THE AXAF DATA ANALYSIS SYSTEM: INFRASTRUCTURE AND NEW FEATURES

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The new AXAF data analysis system, under development at the Smithsonian Astrophysical Observatory/AXAF Science Center, is facing the challenge of fully exploiting the unique AXAF data set. We present here a general view of the system infrastructure and describe in more detail some of its key elements.

1 Introduction

After the launch of *AXAF*, NASA's "Advanced X-ray Astrophysics Facility", in the mid-1998, the astronomical community will have the opportunity to study X-ray data with unprecedented spatial and spectral resolution (e.g. Zombeck 1996). This requires the development of new analysis software and the enhancement of pre-existing analysis tools.

In order to exploit the full *AXAF* potential, the *AXAF* Science Center (ASC) at the Smithsonian Astrophysical Observatory is developing a suite of tools that will allow astronomers to analyze the variety of *AXAF* and related data which will include:

- event lists from the High resolution Camera (HRC), a microchannel plate detector with subarcsec spatial resolution and 16μsec time resolution
- event lists from the *AXAF* CCD Imaging Spectrometer (ACIS) with high (few arcsec) spatial resolution and good ($R \approx 20-50$) energy resolution
- dispersed spectra from the Low Energy and High Energy Transmission Gratings (LETG and HETG respectively) with high energy resolution ($R \approx 1000$)
- aspect data from the Aspect Camera Assembly (ACA) optical CCD.
- derived data product from all the data above

Examples of the new data analysis features required in the system are spatial modelling tools, efficient source detection, ease of filtering, ease of handling multiple spectra, images and derived data products.

The goal of the system is to provide all the needed capabilities in an environment as user-friendly as possible which will be at the same time easy to access for new users, but flexible and powerful enough for expert in-depth analysis; and not too different (at least from a user perspective) from existing and familiar data analysis systems.

We present here a summary of the new data analysis features that we plan to incorporate in the system.

2 Heritage and Compatibility with Existing Data Analysis Systems

The *AXAF* data will comply with a format-independent, object-oriented data model which will assure compatibility with other existing analysis systems, such as IRAF/PROS (Post-Reduction Off-line Software), FTOOLS (a suite of X-ray analysis software) and possibly IDL (a commercial analysis package) and MIDAS/EXSAS (an X-ray data analysis package developed for *ROSAT* data analysis).

The basic analysis system will inherit a lot of the familiar features from the IRAF/PROS software developed for *ROSAT* data analysis, in particular the ability to work with "virtual files" without the need for several intermediate data products (see below).

A major difference will be the possibilty to work directly at the operating system command line, without the need for any specific IRAF installation. Also the *AXAF* tools will be able to read and write both FITS files as well as PROS-style QPOE (Quick Position-Ordered Event) files allowing the user to operate on the files not only with the *AXAF* software but with any other external program such as for example FTOOLS.

All the *AXAF* tools will be accessible

- from the operating system command line interface (CLI)
- from the IRAF Command Language environment
- from a newly developed, user-friendly *AXAF* Graphical User Interface (GUI)

The *AXAF* system will be one of the first generation of astronomical data analysis systems to incorporate GUIs in its initial design.

IRAF-style parameter files – currently used both in IRAF/PROS and FTOOLS – will be adopted, but the user will also be able to specify the parameters on the command line. It will be possible to keep many versions of the same parameter file in a user-specified directory.

The high spatial resolution available with the HRC and ACIS instruments will make spatial analysis and modelling crucial. A new multidimensional

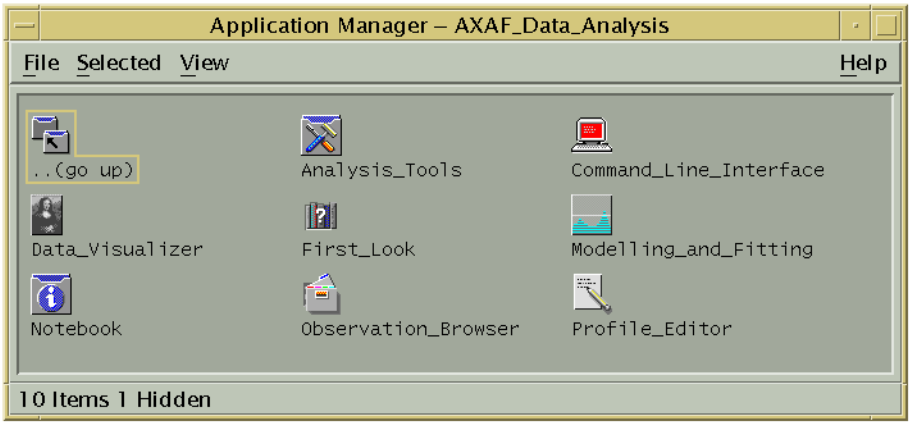

Figure 1: An example of a possible top level entry to the data analysis environment. This figure assumes the Solaris-standard Common Desktop Environment (CDE); other environments would look similar

fitting tool is under development to support simultaneous spatial and spectral modeling and fitting (see below), but spectral modeling and fitting tools in XSPEC (an X-ray spectral fitting software package) will still be applicable to derived data.

3 The *AXAF* "First Look" and Notebook

The "First Look" software is designed to allow the user to perform pre-analysis inspection of the data, without a detailed knowledge of file types, formats, accessory calibration files and display or plot commmands.

The "First Look" option in the data analysis system (Fig. 1) will spawn an observation browser to list all the observations available for analysis and once a particular one is selected, the image, lightcurve and spectrum of the field will appear automatically.

As all the *AXAF* GUIs, the "First Look" windows are completely configurable (for exmaple to allow different default configurations) and every GUI command will be translated into the CLI equivalent so that commands can subsequenlty be logged, edited or collected into scripts.

The *AXAF* Notebook is an example of the comprehensive electronic record-keeping facility offered to the users, where all or a fraction of the commands can be logged and annotated. Text and figures (postscript or some other format) can be added to the notebook during an analysis session.

4 Improved Filtering and Binning Capabilities

The use of "virtual files" in the event filtering process (i.e. the fact that a tool is provided with a string containing a file name and a filtering expression and the tool only operates on the "virtual" filtered file) is already largely used in many of the IRAF/PROS applications. The *AXAF* data analysis system will use a filtering language very similar to IRAF/PROS but will extend this concept. Some of the added capabilities will include:

- filtering consistent across the various attributes of an event file (e.g. time, pha, spatial coordinates) or a table (e.g. magnitude, redshift, etc.) or housekeeping and aspect files
- filtering possible *whenever* an *AXAF* tool calls for an input from an event file or a table
- complicated and user-defined filtering expressions will be allowed

Similarly, extended "binning" capability will be implemented to give the user the ability of binning any pair of attributes to create any generalized 2-D image, not only in spatial coordinates (e.g. [x,y] or [ra,dec]) but also for example in [time,pha] which represent an "image" of spectra as a function of time.

5 Handling of "File Stacks"

The large data set expected from the satellite requires the capability of handling multiple spectra, images or products at the same time, so that repetitive tasks will be easy to perform. We plan to implement the concept of "file stacks" so that every *AXAF* tool which operates on a single file (e.g an event file, a table, a binned image etc.) should be able to operate on a "stack" of them. Examples of the added capabilities that would follow are: the possibility of extracting spectra from a list of sources, fitting the same model over a stack of extracted spectra, detecting sources on a stack of event files filtered at different energy bands (soft, medium, hard, broad).

6 "Joint Mode" Fitting

The current spectral modeling capabilities (as in XSPEC), while powerful, are limited to the spectral domain and the high spatial resolution requires

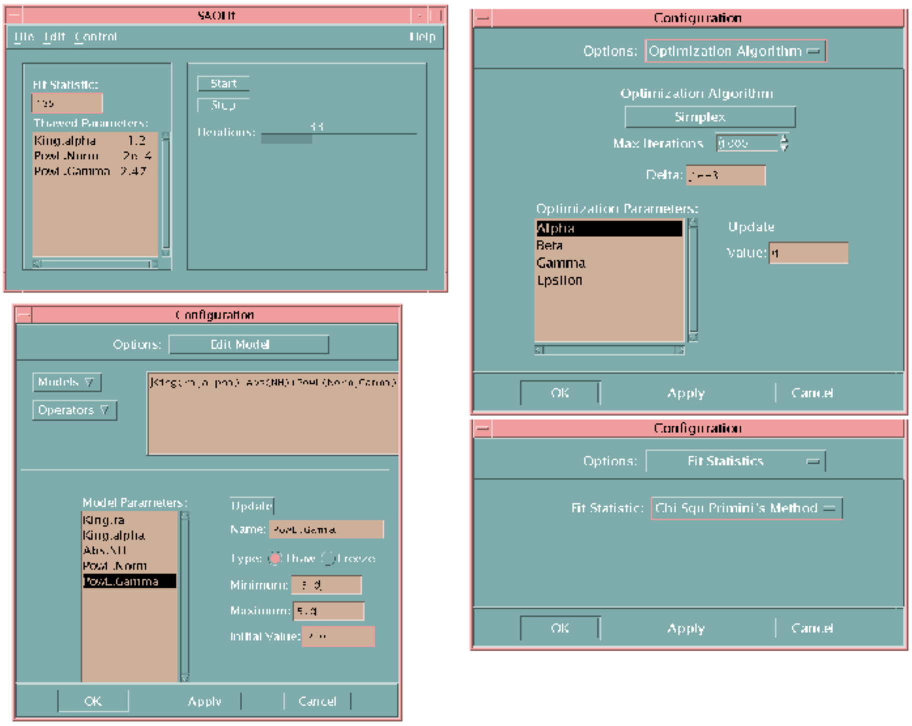

Figure 2: A preliminary example of possible modelling and fitting windows.Temporal, statistical and analytical models will also be included as well as user-defined models.

spatial modeling tools. Also only a limited choice of statistics and optimization methods are currently available to users through XSPEC.

We plan to extend and improve the current modeling and fitting capability with spatial, timing and instrument models. In particular the user will have the possibility of combining (adding, multiplying and "nesting") predefined or user-defined spectral, spatial and timing models and choosing several statistical and optimization methods (Fig. 2).

7 Other New Features

We plan to incorporate various other new features in the system and some other example include:

- efficient source detection able to discriminate extended sources
- ease of transformation and careful handling of coordinate systems
- user access to aspect software
- ease of creating script and composite tools for repetitive tasks
- support tables with images embedded in one of the columns
- careful handling of upper limits and errors

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References

1. M. Zombeck, 1996, "Advanced X-Ray Astrophysics Facility", in Proceedings of the International School of Space Science on X-Ray Astronomy, L'Aquila, Italy, September 1994.