Data Analysis Challenges in the Chandra Orion Ultradeep Project


Abstract

The Chandra Orion Ultradeep Project (COUP) combines 6 consecutive ACIS-I observations of the Orion Nebula Cluster obtained in January 2003, with a total exposure time of 0.84 Ms. Over 1600 point sources are detected in this star-forming region; most show variability in their lightcurves. We describe some of the data analysis challenges specific to this observation, including: source detection with complex backgrounds due to bright sources, resolving crowded sources, spectral fitting of sources lying under readout streaks, and time-varying pile-up. We show some output produced from the custom software we have developed to automate the spatial, spectral, and timing analysis of these sources and to collate the results into user-friendly viewing formats.

Introduction to Chandra COUP Observations

COUP was observed with the Chandra X-ray Telescope on 4 CCDs, marked by VIF, in the following modes: open, PSU/CTI correction; filter on 0.3-8 keV energy band; remover hot pixels; apply GTI; remove out-of-band filter, see details in [16].

Data Reduction Roadmap

Run on 4 CCDs, mark by VIF mode; perform PSU/CTI correction; filter on 0.3-8 keV energy band; remove hot pixels; apply GTI; remove out-of-band filter, see details in [16].

Sources on Readout Trails & PSF Winds

Chandra images of close doubles at sub-sub-arcsecond resolution. We found a few dozens cases in which ACIS images of close doubles are not resolved by eye; this failure begins for source separation < 2.5" on-axis. We employed the flag tool "flagpuf" to detect unresolved cases and create source lists, see details in [16].

Pileup Sources

Bright pileup sources can be easily seen in this image. The streaks from bright pileup sources can be easily seen in this image. The pileup correction is done for physically (vs. statistically) reasonable 2T fit.

Fig. 1. - (Left) Chandra three color raw image of the merged event 2048. It has been constructed from the 0.5-1.5 keV (red), 1.5-2.5 keV (green), and 2.5-8.0 keV (blue) raw images. The merger of all six observations was greatly simplified by keeping the aim point and the roll angle constant! A few dozens of X-ray sources suffered slight photon pileup (10% – 30%) in the CCD detector. At the Maree SX star, the massive O6 star dominating the Trapezium at virtually all wavelengths, suffers very significant pileup. Dozens of readout streaks from bright pileup sources can be easily seen in this image. The sensitivity of sources rapidly deteriorates as one approaches within ~30" of On C due to the background from the local O-star PSF wings. (Right) Enlarged view of the central (7' x 7') image from the deep near-IR VLT survey area. Hundreds of X-ray sources are visible in this field. The X-ray source surface density drops from ~102 sources/arcsec2 at the central parts of the field to ~10.3 sources/arcsec2 at the central parts of the field. A modification of the Galactic plane is shown for the radio flaring source [8]. For more details on the pileup source list, see details in [16].

Data Analysis on the Chandra Orion Ultradeep Project

ACIS sources are listed in Table 1 with integrated X-ray properties. The luminosities of these sources are comparable to previous data, with the exception of the luminosity of the bright COUP sources XSPEC provides two different solutions with equally well-fitting counts, but one needs 2T models most of the time to simultaneously fit the low and high-energy kT. For the hundreds of sources including: Chandra ACIS-I [9]. Chandra HRC [9]. PMS members [10]. Chandra [12]. NVSS [10]. Talk about the properties of the COUP X-ray sources.

Fig. 2. - While merging the merged-aspect-hipplots for COUP project we found the difference between the exposure of the merged cut file and the duration of the merged aspartic histogram to be unusually high at ~11 seconds, which lead to the flux errors on the order of ~10^%. The reason of the high xT1 is the unusually high number of Good Time Intervals recorded for six COUP observations, especially for the last one, when it reaches 45 s in the GTC table. Each phase-true value is divided by the fiducial energy of 1.5 keV, 3. to extract the background from the sweeze-cheese event list and to scale it, using the integrated exposure in the region, 4. to compute instrumental responses (RMF and ARF) with ARFs, corrected for the PSF fraction enclosed by the extraction regions and for the hydrocarbon build-up on the detectors [10]; 5. create source spectra and scaled local background spectra; 6. group spectra; 7. compute photometry; and 8. perform automated spectral fitting spanning the XSPEC v11.2 tool. Run Bayesian block IDL package; see details in [40] to perform timing analysis. Create source tables with integrated list properties.

Fig. 3. - Cumulative distributions of fluxes between X-ray and IR positions. Our X-ray positions are superimposed on HST counterparts. 0.22" for 2MASS counterparts, and 0.15" for MLLA counterparts. There is virtually no any ambiguity between catalogued sources and COUP sources, except for couple dozens of close doubles, when COUP source is a double star with a single IR counterpart, and vice-versa.

Fig. 4. - The source detection programs often confused bright sources including: Chandra ACIS-I [9]. Chandra HRC [9]. PMS members [10]. Chandra [12]. NVSS [10]. Talk about the properties of the COUP X-ray sources.

Fig. 5. - The other tricks can be used to find different sources. As example, photon arrival diagrams indicate different intervals, which occurred from each of the components, the flare at ~20s for the first component and the flare at ~30s for the second component.

Fig. 9. - The atlas is a color PDF file summarizing each source on page: it has light curve, photon arrival diagram, spectral fits, raw, PSF reconstructed and smoothed images, postage-stamps of the source neighborhood; as well as various tabulated quantities. Eric Feigelson (PI of COUP Project) predicts that these atlas pages will prove very useful for the science efforts. As example, the current version of pages for a single source is shown below.