SXT CALIBRATION NOTE 36

SXT X-RAY AND OPTICAL AXES

R. A. Fuller, J. R. Lemen Rev. A, 6-Jan-94

1. INTRODUCTION

References: SXT Calibration Notes 1, 4, 18

In this report:

CCDx(F) = CCDx(Flight)
CCDx(L) = CCDx(Lab) (Lab stands for WSMR test data)

and

CCDx(F) = 1049 - CCDx(L)
CCDy(F) = CCDy(L)

Definitions :

Inner-region - The part of the axial-response curve that is due to the objective's X-ray characteristics. This is the region that is within approximately 20 arc-min of the optical axis.

Outer "vignetted" region - The part of the response curve that is a combination of the effects due to the objective's response and due to internal occultation (vignetting).

2. PROCEDURE AND ANALYSIS OF WSMR DATA

In this report the SXT X-ray axis for the inner-region of the SXT field-of-view is determined. For a perfect mirror, the optical axis is a longitudinal line that defines the central axis of the annular X-ray mirror. Although a physical measurement could have been made to the precision of one 18.3 micron pixel, it would not have been practical in the case of SXT. In addition, the SXT mirror is not perfect, and so such a measurement may not be relevant.

Knowledge of the optical axis is mainly needed to determine the effective area of the telescope as a function of off-axis angle and photon energy. This subject is discussed further in Cal Note 37. In this report we define the optical axis as the position in the telescope field-of-view where the effective area is maximum.

The data analyzed in this report were obtained at the first White Sands Missile Range (WSMR1) series of tests in April 1991. The SXT configuration was nearly as it was for flight, except, that a different

CCD was used, and there were no entrance filters or X-ray analysis filters installed during the calibration. The SXT was pointed to various off-axis positions and the signal in the CCD was recorded. A proportional counter was used to monitor the incident X-ray beam flux. An analysis of the proportional counter data showed that the variations in the incident beam were less than one sigma. Thus, for the purpose of this analysis, the incident X-ray flux was considered to be a constant.

A preliminary analysis of the off-axis response was made by L. Acton and reported in the the Red-Book paper by Tsuneta et al, Solar Phys, 136, 37, (1991) in Figure 3. From this figure one can see that the inner-region portion of the field-of-view can be described by a linear curve. Therefore, the analysis approach we adopted was to perform a least-squares fit to the data with four parameters: two describing the position of the optical axis and two describing the linear off-axis function. Table 1 shows the results from for the optical axis from this and previous studies.

Table 1: SXT X-ray Inner-region Optical Axis

CCDx(L)	CCDx(F)	CCDy(F)		COMMENTS	
538	511	640		Experiment Interface Control Agreement	
502	547	751	+	Minima in FWHM, MSFC2	(Cal Note 1)
519	530	603		Mirror reference surface	(Cal Note 4)
526	523	646	*	Effective area, MSFC2	(Cal Note 18)
522	527	640		WSMR2: Al K outside of focus	
534	515	633		WSMR1: Adopted value	(Cal Note 36)

Notes:

+ These values were determined from data taken during the second visit to Marshall Space Flight Center (MSFC) in May-June 1989. The results represent where the FWHM of the best focus data is minimized.
* MSFC2 data analyzed to give the maximum effective area.

Two results reported in Table 1 are derived from data taken at Marshall Space Flight Center. The MSFC2 results labeled with a "+" were made by finding the position where full-width half-maximum (FWHM) fits to the best focus data were minimized. Notice that these values are considerably different from the MSFC2 results labeled "*" which were determined to be the position of the maximum effective area.

3. DISCUSSION AND RESULTS

The WSMR1 data analyzed in this report were obtained at three different energies: C K (.277 keV), Al K (1.49 keV), and Ag L (2.98 keV). The data were obtained for all lines at best focus and for Al K with the CCD in front of and behind best focus. A summary of the results is shown in Table 2 along with the correlation coefficients from the least-squares fitting.

Table 2: WSMR1 OPTICAL AXIS DATA

Line	Focus	CCDx(L)	CCDx(F)	CCDy(F)	Correlation Coef
Al K	Best	511	538	574	0.949
* C K(1)	Best	524	525	620	0.869
C K(2)	Best	510	539	645	0.863
* Ag L	Best	543	506	643	0.975
* Al K	In	541	508	630	0.975
* Al K	Out	527	522	639	0.978
* MEAN		534(+/-10)	515(+/-10)	633(+/-10)	

The MEAN line is the mean of the "*" values.

The "MEAN" results are the averages of the entries labeled with a "*". The reported uncertainties are the standard deviations of the four measurements. The C K data were taken on two separate days, but only the first set of data was included in the analysis. The Al K out-of-focus data had significantly better counting statistics compared to the best focus data. We decided not to include the Al K best focus data.

The reported result is a average of four data sets. The same result was achieved when these four data sets were combined before applying the fitting analysis. The X-ray optical axis has a somewhat large uncertainty (+/- 10 pixels in each direction), since the effective area function is broad near the center of the field of view of the telescope.

In Table 1 we also report the results of data taken at a second test performed at White Sands (WSMR2) with Al K outside of focus. The comparison for Al K (out) is relatively good (compared to the uncertainty of +/-10 pixels) between WSMR1 (Table 1) and WSMR2 (Table 2).

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4. COMPARISON TO OPTICAL AXES

The relative offsets between the X-ray optical axis and the optical axes in the Wide band or Narrow band filters were determined by Jean-Pierre Wuelser and reported in a 22-Oct-92 E-mail message. Wuelser's results have been combined with the reported values above (Table 1) in the following table.

Table 3: Optical Axis (CCD Flight Full-Res Pixels)

	CCDx(F)	CCDy(F)
X-ray	515	633
Narrow Band (NaBan)	514.64	634.47
Wide Band (WdBan)	515.24	634.26

These values can be obtained using an IDL routine written by R. Fuller called GT_SXT_AXIS. The next three lines will reproduce the values in the table above. Note that the routine also accepts an index or roadmap data structure.

```
IDL> print,gt_sxt_axis(0)         ; 0=X-ray
IDL> print,gt_sxt_axis(1)         ; 1=NaBan
IDL> print,gt_sxt_axis(2)         ; 2=WdBan
IDL> print,gt_sxt_axis(1,/rel)    ; NaBan relative to X-ray
```

The sign convention can be understood if you remember that the NaBan image is Northeast of the X-ray image. J.-P. Wuelser did not determine absolute values, but only relative to each other. His original report read as follows:

Filter Pair	x (East/West)	y (North/South)
NaBan boresight - X-ray boresight	-0.36 (+/- 0.18)	+1.47 (+/- 0.28)
WdBan boresight - NaBan boresight	+0.60 (+/- 0.10)	-0.21 (+/- 0.06)

where the negative values indicate West and South, respectively. These values can be obtained with the routine GT_SXT_AXIS:

```
IDL> print,gt_sxt_axis(1,/rel)                  ; NaBan - X-ray
IDL> print,gt_sxt_axis(2)-gt_sxt_axis(1)        ; WdBan - X-ray
```

From acton@isass4.solar.isas.ac.jp Thu Feb 3 23:59:21 1994
Received: by isass4.solar.isas.ac.jp (5.57/Ultrix3.0-C)
id AA05989; Fri, 4 Feb 94 16:56:30 +0900
Date: Fri, 4 Feb 94 16:56:30 +0900
From: acton@isass4.solar.isas.ac.jp (Loren W. Acton)
Message-Id: <9402040756.AA05989@isass4.solar.isas.ac.jp>
To: lemen@sxt3.space.lockheed.com
Subject: Outer vignette cone.
Cc: acton@isass4.solar.isas.ac.jp, fuller@flare.stanford.edu,
sxthdwe@isass4.solar.isas.ac.jp
Status: RO

Jim,

I have analyzed the following starburst data:

7	27-FEB-92	08:55:39	QT/H	Open /AlMg	Half	Norm	C	23	2668.0	512x512
8	27-FEB-92	09:02:37	QT/H	Open /Al.1	Half	Norm	C	23	2668.0	512x512
9	27-FEB-92	09:51:05	QT/H	Open /Al.1	Half	Norm	C	23	2668.0	512x512
10	27-FEB-92	09:59:37	QT/H	Open /Al.1	Half	Norm	C	23	2668.0	512x512
11	27-FEB-92	10:01:45	QT/H	Open /AlMg	Half	Norm	C	23	2668.0	512x512
12	27-FEB-92	10:12:25	QT/H	Open /Al.1	Half	Norm	C	23	2668.0	512x512
13	27-FEB-92	10:14:33	QT/H	Open /AlMg	Half	Norm	C	23	2668.0	512x512

Images 7 and 8 were taken as for pre-flare subtraction. In the case of Al.1 I added up images 9, 10, and 12 to improve statistics--although it doesn't really make much difference.

I then wrote a small program, draw_circle.pro (which I have put online) with input parameters of the device coordinates of the circle center and radius. I've manually fitted the circle to the vignette ring in the combined Al.1 image and to AlMg (image 11 minus image 7). Here is the eyeball successful fit command.

```
IDL> draw_circle,266,313,261,color=175
```

Where

```
x_center = 266 = 532 in FR pixels
y_center = 313 = 626 in FR pixels
radius   = 261 = 21.4 arcmin
```

which is reasonable agreement with what is in sxt_vignette

```
Outer-region (r > 21 arc-min)  530   628  (determined fr flight data by LWA)
```

The pictures are in /1p/acton/data/starb_920227.sav where the images are in AL_SUM and ALMG, R,G,B give the color table, and BLINK allows you to blink compare the images with and without the circle overlay.

HOWEVER(!)

I then restored /1p/acton/data/starb_920906.sav (which I renamed from yesterday) and drew the circle on the image PIX of the 6-Sep-92 starburst. It totally missed, although the radius is about right for the well-defined part of the circle. Not only does this flare reveal no vignetting at the top of the CCD the lower vignette circle is lower on the CCD. To roughly fit the vignette profile I needed to use

```
IDL> draw_circle,266,292,261,color=170
```

or about 40 FR pixels lower on the image. Thus, it is clear that the vignetting function for SCATTERED x-rays is dependent upon the location of the flare in the field of view.

So, I think that we are best off to use the lab calibration vignetting center and correct the radius of the knee for the finite source distance and use this in SXT_VIGNETTE. The starbust data appear to be useless for deriving this calibration. I've not thought it through to see if this makes sense--scattering in this telescope is so confusing!

What think?

Loren