Implementation of a Background Count Rate Model for the GHRS

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ABSTRACT

This document describes the implementation and usage of a background count rate model for the GHRS detectors.The model uses geomagnetic longitude and latitude to predict the background count rate at the time of observation. The calculation uses a mean relation determined for the FOS, scaled appropriately for Sides 1 and 2 of the GHRS.

1. Introduction

The background seen by the GHRS is discussed in the GHRS Instrument Handbook. The actual background counts are measured during an observation as part of the stepping pattern by specifying the STEP-PATT parameter. However, only a small fraction of the total time is spent accumulating background counts, and so their statistics are poor when the overall exposure time is low. In these cases better results can be achieved by estimating the background.

Because their detectors are so similar, the count rates for the GHRS (Lindler 1995; Hulbert *et. al.* 1995) and the FOS (Hayes and Lindler 1996) have been observed to be very much alike, and they can be characterized as a smooth function of the geomagnetic coordinates of the telescope at the time of the observation. Since the GHRS and FOS background count rates are so similar, we have implemented the original version of the FOS Blue detector background count rate model (Rosenblatt *et. al.* 1992), with appropriate scaling, to serve as the background count rate model for the GHRS Side 1 and Side 2 detectors. The use of a background count rate model for GHRS is available in the latest version of the **calhrs** pipeline, version 1.3.11, the details of which are described in Section 3.

2. Description of the Model

The FOS Blue background count rate model is based upon a bi-cubic spline surface fit to the mean background count rates derived as a function of geomagnetic latitude and lon-

gitude (Rosenblatt *et. al.* 1992). The variation in the background count rates is seen to depend predominantly on geomagnetic latitude. The FOS Blue background count rate model used by **calhrs** is stored in an **stsdas** calibration reference table, arranged as columns containing the geomagnetic latitude and longitude (degrees), and the corresponding background count rate (counts s^{-1} diode^{-1}). The latitudinal component covers a range of –40 to +40 degrees at increments of 5 degrees; the longitudinal component covers a range of 5 to 355 degrees with an increment of 10 degrees. During calibration, the count rate surface is generated based upon the static data contained in the calibration file and is evaluated at the geomagnetic coordinates of *HST* during the observation to generate a predicted background count rate based on the model.

The scaling factors which are needed to adjust the FOS Blue model to be applicable to the GHRS detectors are based upon data in Hayes and Lindler (1996); this paper includes a comparison between the background count rate model for the GHRS and a new analysis of FOS darks covering a longer baseline than the original FOS dark count rate model. The actual factors were derived by taking the average ratio of the latitudinal components only between the GHRS Side 1 and the FOS Blue background count rate models to produce the `d1scale` correction factor. Similarly, the average ratio between the GHRS Side 2 and the FOS Blue data values were used to derive the `d2scale` factor. Figure 1 illustrates the data used to derive the scaling factors; the actual data was provided by Hayes. The solid symbols represent the data which was ratioed between the two instruments for the respective GHRS Side and then averaged to derive the mean scaling factors. These scaling factors are stored as header keywords (D1SCALE and D2SCALE) in a **stsdas** calibration reference table. The correction factors are: `d1scale` = 0.93 and `d2scale` = 1.67. These factors are multiplicative constants applied to the computed background count rate.

3.   Implementation of the Model

Use of the background count rate model has been incorporated into the latest version of the **calhrs** pipeline system, version 1.3.11, which can be found in the **stsdas** package **hst_calib.hrs**; this version of the software was installed in March, 1997. Aside from the background count rate model, **calhrs** is backwards compatible with the OPUS version of the **calhrs** pipeline, version 1.3.10, which was the version current at the time of the *HST* Servicing Mission 2 in February, 1997. The **calhrs** implementation of the background count rate model for the GHRS is based, in part, upon the algorithm which exists in the **calfos** pipeline for the use of a background count rate model and upon the **zdark_model** program written by Don Lindler (private communication 1996).
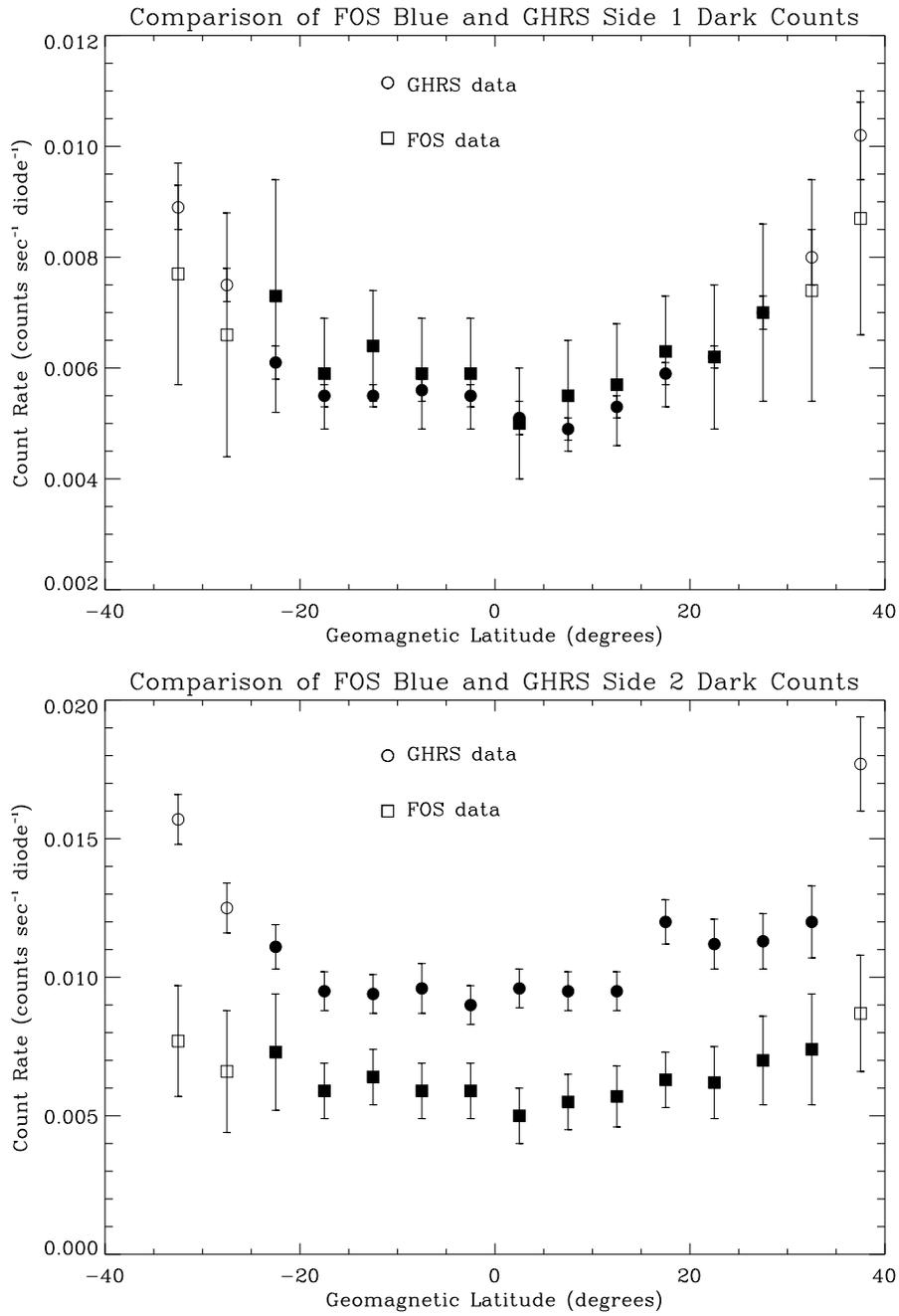
Figure 1: Comparison of FOS and GHRS measured dark counts used for derivation of the scaling factors for the **calhrs** background model. Data are from Hayes and Lindler (1996).

The background modeling works as follows. First, reasonable estimates for the begin and end times of each readout are determined. For the purposes of this algorithm, the begin and end times of the readouts in ACCUM mode are defined to be the packet times (PKTTIME) of the `.ulh` files which precede and follow the readout. Packet times are the timestamps of the files at the time of transmission to the ground. For most ACCUM mode observations, the `.ulh` files which bracket the acquisition of the observation are transmitted to the ground *before* the actual science observations are transmitted. Therefore, the `.ulh` packet times provide a reasonable estimate for the readout begin/end times. In RAPID mode, the individual readouts are not bounded by `.ulh` files (although there is a `.ulh` file which precedes the entire RAPID sequence), and the readouts are transmitted to the ground upon acquisition. Therefore, the end time has been defined to be the packet time of the readout from the `.d0h` file, and the begin time is the end time minus the integration time (STEPTIME) also found in the `.d0h` file. It should be noted that the first two readouts and the last readout of a RAPID sequence do not contain science data and are ignored in the computations performed by **calhrs**.

Once the begin/end times are established, the exposure length of the readout is subdivided into intervals of approximately one minute in duration. At the mid-point of each interval, the geographic and geomagnetic positions are computed from the orbital elements in the `.shh` file. The dark count rate model is then evaluated at the geomagnetic coordinates, and a background count rate is derived for the interval. The count rates for all the intervals are averaged to compute the mean background count rate for the readout. Finally, the mean background count rate is scaled for the appropriate GHRS detector. The computed background is stored in the `.c5h` file, and the net flux is stored in the `.c1h` file.

Since the integration time of each readout of a RAPID observation can be no greater than 12.75 seconds, the computed background count rate for each RAPID readout is, in actuality, based upon only one computation, rather than an average of multiple computations. It should also be noted that after the geographic coordinates of an interval within a readout are computed, the coordinates are compared to a polygon of the South Atlantic Anomaly based upon the *HST* SAA Model 7 as defined in the *HST* Project Data Base. The SAA Model 7 is stored in the file referenced by the SAAHFILE keyword of the `.d0h` file. If the geographic coordinates are found to reside within the SAA polygon, a warning is issued noting that the observation is near the SAA for the indicated readout. If the readout were acquired in or near the SAA, the background count rate derived for the readout will probably be a poor estimate of the true background. The report by Lindler (1995) suggests guidelines as to the applicability of a dark count rate model.

The SAA Model 7 calibration image is a two-dimensional mask of zeros and ones; "zero" represents regions outside of the SAA, and "one" represents the SAA polygon. The calibration image is 360 pixels in the *x*- (longitudinal) direction, covering a range of –180 to +180 degrees. In the *y*- (latitudinal) direction, the image is 180 pixels covering a range

of –90 to +90 degrees. The pixel ($x =1$, $y =1$) corresponds to the data coordinates of (longitude = –180, latitude = –90).

4.   Setting of the Calibration Switches

The background count rate model is invoked through the new calibration switch keyword, BMD_CORR. The two calibration reference files accessed when the background count rate model is invoked are named in the calibration keywords CCRE and SAAHFILE. CCRE represents the background count rate model which is stored as an **stsdas** calibration reference table. SAAHFILE represents the SAA polygon which is stored as an **stsdas** calibration image. Both of these calibration reference files can be obtained from the *HST* archive. For standard OPUS pipeline processing, the BMD_CORR switch would be set to OMIT under all circumstances. Use of the count rate model to compute the background is strictly a post-processing option available through **stsdas**.

BCK_CORR remains the main switch for the option of performing *any* background correction. Dependent on this main switch are four options: MDF_CORR, MNF_CORR, PLY_CORR, and BMD_CORR. MDF_CORR and MNF_CORR control the median and mean filtering of the background, respectively, and are no longer routinely used in the processing. PLY_CORR is the switch which invokes polynomial fitting to the observed background. See the *HST Data Handbook (Version 2, December 1995)* for a discussion of these options. The last option, BMD_CORR, is exclusive from the previous set of three options and invokes only the background model.

The **calhrs** algorithm checks the setting of BCK_CORR to determine if any background removal should be performed. Only if BCK_CORR is set to PERFORM are the remaining switch options examined. If any of the three original switches (MDF_CORR, MNF_CORR, or PLY_CORR) are set to PERFORM, regardless of how BMD_CORR is set, a background correction will be performed based on *observed* data, applying the chosen options. If the BMD_CORR keyword were set to PERFORM (in addition to any of the three original options), it will be reset to SKIPPED. The background count rate model will be invoked when *only* BCK_CORR *and* BMD_CORR are set to PERFORM, and the three other background associated switches are set to OMIT. Since the model background is most relevant in only very specific cases, if there were any conflict between the keyword switches for the derivation of a background spectrum, the standard background would be applied as the default, rather than the model computed background. Informational messages with regard to conflicts in the background options and the resulting action taken by the algorithm are generated.

5. Preparing Archived Data for Processing with CALHRS

At this time in order to use **calhrs** for invocation of the background count rate model, it is necessary to modify the `.d0h` file to incorporate the new calibration keyword switch, BMD_CORR, as well as the two calibration reference file keywords, CCRE and SAAH-FILE. In the **stsdas** package **hst_calib.ctools**, **chcalpar** can be used to update the `.d0h` file.

The researcher will be presented with a list of all the known keywords for the calibration switches and calibration reference files. Each entry will be filled in with information, if any, acquired from the input file (e.g., `z2bd010ft.d0h`). The CCRE, SAAHFILE, and BMD_CORR entries should be blank. At this time, these entries can be filled in manually with the names of the calibration files, and the calibration switch, BMD_CORR, can be set to PERFORM. The remaining calibration switches which refer to the computation of the background should be modified appropriately (see Section 4 of this report). If **chcalpar** is used to add the new calibration keywords to the `.d0h` file, rather than to modify the values of current entries, these new keywords will be appended to the bottom of the `.d0h` file. The position of these keywords in the **chcalpar** listing is the location in which the keywords would normally appear in the `.d0h` file had they been generated by the OPUS pipeline.

6. Processing with calhrs

Once the `.d0h` files have been updated with the new calibration keywords and appropriate values, the **calhrs** software can be invoked in the **stsdas** package **hst_calib.hrs**. If the version of **stsdas** is up-to-date, this will invoke **calhrs**, version 1.3.11, which contains the upgrades to **calhrs** that allow the use of a background count rate model. If there are any conflicts between the calibration keyword settings for the determination of the background, warnings as well as the action taken by the algorithm will be issued.

It is worth noting that consistency checking of the calibration keyword settings is one of the initial tasks performed by **calhrs**. Any warning messages with regard to these settings will be issued near the beginning of the processing run for a specific observation. The **calhrs** algorithm processes the readouts (i.e., groups) for an observation in a successive fashion; each readout is processed through all of the chosen calibration steps before the next readout is examined. Consequently, *readout-independent* messages issued by any of the calibration procedures will be generated generally upon the processing of the first readout; messages which are *readout-dependent* will appear through-out the processing history.

When BCK_CORR is set to PERFORM, **calhrs** issues a message upon the processing of the first readout indicating the source of the background spectrum. In addition, the values (PERFORM, OMIT, SKIPPED) of the calibration keyword switches can be examined

in any of the output calibrated files to determine the background options actually performed. Computation of the background using the count rate model produces a background spectrum in the `.c5h` file which is a constant value as a function of wavelength.

As mentioned earlier, if any readout is found to be near the SAA, a warning is issued. **calhrs** uses the *HST* SAA Model 7 polygon as the reference against which the location of the observation is compared and appropriate messages are issued, if necessary. However, there are GHRS observations which were acquired using different SAA Models. The information regarding the SAA Model used for any particular observation is located in the `.shh` file in the keyword, SAAAVOID. When the background count rate model is chosen, in addition to the background notification, a message is issued which informs the user which SAA model is used for **calhrs** and which SAA model was used for the particular observation.

The location of the telescope for any specified readout can be verified quickly by using the **stsdas** tool, **hstpos**, found in the package **playpen**. This task plots the position of the telescope at the specified time on a Mollweide projection of the world. The time for which the position is generated can be based upon a keyword in the input image header or an ascii file. In order to plot the location of the telescope for a readout which has been identified as being in or near the SAA, the following can be done:

```
> unlearn hstpos
```

This will reset the task to use all of the default values. Then type

```
> hstpos  input=z2bd010ft.ulh[21]  orbit=z2bd010ft.shh[11]
  model=7 marker=circle
```

```
> hstpos  input=z2bd010ft.ulh[22]  orbit=z2bd010ft.shh[11]
  marker=circle append+
```

In this example, a warning was issued by **calhrs** for readout 11 of `z2bd010ft`. These commands will generate the world projection and overplot the SAA Model 7 for reference as seen in Figure 2. The orbital parameters are computed from the `.shh` file for readout 11, and the locations to plot the symbols are determined from the appropriate groups in the `.ulh` file which bracket the particular readout. Recall for ACCUM acquisitions, each readout is typically bracketed by a preceding and following `.ulh`. The `.ulh` file will have twice as many groups as the `.d0h` file to accommodate the bracket of the readout. It can be seen that the path of the telescope will pass into the SAA during readout 11.

Figure 2: A world projection with the location of *HST* depicted at the beginning and end of a specified readout of z2bd010ft by the small circles.
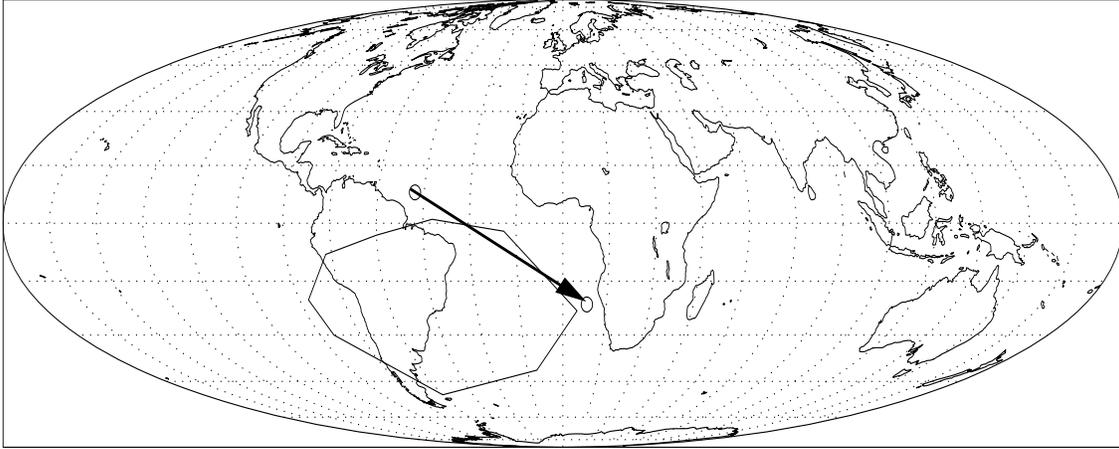
7. Summary

As discussed in Sections 3 and 6, when the background count rate model is invoked for the **calhrs** processing, if the computed geographic coordinates for any of the individual readouts are found to reside within the SAA polygon, a warning is issued noting that the observation is near the SAA for the indicated readout. If the readout were acquired in or near the SAA, the background count rate derived for the readout using the model will probably be a poor estimate of the true background of the observation. Results obtained using the background count rate model to estimate the background level of dark observations acquired by GHRS were contrasted against the measured mean count rate derived for these observations. In all cases, for observations acquired near or in the SAA, the background count rate model severely underestimated the background count rate. As seen in Table 1, the agreement between the model and the measurements is on the order of 4 - 9% for data acquired outside of the SAA. The report by Lindler (1995) contains a thorough discussion of the applicability of a dark count rate model.

Table 1. Comparison of count rates as computed by the background count rate model and measured for specified GHRS dark observations.

OBS	SAA	GHRS Side	Mean Count Rate (model)	Mean Count Rate (ISR-70)
z13x0a	yes	2	0.00966	0.190
z1ih02	yes	2	0.00975	0.156
z1ih06	yes	2	0.01028	0.021
z2am08	yes	1	0.00546	0.018
z1ih05	no	2	0.01099	0.012
z22901	no	2	0.00959	0.010
z26201	no	2	0.01122	0.012
z2620f	no	2	0.01001	0.009

8. Acknowledgments

9. References

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Rosenblatt, E.I, Baity, W.A., Beaver, E.A., Cohen, R.D., Junkkarinen, V.T., Linsky, J.B., and Lyons, R.W. 1992; ISR CAL/FOS 071 "An Analysis of FOS Background Dark Noise" (San Diego: University of California)