines, as well as additional ghosting. The other detectors (2,3,and 4) showed smaller effects, mostly due to a decreasing performance of the electronics. Late April 2006 new GSETs were developed based on raw data taken at that time which has restored the GIS once more to good working order.

A wavelength calibration was determined by Barbara Bromage, and became standard with the use of GSET 22. The use of 4.2 spiral arms became a standard for GSETs up to 2006, when an extra arm was added to the GSETs in order to capture the counts being lost from increased ghosting into the last arm. That required a new wavelength calibration, which was based on the earlier one. Possibly, some GIS software depends on an implicit assumption of the number of spiral arms being 4.2. So far, a problem has not been seen, but the extra arm causes also a very slight shift in the positions of ghosts due to the new wavelength scale fit.

Pointing of the GIS was not investigated until the end of 2005. Initially, the GIS was coaligned with the NIS, and it is likely that this was checked during the SoHO commissioning phase, although I could not find a record. After the SoHO loss, some studies were apparently made by Carl Foley, resulting in a note in the CDS users guide that the GIS was offset relative to NIS by  $10''$ . In talking to some people at RAL, there was rumored to have been a compromise between two values. However, no record of the study could be found. The study I made of the limb position shows clearly that NIS pointing is correct and GIS is offset to the south by  $20''$ , with an additional pointing uncertainty (between subsequent repointings) of up to  $5''$  in any direction; with a FWHM of about  $3''$ . A cause for the pointing uncertainty is not known.

## Chapter 3

# DATABASES AND ARCHIVE

The SoHO operations maintains a log of all commands sent to the SC. Telemetry files that are received are processed to produce the science data (FITS) and raw data files. The CDS science data files are numbered consecutively, with separate files for each raster like: 's'+number+'r'+number. Therefore it is easy to see if a file is missing. The raw files are named according to the date, time, detector number, slit number, and are either of type 'raw' or 'pha'. No list of all the raw files is maintained. They are kept in a separate directory. Filament exposures can be either science mode or raw mode files, but in practice only raw mode files have been obtained during the mission to my knowledge (in science mode they are zone\_id = 7(CALIBRATION) as can be seen in mk\_plan).

In practice, raw files are obtained for different values for the high voltage (HV) setting over the MCP+electrodes of each detector, each slit, and each region. Only when the HV setting is right, the raw data can be used to derive a GSET. For this reason, only certain raw data are important to reference. These raw data files are referred to in either the GSET\_DESC field in the GSET, or in the RAW data base, as referred to in the GSET by the RAW\_ID field.

The GSET descriptions are in turn maintained in a GSET data base. Finally, there is a WAVECAL data base which tracks the wavelength calibration that belongs to each GSET. Both the RAW data base, the GSET data base and the WAVECAL are IDL databases maintained within Solarsoft.

### 3.1 DESCRIPTION OF THE RAW DATABASE

The RAW database does provide some information about the RAW datafile. The key is the RAW\_ID, and the main field is the RAW filename. Using Solarsoft CDS/GIS routines VIEW\_PHA or VIEW\_RAW, a number of parameters will be

determined from the raw data that appear in the RAW database.

The fields in the RAW database are:

FIELD	TYPE	EXAMPLE	DESCRIPTION (note #)
RAW_ID	INT	100	sequential ID number
RAW_DESC	STRING	'2006-04 baseline QS gset'	text describing entry
START_TIME	DOUBLE	1.5249600e+09	start time in TAI
DET_NUM	INT	2	GIS detector
SLIT_NUM	INT	2	CDS slit
HVOLT	INT	205	high voltage setting (1)
LLD	INT	0	lower level discriminator
CNT_RATE	INT	[ 7663, 67 ]	average raw, ULD counts(2)
RAW_FILE	STRING	'200604282104_d2_s2.raw'	file name
FFB	INT	-1	front face bias (3)
FIL_ID	INT	0	filament id (3)
FIL_CUR	INT	0	filament current (3)
ZONE_ID	INT	5	zone_id (4)

Note 1: The high voltage settings are coded as follows:

$$HV = (HVOLT / 255) * 5.09kV \quad (3.1)$$

where HVOLT is the decimal HV value used in the database, GSET, and commanding.

The translation is approximately:

decimal	kilovolt
200	3.99
205	4.09
210	4.19
220	4.39
230	4.59
240	4.79
250	4.99
255	5.09

5.09 kV is the maximum possible value of the high voltage over the detectors.

Note 2: The average count is given, as well the number of counts that are lost above the upper level discriminator. When observing, the operator will start with obtaining these count rates. The GIS calibration scientist then decides, based on the count rates, if the pointing is correct (i.e., a quiet region gives about 8-10 times less than an active region, and a larger slit gives of course more counts as well). The GIS calibration scientist also bases the decision for go/no go on the ULD counts: if the setting of the HV is too high the detector spends too much time in a feedback mode, producing unusable counts that are rejected because they are above the ULD limit. It is thus a sanity check and useful for both instrument safety and saving time.

Note 3: These fields are only interesting for filament observations. The FFB field seems to be filled with +1 or -1 for default or not, and is counterintuitive at that, because the sign of the voltage is opposite.

Note 4: The zone\_ID is

- 4- quiet region, quiet sun
- 5- active region
- 7- filament

The GIS tends to saturation during flares, so GSETS for flares are not made. If an occasional flare is observed, the total count rate needs to be checked in order to establish if the calibration is reliable.

## 3.2 USING THE RAW DATABASE

The RAW database lists RAW files that at some point were thought to be useful. It should include all files used in GSETS, but some GSETS do not list the RAW\_ID but the raw filename in another field instead.

An entry from the RAW database in Solarsoft can be retrieved using GET\_RAW, i.e., to get the information for entry 20, the IDL command 'get\_raw, 20, defraw' will put the information in structure *defraw*. To put information in the RAW database, first edit a structure *defraw*, with RAW\_ID=0, then set *!priv > 1*, and finally use IDL command 'result = add\_raw(defraw)',

I.e.,

```
CIDL: get_raw, 20, def
CIDL: def.raw_id=0
CIDL: def.start_time=ANYTIM2TAI('12-DEC-2008')
... (edit the other fields to with the information of the new raw file)
CIDL: help, def, /st (check the new information carefully.
changes cannot be made to most fields)
CIDL: !priv=2
CIDL: result=add_raw(def) & print, result, def
(now the database will be updated, and def will be updated with the new RAW_ID.
CIDL: !priv=1 (reset )
```

Next action would be to generate a new GSET, which is treated in its own section. Once the new GSET has been generated, you will have to enter the information in the GSET database to be available for planning and within Solarsoft. Remember to write down the RAW\_ID numbers that belongs to the raw files that you will be using for the new GSET.

### 3.3 THE GSET DATABASE

The GSET contains for all 4 detectors the settings for HV and look-up table (LUT) creation, as well as some auxiliary information used during planning.

The database fields are:

FIELD	TYPE	EXAMPLE				DESCRIPTION
GSET_ID	INT	90				Assigned by ADD_GSET
HVOLT	INT Array[4]	211	204	199	198	HV decimal value
LLD	INT Array[4]	0	0	0	0	Lower Level Discriminator
LUT_CHKSUM	STRING Array[4]	0000	0000	0000	0000	not used
LUT_PAR	BYTE Array[4,11]					find using VIEW_RAW
		99	99	99	99	percent
		83	83	83	83	arm end
		31	31	31	31	arm start
		220	200	195	215	k
		226	225	228	225	zpln
		175	251	223	171	phi
		8	8	8	8	nobits (always 8)
		1	2	3	4	detector number
		99	97	105	99	X-gain
		104	106	104	104	Y-gain
		101	104	100	99	Z-gain
RAW_ID	INT Array[4]	116	117	118	119	From making entry in RAW DB
SLIT_NUM	INT	3				
ZONE_ID	INT	4				See the notes to the
FIL_ID	INT	0				RAW DB description
FFB	INT	1				of fields
DET_USED	INT Array[4]	1	1	1	1	should be 1 if all on
GSET_DESC	STRING Array[4]	1 good PHD				note detector 1 (see in mk_plan)
		2 weak line optimised				note det. 2
		good phd				note det. 3
		4 good				note det. 4

Again, these values should be determined using view\_raw to find fitting parameters for the LUT, as described elsewhere. Write them down, and once you have them for all 4 detectors, and have added the raw files to the raw db to get raw\_id's, you can create this structure.

The way I created a new gset entry in the database once all the info was available goes like this:

Retrieve a gset entry for an existing gset, and then edit it for the new values.

Remember to reset the ID to zero.

```
CIDL: get_gset, 66, def (it helps to choose a current gset)
CIDL: def.gset_id=0 (needed for new entry)
CIDL: def.hvolt=[ 200, 200, 201, 203 ] ( here you enter the new values )
... continue until you are done. Check the values:
CIDL: print, LUT (look it over carefully. changes are not possible)
CIDL: !priv=2
CIDL: result=add_gset(def) & print, result, def
CIDL: !priv=0
```

The new gset\_ID should have appeared in the printed structure after the DB add operation. Now you can check that in various ways, for example, mk\_plan should now list the gset for that region, and the GSET\_DESC[1] will appear next to the gset options.

### 3.4 RETRIEVING AND LOADING A WAVECAL

The wavelength calibration needs to be added for each new GSET. If already a wavecal exists for the start and stop parameters, then that can be used for the new GSET by copying it from right the existing wavecal. The wavecal for 4.2 arms originally was for GSET 22. The new one for 5.2 arms is from GSET 82.

Here is the procedure:

```
CIDL: get_wavecal, 'GIS', '', wx, gset_id=82
CIDL: coeff=wx.coeff
CIDL: ... you can edit the coefficients matrix if needed ...
CIDL: result = add_wavecal('24-APR-2016', 'GIS', coeff, $
CIDL: gset_id=181, filename=' tell origin of wavecal ')
```

You first retrieve an existing wavecal. Extract the coefficients matrix. These are the quadratic coefficients in pixel space to get the wavelength for the four detectors. The example extracted the one from GSET 82, so if I have 5.2 spiral arms, I can use this coeff matrix straight for the new gset. The new gset example is for GSET 181. Put in the date field the date of the insertion of this entry, and in the filename field you can enter a description of up to 80 characters, like, 'Copied from GSET 82'.

Once the wavecal database has been updated, the GIS display software will show the proper wavelengths in the plots.

If a new wavecal is needed, you have to observe the sun with the new GSET\_ID first. Once you have the observed spectrum, you will need to make a list of line center and pixel number of the best known lines in the spectrum. Then fit a quadratic through them.

$$wave = a_0 + (a_1 + a_2 * pixno) * pixno \quad (3.2)$$

Do that for all four detectors. Check your fits work. Now you can follow the procedure above, but you edit the coeff matrix with the new coefficients of the quadratic fits to the wavelength before loading the new entry into the database.

## Chapter 4

# PROCEDURES FOR TAKING RAW DATA

### *To Prepare or not to Prepare.....*

If this is the first time that you are going to work on the GIS, it is necessary to familiarize yourself with the GIS. You may want to start with the thesis of Alice Breeveld, called: "Ultraviolet Detectors for Solar Observations on the SOHO spacecraft"(UCL,1996). A scanned copy is available on the GIS MSSL website. Required reading is Chapter 5.1, "Spiral anode theory and GIS simulator; Spiral anode theory" which lays out in detail how the detector works and explains all parameters of the LUT.

Another item to look at is Matthew Whyndham's web pages on the GIS calibration. [http://www.mssl.ucl.ac.uk/\[tilde\]mwt/](http://www.mssl.ucl.ac.uk/[tilde]mwt/) select the 'research option', and read through the links under the heading 'Filament Dumps, Detector flat field, gain depression'.

Finally, before heading to the SOC at GSFC, talk to the operators. They can do raw dumps for which you have well-defined parameters, and then send you the results. A well-defined raw dump would be:

*Take a raw dump for Slit 2, Detector 3, HV =209; point at the quiet sun; continue taking raw data until the count rate goes over 5000.* You could also add that the raw count rate should be from 20-60, and ULD counts not more than 50%, as that is normally part of the procedure. (I did not have to do that, because the operator who worked with me (Ron Yurow) had experience enough to do that part himself.)

A good start is to get RAW dumps for the current GSET, (i.e., slit, zone, + value of the HV). You can then easily check that the GSET is still valid by running `view_raw, gset_id=XX`, with XX the GSET number. Remember, that in order to

do this, a space must be left in the plan, therefore, the science planner and the instrument scientist should be involved in the planning.

A final thing to do is to work with raw data and fit LUT parameters to them. There are several very different LUT parameter settings that will give nearly equal results. Watch for ghosting appearing in those spectral lines that can be ghost-free, and which lines will trade ghosting from shorter to longer wavelengths when parameters change. An example is 180.4 which always will stick out one way or both ways into the other arms. Get familiar with which lines always ghost.

## 4.1 Taking Raw Data at the SOC

First of all, make sure that the SOC knows that you're coming, when you're coming, and make sure to check that you get the preferred unaccompanied weekend access to GSFC if you need it. Otherwise you will have only accompanied access during the weekend, that means the CDS operator. You go to the loo with your GSFC accompaniment! There are several other formalities that need to be taken care of, and the GSFC foreign visitor office needs in some cases 3 weeks to issue permits for access to GSFC. You need that especially since the SOC is located within the secure area.

Check your plans with the CDS operator, and when ask they will be present. Their working hours vary. Before traveling you need to make sure there are enough real-time (commanding) telemetry slots available during working hours, so doing this work during Key holes is not possible. (But that is a good time to schedule the occasional filament dump for which the doors need to be closed).

Once you are at the CDS operations center, you should start with checking the current Sun and decide where you want to point CDS at. Have that ready: Coordinates written down in your notebook. The operator will have to wait till the current plan completes running, and wait for a long enough real-time telemetry slot. You can check the telemetry slots using **mk\_plan**.

You then proceed to give the operator the CDS pointing, Slit, and Detector+voltage. The operator will first park the voltage on all detectors, point the CDS, and then enter the slit and detector+voltage commands. After a few seconds the operator display will show the raw count rate and ULD count rate. These vary from slit to slit and from region to region, and with voltage and detector, and time. Do not confuse the rate with the total raw counts in the observation.

Some Typical values:

SLIT	Region	Det HV	Raw Count Rate	ULD counts
1	4 - QS	1	211	142 48
2	4 - QS	1	212	254 75
2	4 - QS	2	202	126 36
2	4 - QS	3	198	115 18
2	4 - QS	4	198	230 68
3	4 - QS	1	211	10064 2311
1	5 - AR	1	211	498 133
2	5 - AR	1	211	3655 1142

These ballpark numbers are useful for checking your pointing, and to avoid unreasonable settings, e.g., if the ULD counts become too large a percentage of the total count rate. This is the actual count rate on the detector, not the accumulated count rate which is called the same thing in a lot of CDS IDL procedures. In the original instructions the goal was set of 10% ULD counts, but in the 2006 raw data takes it appeared that such a value is unrealistic. The operational values in earlier RAW data for gsets show values between 20-40%. If you are interested you could check that using the gsets and related raw data.

Once you say 'OK' to the count rate, the operator will command the collection of the data to start, and a file will be opened on the disk `$CDS_GIS_RAW`. You can see the filename appearing on a monitor if the operator sets it up right, or you can check in the filesystem (e.g., in `$CDS_GIS_RAW`). You will find, that you can examine the data during collection, with, for example, `view_pha`, or, `view_raw`.

#### 4.1.1 Procedure for taking data for Detector 1, 3, or 4

It is easiest to start with Slit 2, as the PHA for this slit is the best behaved. Also, the voltage settings for the other slits should not be too much different than that for slit 2. The PHA measures the distribution of pulse heights. Ideally, all pulse heights would be similar, giving a sharp peak. In practice, the peak is quite broad, and for Slit 1 the detector response becomes essentially flat. If the pulse height of an event is too weak, the event will not get measured by the electronics. More events are too weak when the HV is too low. When the HV is increased too much, the detector channels may experience a positive feedback due to the excitation of protons from the channel walls, resulting in very large PHA events. These are discarded by establishing the ULD limit. Counts above the ULD limit are discarded. If too many counts fall above the ULD limit, the detector spends a large amount of time in a mode that it is not designed for; thus the percentage of ULD counts should be evaluated in deciding on the correct setting for the HV.

When calibrating the detectors, the calibration scientist has to make allowances for the detector limitations. These limitations include those due to the maximum count rate due to dead time, limitations due to the way the calibration was done in

the past 10 years, and limitations due to the interplay of HV and detector response for each spectral line which varies per detector.

In the following I will therefore lay out in detail the procedure I followed and give my arguments for doing so.

I started with Slit 2, Detector 1, so I will do so here. In a way it is a good illustration, because the detector was so far out of spec.

Each observation is split into two files for analysis. The naming convention is YYYYMMDDHHMMSS\_d#\_s#.raw and YYYYMMDDHHMMSS\_d#\_s#.pha. Each with a 512 byte header. The raw file list then randomly sampled pairs of X,Y positions measured for each event, while the pha file measures a a random sample of pulse heights.

Initially, an exposure was obtained for the HV then currently used in GSET 66. The following figure shows the PHA distributions obtained for that HV setting and subsequent trials.

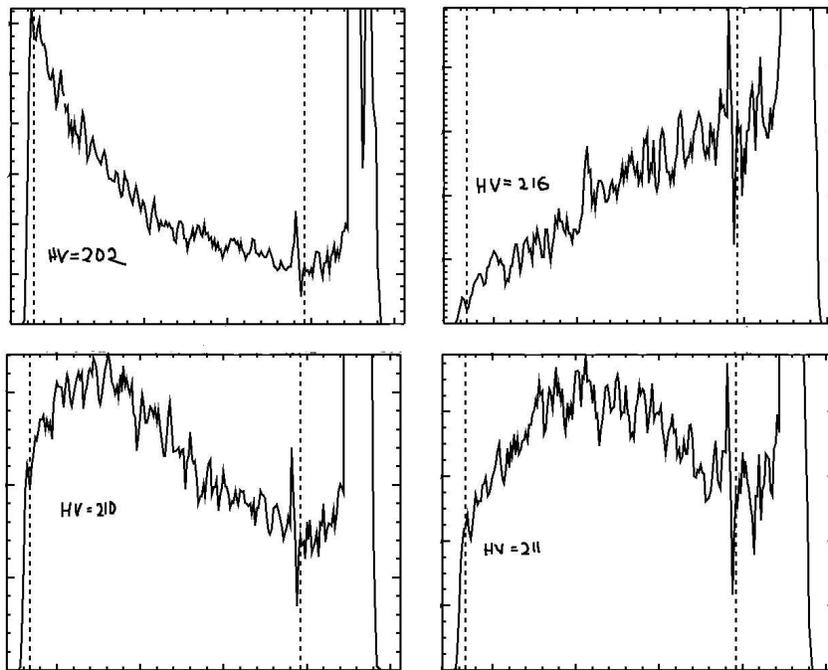


Figure 4.1: Subsequent PHA distributions in calibrating detector 1, slit 2, Quiet Region.

Notice that the HV setting used in GSET 66 at that time produced a PHA with most events at very low pulse height. The HV was clearly too low, and it is

reasonable to assume that counts were not detected due to their low pulse height. Before discussing the raw positional event data that accompanied this observation, I want to point out the subsequent data taken. First a value for the HV which turned out to be too high, with nearly all events going lost above the ULD. The next HV try was better, but the maximum was still on the low side. It took 2 more tries to get the maximum to be just at the 100-110 range, which is considered optimal for detector 1.

Now consider the positional data : You can see that the low HV values give

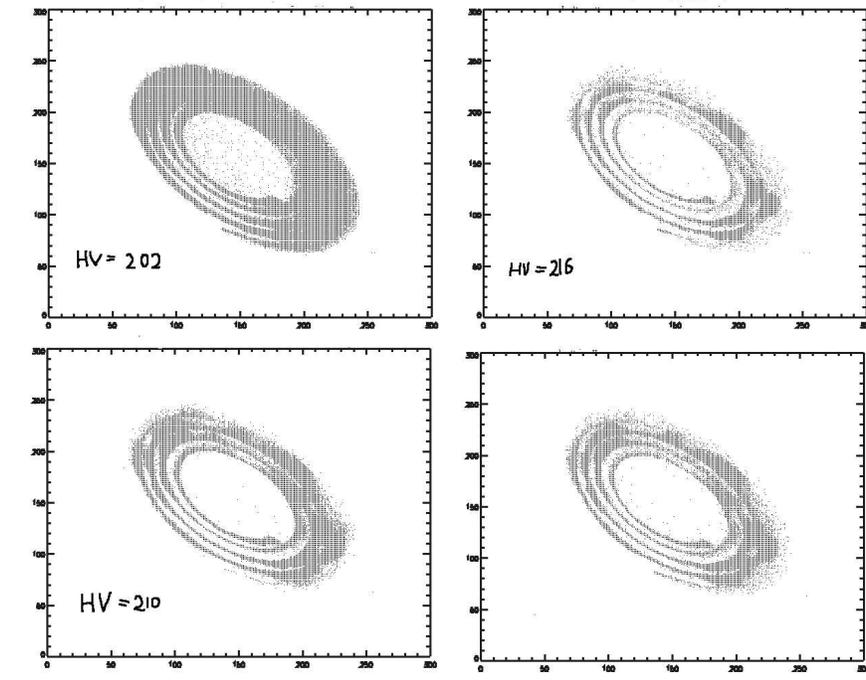


Figure 4.2: Subsequent Count positions in calibrating detector 1, slit 2, Quiet Region.

a washed out appearance, and increased counts lost across spiral arms. High HV sharpens up the spiral arms and decreases ghosting. When calibrating detector 2, the appearance of the spiral arms is one of the indications used to decide that the HV is good or bad.

But not only the HV is important in the calibration. The electronic pre-amplifiers show also aging and that can lead to a distortion of the mapping of the SPAN anode output to the data X,Y values. The next thing is to verify how well the gset still fits. Here, I present the fit in r-theta coordinates of the positional data to GSET 66

LUT parameters.

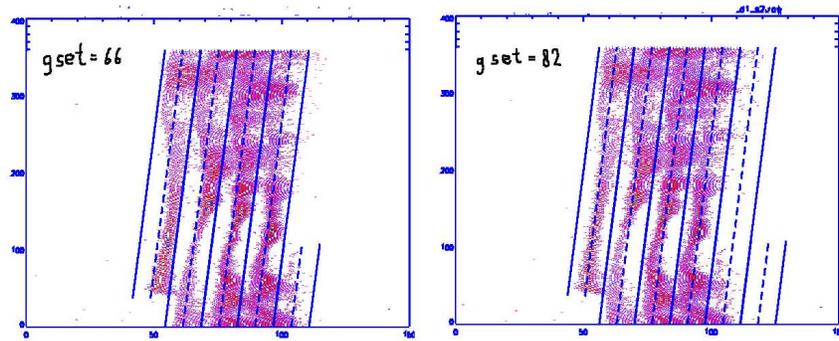


Figure 4.3: Spiral arm fitting in the r-theta plane using the old LUT, but different HV.

Note that in the first figure, at the settings for GSET 66 HV, the spiral arms are not falling within the LUT arm mapping any more. For the new optimized HV, the fit is much better, leading to the conclusion that the aging for detector 1 is mainly due to aging of the MCP, while the electronics shows only a small effect. If the electronics had aged instead of the MCP, the HV would not have to be changed, but changes to the LUT parameters would still be needed. We see this dominating the aging in detectors 3 and 4. Since there is not much to be learned from the PHA plots of detector 3 and 4: they are very similar to those of detector 1, I will not show those here. I only want to note that for detector 3 and 4 the optimum peak in the PHA was judged to fall for PH values in the range 110-140.

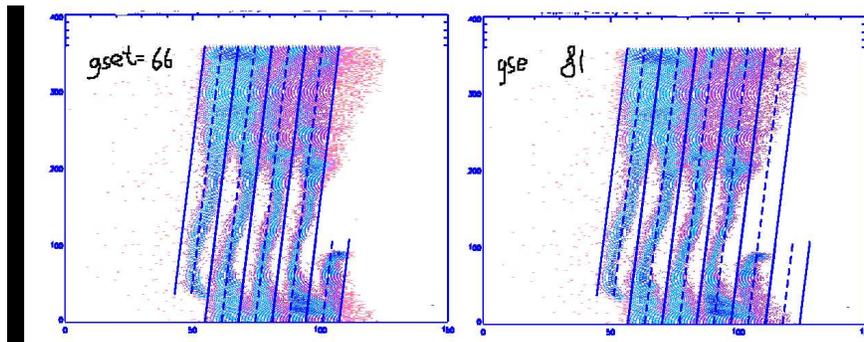


Figure 4.4: Detector 4 for old (66) and new gset (84).

The r-theta fits, for the GSET 66 (the old gset), for detector 3 and 4, and for the new HV settings, are interesting in that they show the LUT parameter changes

needed are not related to HV settings.

#### 4.1.2 Detector 2 procedure

Another useful tool is using the IDL procedure `gis_mapraw.pro`, written by Carl Foley, since it displays the  $r$ -theta plane, the rolled out spiral in pixel number- $r$  space, and the resulting spectrum as function of pixel number. The data has been averaged a factor 5 in the pixel-number plots, which gives a much better view of the lines. The rolled-out spiral forms a strip in pixel-space vs  $r$ , which allows one to see which lines obviously ghost into other regions by following lines of fixed  $r$  from the top of the strip to the bottom. Example command:

```
CIDL: y=gis_mapraw( 66, rawfiles='$CDS_GIS_RAW/200605021619_d2_s2.raw' )
```

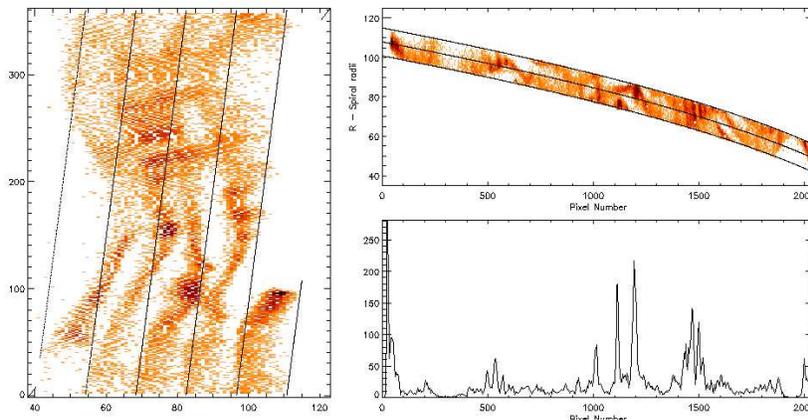


Figure 4.5: Mapping the raw data to the spectrum: `gset 66` to correct `gset66-HV` value in 2006.

This tool is also useful to run during the observing since it allows a quick evaluation of the spectrum to be made. I used this as the main tool to evaluate the data from detector 2.

Notice that the counts in the He II 304 and Fe XI 284 lines increase dramatically with increasing voltage. That is due to restoration of gain in the detector where the line is present. The problem is that these lines are so strong, that they cannot be calibrated, while at the same time restoration of those lines will saturate the detector electronics so that counts from the weaker lines will be depressed. Therefore, these lines must be kept to a reasonably small number of counts by not increasing the HV too much. Over time the weaker lines in det. 2 have not experienced much LTGD yet, but some evidence was noticeable, in particular the arms

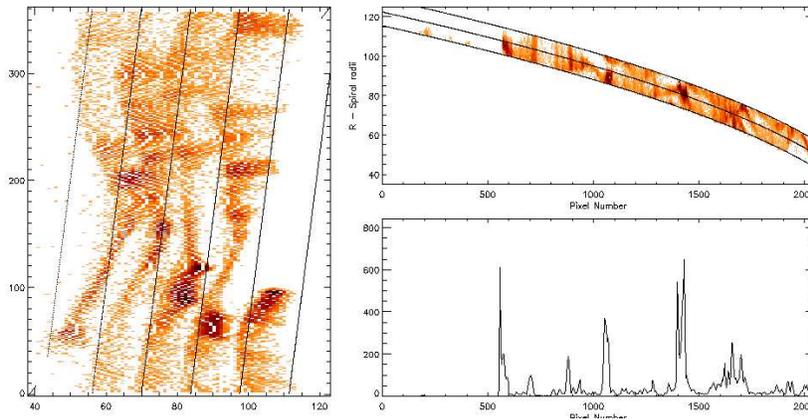


Figure 4.6: Fits to detector 2 raw data for HV=205, gset = 66.

were broadened and looking washed out. That is evidence that the HV was too low for the weak lines. Notice that for higher HV the spectral arms look thinner, and the lines more pronounced. The goal of the calibration for detector 2 is, to maintain a sensitivity of the detector that is consistent with the detector sensitivity over most of the past 10 years, in order to have consistency in the detector response. I therefore compared my iterations to the 1997 spectrum used for the calibration of detector 2 to get a similar appearance.

An unfortunate problem is that the innermost spiral arm seems to have moved until it now overlays the next arm. This is likely due to some degradation of the end of the SPAN anode, but I can only speculate. It poses a big ghosting problem, since both spectral regions overlay each other partly.

The data for Slit 3 have PHA's that have good peaks although (which one ?) showed a large additional peak for low PH. The solution was to find a setting that reduced the peak as much as possible, while keeping a good response.

The data for slit 1 showed nearly flat response at best. If the HV is lowered there appears a negative slope, for higher HV a positive slope. Choosing the flat PHA has been the choice for calibrating GIS in this case.

In solar active regions the count rates are about a factor 5-10 higher, and variable from observation to observation. The best value for the PHA peak is found to be more difficult to determine, and depends in part on the activity in the region the raw data is being taken from. During raw data takes of AR I monitored occasionally the GOES Soft X-ray flux, and kept an eye out for sudden increases in the count rates.

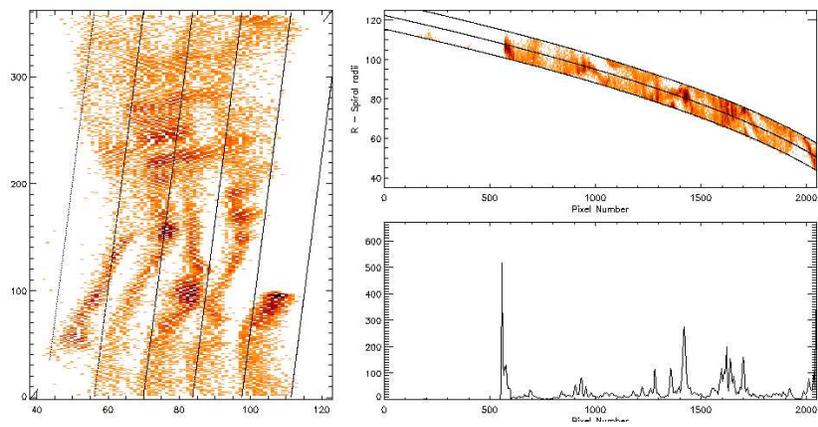


Figure 4.7: Fits to detector 2 raw data for HV=202, gset = 81. Best fit I could get.

## Chapter 5

# PROCEDURES FOR MAKING A NEW GSET

A good overview can be found in the 'SOHO CDS Operations Manual', Issue 0.2, 18 Aug 1995, section 8. This also describes in some detail some of the detector limitations.

The theory for creating a gset is described in the Thesis of A. Breeveld (1996), and implemented in the solarsoft software. I will restrict myself to describing the procedure I used in detail.

Over the years several software programs were written at MSSL in IDL to work with the raw data. Due to changes to the IDL language most of them did no longer work, and it turned out that the 'view\_raw' and 'view\_pha' routines already present in the Solarsoft package were sufficient. The use of 'view\_pha' has been mentioned before, and is not needed for determining the GSET. A useful start is to try to see if the old GSET will work with the new data, by starting with the command,

```
CIDL: view_raw, gset_id=66
```

Giving the gset\_id is optional. In this example I use GSET number 66, but, of course, it may be a different one in your case. I guess you could try all GSETS to see if there is one already that has LUT parameters that fit; I choose not to do that.

You can only fit the LUT parameters to one detector spectrum at a time, while the GSET is for all four detectors, so you have to make sure you record what file you used and the results of the fit.

The default for view\_raw is to display the \*.raw files in the \$CDS\_GIS\_RAW directory, but you can select another directory. Select the file you have decided on from the list.

The program will now display each data point in X,Y space, which forms a

spiral. If you gave the GSET option, the program will continue without stopping until it displays an intensity plot of the spiral arms in r-theta space with the LUT mapping drawn as solid lines on top. The middle of each spiral will be a dashed line.

To make changes, go to menu 1, and give new values for X-gain, Y-gain, Z-gain, and Sum (also called 'zpln'). If you don't, you get a bug. Look at the plot which should show arrows to show at which radius each of the gains has most effect and in what direction.

The Sum(or zpln) parameter is Special, since it has an S-shaped effect: at lower angles it moves the counts to the left and at higher angles, to the right. I found that most raw data plotted for default values of X-gain=1, Y-gain=1, Z-gain=1, and Sum=0, show a big reverse S. So I started to use a negative value for SUM. The possible values for Sum are even, i.e., -20, ..., -10, -8, -4, -2, -0, 2, 4, ... . This usually made the data much straighter. I then plotted the double plot, up to angles of 720, to see if the X-gain needed adjustment, because, the X-gain falls on the edge of the 360-plot. Once that was done, I changed Y-gain and Z-gain. I tried different things, but this worked the best for me. The changes to X-gain, Y-gain, and Z-gain, should not be too large. If a value of 0.1 gets entered by accident, the program crashes, and you're starting over.

Once you have entered values for the gain, choose to do an intensity plot. It shows much better detail of the major lines. Those are the ones that should not ghost. Check where changes are needed and go back to menu 1. If the arms are too tight for the data to fit into, you must change k, phi in menu 2 that appears with the intensity plot. Smaller k is a tighter spiral, larger k a broader one. Phi can go from 0 to 360 (yes, I know, start=3.1 and  $\phi = 360$  is the same as start=4.1 and  $\phi = 0$ , so what? - it works). Make sure that the ghosts of the last spiral arm features fall within the last spiral arm by adjusting stop and start. The default values used to be 3.1 and 7.3, with exceptions of 4.1 and 8.3, but I changed them to 3.1 to 8.3 to capture the ghosts to the outer arm. That affects the wavelength resolution per pixel, (2048 pixels for 5.2 arms), but that unknown number of counts ghosting into the last arm is lost no longer.

Once you have a fit you can write the parameters to the file LUT\_record.txt. However, I found it easier to write them down in my notebook, because you get a whole list of them, and you have to do your bookkeeping. To have the parameters in the file (it appends the next ones) did not work for me.

Once you have all the LUT parameters, HV, RAW\_ID, together for your Slit + Zone setting, you can prepare the GSET as described in the GSET DATABASE section. Again, it helps to have all the results handy in a notebook for making the gset.

Note that the wavelength calibration needs to be loaded as well. If you used

the standards for 'start' and 'stop', then either the wavecal for GSET 22 (for 4.2 spiral windings), or GSET 82 (for 5.2 spiral windings) can be used. The details are described in the WAVECAL DATABASE section.

## Chapter 6

# MONITORING GHOSTS

During the last work at GSFC to update the gsets, additional gsets of a new type were added, with the name 'RAW-BINNED'. They have the same parameters as the corresponding operational gset except for two parameters that determine the number of arms and the start of the arms,  $k$ , and  $\phi$ , which were chosen to maximise the number of spiral arms overlaying the data spiral. The spiral arm map therefore no longer follows the data spiral. In fact any arm of the data spiral will fall in about 3 arms of the spiral map. That means that the data coming down has to be reconstructed in the form of a spiral using the gset used. A figure of such a reconstructed spiral looks like this:

A comparison with the real raw data, see figure 2, shows that the ghosting can be seen also in the reconstructed data. Also, the location of the spirals with respect to the actual gset can be checked by overlaying the actual gset. The current gset is no longer good, if through aging of MCP and/or electronics the spiral shrinks, expands, or flattens in some direction. If the HV needs to be increased, the spiral arms broaden. Making (bi)monthly crosssectional maps is a method to monitor this effect. The location and identification of ghosts can be determined by locating on the about 4.2 spiral arms of actual data where the lines are located. Using the original pre-2006 spectra versus pixel versus spiral arm location is the simplest way to do that.



Figure 6.1: Reconstructed data spiral from the raw-binned data.

## Chapter 7

# RAW-BINNED GSET DATA CALIBRATION

The raw-binned gsets only differ from the operational gsets (usually the one before or after it in sequence) by the number of spiral arms used radially. These increase the radial resolution of the data spiral 2-3 times, with a similar decrease in resolution along the spiral. The data is still calibrated, unlike the real raw dumps which are just sampled data (so the number of lost counts is unknown). The real raw dumps might be helpful to provide typical high resolution radial profiles for reconstruction of the data, but that has not been investigated. Due to the dispersal of the fixed pattern noise over several spirals, a reconstructed spectrum will not suffer much effect of fixed pattern noise.

Doing a full spectral reconstruction involves the following steps.

1. Reconstruct the data spiral from the pixel list using the raw-binned gset.
2. Determine the minima between the data spirals; finding multi-spiral lines
3. Reconstruct the separator between the data spirals keeping multi-spiral lines whole.
4. Integrate between the separatrices to find the intensity as function of spiral coordinate.
5. Calibrate the spiral coordinate to a wavelength scale.

A program exists (`gis_rawbinned.pro`) that does do part of that already. A problem was encountered in the ghosts that are very strong and cross 2-3 spiral arms, like 180.4. Weaker ghosts can easily be handled. Determining the separatrix automatically is made difficult by that problem. Currently, the separatrix can be found

by hand selecting minima in radial plots, and a start has been made with the automated process. Unfortunately, funding problems leave us stuck here.

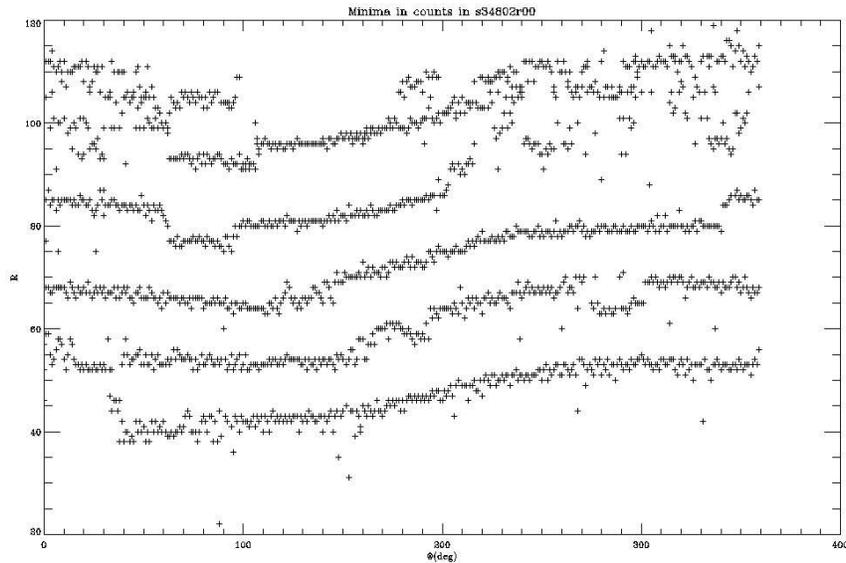


Figure 7.1: Automated detection of inter-arm separatrix using radial profiles of reconstructed raw-binned data.

Reasons to do this properly:

1. Detector 2 does not fit a spiral. Counts are found to have been pretty stable over the last 10 years, so this method should be usable for getting a good spectrum.
2. Ghost-free spectra can be derived.
3. Doubt over where ghosts are can be resolved.
4. Bad, unusable regions can be derived where the spirals overlap (i.e., width  $\zeta$  separation). If it would affect most of the detector, that might be a reason to go to a higher voltage (PHD max  $\zeta$  130), even if counts get lost from the weaker lines.
5. Flares will cause an unpredictable shift in the data spiral. This method is a work-around.
6. Comparison to raw data of operational gset to determine aging.

7. A reason to try using AI techniques that are trained to recognize the ghosting lines.

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#### REFERENCES

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2. N.P.M. Kuin and G. Del Zanna, 2006a: Pointing and alignment of the CDS Grazing Incidence Spectrometer on SOHO. CDS Software Note 57.
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4. M. Whyndham, around 2003: website with GIS calibration notes: <http://www.mssl.ucl.ac.uk/mwt>