The Chandra Source Catalog: Spectral Properties

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Abstract

The first release of the Chandra Source Catalog (CSC) will contain sources identified from eight years' worth of publicly accessible observations. The vast majority of these sources have been observed with the ACIS detector and have spectral information in 0.5-7 keV energy range. Here we describe the methods used to automatically derive spectral properties for each source detected by the standard processing pipeline and included in the final CSC. Hardness ratios were calculated for each source between pairs of energy bands (soft, medium and hard) using a Bayesian algorithm (BEHR, Park et al. 2006). The sources with high signal to noise ratio (exceeding 150 net counts) were fitted in Sherpa (the modeling and fitting application from the Chandra Interactive Analysis of Observations package, developed by the Chandra X-ray Center; see Freeman et al. 2001). Two models were fitted to each source: an absorbed power-law and a blackbody emission. The fitted parameter values for the power-law and blackbody models were included in the catalog with the calculated flux for each model. The CSC also provides the source energy flux computed from the normalizations of predefined power-law and blackbody models needed to match the observed net X-ray counts. In addition, we provide access to data products for each source: a file with source spectrum, the background spectrum, and the spectral response of the detector. This work is supported by NASA contract NAS8-03060 (CXC).

Fitting X-ray Spectra

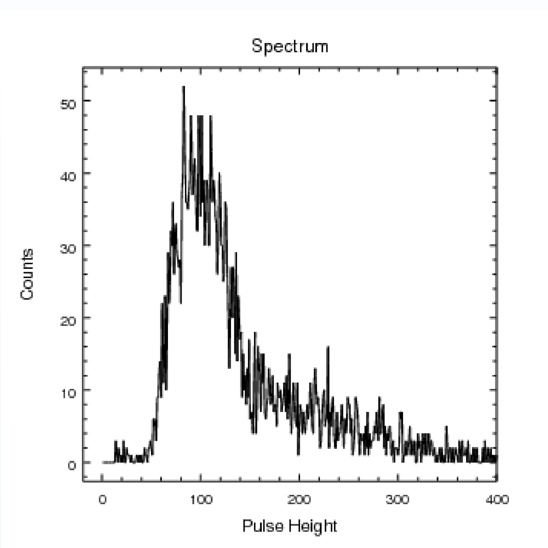

Figure 1. A typical Chandra X-ray spectrum, from data observed with the ACIS detector. ACIS consists of a number of CCD chips that can record not only a photon's position on the detector, but also its energy and time of arrival. When ACIS data are binned by energy, an X-ray spectrum for the observation is created. However, the observed X-ray spectrum is not flux vs. energy (or wavelength), but rather number of detected counts vs. pulse height amplitude for detector channels.

Therefore, models fitted to these data not only have to model emission from the source, but also must include instrumental effects that account for how photons of a given energy are redistributed into a number of ACIS detector channels.

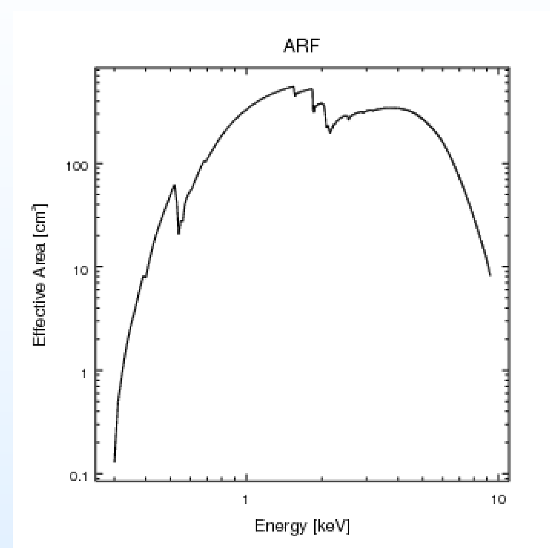

Figure 2. Effective area curve for chip 1 of the Chandra ACIS detector. The effective area varies as a function of energy, quite significantly. This variation must be included in a model fitted to a Chandra observation.

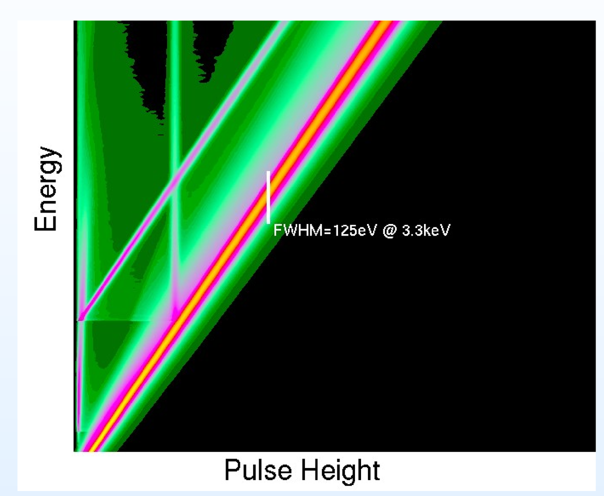

Figure 3. ACIS response matrix. The response matrix accounts for how the detector redistributes photons of a given energy. For photons of energy *E*, there is a probability distribution that describes how many counts can be expected in each detector channel. As this figure shows, the peak of the distribution shifts to greater pulse height amplitudes, or detector channel, as incoming photon energy increases.

When modeling a Chandra X-ray spectrum, the source model must first be multiplied by the effective area curve. Then the result is multiplied by the matrix that redistributes modeled photon flux into detector channels. The end result is a model X-ray spectrum, of counts vs. pulse height amplitude, that can be compared to the observed X-ray spectrum.

Automated Spectral Fits for Chandra Source Catalog

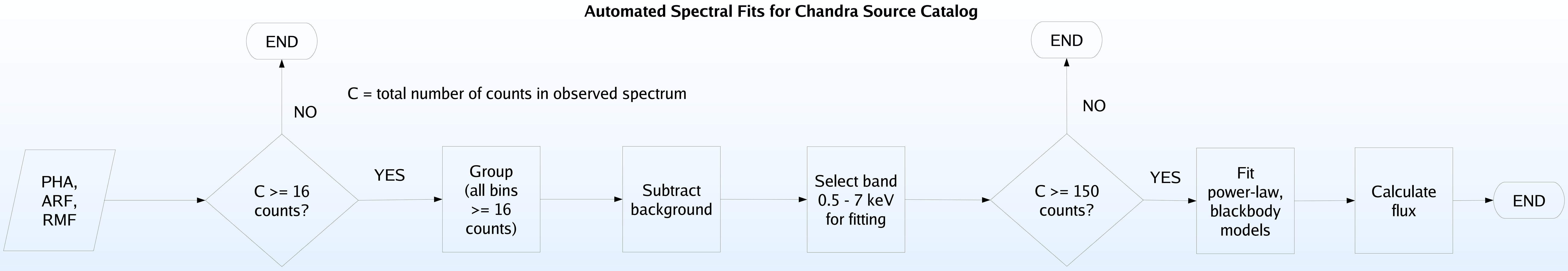

Figure 4. For every source, files containing an observed spectrum (PHA), effective area (ARF), and response matrix (RMF) are fed into a program to automatically fit power-law and blackbody models. (Absorption is also included in both fits.) The counts from the observed spectrum are first grouped (i.e., the counts from consecutive channels with low numbers of counts are grouped together, ensuring that each group has at least the minimum desired number of counts), then background subtracted, and finally filtered to include all counts within the 0.5 - 7.0 keV energy band. If the total number of counts is greater than or equal to a threshold value, then the power-law and blackbody models are each fit to the spectrum, and fitted values for power-law index and blackbody temperature are reported, with confidence limits, so they can be listed as spectral properties for each source. Fluxes for both power-law and blackbody models are also calculated.

Cataloged Spectral Source Properties

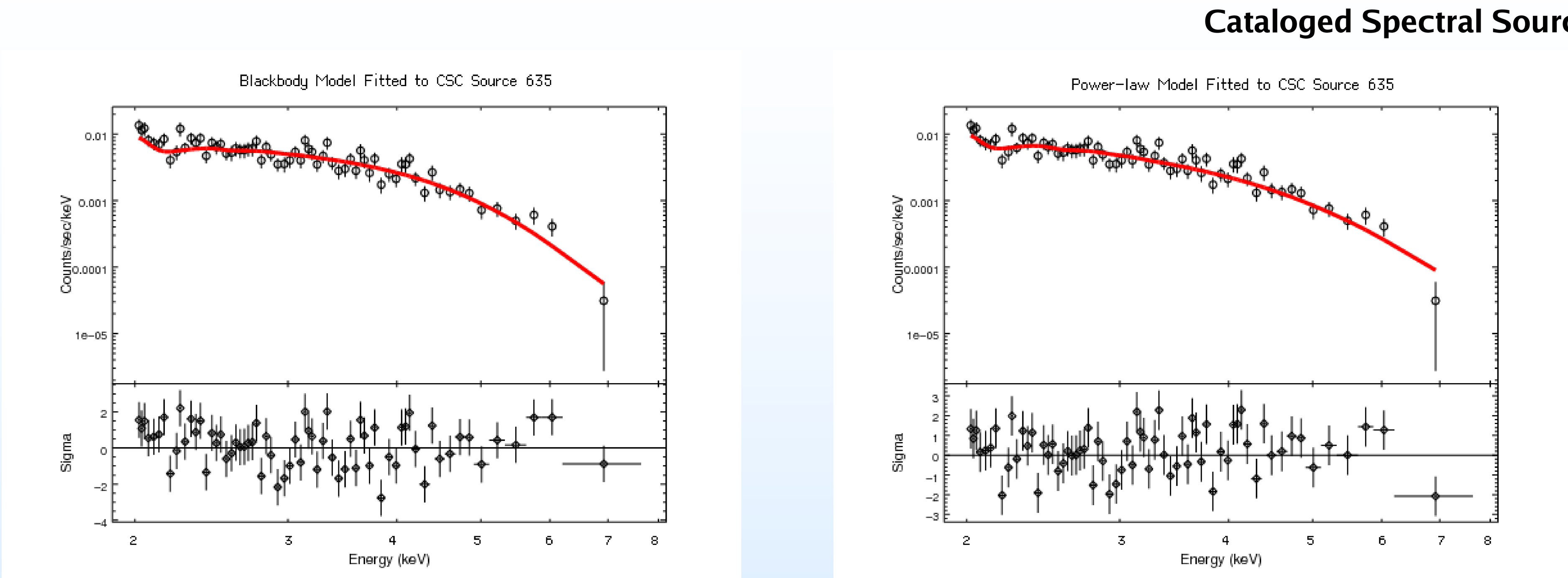

Figure 5. For every source, the catalog contains results from two models fitted to the spectrum: an absorbed blackbody (left) and an absorbed power-law (right). Each plot shows the fitted model as a red curve, with residuals to the fit below. Fitted model parameters from each model are included in the table of spectral source properties to the right.

Table of Spectral Source Properties

hard_ms[1]	medium-to-soft hardness ratio
hard_hs[1]	hard-to-soft hardness ratio
hard_hm[1]	hard-to-medium hardness ratio
alpha[2]	power-law spectral index
flux_powlaw[2]	power-law spectral flux
nh_powlaw[2]	absorption (fit with power-law)
powlaw_stat	goodness of fit
kt[2]	blackbody spectral temperature
flux_bb[2]	blackbody spectral flux
nh_bb[2]	absorption (fit with blackbody)
bb_stat	goodness of fit

[1]Calculated with BEHR algorithm (Park et al., 2006)
[2]1-sigma confidence limits also calculated and listed with these properties

Chandra Energy Bands

ultrasoft	0.2-0.5 keV
soft	0.5-1.2 keV
medium	1.2-2.0 keV
hard	2.0-7.0 keV
broad	0.5-7.0 keV

Acknowledgments

Support of the development of the Chandra Source Catalog is provided by the National Aeronautics and Space Administration through the Chandra X-ray Center, which is operated by the Smithsonian Astrophysical Observatory for and on behalf of the National Aeronautics and Space Administration contract NAS8-03060.