PROS: An IRAF Based System for Analysis of X-ray Data


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Abstract. PROS is an IRAF based software package for the reduction and analysis of X-ray data. The use of a standard, portable, integrated environment provides for both multi-frequency and multi-mission analysis. The analysis of X-ray data differs from that of optical data due to the nature of the X-ray data. The scarcity of data, the low signal-to-noise ratio and the large gaps in exposure time make data screening and masking an important part of the process.

1. Introduction

IRAF/PROS provides a complete end-to-end system for X-ray data analysis (Tody 1986; Worrall et al. 1992). PROS was developed for the analysis of data from the ROSAT and Einstein X-ray missions, but many of the tasks can be used on data from other missions. The AXAF Science Center (ASC) will extend this system to support the AXAF mission. In addition to the PROS software features, we will discuss the design philosophy, development environment and architecture used by PROS to generate a portable, multi-mission software analysis environment.

2. Development Environment

PROS is developed and supported by the SAO/ROSAT Science Data Center (RSDC). The project team is required to provide support for current users, to develop new tasks and updated calibration data, and to generalize the system for additional missions. All of these considerations contributed to the organization of the PROS project.

PROS has been maintaining a semi-annual build cycle, producing major releases in April and October of each year. Between releases, patch updates are issued as necessary to provide up-to-date calibration information, or to address serious bugs. The group provides hotline support for all users. Contact is most frequently via e-mail, but conventional mail and telephone contact are also supported. Each problem report is investigated and an official bug report is made to the prosbug database. The report is reviewed, assigned a priority, and ultimately scheduled for a software upgrade. Meanwhile, when possible, a work-around solution is provided to the user. Problems that have a significant impact on other users are collected and reported to users via the Hints and
Pointers e-mail service. Bug fixes and new tasks are made available in-house in a beta-test account. This test system is also available to users of the RSDC.

Each task in PROS is created by a development team consisting of one programmer, one technical staff member and one scientist. The scientist is responsible for providing the scientific specification for the task. The programmer implements the task. The technical staff assists the programmer and the scientist in testing by developing an automated test script. The test script for each task is incorporated into the system of automated test scripts which are exercised on the beta-test version of each software release.

To simultaneously support users, testers and developers, PROS maintains three separate IRAF/PROS accounts in-house. The primary account is the official IRAF and PROS current release. The second account is the beta-test account for use by the technical staff and the RSDC scientists. The third account is the development account used by the programming staff to implement bug fixes and develop new tasks. The programming account uses the public domain software, Revision Control Software (RCS), to log all modifications to existing code and on-line help files.

This architecture is designed to provide a stable environment for data analysis, while at the same time allowing rapid turn-around of problems and quick feedback on new tasks. It also provides a comprehensive record of both user feedback and programmer updates and changes. These features should ensure a smooth continuation of the IRAF/PROS system into the ASC, which has chosen it as the basis for their analysis system.

3. FITS Support

IRAF/PROS has a complete set of FITS readers/writers to ensure that data be importable into PROS and that results be exportable to other systems. The event-lists for both the US ROSAT data and the Einstein data are provided in FITS bintable format. The European ROSAT data are provided in FITS table format. The fits2gp task converts any of these formats into an IRAF/QPOE file for use within PROS. Additional data, in FITS image and FITS table format, can be read with the TABLES strang task. An attempt to define standard FITS templates for X-ray data has been undertaken to simplify this process in the future (Corcoran et al. 1993).

PROS output files are in QPOE, image or table format, each of which is convertible to FITS. The task qp2fits will write the QPOE file to a FITS bintable file, while the TABLES task stwfits will convert the other formats to FITS for export to other systems.

4. Data Structures

X-ray data have several properties that require special software support. The data files have large dimensions, but very sparse data. Users need to analyze only the data which are of interest, often limited to a small section of the observed field. Also, the data are acquired under constantly varying observing conditions. Therefore, it is important to record the precise observing time and to allow users to define additional intervals for exclusion (Conroy et al. 1992).
4.1. Event List Data

PROS is designed to work on event-list data. However, it is essential that this event-list also be interpretable as an image array. The IRAF/QPOE file was designed to meet this need. It stores the complete event-list data, but it is recognized by all IRAF tasks that accept an input image. The events are automatically converted to an image array within the IRAF environment, with a user-specified resolution. The event format for the QPOE file is self-defining, allowing the QPOE file to be mission independent. The PROS QPOE file is compatible with the Einstein, ROSAT, ASTRO-D and EUVE data files.

Using the same IRAF tasks with QPOE files as with images means that multi-wavelength analysis is easy within the IRAF environment. Optical images from Hubble Space Telescope (HST), radio images from VLA radio observations or X-ray data can all be displayed using exactly the same procedures. Figure 1 shows the use of IRAF/PROS to display results from two different wavelengths.

4.2. Filtering

PROS supports two types of data filtering. The first is the built-in IRAF QPOE filtering that allows users to automatically filter on any of the event attributes. PROS has implemented a second filtering scheme, that extends the allowed attributes to the Temporal Status Conditions. These include most of the instrument and satellite housekeeping parameters, as well as several statuses such as aspect quality, background count rate, and viewing geometry.

4.3. Masking

PROS makes use of the IRAF Pixel Mask (PLIO) to do the spatial selection of photons. Like the QPOE file, the IRAF PLIO file is accepted as an image by all
IRAF tasks. The PROS team has developed the regions interface to facilitate the specification of the desired mask (Mandel et al. 1993). Other image utilities, such as isoreg and imcalc, can also be used to facilitate spatial mask creation.

5. Scientific Analysis Tasks

In addition to the environmental and system features, the PROS system consists of scientific analysis tasks specific to X-ray data. Many of these tasks rely on calibration information that is mission and instrument specific. PROS explicitly supports the ROSAT and Einstein missions by supplying the necessary calibration files for their analysis. As PROS is extended to support other missions, such as AXAF, the design will evolve to make extension to new instruments definable by the user.

All display and graphics tasks will accept image files as well as QPOE and PLIO files. In addition all graphics can be superposed on the TV display (Eisenhamer 1992). A brief overview of the PROS analysis tasks follows.

**tv display** Tasks display and xdisplay will produce a TV display of the data.

**sky grids** The imcontour task (DePonte & Worrall 1992) calculates and graphs the iso-intensity areas of the images and displays them on a skygrid.

**coordinates** Support for the World Coordinate System (WCS) is provided in all the IRAF and PROS tasks. PROS provides additional interfaces to facilitate conversions, including an interactive mode from the image display.

**graphics** All non-image output data files from PROS analysis are produced in TABLE format which can be graphed either with the TABLES sgraph task or with the Interactive Graphics Interpreter igi (Levay 1992).

**source detection** The detect package is designed to perform Maximum Likelihood Source detection on data exhibiting Poisson statistics. It uses a signal-to-noise threshold calculation (DePonte & Primini 1993).

**PRF modeling** The imcalc, immmodel and imsmooth tasks provide the ability to generate complex Point Response Function model images that can be convolved with observations.

**data extraction** The imcnts task is a utilitarian tool used to extract background subtracted counts from complex regions.

**timing corrections** The timcor package provides the conversions from spacecraft clock to UTC and calculation of the barycenter timing correction.

**periodic analysis** The tasks ltcerv and ft provide general capabilities to examine periodic data. The period and fold tasks include a provision for a decaying period. The qpphase task generates a QPOE files with an additional event attribute, phase, that then allows the data to be split according to phase (Manning et al. 1993).
spectrum extraction The qpspec task allows users to extract a background corrected spectrum from a QPOE file for use in PROS or for export to other analysis systems.

model specification and fitting PROS has a flexible spectral model specification language which allows multi-component model fitting. Also, the fit task allows fitting of multiple data sets.

flux conversion Fluxes for any object can be calculated from the xflux task.

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References

Corcoran, M.F., Pence, W., White, R., & Conroy, M. 1993, this volume
Tody, D. 1986, in Instrumentation in Astronomy VI, SPIE, 627, part 2

Discussion

Unknown: How many sites have PROS? How large is the package?
Conroy: PROS currently has 113 registered sites, running under several machine architectures. PROS has approximately 225,000 lines of code.