An Object Oriented Design for Monitoring the Chandra Science Instrument X-Ray Background

J. G. Petreshock, S. J. Wolk, M. Cresitello-Dittmar, T. Isobe

Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138

Abstract. The Monitoring and Trends Analysis (M&TA) System for the *Chandra* X-Ray Observatory consists of multiple software threads designed to monitor and visualize spacecraft behavior. The Science Instrument (SI) background monitoring is one such thread that is designed to compile a temporally and spatially ordered table of the observed flux and energy spectrum in detector coordinates. In this paper we describe the design of the tools, and applications of the data products generated, and the output product flexibility.

1. Introduction

As part of the M&TA[1] System (Wolk et al. 2000) the SI Background (SIB) monitoring thread is based on C++ tools designed with object oriented design methodologies that provide flexibility for generating SIB maps. These tools and several PERL wrapper scripts are woven together to form a pipeline (see figure 1) used by the Chandra[2] X-Ray Center Data Systems (CXCDS) pipeline processing system (Plummer 2001). The resultant products will provide a means for visualization and quantitative analysis of temporal variations in sky emission and instrument background.

The extremely high angular resolution and sensitivity of *Chandra* makes this a unique problem among active X-ray telescopes. But these extremes also hold the promise of producing a background map of unparalleled resolution. We will discuss and demonstrate the current suite of tools used for monitoring the SIB for a single *Chandra* Flight Instrument, the Advanced CCD Imaging Spectrometer (ACIS).

2. Goals and Importance

Understanding *Chandra's* background is an important factor in driving Science Operations (SciOps) decisions. For example, if we detect lower background levels while the spacecraft is within the magnetotail then we can schedule observations of low surface brightness targets during these times.

[1] `http://cxc.harvard.edu/mta`

[2] `http://chandra.harvard.edu/`

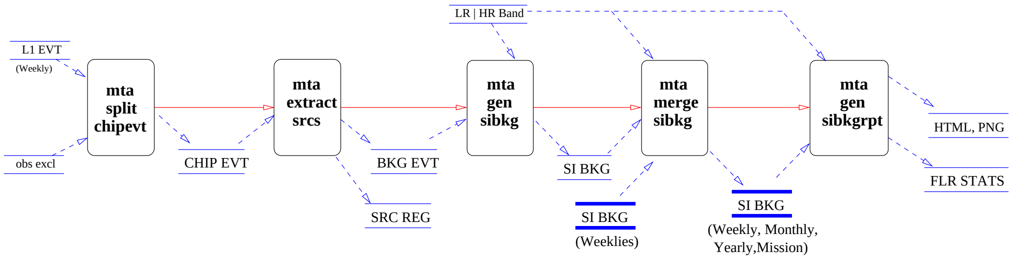

Figure 1. SIB pipeline flow chart

3. Software Requirements

Depending upon the SI configuration and individual observation configurations *Chandra* can collect well over 1.0GB worth of event data per week. This large data volume was another aspect of the SIB monitoring problem that had to be handled. We solved this problem by binning the data by time according to event time stamps thus increasing data manageability.

The SIB monitor is designed to detect temporal and spatial variations in the background count rates and characterize flare properties including; rates, intensities and durations. Flares are identified by comparing background count rates for each energy band against predefined limits. Background values that exceed these limits are flagged as flares. This is demonstrated by Figure 2 which diagrams a one dimensional view of the parameterized temporal and energy binning performed by the SIB tools. These parameters are controlled via the individual tools parameter file using the CXCDS parameter interface library. The flexibility of the parameterization provides control over the data volume and thus increased data manageability. This flexibility also allows users to create products that range from a purely instrumental background analysis to a finely binned sky map.

The SIB monitoring generates FITS compliant binary tables. The CXCDS DataModel (DM) provides the interface between the classes and the FITS file reading and generation. Each class is equipped with data members that store pointers to DM variables used to connect with the FITS file.

4. Classes

The five classes created for the SIB monitor were designed to interface using cascading levels of data encapsulation. This design provides flexibility with class handling. With only slight modifications, specifically function overloading, these classes were capable of being used within both the *mta_gen_sibkg* tool that generates the SIB monitor products as well as the *mta_merge_sibkg* tool that is used to merge multiple SIB monitor products together. To reduce the memory usage by the SIB tools the classes are designed with time being the

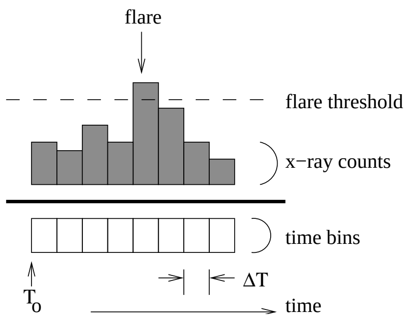

Figure 2. Single energy band Binning Diagram

primary processing key and then followed by sky coordinates (Right Ascension, and Declination) and finally energy. X-Ray Events from input files are processed per time bin (see figure 2). When an event from a new time bin is detected the objects flush their data to a FITS file and the object containers are reset in prepartion for receiving data from the new time bin. The SIB classes are described in the following subsections in order from base classes to higher level derived classes.

4.1. EnergyBand

This class is the basis of the M&TA SIB monitoring, the EnergyBand (EB) class stores information about energy bands such as the number of events, energy ranges, the band name, and a pointer to the output FITS column. The EB class functions to store the information for a time bin and is responsible for writing the data to FITS file.

4.2. EnergyBandContainer

The EnergyBandContainer is a container class for EB objects and stores the information for the energy spectrum as defined by the user configurable energy band definitions files. This container class provides a clean interface hiding the work of event processing from the higher level classes.

4.3. SkyLocation

The SkyLocation class is a derived class from EnergyBandContainer. A SkyLocation object describes the energy spectrum for a given parcel of the sky. For the case that the sky coordinates are undersampled (i.e. sky is resolved into one pixel) the SkyLocation object represents the SIB.

4.4. mtaSIBkgMap

The mtaSIBkgMap is a container class for SkyLocation objects and represents the full observed background map. This is the class responsible for controlling the highest level of event processing and provides a clean control interfaces with the lower level objects.

4.5. EnergyBandDefinitions

This class is used to read and store the EB definitions indicated by the energy band definitions parameter. The sole function for this class it to provided a template to populate new EnergyBandContainer objects. This class is not a derived class and operates in conjunction with the mtaSkyBkgMap class to initialize the required objects for event processing.

5. Data Products

The SIB monitor products for the ACIS instrument contain a column for each energy band defined within the input energy band definitions files as well as a time column, and a flare column. The flare column is defined as an N element bit array that represents each energy band. These FITS products are currently used to generate light curves, flare statistics, and temporal spectral variability plots.

6. Discussion

For any experiment understanding the signal and background components within a data set is a crucial step and SIB monitoring provides a useful quantitative analysis of several background properties. The analysis of SIB properties can also be used to update target scheduling to increase *Chandra's* observational efficiency.

Our application of these simple classes allows us to handle the large volume of X-ray data from *Chandra* efficiently and effectively. The SIB monitor products are ideal for integration into the M&TA trend analysis thread and for use in multisystem correlations with data in existing M&TA databases. The rebinning of sky coordinates allows a basic means for generation of the observed X-ray background map. With future versions of the M&TA SIB monitoring we plan to provide the capability to generate higher resolution background maps by applying archived aspect solution to the background information in detector coordinates. Also, the knowledge acquire by monitoring *Chandra's* SIB can be applied towards future missions and thus potentially increasing cost effectiveness.

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