The HXMT Data Reduction Guide

v2.02 (for hmxmtsoftv2.02)

HXMT User Analysis Software Group¹

¹Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, China

December 6, 2019
# Contents

1 Introduction 1
   1.1 Scope 1
   1.2 Organization of this Guide 1

2 HXMT Instrument 2
   2.1 High Energy X-ray telescope 2
   2.2 Medium Energy X-ray telescope 4
   2.3 Low Energy X-ray telescope 7

3 HXMT Data Specifics and Convetions 10
   3.1 Definitions of Proposal ID, Observation ID and Exposure ID 10
   3.2 The Directory Structure of Level 1 Data Product 10
   3.3 The Data Files of Level 1 Data Product 11

4 HXMT Data Analysis Overview 15
   4.1 HXMTDAS overview 15

5 HE Data Analysis 19
   5.1 Introduction 19
   5.2 Calibration 19
      5.2.1 hepical 19
   5.3 Screening 22
      5.3.1 hegtigen 22
      5.3.2 hescreen 24
   5.4 Extracting High Level Products 26
      5.4.1 hespecgen 26
      5.4.2 helcgen 27
      5.4.3 herspgen 29
      5.4.4 hebkgmap 30
      5.4.5 hhe_spec2pi 31
   5.5 Special Processing 32
      5.5.1 hxmtscreen 32
      5.5.2 hespeccorr 33

6 ME Data Analysis 35
   6.1 Introduction 35
   6.2 Calibration 35
      6.2.1 mepical 35
      6.2.2 megrade 37
   6.3 Screening 37
      6.3.1 megtigen 37
CONTENTS

6.3.2 megti ................................. 39
6.3.3 mescreen .............................. 39
6.4 Extraction of high-level products .......... 41
   6.4.1 mespecgen ........................... 41
   6.4.2 melcgen .............................. 42
   6.4.3 merspgen ............................ 43
   6.4.4 mebkgmap ............................ 43

7 LE Data Analysis .......................... 46
   7.1 Introduction .......................... 46
   7.2 Calibration .......................... 46
      7.2.1 lepical .......................... 46
      7.2.2 lerecon .......................... 48
   7.3 Screening ............................ 52
      7.3.1 legtigen .......................... 52
      7.3.2 legti .............................. 54
      7.3.3 lescreen ........................... 55
   7.4 High level products extraction .......... 56
      7.4.1 lespecgen .......................... 56
      7.4.2 lelcgen ............................ 57
      7.4.3 lerspgen ........................... 58
      7.4.4 lebkgmap ........................... 59

8 Barycentric correction tools and other tools .... 61
   8.1 HXMT hxbary .......................... 61
   8.2 HXMT hxbary2 .......................... 62
   8.3 hobs_info ............................. 63
   8.4 hprint_detid ........................... 63
   8.5 hgti_create ............................ 63

A Installation of the HXMTDAS .................. 65
   A.0.1 Download HXMTDAS source code .......... 65
   A.0.2 Initialization and Setup ............... 66
### List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Three main payloads onboard Insight-HXMT. In the red circle, there are 18 NaI(Tl)/CsI(Na) scintillation detectors for HE. The left side is three ME boxes. The right side is three LE boxes. They all have different FOVs.</td>
</tr>
<tr>
<td>2.2</td>
<td>One detector module for HE. The AGC detector is in the later side of the PHOSWICH.</td>
</tr>
<tr>
<td>2.3</td>
<td>Calibration spectrum of $^{241}$Am. The data were accumulated over one day. The 59.5 keV line was corresponded to 50 Channel.</td>
</tr>
<tr>
<td>2.4</td>
<td>Left: One detector box of ME. Right: Layout of FOVs in one detector box.</td>
</tr>
<tr>
<td>2.5</td>
<td>The emission lines of Ag generated in the detected spectrum of Si-Pin detectors when the incident X-rays had energy more than 25.5 keV(K-edge of Ag).</td>
</tr>
<tr>
<td>2.6</td>
<td>Left: One detector box of LE. Right: four pieces of CCD236.</td>
</tr>
<tr>
<td>3.1</td>
<td>Directory of Observation ID.</td>
</tr>
<tr>
<td>3.2</td>
<td>Directory of Exposure ID.</td>
</tr>
<tr>
<td>3.3</td>
<td>An example of data files in an exposure directory.</td>
</tr>
<tr>
<td>3.4</td>
<td>Files Type.</td>
</tr>
<tr>
<td>5.1</td>
<td>HE data reduction flow diagram.</td>
</tr>
<tr>
<td>5.2</td>
<td>The comparison between the raw light curve and the spike light curve with $\text{binsize} = 0.1\text{s}$ and $\text{Det.ID} = 16$.</td>
</tr>
<tr>
<td>5.3</td>
<td>It is the light curve of event file after $\text{hepcal}$ in the upper panel and the light curve after carrying out $\text{hescreen}$ in the bottom panel.</td>
</tr>
<tr>
<td>5.4</td>
<td>$\text{hxmtscreen}$ data reduction.</td>
</tr>
<tr>
<td>6.1</td>
<td>ME data reduction.</td>
</tr>
<tr>
<td>7.1</td>
<td>LE data reduction.</td>
</tr>
<tr>
<td>7.2</td>
<td>The peak of pedestal events of CCD 0 vs its temperature.</td>
</tr>
<tr>
<td>7.3</td>
<td>The width of pedestal events of CCD 0 vs its temperature.</td>
</tr>
<tr>
<td>7.4</td>
<td>The peak of pedestal events of CCD 0 vs its temperature (after 20180615).</td>
</tr>
<tr>
<td>7.5</td>
<td>The width of pedestal events of CCD 0 vs its temperature (after 20180615).</td>
</tr>
<tr>
<td>7.6</td>
<td>The reconstructed events for CCD 0: raw light curve, single events light curve ($\text{GRADE} = 0$), split events light curve ($\text{GRADE} = 1$) and more split events light curve ($\text{GRADE} = 2$).</td>
</tr>
<tr>
<td>7.7</td>
<td>The ratio of two-split/more-split events($\text{binsize} = 100\text{s}$) of small CCDs to covered CCDs for board 0.</td>
</tr>
<tr>
<td>7.8</td>
<td>The reconstructed events for CCD 0 when $\text{hzscal}$ is set to 5: raw light curve, single events light curve ($\text{GRADE} = 0$), split events light curve ($\text{GRADE} = 1$) and more split events light curve ($\text{GRADE} = 2$).</td>
</tr>
<tr>
<td>7.9</td>
<td>The energy spectra of single events ($\text{GRADE} = 0$), no reconstructed two split events, and the reconstructed two-split events ($\text{GRADE} = 2$).</td>
</tr>
</tbody>
</table>
Chapter 1

Introduction

1.1 Scope

This document is meant as a guide and reference for users who want to use HXMT data to extract scientific products.

1.2 Organization of this Guide

- Chapter 2 describes the HXMT instrument.
- Chapter 3 describes the HXMT data products.
- Chapter 4 describes the overview of data analysis software.
- Chapter 5, 6 and 7 describe the data analysis method of HE, ME and LE, respectively.
- Chapter 8 describe the background modules and the barycenter correction tool.
- Appendix A contains a description of how to install HXMTDAS package.
Chapter 2

HXMT Instrument

The Hard X-ray Modulation Telescope (HXMT) is a large X-ray astronomical satellite with a broad band in 1-250 keV. It was successfully launched on 15th June 2017 in China. It is a low earth orbit telescope with altitude of 550km and inclination of 43 degrees. In order to fulfill the requirements of the broad band spectral and variability observations, three payloads are configured onboard HXMT, which are, High Energy X-ray telescope (HE) using 18 NaI(Tl)/CsI(Na) scintillation detectors for 20-250 keV band, Medium Energy X-ray telescope (ME) using 1728 SiPIN detectors for 5-30 keV band, and Low Energy X-ray detector (LE) using 96 SCD detectors for 1-15 keV band. The three payloads are integrated on a same supporting structure to achieve the same pointing direction, thus they can simultaneously observe the same source. They all have collimators to confine different kinds of field of view (FOV). Figure 1 shows the three main payloads onboard Insight-HXMT and their FOVs.

2.1 High Energy X-ray telescope

Similar to BeppoSAX/PDS and RXTE/HEXTE, HE adopts an array of NaI(Tl)/CsI(Na) PHOSWICHs as the main detectors. The diameter of each PHOSWICH is 190mm. The thickness of NaI(Tl) and CsI(Na) is about 3.5mm and 40mm. The working temperature of PHOSWICH is actively controlled at 18±2°C. The incident X-ray with most of its energy deposited in NaI(Tl) is regarded as a NaI(Tl) event. CsI(Na) is used as an active shielding detector to reject the background events from backside and events with partial energy loss in the NaI(Tl). The scintillation photons generated within the two crystals can be collected by the same photomultiplier tube (PMT). The decay time is 250ns in NaI(Tl) and 630ns in CsI(Na). Signals from the PMT (Hamamatsu R877-01) are pulse shaped to distinguish NaI(Tl) events and CsI(Na) events. The energy loss, time of arrival and the pulse width with each detected event are measured, digitized and telemetered to the ground. The CsI(Na) can be used as a gamma ray burst (GRB) monitor. The detected energy range in normal mode is about 50-800keV and is changed to 250keV-3MeV in GRB mode for CsI(Na) if the high voltage of PMT is decreased.

The collimators of HE define 15 narrow FOV (5.7° × 1.1°), 2 wide FOV (5.7° × 5.7°) and a blind FOV which was covered with 2mm tantalum. They also have different orientations with a step of 60 degrees, as shown in Figure 2.1. With different detector number, we labeled each collimator as shown in Table 2.1

For each PHOSWICH detector, a radioactive source $^{241}$Am with an activity of 200 Bq is embedded into a plastic scintillator (BC-448M) and viewed by a separate Multi-Pixel Photon Counter. They all mounted in the collimator and used as an automatic gain control (AGC) detector as shown in the Figure 2.2. A coincident measurement between the AGC detector (5.5MeV alpha particle) and PHOSWICH detector (59.5keV X-ray) will be labeled as a calibration event. The calibration events are saved like norm events, just have a different flag to discriminate. The spectrum of
Figure 2.1: Three main payloads onboard Insight-HXMT. In the red circle, there are 18 NaI(Tl)/CsI(Na) scintillation detectors for HE. The left side is three ME boxes. The right side is three LE boxes. They all have different FOVs.
CHAPTER 2. HXMT INSTRUMENT

<table>
<thead>
<tr>
<th>Detector ID</th>
<th>Field of View (FoV)</th>
<th>Orientation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$-60^\circ$</td>
</tr>
<tr>
<td>1</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$0^\circ$</td>
</tr>
<tr>
<td>2</td>
<td>$5.7^\circ \times 5.7^\circ$</td>
<td>$+60^\circ$</td>
</tr>
<tr>
<td>3</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$0^\circ$</td>
</tr>
<tr>
<td>4</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$-60^\circ$</td>
</tr>
<tr>
<td>5</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$+60^\circ$</td>
</tr>
<tr>
<td>6</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$0^\circ$</td>
</tr>
<tr>
<td>7</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$-60^\circ$</td>
</tr>
<tr>
<td>8</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$0^\circ$</td>
</tr>
<tr>
<td>9</td>
<td>$5.7^\circ \times 5.7^\circ$</td>
<td>$-60^\circ$</td>
</tr>
<tr>
<td>10</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$+60^\circ$</td>
</tr>
<tr>
<td>11</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$0^\circ$</td>
</tr>
<tr>
<td>12</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$0^\circ$</td>
</tr>
<tr>
<td>13</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$+60^\circ$</td>
</tr>
<tr>
<td>14</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$-60^\circ$</td>
</tr>
<tr>
<td>15</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$+60^\circ$</td>
</tr>
<tr>
<td>16</td>
<td>Blind FoV</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>$5.7^\circ \times 1.1^\circ$</td>
<td>$-60^\circ$</td>
</tr>
</tbody>
</table>

Table 2.1: The collimators of HE define 15 narrow FOV($5.7^\circ \times 1.1^\circ$), 2 wide FOV($5.7^\circ \times 5.7^\circ$) and a blind FOV which was covered with 2mm tantalum. They are distinguished by different detector IDs. They also have different orientations with a step of 60 degrees

calibration events is shown in Figure 2.3. In-flight performance shows that the line centroids of $59.5\text{keV}$ are stable to better than 0.01 channels on a one day timescale. The response of NaI(Tl) is not uniform in its large surface so the calibration events were just used as the gain control and were not suitable to calibrate the gain of NaI(Tl) detectors in-orbit. In the analysis of X-ray spectrum, the radioactive events should be discarded.

Besides the active shielding of CsI(Na), HE also adopts the 18 plastic scintillators(6 on the top and 12 in the later sides of PHOSWICH detectors) as the anti-coincidence detectors(ACD).

### 2.2 Medium Energy X-ray telescope

ME consists of 3 detector boxes as shown in Figure 2.4. Each box has 576 Si-Pin detector pixels read out by 18 ASIC (Application Specified Integrated Circuit). Each ASIC is responsible for the readout of 32 pixels. The working temperature of Si-Pin detectors in orbit is from $-50^\circ C$ to $-5^\circ C$.

For each detector box, the collimators of ME confine 15 ASICs as narrow FOV($1^\circ \times 4^\circ$), 2 ASIC as wide FOV($4^\circ \times 4^\circ$) and one blind FOV. The layout of the FOVs in one detector box is also shown in Figure 2.4. Two in-orbit calibration radioactive sources ($^{241}\text{Am}$) are installed in small FOVs. We labeled cached collimator as shown in Table 2.2

Si-Pin detectors are fixed on the ceramic chip by silver glue. When the energy of incident X-rays is greater than $25.5 \text{keV}$ (K-edge of Ag), they have some probability of penetrating the Si-Pin and react with silver. Ag emission lines will be generated due to the photoelectric effect with electrons in K-shell of Ag and detected by the Si-Pin detectors. Figure 2.5 showed that emission lines of Ag appeared in the detected energy spectrum when incident X-rays had energy more than $25.5 \text{keV}$ in the ground calibration experiments.
2.2. MEDIUM ENERGY X-RAY TELESCOPE

Figure 2.2: One detector module for HE. The AGC detector is in the later side of the PHOSWICH.

Figure 2.3: Calibration spectrum of $^{241}$Am. The data were accumulated over one day. The 59.5 keV line was corresponded to 50 Channel.
Figure 2.4: Left: One detector box of ME. Right: Layout of FOVs in one detector box.

<table>
<thead>
<tr>
<th>Field of View (FoV)</th>
<th>Detector ID</th>
<th>ASIC ID</th>
<th>FPGA</th>
<th>ASIC ID</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-255</td>
<td>0-7</td>
<td>0</td>
<td>0-5</td>
</tr>
<tr>
<td></td>
<td>352-575</td>
<td>11-17</td>
<td>1</td>
<td>0-1</td>
</tr>
<tr>
<td></td>
<td>576-831</td>
<td>18-25</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>928-1151</td>
<td>29-35</td>
<td>2</td>
<td>0-5</td>
</tr>
<tr>
<td></td>
<td>1152-1407</td>
<td>36-43</td>
<td>3</td>
<td>0-5</td>
</tr>
<tr>
<td></td>
<td>1504-1727</td>
<td>47-53</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>$1^\circ \times 4^\circ$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>256-319</td>
<td>8-9</td>
<td>5</td>
<td>0-5</td>
</tr>
<tr>
<td></td>
<td>832-895</td>
<td>20-27</td>
<td>6</td>
<td>0-5</td>
</tr>
<tr>
<td></td>
<td>1408-1471</td>
<td>44-45</td>
<td>7</td>
<td>0-5</td>
</tr>
<tr>
<td></td>
<td>320-351</td>
<td>10</td>
<td>8</td>
<td>0-5</td>
</tr>
<tr>
<td>$4^\circ \times 4^\circ$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>896-927</td>
<td>28</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>1472-1503</td>
<td>46</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>blind FoV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>192</td>
<td>6</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>352</td>
<td>11</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>768</td>
<td>24</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>928</td>
<td>29</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Calibration source</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.2: The ME collimators
2.3 LOW ENERGY X-RAY TELESCOPE

LE also consists of three detector boxes and each box contains 32 CCD236 which is a kind of Swept Charge Devices (SCD). CCD236 is a second-generation SCD, which has been developed by e2v company with full considerations of the requirement of LE. It is built with a sensitive area of about 4 cm$^2$ and has four quadrants. In each quadrant, the L-shaped electrodes guide the charge towards the diagonal first and then to a common readout amplifier in the central region. In the continuous readout mode, the total readout time is only about 1 ms with a guaranteed energy resolution. Figure 2.6 shows the detector box of LE and photograph of four pieces of CCD236. The working temperature in-orbit for CCD236 is about from -80°C to -30°C.

For each detector box of LE, collimators define four kinds of FOVs. Twenty CCD236 have narrow FOVs with 1.6°x 6°. Six CCD236 have wide FOVs with 4°x 6°. Two CCD236 have blind FOVs and one of them has carried a $^{55}$Fe radioactive source. Four CCD236 have a very large FOV with about 50−60°x 2−6°.
<table>
<thead>
<tr>
<th>Detector ID</th>
<th>Field of View (FoV)</th>
<th>CCD number</th>
<th>AD number</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/32/64</td>
<td>1.6° × 6°</td>
<td>CCD 0/8/16</td>
<td>CDS A Group0/4/8</td>
</tr>
<tr>
<td>1/33/65</td>
<td>4° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/34/66</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/35/67</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4/36/68</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/37/69</td>
<td>4° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/38/70</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7/39/71</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8/40/72</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9/41/73</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10/42/74</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11/43/75</td>
<td>4° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12/44/76</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13/45/77</td>
<td>blind FoV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14/46/78</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15/47/79</td>
<td>4° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16/48/80</td>
<td>50 ~ 60° × 2 ~ 6°</td>
<td>CCD 4/12/20</td>
<td>CDS C Group2/6/10</td>
</tr>
<tr>
<td>17/49/81</td>
<td>50 ~ 60° × 2 ~ 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18/50/82</td>
<td>50 ~ 60° × 2 ~ 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19/51/83</td>
<td>50 ~ 60° × 2 ~ 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20/52/84</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21/53/85</td>
<td>blind FoV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22/54/86</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23/55/84</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24/56/88</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25/57/89</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26/58/90</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27/59/91</td>
<td>4° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28/60/92</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29/61/93</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30/62/94</td>
<td>1.6° × 6°</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31/63/95</td>
<td>4° × 6°</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.3: The LE detect
Figure 2.6: Left: One detector box of LE. Right: four pieces of CCD236
Chapter 3

HXMT Data Specifics and Conventions

3.1 Definitions of Proposal ID, Observation ID and Exposure ID

The observation data of Insight-HXMT is organized by Proposal-Observation-Exposure. Proposal ID is the unique ID of the approved proposal, which is assigned after the annual proposal collection. The proposal ID is named like "Paattmmm", where "aa" is the sequence of the annual proposal collection, "tt" is the type of proposal, "mmm" is the given sequence of proposal ID.

Observation is the basic unit of the available time. The telescope time is scheduled one by one observation. The observation ID is unique identification of the observation. Because an observation must belong to a special proposal, the observation ID is composed of the ID of corresponding proposal and sequence number (3 digits, start from 001). For example P0102005003, "P0102005" is the proposal ID and "003" is the sequence number, it means this observation is the 3rd observation of proposal P0102005.

Usually a pointing observation lasts several hours and the data volume exceeds several GBs. To reduce the single file size, an observation is man-made split into multiple segments (named exposure), which is only a time fragment in an observation without the traditional exposure concept of camera or CCD image instrument. An exposure usually includes three-hour span, whose start time and end time are determined by SAA or Earth-Shadow gap closest to three hours. But in special situations (relating to the position of satellites, the earth and the sun), few exposures will exceed six hours. Exposure ID is the identification of the exposure, which is composed of exposure sequence + observation date + day sequence + sequence in day. For example, in exposure ID P010200500308-20171106-03-04, P010200500308 indicates it is the 8th exposure of the observation P0102005003, the date of exposure start is 20171106, this date is the 3rd day of the observation, and the exposure is the 4th exposure of this observation in 20171106. There is also a short format Exposure ID used for filename. It only reserves part of exposure sequence, for example P010200500308.

3.2 The Directory Structure of Level 1 Data Product

For Scientific user, data analysis starts from Level 1 data product. Level 1 data files are arranged in a hierarchical directory tree with the cue of Observation ID - Exposure ID. The root directory of every product is named by the Observation ID. There are three types of catalogues: List Files,
3.3. THE DATA FILES OF LEVEL 1 DATA PRODUCT

Exposures Directory and Auxiliary Data for whole observation.

- **List Files:**
  Two List File are provided in root of 1L product. "FileList.FITS" contains all files information of archived observation, include filename, file path, file size, type of file and md5 checksum and so on. "ExpoList.XML” gives exposures list in this observation.

- **Exposures Directory:**
  Each exposure has a separate directory to store events and engineering data collected in the exposure period.

- **Auxiliary Data Directory:**
  Two Auxiliary Data Directories are designed in root directory. "ACS" directory stores attitude and orbit data. "AUX" is used for auxiliary data originated from ground segment, such as Data Quality Report, GTI, EHK and so on. Important one is EHK file, it is needed in data analysis. These "ACS" and "AUX" catalogs are serve for whole observation period, distinguished from same catalogs in exposure directory, which only covered exposure period.

There are also a sub lever directory in each exposure directory. The sub-directory is divided according to source instrument. "ACS" and "AUX" contain same data as homonymic catalogs in root directory. "HE", "ME" and "LE" directories respectively store Events and Engineering Data from HE, ME and LE telescope.

### 3.3 The Data Files of Level 1 Data Product

Data files of Level 1 Product are named as follow format:

"HXMT_exposure-id_type_FFFFFF_Vn_Li1P.FITS"

The filename is composed with seven segment. The capital letters are fixed, and the lowercase letters are variable according to different file types and exposures.
• HXMT - Fixed Prefix for all data files.
• exposure-id - Short format Exposure ID
• type - Abbreviated name of file type
• FFFFFF - Reserved segment for future, filled with FF now
• Vn - File Version. V is fixed prefix, n is character from 1-9, a-z
• L1P - Fixed part. L1 indicate it is a Level 1 data file. P is abbreviation of Pointing Observation-Mode
• FITS - Fixed file extension name, indicating this is a Fits format file.

This is an example of data files in an exposure directory (see Figure 3.3).
All file types appear in above example are shown in the following table (see Figure 3.4):
Figure 3.3: An example of data files in an exposure directory.
### Abbreviated Type Name and Data Content

<table>
<thead>
<tr>
<th>Abbreviated Type Name</th>
<th>Data Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>HE-Evt</td>
<td>HE Events</td>
</tr>
<tr>
<td>HE-RadEvt</td>
<td>HE Radioactive Events</td>
</tr>
<tr>
<td>HE-ShltEvt</td>
<td>HE Sheltered Detector Events</td>
</tr>
<tr>
<td>HE-InsStat</td>
<td>HE Instrument Status</td>
</tr>
<tr>
<td>HE-TH</td>
<td>HE Temperature</td>
</tr>
<tr>
<td>HE-Cnts</td>
<td>HE Counts</td>
</tr>
<tr>
<td>HE-DTime</td>
<td>HE DeadTime</td>
</tr>
<tr>
<td>HE-HV</td>
<td>HE High Voltage</td>
</tr>
<tr>
<td>HE-PM</td>
<td>HE Particle Monitor</td>
</tr>
<tr>
<td>ME-Evt</td>
<td>ME Events</td>
</tr>
<tr>
<td>ME-RadEvt</td>
<td>ME Radioactive Events</td>
</tr>
<tr>
<td>ME-ShltEvt</td>
<td>ME Sheltered Detector Events</td>
</tr>
<tr>
<td>ME-CirPara</td>
<td>ME Circuit Parameter</td>
</tr>
<tr>
<td>ME-InsStat</td>
<td>ME Instrument Status</td>
</tr>
<tr>
<td>ME-TH</td>
<td>ME Temperature</td>
</tr>
<tr>
<td>ME-Cnts</td>
<td>ME Counts</td>
</tr>
<tr>
<td>LE-Evt</td>
<td>LE Events</td>
</tr>
<tr>
<td>LE-RadEvt</td>
<td>LE Radioactive Events</td>
</tr>
<tr>
<td>LE-ShltEvt</td>
<td>LE Sheltered Detector Events</td>
</tr>
<tr>
<td>LE-WFOVEvt</td>
<td>LE Wide FOV Events</td>
</tr>
<tr>
<td>LE-ForcedEvt</td>
<td>LE Forced Trigger Events</td>
</tr>
<tr>
<td>LE-CirPara</td>
<td>LE Circuit Parameter</td>
</tr>
<tr>
<td>LE-InsStat</td>
<td>LE Instrument Status</td>
</tr>
<tr>
<td>LE-TH</td>
<td>LE Temperature</td>
</tr>
<tr>
<td>LE-Cnts</td>
<td>LE Counts</td>
</tr>
<tr>
<td>Att</td>
<td>Attitude</td>
</tr>
<tr>
<td>Orbit</td>
<td>Orbit</td>
</tr>
<tr>
<td>EHK</td>
<td>Extend Housekeeping Data</td>
</tr>
</tbody>
</table>

Figure 3.4: Files Type.
Chapter 4

HXMT Data Analysis Overview

4.1 HXMTDAS overview

The Insight-HXMT Data Analysis Software package (HXMTDAS) is to achieve the HXMT data analysis processing and extract scientific products. Its purpose is to achieve scientific products, such as energy spectra, light curves, Ancillary Response Files (ARF), Redistribution Matrix Files (RMF) and background files. It provides several tasks with each task is to accomplish a step of data analysis. These tasks are written in ftools style and are fully compatible with the HEASoft software.

The processing procedures of HXMTDAS package is organized into three distinct stages for the calibration, the screening and the extraction of high-level scientific products. The input is a observation (call exposure number) from the HXMT level 1 (1L) data products and has FITS format. Now, HXMTDAS (version 2) is extensively used in HXMT team. It has two run styles:

• Command Line style:

  ```
  hepical evtfile=HXMT_P010130600202_HE-Evt_FFFFFF_V1_1RP.FITS
  outfile=he_pi.fits evtnum=5 timedel=0.00008
  ```

• or User interface style:

  ```
  hepical evtnum=5 timedel=0.00008
  hepical : ###############################################################################
  hepical : HXMT HE task, hepical is running
  Name of the input 1-L Event FITS file[] HXMT_P010130600202_HE-Evt_FFFFFF_V1_1RP.FITS
  Name of the output calibrated Event FITS file[] he_pi.fits
  hepical : HXMT HE task, hepical is running successfully!
  hepical : ###############################################################################
  ```

Since the input parameters are important to these tasks, some common parameters are listed as follows:

• `evtfile`[filename], name of the input 1L/reconstructed/screened Event FITS file;

• `outfile`[string/filename], name of the output event FITS file/output prefix for spectra/light curves;

• `baddetfile`[filename], name of the Bad Detector FITS file or NONE for none;
- userdetid[string], detectors selection of each payload, some regulations: a set of detectors which are delimited by comma or blank character with each other will constitute a spectrum/light curve; more spectra/light curves is delimited by semicolon (";"); "-" (hyphen) means "to"; it can be set to a file (e.g., @+filename);

- starttime/stoptime[real], starting/stop time for summation (DEFAULT = 0.);

- minPI/maxPI[integer], minimum/maximum PI to consider (DEFAULT = 0).

### Calibration

<table>
<thead>
<tr>
<th>Payload</th>
<th>Task name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HE</td>
<td>hepical</td>
<td>remove spike events caused by electronics and do gain correction</td>
</tr>
<tr>
<td>ME</td>
<td>mepical</td>
<td>do gain correction</td>
</tr>
<tr>
<td></td>
<td>megrade</td>
<td>calculate event grade and deadtime of each FPGA</td>
</tr>
<tr>
<td>LE</td>
<td>lepical</td>
<td>do gain correction and subtract event noise</td>
</tr>
<tr>
<td></td>
<td>lerecon</td>
<td>reconstruct two split events, and assign event grade</td>
</tr>
</tbody>
</table>

At this stage, the values of Pulse Invariant (PI) are calculated from the raw values of Pulse Height Amplitude (PHA) of each event, accounting for temporal changes in gain and energy offset.

Users are advised to download the new HXMT CALDB. If the parameter ’gainfile’ of these tasks is set to CALDB (gainfile=CALDB), these tasks will use the gain files from CALDB. Otherwise, the parameter can be directly set to the gain file path.

The HE task hepical can be used to find the spike events with the default parameters timedel=0.00008 evtnum=5 lowchan=0 and highchan=255. If users who don’t care low energy band can set highchan=35 (and then remove the low band at screening). The meaning of these parameters is below:

- timedel: time bin size for removing events led by electronic instrument;
- evtnum: continuous events number at time interval ‘timedel’ between ‘lowchan’ and ‘highchan’;
- lowchan: low channel considered to removing spike events;
- highchan: high channel considered to removing spike events.

The task megrade calculates the grade column for the input event file and write the values in the output file, and higher grade events will be automatically removed from the event list. This task can calculate the deadtime for each FPGA. The parameter ’deadfile’ can be set to ”NONE”, but the mespecgen and melegen will require the deadtime file created by this task. Other parameter ’binsize’ (DEFAULT = 1s) is used to set the time interval of each deadtime calculation.

The task lepical will calculate the peak noise used pedestal events accumulated time of ’maxtimedel’ (DEFAULT = 60s); The task lerecon will reconstruct two split events, and assign grade (0:ALL; 1:Single Event; 2:Two-Split Event), but now, we recommend users use only the single event.

For these tasks, the GTI extension(s) present in the input file will be copied to the output file without changes.

There is a simple correlation between PI and energy:

- for LE: PI=(E-0.1)/13*1536;
- for ME: PI=(E-3)/60*1024.
Screening

<table>
<thead>
<tr>
<th>Payload</th>
<th>Task name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HE</td>
<td>hegtigen</td>
<td>generate a FITS file of good time interval</td>
</tr>
<tr>
<td>HE</td>
<td>hescreen</td>
<td>use GTI together with other criteria to screen the data</td>
</tr>
<tr>
<td>ME</td>
<td>megtigen</td>
<td>generate a FITS file of good time interval</td>
</tr>
<tr>
<td>ME</td>
<td>megti</td>
<td>generate a new GTI file to eliminate some bad time intervals from above GTI file</td>
</tr>
<tr>
<td>ME</td>
<td>mescreen</td>
<td>use GTI together with other criteria to screen the data</td>
</tr>
<tr>
<td>LE</td>
<td>legtigen</td>
<td>generate a FITS file of good time interval</td>
</tr>
<tr>
<td>LE</td>
<td>legti</td>
<td>generate a new GTI file to eliminate some bad time intervals from above GTI file</td>
</tr>
<tr>
<td>LE</td>
<td>lescreen</td>
<td>use GTI together with other criteria to screen the data</td>
</tr>
</tbody>
</table>

The Good Time Intervals (GTIs) are calculated considering two sets of parameters, one related to the extended housekeeping (EHK) file, the other one related to temperature file (internal criteria). For HE, particle flux file can be used (if users don’t want to use, please set 'pmfile' to 'NONE'). The criteria associated to "expr" parameter (when 'defaultexpr' parameter set to "NONE") for each payload is listed below:

- **HE:** \( ELV > 10 \&\& COR > 8 \&\& SAA\_FLAG == 0 \&\& ANG\_DIST < 0.04 \&\& T\_SAA > 300 \&\& TN\_SAA > 300 \)

- **ME:** \( ELV > 10 \&\& COR > 8 \&\& SAA\_FLAG == 0 \&\& ANG\_DIST < 0.04 \&\& T\_SAA > 300 \&\& TN\_SAA > 300 \)

- **LE:** \( ELV > 10 \&\& COR > 8 \&\& DYE\_ELV > 30 \&\& SAA\_FLAG == 0 \&\& ANG\_DIST < 0.04 \&\& T\_SAA > 300 \&\& TN\_SAA > 300 \)

We recommend users set 'defaultexpr' to NONE and use expr parameter. If these GTI tasks report the following error:

"please set parameter 'expr' when 'defaultexpr']='NONE'"

please use these tasks with the 'expr' parameter, for example, hegtigen expr=" \( ELV > 10 \&\& COR > 8 \&\& SAA\_FLAG == 0 \&\& ANG\_DIST < 0.04 \&\& T\_SAA > 300 \&\& TN\_SAA > 300 \)"

Sometimes, there are still some bad time intervals in GTI files. The tasks of megti and legti are used to eliminate these intervals and new GTI files will be generated for ME and LE, respectively.

The screening criteria used to generate the cleaned event file are listed as follows:

- **Removal of the bad time intervals** (using the GTI file('gtifile') and event file);

- **Removal of the bad detectors('baddetfile' parameter);

- **Removal of the bad events** (pedestal events/events with higher grade);

For HE, 'anticoincidence' can be used (set to 'yes') to reduce particle background; 'minpulsewidth' (DEFAULT = 54) and 'maxpulsewidth' (DEFAULT = 70) are the minimum and maximum Pulse Shape Discriminator for NaI, respectively.
### Extracting high-level Products

<table>
<thead>
<tr>
<th>Payload</th>
<th>Task name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HE</strong></td>
<td>hespecgen</td>
<td>extract spectra</td>
</tr>
<tr>
<td></td>
<td>helcgen</td>
<td>extract light curves</td>
</tr>
<tr>
<td></td>
<td>herspgen</td>
<td>generate response file</td>
</tr>
<tr>
<td></td>
<td>hebkgmap</td>
<td>generate background file</td>
</tr>
<tr>
<td><strong>ME</strong></td>
<td>mespecgen</td>
<td>extract spectra</td>
</tr>
<tr>
<td></td>
<td>melcgen</td>
<td>extract light curves</td>
</tr>
<tr>
<td></td>
<td>merspgen</td>
<td>generate response file</td>
</tr>
<tr>
<td></td>
<td>mebkgmap</td>
<td>generate background file</td>
</tr>
<tr>
<td><strong>LE</strong></td>
<td>lespecgen</td>
<td>extract spectra</td>
</tr>
<tr>
<td></td>
<td>lelcgen</td>
<td>extract light curves</td>
</tr>
<tr>
<td></td>
<td>lerspgen</td>
<td>generate response file</td>
</tr>
<tr>
<td></td>
<td>lebkgmap</td>
<td>generate background file</td>
</tr>
</tbody>
</table>

At this stage, the high-level products are extracted from the screened event file. The products include the energy spectra, response file (RSP), light curves and background files. The RSP files can be obtained from the CALDB and the background modules will be provided in future.

To extract a spectrum, users can set the parameter 'groupmin' to rebin the spectrum. The deadtime is calculated for all GTIs and the value of deadtime subtract from the total GTIs is the exposure.

To extract a light curve, users must set the bin size ('binsize') of the light curves. Sometimes, the start or end of the GTIs may fall within a bin size and the column named 'fracexp' in the light curve will give the value as the proportion of the bin shortening for each bin. The deadtime correction (set parameter 'deadcorr' to yes) is done bin by bin using the deadtime file (the parameter 'deadfile'). If he parameters of aligncorr and attfile are set to yes and the attitude file, respectively, the psf correction will be done bin by bin.

To extract background both for spectra and light curves, hebkgmap, mebkgmap and lebkgmap are used to generate background files for HE, ME and LE, respectively.

### Other tools

- **hxmtscreen**
  This task is used to repeat to screen these screened event files which are generated by hescreen/mescreen/lescreen. The output event file only includes a common GTI extension. The parameter 'usergtifile' can be set to "NONE" or a text file (each line has a format of "start-time stop-time") and the common GTI will consider the GTIs in text file.

- **hxbary**
  Do barycenter correction for HE, ME and LE. The time is corrected from TT to TDB (accuracy <1us) and written to a new column named TDB.
Chapter 5

HE Data Analysis

5.1 Introduction

This chapter contains the details of the current status of the HE data analysis.

The processing procedures include three major steps: calibration (stage 1), screening (stage 2) and extraction of high-level scientific products (stage 3). For stage 1, the EVT file is processed to produce a calibrated EVT file; for stage 2, the calibrated EVT file is filtered by applying cleaning criteria to produce a cleaned EVT file; for stage 3, the high-level scientific products are generated. The following sections describe the analysis steps that are presented in Fig. 5.1.

5.2 Calibration

5.2.1 hepical

Remove spike events caused by electronic system and calculate PI column values of HE event files. Currently, we can’t do gain correction between their PMTs, so the PI value of each event is equal to its raw ADC channel.

PARAMETER

The parameters of this task are listed below:

- evtfile [file name]
  Name of the input 1-L event FITS file.

- outfile [file name]
  Name of output calibrated event FITS file.

- gainfile [file name]
  Name of the input gain FITS file.
  If set to CALDB, use the file in the Calibration Database(DEFAULT=CALDB).

- seed [int]
  Input seed for random number generator.

- timedel [real]
  Time bin size for removing events led by electronic instrument(DEFAULT = 0.000080).

- evtnum [int]
  Continuous events number at time interval 'timedel' between 'lowchan' and 'highchan' to consider(DEFAULT = 5).
CHAPTER 5. HE DATA ANALYSIS

Figure 5.1: HE data reduction flow diagram.
5.2. CALIBRATION

- lowchan [int]
  Low channel considered to removing events led by electronic instrument (DEFAULT = 0).

- highchan [int]
  High channel considered to removing events led by electronic instrument (DEFAULT = 255).

- glitchfile [file name]
  Name of the output file of spike events (DEFAULT = NONE).

- clobber [boolean]
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists (DEFAULT=yes).

- history [boolean]
  If 'history=yes' the parameter values and other information are written in HISTORY keywords (DEFAULT=yes).

- chatter [integer]
  Chatter Level (min=0, max=5) (DEFAULT=2). It is used to control the output message.

USAGE

NOTE: This task can’t do gain correction between all detectors currently, so we recommend that users extract energy spectrum for each detector at the stage 3.

- General usage

```
hepical evtfile=HXMT_P010129300302_HE-Evt_FFFFFF_V1_L1P.FITS
outfile=he_calibration.FITS
```

The structure (Header, GTI extension and Events extension) of HXMT_P010129300302_HE-Evt_FFFFFF_V1_L1P.FITS will copy to the new files.

- If users want to get the spike events, please set glitchfile not to 'NONE'.

```
hepical glitchfile=he_spike.FITS
```

The default values to remove spike events are lowchan = 0 highchan = 255 timedel = 0.00008 and evtnum = 5. Figure. 5.2 shows the comparison between the raw light curve and the spike events removed by this tool (binsize = 0.1s).
CHAPTER 5. HE DATA ANALYSIS

Figure 5.2: The comparison between the raw light curve and the spike light curve with $\text{binsize} = 0.1\text{s}$ and $\text{Det}_\text{ID} = 16$.

- This tool needs CALDB environment. The default $\text{gainfile}$ should be set to 'CALDB', but users can assign the gain file, by:

  ```
  hepical gainfile=${\text{CALDB}}/data/hxmt/he/bcf/hxmt_he_gain_20171030_v1.fits
  ```

5.3 Screening

5.3.1 hegtigen

Generate a FITS file of good time interval (GTI).

**PARAMETER**

The parameters of this task are listed below:

- **hvfle [file name]**
  Name of the input 1-L High Voltage FITS file.

- **tempfile [file name]**
  Name of the input 1-L Temperature FITS file.

- **ehkfile [file name]**
  Name of the input 1-L ehk FITS file.

- **outfle [file name]**
  Name of output GTI FITS file.

- **rangefile [file name]**
  Name of the input parameter configure FITS file. Default is ‘$\text{HEADAS/refdata/herangefile.fits}$’.

- **ascendfile [file name]**
  Name of the input fits for high bkg (provided by bkg team). Can set to ‘$\text{HEADAS/refdata/HE\_D0\_C26-255\_Ascend\_PHA\_Map.txt}$’ or NONE.
5.3. SCREENING

- **descendfile [file name]**
  Name of the input fits for high bkg (provided by bkg team). Can set to `$HEADAS/refdata/HE_D0_C26-255_Descend_PHA_Map.txt` or NONE.

- **defaultexpr [string]**
  EHK Selection Expression: YES to use parameter 'heranefile'/ NO for user setting/ NONE to use parameter 'expr' and only create a GTI extension.

- **ELV [real]**
  Pointing direction above Earth(>°deg) or < 0 for default.

- **DYE_ELV [real]**
  Pointing direction above bright Earth(>°deg) or < 0 for default.

- **SAA_FLAG [bool]**
  Exclude the data in SAA.

- **T_SAA [real]**
  Time since SAA passage(>s) or < 0 for default.

- **TN_SAA [real]**
  Time to next SAA passage(>s) or < 0 for default.

- **COR [real]**
  Min Cut-off Rigidity value(>GeV) or < 0 for default.

- **MOON_ANGLE [real]**
  The Moon Angle is bigger than(>°deg) or < 0 for default.

- **SUN_ANGLE [real]**
  The Sun Angle is bigger than(>°deg) or < 0 for default.

- **ANG_DIST [real]**
  The offset angle from the pointing direction.

- **pmfile [file name]**
  Name of the input Particle Monitor FITS file.

- **pmexpr [string]**
  Selection Expression for Particle Monitor File (DEFAULT = NONE).

- **expr [string]**
  Selection Expression for EHK file (DEFAULT=NONE), if defaultexpr=NONE, expr must be set.

- **prefr [real]**
  Pre-Time Interval factor [0,1].

- **postfr [real]**
  Post-Time Interval factor [0,1].

- **clobber [boolean]**
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists(DEFAULT=yes).

- **history [boolean]**
  If 'history=yes' the parameter values and other information are written in HISTORY keywords (DEFAULT=yes).

- **chatter [integer]**
  Chatter Level (min=0, max=5)(DEFAULT=2).
CHAPTER 5.HE DATA ANALYSIS

USAGE
- General usage

hegtigen hvfile=HXMT_P010129300302_HE-HV_FFFFFF_V1_L1P.FITS \
tempfile=HXMT_P010129300302_HE-TH_FFFFFF_V1_L1P.FITS \
ehkfile=HXMT_P010129300302_EHK_FFFFFF_V1_L1P.FITS \
outfile=he_gti.FITS defaultexpr=NONE \
expr="ELV>10&&COR>8&&SAA_FLAG==0&&ANG_DIST<0.04&&T_SAA>300&&TN_SAA>300"

Currently, we recommend users set the parameter defaultexpr to NONE, not to YES/NO.

- If users want to use particle monitor, users should set pmfile and pmexpr correctly. For example:

hegtigen hvfile=HXMT_P010129300302_HE-HV_FFFFFF_V1_L1P.FITS \
tempfile=HXMT_P010129300302_HE-TH_FFFFFF_V1_L1P.FITS \
ehkfile=HXMT_P010129300302_EHK_FFFFFF_V1_L1P.FITS \
outfile=he_gti.FITS defaultexpr=NONE \
expr="ELV>10&&COR>8&&SAA_FLAG==0&&ANG_DIST<0.04&&T_SAA>300&&TN_SAA>300 \

pmfile=HXMT_P010129300302.HE-PM_FFFFFF_V1_L1P.FITS \
pmexpr="Cnt_PM_0<100&&Cnt_PM_1<100&&Cnt_PM_2<100"

- If users want to set their own criteria for high voltage or temperature, users can modify the herangefile.fits and set the rangefile parameter. For example:

hegtigen rangefile=/Users/zhaohs/workarea/Heasoft/heasoft-6.16/hxmt/HE/rangefile.fits 
The default value of herangefile.fits is "$HEADAS/refdata/herangefile.fits".

- History keywords in GTI file (GTIDesc extension):
 Users can ignore these keywords such as 'HISTORY P8 ELV = 5', 'HISTORY P10 COR=5', etc, when the parameter defaultexpr = NONE, and users only concern the "expr" keyword (HISTORY P18 expr="ELV > 10&&ANG DIST < 0.1&&SAA_FLAG == 0").

- This version has removed some region where the background can’t be estimated very well, so the good time intervals will be less than those in previous version(2.0/2.01). If users don’t care the background estimation, users can set the parameter ascend file and descend file to NONE, and will get more GTIs. For example:

hegtigen defaultexpr=NONE 
expr="ELV>10&&COR>8&&SAA_FLAG==0&&ANG_DIST<0.04&&T_SAA>300&&TN_SAA>300 
ascendfile=NONE descendfile=NONE

5.3.2 hescreen

Exclude some of the photons in event file.

PARAMETER

The parameters of this task are listed below:

- evtfile [file name]
  Name of the calibrated event FITS file.

- outfile [file name]
  Name of output screened event FITS file.
5.3. SCREENING

- **gtifile** [file name]
  Name of the input gti FITS file.

- **baddetfile** [file name]
  Name of the input bad detector configure file. Always set to "$HEADAS/refdata/hedetectorstatus.fits".

- **userdetid** [string]
  Detector ID (0-17) Selection (ID List).

- **anticoincidence** [bool]
  The Logical Anticoincidence Selection used(18ACD)? (yes/no)(DEFAULT = yes).

- **eventtype** [int]
  Type of Event: 0:ALL; 1:X-ray; 2:Calibration Source

- **starttime** [real]
  Starting time for summation (DEFAULT = 0.).

- **stoptime** [real]
  Ending time for summation (DEFAULT = 0.).

- **minPI** [int]
  Minimum PI to consider.

- **maxPI** [int]
  Maximum PI to consider.

- **minpulsewidth** [int]
  Minimum Pulse Shape Discriminator for NaI and CsI (DEFAULT = 54).

- **maxpulsewidth** [int]
  Maximum Pulse Shape Discriminator for NaI and CsI (DEFAULT = 70).

- **clobber** [boolean]
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists(DEFAULT=yes).

- **history** [boolean]
  If 'history=yes' the parameter values and other information are written in HISTORY keywords(DEFAULT=yes).

- **chatter** [integer]
  Chatter Level (min=0, max=5)(DEFAULT=2).

**USAGE**

- General usage

  ```
  hescreen evtfile=he_calibration.FITS gtifile=he_gti.FITS \
  outfile=he_screen.FITS userdetid="0-17"
  ```

- If users don’t want to use logical anticoincidence array, users can set **anticoincidence** to no (DEFAULT=yes). But, the background generation module need **anticoincidence = yes**.

- The parameters of **minpulsewidth** and **maxpulsewidth** can be set to any values (DEFAULT=54, 70), but for background generation, only the default values are considered.
Example
In figure5.3 the upper panel showed the light curve of event file(obsID:P010129800201) after carrying out *hepical*. The bottom panel is the light curve after *hescreen*. The "0-15,17" detectors were selected. And the NaI photons which have pulsewidth between 20 to 70 were selected as well.

![Graphical representation of the light curve](image)

Figure 5.3: It is the light curve of event file after *hepical* in the upper panel and the light curve after carrying out *hescreen* in the bottom panel

### 5.4 Extracting High Level Products

#### 5.4.1 hespecgen

Extract spectra.

**PARAMETER**

The parameters of this task are listed below:

- **evtfile [file name]**
  
  Name of the screened event FITS file.

- **outfile [file name]**
  
  Name of the output prefix to PHA FITS file.
5.4. EXTRACTING HIGH LEVEL PRODUCTS

- **deadfile [file name]**
  Name of the input 1-L Dead time FITS file.

- **userdetid [string]**
  Detector ID (0-17) Selection (ID List), such "0-17; 0 1 2 3; 4,5,6,7; 8-10,11"

- **eventtype [int]**
  Type of Event: 0:ALL; 1:X-ray; 2:Calibration Source

- **starttime [real]**
  Starting time for summation (DEFAULT = 0.)

- **stoptime [real]**
  Ending time for summation (DEFAULT = 0.)

- **minPI [int]**
  Minimum PI to consider

- **maxPI [int]**
  Maximum PI to consider

- **groupmin [int]**
  Counts per group in grouped spectrum (DEFAULT = 20)

- **clobber [boolean]**
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists(DEFAULT=yes).

- **history [boolean]**
  If 'history=yes' the parameter values and other information are written in HISTORY keywords(DEFAULT=yes).

- **chatter [integer]**
  Chatter Level (min=0, max=5)(DEFAULT=2).

### USAGE

- General usage

  ```plaintext
  hespecgen evtfile=he_screen.FITS \
  deadfile=HXMT_P010129300302_HE-DTime_FFFFFF_V1_L1P.FITS \
  outfile=spec userdetid="0;1;2;3;4;5;6;7;8;9;10;11;12;13;14;15;16;17"
  ```

- If users want to check X-ray of calibration source, users should set the parameter `eventtype = 2` (DEFAULT is 1, only source X-ray). Thus, users would set the parameter `eventtype = 0/2` for `hescreen`.

- Currently, we recommend users extract spectrum for each detector, since the gain correction is not done between these detectors.

#### 5.4.2 helcgen

Extract light curve.
CHAPTER 5. HE DATA ANALYSIS

PARAMETER
The parameters of this task are listed below:

- **evtfile [file name]**  
  Name of the screened event FITS file.

- **outfile [file name]**  
  Name of the output prefix to PHA FITS file.

- **deadfile [file name]**  
  Name of the input Dead time FITS file.

- **binsize [real]**  
  Time Bin Size.

- **userdetid [string]**  
  Detector ID (0-17) Selection (ID List), such ”0-17; 0 1 2 3; 4,5,6,7; 8-10,11”

- **eventtype [int]**  
  Type of Event:0:ALL; 1:X-ray; 2:Calibration Source

- **starttime [real]**  
  Starting time for summation (DEFAULT = 0.)

- **stoptime [real]**  
  Ending time for summation (DEFAULT = 0.)

- **minPI [int]**  
  Minimum PI to consider

- **maxPI [int]**  
  Maximum PI to consider

- **deadcorr [bool]**  
  Correct light curve used dead time (yes/no) (DEFAULT = yes).

- **aligncorr [bool]**  
  Correct light curve used time-dependent PSF(alignment) correction, at the same time, users should set ’attfile’

- **attfile [file name]**  
  Name of the input 1-L Attitude FITS file (psf correction, set aligncorr=yes)

- **(clobber=no) [boolean]**  
  If ’clobber’=yes and outfile=filename, the file with the same name will be overwritten if it exists.

- **(history=yes) [boolean]**  
  If ’history=yes’ the parameter values and other information are written in HISTORY keywords.

- **(chatter = 2) [integer]**  
  Chatter Level (min=0, max=5)
5.4. EXTRACTING HIGH LEVEL PRODUCTS

USAGE
- General usage

helcgen evtfile=he_screen.FITS \
    deadfile=HXMT_P010129300302_HE-DTime_FFFFFF_V1_L1P.FITS \
    outfile=spec userdetid="0;1;2;3;4;5;6;7;8;9;10;11;12;13;14;15;16;17" bin-size=1

5.4.3 herspgen
Generate the response file of energy spectrum.

PARAMETER
The parameters of this task are listed below:

- phafile [file name]
  Name of the input PHA FITS file.

- outfile [file name]
  Name of the output RSP FITS file.

- attfile [file name]
  Name of the input 1-L Attitude FITS file.

- ra [real]
  Source RA (degrees), from 0 to 360°.

- dec [real]
  Source DEC (degrees), form −90 to 90°.

- (clobber=no) [boolean]
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists.

- (history=yes) [boolean]
  If 'history=yes' the parameter values and other information are written in HISTORY keywords.

- (chatter = 2) [integer]
  Chatter Level (min=0, max=5)

USAGE
- General usage

herspgen phafile=spec_g0_0.pha \
    attfile=ACS/HXMT_P010129300302_Att_FFFFFF_V1_1RP.FITS \
    outfile=he_rsp.fits ra=-1 dec=-91

- If users set ra and dec to −1 and −91, respectively, the task will read their real values from spectrum file.

- This version can't generate response file for blind detector.
5.4.4 hebkgmap

The HE background is generated by hebkgmap. The background spectra are generated separately in this version. The background light-curve is for all non-blind detectors.

**USAGE**

To see the usage, you could run "hebkgmap -h". The format of using the hebkgmap command may look like this:

Method 1: hebkgmap lc/spec hescreen.FITS ehkfile.fits gtifile.fits deadtime.fits cnamencpecname chmin chmax outnam_prefix

Method 2: Using interactive method in prompt.

Method 3: hebkgmap sflag=lc/spec evtfile=screen.FITS ehkfile=ehkfile.fits gtifile=gtifile.fits dtname=deadtime.fits srcdat=lcname/specname chmin=chmin chmax=chmax outnam=outnam_prefix

**Parameters input**

- **lc/spec**: [char]
  - lc for background light curve and spec for background spectrum

- **hescreen.FITS** (include all events of blind detector 16): [fits file]
  - the event file that includes the events of blind detectors.

- **ehkfile.fits**: [fits file]
  - the EHK file for the observation

- **gtifile.fits**: [fits file]
  - the GTI file for HE

- **deadtime.fits**: [fits file]
  - the Dead Time file for HE

- **lcname/specname**: [file name]
  - the ASCII file, in which the name of the light curves or the spectra you want to analysis should be written

- **chmin**: [int]
  - minimum channel for light curves or spectra

- **chmax**: [int]
  - maximum channel for light curves or spectra

- **outnam_prefix**: [char]
  - the output prefix for the light curves or spectra

**Example**

Here we present the general case for creating background files of light curves and spectra.

1. Generate background spectra

   If 18 spectra of HE have been generated, hespec_0.pha, hespec_1.pha, hespec_2.pha, ..., hespec_17.pha, then save these names to an ASCII file named specname.txt. The sequence numbers 0, 1, 2, ... 17 are the detector ID of HE. The content of ASCII filespecname.txt look like this:
5.4. **EXTRACTING HIGH LEVEL PRODUCTS**

hespec_0.pha
hespec_1.pha
hespec_2.pha
hespec_3.pha
hespec_4.pha
hespec_5.pha
hespec_6.pha
hespec_7.pha
hespec_8.pha
hespec_9.pha
hespec_10.pha
hespec_11.pha
hespec_12.pha
hespec_13.pha
hespec_14.pha
hespec_15.pha
hespec_16.pha
hespec_17.pha

You may perform the command

```
hebkgmap spec hescreen.FITS ehkfile.fits gtifile.fits deadtime.fits specname.txt 0 255 he_specbkg
```

(2) Generate background lightcurve

If lightcurve of HE has been generated and its name is *he.lc* then write the name of light curve file to an ASCII file named *lcname.txt*. The content of ASCII *lcname.txt* should be like this:

```
he.lc
```

The channel range selected for the lightcurve is 25 to 100(roughly refers to 28.5–128 keV). Now you may perform the command

```
hebkgmap lc hescreen.FITS ehkfile.fits gtifile.fits deadtime.fits lcname.txt 25 100 he_lcbkg
```

### 5.4.5 **hhe_spec2pi**

Create the merged spectrum for HE of Insight-HXMT.

**USAGE**

```
hhe_spec2pi src.dat bkg.dat rsp.dat hesrc.pi hebkg.pi hersp.rsp
```

- **src.dat**: includes the spectral file names of HE.
- **bkg.dat**: includes the background file names of HE.
- **rsp.dat**: includes the response file file names of HE.
- **hesrc.pi**: the output file name of merged source spectrum.
- **hebkg.pi**: the output file name of the merged background spectrum.
- **hersp.rsp**: the output file name of merged response file.
5.5 Special Processing

*hxmtscreen* is used to re-screen the screened event file and *hespeccorr* is used to correct exposure time (see Figure 5.4).

### 5.5.1 hxsmtscreen

For a combined events files, there are more than one detector and each detector has its own good time intervals. But, sometimes, users want to extract spectra/light curves at same time intervals for different detectors. This task is used to re-screen the screened event files and a common GTIs will be given.

**PARAMETER**

The parameters of this task are listed below:

- **evtfile [file name]**
  
  Name of the input screened Event FITS file.

- **outfile [file name]**
  
  Name of the output new screened Event FITS file.
5.5. SPECIAL PROCESSING

- **usergtifile [file name]**
  Name of the input User GTI file (txt format).

- **userdetid [string]**
  Detector ID Selection (ID List).

- **clobber [integer]**
  If 'clobber'=yes and outfile=filepath, the file with the same name will be overwritten if it exists.

- **(history=yes) [boolean]**
  If 'history=yes' the parameter values and other information are written in HISTORY keywords.

- **(chatter = 2) [integer]**
  Chatter Level (min=0, max=5)

**USAGE**

- General usage

  \[ 
  \text{hxmmtscreeevtfile=he\_screen.fits outfile=he\_screen2.fits} \backslash
  \text{userdetid=0-17 usergtifile=NONE} \]

  - If users set **usergtifile** to **NONE**, this task will only consider the GTI extensions from **evtfile**. The format of user GTI file(parameter of **usergtifile**) is a ASCII format file, and each line includes a good time interval, such as 

    \[ \begin{align*} 
    t_1 & \quad t_2 \\
    t_3 & \quad t_4 
    \end{align*} \]

  - This task can be used to re-screen the HE/ME/LE screened file.

5.5.2 hespeccorr

The spike events have influence over exposure/effective area. **hespeccorr** is used to correct the exposure time of the spectrum by removing bad time intervals of spike events

**PARAMETER**

The parameters of this task are listed below:

- **phafile [file name]**
  Name of the input PHA FITS file.

- **glitchfile [file name]**
  Name of the input HE Glitch-Event FITS file.

- **deadfile [file name]**
  Name of the input Dead time FITS file.

- **clobber [integer]**
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists.

- **(history=yes) [boolean]**
  If 'history=yes' the parameter values and other information are written in HISTORY keywords.
• (chatter = 2) [integer]
  Chatter Level (min=0, max=5)

**USAGE**

- General usage

  ```bash
  hespeccorr phafile=he_g0_0.pha glitchfile=glitch.fits \
  deadfile=HXMT_P010129300302_HE-DTime_FFFFP_V1_L1P.FITS
  ```

  This task will correct the exposure time of `phafile`.

- `glitchfile` is created by `hepical`

- This task is used to estimate exposure time when `hepical lowchan = 0 highchan = 255`.

- After correction, the exposure time \((P010130600202 - 20170828 - 01 - 01)\) is modified from 3055.327 to 3054.969\(s\). So, this correction does not need to be done.
Chapter 6

ME Data Analysis

6.1 Introduction

The processing procedures include three major steps: calibration (stage 1), screening (stage 2) and extraction of high-level scientific products (stage 3). For stage 1, the EVT file is processed to produce a calibrated EVT file; for stage 2, the calibrated EVT file is filtered by applying cleaning criteria to produce a cleaned EVT file; for stage 3, the high-level scientific products are generated.

Fig. 6.1 shows the ME data reduction.

6.2 Calibration

6.2.1 mepical

Calculate PI column values of ME event files

PARAMETER

The parameters of this task are listed below:

- `evtfile [file name]`
  Name of the input 1-L event FITS file.

- `tempfile [file name]`
  Name of the input 1-L temperature FITS file.

- `outfile [file name]`
  Name of output event FITS file.

- `gainfile [file name]`
  Name of the input gain FITS file. If set to CALDB, use the file in the Calibration Database.

- `seed [int]`
  Input seed for random number generator

- `(clobber=no) [boolean]`
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists.

- `(history=yes) [boolean]`
  If 'history=yes' the parameter values and other information are written in HISTORY keywords.
CHAPTER 6. ME DATA ANALYSIS

Figure 6.1: ME data reduction.
6.3. SCREENING

- (chatter = 2) [integer]
  Chatter Level (min=0, max=5)

USAGE
- General Usage
  `<mepevalc> <evtfile> <outfile> <deadfile> <binsize> <clobber> <history> <chatter>`
  
  `<evtfile>` = HXMT_P010130600202_ME-Evt_FFFHHH_V1_1RP.FITS
  `<tempfile>` = HXMT_P010130600202_ME-TH_FFFHHH_V1_1RP.FITS
  `<outfile>` = `me_pi.fits`
  `<deadfile>` = `dead.fits`

6.2.2 megrade
Calculate Grade column values of ME calibrated event files and calculate dead time of each FPGA.

PARAMETER
The parameters of this task are listed below:

- `evtfile` [file name]
  Name of the input calibrated event FITS file.

- `outfile` [file name]
  Name of output event FITS file.

- `deadfile` [file name]
  Name of output dead FITS file. If set to NONE, this file can’t be created.

- `binsize` [real]
  Time interval to create dead FITS file.

- (clobber=no) [boolean]
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists.

- (history=yes) [boolean]
  If 'history=yes' the parameter values and other information are written in HISTORY keywords.

- (chatter = 2) [integer]
  Chatter Level (min=0, max=5)

USAGE
- General Usage
  `<mepevalc> <evtfile> <outfile> <deadfile> <binsize> <clobber> <history> <chatter>`
  
  `<evtfile>` = `me_pi.fits`
  `<outfile>` = `me_grade.fits`
  `<deadfile>` = `dead.fits`

- If users want to get dead time less than 1 second, users can set the parameter of `binsize` ≤ 1 (such as 0.1)

6.3 Screening

6.3.1 megtigen
Generate a FITS file of good time interval (GTI).
PARAMETER

The parameters of this task are listed below:

- **tempfile** [file name]
  Name of the input 1-L Temperature FITS file.

- **ehkfile** [file name]
  Name of the input 1-L ehk FITS file.

- **outfile** [file name]
  Name of output event FITS file.

- **rangefile** [file name]
  Name of the input parameter configure FITS file. Always set to \$HEADAS/refdata/merangefile.fits’.

- **defaultexpr** [string]
  EHK Selection Expression: YES to use parameter ’merangefile’/ NO for user setting/ NONE to use parameter ‘expr’ and only create a GTI (for EHK) extension.

- **ELV** [real]
  Pointing direction above Earth(>°deg) or < 0 for default.

- **DYE_ELV** [real]
  Pointing direction above bright Earth(>°deg) or < 0 for default.

- **SAA_FLAG** [bool]
  Exclude the data in SAA.

- **T_SAA** [real]
  Time since SAA passage(>s) or < 0 for default.

- **TN_SAA** [real]
  Time to next SAA passage(>s) or < 0 for default.

- **COR** [real]
  Min Cut-off Rigidity value(>GeV) or < 0 for default.

- **MOON_ANGLE** [real]
  The Moon Angle is bigger than(>°deg) or < 0 for default.

- **SUN_ANGLE** [real]
  The Sun Angle is bigger than(>°deg) or < 0 for default.

- **ANG_DIST** [real]
  The offset angle from the pointing direction <°deg or <= 0 for default.

- **expr** [string]
  Selection Expression for EHK file (DEFAULT=None), if defaultexpr=None, expr must be set.

- **prefr** [real]
  Pre-Time Interval factor [0,1].

- **postfr** [real]
  Post-Time Interval factor [0,1].

- **(clobber=no)** [boolean]
  If ’clobber’=yes and outfile=filename, the file with the same name will be overwritten if it exists.
6.3. SCREENING

- (history=yes) [boolean]
  If 'history=yes' the parameter values and other information are written in HISTORY keywords.

- (chatter = 2) [integer]
  Chatter Level (min=0, max=5)

USAGE

- General Usage
  megtigen defaultexpr=NONE expr="ELV > 10&&COR > 8&&SAA_FLAGS == 0&&ANG_DIST < 0.04&&T_SAA > 300&&T_N_SAA > 300"
  tempfile=HXMT_P01013000202_ME-TH_FFFFF_V1_1RP.FITS
  ehkfile=../AUX/HXMT_P01013000202_EHK_FFFFF_V1_1RP.FITS outfile=me_gti.fits

  History keywords in GTI file (GTIDesc extension)
  Users can ignore these keywords such as 'HISTORY P8 ELV=5', when the parameter defaultexpr = NONE, and users only concern the expr keyword for event selection.

6.3.2 megti

megtii is an auxiliary software to select GTI of ME according to the GTI file generated by megtigen. megti could also be used to select the pixels of ME, which will be input in mescreen and mebkgmap.

USAGE

1) GTI update

megtii evtfile oldgtiname newgtiname

- 'evtfile' is the event file name generated by megrade;
- 'oldgtiname' is the GTI name generated by megtigen
- 'newgtiname' is the out file name for the updated GTI.

2) GTI update and pixel selection

megtii megradename oldgtiname newgtiname $HEADAS/refdata/medetectorstatus.fits newmedetectorstatus.fits

- 'evtfile' is the event file name generated by megrade;
- 'oldgtiname' is the GTI name generated by megtigen;
- 'newgtiname' is the out file name for the updated GTI.
- '$HEADAS/refdata/medetectorstatus.fits' is the file name of old pixel status of ME.
- 'newmedetectorstatus.fits' is output file name for the updated pixel status.

6.3.3 mescreen

Use GTI together with other criteria to screen the ME data.
CHAPTER 6. ME DATA ANALYSIS

PARAMETER
The parameters of this task are listed below:

- **evtfile** [file name]
  Name of the calibrated event FITS file.

- **outfile** [file name]
  Name of output screened event FITS file.

- **gtifile** [file name]
  Name of the input gti FITS file.

- **baddetfile** [file name]
  Name of the input bad detector configure file. Always set to `$HEADAS/refdata/medetectorstatus.fits`.

- **userdetid** [string]
  Detector ID (0-53) Selection (ID List).

- **starttime** [real]
  Starting time for summation (DEFAULT = 0.).

- **stoptime** [real]
  Ending time for summation (DEFAULT = 0.).

- **minPI** [int]
  Minimum PI to consider.

- **maxPI** [int]
  Maximum PI to consider.

- **(clobber=no)** [boolean]
  If 'clobber=yes' and outfile=filename, the file with the same name will be overwritten if it exists.

- **(history=yes)** [boolean]
  If 'history=yes' the parameter values and other information are written in HISTORY keywords.

- **(chatter = 2)** [integer]
  Chatter Level (min=0, max=5)

USAGE

- **General Usage**
  
  ```
  mescreen(evtfile=me_grade.fits gtifile=me_gti.fits outfile=me_screen.fits userdetid="0-53" baddetfile=newmedetectorstatus.fits
  ```

  - the bad detectors will be removed this task. In the old version, the default file of bad detector file is `$HEADAS/refdata/medetectorstatus.fits`. But in this version, the bad detector file should originated from megli module.

  - Currently, the blind FOV detectors must be included in this stage and these detectors will be used by background modules.
6.4 Extraction of high-level products

6.4.1 mespecgen

Extract spectra.

PARAMETER

The parameters of this task are listed below:

- **evtfile** [file name]
  Name of the screened event FITS file.

- **outfile** [file name]
  Name of the output prefix to PHA FITS file.

- **deadfile** [file name]
  Name of the input Dead time FITS file (created in megrade task).

- **userdetid** [string]
  Detector ID (0-53) Selection (ID List), such "0-17; 0 1 2 3; 4,5,6,7; 8-10,11"

- **starttime** [real]
  Starting time for summation (DEFAULT = 0.)

- **stoptime** [real]
  Ending time for summation (DEFAULT = 0.)

- **minPI** [int]
  Minimum PI to consider

- **maxPI** [int]
  Maximum PI to consider

- **groupmin** [int]
  Counts per group in grouped spectrum (DEFAULT = 20)

- **(clobber=no)** [boolean]
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists.

- **(history=yes)** [boolean]
  If 'history=yes’ the parameter values and other information are written in HISTORY keywords.

- **(chatter = 2)** [integer]
  Chatter Level (min=0, max=5)

USAGE

- **General Usage**
  
  mespecgen evtfile=me_screen.fits deadfile=dead.fits userdetid="0 1 2 3 4 5 6 7 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 47 48 49 50 51 52 53;10 28 46" outfile=pha

- **Currently, only small FOV detectors can be used to generate spectra. The detector ID list for small FOV is: 0 1 2 3 4 5 6 7 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 47 48 49 50 51 52 53.
6.4.2 melcgen

Extract light curves.

PARAMETER

The parameters of this task are listed below:

- evtfile [file name]
  Name of the screened event FITS file.

- outfile [file name]
  Name of the output prefix to PHA FITS file.

- deadfile [file name]
  Name of the input Dead time FITS file.

- binsize [real]
  Time Bin Size.

- userdetid [string]
  Detector ID (0-53) Selection (ID List), such "0-17; 0 1 2 3; 4,5,6,7; 8-10,11"

- starttime [real]
  Starting time for summation (DEFAULT = 0.)

- stoptime [real]
  Ending time for summation (DEFAULT = 0.)

- minPI [int]
  Minimum PI to consider

- maxPI [int]
  Maximum PI to consider

- deadcorr [bool]
  Correct light curve used dead time (yes/no) (DEFAULT = yes).

- aligncorr [bool]
  Correct light curve used time-dependent PSF(alignment) correction, at the same time, users should set 'attfile'

- attfile [file name]
  Name of the input 1-L Attitude FITS file (psf correction, set aligncorr=yes)

- (clobber=no) [boolean]
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists.

- (history=yes) [boolean]
  If 'history=yes' the parameter values and other information are written in HISTORY keywords.

- (chatter = 2) [integer]
  Chatter Level (min=0, max=5)
6.4. EXTRACTION OF HIGH-LEVEL PRODUCTS

USAGE

- General Usage
  
  melegen evtfile=me_screen.fits deadfile=dead.fits userdetid="0-53" outfile=lg binsize=1

- In order to get accurate background, only small FOV detectors can be used to generate light curves. The detector ID list for small FOV is: 0 1 2 3 4 5 6 7 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 47 48 49 50 51 52 53.

6.4.3 merspgen

Generate the response file of energy spectrum.

PARAMETER

The parameters of this task are listed below:

- phafile [file name]
  Name of the input PHA FITS file.

- outfile [file name]
  Name of the output RSP FITS file.

- attfile [file name]
  Name of the input 1-L Attitude FITS file.

- ra [real]
  Source RA (degrees), from 0 to 360°.

- dec [real]
  Source DEC (degrees), from −90 to 90°.

- (clobber=no) [boolean]
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists.

- (history=yes) [boolean]
  If 'history=yes’ the parameter values and other information are written in HISTORY keywords.

- (chatter = 2) [integer]
  Chatter Level (min=0, max=5)

USAGE

- General usage
  
  merspgen phfile = spec_g0_0.fits attfile = ACS/HXMT_P010129300302_Att_FFFFV11RP.FITS 
  outfile = le_rsp.fits ra = −1 dec = −91

- If users set ra and dec to −1 and −91, respectively, the task will read their real values from spectrum file.

6.4.4 mebkgmap

The background of ME for small FOV is generated by mebkgmap. The background spectrum and light curve are generated from the screened event file, which is generated by mescreen and includes all events of blind detectors.
 USAGE

Like hebkmap, you can execute "mebkgmap -h" for help. The format looks like this:

Method 1: mebkgmap lc/spec screen.FITS ehkfile.fits gtifile.fits deadtime.fits
tempname lcname/specname chmin chmax outnam_prefix baddetfile

Method 2: Using interactive method in prompt.
Method 3: mebkgmap sflag=lc/spec evtfile=screen.FITS ehkfile=ehkfile.fits
         gtifile=gtifile.fits dtname=deadtime.fits tempname=tempname
         srcdat=lcname/specname chmin=chmin chmax=chmax outnam=outnam_prefix
         baddetfile=baddetfile

Parameters input:

- lc/spec: [char]
  lc for background light curve and spec for background spectrum

- mescreen.FITS(include all events of blind detectors 10, 28, 46): [fits file]
  the event file that includes the events for blind detectors.

- ehkfile.fits: [fits file]
  the EHK file for the observation

- gtifile.fits: [fits file]
  the GTI file for ME

- deadtime.fits: [fits file]
  the Dead Time file for ME

- tempfile.fits: [fits file]
  the temperature file for ME

- lcname/specname: [file name]
  the ASCII file, in which the name of the light curves or the spectra you want to analysis
  should be written

- chmin: [int]
  minimum channel for light curves or spectra

- chmax: [int]
  maximum channel for light curves or spectra

- outnam_prefix: [char]
  the output prefix for light curves or spectra

- baddetfile: [char]
  the file name of ME detector status including the information of bad pixels

Example

Here we present the general case for creating background files of light curves and spectra.

1. Generate background spectrum

   If small FOV spectrum of ME has been generated and its name mespec.pha, then save these
   names to specname.txt. The content of ASCII file specname.txt should be like this:

   mespec.pha
Now you can execute the command

```bash
mebkgmap spec mescreen.FITS ehkfile.fits gtifile.fits deadtime.fits tempfile.fits specname.txt 0 1023 me_specbkg
```

If the file including bad pixel information generated by `megti` is `newdet.fits`, the background spectrum could be generated by

```bash
mebkgmap spec mescreen.FITS ehkfile.fits gtifile.fits deadtime.fits tempfile.fits specname.txt 0 1023 me_specbkg newdet.fits
```

(2) Generate background lightcurve

If lightcurve of ME has been generated and its name is `me.lc`. Save this name to `lcname.txt`. The channel range for the lightcurve is 119 to 290 (roughly refers to 10–20 keV).

```bash
mebkgmap lc mescreen.FITS ehkfile.fits gtifile.fits deadtime.fits tempfile.fits lcname.txt 119 290 me_lcbkg
```

If the file including bad pixel information generated by `megti` is `newdet.fits`, the background light curve could be generated by

```bash
mebkgmap lc mescreen.FITS ehkfile.fits gtifile.fits deadtime.fits tempfile.fits lcname.txt 119 290 me_lcbkg newdet.fits
```
Chapter 7

LE Data Analysis

7.1 Introduction

The LE processing procedures include three major steps: calibration (stage 1), screening (stage 2) and extraction of high-level scientific products (stage 3). 7.1 shows the LE data reduction.

7.2 Calibration

7.2.1 lepical

Calculate PI column values of LE event files and remove noise for each event.

PARAMETER

The parameters of this task are listed below:

- evfile [file name]
  Name of the input 1-L event FITS file.

- outfile [file name]
  Name of output event FITS file.

- tempfile [file name]
  Name of the input 1-L temperature FITS file.

- gainfile [file name]
  Name of the input gain FITS file. If set to CALDB, use the file in the Calibration Database.

- maxtimedel [real]
  Accumulate time interval (s) for calculation noise.

- clobber [boolean]
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists (DEFAULT=yes).

- history [boolean]
  If 'history=yes' the parameter values and other information are written in HISTORY keywords (DEFAULT=yes).

- chatter [integer]
  Chatter Level (min=0, max=5)(DEFAULT=2). It is used to control the output message.
7.2. CALIBRATION

![Diagram of LE data reduction process]

Figure 7.1: LE data reduction.
Figure 7.2: The peak of pedestal events of CCD 0 vs its temperature.

**USAGE**

- General usage
  - Lepical event file=HXMT_P010129000101.LE-Evt_00001.P1P.FITS
  - Temp file=HXMT_P010129000101.LE-TH_00001.P1P.FITS
  - Out file=le.pi.FITS

- If users want to see the pedestal events, users can set pedestal file not to NONE.
  - Lepical pedestal file=le_pedestal.FITS

The output file includes columns of "Time", "Peak" and "Width", which describe the time, peak (96 columns) and width (96 columns) of the pedestal events, respectively.

Figure 7.2 and 7.3 show the peak and width of pedestal events of CCD 0 vs its temperature. The peak and width always are constant with the small change of temperature (from $-50^\circ$ to $-55^\circ$). But after 20180615, the CCD temperature control has some problem (still in normal working range), the peak and width vary greatly with the change of temperature (Fig. 7.4 and Fig. 7.5, P011466107804). Luckily, this problem only has influence on pedestal noise and the lepical can meet the requirement of large peak/width range of pedestal events.

### 7.2.2 lecrecon

Reconstruct two split events, and assign grade.

**PARAMETER**

The parameters of this task are listed below:

- evtfile [file name]
  Name of the input 1-L event FITS file.

- outfile [file name]
  Name of output event FITS file.

- instatusfile [file name]
  Name of the input 1-L detector status FITS file.
7.2. **CALIBRATION**

Figure 7.3: The width of pedestal events of CCD 0 vs its temperature.

Figure 7.4: The peak of pedestal events of CCD 0 vs its temperature (after 20180615).
Figure 7.5: The width of pedestal events of CCD 0 vs its temperature (after 20180615).

- **hzscale [integer]**
  A scale to calculate split events, e.g. two events with time interval less than 10µs×hzscale will be reconstructed to one event (two-split event) (DEFAULT=1).

- **clobber [boolean]**
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists (DEFAULT=yes).

- **history [boolean]**
  If 'history=yes' the parameter values and other information are written in HISTORY keywords (DEFAULT=yes).

- **chatter [integer]**
  Chatter Level (min=0, max=5) (DEFAULT=2).

**USAGE**
- General usage
  
  ```
  lerecon evtfile=le_pi.FITS instatusfile=HXMT_P010129900101_LE-InsStat_FFFFFF_V1_L1P.FITS outfile=le_recon.FITS
  ```

  There are three grades: 0 means normal events (single events), 1 means split events (two split events) and 2 means more split events (> 2). Figure 7.6 shows the raw events light curve (binsize = 0.1s) and the light curves for GRADE = 0, 1, 2, respectively. The light curve of raw events has some spikes which is due to continuous split events. Figure 7.7 shows the ratio of two-split/more-split events of small CCDs of board 0 to covered CCDs of board 0. The more-split events number is linear with particle background.
Figure 7.6: The reconstructed events for CCD 0: raw light curve, single events light curve (\(GRADE = 0\)), split events light curve (\(GRADE = 1\)) and more split events light curve (\(GRADE = 2\)).

Figure 7.7: The ratio of two-split/more-split events (\(binsize = 100\) s) of small CCDs to covered CCDs for board 0.
the $hzrescal$ parameter

The light curve of two-split events (shown in Fig. 7.6) has some spikes which maybe due to more-split event has event missing (pixel energy deposit below threshold). In order to reduce their cases, users can enlarge $hzrescal$. Figure 7.8 shows the reconstructed events for CCD 0 when $hzscale = 5$ is set to 5. The spike number is significantly decreased and the number of single events is reduced by 1.3%.

CasA is used to check the two-split event and Figure 7.9 shows the energy spectra of single events, no reconstructed two split events, and the reconstructed two-split events.

7.3 Screening

7.3.1 legtigen

Generate a FITS file of good time interval (GTI).

PARAMETER

The parameters of this task are listed below:

- **evtfile [file name]**
  
  Name of the input 1-L event FITS file.

- **instatusfile [file name]**
  
  Name of the input 1-L detector status FITS file.
Figure 7.9: The energy spectra of single events ($GRADE = 0$), no reconstructed two split events, and the reconstructed two-split events ($GRADE = 2$).

- **tempfile** [file name]
  Name of the input 1-L Temperature FITS file.

- **ehkfile** [file name]
  Name of the input 1-L ehk FITS file.

- **outfile** [file name]
  Name of output event FITS file.

- **rangenfile** [file name]
  Name of the input parameter configure FITS file. Always set to '$HEADAS/refdata/lerangetfile.fits'.

- **defaultexpr** [string]
  EHK Selection Expression: YES to use parameter 'lerangetfile'/ NO for user setting/ NONE to use parameter 'expr' and only create a GTI extension.

- **ELV** [real]
  Pointing direction above Earth(>?deg) or < 0 for default.

- **DYE_ELV** [real]
  Pointing direction above bright Earth(>?deg) or < 0 for default.

- **SAA_FLAG** [bool]
  Exclude the data in SAA.

- **T_SAA** [real]
  Time since SAA passage(>?s) or < 0 for default.

- **TN_SAA** [real]
  Time to next SAA passage(>?s) or < 0 for default.

- **COR** [real]
  Min Cut-off Rigidity value(>?GeV) or < 0 for default.
CHAPTER 7. LE DATA ANALYSIS

- **MOON ANGLE**[real]
The Moon Angle is bigger than (>°deg) or < 0 for default.

- **SUN ANGLE**[real]
The Sun Angle is bigger than (>°deg) or < 0 for default.

- **ANG_DIST**[real]
The offset angle from the pointing direction (<°deg) or <= 0 for default.

- **expr**[string]
  Selection Expression for EHK file (DEFAULT = NONE), if defaultexpr = NONE, expr must be set.

- **prefr**[real]
  Pre-Time Interval factor [0, 1].

- **postfr**[real]
  Post-Time Interval factor [0, 1].

- **(clobber=no)**[boolean]
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists.

- **(history=yes)**[boolean]
  If 'history=yes' the parameter values and other information are written in HISTORY keywords.

- **(chatter = 2)**[integer]
  Chatter Level (min=0, max=5)

**USAGE**

- **General usage**

  ```
  legtigen defaultexpr=NONE
  expr=ELV > 10&&DY_E_ELV > 30&&COR > 8&&ANG_DIST < 0.04&&SAA_FLAG ==
  0&&T_SAA > 300&&TN_SAA > 300
  evtfile=NONE instatusfile=HXMT_P010130600202_LE-InsStat_FFFFFF_V1.1RP.FITS
tempfile=HXMT_P010130600202_LE-TH_FFFFFF_V1.1RP.FITS
ekhfile=../AUX/HXMT_P010130600202_EHK_FFFFFF_V1.1RP.FITS outfile=le.gti.fits
  ```

- **parameter of evtfile**
  If this parameter is not set to NONE (or is set to a wrong file), the trigger event rate will be considered to calculate the good time intervals. But in 1L data, the time of data overflow has been abandoned.

- **Now, we recommend users set the defaultexpr to NONE and use expr as selection expression of GTIs.**

- **Since the legti module can modify the output of this task, the evtfile can be set to NONE.**

### 7.3.2 legti

*legt* is an auxiliary software to select GTI of LE according to the GTI file generated by *legtigen*.
7.3. SCREENING

USAGE
legen evtfile oldgtiname newgtiname

- 'evtfile' is the event file name generated by *lerecon*.
- 'oldgtiname' is the GTI name generated by *legtigen*.
- 'newgtiname' is the out file name for the updated GTI.

7.3.3 lescreen

Use GTI together with other criteria to screen the LE data.

PARAMETER

The parameters of this task are listed below:

- **evtfile** [file name]
  Name of the calibrated event FITS file.

- **outfile** [file name]
  Name of output screened event FITS file.

- **gtifile** [file name]
  Name of the input gti FITS file.

- **baddetfile** [file name]
  Name of the input bad detector configure file. Always set to ´$HEADAS/refdata/ledetectorstatus.fits´.

- **userdetid** [string]
  Detector ID (0-95) Selection (ID List).

- **eventtype** [int]
  Type of Event:0:ALL; 1:Single Event; 2:Two-split Event

- **starttime** [real]
  Starting time for summation (DEFAULT = 0.).

- **stoptime** [real]
  Ending time for summation (DEFAULT = 0.).

- **minPI** [int]
  Minimum PI to consider.

- **maxPI** [int]
  Maximum PI to consider.

- **(clobber=no)** [boolean]
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists.

- **(history=yes)** [boolean]
  If 'history=yes' the parameter values and other information are written in HISTORY keywords.

- **(chatter = 2)** [integer]
  Chatter Level (min=0, max=5)
CHAPTER 7. LE DATA ANALYSIS

USAGE

• General usage

\[
\text{lescreen e}v\text{tfile }= \text{le}_\text{recon}.f\text{its }g\text{ti file }= \text{le}_\text{gti}.f\text{its }\text{userdetid}=0-95 \text{ eventtype}=1 \text{ outfile}=\text{le}_\text{screen}.f\text{its}
\]

• In order to get accurate background, only small FOV detectors are used to do analysis. The detector ID list for small FOV is: 0 2-4 6-10 12 14 20 22-26 28 30 32 34-36 38-42 44 46 52 54-58 60-62 64 66-68 70-74 76 78 84 86 88-90 92-94.

• Currently, the blind FOV detectors must be included in this stage and these detectors will be used by background modules. The blind FOV detector ID list is: 13, 45, 77.

• So, the parameter of userdetid should be set to 0 2-4 6-10 12 14 20 22-26 28 30 32 34-36 38-42 44 46 52 54-58 60-62 64 66-68 70-74 76 78 84 86 88-90 92-94; 13, 45, 77.

• The GTI file is better originated from legti module.

7.4 High level products extraction

7.4.1 lespecgen

Extract spectra.

PARAMETER

The parameters of this task are listed below:

• evtfile [file name]
  Name of the screened event FITS file.

• outfile [file name]
  Name of the output prefix to PHA FITS file.

• userdetid [string]
  Detector ID (0-95) Selection (ID List), such "0-31; 0 1 2 3; 4,5,6,7; 8-10,11"

• eventtype [int]
  Type of Event: 0: ALL; 1: Single Event; 2: Two-Split Event

• starttime [real]
  Starting time for summation (DEFAULT = 0.)

• stoptime [real]
  Ending time for summation (DEFAULT = 0.)

• minPI [int]
  Minimum PI to consider

• maxPI [int]
  Maximum PI to consider

• groupmin [int]
  Counts per group in grouped spectrum (DEFAULT = 20)

• (clobber=no) [boolean]
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists.
7.4. HIGH LEVEL PRODUCTS EXTRACTION

- (history=yes) [boolean]
  If 'history=yes' the parameter values and other information are written in HISTORY keywords.

- (chatter = 2) [integer]
  Chatter Level (min=0, max=5)

USAGE

- General usage
  lespecgen evtfile=le_screen.fits userdetid="0 2-4 6-10 12 14 20 22-26 28-30 32 34-36 38-42 44 46 52 54-58 60-62 64 66-68 70-74 76 78 84 86-90 92-94;13 45 77" outfile=pha eventtype=1

- To get a accurate background, we recommend users use the detector list "0 2-4 6-10 12 14 20 22-26 28 30 32 34-36 38-42 44 46 52 54-58 60-62 64 66-68 70-74 76 78 84 86 88-90 92-94" and single event.

7.4.2 lelcgen

Extract light curves.

PARAMETER

The parameters of this task are listed below:

- evtfile [file name]
  Name of the screened event FITS file.

- outfile [file name]
  Name of the output prefix to PHA FITS file.

- binsize [real]
  Time Bin Size.

- userdetid [string]
  Detector ID (0-95) Selection (ID List), such as "0-95; 0 1 2 3; 4,5,6,7; 8-10,11"

- eventtype [int]
  Type of Event: 0:ALL; 1:Single Event; 2:Two-Split Event

- starttime [real]
  Starting time for summation (DEFAULT = 0.)

- stoptime [real]
  Ending time for summation (DEFAULT = 0.)

- minPI [int]
  Minimum PI to consider

- maxPI [int]
  Maximum PI to consider

- aligncorr [bool]
  Correct light curve used time-dependent PSF(alignment) correction, at the same time, users should set 'attfile'

- attfile [file name]
  Name of the input 1-L Attitude FITS file (psf correction, set aligncorr=yes)
• (clobber=no) [boolean]
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists.

• (history=yes) [boolean]
  If 'history=yes' the parameter values and other information are written in HISTORY keywords.

• (chatter = 2) [integer]
  Chatter Level (min=0, max=5)

**USAGE**

- General usage
  `lelcgen evtfile=le_screen.fits outfile=lg binsize=1 userdetid=0 − 95`

- In order to get accurate background, only small FOV detectors can be used to generate light curves. The detector ID list for small FOV is: 0 2-4 6-10 12 14 20 22-26 28 30 32 34-36 38-42 44 46 52 54-58 60-62 64 66-68 70-74 76 78 84 86 88-90 92-94.

**7.4.3 lerspgen**

Generate the response file of energy spectrum.

**PARAMETER**

The parameters of this task are listed below:

- phafile [file name]
  Name of the input PHA FITS file.

- outfile [file name]
  Name of the output RSP FITS file.

- attfile [file name]
  Name of the input 1-L Attitude FITS file.

- tempfile [file name]
  Name of the input 1-L Temperature FITS file.

- ra [real]
  Source RA (degrees), from 0 to 360°.

- dec [real]
  Source DEC (degrees), form −90 to 90°.

- (clobber=no) [boolean]
  If 'clobber'=yes and outfile=filename, the file with the same name will be overwritten if it exists.

- (history=yes) [boolean]
  If 'history=yes' the parameter values and other information are written in HISTORY keywords.

- (chatter = 2) [integer]
  Chatter Level (min=0, max=5)
7.4. HIGH LEVEL PRODUCTS EXTRACTION

USAGE
- General usage
  - lerspgen phafile = spec_g0_0.fits temp=HXMT_P010130600202_LE-TH_FFFFFF_V1.IRP.FITS
  - attfile = ACS/HXMT_P010129300302_Att_FFFFFF_V1.IRP.FITS outfile = le_rsp.fits
  - ra = −1 dec = −91

- If users set ra and dec to −1 and −91, respectively, the task will read their real values from spectrum file.

7.4.4 lebkgmap

The background of LE for small FOV is generated by lebkgmap. The background spectrum and light curve are generated from screened event file, which is generated by lescreen and includes all events of blind detectors.

Usage
Run "lebkgmap -h" for help. The format of using lebkgmap is:

Method 1: lebkgmap lc/spec screen.fits gtifile.fits lcname/specname chmin chmax outnam_prefix
Method 2: Using interactive method in prompt.
Method 3: lebkgmap sflag=lc/spec evtfile=screen.FITS gtifile=gtifile.fits
srcdat=lcname/specname chmin=chmin chmax=chmax outnam=outnam_prefix

Parameters input
- le/spec: [char]
  - lc for background light curve and spec for background spectrum
- lescreen.FITS (include all events of blind detectors 13,21,45,53,77,85): [fits file]
  - event file that includes the events for ALL blind detectors.
- gtifile.fits: [fits file]
  - the GTI file for LE
- lcname/specname: [file name]
  - the ASCII file, in which the name of the light curves or the spectra you want to analysis should be written
- chmin: [int]
  - minimum channel for light curves or spectra
- chmax: [int]
  - maximum channel for light curves or spectra
- outnam_prefix: [char]
  - the output prefix for light curves or spectra

Example
(1) Generate background spectrum
If small FOV spectrum of LE has been generated and its name lespec.pha, then save its name to specname.txt. Run the command:

lebkgmap spec lescreen.FITS gtifile.fits specname.txt 0 1535 le_specbkg
(2) Generate background light curve

If lightcurve of LE has been generated and its name is le.lc, save its name to lcname.txt. The channel range for the lightcurve is 106 to 1069 (roughly refers to 1.0–10 keV). Run the command:

```
lebkgmap lc lescreen.FITS gtifile.fits lcname.txt 106 1069 lebkg
```
Chapter 8

Barycentric correction tools and other tools

8.1 HXMT hxbary

Changing the arrival time of a photon from TT (Terrestrial Time) to TDB (Barycentric Dynamic Time).
The arrival times of photons are corrected to the solar system barycentric center, considering the
time delay due to the movement of the spacecraft and the earth, the proper motion of the object,
and the relativistic effects (Einstein delay, shapiro delay). After barycentering, a new column
named "TDB" is added in the last column of the extension, in MET seconds to the reference
epoch. Thus, to compute the MJD time from barycentered files, referred to the TDB system, one
should use one of the following formulae,

\[ \text{MJD(TDB)} = (\text{MJDREFI}+\text{MJDREFF})+(\text{TDBTIME}+\text{TIMEZERO})/86400. \]

PARAMETER

The parameters of this task are listed below:

- **evtfile [file name]**
  Name of the input event FITS file.

- **orbitfile [file name]**
  Name of the orbit FITS file

- **ra [real]**
  Right ascension of the object (in degrees)

- **dec [real]**
  Declination of the object (in degrees)

- **eph [int]**
  the choice of the ephemeris, 1 for DE200 and 2 for DE405

- **tdbtdf [string]**
• `iftephfile`
  the path of the IF TDB correction file (DEFAULT=$HEADAS/refdata/TIMEEPH_short.te405)


• `eph200file`
  the path of the DE200 ephemeris file (DEFAULT=$HEADAS/refdata/DE200.1950.2050)

• `eph405file`
  the path of the DE405 ephemeris file (DEFAULT=$HEADAS/refdata/DE405.1950.2050)

• `history [boolean]`
  If 'history=yes' the parameter values and other information are written in HISTORY keywords (DEFAULT=yes).

• `chatter [int]` Chatter level

**USAGE**

```
hxbary evtfiile=PATH/to/event.fits orbitfile=PATH/to/orbit.fits \ ra=86.2 dec=22.01 eph=2
```

### 8.2 HXMT hxbary2

Changing the arrival time of a photon from TT (Terrestrial Time) to TDB (Barycentric Dynamic Time). It is quite similar with hxbary, while the extension number and the column number can be specified to do SSB corrections.

**PARAMETER**

The parameters of this task are listed below:

• `evtfiile [file name]`
  Name of the input event FITS file.

• `exten_num [int]`
  The extension to be corrected.

• `exten_col [int]`
  The column number in the extension to be corrected.

• `orbitfile [file name]`
  Name of the orbit FITS file

• `ra [real]`
  Right ascension of the object (in degrees)

• `dec [real]`
  Declination of the object (in degrees)

• `eph [int]`
  the choice of the ephemeris, 1 for DE200 and 2 for DE405

• `tdbdtdfile [string]`
  the path of the TDB correction file (DEFAULT=$HEADAS/refdata/TDB.1950.2050)

• `iftephfile`
  the path of the IF TDB correction file (DEFAULT=$HEADAS/refdata/TIMEEPH_short.te405)
8.3. HOBS_INFO

- **eph200file**
  the path of the DE200 ephemeris file (DEFAULT=$HEADAS/refdata/DE200.1950.2050)

- **eph405file**
  the path of the DE405 ephemeris file (DEFAULT=$HEADAS/refdata/DE405.1950.2050)

- **Clobber [boolean]**
  If clobber=yes and outfile=filename, the file with the same name will be overwritten if it exists. exists(DEFAULT=yes).

- **History [boolean]**
  If 'history=yes' the parameter values and other information are written in HISTORY keywords(DEFAULT=yes).

- **Chatter [int]**
  Chatter level

**USAGE**

```
hxbary evtfile=PATH/event.fits exten_num=1 exten_col=1 orbitfile=PATH/orbit.fits ra=86.2 dec=22.01 eph=2
```

8.3  **hobs_info**

Print some information for observations.

**USAGE**

Run "hobs_info -h" for help. The format of using hobs_info is:

```
 hobs_info data_path
```

Example:
```
hobs_info ./P0101299/
```

8.4  **hprint_detid**

Print the information of detectors of Insight-HXMT.

**USAGE**

```
hprint_detid
```

8.5  **hgti_create**

Create GTI file for Insight-HXMT with the same information as the GTI sample.
CHAPTER 8. BARYCENTRIC CORRECTION TOOLS AND OTHER TOOLS

USAGE

hgti_create GTI_sample.fits gti.txt out.fits

'GTI_sample.fits' is GTI file name, which could be generated by legtigen/megtigen/hegtigen.
'gti.txt' is input file name, which includes two columns START and STOP time.
'out.fits' is the out file name.

Example:

hgti_create LE_oldgti.fits gti.txt out.fits
hgti_create ME_oldgti.fits gti.txt out.fits
hgti_create HE_oldgti.fits gti.txt out.fits
Appendix A

Installation of the HXMT DAS

A.0.1 Download HXMTDAS source code

(1) Download HXMTDAS source code (new installation)
Download HXMT SOURCE CODE

gunzip hxmtsoftv2.01.tar.gz

tar vxf hxmtsoftv2.01.tar;

 cd hxmtsoftv2.01;

 cd BUILD_DIR;

./configure –prefix=DIR (DIR, install path)

make

make install

(2) If you have installed HXMTDAS on your computer.
For example, your source code is located in /home/hxmtsoft directory.
Source your HEADAS environment, eg, source install/x86_64-apple-darwin13.4.0/headas-init.sh
Download the HXMTDAS SOURCE CODE, and then use commands below in sequence:

gunzip hxmtsoftv2.01.tar.gz

tar vxf hxmtsoftv2.01.tar

 cd hxmtsoftv2.01

 cp -r hxmt /home/hxmtsoft/

 rm -r hxmt/BUILD_DIR

 hmake

 hmake install

(3) If you want to use the lastest HEAsoft, and install hxmt and HEAsoft at the same time.
step 1:
Download the HEAsoft from HEASARC.
Please make sure the source code must have ‘attitude’ and ‘heacore’ components
Use commands gunzip and tar to decompress the package.
step 2:
Download the HXMTDAS.
gunzip hxmtsoftv2.01.tar.gz

tar vxf hxmtsoftv2.01.tar;

step 3:
copy the hxmt component from HEADAS package to HEAsoft package.
step 4:
Change the directory to HEAsoft/BUILD_DIR
open the configure file and modify `mpfit_required=no` to `mpfit_required=yes`
`./configure --prefix=DIR (DIR, install path) --with-components=hxmt (for example --with-components=heacore
tcltk external attitude heasptools heatools heagen demo suzaku swift Xspec integral maxi nicer
mustar hitomi xmm glast ftools GSSC heasim hxmt)
make
make install

A.0.2 Initialization and Setup

for tcsh:
setenv HEADAS DIR/PLATFORM
alias hxmtinit 'source $HEADAS/headas-init.csh'
for bash:
export HEADAS=DIR/PLATFORM
alias hxmtinit=". $HEADAS/headas-init.sh"

In the examples above, (PLATFORM) is a placeholder for the platform-specific string denoting your machine's architecture, for example: i686-pc-linux-gnu-libc2.12.
Bibliography