

# **XMM Interactive Analysis**

Hassan Siddiqui and the XMM SOC Team

European Space Research and Technology Centre (ESTEC), Space Science Department,  
Astrophysics Division, Postbus 299, NL-2200 AG Noordwijk, The Netherlands

## **ABSTRACT**

The Interactive Analysis Software will assist the Guest Observer in swiftly analyzing observed data to obtain the appropriate science. This paper provides a brief description of this software.

### **1. Introduction**

Raw observation data from XMM is sent to the Guest Observer (GO), via the Science Operations Centre (SOC), in the form of a CDROM. The raw event files, housekeeping and ancillary data are called collectively the Observation Science File (ODF). In addition, the CDROM contains pre-processed data outputted from the Pipeline processing subsystem (PPS) and the latest calibration data (the Current Calibration File, or CCF).

The question is: how does one get from the CDROM to the actual science?

All science analysis tasks are grouped under the umbrella of the Science Analysis Subsystem, or SAS. This contains two components: the PPS, as mentioned above, and the Interactive Analysis Software, or IAS. It is the latter that serves the purpose of getting the GO from the CDROM to the science.

### **2. Data Flow**

Figure 1 shows a schematic showing the data flow from the XMM observatory to the eventual scientific results. For more information, the reader is referred to Fred Jansen's talk "XMM Data Analysis: Overview" in these proceedings. In brief, event and housekeeping data are telemetered down via ground stations to the Mission Operations Centre, or MOC, and are subsequently processed by the SOC. The SOC creates the ODF, generates the preprocessed data via the PPS, and packages these data in addition to the latest CCF into a CDROM which is sent to the GO. The GO may then run the IAS using, in general, the preprocessed data and CCF as inputs (in the case of OM grism analysis, the ODF data must be used directly, see section 6.3).

He/she may, optionally, re-run the PPS on the ODF data if, for example, more up-to-date calibration data are available, and run the IAS on the resultant products.

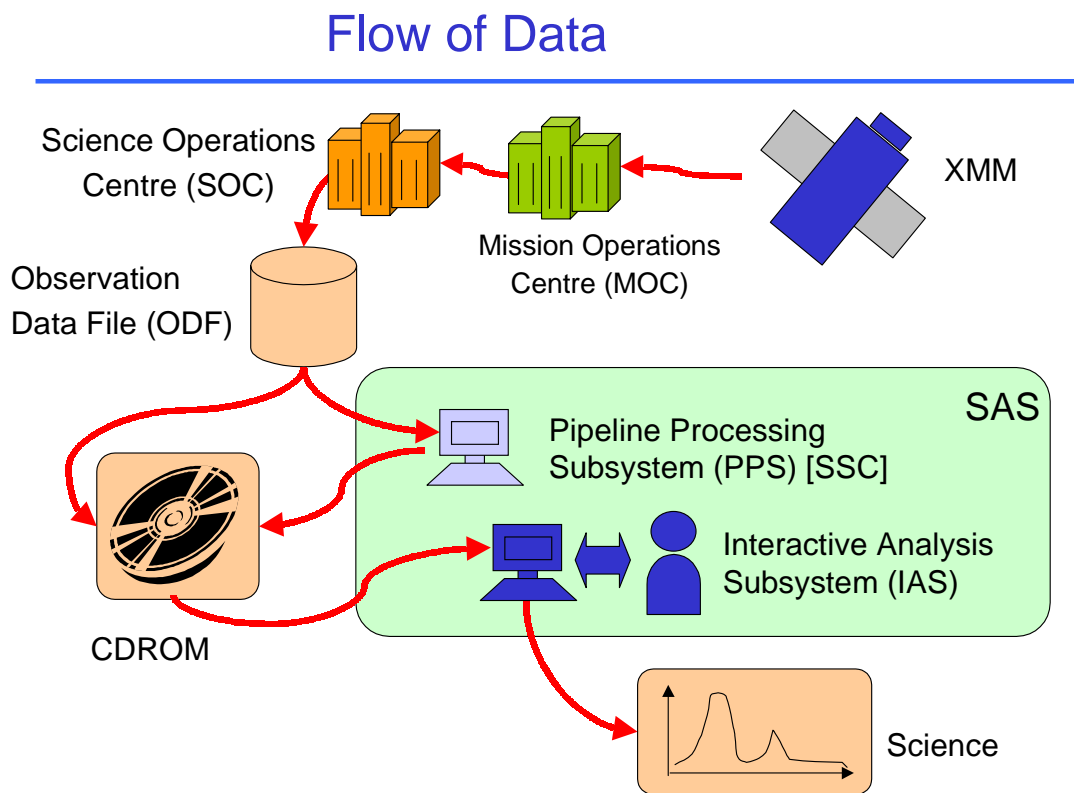


Fig. 1.— A schematic showing the data processing flow from the XMM observatory to the eventual science.

### 3. Why Interactive Analysis ?

It's interactive because the GO will require more flexibility to tailor the analysis to his/her needs compared with that provided by automated software. In addition the GO may need to change his/her approach depending on intermediate results. Such power can only be obtained through an interactive package.

An interactive environment is needed for source selection, for example to ensure the optimal signal-noise ratio. Accurate background subtraction requires interactive input. In the case of the RGS and OM grism data, obtaining an accurate wavelength scale is an interactive process.

### 4. Basic component of the IAS: the task

The IAS, like the PPS, is made up of a sequence of software programs (tasks) taken from a single 'pool' of SAS tasks. It is common to find a number of tasks used as part of the PPS to be used within the IAS as well. These tasks will be written in C++, Fortran-90, or in the Perl scripting language. These will share a common parameter library so their interface will be the same. In addition to SAS tasks, the IAS will make use of third party applications where necessary, such as XSPEC <sup>1</sup> for spectral fitting, and XRONOS <sup>2</sup> for detailed timing analysis. The FTOOLS suite of tasks (The FTOOLS Group 1997) is also fully supported by the IAS, and can be used in situations where there is limited coverage by the more XMM-specific SAS tasks.

### 5. Basic Layout of the IAS

The IAS starts by running an event selection procedure on pre-processed event files from the PPS, the result of which are binned datasets. Events can be selected based on constraints on any of the raw observables in the input event list (x or y position, energy or time etc), and the output binned datasets can have any dimensionality, but most likely will be either an image, spectrum or time series. This event selection phase will be covered by a single task `evselect`.

### 6. Examples of Analysis Scenarios

Subsequent analysis depends on the instrument in question (EPIC, RGS or OM), and the type of binned data being analyzed (image, spectra or time series). The SAS developers are currently investigating a range of analysis scenarios to aid in scoping the tasks necessary to perform interactive

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<sup>1</sup>For the latest manual, refer to [http://heasarc.gsfc.nasa.gov/docs/xanadu/xspec/u\\_manual.html](http://heasarc.gsfc.nasa.gov/docs/xanadu/xspec/u_manual.html)

<sup>2</sup><http://legacy.gsfc.nasa.gov/docs/xanadu/xronos/xronos.html>

analysis. This section describes an example scenario for each instrument.

### 6.1. EPIC

For example, EPIC spectral analysis would probably consist of the generation of the raw spectrum, followed by background subtraction (which will be covered by the SAS task `backcorr`, or a combination of `evselect` and `arithmetic`) and exposure correction (`eexpmap`, `arithmetic`). Given that the reduced data will be analyzed by XSPEC, a Redistribution Matrix File (RMF) and Ancillary Response File (ARF) will be required (see the XSPEC user manual); these will be generated on a source-by-source basis using the SAS tasks `rmfgen` and `arfgen`. These stages are summarized in figure 2.

### 6.2. RGS

The general stages are summarized in figure 3. The RGS provides spectral data and there are two independent means of measuring the energy for a given event: by the spatial dispersion, and by the CCD channel value. Along the dispersion direction, the spectral orders overlap as a consequence of the grating properties. The orders also overlap in the CCD channel direction, due to the CCD response (figure 4). Thus, one of the first steps in reducing RGS data is to separate the orders.

A crude means of separating data is to use the task `rgsregion`, which uses the event list to generate regional information in PHA-dispersion space which can be used by `evselect` to filter out data which overlaps another order.

While basic wavelength calibration is performed by the PPS, improved calibration should be done, within the IAS framework, if accurate spectroscopy is required. To do the IAS will provide tools to enable the user to identify various spectroscopy lines/complexes and compare these against atomic data; repeating this process for enough ‘points’ spread suitably across the spectrum will provide an acceptable level of accuracy.

Finally, spectral analysis will need to be performed. The traditional ‘fitting’ approach used in X-ray astronomy (eg in XSPEC) is a possibility, but, as pointed out earlier, there are *two* measurements for the energy of an event (XSPEC can only handle one at a time) which suggests a more sophisticated spectral fitting application should be considered, involving a 3D RMF (response as a function of CCD channel, wavelength and incident photon energy). This issue is currently being investigated. An alternative approach to fitting is spectroscopic analysis, in which individual lines or complexes are investigated rather than the spectrum as a whole. An SAS task will be developed for this purpose.

## Example of EPIC Spectral Analysis

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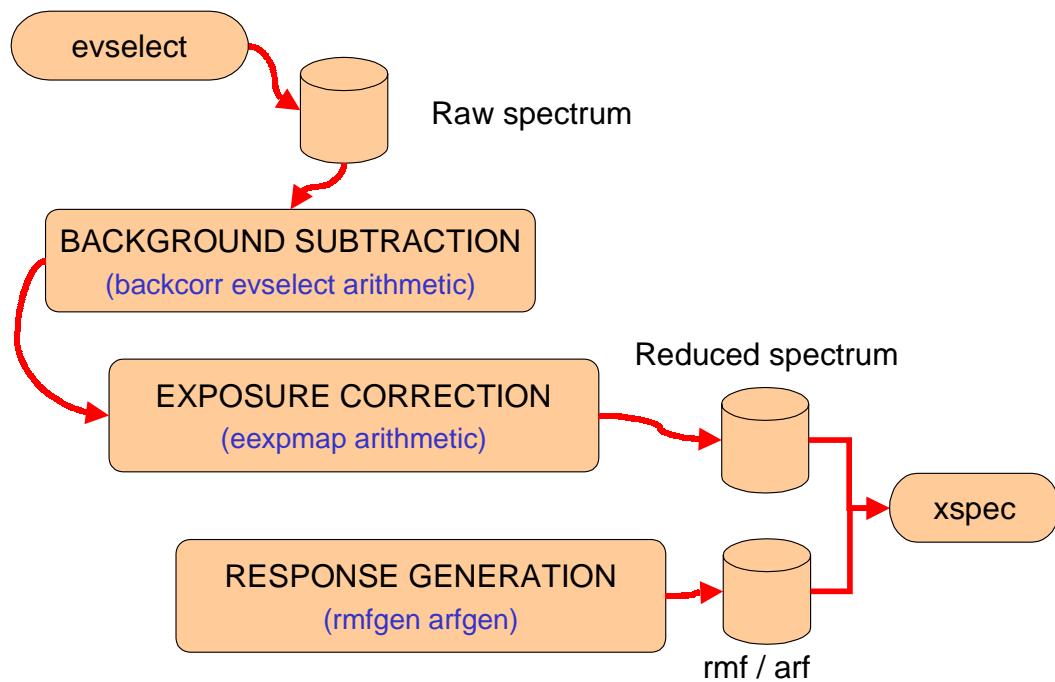


Fig. 2.— An example of some general stages which could be used for EPIC spectral analysis. SAS tasks which would be used in each stage are shown in brackets.

## Example of RGS Data Analysis

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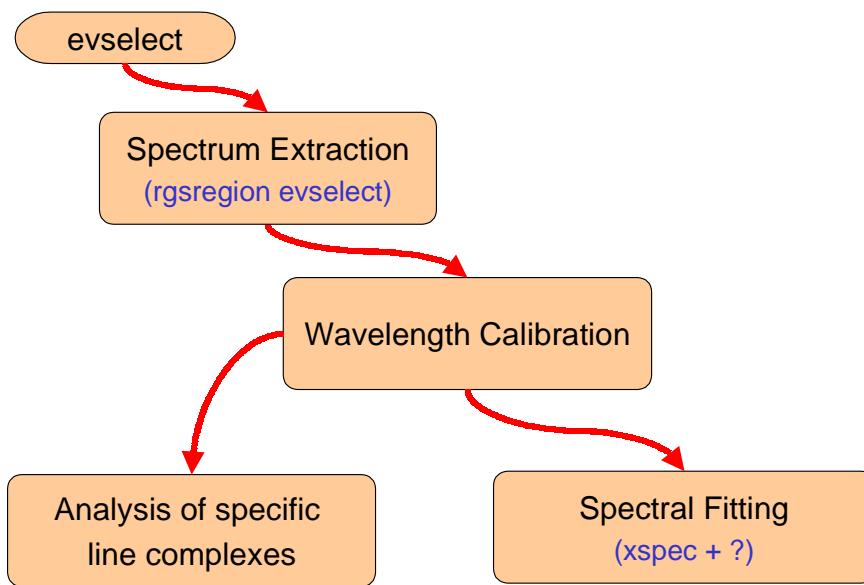
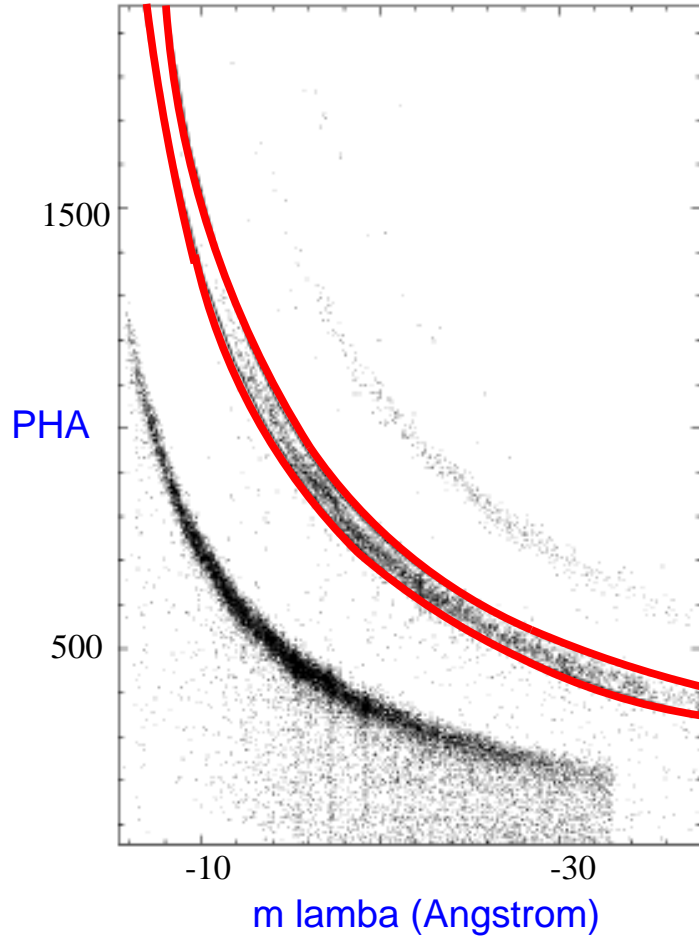


Fig. 3.— An example of stages used during RGS analysis. SAS tasks are shown in brackets.



Courtesy Tim Harries

Fig. 4.— An example of a ‘Banana Plot’.

### 6.3. OM

A final example is with regards to OM grism analysis (fig 5). As no pipeline processing is performed on OM grism data the ODF data must be used directly. These are in the form of images, which measure counts as a function of dispersion and cross-dispersion directions. The wavelength scale must first be established, by either identifying the zero order spectrum or using a similar technique to that used by the RGS. After that, the user must identify the extraction region and extract the spectrum over that region. The next two steps would be flat-fielding followed by background subtraction. The spectrum is then ready for more detailed analysis, using tasks such as IRAF or MIDAS.

## 7. How are tasks invoked?

There are two ways to run a task:

1. From the command line,
2. or from the Graphical User Interface (GUI) included in the IAS software package.

To run a task from the command line, the task name should be entered, followed by a list of parameter values:

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taskname --parameter1=value1 --parameter2=value2 ...
```

Figure 6 shows an example layout of the GUI, within which **all** interactive analysis tasks can be run. The GUI has a command window (top-left), from which tasks can be executed. Log messages are also displayed in this window. To invoke a task, the user would select the task from the command window, and a dialog would then appear (bottom-left), allowing the user to enter various parameters appropriate to that task. How the user modifies a parameter depends on the parameter ‘type’: for example, if the parameter corresponds to a boolean (true/false) type the GUI provides a radiobutton which can be toggled between two states; if it corresponds to a file name then the GUI will provide an option to launch a file browser.

Certain parameters will have certain constraints. For example, if the parameter is a number, then the user will be restricted to entering values over the numerical range for which the parameter is valid. The GUI will also have a means of viewing data - in the example layout a spectrum is shown.



## Example of OM Grism Analysis

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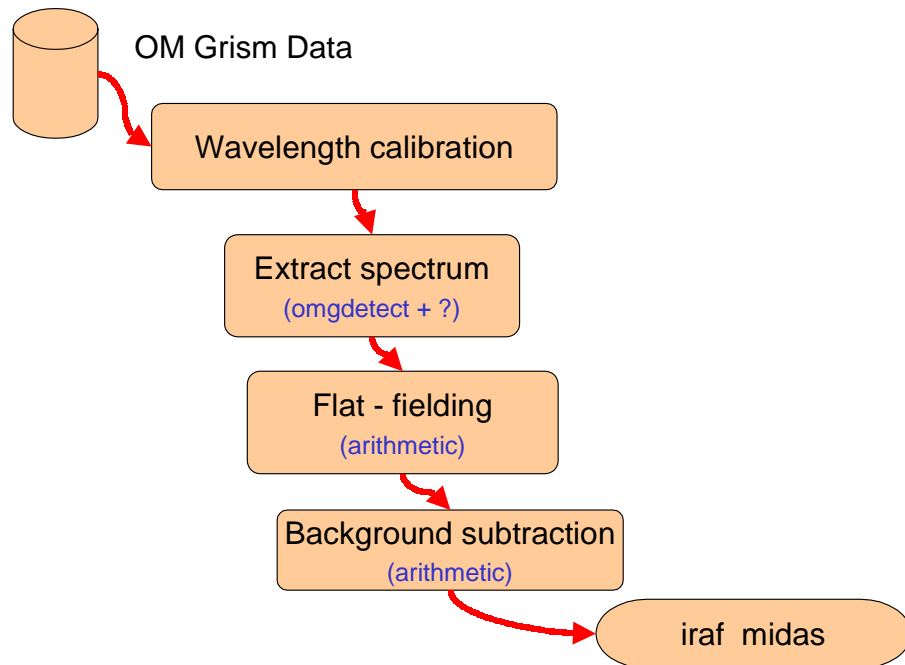


Fig. 5.— An example of stages used during OM grism analysis. SAS tasks are shown in brackets.

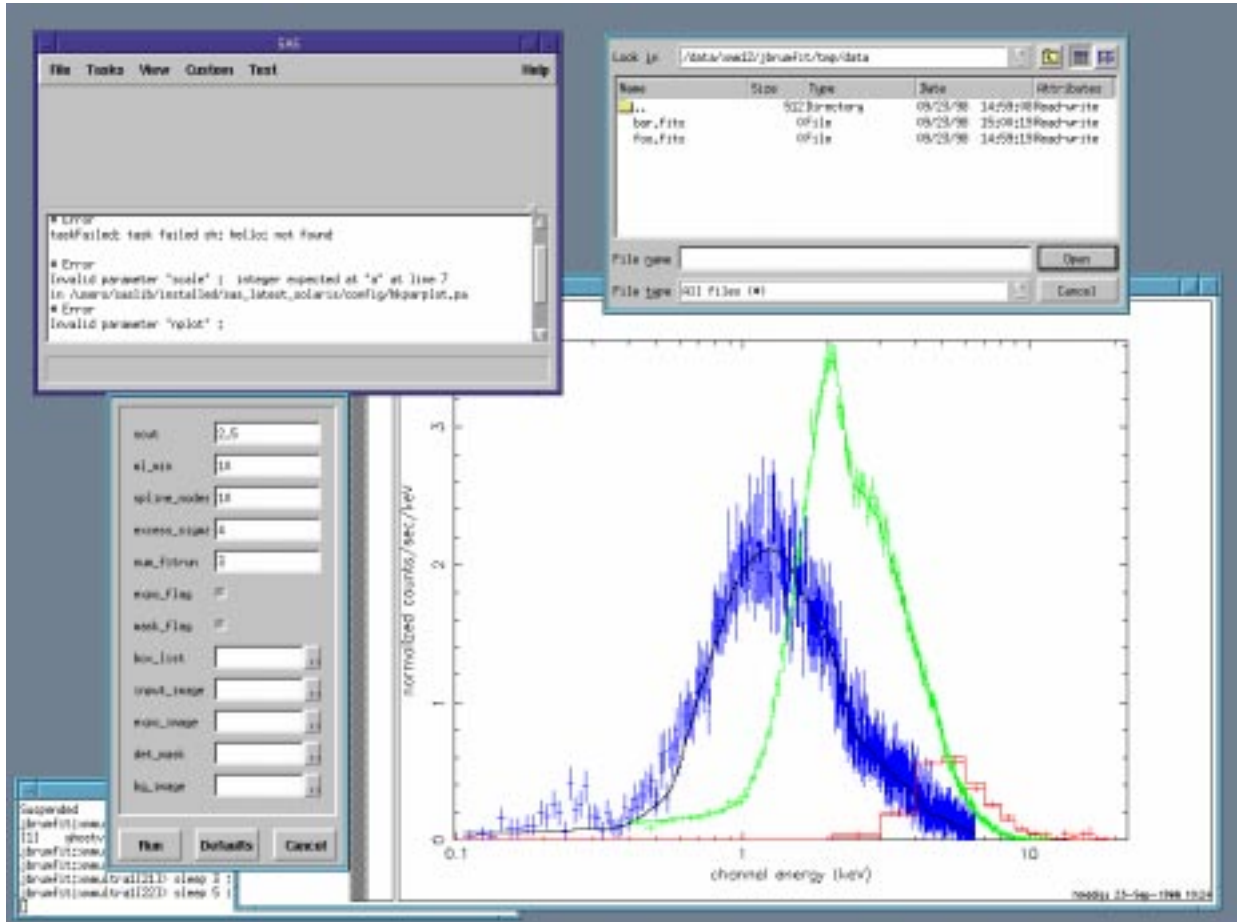


Fig. 6.— A prototype of the IAS Graphical User Interface (GUI). The window to the top left is the command window, from which tasks can be invoked. It also gives error or log messages. The window below allows the user to configure parameters for a given task, and the window to the top right is a file browser enabling the user to select files as input to a task. A graphical viewer will be provided to display data (bottom-right).

## 8. Some points about the IAS

A few points should be noted about the IAS:

1. The IAS can read in and write out FITS files (this makes sense, given that the ODF and CCF are in FITS form).
2. FTOOLS are supported within the IAS framework. While it is intended that the majority of IAS operations will be performed by dedicated, XMM-specific SAS tasks, the use of FTOOLS allows for a little more flexibility in the IAS, for those cases in which certain operations cannot be done by SAS tasks but are possible using a combination of FTOOLS programs (this, however, does **not** imply that the majority of IAS operations can be performed by FTOOLS).
3. The IAS can read in the output of the Science Simulator (SciSim)<sup>3</sup>. This is a very powerful feature, in that it allows simulated data to be analyzed in much the same way as real data. This can be useful during proposal writing, to aid in preparing a specific set of analysis steps while waiting for the ‘real’ data to be delivered, or to compare model scenarios against real observed data.
4. Finally, as mentioned before, a number of third party tools will be used in the IAS. This list is likely to include XSPEC, XRONOS, SAOIMAGE, SAOTNG and IRAF.

## 9. When’s it available, and what form will it be in?

The IAS will be released to the astronomical community in late 1999. It will be available, in the form of a binary executable for Solaris machines, which can be FTP’d from the SOC. Source files will also be available from the same area. Every effort has been made to avoid platform-dependent features in the code, which allows for the possibility to port the IAS to platforms other than Solaris.

Hardware, on which the IAS will be installed, will also be available at the SOC (VILSPA) for Guest Observer use.

## 10. Summary

To summarize:

- The Interactive Analysis Software will be available to the astronomical community in late 1999.

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<sup>3</sup><http://astro.estec.esa.nl/XMM/scisim/scisim.html>

- This will aid the Guest Observer to analyze raw XMM data he/she receives from the SOC.
- The IAS will be available in the form of a binary executable for Solaris platforms.
- The IAS will make use of established third party tools, such as XSPEC and XRONOS.

## 11. Further Reading

The XMM Home Page (<http://astro.estec.esa.nl/XMM/xmm.html>) will in due course provide up-to-date information about the Science Analysis Subsystem as a whole. Such information will include release announcements, FAQs, links to detailed task documentation and latest news.

The principal documents covering the Science Analysis Subsystem are the SAS User Requirements Document (ESA 1997) and the SAS Software Specification Document (ESA 1998).

## REFERENCES

- The FTOOLS Group 1997, “Users’ Guide to FTOOLS Release 4.0”, High Energy Astrophysics Science Archive Research Center NASA Goddard Space Flight Center
- ESA 1997 “Software Specification Document for the XMM Science Analysis Subsystem” XMM-PS-GM-12, Issue 1.0
- ESA 1998 “User Requirements Document for the XMM Science Analysis Subsystem” XMM-PS-GM-13, Issue 2.0