Testing ACIS Low Energy Response using Observations of Three Pulsars

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ABSTRACT

We present the results of the application of the ACISABS tool to the data on three pulsars observed with Chandra to demonstrate the current status of the ACIS low energy response. The ACIS spectra for each source were compared to LETGS and archival ROSAT PSPC spectra to determine the quality of the ACIS fit both before and after using the ACISABS tool. We also summarize the physical model spectral parameters and their errors in both cases.

Introduction

We analyzed 3 pulsars, PSR B0656+14, B1055-52 and the millisecond pulsar J0437-4715, using the modified effective areas modified with the ACIS-ABS tool. The ACISABS tool uses the fit to the ratio of the Mn L complex to Mn K lines that has been monitored throughout the mission (see Plucinsky et al. 2002 for more details). The fit was produced using

$$\frac{\mathrm{Mn\ L}}{\mathrm{Mn\ K}} = N_o \times \exp[-\tau_\infty \times (1 - \exp(-t/t_o))] \tag{1}$$

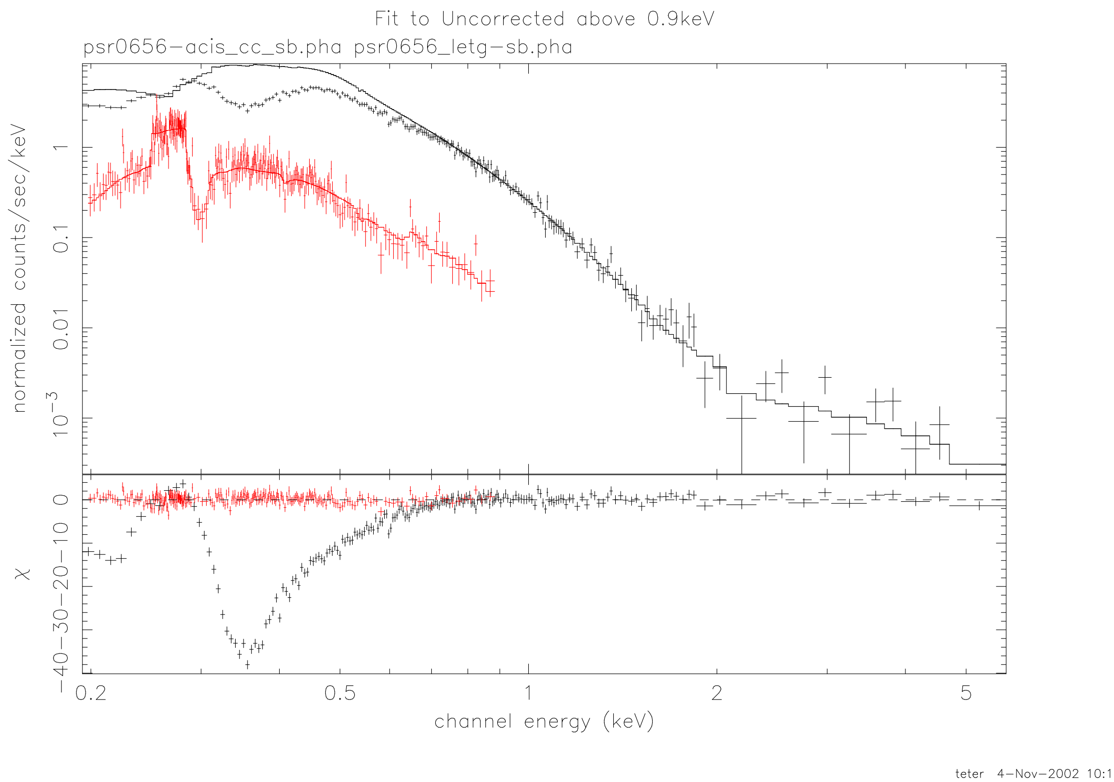
where $N_o = 0.00722 \pm 0.00007$, $\tau_\infty = 0.582 \pm 0.024$, $t_o = 620. \pm 66$ days, t is the number of days since launch. This rate is used to compute the thickness of a hydrocarbon layer that has a composition assumed to be $C_{10}H_{20}O_2N_1$. In the XSPEC implementation of the ACISABS tool, τ_∞, t_o, t, and the relative concentration of the elements can be adjusted to improve the fit.

To determine the quality of the correction, we used data from other instruments for the low energies. In the case of PSR B0656+14, we used data from the *Chandra* HRC/LETG (LETGS hereafter) observation. For PSR B1055-52 and J0437-4715, we used observations from the *ROSAT* PSPC.

PSR B0656+14

PSR B0656+14 was observed in Dec 2001, 875 days after launch, using 50 ks exposure in continuous clocking (CC) mode. The LETGS observation from Jan 2000, 25 ks exposure time, provides low energy reference. The spectrum of PSR B0656+14 can be fitted with a 3 component model, a soft blackbody with temperature $\sim$70 eV, a hard blackbody with temperature $\sim$135 eV, and a power-law with index $\sim$2.

The LETGS is binned to approximately 100 counts per bin. The ACIS spectrum is binned to a minimum of 10 counts per bin, but most of the bins have over 100 counts. The LETGS spectrum was used between 0.2 and 1.0 keV. For all fits, the ACIS spectrum was not used above 6.0 keV due to increased background.

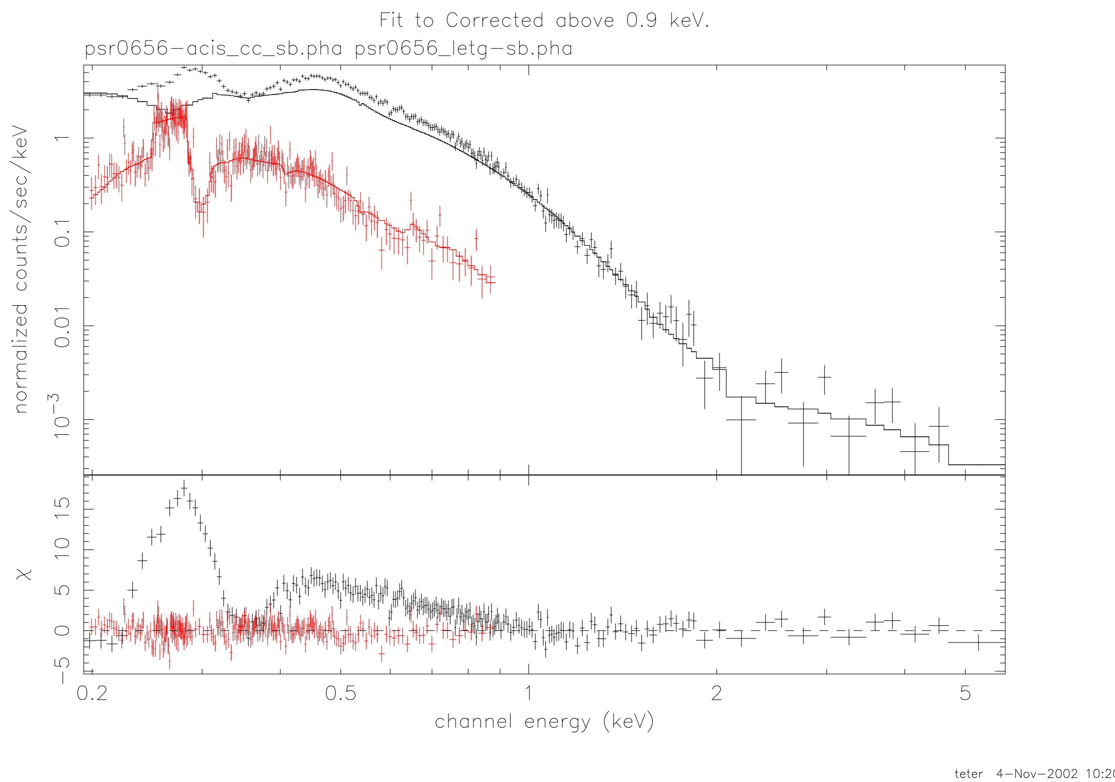


Pulsar B0656+14 fit to LETGS below 1.0 keV and ACIS above 0.9 keV.The ACIS residuals show the large deviation due to the contamination layer.

1. The physical model is 2 blackbodies and a power-law.

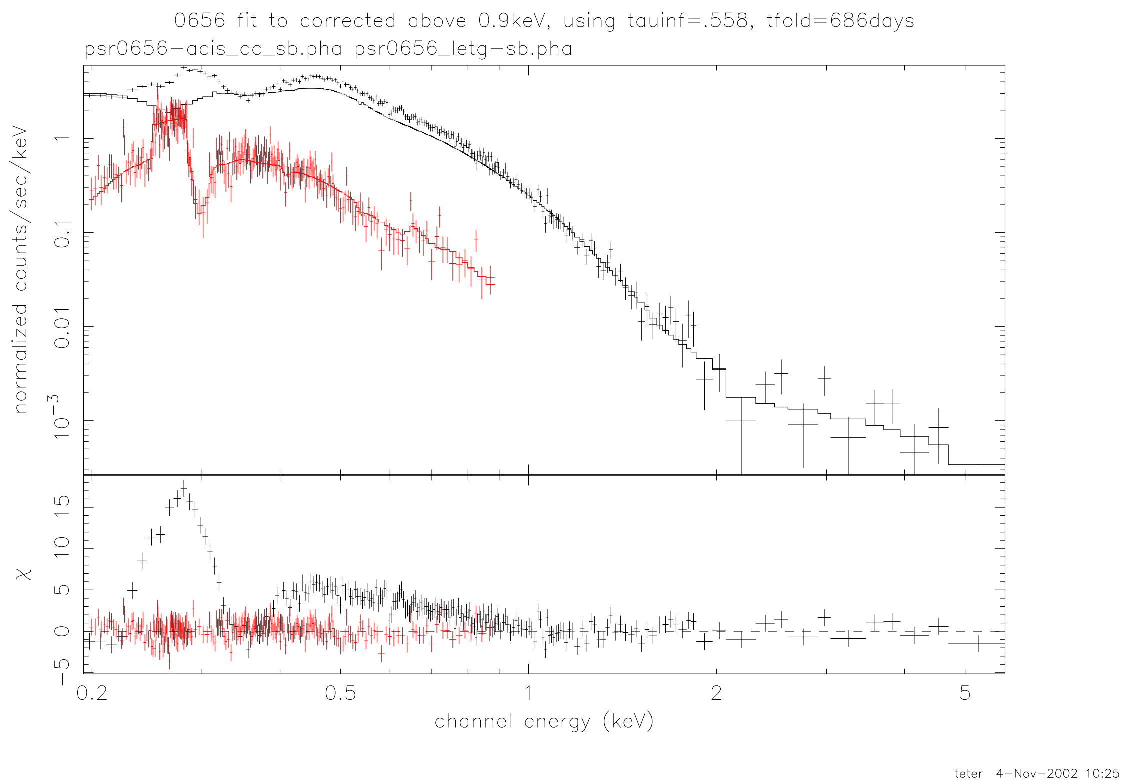
2. The spectral parameters are: $n_H = 2.29 \pm 0.09 \times 10^{20}\mathrm{cm}^{-2}$, $kT_1 = 68 \pm 1$ eV, $N_1 = 1.03 \pm 0.09 \times 10^5$, $kT_2 = 127 \pm 3\mathrm{eV}$, $N_2 = 860 \pm 410$, $\Gamma = 1.9 \pm 0.5$, and $N_\Gamma = 2.6 \pm 2.4 \times 10^{-5}$. (The units of blackbody normalization is $\mathrm{km}^2/10$ kpc^2. The units of power-law normalization is counts cm^{-2} s^{-1} keV^{-1} at 1 keV.)

3. Shows the extent of the contamination that will be subsequently corrected using ACISABS.



Pulsar B0656+14 fit to LETGS below 1.0 keV and ACIS above 0.9 keV using the default ACISABS contamination model ($\tau_\infty = 0.582$, $t_{fold} = 620$ days). The ACIS residuals show the large below discrepancy 0.9 keV, suggesting an overcorrection for the contamination layer.

1. Same spectral model with new physical parameters: $n_H = 2.25 \pm 0.09 \times 10^{20} \mathrm{cm}^{-2}$, $kT_1 = 65 \pm 1$ eV, $N_1 = 1.35 \pm 0.09 \times 10^5$, $\mathrm{kT}_2 = 127 \pm 3\mathrm{eV}$, $N_2 = 1200 \pm 430$, $\Gamma = 1.8 \pm 0.5$,and $N_\Gamma = 2.1 \pm 2.1 \times 10^{-5}$.

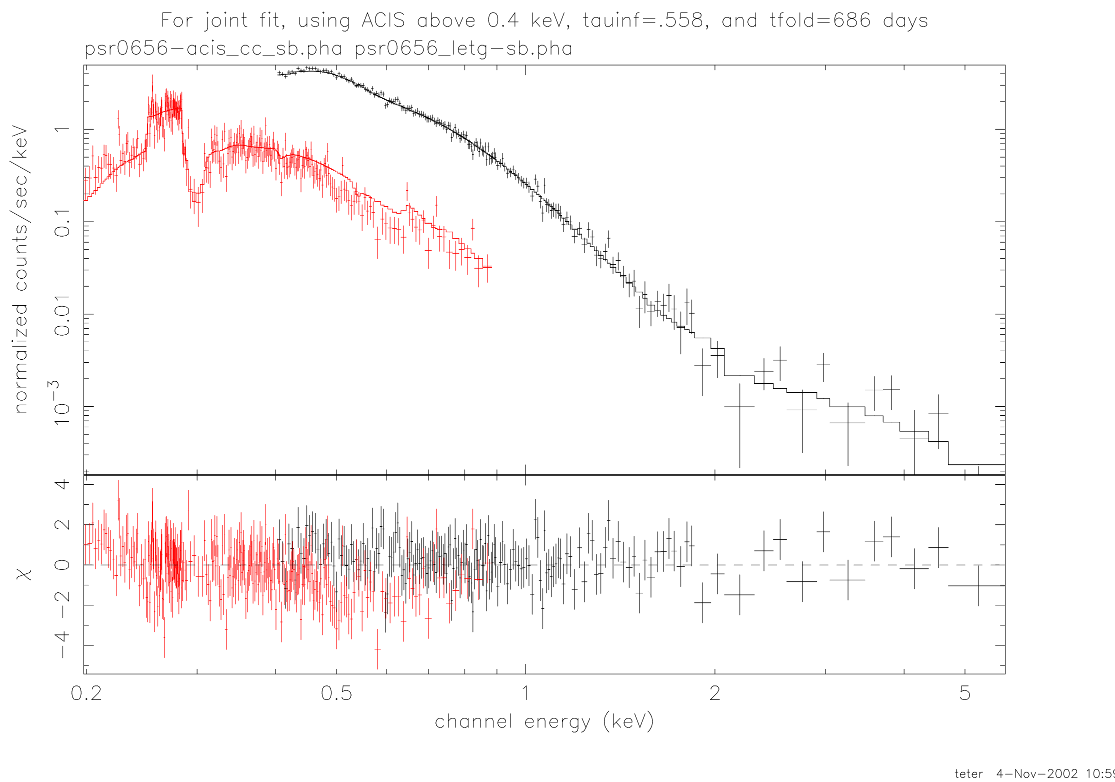


No Fitting. Adjusted contamination layer model to minimum values for the parameters in equation 1: $\tau_\infty = 0.558$, $t_{fold} = 686$ days. The overcorrection is improved slightly.

1. Same physical parameters as used for previous figure. No fitting was done.

2. To correct the fit, the number of days since launch would be 410±9, using default concentrations of elements and ACIS data above 0.4 keV.

3. Allowing concentrations to vary does not improve the fit results for ACIS data above 0.4 keV. Default values seem about the best.



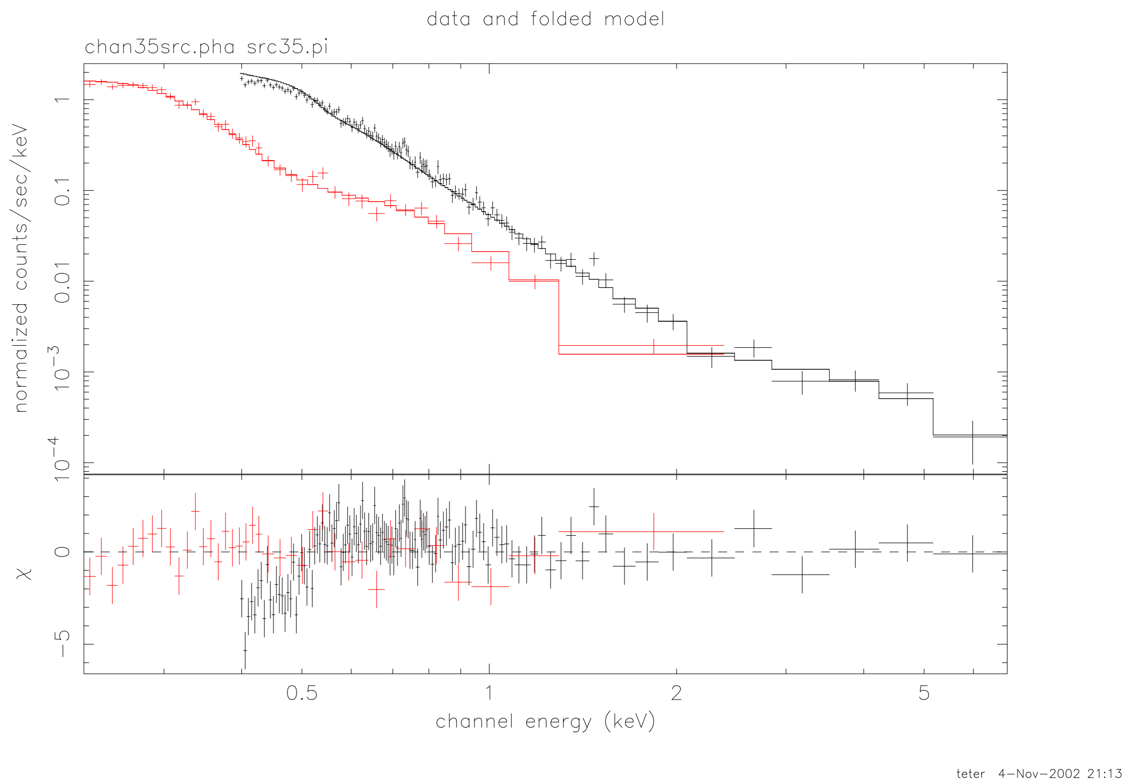
Pulsar 0656 fit to LETGS below 1.0 keV and ACIS above 0.4 keV using the contamination model. Adjusted contamination layer model to minimize correction. $\tau_\infty = 0.558$, $t_{fold} = 686$ days. The overcorrection seems to disappear, but it can be seen in the residuals for the LETGS.

1. Same physical model. New fit parameters are: $n_H = 2.25 \pm 0.09 \times 10^{20}\mathrm{cm}^{-2}$, $kT_1 = 65 \pm 1$ eV, $N_1 = 1.35 \pm 0.09 \times 10^5$, $\mathrm{kT}_2 = 127 \pm 3\mathrm{eV}$, $N_2 = 1200 \pm 430$, $\Gamma = 1.8 \pm 0.5$,and $N_\Gamma = 2.1 \pm 2.1 \times 10^{-5}$.

PSR B1055-52

PSR B1055-52 was observed in Jan 2000, 166 days after launch, using a 50 ks exposure in CC mode. The focal plane temperature for this observation was at -110 degrees. The Rosat PSPC observation, which provides the low energy reference, occurred in Jan 1992 for 15 ks exposure. The spectrum of PSR B1055-52 can be fitted with a 3 component model, a soft blackbody with temperature $\sim$72 eV, a hard blackbody with a temperature $\sim$140 eV, and a power-law with index $\sim$1.7.

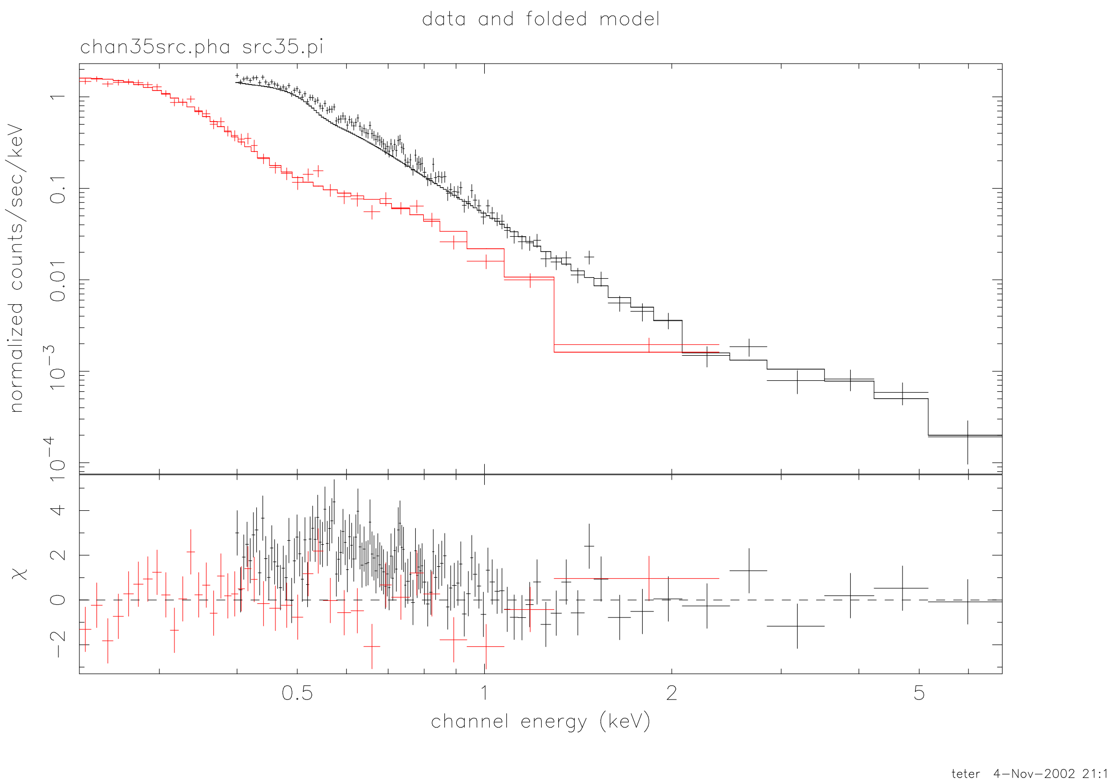
Both the PSPC and ACIS data are binned to 35 counts per bin. The PSPC spectrum was used above energies 0.22 keV. The ACIS spectrum was not used above 8 keV for any of the fits due to increased background.



Pulsar 1055 fit to PSPC and ACIS above 0.9 keV without the ACISABS contamination model. Shows deviation of ACIS spectrum.

1. Model parameters are: $n_H = 1.86 \pm 0.10 \times 10^{20}\mathrm{cm}^{-2}$, $kT_1 = 67 \pm 2$ eV, $N_1 = 2.4 \pm 0.6 \times 10^4$, $\mathrm{kT}_2 = 140 \pm 9\mathrm{eV}$, $N_2 = 70 \pm 70$, $\Gamma = 1.66$, and $N_\Gamma = 1.9 \pm 0.4 \times 10^{-5}$.

2. ACIS spectrum above 0.5 keV seems to be consistent with the PSPC spectrum. Large scatter of PSPC data might be inaccuracies in PSPC response.



Pulsar 1055 fit to PSPC and ACIS above 0.9 keV with the default ACISABS contamination model. Clear overcorrection seen.

1. Model parameters are: $n_H = 1.94 \pm 0.10 \times 10^{20}\mathrm{cm}^{-2}$, $kT_1 = 66 \pm 1$ eV, $N_1 = 2.6 \pm 0.6 \times 10^4$, $\mathrm{kT}_2 = 144 \pm 8\mathrm{eV}$, $N_2 = 69 \pm 56$, $\Gamma = 1.66$, and $N_\Gamma = 1.9 \pm 0.4 \times 10^{-5}$.

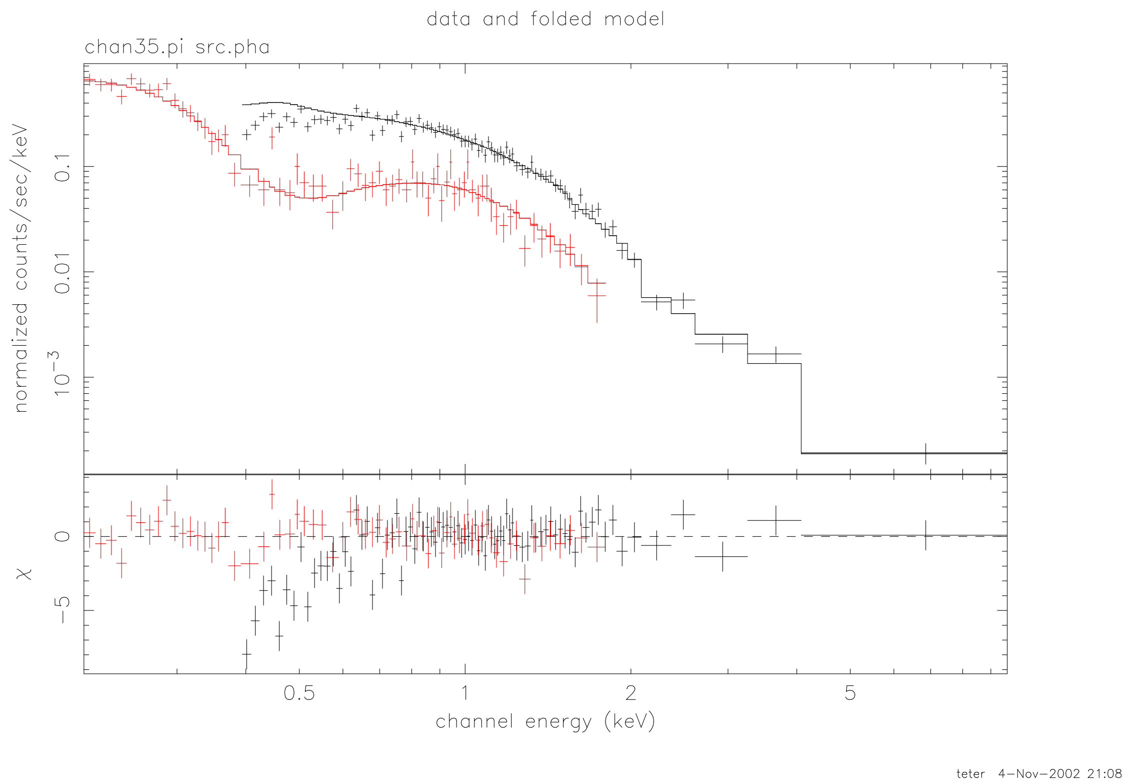
2. Similar overcorrection may be due to PSPC response. It is known that PSPC differs from LETGS by a factor of ~0.2.

3. Best fit number of days was found to be 50±6. Again a very drastic overcorrection than is predicted by ACISABS.

PSR J0437-4715

PSR J0437-4715 was observed in May 2000, 312 days after launch, using the TE mode for a 25 ks exposure. A 10 ks *Rosat* PSPC exposure of Jul 1994 is used as the low energy reference. The spectrum of the millisecond pulsar J0437-4715 can be fit with a simple model consisting of a blackbody of temperature $\sim$ 240 eV, and a power-law of index $\sim$ 3.

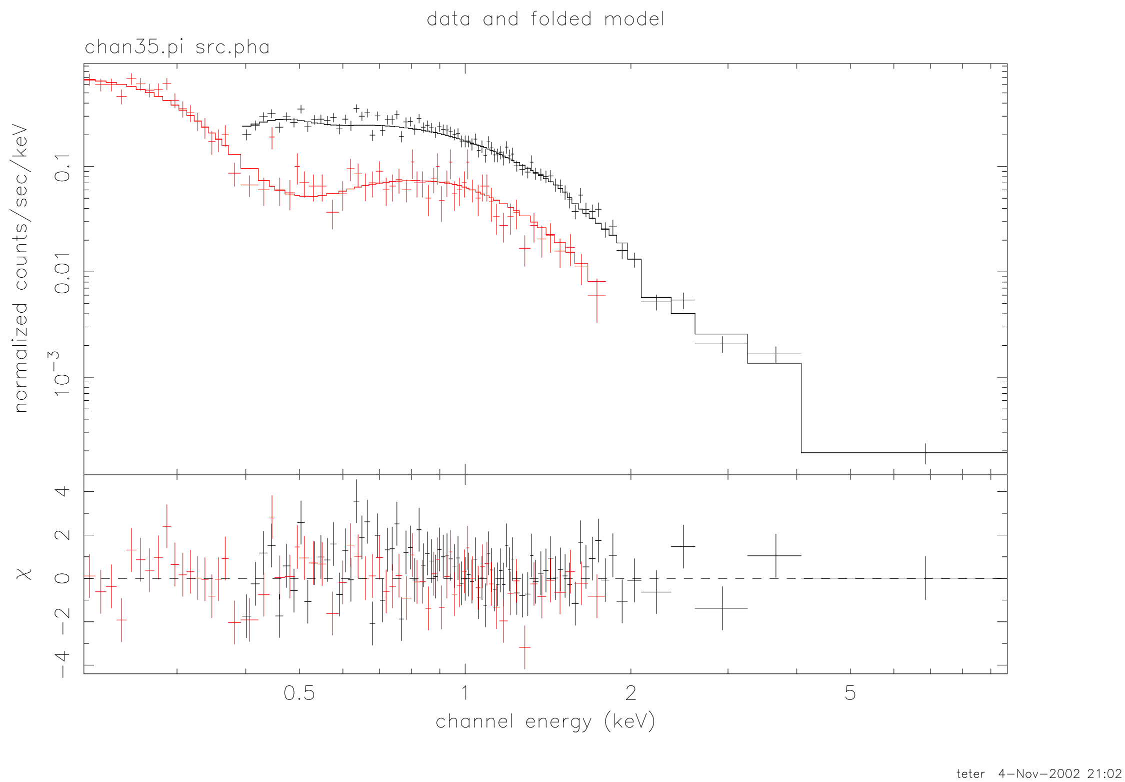
The ACIS data is binned at a minimum of 35 counts while the PSPC data was binned at about 10 counts per bin. The PSPC data was used above 0.22 keV. ACIS data above 10 keV was excluded due to increased background.



Pulsar J0437 fit to PSPC and ACIS above 0.9 keV without ACISABS correction.

1. Model parameters are: $n_H = 6.1 \pm 3.8 \times 10^{19} \mathrm{cm}^{-2}$, $kT = 240 \pm 70$ eV, $N = 12 \pm 2$, $\Gamma = 2.7 \pm 0.1$, and $N_\Gamma = 1.2 \pm 0.3 \times 10^{-4}$.

2. ACIS spectrum fits model fairly well down to 0.6 keV, but there is substantial scatter.



Pulsar J0437 fit to PSPC and ACIS above 0.9 keV with default ACISABS correction. The correction is very good in this case.

1. Model parameters are: $n_H = 5.6 \pm 3.9 \times 10^{19}\text{cm}^{-2}$, $kT = 240 \pm 70$ eV, $N = 14 \pm 3 \times 10^4$, $\Gamma = 2.7 \pm 0.1$, and $N_\Gamma = 1.2 \pm 0.3 \times 10^{-4}$.

2. The ACISABS give an excellent correction in this case.

CONCLUSIONS

1. The ACISABS correction is a vast improvement over uncorrected ACIS spectra.

2. The overcorrection seen in 2 of the fits suggests that the model needs some improvement.

3. There might be a difference between ACIS CC and TE modes with regard to calibration.

4. Additional work is needed for cross calibration for all instruments, including the *Rosat* PSPC.

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