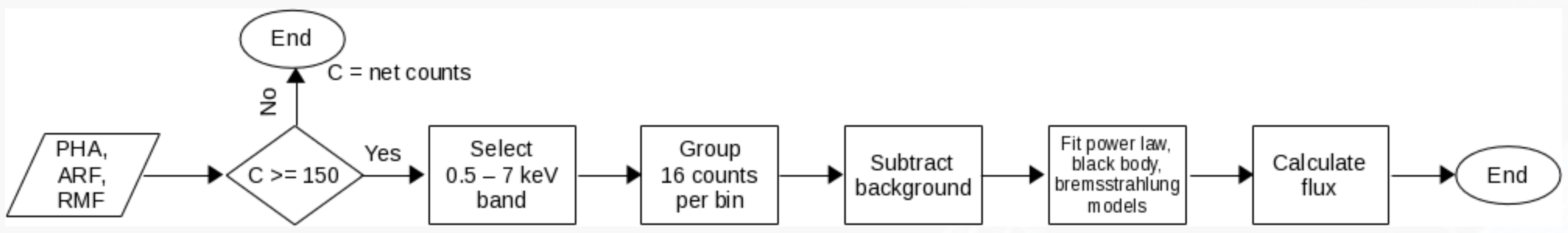
The Chandra Source Catalog 2.0: Spectral Properties

Michael L. McCollough[1], Aneta Siemiginowska[1], Douglas Burke[1], Michael A. Nowak[4], Francis A. Primini[1], Omar Laurino[1], Dan T. Nguyen[1], Christopher Allen[1], Joseph B. Miller[1], Craig S. Anderson[1], Jamie A. Budynkiewicz[1], Judy C. Chen[1], Francesca Civano[1], Raffaele D'Abrusco[1], Stephen M. Doe[2], Ian N. Evans[1], Janet D. Evans[1], Giuseppina Fabbiano[1], Danny G. Gibbs II[1], Kenny J. Glotfelty[1], Dale E. Graessle[1], John D. Grier[1], Roger M. Hain[1], Diane M. Hall[3], Peter N. Harbo[1], John C. Houck[1], Jennifer Lauer[1], Nicholas Lee[1], J. Rafael Martinez-Galarza[1], Jonathan C. McDowell[1], Warren McLaughlin[1], Douglas L. Morgan[1], Amy E. Mossman[1], Joy S. Nichols[1], Charles Paxon[1], David A. Plummer[1], Arnold H. Rots[1], Beth A. Sundheim[1], Michael S. Tibbetts[1], David W. Van Stone[1], Panagoula Zografou[1]

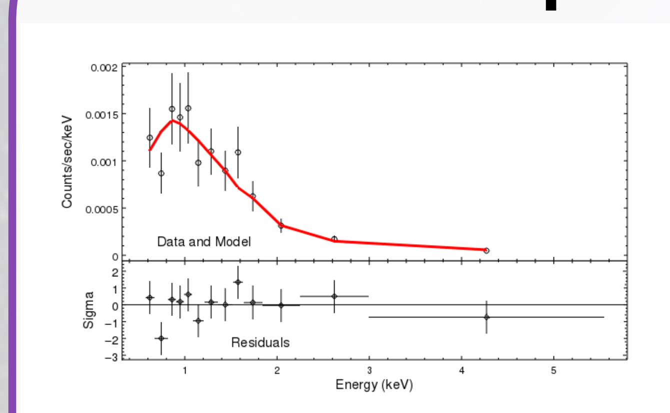
[1]Smithsonian Astrophysical Observatory [2] formerly Smithsonian Astrophysical Observatory [3]Northrop Grumman Mission Systems
[4]MIT Kavli Institute for Astrophysics and Space Research

1. Specfit

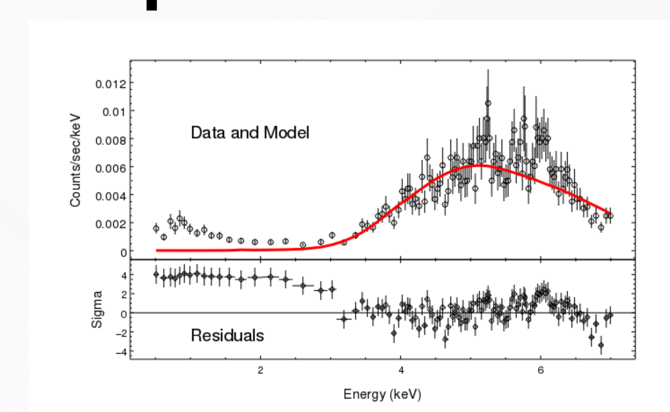
- Specfit is a pipeline tool designed to do automated spectral fits for three absorbed spectral models using Sherpa (Freeman, Doe, Siemiginowska, SPIE Proc. Vol. 4477, p26, 2001).
- For each source a pha (spectrum file), rmf (redistribution matrix file), and arf (auxiliary response file) is created.
- Each source with 150 or more counts will have a spectral fit for three models (power law, black body, bremsstrahlung).
- The spectra are grouped with 16 counts per bin for the 0.5-7.0 keV energy band.
- A chi-squared fit statistic and confidence method are used in the fitting process and error determination.



2. Examples of Spectral Fits



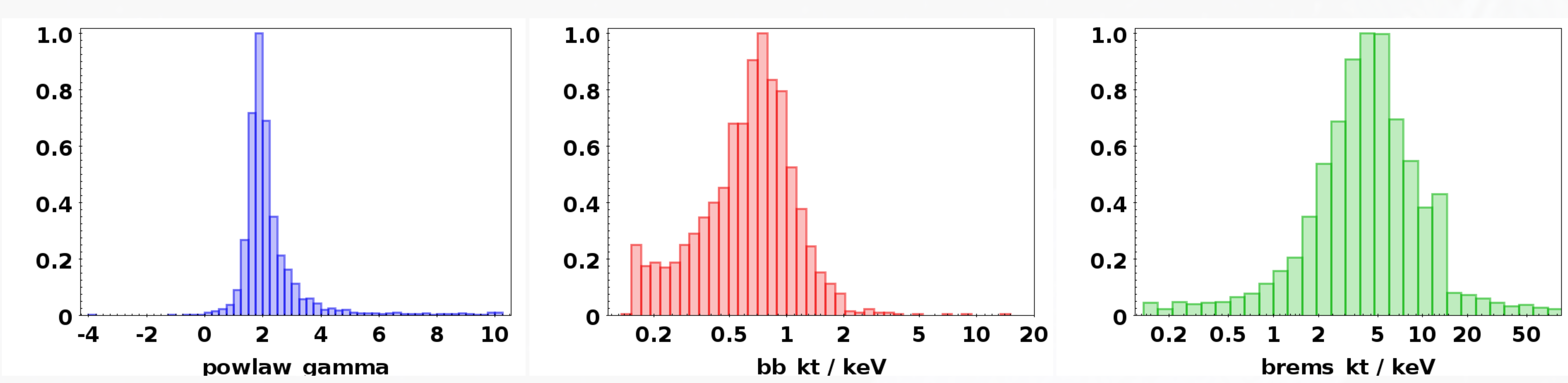
- Spectrum, fit, and residual of a good (reduced chi-squared of 0.89) power-law fit of a 250 count source.
- Photon index = 2.35 (0.17 – 2.74)
- Absorption column = 8.06x10^{20} cm^{-2} (4.21-20.58)x10^{20} cm^{-2}



Some sources with high S/N require complex models (multiple components) and the simple models used in the pipeline can result in a 'bad' fit. In the above case for a power-law model indicate a bad fit (rstat >3) and require an Additional low energy model component.

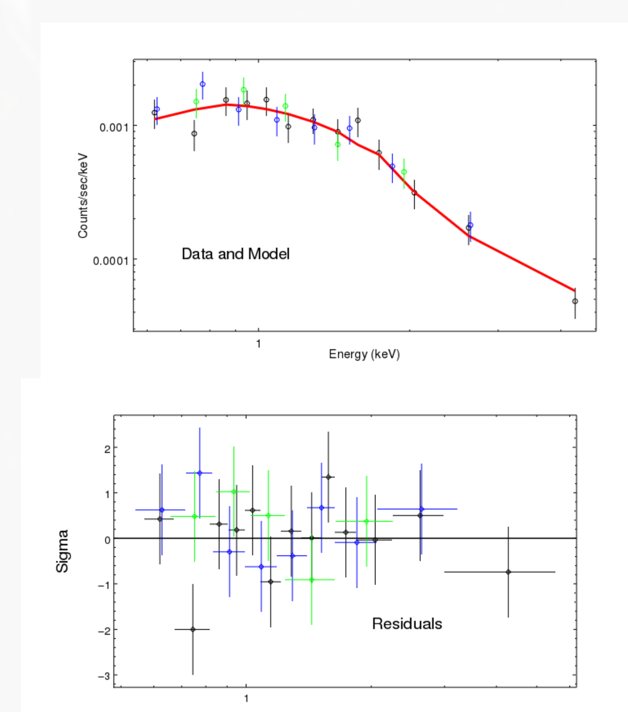
3. Initial Results

- From the initial CSC 2.0 spectral fit run of 138,421 sources 8,133 sources meet the spectral fit criteria.
- Power-Law: 5756 sources (71%) were well fit by a power law model (reduced chi-square of 1.25 or less) with a median photon index of 1.96. I Black Body: 2066 sources (25%) were well fit by a black body with a median kT of 0.67 keV. I Bemsstrahlung: 5318 sources (65%) were well fit by bremsstrahlung model) with a median kT of 4.47 keV.

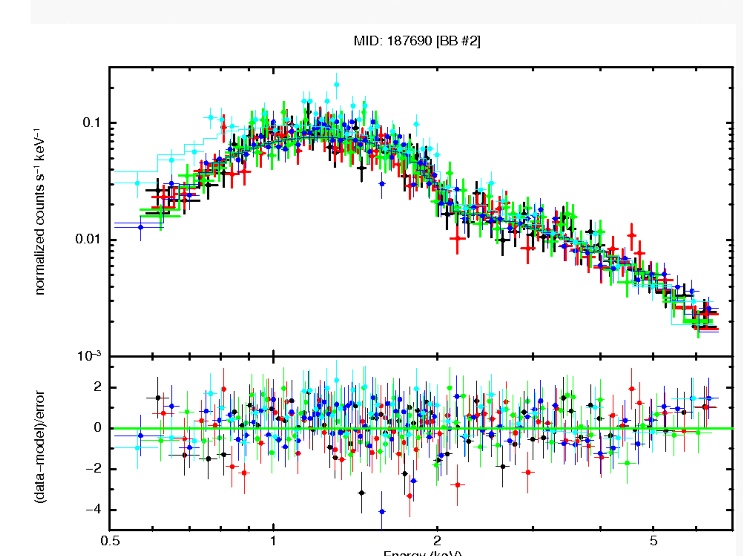


4. Joint Spectral Fits (Bayesian Blocks)

- Sources which are observed multiple times are grouped into 'blocks' of observations. In each block, a constant source flux is consistent with the fluxes of all observations in the block, in the s, m, h, and b bands (see Primini et al. Poster 238.02, this session for details).
- All spectra in the block are simultaneously fit with the assumed models if the sum counts in these spectra are ≥ 150 counts in the 0.5-7 keV band.
- The block with the largest total exposure is promoted as the 'best block', and its spectral properties are reported in the catalog database.
- Spectral properties for all blocks are contained in the Master Source Bayesian Blocks Source Properties (blocks3.fits) data product.



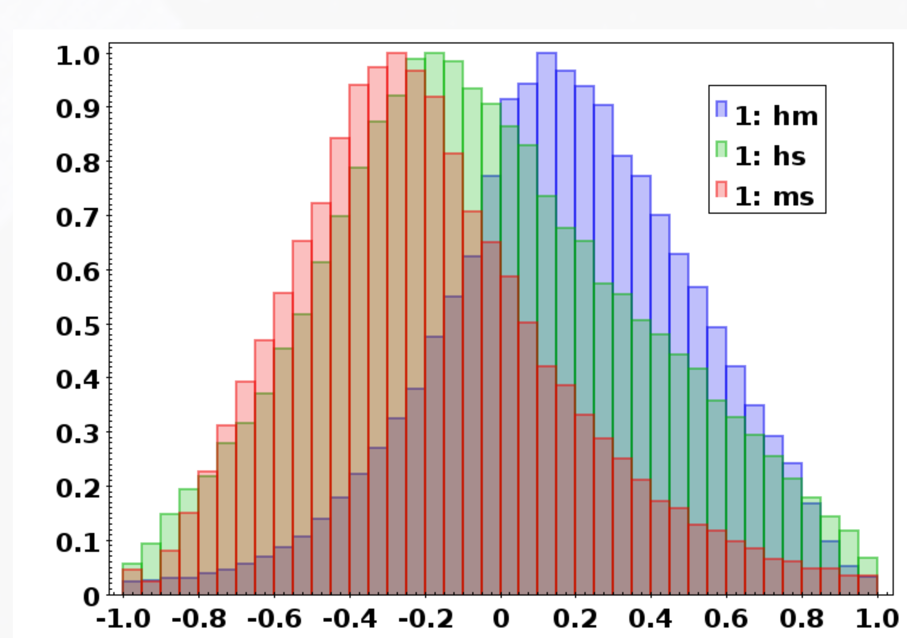
A plot of a joint fit with the spectrum and fit (top) and the residuals (bottom).



Joint fit of a source in M81. Different colors are different observations (obsids).

5. Hardness Ratios

Source hardness ratios were calculated directly from the net source counts using a Bayesian algorithm (Park et al. 2006, ApJ, 652, 610) to account for the Poisson statistics within both the source and background regions. Normalization factors were used to convert the net source counts to fluxes in each of three energy bands: soft (s: 0.5-1.2 keV), medium (m: 1.2-2 keV), and hard (h: 2-7 keV). In CSC 2.0, we use the probability distributions calculated for the fluxes to calculate explicitly the full probability distribution for the hardness ratio, which is defined as: $H_{xy} = (F_x - F_y)/(F_x + F_y)$, where $F_{x,y}$ is the photon flux in a given energy band. This hardness ratio can range from values of -1 (softer) to 1 (harder). Hardness ratio error bars are directly determined from the hardness ratio probability distribution, $P(H_{xy})$, by choosing a probability value P_{cut}, such that integrating over The range of Hxy where $P(H_{xy}) > P_{cut}$ equals 0.68 (i.e., one sigma). This can lead to asymmetric error bars that properly account for the hardness ratio bounds at -1 and 1.



A normalized histogram plot of the hardness ratio distributions (138,421 sources).

6. Model Energy Fluxes

- For each of the source a model energy flux is estimated for four absorbed spectral models (power-law, black body, bremsstralung, and APEC).
- These fluxes are derived from the binned images and used fixed spectral parameters. The spectral parameters were determined by fitting ~4000 sources from the CSC 1.1.
- Default parameters values: Power-law (photon index = 2.0), Black-Body (kT = 0.75 keV), Bremsstralung (kT =3.5 keV), APEC (kT = 6.5 keV, z = 0 and abundances = solar).
- The absorption column is determined using COLDEN (Galactic coordinates of the source).

This work has been supported by NASA under contract NAS 8-03060 to the Smithsonian Astrophysical Observatory for operation of the Chandra X-ray Center.

CHANDRA SOURCE CATALOG