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XAssist: A System for the Automation of X-ray Astrophysics Analysis

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Abstract. XAssist is a NASA AISR-funded project for the automation of X-ray astrophysics, with emphasis on galaxies. It is nearing completion of its initially funded effort, and is working well for *Chandra* and *ROSAT* data. Initial support for *XMM-Newton* data is present as well. It is capable of data reprocessing, source detection, and preliminary spatial, temporal and spectral analysis for each source with sufficient counts. The bulk of the system is written in Python, which in turn drives underlying software (CIAO for *Chandra* data, etc.). Future work will include a GUI (mainly for beginners and status monitoring) and the exposure of at least some functionality as web services. The latter will help XAssist to eventually become part of the VO, making advanced queries possible, such as determining the X-ray fluxes of counterparts to HST or SDSS sources (including the use of unpublished X-ray data), and add the ability of "on-the-fly" X-ray processing. Pipelines are running on *ROSAT*, *Chandra* and now *XMM-Newton* observations of galaxies to demonstrate XAssist's capabilities, and the results are available online (in real time) at http://www.xassist.org. XAssist itself as well as various associated projects are available for download.

1. Introduction

We are currently in a renaissance for X-ray astronomy, with two major missions, *Chandra* and *XMM-Newton*, currently operating. These missions are producing large amounts of archival data, which is supplementing existing databases from missions such as *ROSAT* and *ASCA*. Historically, only X-ray "experts" usually attempted the analysis of X-ray data. This is because there were fundamental differences in the analysis of X-ray data compared with other bandpasses, most notably the fact that individual photons are detected as opposed to the accumulation of (only) spectra or images. Most modern X-ray detectors are imaging spectrometers so each observation results in a photon list from which images, spectra and light curves can be extracted. In general the numbers of photons are small so Poissonian rather than Gaussian statistical methods must be used. The spectral and spatial resolution of most detectors is moderate at best and forward-fitting convolution methods are needed to properly fit the data. All of

these factors limit the accessibility of the X-ray data to non-experts. In addition each mission tends to have its own unique software package for the reduction and analysis of the data, and X-ray data often require reprocessing as the calibration improves. These latter two factors also limit the ability of experts to take advantage of all available data for a given project, particularly large-scale surveys.

We have developed a software package to address these concerns. XAssist is capable of performing data reduction and preliminary analysis for *ROSAT*, *Chandra* and *XMM-Newton* data. It is fully automatic making it well-suited for surveys, as well as for the reprocessing of existing data. Below we will discuss its capabilities and prospects for the future.

2. Capabilities

XAssist currently has the following capabilities:

- Downloads data
- Reprocesses data
- Creates exposure maps and detector masks (if possible)
- Detects sources (using built-in routine for *ROSAT* and *ASCA*, CIAO wavdetect for *Chandra*, etc.)
- Fits each source with "simple" (i.e., not including point-spread function) model to establish source extent and (Poisson-correct) significance (using the stand-alone python program ximgfit[1])
- Flags extended, confused and problematic sources
- Computes median (or mean) background level
- Excludes times of high background
- Extracts spectra, "postage stamp" images, and light curves of each source for more detailed analysis (a simple power-law model is fit to sources with more than 100 sources)
- Optionally performs chip-by-chip analysis (relevant just for *Chandra* right now)
- Analysis can be restricted to an energy band
- Large emphasis on detailed reporting
- Looks for correlations of X-ray sources with astronomy databases and provides links on the detailed source web reports to query Simbad (see below)

Note that in the case of *Chandra* analysis, most of the data reduction steps are based on the "threads" reported in the *Chandra* web site.[2] Most parameters controlling XAssist are read from IRAF/FTOOLS-style parameter file, and can be set on the command-line as well (allowing for the automated setup of XAssist for surveys). XAssist can be run (and configured) interactively (with a text-based interface).

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[1] `http://www.xassist.org/xassist/Download.jsp`

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

3. Sample Output

Figure 1 shows images created as part of the report for the processing of the *Chandra* observation NGC 1569. Figure 2 shows the detailed report generated for a source. While there are admittedly "warts" that occur (as in any automated system), this example demonstrates that even in moderately crowded fields the system performs well and continues to the point of fitting a power-law spectrum model to the source spectrum. Obviously, this opens a powerful possibility for virtual observatories, namely that searches could be performed on high-level quantities such as spectral slope. Even though human inspection would of course still be necessary for science-grade results, an automated system such as this could cull samples and produce usable results for many of the sources, both of which would be particularly useful prior to observing proposal deadlines (especially if the data of interest had only recently become publically available and had not been published yet). Queries are also submitted to HEASARC to find correlations of X-ray sources with 2μass, USNO, FIRST, and other catalogs.

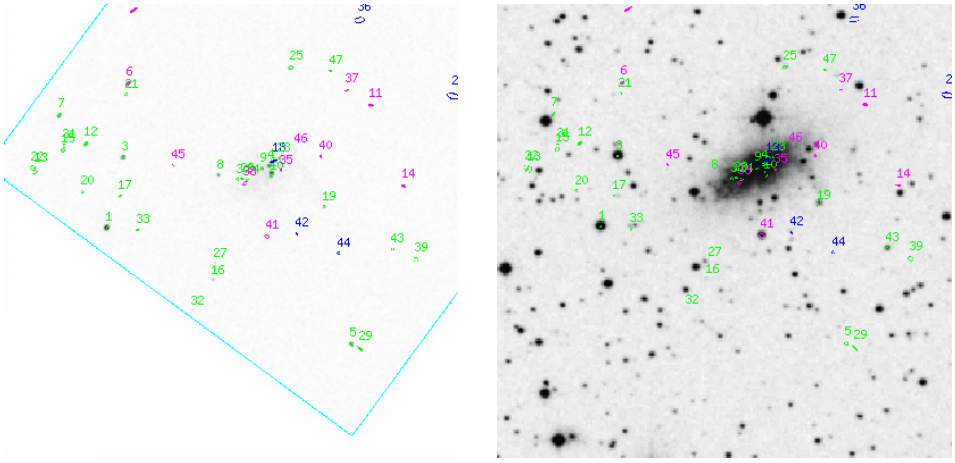

Figure 1. *Chandra* ACIS (left) and DSS (right) images of NGC 1569. Detected X-ray sources are marked in both images. The color code is: green = point source, red = problematic/questionable source, blue = extended source, magenta = asymmetric source (may be extended), cyan = estimated detector boundary.

4. Pipelines

To demonstrate XAssist's capabilities, pipelines[3] have been set up to run XAssist on *ROSAT* HRI and *Chandra* observations of RC3 galaxies. The *ROSAT* analysis is nearing completion, and crontab jobs are checking for the public release of *Chandra* observations that may containing RC3 galaxies in the FOV of

[3] `http://www.xassist.org/xassist/Pipelines.jsp`

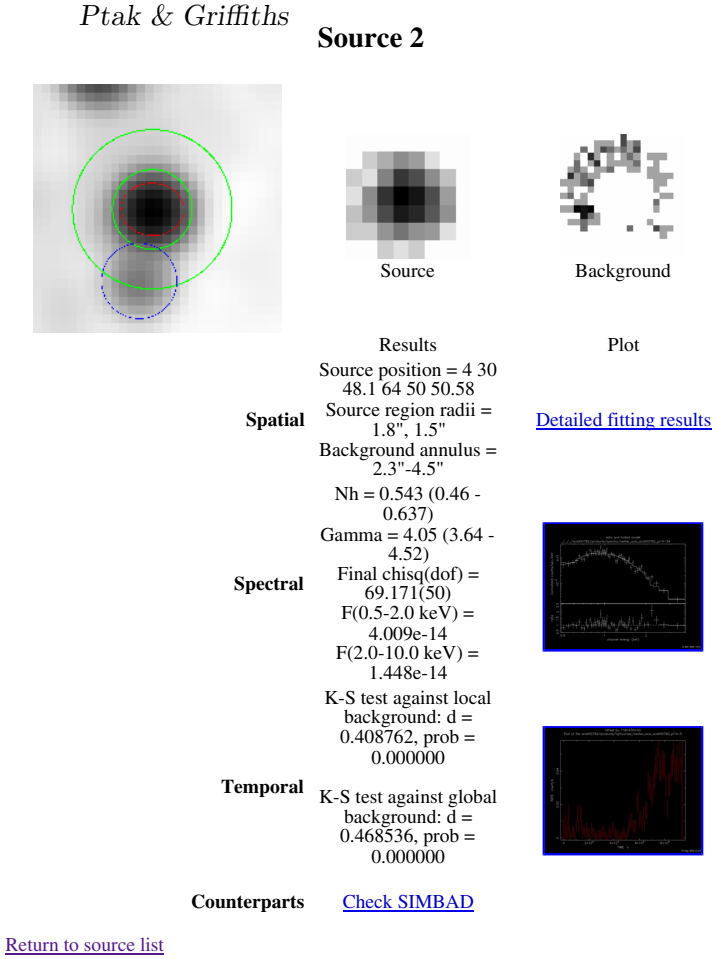

Figure 2. Detailed web page report for a source in the *Chandra* observation of NGC 1569.

view, and these data sets are downloaded (using the script cda.py also available for download). *XMM-Newton* has recently been added as a supported mission, and we are in the process of establishing a pipeline for public *XMM* data. The pipeline products are searchable and work is in progress to allow users to request fields to be added to the processing lists.

5. Current and Future Work

Tasks include: (*i*) finishing off details (especially for *ASCA* and *ROSAT* PSPC analysis), (*ii*) better installation and configuration support (including the creation of a GUI), (*iii*) web access to XAssist, and (*iv*) web services: limited status reporting is already available using SOAP and it will be possible to request full or partial processing of data via SOAP requests.