Technical White Paper for the
Ulysses-HISCALE Background Rate Software

J. D. Patterson and T. P. Armstrong

20th February 2001

*Fundamental Technologies, LLC*
2411 Ponderosa Dr., Suite A
Lawrence, KS 66046
Phone: (785) 840-0800
Fax: (785) 840-0808

**Abstract**

This software is provided to the HISCALE Team for the purpose of determining the background levels in the MFSA and RATE data for the M, F, M' and F' detectors. The background rates provided by this software are the result of the application of a technique demonstrated by Patterson and Armstrong [2001] of using the IMP-8 data to determine the GCR contribution to the overall background rates. A data quality flag is included in the software to warn the user. The normalization factors for the model spectrum used to determine the background rates is provided in a separate file. The team will be provided with updated normalizations as more data are made available.
1 Introduction

In previous studies, the background rates for the HISCALE detectors were determined by searching the data time-series for minimum counts and assuming that the background rates were time invariant [Simnett, 1994]. Other studies made the assumption that the background rates varied with heliolatitude [Tappin, 1994]. These earlier attempts dismissed the possibility of a time-varying background rate. With the over 10 years of data now collected by HISCALE, a time-varying trend in the GCR-induced background rates was noticed [Patterson, 2001]. The trend was only noticed as a result of the simultaneous investigation of the data from IMP-8 and Ulysses. The results of our method to determine a rough value for the HISCALE backgrounds were noticed to bear a strong resemblance to the IMP-8 P11 time-series. It was then realized that the correlation between the two could be made. The process of utilizing the IMP-8 data to model the HISCALE background is presented in a report by Patterson [2001] to the HISCALE team. Details about the computational methods and models can be found in Patterson’s report. This document focuses on the application of the results of the model. The other component to the total HISCALE background rates are the rates induced by the RTG gamma rays. Many experimental measurements and numerical simulations have been done to determine the contribution to the total background rates by the RTG. A preflight measurement was taken with the RTG and the HISCALE package in the same relative positions they now have on the spacecraft [Gold, 1984], and a numerical simulation of the response was done by Gomez [1996]. The RTG-induced rates used in the ULYBKGR.FOR subroutine are those obtained by the Patterson [2001] study.

2 Structure

The tabular data accessed by ULYBKGR.FOR is provided via a series of DATA statements rather than reading the data from a file on disc. The drawback is that the subroutine must be recompiled at each update to the available data, whereas the advantage is the increase in the speed of the software. Disc I/O is slow and with the large quantity of data used by ULYBKGR,FOR the access time will be high. With the data compiled into the object file, the access time is greatly reduced, thereby reducing the amount of costly CPU time required. All of the time-invariant data are contained within the ULYBKGR.FOR file, but the time-varying normalization factors are contained in a separate file, SCALE.INC. This is done to allow for easy updates to the software as more data are made available. Upon taking the day-of-mission (DOM) as an input from the user, the subroutine loads the tabular data required. These data include the energy thresholds for the MFSA and RATE channels, the RTG contribution to the background, the parameters for the modeled MFSA background spectrum, and the time-varying normalization of the background spectrum, and then the midpoint energies for the MFSA channels are computed. The DOM is compared
to the available range of days in the current data set. If the DOM is within
the available range, then the program continues with no changes. If the DOM
requested by the user is outside the available range, then the last day of data
available is used instead and the data quality flag is set to a value of two,
indicating an estimated result. Once the normalization data for the requested
day are acquired, the GCR contribution to the MFSA background are computed
using the following model:

\[ R_{GCR-background}(E, t) = A(t) \cdot \left[ \frac{a}{(E - b)^c \cdot \exp \left( \frac{d}{E - p} \right) - e} - f \right]. \]

The parameters \( a \) through \( f \) are defined in the software as the array FIT.
A in the equation above is the normalization factor for the requested DOM,
The resulting GCR-induced rates are then added, channel-by-channel, to the
RTG-induced rates to yield the total background rates in the MFSA channels.
In order to obtain the background rates for the RATE channels, the MFSA
data were integrated over the individual RATE channel energy passbands. As
an example, here is how the background rate for P3 is determined:

\[
\text{ratebkgr}(1, 3) = \\
+ \frac{(\text{mfsaeng}(13) - \text{rateeng}(1, 3))}{(\text{mfsaeng}(12) - \text{mfsaeng}(13))} \times \\
+ \text{mfsabkgr}(1, 12) - \text{mfsabkgr}(1, 13) + \text{mfsabkgr}(1, 14) + \\
+ \frac{(\text{rateeng}(1, 4) - \text{mfsaeng}(15))}{(\text{mfsaeng}(15) - \text{mfsaeng}(16))} \times \\
+ \text{mfsabkgr}(1, 15)
\]

Similar methods are used for the other RATE channels. With the background
rates now determined for the MFSA and RATE channels, the values and the
data quality flag are returned to the user.

3 Usage

This software is a FORTRAN77 subroutine which accepts from the user the
day-of-mission (DOM) and returns two arrays containing the MFSA and RATE
block background rates and a data quality flag. The two data arrays contain the
background rates in the 32 MFSA channels of the M, F, M', and F' detectors,
the eight RATE channels for M and M' (P1 to P8), and the seven RATE channels
for F and F' (E1 to FP7). Here is a sample calling statement:

\[
\text{CALL ULYBKG}(\text{DOM}, \text{RATEBKGR}, \text{MFSABKGR}, \text{DQF})
\]

where the arguments are declared in the following manner:

\[
\text{INTEGER*2 DOM} \\
\text{REAL*4 RATEBKGR}(4, 8) \\
\text{REAL*4 MFSABKGR}(4, 32) \\
\text{INTEGER*2 DQF}
\]
REFERENCES

The day-of-mission numbering begins with day 318 of 1990 as day 1. All other days are numbered sequentially from that initial date with no gap. The first coordinate for the data arrays indicates the detector where 1=M, 2=F’, 3=M’, and 4=F. The second coordinate indicates the energy channel. For the F and F’ portions of the RATEBKGR array, the eighth element is unused and set to zero. Therefore, the background rate for P5’ would be stored in RATEBKGR(3,5). The data quality flag, DQF, has the value 1 if the data are good and without availability errors. DQF has a value of 2 if the DOM requested is outside the bounds of the current version of the software. When this occurs, the last value of the normalization factor is used.

4 Applying Updates

The initial version of the SCALE.INC file contains data up to and including the 3644th day of the mission. As more IMP-8 data and HISCALE data are made available, this file will be updated and distributed to the HISCALE team. To apply the updates, simply remove or rename the previous copy of the SCALE.INC file and place the new version in the same directory as the ULYBKGR.FOR source code. The version number for the SCALE.INC file can be found at the top of the file within the header block. With the new version of the include file in place, recompile the ULYBKGR.FOR code so that the new data are incorporated in the object file.

References


Appendix A: ULYBKGR.FOR Source Code

This is the FORTRAN77 source code for the ULYBKGR.FOR subroutine. This code was written for an i586 machine running RedHat Linux 7.0, but there is no platform-specific code involved. The code should compile as-is, without modification, on any architecture-OS combination.

c******************************************************************************c
   The program ULYBKGR.FOR uses the results of a study by
   J. D. Patterson and T. P. Armstrong on the sources of background
   counts produced in the H, F, M' and F' detectors of EPAM and
   H/SCALE. This program takes as its input a requested time
   in the form of day-of-mission (DOM) and returns the background
   rates in MFSR and RATE channels of the H, F, M' and F' detectors
   of the H/SCALE instrument. Variable definitions are given
   in the variable declaration section of the following code.
   Please direct any questions about this software or the study
   that made this software possible to Doug Patterson at
   dpatter@lyssses.ftecs.com. Fundamental Technologies, LLC owns
   the copyright to this software. Modifications or unauthorized
   distribution of this software is prohibited.
   J. Douglas Patterson, Jan. 2001
   Fundamental Technologies, LLC
   2411 Ponderosa Dr. Suite A
   Lawrence, KS 66046
   tel. (785) 840-0800
   fax. (785) 840-0808
   c******************************************************************************c
subroutine ulybkgd(dom,mfsakgr,ratelkgd,domflag)
c implicit none
   c******************************************************************************c
   ** Variable Declarations and Definitions **
c character*365 header !text variable to skip file headers
character*80 grfile !filename containing GCR rates
c integer i,j,k,q !dummy indices
integer dom !day-of-mission time from driver
integer domflag !data availability flag
   !1=dom is within available range
   !2=dom is outside available range
integer year,day !year and day for data from GCR file
c real fit(8) !Fit parameters for modeled background
real rtgkgd(4,32) !RTG-induced rates (detector,MFSR channel)
   !detector, 1=H, 2=F', 3=M', 4=F'
real inputgr(32) !GCR-induced rates per record (channel)
real gcrkgd(32) !GCR-induced rates (MFSR channel)
real mfseng(33) !MFSR energy thresholds (channel)
REFERENCES

real mfsamid(32) ! MFSA mid-point energies (channel)
real rateeng(4,9) ! RATE energy thresholds (detector,channel)
!detector, 1=1, 2=2', 3=3', 4=4'
real mfsabkgd(4,32) ! MFSA background rates (detector,channel)
!detector, 1=1, 2=2', 3=3', 4=4'
real ratebkgd(4,32) ! RATE background rates (detector,channel)
!detector, 1=1, 2=2', 3=3', 4=4'

#include 'scale.inc'

***************************************************************************
** Define MFSA and RATE Energy Thresholds **
***************************************************************************
do i=1,32
  mfsamid(i)=sqrt(mfsaeng(i)*mfsaeng(i+1))
end do

data rateeng/ 56.00, 42.00, 61.00, 40.00, + 76.00, 64.00, 77.00, 66.00, + 130.0, 112.0, 127.0, 107.0, + 214.0, 176.0, 207.0, 170.0, + 337.0, 290.0, 335.0, 290.0, + 594.0, 544.0, 601.0, 540.0, + 1073., 761.0, 1123., 765.0, + 1802., 1223., 1874., 1223., + 4752., 4974., 4752., 4942./

***************************************************************************
** Define RTG and CCR-Induced Background Rates **
***************************************************************************
data rtgabkgd/ 1.67E-01, 4.76E-01, 8.94E-03, 0.00E+00, + 9.23E-02, 2.45E-01, 1.39E-02, 1.48E-03, + 5.78E-02, 1.09E-01, 3.39E-02, 1.07E-02, + 5.94E-02, 9.71E-02, 8.48E-02, 3.47E-02, + 8.0E-02, 1.43E-01, 1.56E-01, 6.53E-02, + 8.54E-02, 1.54E-01, 2.05E-01, 7.00E-02, + 9.46E-02, 1.87E-01, 3.01E-01, 7.26E-02, + 1.27E-01, 2.39E-01, 3.27E-01, 8.92E-02, + 1.47E-01, 2.68E-01, 3.87E-01, 9.68E-02, + 1.51E-01, 2.72E-01, 4.06E-01, 1.00E-01, + 1.43E-01, 2.45E-01, 3.84E-01, 9.98E-02, + 1.32E-01, 2.16E-01, 3.56E-01, 9.00E-02, + 1.11E-01, 1.79E-01, 3.20E-01, 7.73E-02, + 9.20E-02, 1.69E-01, 2.80E-01, 6.67E-02, + 7.80E-02, 1.23E-01, 2.37E-01, 4.94E-02, + 6.60E-02, 9.66E-02, 1.96E-01, 3.66E-02, + 4.00E-02, 5.28E-02, 1.29E-01, 2.11E-02, +
data fit/ 8000,-12.8,1.74,209,-0.698,-0.002/
if (dom.gt.nscl) then
  dom=nscl
  domflag=2
else
  domflag=1
end if

do j=1,32
  gcrbkgr(j)=cle(dom)*(fit(1)/(((mfsamid(j)-fit(2))*fit(3))
+ *exp(fit(4)/(mfsamid(j)-fit(2)))-fit(5))-fit(6))
end do

** Determine the MFSA and RATE Background Rates **
** for the Given Day-Of-Mission **

** MFSA Rates **
do i=1,4
  do j=1,32
    mfsabkgr(i,j)=gcrbkgr(j)+rtghkgr(i,j)
  end do
end do

** M and M' Rates **
do i=1,3,2
  ratebkgr(i,1)=
+ ((mfsaeng(9)-rateeng(i,1))/(mfsaeng(9)-mfsaeng(9)))*
+ mfsabkgr(i,1,0)+mfsabkgr(i,1,9)+
+ ((rateeng(i,2)-mfsaeng(10))/(mfsaeng(10)-mfsaeng(11)))*
+ mfsabkgr(i,1,10)
  ratebkgr(i,2)=
+ ((mfsaeng(11)-rateeng(i,2))/(mfsaeng(10)-mfsaeng(11)))*
+ mfsabkgr(i,10)+mfsabkgr(i,1,11)+
+ ((rateeng(i,3)-mfsaeng(12))/(mfsaeng(12)-mfsaeng(13)))*
+ mfsabkgr(i,1,12)
  ratebkgr(i,3)=
+ ((mfsaeng(13)-rateeng(i,3))/(mfsaeng(12)-mfsaeng(13)))*
REFERENCES

+ mfsabkg(i,12)+mfsabkg(i,13)+mfsabkg(i,14)+
+ ((rateeng,i,4)-mfsaeng(15))/mfsaeng(16))-
+ mfsabkg(i,15)
ratebkg(i,4)=
+ ((mfsaeng(16)-rateeng(14))/mfsaeng(16))-
+ mfsabkg(i,15)+mfsabkg(i,16)+
+ ((rateeng(14)-mfsaeng(17))/mfsaeng(16))-
+ mfsabkg(i,17)
ratebkg(i,5)=
+ ((mfsaeng(18)-rateeng(15))/mfsaeng(18))-
+ mfsabkg(i,17)+mfsabkg(i,18)+mfsabkg(i,19)+
+ ((rateeng(16)-mfsaeng(20))/mfsaeng(20)-mfsaeng(21))-
+ mfsabkg(i,20)
ratebkg(i,6)=
+ ((mfsaeng(21)-rateeng(16))/mfsaeng(21))-
+ mfsabkg(i,20)+mfsabkg(i,21)+mfsabkg(i,22)+
+ ((rateeng(17)-mfsaeng(23))/mfsaeng(23)-mfsaeng(24))-
+ mfsabkg(i,23)
ratebkg(i,7)=
+ ((mfsaeng(24)-rateeng(17))/mfsaeng(24))-
+ mfsabkg(i,23)+mfsabkg(i,24)+mfsabkg(i,26)+
+ ((rateeng(18)-mfsaeng(26))/mfsaeng(26)-mfsaeng(27))-
+ mfsabkg(i,26)
ratebkg(i,8)=
+ ((mfsaeng(27)-rateeng(18))/mfsaeng(27))-
+ mfsabkg(i,26)+mfsabkg(i,27)+mfsabkg(i,28)+
+ mfsabkg(i,29)+mfsabkg(i,30)+
+ ((rateeng(19)-mfsaeng(31))/mfsaeng(31)-mfsaeng(32))-
+ mfsabkg(i,31)
end do

** F and F’ Rates **
do i=2,4,2
  ratebkg(i,1)=
+ ((mfsaeng(7)-rateeng(i,1))/mfsaeng(7)-mfsaeng(6))-
+ mfsabkg(i,16)+mfsabkg(i,17)-mfsabkg(i,18)+
+ ((rateeng(1,2)-mfsaeng(9))/mfsaeng(10)-mfsaeng(9))-
+ mfsabkg(i,19)
ratebkg(i,2)=
+ ((mfsaeng(10)-rateeng(i,2))/mfsaeng(10)-mfsaeng(9))-
+ mfsabkg(i,19)+mfsabkg(i,20)+
+ (rateeng(i,3)-mfsaeng(11))/mfsaeng(12)-mfsaeng(11))-
+ mfsabkg(i,11)
ratebkg(i,3)=
+ ((mfsaeng(12)-rateeng(i,3))/mfsaeng(12)-mfsaeng(11))-
+ mfsabkg(i,11)+mfsabkg(i,12)-mfsabkg(i,13)+
+ (rateeng(i,4)-mfsaeng(14))/mfsaeng(15)-mfsaeng(14))-
+ mfsabkg(i,14)
ratebkg(i,4)=
+ ((mfsaeng(15)-rateeng(i,4))/mfsaeng(15)-mfsaeng(14))-
+ mfsabkg(i,14)+mfsabkg(i,15)+
+ (rateeng(i,5)-mfsaeng(16))/mfsaeng(17)-mfsaeng(16))-
+ mfsabkg(i,16)
ratebkg(i,5)=
+ ((mfsaeng(21)-rateeng(i,6))/mfsaeng(21)-mfsaeng(20))-
+ mfsabkg(i,20)+
+ (rateeng(i,7)-mfsaeng(21))/mfsaeng(22)-mfsaeng(21))-

8
REFERENCES

+ mfsabkgr(i,21)
  ratebkgr(i,6)=
+ ((mfsaeng(22)-rateeng(i,7))/(mfsaeng(21)-mfsaeng(22)))*
+ mfsabkgr(i,21)+mfsabkgr(i,22)+mfsabkgr(i,23)+
+ ((rateeng(i,8)-mfsaeng(24))/(mfsaeng(23)-mfsaeng(24)))*
+ mfsabkgr(i,24)
  ratebkgr(i,7)=
+ ((mfsaeng(25)-rateeng(i,8))/(mfsaeng(24)-mfsaeng(25)))*
+ mfsabkgr(i,24)+mfsabkgr(i,25)+mfsabkgr(i,26)+
+ mfsabkgr(i,27)+mfsabkgr(i,28)+mfsabkgr(i,29)+
+ mfsabkgr(i,30)+
+ ((rateeng(i,9)-mfsaeng(31))/(mfsaeng(30)-mfsaeng(31)))*
+ mfsabkgr(i,31)
  ratebkgr(i,8)=0.00
end do

c
return
end

9
Appendix B: SCALE.INC Source Code

This is the file which contains the normalization factors for the HISCALE background model. Each new update to the software will include a current SCALE.INC file that contains the latest results. This file also will update the size of the SCLE vector as more data are included.

```c
******************************************************************************
SCALE.INC is part of the ULYBKGR.FOR subroutine for determining
the background rates for the M, F, M', and F' detectors of the
HISCALE instrument on board Ulysses. The data contained here
are the time-varying normalization factors for the modeled GCR
correction to the total HF5A background rates.

Please direct any questions about this software or the study
that made this software possible to Doug Patterson at
dpatter@ulyssees.fitecs.com. Fundamental Technologies, LLC owns
copyright to this software. Modifications or unauthorized
distribution of this software is prohibited.

J. Douglas Patterson, Jan. 2001
Ver. 1.0
Fundamental Technologies, LLC
2411 Ponderosa Dr. Suite A
Lawrence, KS 66046
tel. (785) 840-0800
fax. (785) 840-0808
******************************************************************************

real scle(3644) !Normalization of GCR-induced background
integer nscl !No. of elements in SCLE vector

nscl=3644

data scle/ .524, .527, .529, .533, .536,
  + .539, .542, .542, .542, .542,
  + .543, .544, .545, .546, .547,
  + .546, .544, .540, .540, .544,
  + .560, .564, .561, .543, .533,
  + .562, .519, .520, .526, .536,
  + .542, .548, .545, .541, .536,
  + .532, .522, .525, .526, .531,
  + .538, .541, .539, .540, .545,
  + .560, .554, .564, .554, .554,
  + .563, .562, .562, .556, .556,
  + .560, .564, .567, .567, .566,
  + .563, .565, .567, .568, .568,
  + .564, .562, .559, .559, .569,
  + .569, .560, .871, .899, .637,
  + .866, .704, .711, .701, .678,
  + .948, .606, .579, .570, .577,
  + .593, .602, .598, .586, .576,
  + .570, .573, .577, .582, .586,
  + .588, .588, .588, .589, .599,
  + .589, .590, .596, .604, .609,
```
REFERENCES

+ 1.210, 1.220, 1.230, 1.230, 1.230,
+ 1.230, 1.220, 1.210, 1.220, 1.220,
+ 1.200, 1.190, 1.190, 1.190, 1.200,
+ 1.200, 1.210, 1.210, 1.210, 1.220,
+ 1.200, 1.200, 1.190, 1.190, 1.180,
+ 1.190, 1.190, 1.200, 1.200, 1.210,
+ 1.210, 1.220, 1.220, 1.220, 1.220,
+ 1.220, 1.220, 1.210, 1.210, 1.210,
+ 1.220, 1.220, 1.210, 1.220, 1.220,
+ 1.220, 1.220, 1.220, 1.220, 1.220,
+ 1.220, 1.230, 1.230, 1.230, 1.230,
+ 1.230, 1.230, 1.220, 1.220, 1.220,
+ 1.230, 1.230, 1.220, 1.220, 1.220,
+ 1.230, 1.230, 1.230, 1.230, 1.230,
+ 1.230, 1.230, 1.230, 1.230, 1.230,
+ 1.230, 1.230, 1.230, 1.230, 1.230,
+ 1.230, 1.230, 1.230, 1.230, 1.230,
+ 1.230, 1.230, 1.230, 1.230, 1.230,
+ 1.230, 1.230, 1.230, 1.230, 1.230,
+ 1.230, 1.230, 1.230, 1.230, 1.230,
+ 1.230, 1.230, 1.230, 1.230, 1.230,
+ 1.230, 1.230, 1.230, 1.230, 1.230,
+ 1.230, 1.230, 1.230, 1.230, 1.230,
+ 1.230, 1.230, 1.230, 1.230, 1.230,
+ 1.230, 1.230, 1.230, 1.230, 1.230,
+ 1.230, 1.230, 1.230, 1.230, 1.230,