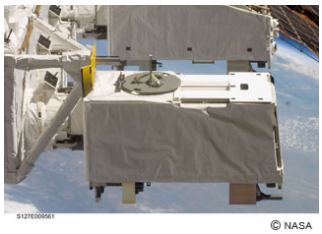

MAXI Software Usage Guide

Version 2.11

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DOCUMENT TITLE : MAXI Archive			
ISSUE	DATE	PAGES AFFECTED	DESCRIPTION
Version 1.0	Oct 2018	All	First draft
Version 2.0	Jul 2025	All	Revision to use mxpipeline
Version 2.1	Aug 2025	Pg. 25	Updated maxlines help text
Version 2.11	Sep 2025	Pg. 9	Replace emdash with '--'

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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: these instructions are based on the newest set of tools (including ***mxpipeline***) released with version 6.36. 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 included with HEAsoft 6.36 are listed in Table 1. Table 1 includes ***hpextract,*** a generic tool replacing the MAXI-specific ***mxextract*** tool.

Table 1	
mxauxlist	- Generate lists of MAXI auxiliary files.
mxevtfilter	- Generate filtered event files and images.
mxevtgti	- Generate scan intervals in which the source is in the field of view
mxgrmfgen	- Generate the response matrix file for GSC instrument.
mxgtiwmap	- Calculate a weighted spatial distribution of events on the detector.
mxlcraw	- Generate scan-based raw data
mxlcurve	- Calculate a source light curve.
mxpha	- Calculate source and background spectra.
mxpipeline	- Generate the high level products (images, lightcurves, spectra, and response) for both instruments.
mxpsfcorr	- Calculate point spread function correction factor.
mxregion	- Generate source and background region files.

mxscancond	- Define scan conditions for each scan.
mxscancur	- Determine the relative source position and effective area.
mxsim_bgd	- Calculate simulated background events.
mxsim_psf	- Calculate simulated point spread function events.
mxsrmfgen	- Generate the response matrix file for SSC instrument.
mxtilelist	- Generate a list of all HEALPixel tiles around the target.
mxdownload_wget	- Search and retrieve the archived MAXI data for a given sky position and time interval
mxversion	- Print the MAXI software package version
hpextract	- Combine HEALPixel event tiles into camera-specific event files

Although the MAXI software package contains many tools, users would need ***mxdownload_wge.plt*** to retrieve data from the archive and ***mxpipeline*** which invoke all other tools to generate high level products. Users would rarely need to run the other tools directly.

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). These are all bundled in the standard HEASoft packge.

1.3 MAXI calibration data

The MAXI calibration files are needed to run the MAXI tools, to generate the spectra and light curves for a given sky position, and to generate response function files. 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).

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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{0,1,2,3,4,5,6,7,8,9,a,b}_hvxxx_bgtemplate _YYYYMMDD.fits	Simulated background template files for 1550 V (803) and 1650 V (854)
mx_gsc_bexsigm24_YYYYMMDD.fits	1-D point spread function at the Beryllium window
mx_gsc_soyuzgti_YYYYMMDD.fits	Information on the time when Soyuz were docks to the ISS
mx_gsc_mfptab_YYYYMMDD.fits	Table of X-ray mean free path in beryllium
mx_gsc_ssdock_YYYYMMDD.fits	Information on the time when space shuttles were docked 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

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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) :

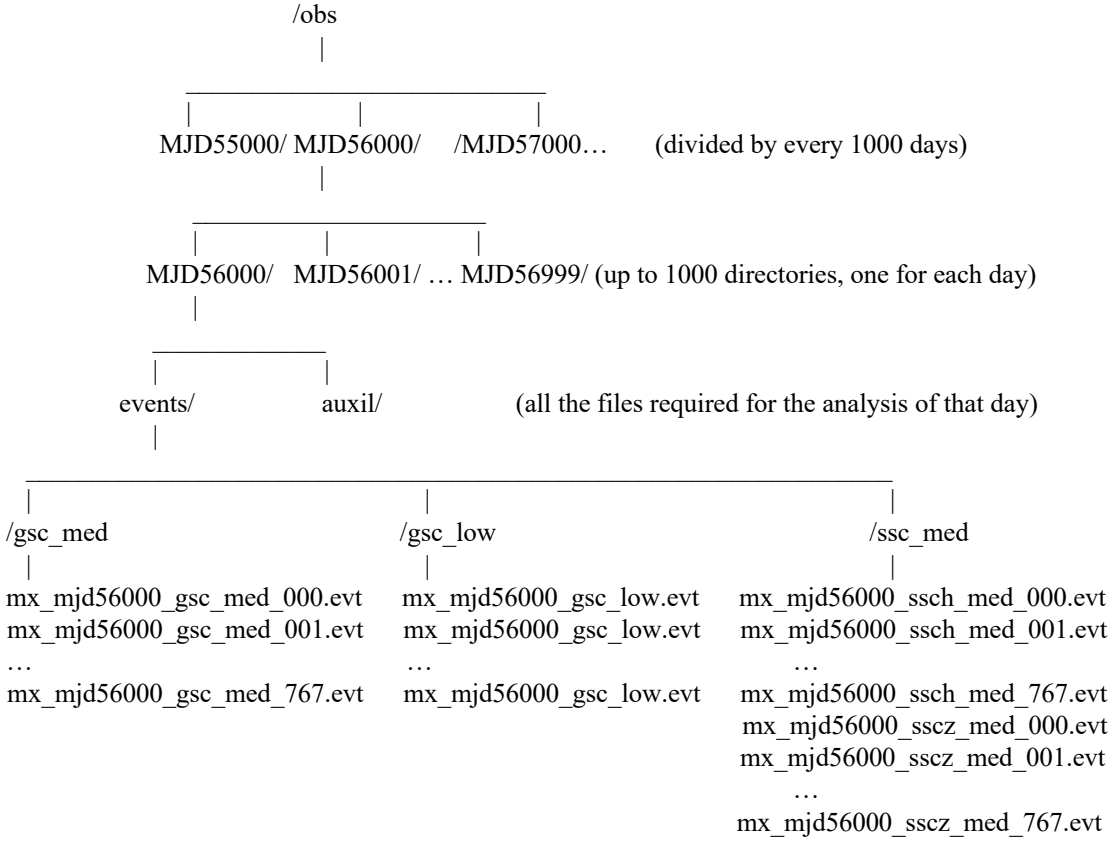

Fig 1 Structure of the archive

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, MJD56000 includes sub-directories from MJD 56000 to 56999. Below this directory, data are divided in subdirectories containing one day of data, named after the MJD of that day. Each subdirectory has all the files required for the data analysis of that day. The earliest day available is MJD 55044: event data start at MJD 55051. The finalized processing data is available the HEASARC and DARTS archive sites roughly two to three weeks after acquisition and is updated once a week. 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 bitrates (SSC has only medium bit-rate data).

For each day, the science data have been divided in HEALPix sky regions (Region Event Files) to cover the entire sky. The sky regions are the same for the GSC and SSC and 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 7.329 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. Data can also be missing for other reasons (e.g. MAXI shutdown, downlink problems, processing errors).

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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.

GSC data is available up to the present with the most recent data lagging about two weeks to allow for final processing. The SSC data ceased being collected on MJD 59751 (2022-06-21).

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

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

- Up to 768 event files for the GSC (all the 12 counters combined) in low bit rate and, if available, a similar set in the medium bit rate
- Up to 768 event files for the SSC horizontal array (SSC-H) in the medium bit rate if available
- Up to 768 event files for the SSC zenithal array (SSC-Z) in the 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 000 to 767.

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 GSC 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.iac	ISS attitude file
mx_mjdMMMMM.iat	ISS attitude file (preferred)
mx_mjdMMMMM.isa	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_att.hk	Attitude housekeeping file
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

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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.pl***, which downloads the region event files (and associated auxiliary data) relevant to a specific coordinates and time interval.

mxdownload_wge.plt is part of the MAXI package. The script queries the archive for specific coordinates and time intervals and has options to list the data available in the archive for these parameters or download the data to a local disk. The script always downloads one additional day at the end of the specified time interval to account for ***mxpipeline*** using information of the day after the observation. ***mxdownload_wge.plt***, has many options that can be viewed by invoking either the command "***fhelp mxdownload_wget.pt***" (which uses the HEAsoft help interface) or the command "***mxdownload_wge.plt –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
```

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 Example 2 above).

The downstream software, e.g. ***mxpipeline***, requires that the data be organized as in the archive. Therefore ***mxdownload_wget.pl*** creates the directory structure as shown in Fig 1. Users should be aware that if data are obtained from the archive not using the ***mxdownload_wget.pl*** script, the data will need to be organized as in the archive before starting the analysis with ***mxpipeline***.

2 Analyzing the MAXI data

2.1 Data products created by mxpipeline

mxpipeline is a perl script that runs several MAXI and HEASoft tasks to generate images, light curves, spectra, and response files. It replaces the earlier pipeline script, ***mxproduct***. Improvements and changes are discussed in more detail below. Users familiar with ***mxproduct*** should need only minor adjustments to use ***mxpipeline***. Key changes are support for simulated background events, point spread function corrections, and the ability to generate source and background regions files. ***mxpipeline*** supports defining a background region offset from the source, or even processing source-only data. The collimator angle limit method for obtaining background included with ***mxproduct*** is no longer supported.

Within ***mxpipeline,*** the MAXI tasks are invoked in the following order:

1. ***hpextract*** - Create a single camera-specific event file from a collection of region event files (HEAPixels).
2. ***mxregion*** – Create source and background regions. Includes the ability to exclude potentially confusing sources in crowded fields. Skipped if region files are specified.
3. ***mxevtgti*** – Use the event files made by ***hpextract*** to compute time intervals in which the target is in the field of view.
4. ***mxevtfilter*** – Generate images in each energy band requested and create event files filtered on key characteristics (source and background, camera voltage states, etc.).
5. ***mxscancond*** – Compile scan-by-scan information on instrument and environment characteristics, including obstructions from solar panels, docked space shuttle, voltage, and low exposure scans.
6. ***mxlcraw*** – Combine scan condition information with raw source and background counts in each energy band with correction factors.
7. ***mxlcurve*** - Create light curve files.
8. ***mxscancur*** – Create time-dependent records for relative observation angles and instantaneous effective area for each detector.
9. ***mxgtiwmap*** - Create an exposure histogram for each incident angle of a given RA, DEC and the associate wmap file.
10. ***mxgrmfgen, mxsrmfgen*** - Create a response file for GSC and SSC.

By default**,** ***mxpipeline*** 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*_XXX.evt	Event file that merges all the individual events files containing the source position
*source*_XXX.img	Image obtained from the merged event file (source and background image planes in separate image arrays)
*source*_XXX_src.pi	Source spectrum
*source*_XXX_bgd.pi	Background spectrum
*source*_XXX.rsp	Response to use with the source spectrum
*source*_XXX_src.reg	DS9 style region file for source
*source*_XXX_bgd.reg	DS9 style region file for background
*source*_XXX.lc	Lightcurve
mxpipeline.log	Log file

where *source* is the name specified using the ***mxpipeline*** parameter *object*, XXX is either *gsc* or *ssc*. The mxpipeline.log contains all the commands and parameters used by ***mxpipeline*** during the run and it is useful to check for errors or to re-create science files with different settings.

mxpipline also generates several intermediate files that can be retained by setting the parameter *cleanup=no*: otherwise, these intermediate files are deleted. Table 5 lists all intermediate files:

Table 5		
GSC	***SSC***	***which***
*source*_gsc_wmap.fits	*source*_ssc_wmap.fits	*both*
*source*_X[n-m]_YYY.pi	*source*_X[n-m]_YYY.pi	*both*
*source*_X[n-m]_YYY_ZZZZv.pi		*gsc*
*source*_X[n-m].evt	*source*_X[n-m].evt	*both*
*source*_X[n-m]_fov.evt	*source*_X[n-m]_fov.evt	*both*
*source*_X[n-m]_fov_YYY.evt	*source*_X[n-m]_fov_YYY.evt	*both*
*source*_X[n-m]_YYY_spec.evt	*source*_X[n-m]_YYY_spec.evt	*both*
*source*_X[n-m]_fov_ZZZZv.evt		*gsc*
*source*_X[n-m]_fov_YYY_ZZZZv.evt		*gsc*
*source*_X[n-m]_psf.evt		*gsc*
*source*_X[n-m]_bgdsim.evt		*gsc*
*source*_X[n-m]_fov.gti	*source*_X[n-m]_fov.gti	*both*
*source*_X[n-m]_fov_ZZZZv.gti		*gsc*
*source*_X[n-m]_scancond.gti	*source*_X[n-m]_scancond.gti	*both*
*source*_X[n-m]_spec.gti	*source*_X[n-m]_spec.gti	*both*
*source*_X[n-m]_ZZZZv_tot.gti	*source*_X[n-m]_tot.gti	*both*
*source*_gsc_all.gti	*source*_ssc_all.gti	*both*
*source*_X[n-m]_ZZZZv_spec.gti		*gsc*
*source*_gsc_YYY_ZZZZv_spec.gti	*source*_ssc_YYY_spec.gti	*both*
	*source*_X[n-m].rmf	*ssc*
	*source*_X[n-m]_YYY.img	*ssc*
*source*_X[n-m]_psfcorr.fits		*gsc*
*source*_X[n-m]_scancond.fits	*source*_X[n-m]_scancond.fits	
*source*_gsc_mask.fits	*source*_ssc_mask.fits	*both*
*source*_gsc_scancur.fits	*source*_ssc_scancur.fits	*both*
*source*_gsc_tiles.list	*source*_ssc_tiles.list	*both*
	*source*_ssc[n-m]_tiles.list	*ssc*
*source*_gsc_evt.list	*source*_ssc_evt.list	*both*
*source*_gsc_YYYevt.list	*source*_ssc_YYYevt.list	*both*
*source*_gsc_YYYevt_ZZZZv.list		*gsc*
*source*_gsc_evtfovscan_YYY.list	*source*_ssc_evtfovscan_YYY.list	*both*
*source*_gsc_scancond.list	*source*_ssc_scancond.list	*both*

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*source*_gsc_fov.list	*source*_ssc_fov.list	*both*
*source*_gsc_fov_YYY.list	*source*_ssc_fov_YYY.list	*both*
*source*_gsc_fovgti.list	*source*_ssc_fovgti.list	*both*
*source*_gsc_psf.list		*gsc*
*source*_gsc_bgdsim.list		*gsc*

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. The same source and background region files generated by the code (or provided by the user) are used for both GSC and SSC.

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3 How to run mxpipeline

mxpipeline requires just four basic parameters: All other parameters are optional. These required parameters are the source coordinates (set using the parameters *ra* and *dec*), and the start and stop time (set using the parameters *tstart* and *tstop*). The most basic command therefore would be:

```
mxpipeline ra=RA dec=Dec tstart="YYYY-MM-DD" tstop="YYYY-MM-DD"
  or
mxpipeline RA Dec YYYY-MM-DD YYY-MM-DD
```

Any additional parameters can be specified with "parameter=value" added at the end of the basic ***mxpipeline*** command as shown above.

RA and Dec are given in degrees (J2000) and the start and stop are specified as YYYY-MM-DD. The start and stop can also be given in the form YYYY-MM-DDThh:mm:ss. Note that if stop is given as YYYY-MM-DD with no hh:mm:ss, the stop time will be interpreted as stopping at the **end** of that specified day.

If no additional parameters are specified, the products are generated for the GSC low bit rate data. The source area is defined a circle around the target with a radius of 1.6 degrees, and a background is defined by a concentric circular region 3.0 degrees in radius centered on the target, but with an inner radius of 1.7 degrees excluded. Images and lightcurves are generated for the target in two energy bands, 2-6 and 6-20 keV, and spectra covering the full energy range using all available data. Lightcurves are made with 1.0 day bins. A master event file is also created. The files will use the default prefix *target* and products generated will be in the directory products/.

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

```
plist mxpipeline
```

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

```
fhelp mxpipeline
```

The help document for ***mxpipeline*** is also included at the end of this document.

The most used optional parameters are described below.

3.1 Setting the detector and bit rate

The GSC data are taken in two bit rates (low and med) and SSC is in one (med). ***mxpipeline*** can process, in a single run, one GSC bit rate and the SSC data. To perform both GSC and SSC processing, specify *detector*="gsc_low,ssc" or "gsc_med,ssc". Processing both bit rates of GSC is not supported: if both GSC bit rates are desired, they must be processed separately (and with different *outpath* settings to prevent files from clobbering each other).

3.2 Setting the OBJECT keyword

The parameter *object* allows the user to specify the keyword value for OBJECT in the output products. The default is "target" if not set otherwise. A filename prefix is generated from this setting, but to make names compatible with Unix conventions, the prefix for files is modified from the *object* parameter in the following fashion:

- The prefix is always lower case;
- The prefix converts coordinates in names that are celestial coordinates with 'n' for northern sources (positive declination) and 's' for southern sources (negative declination);
- The prefix converts coordinates in names that are in galactic coordinates with '+' replaced by 'p' and '-' by 's';

- The prefix removes '-', '_', and any whitespace;
- Decimal points in coordinates are replaced with '_'.

Some examples:
object="Crab" => prefix is "crab"
object="Terzan 5" => prefix is "terzan5"
object="GX 5-1" => prefix is "gx5m1"
object="Swift J2345.1-7804" => prefix is "swiftj2345_1s7804"
object="Cyg X-1" => prefix is "cygx1"

The *object* parameter cannot include characters like '[' or '}' which have special meanings in Unix.

Example:

Set OBJECT to "Crab" with all files beginning with "crab" and the OBJECT keyword in output files is set to "Crab".

```
mxpipeline ra=RA dec=Dec tstart="YYYY-MM-DD" tstop="YYYY-MM-DD" object="Crab"
```

3.3 Using input source and background region files.

The parameters *src_regfile* and *bkg_regfile* can be set to use region files instead of generating them. Note that these must be DS9 compatible format files with all coordinates given in the fk5 coordinates system and with units of degrees for RA and Dec. The MAXI software expects geometry to be defined with "circle" or "circle-circle" formats: other geometries are not well tested.

A background region must not extend beyond the search radius of the observed events, or background will not estimated correctly.

EXAMPLE INPUT REGION FILES

Source region file:
```
# 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")
```

Background region file:
```
# 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")
```

These example files 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 concentric background region with 10800 arcsec (3 deg) radius with an inner circle removed of radius 7200 arcsec (2 deg).

The MAXI tool ***mxregion*** makes region files and can be used to create files without using ***mxpipeline***.

EXAMPLE USE OF REGION FILE INPUTS

Process GSC low data using input region files for source and background:

```
mxipeline ra=RA dec=Dec tstart=”YYYY-MM-DD” tstop=”YYYY-MM-DD”
src_regfile=source.reg bkg_regfile=background.reg
```

3.4 Automatically exclude known bright sources

The MAXI reference data includes a catalog of known bright sources and by setting the parameter catalog to REFDATA (the default setting), ***mxpipeline*** will use ***mxregion*** to generate source and region files that exclude these sources.

EXAMPLE

```
mxpipeline ra=270.290545 dec=-25.078922 object=”GX 5-1” tstart=2010-11-10
tstop=2010-11-19 src_radius=1.6 bkg_inner_radius=1.7 bkg_outer_radius=3.0
confusion_radius=1.0 catalog=REFDATA
```

This sets a source position with a region 1.6 degrees around the source, a background region 3.0 degrees around the source with an inner circle removed with a 1.7-degree radius, and the tool ***mxregion*** will read the built-in bright source catalog in the reference data area and carve out 1.0 degree radius circle around any sources found in the catalog. The OBJECT keyword will be set to “GX 5-1” and the filenames will use the prefix “gx5m1”. Note that all the values for region settings above are default settings. The same result could be obtained with:

```
mxpipeline ra=270.290545 dec=-25.078922 object=”GX 5-1” tstart=2010-11-10
tstop=2010-11-19
```

The resulting regions look like this:

gx5m1_src.reg:

```
# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal" select=1
highlite=1 dash=0 fixed=0 edit=1 move=1 delete=1 include=1 source=1 fk5
circle(270.290545,-25.078922,5760.000000") # color=green width=2
-circle(272.685000,-26.150000,3600.000000") # color=green dash=1 width=2
```

gx5m1_bkg.reg:

```
# Region file format: DS9 version 4.1
global color=green dashlist=8 3 width=1 font="helvetica 10 normal" select=1
highlite=1 dash=0 fixed=0 edit=1 move=1 dele
te=1 include=1 source=1
fk5
circle(270.290545,-25.078922,10800.000000") # color=green width=2
-circle(270.290545,-25.078922,6120.000000") # color=green dash=1 width=2
-circle(266.983000,-26.564000,3600.000000") # color=green dash=1 width=2
-circle(267.233000,-24.895000,3600.000000") # color=green dash=1 width=2
-circle(268.063000,-22.343000,3600.000000") # color=green dash=1 width=2
-circle(272.685000,-26.150000,3600.000000") # color=green dash=1 width=2
```

where the source region is a 1.6 degree (5760 arcsec) radius circle around GX 5-1 and a 1.0 degree (3600 arcsec) radius around neighbouring source SAX J1810.8-2609 to exclude it, and the background region is a 3.0 degree (10800 arcsec) radius around GX5-1, with a 1.7 degree (6120 arcsec) inner radius removed, and 4 neighbouring sources (SAX J1810.8-2609, XTE J1752-223, Terzan 5, and GX 3+1) also removed, each with 1.0 degree exclusion circles. No other known sources in the MAXI bright source catalog overlap with the source or background regions.

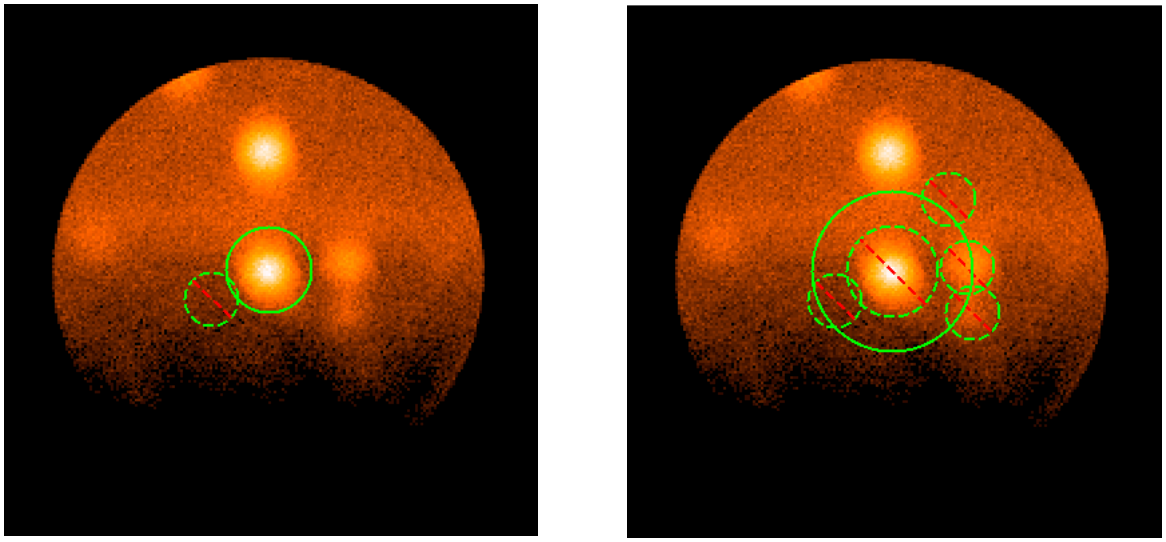


Fig 2. Example image of GX 5-1 as seen by MAXI with a default source region definition (left) and default background region definition (right). All events within 8 degrees of GX 5-1 are shown. Dashed lines with red slashes show exclusion regions of 1 degree radius around known bright sources found in the MAXI bright source catalog. In the source region, a single bright source (SAX J1810.8-2609) is excluded, while in the background region, three additional intruding sources (top to bottom on right: XTE J1752-223, Terzan 5, and GX 3+1) as well as SAX J1810.8-2609 are excluded. Other bright sources (such as the dominant GX 9+1 (top center)) are far enough from the outer radius of the background region to not require exclusion.

3.5 Using a custom bright source catalog.

The user can replace the MAXI catalog with their own catalog by setting *catalog* to "None" and *user_catalog* to a filename. The user-provided catalog should be an ASCII file with one source per line, and each source is provided as either RA and Dec or RA, Dec, and Name with each separated by a column.

```
mxpipeline ra=RA dec=DEC tstart=YYYY-MM-DD tstop=YYYY-MM-DD catalog=NONE
user_catalog=user_catalog.txt
```

or if the user catalog is a supplement, not a replacement, for the built-in bright source catalog:

```
mxpipeline ra=RA dec=DEC tstart=YYYY-MM-DD tstop=YYYY-MM-DD catalog=REFDATA
user_catalog=user_catalog.txt
```

3.6 Specify energy bands

mxpipeline generates light curves and images in up to three different energy bands. The default energy bands are defined by the ASCII format file "maxi_energy_bands.txt" stored in the reference data area. This file contains:

```
# GSC
# conversion 50 eV/ch
#  min_ch    max_ch  min_ene   max_ene
   40        120     2.0       6.0
   120       400     6.0       20.0
# SSC
# conversion 3.65 eV/ch
#  min_ch    max_ch  min_ene   max_ene
   192       1918    0.7       7.0
```

where lines that start with "#" are comments and ignored, and the columns contain (in order) the start and stop PI channel number and the start and stop energy levels in keV. To set different energy ranges, the parameter *eband_fname* can be set to a local file in the same format with the desired settings. The software can support a total of up to three bands. Note that the comment lines "# GSC" and "# SSC" lines are required.

EXAMPLE

```
mxpipeline ra=RA dec=Dec tstart="YYYY-MM-DD" tstop="YYYY-MM-DD"
eband_fname=ebands.txt
```

where the file `ebands.txt` sets two energy bands for GSC from 2-8 keV and a second 12-20 keV, and none for SSC:

```
# GSC
# conversion 50 eV/ch
#  min_ch    max_ch  min_ene   max_ene
   40        160     2.0       8.0
   240       400     12.0      20.0
# SSC
```

3.7 Use simulated background

mxpipeline includes a new tool, ***mxsim_bgd***, to generate simulated background events using known characteristics of the instrument, cosmic X-ray background, and other noise sources such as the radioactive power source in the Soyuz spacecraft when docked. This is performed by setting the parameter *backmodel* to yes (The default is no):

```
mxpipeline ra=RA dec=Dec tstart="YYYY-MM-DD" tstop="YYYY-MM-DD" backmodel=yes
```

The necessary ancillary information to generate the simulated background, such as the docking dates for Soyuz, are obtained from CALDB unless set otherwise.

3.8 Other 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 get data a day past the date_to setting (Feb 1 2010 in this example). ***mxpipeline*** is run in the same directory that contains the `obs/` directory. The command is:

```
mxpipeline ra=83.633083 dec=22.014500 tstart="2010-01-01" tstop="2010-01-31"
object="Crab"
```

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

```
mxpipeline object="Crab" datapath=/My/Data/Maxi search_radius=10 ra=83.633083
dec=22.014500 tstart="2010-01-01" tstop="2010-01-31"
```

.

- Run ***mxpipeline*** on SSC data only. Note that this would also require downloading SSC data with the setting *-instruments ssc_med* with ***mxdownload_wget.pl***.

```
mxpipeline object="Crab" outpath="test1" detector=ssc_med ra=83.633083
dec=22.014500 tstart="2010-01-01" tstop="2010-01-31"
```

3.9 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 use of simulated background is restricted to only certain cameras with GSC data and cannot generate results above 20 keV. Not all voltages are supported. Those supported are the most common settings in the MAXI data. Simulated background is not available for SSC data.

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

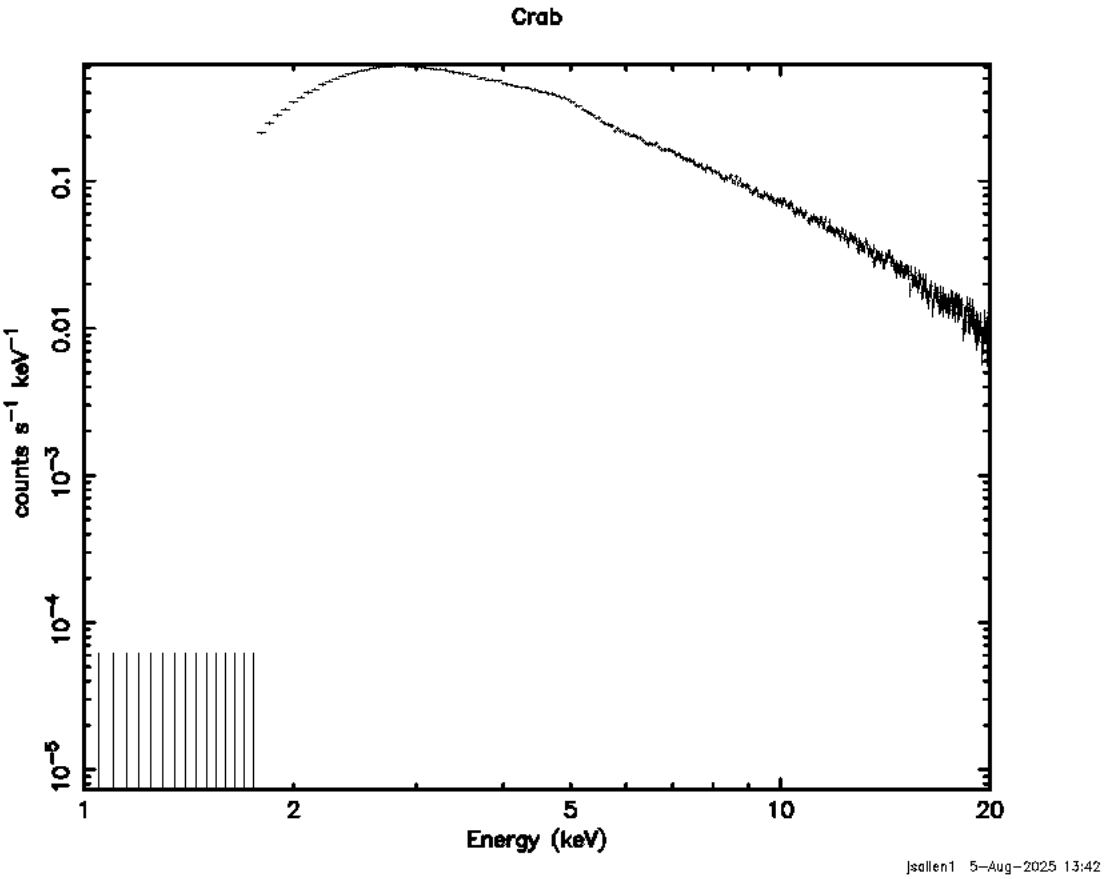
- The source and background region files have only been tested with circles. Other shapes are not well tested and might not work as intended. If the background region is too far from the source, the background may be not well estimated.

4 Data analysis of the products

The products output from ***mxpipeline*** can be used directly in XSPEC and XRONOS. All products files generated by ***mxpipeline*** 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_gsc_src.pi"
back 1   "crab_gsc_bgd.pi"
resp 1   "crab_gsc.rmf"
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 20
plt> plot
```



The calculated light curves (crab_gsc_bin.lc) contains several extensions. Assuming there are two energy bands, there will be six extensions:

- Scan length bins for the first energy bin
- Scan length bins for the second energy bin
- Scan length bins for the ratio of second to first
- Time binned light curve for the first energy bin
- Time binned light curve for the second energy bin
- Time binned light curve for the ratio of second to first

Each extension has columns TIME, START, STOP, RATE (or RATIO), ERROR, and FRACEXP. The measure of time in these columns is MJD.

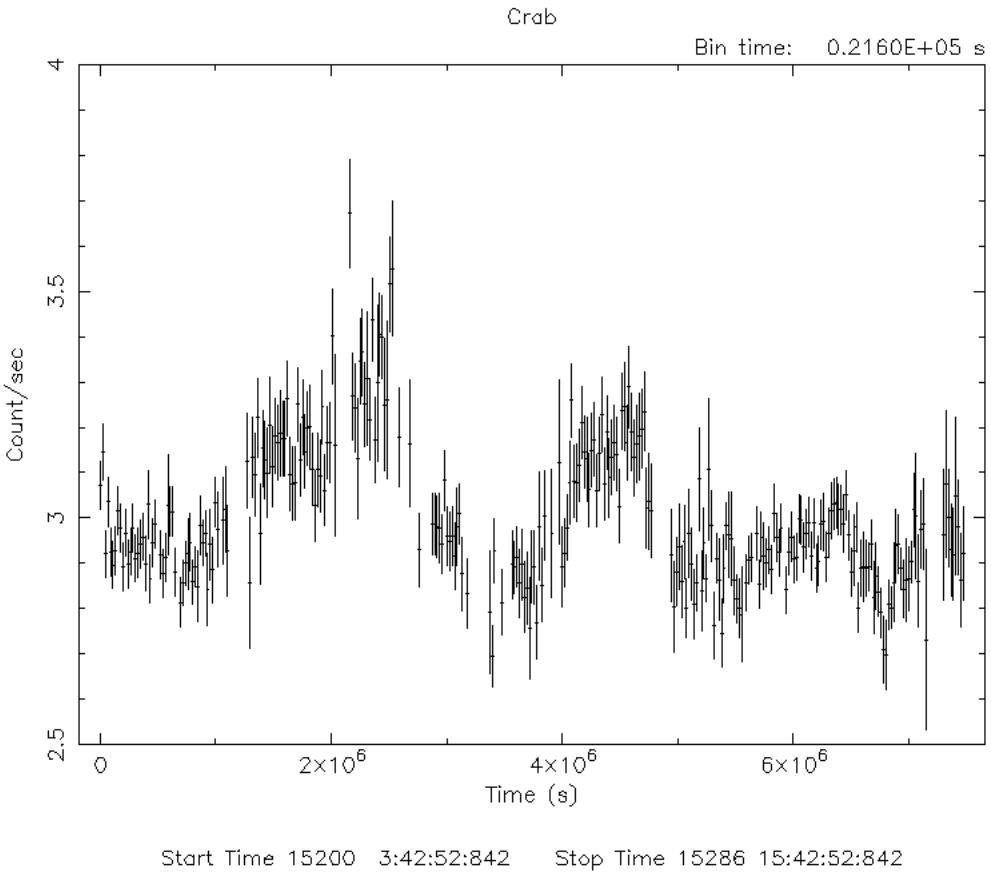
The integration period for each scan is typically 40-200 seconds, the duration of a single MAXI scan, with typical intervals of roughly 92 minutes between scans (the ISS orbital period), but for some viewing geometries, this may be as short as 15 minutes. The binned extensions match the setting of *timebin,* with a default setting of 1 day.

The lightcurve(s) can be plotted using ***fplot***, specifying *TIME* for the X-axis, and the *RATE* and *ERROR* columns as the Y-axis and Y-axis error, respectively. The following examples use the binned rates in the first energy band (2-6 keV when run with default energy bands).

```
fplot infile=”crab_gsc_bin.lc[4]” xparm=TIME yparm=”RATE[ERROR]” device=”/xw”
rows=- pltcmd=’’
```

Similar results can be found using the general plotting tool ***lcurve*** in HEAsoft:

```
lcurve nser=1 cfile1="crab_gsc_bin.lc[4]" window="-" dtnb=INDEF nbint=INDEF
outfile=" " plot=yes  plotdev="/xw"
```



A realistic simulation under optimal observation conditions suggests that MAXI will provide all-sky images of X-ray sources of ~20 mCrab (7 x 10^{-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*)

.

5 Help for mxpipeline

mxpipeline is an end-to-end processing tool to take raw MAXI data and generate images, lightcurves, spectra, response files, and event files. It requires that MAXI event and auxiliary files have been downloaded, the FTOOLS environment defined, and that CALDB with MAXI files is available. Data may be processed from GSC and/or SSC instruments, and GSC may be from one or the other of GSC_LOW or GSC_MED.

The tool runs a series of MAXI-specific and general FTOOLS to select raw event tiles within a radius of the given source position, calculate good time intervals, generate standard products, and perform all processing needed to make those products. Lightcurves are generated with scan-resolution (one value per ISS orbit) and bin-resolution time intervals, based on the setting *lcbin*.

Although there are a very large number of possible input parameters, most have default settings appropriate for common scenarios. The configurations of most interest are likely:

- Obtain products for a source position and time range without any background;
- As above, but obtaining a background from a region either near the source, or an annular ring around the source;
- Estimate background using a simulator. Note that this feature is only supported for GSC data and only for the most common voltage states.

Most other customized settings (selecting specific voltages, using local files in the place of reference data or the MAXI calibration database, etc.) are useful for only very specific analysis goals.

Alternatives to CALDB for key characteristics should be used with caution and are not recommended.

PARAMETERS

ra [real] (J2000; degrees
: Right ascension of the source.

dec [real] (J2000; degrees)
: Declination of the source.

tstart [string]
: Start date of the observation. The parameter can be entered in the format yyyy-mm-ddThh:mm:ss or yyyy-mm-dd (to start at 00:00:00).

tstop [string]
: Stop date of the observation. The parameter can be entered in the format yyyy-mm-ddThh:mm:ss or yyyy-mm-dd. If hh:mm:ss is not included, the stop date will include all data up to and including the end of the stop date (i.e. to end at 23:59:59).

(eband_fname = "NONE") [string]
: Up to three different energy bands can be supported. If set to "NONE" (default) or "REFDATA", the default energy band specification file provided in REFDATA will be used. This defines 2-6 keV and 6-20 keV bands for GSC, and a single 0.7-7.0 keV band for SSC. If a file name is given, that file needs the following format:

```
# GSC
# conversion 50 eV/ch
#  min_ch    max_ch  min_ene   max_ene
   40        120     2.0       6.0
   120       400     6.0       20.0
# SSC
# conversion 3.65 eV/ch
#  min_ch    max_ch  min_ene   max_ene
```

```
192        1918     0.7        7.0
```

Lines that begin with # indicate comments, but the lines "# GSC" and "# SSC" are required. The energy range settings are used to make images and lightcurves: spectra will reflect the full range supported by the MAXI instrument independent of these settings.

(object = "target") [string]
The name of the target object: this will be used for file names and setting the OBJECT keyword value in FITS format product files. Default is "target". Note that in addition to be set as the OBJECT keyword, this value is also used to set the rootname of all files, but transposed to make valid Unix filenames without special characters. E.g. 'object="Cyg X-3"' would set OBJECT in all files to be "Cyg X-3" and all files will start with 'cygx3'.

(datapath = "./obs") [string]
Path to the raw data. By default, this is './obs', matching the output settings in ***mxdownload_wget.pl***, the recommended tool for downloading MAXI raw data. The event tiles are arranged in the standard way ([datapath]/MJD##000/MJD####/events/[detector]/...) below this root directory.

(detector = "gsc_low") [string])
The name of the MAXI detector(s). Should be one of 'gsc_low', 'gsc_med', or 'ssc' ('ssc_med' is also accepted). The default is 'gsc_low'. To process both GSC and SSC data, specify both separated by a comma (e.g. 'gsc_med,ssc_med'). Only one GSC datamode can be supported at a time (i.e. 'gsc_low,gsc_med' is not supported).

(auxpath = "trend") [string]
The local path to the list files for the assorted auxiliary files. The default is "trend". If the directory does not yet exist, it will be created. If existing files are found in this location, they are checked to ensure they include the requested date range and replaced if not. Replacement is blocked by setting *clobbe*r to 'no' (see below).

(outpath = "products") [string]
The local path in which to place final product files. The default is "products". If the directory does not yet exist, it will be created.

(leapsecfile = "REFDATA") [string]
If set to "REFDATA" (default), use the built-in reference file for defining leap seconds. If set to “CALDB”, use the leap second file in the MAXI CALDB. Otherwise, use the specified file name.

(gsc_exclude = "NONE") [string]
Provide a comma-separated list of any GSC camera(s) to exclude from consideration.

(attlist = "NONE") [string]
Name for the output attitude list file created by combining the .att attitude files in the auxiliary data. The use of .att files is supported, but they are not considered as reliable as the .iat version of the attitude files. This parameter is set to "NONE" by default.

(iatlist = "iatlist.fits") [string]
Name for the output attitude list file created by combining the .iat attitude files in the auxiliary data. The default is "iatlist.fits". The .iat versions of ISS attitude is recommended for MAXI data analysis.

(iaclist = "NONE") [string]
Name of the output attitude file created by listing the .iat files for all dates they are available, and .att on where .iat is not available. This feature is obsolete as reprocessing of MAXI data means .iat is available for all valid MAXI dates. The default setting of "NONE" disables the generation of this file.

(isalist = "isalist.fits") [string]

Name of the output file listing the auxiliary .isa files for all dates they are available. These files contain the solar panel ancillary joint angles used in combination with the solar paddle angles (.isp files; see below) to determine scan intervals in which the field of view is obscured by the ISS solar panels. The default is "isalist.fits". This is ignored in SSC processing as the solar panels never obstruct those cameras.

(isplist = "isplist.fits") [string]
Name of the output file cataloging the complete of auxiliary.isp files for all dates they are available. These files contain the solar paddle angles and when used in combination with the .isa files (see above), determine times when the ISS solar panels obstruct the GSC field of view. The default setting is "isplist.fits". This is ignored when processing SSC data as the solar panels do not obstruct the SSC at any time.

(vclist = "vclist.fits") [string]
Name of the output list file of GSC housekeeping files used to monitor veto carbon conditions. The default is "vclist.fits", but can be set to "NONE" unless GSC processing with simulated background events will be performed as this is the only application that needs these files.

(search_radius = 8.0) [real] (degrees)
Search radius around the target sky location. The default value is 8.0 degrees. All raw data tiles containing data within this search radius will be collected, and image files will contain events within this radius.

(nx = 200) [integer] (pixels)
The number of pixels on the X-axis when mapping events to X positions in the image array. The default value is 200 pixels. If set to a negative number, the code will read the value set for NX in the raw event MAXI tiles or 2 x 'search_radius' / 'pixsize', whichever is larger.

(ny = 200) [integer] (pixels)
The number of pixels on the Y-axis when mapping events to Y positions in the image array. The default value is 200 pixels. If set to a negative number, the code will read the value set for NY in the input raw event MAXI tiles or 2 x 'search_radius' / 'pixsize', whichever is larger.

(pixsize = 0.1) [real] (degrees)
The size of pixels, in degrees, in image arrays. If set to a negative number, the code will read the value for pixel size from the input raw event MAXI tiles. The default value is 0.1 degrees

(src_regfile = ' ') [string] (filename)
If set to "NONE" or blank (default), the code will generate a new circular source region file around the source defined by 'src_radius' (see below). If set to a filename, use that file to define the source region and do not generate any new region file.

(bkg_regfile = ' ') [string] (filename)
If set to "NONE" or blank (default), the code will generate a new background region file defined by input parameters 'bkg_ra', 'bkg_dec', 'bkg_outer_radius' and 'bkg_inner_radius' (see below) unless simulated background data is requested (in which case the source and background region files are identical). This setting is ignored if 'bkg_outer_radius' is set to a negative number (i.e. no background will be defined.) If set to a filename, use that file to define the background region and do not generate any new region file.

(src_radius = 1.6) [real] (degrees)
The radius of a circle around the source used to define the source region. The default setting is 1.6 degrees.

(bkg_ra = -1.0) [real] (J2000; degrees)
Right ascension of the center of the background region. Set to a negative value (default) to use the same central sky location for source and background. Valid positive values are 0 – 360 degrees in J2000 coordinates.

(bkg_dec =) [real] (J2000; degrees)

.

Declination of the center of the background region. Ignored if the background is centered on the source (i.e. 'bkg_ra' is less than zero) or if no background is requested (i.e. 'bkg_outer_radius' is less than zero). Valid values are -90 – 90 degrees in J2000 coordinates.

(bkg_outer_radius = 3.0) [real] (degrees)
Outer radius of the background region. Set to a negative value to skip creating a background region file. Default is 3.0 degrees.

(bkg_inner_radius = 1.7) [real] (degrees)
Inner radius of the background region, excluded from the background to define an annulus. If the background region is centered on the source, this should be at least 0.1 degree larger than source radius. Set to 0 to skip (i.e. background region is a circle, not an annulus). Default is 1.7 degrees.

(catalog = "REFDATA") [filename]
A bright source catalog in FITS format. Set to "NONE" to skip. Set to "REFDATA" (default) to use the default MAXI bright source catalog file included with HEASoft. Set to a filename to use a different catalog of bright sources.

(confusion_radius = 1.0) [real] (degrees)
Radius around any bright sources in the catalog(s) to exclude. Ignored if no catalogs are set. Default is 1.0 degrees.

(reject_radius = 0.7) [real] (degrees)
Radius around input source location within which any known bright source is NOT excluded. If there is a neighboring known bright source within this radius, it is presumed not possible for MAXI to resolve them as separate objects, and the region file will not attempt to exclude it. This also prevents confusion possible from inexact matches between the catalog and the input RA and Dec setting. Default is 0.7 degrees.

(usercat = "NONE") [filename]
Set to "NONE" to ignore (default). A user supplied catalog of sources. This should be a text file with comma separated values, one source per line, in either of the following formats: RA, DEC; or Name, RA, DEC. Sky coordinates must be in J2000 expressed as decimal degrees. This file can supplement the catalog file or replace it: in the latter case, by setting the bright source catalog to "NONE".

(binwidth = 1) [real] (s)
The size of time bins to use in field-of-view GTI files. The default setting is 1 second. Note this is not the same as 'dt', the time bin size used for computing effective area for spectra (see below).

(threshold = 1.0) [real] (count/s)
The minimum rate above which data will be considered when looking at event rates to construct GTI. The default setting of 1.0 will include in GTI consideration time bins with rates greater than 1.0.

(timegap = 50.0) [real] (s)
The minimum interval of time between adjacent events to be considered part of the same scan, in seconds. The default is 50.0 seconds.

(usergti = "NONE") [filename]
Limit the consideration of events to only intervals defined by this file. If set to "NONE" (default), no user GTI file will be used.

(maxlines = 5000000) [integer]
For long time span products, event files or light curves can be generated with are large enough to cause memory issues. Breaking processing into pieces may be helpful to avoid processing issues by setting an upper limit on the number of data rows (events or light curve bins) to load at once. The default setting is 5000000.

.

(hvlist = "CALDB") [string]
A list of high voltage state settings for GSC. This may be a comma-delimited list, or the name of a text file containing a list of files, one per line, preceded by an '@' character. If set to "CALDB" (default), the high voltage history is obtained by reading the MAXI calibration database. Ignored if the detector is SSC.

(ssdockinfo = "CALDB") [filename]
Name of the file containing information about the presence of a docked space shuttle which obscures the GSC instrument field of view. Set to "NONE" to disable. The default setting of "CALDB" will obtain this information from the MAXI calibration database. Not applicable to SSC processing as the space shuttle does not obscure these cameras when docked.

(teldef_gsc = "CALDB") [file list]
A list of files containing the TELDEF information for the GSC cameras. This may be a comma-delimited list, or the name of a text file containing a list of files, one per line, preceded by an '@' character. The default setting of "CALDB" will obtain this information from the MAXI calibration database.

(teldef_ssc = "CALDB") [file list]
A list of files containing the TELDEF information for the SSC cameras. This may be a comma-delimited list, or the name of a text file containing a list of files, one per line, preceded by an '@' character. The default setting of "CALDB" will obtain this information from the MAXI calibration database.

(colea_gsc = "CALDB") [file list]
A list of files containing the collimator effective area maps for each GSC camera. This may be a comma-delimited list, or the name of a text file containing a list of files, one per line, preceded by an '@' character. The default setting of "CALDB" will obtain this information from the MAXI calibration database.

(colea_ssc = "CALDB") [file list]
A list of files containing the collimator effective area maps for each SSC camera This may be a comma-delimited list, or the name of a text file containing a list of files, one per line, preceded by an '@' character. The default setting of "CALDB" will obtain this information from the MAXI calibration database.

(angsepar = 0.3) [real; degrees]
If using observed background, the amount of tolerated offset between the center of the source and background pointing before the code presumes background and source sky positions are not concentric.

(max_colphi = 37.6) [real] (degrees)
The maximum collimator phi angle considered valid: values outside this range are treated as out of view. The default is 37.6 degrees, appropriate for GSC. Should be set to 45.0 for SSC which has a wider field of view.

(min_colea = 1.25) [real] (cm^s s)
The minimum collimator effective area in cm^2 s (default GSC=1.25, SSC=0.25). Intervals with less than this effective area will be flagged as "low exposure".

(min_obscured_spss = 1.5) [real] (degrees)
The minimum angular separation between the instrument pointing direction and the solar panels and/or spacecraft: if an interval includes time less than this angle from either of these obstructions, an obstruction flag will be set. Ignored when processing SSC data.

(min_obscured_wire = 0.75) [real] (degrees)
The minimum separation from central wire which obscured the view of the GSC cameras. Ignored when processing SSC data.

(angsepar = 0.3) [real] (degrees)
If using observed background, the amount of tolerated offset between the center of the source and background pointing before the code presumes background and source sky positions are not concentric.

.

(vlfilt = yes) [boolean]
A flag to indicate whether to filter out incomplete scans with very low total area ("yes" to exclude (default); or "no" to retain them).

(crabratefile = "CALDB") [filename]
Name of the Crab rate map file, which gives the observed Crab spectra at different locations of the detector and used to compute a modelled spectrum. If set to "CALDB" (default), the file is obtained from the MAXI calibration database.

(bexsigmafile = "CALDB") [filename]
Name of the file containing the position-dependent one-dimensional point spread function (the X direction at the Beryllium window). If set to "CALDB" (default), the file is obtained from the MAXI calibration database.

(backmodel = no) [boolean]
Setting to generate GSC simulated background evets. Default is 'no'. If set to 'yes', simulate events over the source region to model background accounting for contributions from the background noise of the instrument (NXB: Non X-ray background), additional background X-ray noise from a Soyuz spacecraft if present, and cosmic X-ray background (CXB) contributions.
NOTE: The background model is not supported for SSC, nor for certain specific GSC cameras and voltages (6, 9, 10 & 11 for both 1550V and 1650V, plus 0, 3, 4, & 5 for 1550V). The setting is therefore ignored for SSC, and unsupported camera/voltage combinations will not be included in lightcurves and spectra products for GSC.

(soyuzgti = "CALDB") [file list]
A file defining the times when a Soyuz spacecraft is docked at the ISS. Soyuz carries an radioactive source, which increases the MAXI background noise rate. The default setting of "CALDB" will obtain this information from the MAXI calibration database.

(bgtemplatefile = "CALDB") [filename]
Name of the background template file containing the camera and voltage specific settings for the cosmic X-ray background, non-X-ray background, and Soyuz-generated background used to simulate background events. If set to "CALDB" (default), the file is obtained from the MAXI calibration database.

(sim_scale = 10) [integer]
Simulation scale factor, such that the simulated events are made at 'sim_scale' times the simulated observation data rate. A higher value provides better statistical accuracy, but takes longer to compute. The default value is 10.

(sim_enelo = 2.0) [real] (keV)
Lower energy bound for simulated background events. Ignored if not generating simulated background. The default is 2.0 keV and the maximum range supported is 0.0 - 25.0 keV. Note, however, that CALDB only generates meaningful values in the 2.0 - 20.0 keV range.

(sim_enehi = 20.0) [real] (keV)
Upper energy bound for simulated background events. The default is 20.0 keV and the maximum range supported is 0.0 - 25.0 keV. Note, however, that CALDB only generates meaningful values in the 2.0 - 20.0 keV range.

(hvsel = 0) [integer]
Flag setting for indicating which high voltage settings to include in data. Allowed settings are:
0 (include both 1650 V and 1550 V data) (default);
1 (only include 1650 V data);
2 (only include 1550 V data).

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Ignored when processing SSC data.

(lowexpo_limit = 20.0) [real] (cm^2 s)
Threshold value to set a low exposure flag for any individual camera scan. Default value is 20.0 cm^2 s.

(use_c1c2 = yes) [boolean]
A flag, set to "yes" (default) or "no", to include anodes C1 and C2 in the analysis of GSC data. Ignored when processing SSC data.

(lcbin = 1.0) [real] (days)
The size of the bins to use when making binned lightcurve data. Default setting is 1.0 days.

(coltha_max_gsc = 5.0) [real] (degrees)
The maximum absolute value of source theta relative to a GSC camera in degrees. Default setting is 5.0 degrees.

(coltha_max_ssc = 5.0) [real] (degrees)
The maximum absolute value of source theta relative to an SSC camera in degrees. Default setting is 5.0 degrees.

(dt = 1) [real] (seconds)
The length of each time step in seconds when calculating theta, phi, and instantaneous collimator effective area used for spectral response function math (NOT the same as the time bins used for field-of-view GTI ('timebin')). Smaller time settings provide better granularity and more precise measurement of total effective area in spectral products at the expense of longer computation time. The default step size is set to 1.0 seconds.

(obscol_dname = "REFDATA") [string]
The directory where the field of view parameter files exist. If set to "REFDATA" (default), these files are obtained from the built-in reference data directory.

(colssc = "CALDB") [filename]
List of the collimator slat-plane position files for the SSC instrument. This may be "CALDB" (default), a comma-delimited list, or the name of a text file containing a list of files, one per line, preceded by an '@' character. If set to "CALDB", obtain the SSC collimator slate-plate position files from the MAXI calibration database.

(arfcorr_gsc = "CALDB") [filename]
List of ancillary response function (ARF) files for the GSC cameras. This may be "CALDB" (default), a comma-delimited list, or the name of a text file containing a list of files, one per line, preceded by an '@' character. If set to "CALDB", obtain the ARF files from the MAXI calibration data files.

(arfcorr_ssc = "CALDB") [filename]
List of ancillary response function (ARF) files for the SSC cameras. This may be "CALDB" (default), a comma-delimited list, or the name of a text file containing a list of files, one per line, preceded by an '@' character. If set to "CALDB", obtain the ARF files from the MAXI calibration data files.

(rmffile_gsc = "CALDB") [filename]
List of response matrix files (RMFs) for the GSC cameras. This may be "CALDB" (default), a comma-delimited list, or the name of a text file containing a list of files, one per line, preceded by an '@' character. If set to "CALDB", obtain the RMFs from the MAXI calibration database.

(rmffile_ssc = "CALDB") [filename]
List of response matrix files (RMFs) for the SSC cameras. This may be "CALDB" (default), a comma-delimited list, or the name of a text file containing a list of files, one per line, preceded by an '@' character. If set to "CALDB", obtain the RMFs from the MAXI calibration database.

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(quanteff = "CALDB") [filename]
List of the quantum efficiency files for the SSC camera. If set to "CALDB" (default), these files are obtained from the MAXI calibration database.

(cleanup = no) [boolean]
Determines whether to delete temporary files. When set to no (default), intermediate files will be retained.

(clobber = no) [boolean]
Overwrites the existing output file if set to yes. Default is no.

(chatter = 1) [integer]
Sets the amount of output from the code. Values range from 0 (little to no output) to 3 (verbose). Default value of 1 provides basic details.

(logfile = "!DEFAULT") [string]
Record output from running this tool in a logfile. If set to "DEFAULT", the output logfile will be named 'mxpipeline.log'. If preceded by the '!', any existing file with the same name will be overwritten; otherwise, this output will be appended to an existing file. No log file made if set to NONE. The default setting is "!DEFAULT".

(history = yes) [boolean]
Records tool parameters in HISTORY keywords if set to yes (default).

(debug = no) [boolean]
If set to yes, the code will provide detailed logging of variables and settings. This can be useful when debugging features in the code or deciphering unexpected error conditions. Default is no.

(mode=ql) [string ql|hl|q]
Mode to query the parameter file. The default value, 'ql' sets non-hidden parameters to query and learn/remember, which can be useful when repeating similar processes multiple times (such as generating products for multiple sources in the same fashion for each). Acceptable values include:
'ql' (query and learn/remember),
'hl' (hidden and learn/remember),
'q' (query but don't remember),
'h' (hidden).(Optional)

EXAMPLES

1. Create products for dates 2010-01-04 to 2010-01-07 (inclusive) using using GSC_LOW data with a source region defined by a 2.0 degree radius circle around the Crab, and obtain background measurements using an annulus around the source with an outer radius of 3.0 degrees and inner radius of 2.3 degrees. Make binned lightcurves with 0.25 day bin size. Overwrite any pre-existing files if found. Include the settings used to make the files in the HISTORY keywords of these product files. The tool will generate a log file named 'mxpipeline.log', clobbering any prior log file with that name. Generates event, spectra, image, and lightcurves, plus a number of additional intermediate products: retain all these files and place them in the directory "products" (default 'datapath').

```
mxpipeline ra=83.633083 dec=22.0145 tstart=2010-01-04 tstop=2010-01-07
object="Crab" detector=gsc_low src_radius=2.2 bkg_outer_radius=3.0
bkg_inner_radius=2.3 lcbin=0.25 clobber=yes cleanup=no history=yes
```

2. Create images, lightcurve, spectra and event files for Cyg X-3 for all days in July 2021. Define the source region to be a 1.6 degree radius circle around the source, and generate simulated background event

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files for the GSC medium download rate data. Use a local customized energy band definition to get three bands defined for 2-6, 6-12, and 12-20 keV (respectively referred to here as soft, medium, and hard). When making lightcurves, make one day long time bins. Filter out any very low effective area scans when making spectra and lightcurves (However, all data for all available cameras and voltages will be included in the image products.). All file names will have the prefix 'cygx3', while the OBJECT keyword in products to be 'Cyg X-3'. The X and Y columns in the event files and image array in the images will use the same settings as those found in the source raw event tiles (255 x 255 with a pixel size of 0.1 deg/pixel).

```
mxpipeline ra=308.107417 dec=40.957750 tstart=2021-07-01 tstop=2021-07-31
eband_fname=cygx3_ebands.txt object="Cyg X-3" detector=gsc_med
search_radius=8 src_radius=1.6 backmodel=yes nx=-99 pixsize=-99 lcbin=1.0
chatter=3 debug=yes clobber=yes cleanup=no vlfilt=yes
```

The energy band file cygx3_ebands.txt would read as:

```
# GSC
# conversion 50 eV/ch
#  min_ch    max_ch  min_ene   max_ene
   40        120     2.0       6.0
  120        240     6.0       12.0
  240        400     12.0      20.0
```

The lightcurve file generated, cygx3_gsc_bin.lc, contains six extensions: one for each of the three energy bands, plus one for each of (in order) the ratios hard/soft, hard/medium, and medium/soft. There will be a single image file 'cygx3_gsc.img' with a primary image array and two image extensions which contain, respectively, the soft, medium, and hard energy band images.

In this particular example, events are found in the MAXI event tiles from GSC Camera 1 & 6, but are then excluded from consideration because the simulated background generator is not enabled for these cameras given their voltages states during this time interval. The typical observer will have no a priori knowledge of camera availability or voltage settings: the code automatically handles these conditions and provides warnings when cameras need to be excluded for unsupported voltage conditions.

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