Chandra Source Catalog Review

Science Use Cases II

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Science Use Cases

- One cut on science use cases was presented previously based on 3 categories of scientific functionality — X-ray classification, crossmatch, and detailed studies
- An alternative view distinguishes based on catalog usage, where we consider two broadly distinct approaches
  - "Simple" science use cases that employ only the tabular catalog data (and possibly the Level 1 – 2 observation-based data recorded in the *Chandra Data Archive*) to support scientific investigations (in a similar manner to how other purely tabular catalogs work)
  - "Catalog Enabled" science use cases that in addition employ the live data objects directly to support scientific investigations that would otherwise be difficult to perform
- Both of these approaches to catalog usage can be relevant to any of the 3 categories based on scientific functionality

Simple Science Use Case — SED Crossmatch

- Extract the spectral energy distributions (SEDs) of star formation knots identified in all common pointed *HST*, *Spitzer*, and *Chandra* observations of starburst galaxies to determine effective temperatures, bolometric luminosity, and derive star formation rates
  - Identify candidate targets from observation catalogs
  - Identify candidate X-ray- or UV-bright sources in images
  - Extract source fluxes or upper limits in each band
  - Select sources based on X-ray/UV/IR flux ratios
  - Construct SED and fit models

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  - Identify candidate targets from observation catalogs
    - Use Open SkyQuery to locate catalog data based on cross-matching pointed observations from the three missions
  - Identify candidate X-ray- or UV-bright sources in images
    - Search *Chandra Source Catalog* to identify candidate X-ray bright sources
    - Use SIAP to retrieve *HST* UV/optical and *Spitzer* IR images and execute a workflow (or script) to detect sources by running `wavdetect` or `SExtractor` over the images

Simple Science Use Case — SED Crossmatch

- Extract source fluxes or upper limits in each band
  - Use *Chandra Source Catalog* fluxes for X-ray detected sources, or execute a workflow (or script) to extract sensitivity-based upper limits for sources without X-ray detections
  - Use source fluxes from **`wavdetect`** or **`SExtractor`** runs (or alternative method) for *HST* and *Spitzer* data
- Select sources based on X-ray/UV/IR flux ratios
  - Import source fluxes and upper limits into SSAP tools and select sources based on X-ray/UV/IR flux ratios
- Construct SED and fit models
  - Use VO spectral tools to construct SED and fit model
  - Use model to determine effective temperature, bolometric luminosity, and star formation rate

Catalog Enabled Science Use Case — X-ray Jets

- Brightness of X-ray jets versus redshift (Schwartz 2002, ApJL, 569, 23)
  - Identify candidate X-ray sources from public imaging observations, either directly or by cross-matching with existing AGN catalogs
  - Search candidate X-ray sources for jets
  - Extract the jet photons and fit a spectral model to the X-ray data
  - Identify matching UV/optical data for the jet regions, and construct the jet SEDs
  - Construct number density plots of X-ray jets versus redshift

Catalog Enabled Science Use Case — X-ray Jets

- Brightness of X-ray jets versus redshift (Schwartz 2002, ApJL, 569, 23)
  - Identify candidate X-ray sources from public imaging observations, either directly or by cross-matching with existing AGN catalogs
    - Search *Chandra Source Catalog* for sources that have companions within 15" radius, or non-point sources that have a deconvolved source extent smaller than 15", and whose hardness ratio is harder than some predefined cutoff value
    - Use Open SkyQuery to crossmatch the *Chandra Source Catalog* with existing AGN catalogs and perform the search as above but selecting only candidates that satisfy the cross-match criteria
  - Search candidate X-ray sources for jets
    - For each candidate source, retrieve the event data object and execute a workflow (or a script that uses the *Chandra Source Catalog* API interface) to apply a morphological filter to the events to search for the presence of quasi-linear features

Catalog Enabled Science Use Case — X-ray Jets

  - Extract the jet photons and fit a spectral model to the X-ray data
    - Execute a workflow to retrieve the PSF information for the jet sources, construct source regions that include the jet photons but exclude the AGN point source photons, and extract jet source photons for analysis
    - Use the Open SkyQuery crossmatch results to get known or photometric redshifts for the sources
    - Execute a workflow to perform spectral fits to the X-ray event data using **`Sherpa`**, including corrections for redshift and Galactic N_H (latter extracted from the *Chandra Source Catalog*)
  - Identify matching UV/optical data for the jet regions, and construct the jet SEDs
    - Perform a SSAP search to identify the relevant data and use the VO spectral tools to extract the optical fluxes from the X-ray jet regions and construct the SED

Catalog Enabled Science Use Case — X-ray Jets

- Construct number density plots of X-ray jets versus redshift
  - Pass the redshifts identified earlier for the sources with X-ray jets to VOPlot to generate number density plots by constructing histograms within user specified redshift bins
  - Execute appropriate statistical tests to determine whether the number density is correlated with redshift

What-If Science Use Case — Comparing Populations

- In addition to directly addressing scientific questions with *Chandra* data, the *Chandra Source Catalog* also directly addresses the formulation of scientific studies by supporting "what-if" type problems
  - These problems typically involve identifying objects with predefined characteristics for further study
- As an example, consider whether the population of compact X-ray sources in Cen A the same as the general population of compact X-ray sources in other similar galaxies?
  - Identify candidate matching galaxies based on morphological type, redshift, ...
  - Identify X-ray sources within D_{25} of each galaxy
  - Compare number density, mean hardness ratios, mean source spectra, ...
  - Are there identifications for the sources ?

What-If Science Use Case — Comparing Populations

- Is the population of compact X-ray sources in Cen A the same as the general population of compact X-ray sources in other similar galaxies?
  - Identify candidate matching galaxies based on morphological type, redshift, ...
    - Use Open SkyQuery to identify matching galaxies based on selection criteria, and return positions and sizes
  - Identify compact X-ray sources within D_{25} of each galaxy
    - Search *Chandra Source Catalog* to identify X-ray sources within the prescribed search radii around Cen A and each matching galaxy location, and which are unresolved or have extents < 3”

What-If Science Use Case — Comparing Populations

  - Compare number density, mean hardness ratios, mean source spectra, ...
    - Compute the mean number density and variance as a function of isophotal radius, and the means and variances of the hardness ratios, ... for the matching galaxies and for Cen A
    - Execute a workflow (or a script that uses the *Chandra Source Catalog* API interface) to retrieve the X-ray event data objects and perform similar spectral fits (e.g., absorption + power-law, or thermal plasma) to the sources using `Sherpa` (or your favorite spectral fitting package) and compare the resulting fits
  - Are there identifications for the sources ?
    - Use Open SkyQuery to search for crossmatch identifications at the X-ray source positions

Simplifying Analysis — ULX Source Catalog

- A significant impact of the *Chandra Source Catalog* is the ability to simplify data analysis and reduce the expense and resources required to perform a study
  - We expect that this will be particularly appreciated by observers at proposal time!
- As an example, consider the resources required to complete the study of ultra-luminous X-ray sources in galaxies by Swartz et al. (2004, ApJS, 154, 519)
  - Data transfer volume was large
  - Constructing source response files slow
  - Source list from user source detection contaminated by streak, edge effects — required extensive manual editing
  - Analysis took ~1.5 years

Simplifying Analysis — ULX Source Catalog

- Study of ultra-luminous X-ray sources in galaxies by Swartz et al. (2004, ApJS, 154, 519)
  - Data transfer volume was large
    - Large volume results from having to download a large number of entire observation datasets, even though the data for a few sources per observation were relevant;
    - The volume is much smaller when starting with *Chandra Source Catalog* products, since the data products can be retrieved on a per-source, rather than per-observation, basis
  - Constructing source response files slow
    - Response files for each observation and source will be included as data objects in the *Chandra Source Catalog*
      - For many studies and sources, these calibration products will be directly usable “as-is” (although we would still recommend that the calibration products that are dependent on the model source spectrum be recomputed if the highest fidelity is needed and the S/N of the source detection warrant doing so)

Simplifying Analysis — ULX Source Catalog

- Source list from user source detection contaminated by streak, edge effects — required extensive manual editing
  - *Chandra Source Catalog* source lists will be inherently "clean" to a high degree of accuracy
    - The methods being developed for the *Chandra Source Catalog* are candidates for retro-fitting into the Level 2 standard data processing pipeline, but this will not affect datasets already present in the *Chandra Data Archive*
- Analysis took ~1.5 years
  - The *Chandra Source Catalog* will substantially reduce this time