Dark Count Statistics for GHRS Detectors: A Test of Noise Rejection with FLYLIM

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Abstract

GHRS calibration proposal 4012 was designed to obtain the statistical data needed to plan an operational strategy for observing faint targets with the GHRS. The FLYLIM noise rejection strategy is potentially of most use when one is observing an object so faint that source counts are well below the level of the detector dark count. In that case it is possible to reject multiple-count integrations as instances of higher-than-average noise without the risk of discarding exposures containing genuine signal. The data obtained in proposal 4012 show that when FLYLIM count rejection is used on the GHRS Detector 2 the dark noise is reduced by a factor of four (4) over what is seen well outside the South Atlantic Anomaly (SAA). The rejection of some lines of data resulted in an increase in execution time by about 25 percent over the nominal exposure time.

I. Introduction

Observations obtained in GHRS calibration proposal 4012 were designed to obtain the statistical data needed to plan an operational strategy for observing faint targets with the GHRS. The proposed test involved only the use of Side 2, since only this side of the GHRS can benefit from the results of this test at the present time. Due to the loss of the GHRS low-resolution mode (with G140L on Side 1), most observing programs that had originally specified G140L have been changed to use G160M instead. These programs then see an overall higher dark count rate since the SV-measured GHRS background at 0° geolatitude for the Detector 1 was 0.005 cts/s/diode, but for Detector 2 it was 0.008 cts/s/diode (Ebbets 1991). Hence, the problem of reducing the GHRS dark-count has become even more acute. The FLYLIM[2] noise rejection strategy is potentially of most use when one is observing an extremely faint object—one that is so faint that source counts are well below the level of the detector dark count. In that case it is possible to reject multiple-count integrations as instances of higher-than-average noise without the risk of discarding exposures containing genuine signal.

For GHRS calibration proposal 4012, dark count observations in RAPID[2] and PHOTOSCAN[2] modes were taken at various times. The RAPID observations provide lines of raw, unprocessed data every 0.35 seconds for the period of the exposure, providing statistical data on the distribution of bursts of counts produced by particle

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2. see Proposal Instructions

radiation. With these statistics, methods of noise removal can be evaluated. The PHOTOSCAN dark observation had the onboard data quality check FLYLIM enabled to discard every line of data that had more than one count total in the 0.2 second STEP-TIME[1] integration period. The observations relayed to the ground were the summation of all lines of data that had one or zero counts. This observation achieves the lowest dark count available with onboard data processing with very faint targets. The primary purpose of this proposal was to evaluate achievable dark count rates for Detector 2, although originally it was intended for Detector 1.

Both observations were scheduled relative to the South Atlantic Anomaly. Evaluation of the data depends upon knowing the radiation environment. The RAPID observation started well before the entry into the SAA, to provide statistics during the quiet part of the orbit. This observation ended in the SAA to allow evaluation of dark count statistics as the radiation increased, see Figure 1 which is explained in the next section.

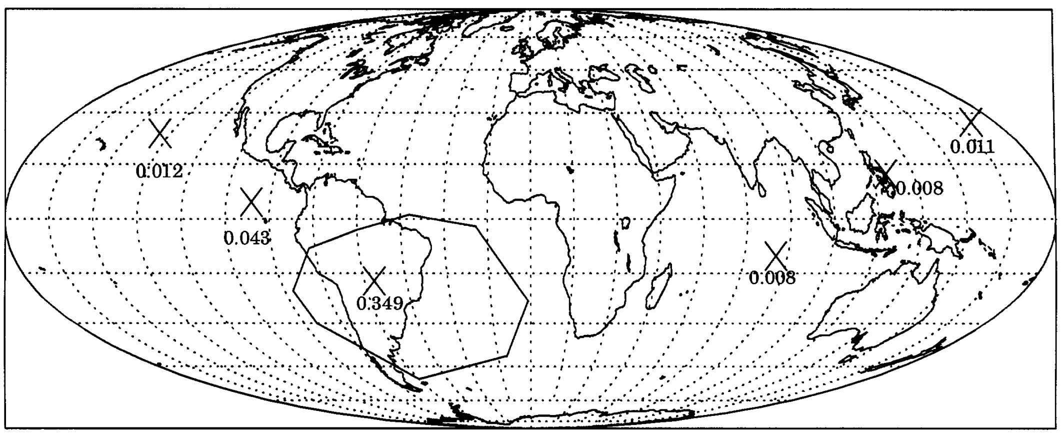

Figure 1: Rapid mode observation locations and mean dark count rate in cts/sec/diode.

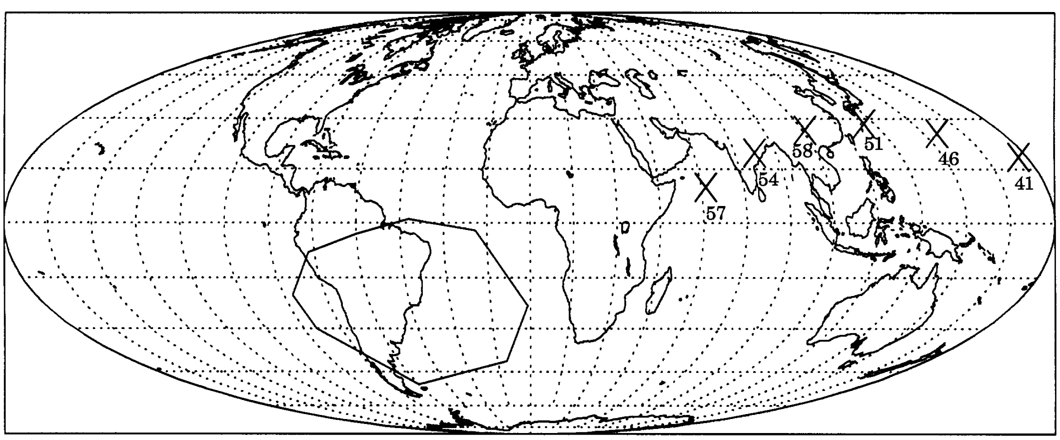

Figure 2: Photoscan mode observation locations and number of extra pattern repeats.

The PHOTOSCAN observation was designed to measure the ultimate achievable dark count using onboard data processing and was run in a quiet portion of the orbit. The PHOTOSCAN observation required special handling to set the value of the

1. see Proposal Instructions.

OTFA (on-the-fly-adder) acceptance limit, FLYLIM. The default setting for FLYLIM is the maximum possible value of 33554431 to disable this feature. For this test the value of FLYLIM was set to one to force rejection of all multiple count lines of data, see Figure 2.

The following special scheduling requirements were imposed:

1. All observations used orbits which include SAA passages.
2. For the RAPID mode exposures, the observation began 50 minutes before crossing the western boundary of the SAA.
3. For the PHOTOSCAN mode exposures, the observation began 45 minutes after crossing the western boundary of the SAA.
4. Rejection of multiple count data in PHOTOSCAN observations can increase execution time by 50 percent of exposure time for Detector 2. No schedule adjustments are required since the only the last sub-exposures will be lost.

II. Data

Table 1 contains the list of the rootnames for this observation. The first six data sets are the Rapid mode data; the last is the Photoscan data.

Figure 1 is a Mollweide projection of the world with the SAA drawn in. The location of the first group of each of the Rapid mode data sets is indicated with an X. The Rapid observations began over the Indian Ocean and proceeded to the East, ending in the SAA. Underneath each X is the average dark count rate (in cts/s/diode) for all 1,963 groups in the calibrated data set.

Table 1: 4012 Data Sets

Rootname	Date
z14n0101t	19 Oct 92
z14n0102t	19 Oct 92
z14n0103t	19 Oct 92
z14n0104t	19 Oct 92
z14n0105t	19 Oct 92
z14n0106t	19 Oct 92
z14n0201t	6 Feb 93

Likewise, Figure 2 is the same projection with the start of the PHOTOSCAN exposures indicated with an X. The exposures begin in the East and proceed westward. Under each X you will find the amount of extra time required to collect the data (due to the setting of FLYLIM) expressed as a percent difference. The proposal request for 6 exposures of 300 sec each translates into a data set consisting of 42 bins, every 7 bins being the nominal 300 sec exposure. Since turning on FLYLIM leads to the discarding of some data, the actual time required to collect the 7 bins is greater than 300 sec because the pattern has to be repeated until the 300 sec exposure time is reached, see Table 2.

Table 2: Comparison of Observation Times to Nominal Exposure Times

UDL Packet Times (MJD) First	UDL Packet Times (MJD) Second	Difference in Packet Times (seconds)	Percent Difference over Nominal Duration of 301.8s	Calculated Number of Patterns Executed	Number of Patterns over Nominal of 215	Percentage of Extra Patterns
49024.025	49024.029	382.119	26.6	272	57	26.7
49024.029	49024.033	377.379	25.0	269	54	25.1
49024.033	49024.038	383.999	27.2	273	58	27.3
49024.038	49024.042	373.999	23.9	266	51	24.0
49024.042	49024.047	367.249	21.7	261	46	21.7
49024.047	49024.051	360.379	19.4	256	41	19.5
	Average Percent Differences		24.0			24.0

III. Analysis

Diodes 342 and 442 were misbehaving during the RAPID mode observations since RAPID observations skip the normal diode quality processing. In order that their out-of-range values not dominate the statistics, both values were changed to zero before the data were processed. The STSDAS software could have filtered out these diodes itself, but it calculates the mean dark count before determining which diodes are out of range.

Table 3 lists the mean dark count statistics as calculated by the STSDAS task, darkstat for each of the rootnames in Table 1.

Table 3: Dark Count Statistics

FLYLIM Rejection Used?	Rootname	Mean	Sigma
No	z14n0101t	0.008	0.149
	z14n0102t	0.008	0.152
	z14n0103t	0.011	0.180
	z14n0104t	0.012	0.185
	z14n0105t	0.043	0.351
	z14n0106t	0.349	0.938
Yes	z14n0201t	0.002	0.007

If the numbers in Table 3 and in Figure 1 are compared to the locations of the observations with respect to the SAA, you can see that the dark count steadily increases as the telescope approaches the SAA. You can also see from above that the mean dark count for the FLYLIM observation is one-quarter that for the normal dark observations well away from the SAA.

One can calculate the nominal exposure time for the PHOTOSCAN observation without the FLYLIM rejection (or if none of the bins of data contained greater than 1 count). The nominal duration is:

$$0.8 \text{ sec} + (7 \text{ bins/patt}) \times (0.2 \text{ sec/bin}) \times (215 \text{ patt}) = 301.8 \text{ sec},$$

where 0.8 sec is the overhead required for the PASS deflections which clear the buffer and the end of an exposure, 0.2 sec/bin is the STEP-TIME, 7 bins/patt is the number of groups per exposure, and 215 patterns are needed to get the requested exposure time.

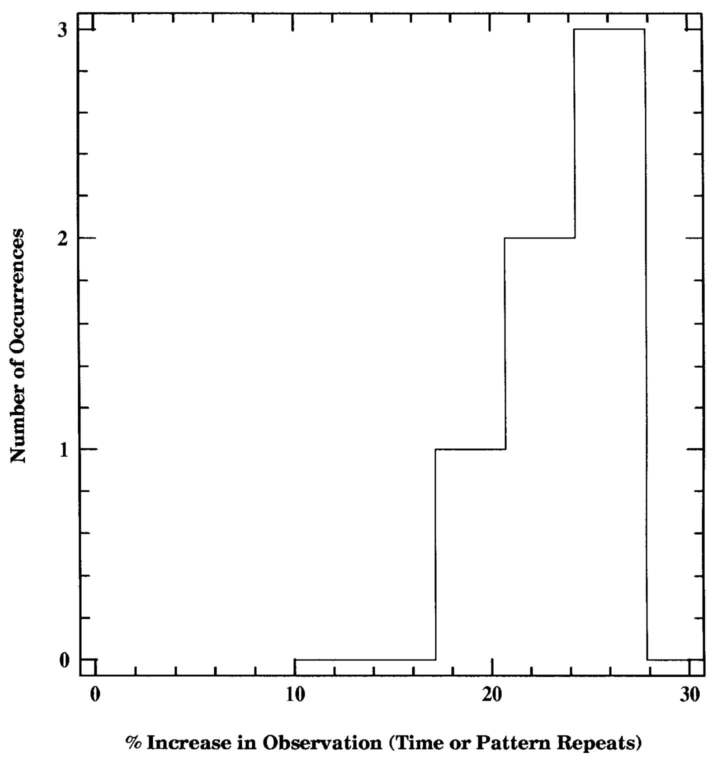

Figure 3: Histogram of percent differences.

There are two ways to view the effects of the setting of FLYLIM. In the first, we calculate the observation duration from the difference in the Unique Data Log (UDL) Packet times. (UDL dumps occur right before and right after the taking of the science data; the dumps are time-tagged.) We then compare that duration to the nominal duration to see how much extra time was used. Alternately, we can substitute the observation duration for the nominal duration in the above equation, and calculate the number of patterns which were actually executed. Table 2 shows the results of both calculations, which agree quite well.

Figure 3 shows a histogram of these percentages. While the average increase to the exposure in time or repeats of patterns is 24 percent, the distribution for the six observations ranges up to 27 percent.

Conclusions

Using FLYLIM noise rejection well outside of the SAA can reduce the dark noise in GHRS Detector 2 by a factor of 4 while increasing the observation time by only about 24 percent on average. For routine operational use, the exposure times should be padded by an amount on the order of 30 percent of the nominal exposure time to ensure that the observations complete.

References

Ebbets, D. GHRS Science Verification Report. May 1991.