Enhancements of MKRMF

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Abstract.
MKRMF, a data analysis tool of the Chandra X-ray Science Center (CXC), has evolved to more effectively create response matrix files (RMF). It provides new and enhanced features: uniform binning syntax, all-inclusive FITS embedded function (FEF) file extraction, and non-linear EBOUNDS calculation. This paper describes the algorithm, application interfaces and highlights of the future development.

1. Introduction

MKRMF generates a response matrix for an arbitrary redistribution function over a 2-dimensional grid plane. Since last reported by He (1999) it has evolved to include:

- uniform binning syntax and rebinned RMF output,
- application of generic FEF file, and
- non-linear EBOUNDS calculations to closer reflect real gains.

The tool's parameter file (mkrmf.par) has been accordingly updated, as listed in Table 1. The table highlights the most important parameters.

2. Uniform Binning Syntax and Rebinned Output

In conjunction with CXC Data Model (DM) filtering, MKRMF adopts the DM grid binning syntax for the "axis1" and "axis2" parameters. The binning syntax is consistent with other CIAO tools. As previously defined, the binning syntax is grouped into two categories: command line and ASCII table file. The command line input allows the user to specify discrete grids in lower bound, upper bound, and binning type, separated by ":". The grid type can be specified as linear or logarithmic binning for either the binning step or the total number of bins. The ASCII file input allows the user to tabulate an arbitrary grid. The file format

Table 1. Input Parameters for MKRMF

Name	Default Value(if any)	Description
infile		name of FEF input file
outfile		name of RMF output file
axis1		axis-1(name=lo:hi:btype)
axis2		axis-2(name=lo:hi:btype)
logfile		name of log file
thresh	1e-05	low threshold of energy cut-off in keV
outfmt	legacy	RMF output format (legacy—cxc)
clobber	yes	overwrite existing output file (yes—no)?
verbose	0	verbosity level (0 = no display)

contains two columns: lower and upper bounds. Table 2 summarizes the binning syntax.

Table 2. Binning Syntax

Syntax	Description	Example
<axis-name>=<min>:<max>:<bin-num>	linear bin in bin number	pi=1:1024:#1024
<axis-name>=<min>:<max>:<bin-step>	linear bin in bin step	energy=0.1:10.0:0.05
<axis-name>=<min>:<max>:<bin-step>L	logarithimic bin in bin step	energy=0.1:10.0:0.05L
<axis-name>=<min>:<max>:<bin-num>L	logarithimic bin in bin number	energy=0.1:10.0:#1500L
<axis-name>=<text-file>	grids tabulated in ASCII file	energy=grid(eng.txt)

MKRMF always computes the matrix (and EBOUNDS) at full resolution at the specified <min>:<max> range. The matrix can be binned by specifying bin type and step size. MKRMF will use this information to scale down the output to the requested bin size.

3. New FEF File

A FEF FITS binary table is a CXC format convention to allow specification of an n-dimensional image in the form of an analytic function of n variables in a FITS binary table HDU. This file format has been developed to be extremely generic and to allow very cost effective reuse (Rots 2000).

MKRMF takes the analytic redistribution functions which are conventionally expressed by columns of independent function variables. These function variable columns are stored in the FEF format and used by MKRMF to create standard response matrices. Prior to the release of CIAO 2.0, a FEF file existed for each individual spatial region for which (different) redistribution functions were defined. Because of this, those who wished to perform analyses over large spatial regions or over multiple chips potentially had to keep track of a large number of files. In CIAO 2.0, these files have been merged into a single file, an all-inclusive and spatial varying FEF file. In addition to columns contain-

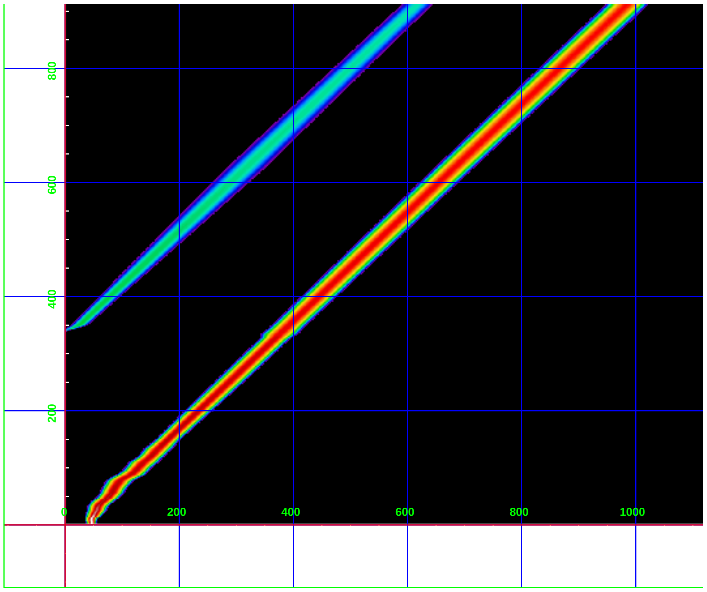

Figure 1. RMF MATRIX Output.

ing redistribution function parameter values, the new FEF file contains new columns `CCD_ID`, `CHIPX`, and `CHIPY`, which provide the location and bounds for each spatial region. Another new column, `REGNUM`, contains an integer value that identifies each spatial region uniquely. The new FEF format also encapsulates the gain relationship of the CCD for energy in a specific region. This relationship is defined by a new column, `CHANNEL` (or PHA), mapped to `ENERGY` in that region. By introducing the (`ENERGY, CHANNEL`) pair columns, the generic FEF extractor can effectively result in data block consisting of one region for each energy when a DM filter is applied to the FEF file, therefore, the generic FEF file is effectively reusable and backward compatible.

The MKRMF user must now use DM syntax to retrieve information for one spatial region, as shown in this example:

```
mkrmf infile=fef.fits[ccd_id=7, chipx=(1:100),chipy=(1:32)]
```

when mkrmf executes the program with an input FEF file named `"fef.fits"`, it extracts the data containing (`ENERGY, CHANNEL`) gain and redistribution function variables internally sorted for `CCD_ID` of 7 with chip pixel range of 1 to 100 and 1 to 32 along X- and Y-Axis, respectively. Figure 1 illustrates two MATRIX components generated on a FEF file with the filter above for a combination of ten embedded Gaussian functions on linear binned pha-energy grids.

4. Non-linear EBOUNDS Interpolation

In previous releases, the EBOUNDS array was calculated through a linear analytic expression of two constant parameters (keywords): `SCALE` and `OFFSETS`.

MKRMF now employs a new algorithm for the gain calculation from data tabulated in the new FEF file. The originally linear interpolation still exists for backwards compatibility.

The `CHANNEL` and `ENERGY` pairs in the new FEF file encapsulate the piecewise linear gain information within a given (`CHIPX, CHIPY`) region for each specific energy value. Our new scheme to calculate the EBOUNDS array is to linearly interpolate the energy for a given pha value from the pairs of channel and corresponding energies that bound the pha value. The EBOUNDS energy derived in this way represents the variation of the CCD gain in that region, or an effectively non-linear and spatial varying relationship.

5. Future Developments

Future focus will be on multi-region RMF calculations. The current tool provides RMF output limited to one region characterized by the same response function within the given (`ENERGY, CHANNEL`) range. However, those parameters are also functions of spatial variables. This limitation will be removed by taking a weighting factor into consideration for each region, so a multi-region RMF output can be achieved by applying the weighting to redistribution functions of the interesting regions. As such, MKRMF data I/O is expected also to be updated in the future. The user interface to MKRMF will also be evaluated to make it easier for users.

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References

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