Default Spectral Fit Parameters for the Chandra Source Catalog 2.0

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As part of the Chandra Source Catalog 2.0 (CSC 2) a flux based on the fixed set of spectral models (model flux) is calculated for all of the true and marginal source detections, no matter the number of source counts. In order to determine a default set of model parameters for the uniform calculations of the model flux, the existing spectra from the Chandra Source Catalog v.1.1 (CSC 1.1) were used. There are four models selected for these calculations: (1) an absorbed power law; (2) an absorbed black body; (3) an absorbed bremsstrahlung; and (4) an absorbed APEC model. These models were used to fit the sources with > 150 net counts in the 0.5-7.0 keV energy band.

To determine the default set of spectral fit parameters the tool ***specfit*** (which incorporates Sherpa fitting package) was used to fit spectra taken from CSC 1.1. A subset of 3891 sources from the CSC 1.1 catalog was selected to sample low, intermediate, and high count sources. All the sources were required to have more than >150 net counts in the 0.5-7.0 keV energy band. The spectra were grouped into 16 count bins and a chi-squared statistic was used in the fitting. The results of all of the fits can be found in Table 1 and a summary at the end of the memo.

Power-Law Model: We fit CSC 1.1 spectra (pha3, rmf3, arf3) of 3891 sources with > 150 net counts using an absorbed power law. Figure 1 shows histogram plots of the best-fit photon index values, gamma. The red histogram marks all the fits (3891), and the blue one marks the fit with a good reduced χ^2 ($\leq$ 1.25; 2349 sources). The median value of gamma is equal to 2.24 for all the fits, and 2.02 for those with a good reduce χ^2. The mode of best-fit gamma is located within 1.75-2.0. Table 1 lists the results. The default gamma parameter value of **2.0** was assumed for the power-law model flux calculations.

Black body Model: We fit CSC 1.1 spectra (pha3, rmf3, arf3) of 3,891 sources with >150 net counts using an absorbed black body model. Figure 2 shows histogram plots of the best-fit temperature (kT) values. The red marks all the fits (3891), and the blue marks the results that have a good reduced χ^2 ($\leq$ 1.25; 755). The median value of the best- fit kT is located at 0.52 keV for all the fits, and at 0.72 keV for those fits with a good reduced χ^2. The mode of the distribution is located within the 0.70 -0.79 keV bin for the good fits. Table 1 contains the summary of the results. We assumed the default value of kT to be 0**.75** keV to be used in the black body model flux calculations.

Bremsstrahlung Model: We fit CSC 1.1 spectra (pha3, rmf3, arf3) of 3,891 sources with >150 net counts using an absorbed bremsstrahlung model. Figure 3 shows histogram plots of the best-fit temperature (kT) values. The red histogram marks all the fits (3891) and the blue one marks the results that have good reduced χ^2 ($\leq$ 1.25; 2076 sources). The median value of the kT for all the fits is located at 3.00 keV, and at 4.03 keV for those with a good reduced χ^2. The mode of the distribution of the good fits is located in the 3.05-3.81 keV bin. If we exclude the hard spike (at around 100 keV, i.e. kT has pegged to the maximum allowed model parameter value) then the mean (kT=5.95 keV) becomes closer to the median and mode for the results with a good reduced χ^2. We assumed a default value of kT to be **3.5 keV** for the bremsstrahlung model flux calculations.

<u>APEC Model</u>: We fit CSC 1.1 spectra (pha3, rmf3, arf3) of 3,891 sources with >150 net counts using an absorbed APEC model. We fixed the abundances to be Solar and redshift (z) to be zero. Figure 4 shows histogram plots of the best-fit kT values. The red marks all the fits (3891) and blue one marks the fits with a good reduced χ^2 ($\leq$ 1.25; 1303 sources). The median best-fit value of kT is located at 1.60 keV for all fits, and at 6.07 keV for those with a good reduced χ^2. The mode of the distribution for the good fits is located in the 5.96-7.45 keV bin. We assumed a default value of kT to be **6.5 keV** for APEC model flux.

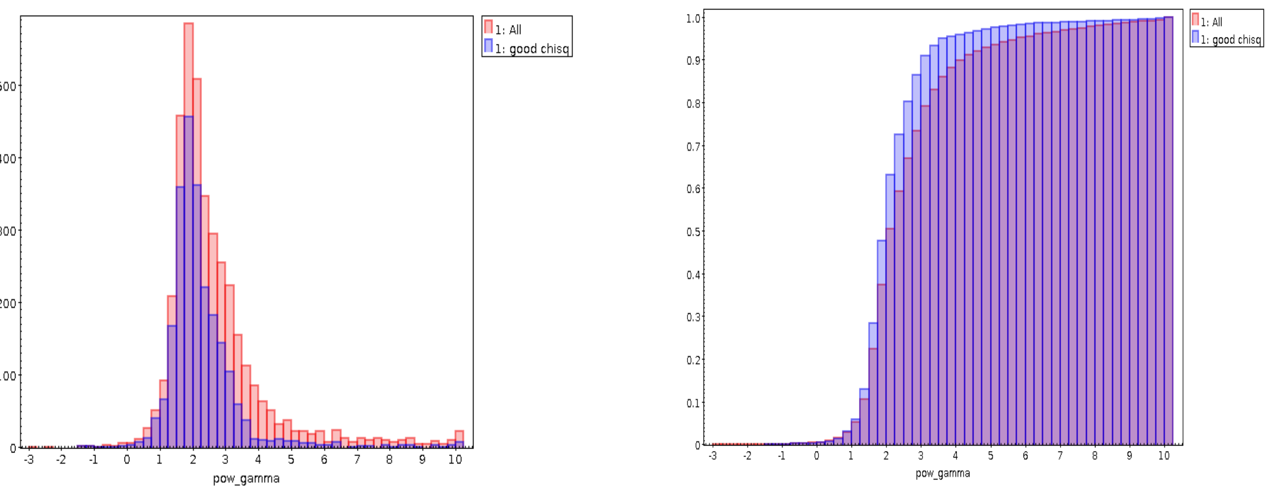

Fig. 1: The histograms of the power law photon index (pow_gamma) for all the best-fit values of the model fits to the CSC 1.1 data. The red marks all the fits and the blue marks the results with a good reduced χ^2. (*left*) A histogram of the best-fit pow_gamma. (*right*) A normalized cumulative histogram of the best-fit pow_gamma.

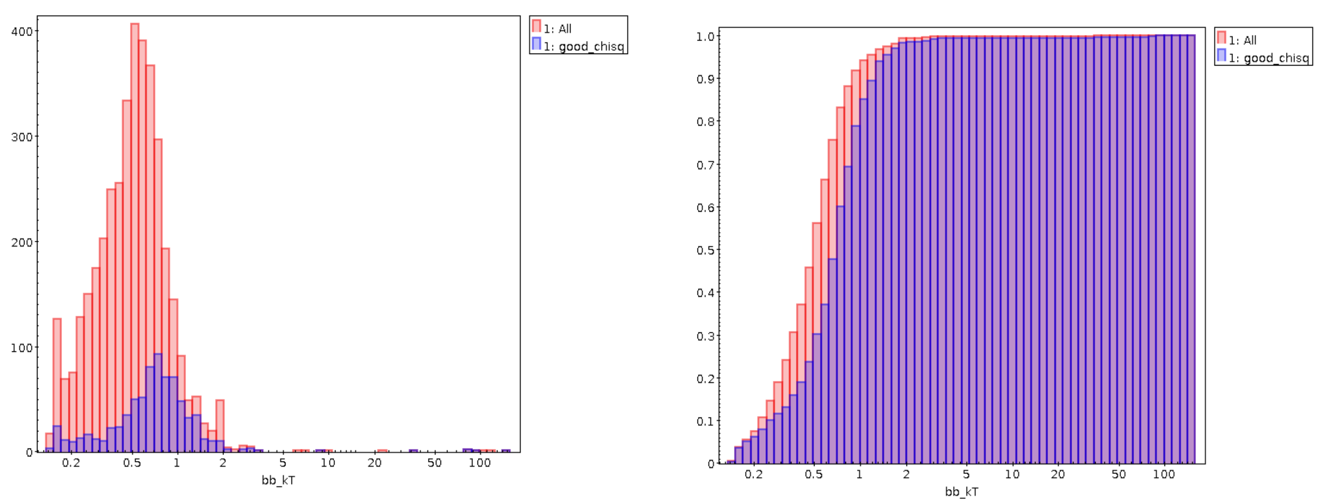

Fig. 2: The histograms of the best-fit kT values for the black body model fits to the CSC 1.1 data. The red histogram marks all the fits and the blue one the fits with a good reduced χ^2. (*left*) A histogram of the best-fit fit values of kT. (*right*) A normalized cumulative histogram of the best-fit kT values.

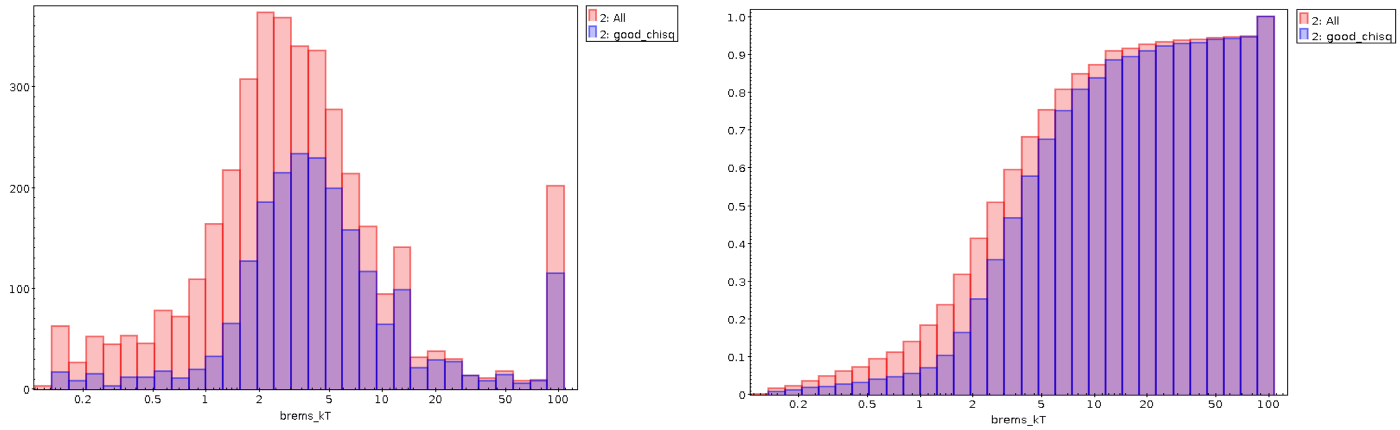

Fig. 3: The histograms of Bremsstrahlung best-fit kT values for the CSC 1.1 data. The red marks all the fits, and the blue the fits with a good reduced χ^2. (*left*) A histogram of the best-fit values of kT. (*right*) A normalized cumulative histogram of the best-fit kT values.

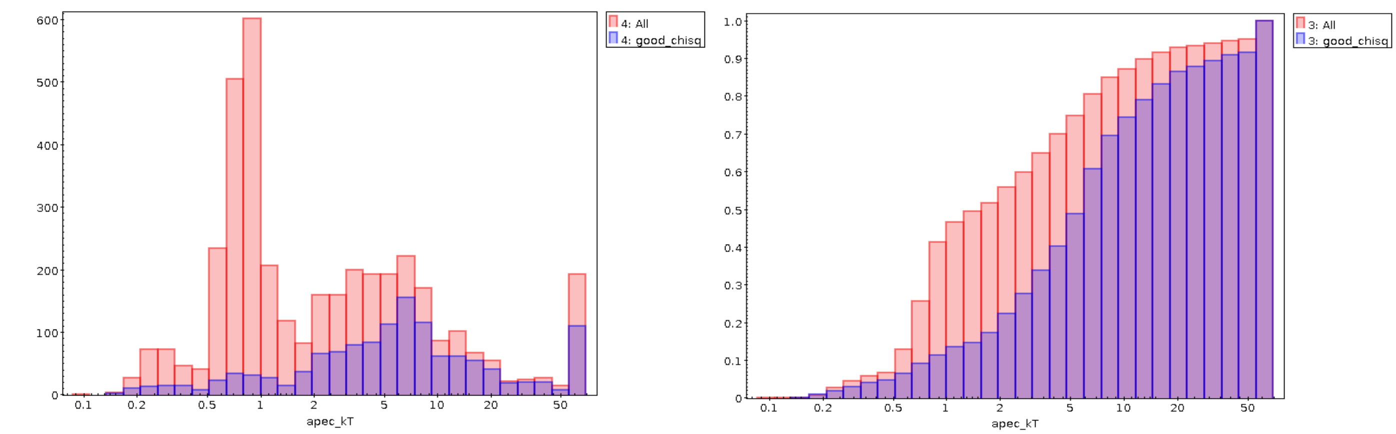

Fig. 4: The histogram of APEC best-fit model kT values for the CSC 1.1 data. The red marks all fits, and the blue ones the fits with a good reduce χ^2. (*left*) The histogram of the best-fit values of kT. (*right*) A normalized cumulative histogram of the best-fit kT values.

<u>Absorption Model</u>: For all the above model fits we included an absorption model component (**phabs**). We found the distributions of the absorption column density, NH, to cluster around two peaks. As an example, we show the results for the power-law model in Fig. 5. One peak is located at around $\sim 7\times 10^{21}$ cm^{-2}, and another peak at around $\sim 10^{15}$ cm^{-2}. This latter peak is unrealistic given that the expected lower bound to the column density is around $\sim 10^{19}$ cm^{-2}, as determined by the density of the ISM inside the local bubble (Cox & Reynolds, 1987, ARA&A, 25, 303; Egger & Aschenbach, 1995, A&A, 294, L25). A study (Brassingon, et al. 2010, ApJ, 725, 1805) has shown that these low NH values are likely a result of fitting spectra with a simple model, while the true spectra are more complex and likely require multiple spectral components to describe the X-ray data. This leads to the NH values being artificially low. We decided to use the ***colden*** value of NH for each source (http://cxc.cfa.harvard.edu/ciao/ahelp/colden.html) which gives the measured Galactic value of NH at a given source location.

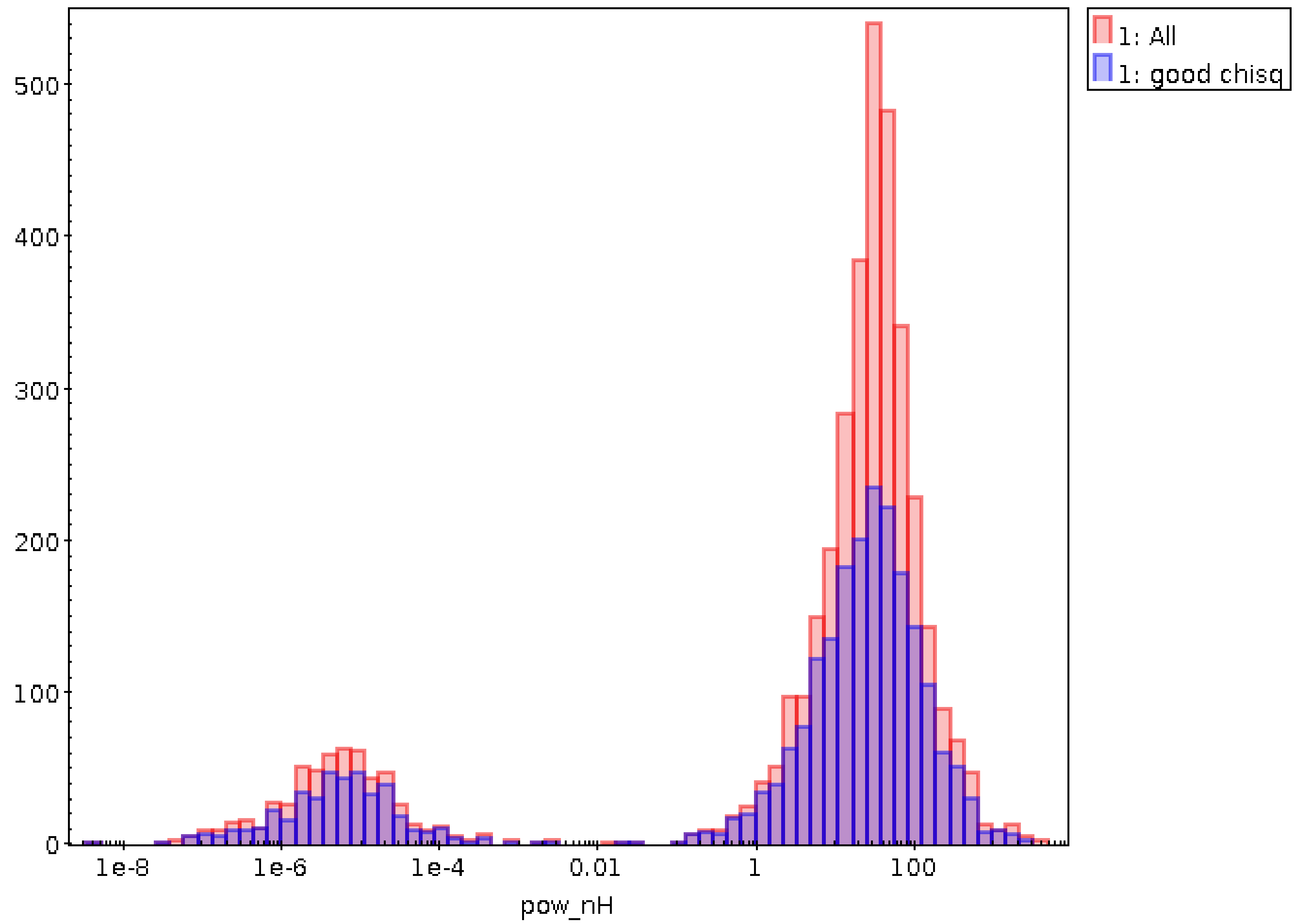

Fig. 5: The histogram of NH values from the power-law model fits to the CSC 1.1 data. The red histogram marks all the fits and the blue one the fits with a good reduced χ^2. The low NH peak represents the values that are lower than the ones estimated for the Galactic NH (~ 0.1 is the minimum Galactic NH in the given units). These are likely sources which have multiple spectral components.

Model	***Parameter***	***Chisq***	***Number***	***Mean***	***Median***	***Mode***	***Q90***
Power-law	*Γ*	*All*	*3891*	*2.68*	*2.24*	*1.75-2.00*	*4.27*
Power-law	*Γ*	*≤ 1.25*	*2349*	*2.27*	*2.02*	*1.75-2.00*	*3.17*
Black Body	*kT*	*All*	*3891*	*0.76*	*0.52*	*0.49-0.55*	*0.94*
Black Body	*kT*	*≤ 1.25*	*755*	*1.36*	*0.72*	*0.70-0.79*	*1.29*
Brems	*kT*	*All*	*3891*	*9.71*	*3.00*	*1.95-2.44*	*13.58*
Brems	*kT*	*≤ 1.25*	*2076*	*11.42*	*4.03*	*3.05-3.81*	*19.928*
Brems	*kT*	*≤ 70 keV*	*1953*	*5.95*	*3.84*	*3.05-3.81*	*12.50*
APEC	*kT*	*All*	*3891*	*7.13*	*1.60*	*0.80-1.00*	*15.25*
APEC	*kT*	*≤ 1.25*	*1303*	*12.53*	*6.07*	*5.96-7.45*	*41.31*

Table 1: The results from the spectral fits with the resultant mean, median, mode and Q90 values. For the bremsstrahlung fits (Brems) an additional check was done of the good reduce χ^2 (≤ 1.25) values with the high kT (a result of the fits pegging to the maximum value) removed.

Summary of the Chosen Canonical Default Values for Model Flux Parameters

Power-law: *gamma* = **2.0** (agreement between the median and mode value)

Black Body: *kT* = **0.75** *keV* (mode is slightly higher than the median)

Bremsstrahlung: *kT* = **3.5** *keV* (mode is slightly higher than the median)

APEC Model: *kT* = **6.5** *keV* (mode is higher than the median)

NH: *NH* should be chosen using the colden value for the source location.
(http://cxc.cfa.harvard.edu/ciao/ahelp/colden.html)