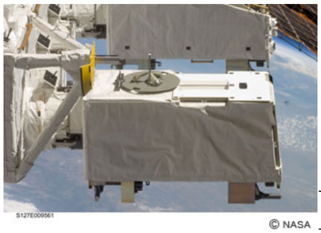MAXI

MAXI Software Usage

Version 1

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ISSUE	DATE	PAGES AFFECTED	DESCRIPTION
Version 1.0	Oct 2018	All	First draft

1 Getting software, calibration and data

1.1 Software and calibration

This document describes how to use the MAXI software package with the archival MAXI data. To analyze the MAXI data, users would need the MAXI software package as well as the calibration data. The MAXI software package is available within HEAsoft starting from version 6.25. The software is obtainable from the HEASARC software download page:

https://heasarc.gsfc.nasa.gov/docs/software/lheasoft/download.html

The MAXI package is available either as source code or binary version together with the installation guide at

https://heasarc.gsfc.nasa.gov/docs/software/lheasoft/install.html.

The MAXI calibration data are part of the CALDB database distributed from the HEASARC. The calibration data are available as tar files from HEASARC page dedicated to MAXI:

https://heasarc.gsfc.nasa.gov/docs/heasarc/caldb/maxi/

The MAXI CALDB page includes links to the CALDB installation guide. CALDB can be installed locally on user disk or use in remote directly from the HEASARC server. The CALDB tar files are one for the GSC instrument (~ 1.2GB in size) and a second for the SSC instrument (~3.8MB).

1.2 MAXI software

The MAXI package includes the specific MAXI tasks as well as many of the HEAsoft general packages and mission independent packages to manipulate FITS files. The specific MAXI tools are listed in Table 1.

Table 1	
mxextract	- Extract source event from multiple HEALPix event files.
mxgrmfgen	- Generate the response matrix file for GSC instrument.
mxgscandat	- Calculate the time to when a source is in each of the GSC FOV detectors.
mxgtiwmap	- Calculate a weighted spatial distribution of events on the detector.
mxlscan	- Calculate a source light curve.
mxproduct	- Generate the high level products (images light curves spectra and response) for both instruments.
mxscancur	- Determine the source position relative to the GSC or SSC instrument.
mxsrmfgen	- Generate the response matrix file for SSC instrument.
mxsscandat	- Calculate the time to when a source is in SSC instrument FOV.

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mxdownload_wget	- Search and retrieve the archived MAXI data for a given sky position and time interval
mxversion	- Print the MAXI software package version

Althought the MAXI software package contains many tools, users would need ***mxdownload_wget*** to retrieve data from the archive and ***mxproduct*** which invoke all other tools to generate high level products. Users would rarely need to run the other tools.

The additional HEAsoft packages are : General_Use FTOOLs (Attitude, Caltools, Futils, Fimage, HEASARC, HEASim, HEASPtools, HEAtools, HEAGen, FV and Time) , and XANADU (Ximage, Xronos, Xspec).

1.3 MAXI calibration data

The MAXI calibration files are needed to run the MAXI tools, in order to generate the spectra and light curves for a given sky position, and to generate response function files (rsp). The files needed to calibrate and screen the Processed and Cleaned data sets are not included in CALDB.
The calibration data are stored in CALDB with the following directory structure

```
                         /maxi
              /gsc                          /ssc
/bcf   caldb.indx  /cpf  /index      /bcf  caldb.indx   /cpf   /index
```

The /bcf directories contain files which are not directly related to creating or applicable to the higher level products extracted from the Region Event Files event. The /index directory includes the archive of the caldb index files for any previous update.
The files in CALDB are listed in Table 2.

Table 2	
Filename	**Description**
GSC/BCF	
mx_gsc{0,1,2,3,4,5,6,7,8,9,a,b}_colea_YYYYMMDD.fits	Integrated collimator effective area per counter as a function of photon incident angle in COL coordinate (theta,phi).
mx_gsc{0,1,2,3,4,5,6,7,8,9,a,b}_hvhist_YYYYMMDD.fits	HV history data
mx_gsc{0,1,2,3,4,5,6,7,8,9,a,b}_piparam_YYYYMMDD.fits	PI spectral-channel parameters
mx_gsc{0,1,2,3,4,5,6,7,8,9,a,b}_teldef_YYYYMMDD.fits	Teldef
mx_gsc_mfptab_YYYYMMDD.fits	Table of X-ray mean free path in beryllium
mx_gsc_ssdock_YYYYMMDD.fits	Information on the time of

	Space Shuttles to the ISS
GSC/CPF	
mx gsc{0,1,2,3,4,5,6,7,8,9,a,b}_arfcorr_YYYYMMDD.fits	Arf correction files.
mx_gsc{0,1,2,3,4,5,6,7,8,9,a,b}_hvxxx_detxXXXX.rmf	Rmf file for GSC.
SSC/BCF	
mx_ssc{h,z}_teldef_YYYYMMDD.fits	Telescope definition files.
mx_ssc{h,z}_colea_YYYYMMDD.fits	Collimator effective area.
mx_ssc{h,z}_quanteff_YYYYMMDD.fits	Quantum efficiency of CCD.
mx_ssc{h,z}_rnfparam_YYYYMMDD.fits	Parameters to create RMF.
mx_ssc{h,z}_col_YYYYMMDD.fits	Collimator slat-plane position.
SSC/CPF	
mx_ssc{h,z}_arf_YYYYMMDD.fits	arf

1.4 MAXI data

The MAXI archive has the science data in the “obs” directory path. The structure of the obs/ directory is as follows (Fig 1) :

```
                      /obs
                        |
             ___________________________
             |             |             |
        MJD55000/ MJD56000/    /MJD57000…      (divided by every 1000 days)
                        |
              ______________________
              |          |           |
        MJD56000/   MJD56001/ … MJD56999/ (up to 1000 directories, one for each day)
              |
           _____________
           |             |
     events/            auxil/              (all the files required for the analysis of that day)
           |
  __________________________________________
  |                         |               |
/gsc_med                  /gsc_low        /ssc_med
  |                         |               |
mx0000_mjd56000_gsc_med.evt   mx0000_mjd56000_gsc_low.evt   mx0000_mjd56000_ssch_med.evt
mx0001_mjd56000_gsc_med.evt   mx0001_mjd56000_gsc_low.evt   mx0001_mjd56000_ssch_med.evt
…                             …                             …
mx0767_mjd56000_gsc_med.evt   mx0767_mjd56000_gsc_low.evt   mx0767_mjd56000_ssch_med.evt
                                                            mx0000_mjd56000_sscz_med.evt
                                                            mx0001_mjd56000_sscz_med.evt
                                                            …
                                                           mx0767_mjd56000_sscz_med.evt
```

Fig 1 Structure of the archive

The data are first divided in directories containing up to 1000 days named as MJDXXXXX where XXXXX is the MJD value corresponding to the 1000 included in the directory. For example MJD55000 includes sub-directories from MJD 55000 to 55999. Below the data are divided in subdirectories containing one day of data, named after the MJD of that day Each sub-directory has all the files required for the data analysis of that day.
Each day's directory contains the events/ and auxil/ directories. The events directory has up to three sub-bit directories gsc_low/ gsc_med/ ssc_med/ corresponding to the instruments bit-rates (SSC has only medium bit-rate data).

For each day, the science data have been divided in HEALPix sky regions (Region Event File) to cover the entire sky. The sky regions are the same for the GSC and SSC and the each event file contains science data for a specific sky region (see Appendix for the coordinates of the region center). The gsc_low/ and gsc_med/ subdirectories have up to 768 Region Event Files each corresponding to the 768 HEALPix regions, each of 7.329 x 7.3298 sq deg,. The ssc_med/ has up to 768 files for the Z array and 768 for the H. MAXI does not cover all the 768 sky regions every day; some regions may not be available on a particular day. Also, data can be missing for other reasons (e.g. MAXI shutdown, downlink problems, processing errors).
If a HEALPix region is not observed within a day, or there are other problems that prevent creation of the HEALPix file, event files are not created. The event data in the archive are cleaned for unwanted time intervals, such as when the instrument and orbital parameters are out of nominal settings range.

The auxil/ directory contains all files required for data analysis for that particular day (Table 1).

The Region data set includes the following science event data files for each day:

- 768 event files for the GSC (all the 12 counters combined) in low bit rate and if available a similar set in medium bit rate
- 768 event files for the SSC horizontal array (SSC-H) in medium bit rate if available
- 768 event files for the SSC zenithal array (SSC-Z) in medium bit rate if available

The filename for the event files follows the convention:

- mx_mjdMMMMM_gsc_BIT_NNN. evt
- mx_mjdMMMMM_sscC_BIT_NNN.evt

where MMMMM indicates the MJD date, C is set h or z to id the horizontal and zenithal SSC arrays respectively, BIT is the bit-rate, either med or low and NNN is the region ID running from 001 to 768 and.
For each day interval there are several auxiliary files. Table 3 lists all possible auxiliary files :

Table 3	
Auxiliary filename	**Description**
mx_mjdMMMMM.att	Attitude file valid for GSC and SSC
mx_mjdMMMMM.orb	Orbit file valid for GSC and SSC
mx_mjdMMMMM.tim	Time info used in processing, valid for GCS and SSC
mx_mjdMMMMM.fra	Free-run clock file for GSC-A(GSC0,1,2,3,4,5)

mx_mjdMMMMM.frb	Free-run clock file for GSC-A(GSC0,1,2,3,4,5)
mx_mjdMMMMM.iat	ISS attitude file
mx_mjdMMMMM.ias	ISS ancillary file: Joint angles of solar paddles: alpha
mx_mjdMMMMM.isp	ISS ancillary file: Joint angles of solar paddles: beta
mx_mjdMMMMM.mkf	Make filter file valid for the GSC and SSC
mx_mjdMMMMM_gsc.hk	GSC housekeeping file
mx_mjdMMMMM_ssch_dp.hk	SSC-H array data processor housekeeping file
mx_mjdMMMMM_ssch_e.hk	SSC-H array housekeeping file related to the CCD
mx_mjdMMMMM_sscz_dp.hk	SSC-Z array data processor housekeeping file
mx_mjdMMMMM_sscz_e.hk	SSC-Z array housekeeping file related to the CCD
mx_mjdMMMMM_ssch.mkf	Housekeeping for the SSC-H array related to the CCD
mx_mjdMMMMM_sscz.mkf	Housekeeping for the SSC Z array related to the CCD
mx_mjdMMMMM_gscM_BIT.gti	GTI for each of the GSC counter for the HV on/off. M is a value from 0-9 or a,b and BIT is either low or med

1.5 Download the MAXI data from the archive

To download the data, users can either use the DARTS or HEASARC archive interfaces. or use the PERL script ***mxdownload_wget,*** which downloads only the region files relevant to a specific coordinates and time interval.
mxdownload_wget is part of the MAXI package. The scripts allows querying the archive for specific coordinates and time intervals, and has options to just list the data available in the archive for these parameters or actually download the data on a local disk. The script always downloads one additional day at the end of the specified time interval because the task ***mxproduct*** uses information of the day after the observation. ***mxdownload_wget***, has many options that can be viewed by invoking either the command "***fhelp mxdownload_wget***" (which uses the HEAsoft help interface) or the command "***mxdownload_wget –help***".

Example 1 : List the data available for a given coordinates/ time interval without downloading.

mxdownload_wget.pl -coordinates 83.633083,22.0145 -date_from 2010-01-01 -date_to 2010-01-02--dryrun

This command lists all available event data in the archive.

Example 2 : Download the data for a given coordinates and time interval for all instruments.

mxdownload_wget.pl --coordinates 55.5,15.0 --dates 2016-09-30,2016-10-01 --instruments all --chatter 2

The script downloads the MAXI data organized in the same way of the MAXI archive: directories of one day with event data files and the necessary auxiliary files for the MAXI data

analysis. By default event data are downloaded only for the gsc_low. Data from other instrument/rate can be obtained using the option "instruments" (as in the example 2).
The downstream software , e.g. ***mxproduct***, requires that the data be organized as in the archive. Therefore ***mxdownload_wget*** creates the directory structure as in Fig 1. Users should be aware that if data are obtained from the archive not using the *mxdownload_wget* script , before starting the analysis with ***mxproduct*** the data should be organized as in the archive.

2 Analyzing the MAXI data

2.1 Data products by mxproduct

mxproduct is a perl script that runs several MAXI and HEAsoft tasks to generate images, light curves, spectra, and response files. Within ***mxproduct,*** the MAXI tasks are invoked in the following order :

1. *mxextract* - Create a single event file from a collection of event files for a given RA, DEC and radius.
2. *mxscancur* - Create a file to describe the observation/instrument specific conditions.
3. *mxgscandat, mxsscandat* - Create specific scan history files for GSC and SSC.
4. *mxlcscan* - Create light curve files.
5. *mxgtiwmap* - Create an exposure histogram for each incident angle of a given RA, DEC
6. *mxgrmfgen, mxsrmfgen* - Create a response file for GSC and SSC.

By default***, mxproduct*** creates the following set of data products, and places them in a directory named *products/*. Table 4 lists all file products :

Table 4	
Filename	***Description***
*source*_X_YYY.evt	Event file that merges all the individual events files containing the source position
*source*_X_YYY.img	Image obtained from the merged event file
*source*_X_YYY_wmap_src.img	Weighted source image
*source*_X_YYY_wmap_bgd.img	Weighted background image
*source*_X_YYY_src.pi	Source spectrum
source_X_YYY_bgd.pi	Background spectrum
source_X_YYY.rsp	Response to use with the source spectrum
source_X_YYY.lc	Source light curve 2.0–5.95 and 6.0–11.95 keV for the GSC, 0.7–1.997 and 2.0–6.997 keV for the SSC
*source*_X_YYY_scancur.fits	Observation/instrument parameters for the time interval selected
*source*_X_YYY_commands.log	Log file

where *source* is the name specified using the ***mxproduct*** parameter *object* , X is either *g* for GSC or *s* for SSC and YYY is the bit mode *med* or *low*.
The *source*_X_YYY_commands.log contains all the commands and parameters used by ***mxproduct*** during the run and it is useful to check for errors or to re-create science files with different settings.
mxproduct also generates several intermediate files that can be retained by setting the parameter *cleanup=no* (or *cleanup=0*): otherwise, by default, these intermediate files are deleted. Table 5 lists all intermediate files:

Table 5		
GSC	***SSC***	***which***
*source*_X_YYY_scandat.fits	*source*_X_YYY_scandat.fits	*both*
*source*_X_YYY_wmap.fits	*source*_X_YYY_wmap.fits	*both*
*source*_X[n-m]_YYY_ZZZZv_LLLpi	*source*_X[n-m]_YYY_LLLpi	*both*
*source*_X[n-m]_YYY_ZZZZv_LLLevt	*source*_X[n-m]_YYY_LLLevt	*both*
*source*_X[n-m]_YYY.evt	*source*_X[n-m]_YYY.evt	*both*
*source*_X_YYY_gti.fits	*source*_X_YYY_gti.fits	*both*
*source*_user_gti.fits	*source*_user_gti.fits	*both*
*source*_X[n-m]_YYY_ZZZZv_hvgti.fits		*gsc*
*source*_X[n-m]_YYY_fovgti.fits		*gsc*
*source*_X[n-m]_YYY_fovgti_LLL.fits	*source*_X[n-m]_YYY_fovgti_LLL.fits	*both*
*source*_X[n-m]_YYY_ZZZZv_gti.fits	*source*_X[n-m]_YYY_gti.fits	*both*
*source*_X[n-m]_YYY_ZZZZv_gti_LLL.fits	*source*_X[n-m]_YYY_gti_LLL.fits	*both*
*source*_X[n-m]_YYY_gti.fits		*gsc*
*source*_X[n-m]_YYY_gti_LLL.fits		*gsc*
	*source*_X[n-m]_YYY.rsp	*ssc*
	*source*_X[n-m]_YYY.img	*ssc*
gsc.list	*ssc.list*	*both*
gsccamera.list	*ssch.list, sscz.list*	*both*
gsc_pi_ch.list	*ssc_pi_ch.list*	*both*

where for the GSC X[n-m] is g[0-b] (the unit detectors are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b) and for the SSC X[n-m] is s[h-z] (the unit detector are h for horizontal and z for zenith); ZZZZ is the GSC voltage set either to 1550V or 1650V; LLL is set to src or bgd for source or background.

Figure 1 shows the flow diagram of ***mxproduct*** to generate the products.

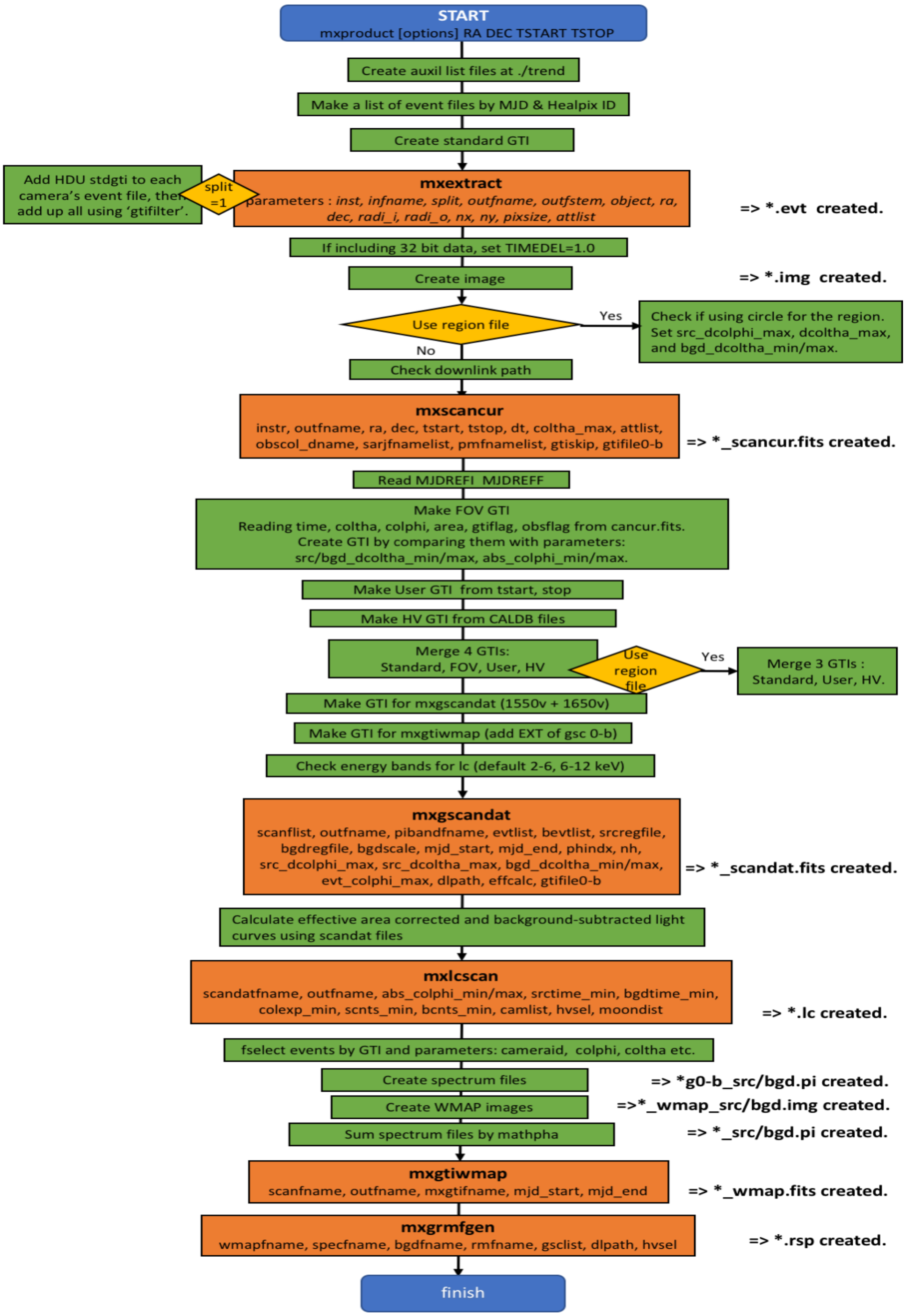

Fig 1 ***mxproduct*** diagram software flow

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2.2 How to run mxproduct

mxproduct requires four parameters to be set. All the other parameters are optional. The required parameters are: the source coordinates provided as RA and Dec (using the parameters ra and dec), and the start and stop time (using the parameters tstart and tstop). The command therefore would be:

mxproduct ra= RA dec=Dec tstart="YYYY-MM-DD" tstop=" YYYY-MM-DD" {PARAMETERS}

or

mxproduct RA Dec tstart tstop {PARAMETERS}

RA and Dec are in degrees and the start and stop are specified as YYYY-MM-DD. If no additional parameters are specified, the products are generated only for the GSC low .The source data are selected by elongation angles from the target position in a scan direction and perpendicular to the scan direction, the background data are selected before and after the scan of the source. The light curves are created with a default energy band (see below). ***mxproduct*** requires an input data directory named obs/ with the same archive structure as shown in Fig 1. ***mxproduct*** has to be run either in the directory containing obs/ or using the parameter *datapath* to specify the directory path where the obs/ is located. The filenames of the products are generated with a default prefix 'target' (in place of *source* as in table 4) and stored in a directory named *products*.

To list all possible parameters and their defaults users can type :

plist mxproduct

To get the help for ***mxproduct*** users can type :

fhelp mxproduct

The important optional parameters are the following:

a) Instrument setting

The GSC data are taken in two bit rates (low and med) and SSC is only one bit rate (med). ***mxproduct*** can process, in a single run, one GSC bit rate data and the SSC data . To process both GSC bit rate ***mxproduct*** has to be run twice. The parameters that allow selecting which instrument data to process and the bit rate are:

- skip_gsc=0 process the GSC (default); set to 1 to skip GSC processing
- skip_ssc=1 do not process the SSC (default); set to 0 to process the SSC data
- gscdl= low process the low bit rate (default) ; set to med to use the med bit rate data

Examples :

To process only the GSC low data the command is :

mxproduct ra= RA dec=Dec tstart="YYYY-MM-DD" tstop=" YYYY-MM-DD"

To process the GSC low data and the SSC data the command is *mxproduct ra= RA dec=Dec tstart="YYYY-MM-DD" tstop=" YYYY-MM-DD" skip_ssc=0*

To process only the GSC med data the command is:
mxproduct ra= RA dec=Dec tstart="YYYY-MM-DD" tstop=" YYYY-MM-DD" gscdl=med

b) Prefix for output filename , input and output directory

The parameter *object* allows the user to specify a prefix to the out filename and *outpath* to specify a directory name where to place the products. By default they are set to *target* and *product* respectively. The parameter *datapath* sets the path where the directory *obs/* of the input files are located. If not set, by default, it uses the current directory.

Examples :
Process only the GSC low data and set the prefix for the output filenames to "crab":

mxproduct ra= RA dec=Dec tstart="YYYY-MM-DD" tstop=" YYYY-MM-DD" object=crab

Process only the GSC low data, set the prefix for the output filenames to "crab", and place the output file in a directory named myproducts:

mxproduct ra= RA dec=Dec tstart="YYYY-MM-DD" tstop=" YYYY-MM-DD" object=crab outpath=myproducts

c) Specify region file
To specify the region selection, the parameters are :

srcregfile_gsc	Source region filename GSC
srcregfile_ssc,	Source region filename SSC
bgdregfile_gsc	Background region filename GSC
bgdregfile_ssc	Background region filename SSC

The region-file format is the ds9 format in plain text with the fk5 coordinate system in degrees. When saving a region file in ds9, select the coordinates **in degrees**.. For the source, set the 'circle' region area, and a "circle - circle" for the background (i.e. the background is a larger circle with a smaller at its center removed: an annulus). The background region must to be within 8.0 degrees of the center coordinates. A sample source region file looks like:

```
# Region file format: DS9 version 4.1  global color=green dashlist=8 3
width=1 font="helvetica 10 normal roman" select=1 highlite=1 dash=0
fixed=0 edit=1 move=1 delete=1 include=1 source=1  fk5
circle(49.951,41.512,6000")
```

A matching background region would be :

```
# Region file format: DS9 version 4.1  global color=green dashlist=8 3
width=1 font="helvetica 10 normal roman" select=1 highlite=1 dash=0
fixed=0 edit=1 move=1 delete=1 include=1 source=1  fk5
circle(49.951,41.512,108000")
```

```
-circle(49.951,41.512,7200")
```

(i.e. define the source region as a circle with 6000 arcsec (1.667 deg) radius around 49.951 deg R.A., 41.512 deg Dec, and a background region centered on the same location, with 10800 arcsec (3 deg) radius with a circle removed of radius 7200 arcsec (2 deg).

Example :
Process only the GSC low data with region file for source and background:

mxproduct ra= RA dec=Dec tstart="YYYY-MM-DD" tstop=" YYYY-MM-DD" srcregfile_gs=source.reg bgdregfile_gsc =background.reg

The following figures show examples of WMAP image of the Crab for source and background regions without (default settings) and with the region files. Without region files, the default source and background data are selected by elongation angles from the target in a scan direction and in a direction perpendicular to the scan direction. The generated images are neither exposure-corrected nor background-subtracted

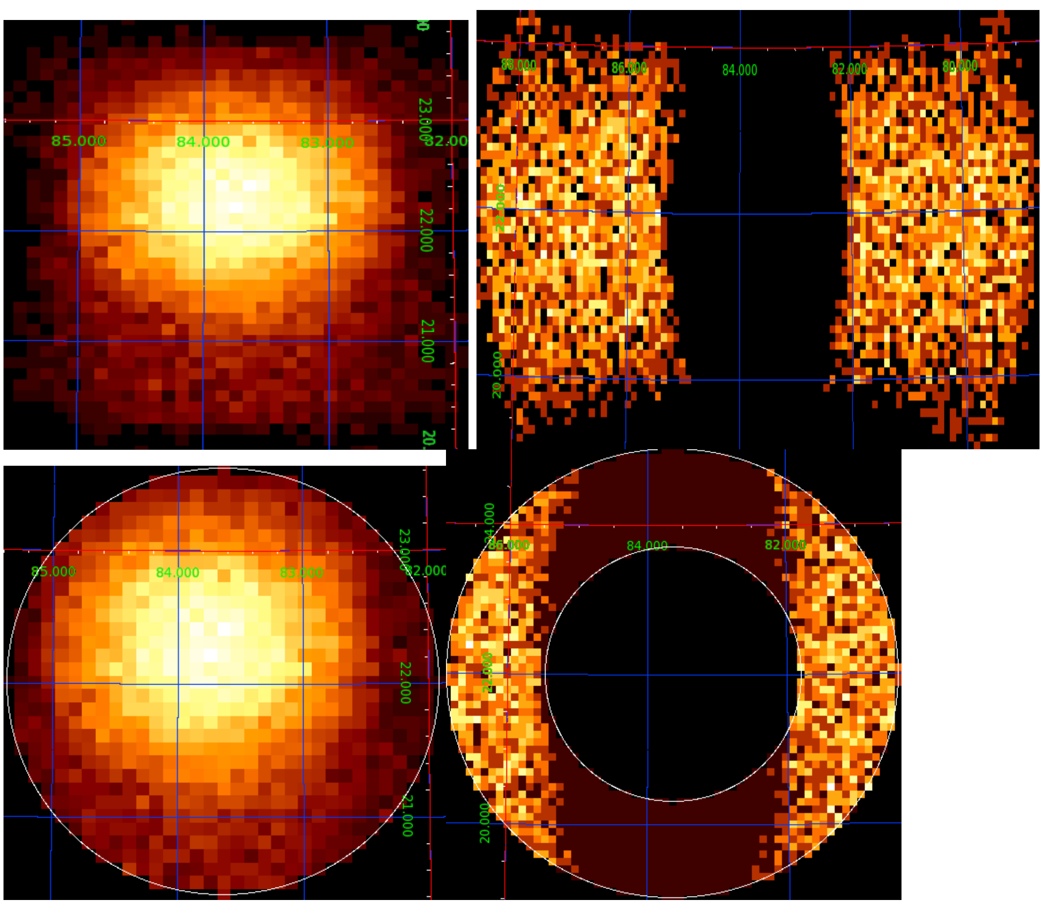

Fig 2 From left to right, a source WMAP image and a background WMAP image without region

files, a source WMAP image and a background image with region files.

d) Specify energy band

mxproduct, generates multi-band light curves stored in multiple extensions in a single output FITS file. The default energy bands are 2.0–5.95 and 6.0–11.95 keV for GSC, 0.7–1.997 and 2.000–6.997 keV for SSC. To change the energy bands, users can input a plain text file that describes the desired energy bands using the parameters:

ebandfname_gsc GSC Eband filename
ebandfname_ssc SSC Eband filename

The format of the plain text file containing the energy bands has each line consisting of a pair (Minimum, Maximum) of the energy in keV, separated by a single space. The following is an example for specifying three energy bands, 2–5.95, 6–11.95, and 12–20 keV.

```
2.0 5.95
6.0 11.95
12.0 20.0
```

Examples :

Process only the GSC low data with the user selected GSC energy bands stored in the file ebands.txt:

mxproduct ra= RA dec=Dec tstart=”YYYY-MM-DD” tstop=” YYYY-MM-DD” ebandfname_gsc=ebands.txt

e) Retain the intermediate file

During the processing, many intermediate files (GTI files, spectrum files for individual cameras, *etc*) are created in the same *products* directory. By default, these files are deleted after the processing. To retain these files, set the parameter *cleanup* to “no”.

2.3 Examples

- Extract products for the GSC low for the Crab for the entire month of Jan 2010.
  To download the data we use the command :

  mxdownload_wget.pl -coordinates 83.633083,22.0145 -date_from 2010-01-01 -date_to 2010-01-31

  The data are placed in the obs/ directory located in the same directory where the command was issued. Note, as mentioned earlier, this will actually get data a day past the date_to setting (Feb 1 2010 in this example). ***mxproduct*** is run in the same directory that contains the obs/ directory. The command is:

  mxproduct ra=83.633083 dec=22.014500 tstart=”2010-01-01” tstop=” 2010-01-31” object=crab

- Run ***mxproduct*** on the same data, but with the obs/ directory is located in */My/Data/Maxi/* . Process all data within a 10 degree radius of the Crab:

  mxproduct object=crab datapath=/My/Data/Maxi radi_o=10 ra=83.633083 dec=22.014500 tstart="2010-01-01" tstop="2010-01-31"

- Run ***mxproduct*** on the same data, specifying the region file for source, src.reg, and for background, bgd.reg .

  mxproduct object=crab srcregfile_gsc=src.reg bgdregfile_gsc=bgd.reg ra=83.633083 dec=22.014500 tstart="2010-01-01" tstop=" 2010-01-31"

- Run ***mxproduct*** on the same data, but specify different energy band for the light curve. The energy band values are stored in the gsc_eband.list file. Write the outfiles in the directory named test1/
  mxproduct object=crab ebandfname-gsc=gsc_eband.list outpath= test1 ra=83.633083 dec=22.014500 tstart="2010-01-01" tstop=" 2010-01-31"

- Run ***mxproduct*** on SSC data only (note that this would also require setting "-instruments ssc" in mxdownload_wget.pl earlier to obtain the necessary SSC files)
  mxproduct object=crab skip-gsc=1skip-ssc=0 test1 ra=83.633083 dec=22.014500 tstart="2010-01-01" tstop=" 2010-01-31"

2.4 Caveats

- The GSC low (gsc_low/) data are always available (unless tiles or data are missing because the entire instrument was not operating, or a section of sky was not observed) , but the gsc_med data is not as consistently available. The latter is calibrated up to 30 keV.

- The generated images are neither exposure-corrected nor background-subtracted.

- The source and background region files only allow circles. Other shapes are not accepted. If the background region is too far from the source, the background may be not well estimated.

- When neighboring sources are excluded from the source/background region, the effective area may not be accurate.

- *mxproduct* calculates exposure at the target position, RA and DEC specified in the command line. It is assumed that the region file to extract the events, if specified, is centered and covers the entire point spread function (PSF). When the center position of the region file is shifted from the center, and/or part of the PSF are missing (e.g. to exclude a contaminating source), the exposure may not be correct. Even in such a case, the background scale factor is correct,

.

and the background subtracted spectra and light curves are calculated.

- If a neighboring object brightens unexpectedly, the background flux will appear to be higher, and hence the target flux will appear to be lower.

- A realistic simulation under optimal observation conditions suggests that MAXI will provide all-sky images of X-ray sources of ~20 mCrab (7e-10 erg/cm2/s in the energy band of 2–30 keV) from observations during one ISS orbit (90 min), ~4.5 mCrab for one day, and ~2 mCrab for one week. (*Matsuoka et al. PASJ 61, 999, 2009*)

- *mxproduct* runs without region files, however, the estimated background level might be underestimated. We recommend using options, *srcregfile_gsc, bgdregfile_gsc, srcregfile_ssc, bgdregfile_ssc* to specify regions

- The light curves **are** not corrected for the effective area. The absolute count rate for the low energy band is underestimated by ~10%. The light curves may show some jumps, which might be artificial (not related to the target). The light curves shown below are from the Crab . There is a 10% reduction compared to results using the MAXI on-demand process (http://maxi.riken.jp/mxondem/), particularly below 4 keV.

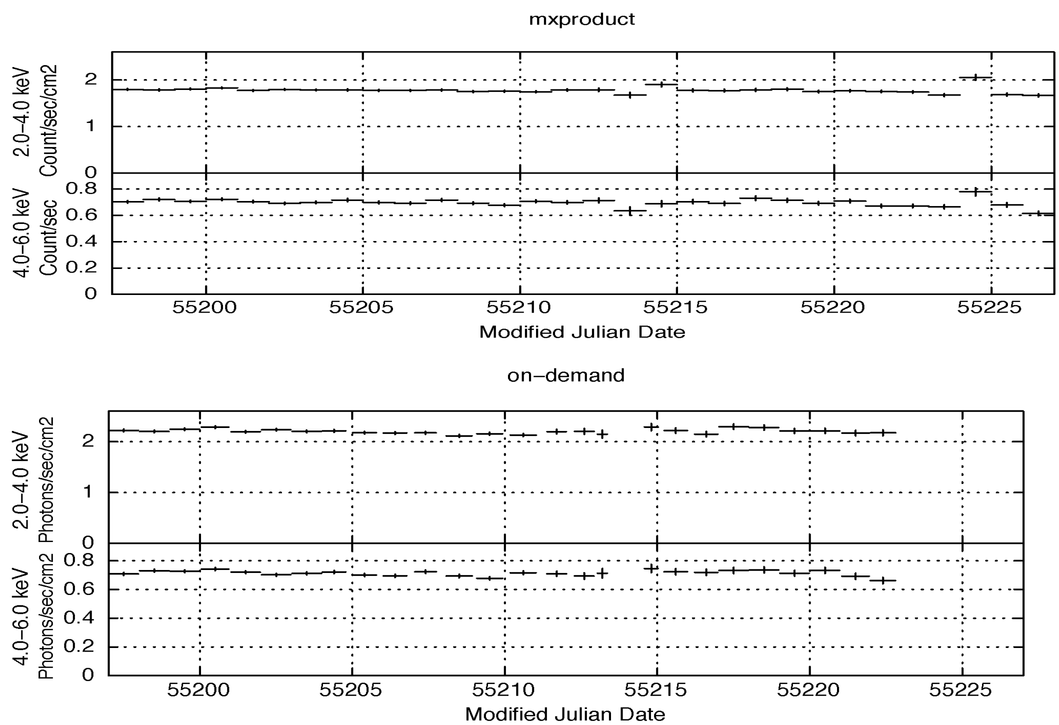

Fig 3 The light curves of the Crab from 2010-01-01 (MJD=55197) to 2010-01-31 (MJD=55227) created by mxproduct and from the on-demand webpage.

2.5 Data analysis of the products

The products output from ***mxproduct*** can be used directly in XSPEC and XRONOS. All products files generated by ***mxproduct*** are in the standard FITS format.
The following is the standard entry-level procedure with the XANADU/HEAsoft spectral-analysis package XSPEC to view the background-subtracted spectrum.

```
>xspec
 cpd /xw
 data 1:1 "crab_gsum_src.pi"
 back 1   "crab_gsum_bgd.pi"
 resp 1   "crab_gsum.rsp"
 setplot energy
 ignore bad
 iplot ldata
 plt>  log x on 1
 plt>  log y on 1
 plt> label t crab
 plt> lwidth 5
 plt> rescale x 1 10
 plt>plot
```

The GSC has 2 data types: gsc_low and gsc_med. GSC consists of 12 counters, with the counter ID = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, a, b. Data are taken in two bit rates: gsc_low and gsc_med. The products are generated for each individual bit rate where all the counters are summed up.
The recommended energy ranges for gsc_low and gsc_med, are 2-20 keV and 2-30 keV respectively. The SSC has only 1 data type: ssc_med.
The SSC has 2 cameras, SSC-h and SSC-z. The products generated by ***mxproduct*** are the sum of the two cameras. The recommended energy range for the SSC is 0.7-7 keV. The width of the spectral bin is 50 eV for GSC, and 3.65 eV for SSC.

The calculated light curves (crab_gsum.lc as for the example above) contain the same number of the FITS extensions as that of the energy bands specified in the input text file (gsc_eband.list in the example above) with the ebandfname_gsc (or ebandfname_ssc) option. Each FITS Extension is named *LCDAT_PIBANDn* for the *(n+1)*-th line of the energy band in the input gsc_eband.list. Example: the FITS Extension *LCDAT_PIBAND0* contains the rates for the energy-band of the first line in gsc_eband.list. The integration time for each bin in the light curve is 40–200 seconds, which corresponds to the period of a single MAXI scan in which the source is in the field-of-view. The light curve bins are separated by the intervals between the two successional scans, which are ~92 min (= ISS orbital period) in most cases, but can be as short as ~15 min.
The light curve(s) can be plotted using fplot, specifying *TIME* for the X-axis, and the *RATE* and *RERR* columns as the Y-axis and Y-axis error, respectively. The following is the example with the general plotting tool LCURVE in HEAsoft:
> lcurve nser=1 cfile1="products/crab_gsum.lc" window="-" dtnb=INDEF nbint=INDEF outfile=" " plot=yes plotdev="/xw"

Appendix A: RA and Dec center of the Region files

The two lists gives the coordinates of the RA and Dec of the 768 region files Each row contains 8 values.

List of RA :
45.000000, 135.000000, 225.000000, 315.000000, 22.500000, 67.500000, 112.500000, 157.500000,
202.500000, 247.500000, 292.500000, 337.500000, 15.000000, 45.000000, 75.000000, 105.000000,
135.000000, 165.000000, 195.000000, 225.000000, 255.000000, 285.000000, 315.000000, 345.000000,
11.250000, 33.750000, 56.250000, 78.750000, 101.250000, 123.750000, 146.250000, 168.750000,
191.250000, 213.750000, 236.250000, 258.750000, 281.250000, 303.750000, 326.250000, 348.750000,
9.000000, 27.000000, 45.000000, 63.000000, 81.000000, 99.000000, 117.000000, 135.000000,
153.000000, 171.000000, 189.000000, 207.000000, 225.000000, 243.000000, 261.000000, 279.000000,
297.000000, 315.000000, 333.000000, 351.000000, 7.500000, 22.500000, 37.500000, 52.500000,
67.500000, 82.500000, 97.500000, 112.500000, 127.500000, 142.500000, 157.500000, 172.500000,
187.500000, 202.500000, 217.500000, 232.500000, 247.500000, 262.500000, 277.500000, 292.500000,
307.500000, 322.500000, 337.500000, 352.500000, 6.428571, 19.285714, 32.142857, 45.000000,
57.857143, 70.714286, 83.571429, 96.428571, 109.285714, 122.142857, 135.000000, 147.857143,
160.714286, 173.571429, 186.428571, 199.285714, 212.142857, 225.000000, 237.857143, 250.714286,
263.571429, 276.428571, 289.285714, 302.142857, 315.000000, 327.857143, 340.714286, 353.571429,
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