An Update to the HRC-I Quantum Efficiency Model

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Introduction

We present an update to the HRC-I MCP quantum efficiency (QE) model based on calibration observations of the variable blazar PKS 2155-304 taken in November 2002. The HRC-I observation of PKS 2155-304 was taken between two HRC-S/LETG observations of the source. These HRC-S/LETG observations allowed us to model the source and predict a count rate for the HRC-I observation. We found that this predicted rate (based on the old (v2.1) HRC-I QE model) is ~7% lower than the observed rate. Therefore, we have increased the MCP QE model of the HRC-I in the energy range 0.277 - 1.0 keV where PKS 2155-304 radiates strongly and where we previously had no flight data. With this update, we bring the observed and predicted count rates for PKS 2155-304 to within ~1% agreement. Outside of 0.277 - 1.0 keV, the predictions of the current QE model (v. 2.1) are consistent with observations of the other calibration sources - HZ 43, Cas A, and G21.5-0.9.

Adjusting the QE Model

The on-axis quantum efficiency is monitored with regular calibration observations of three sources which radiate in generally distinct regimes: HZ 43 (below 0.2 keV), Cas A (0.7-2.5 keV), and G21.5-0.9 (above 1 keV). Observations of these sources have allowed us to test and constrain the QE model in the respective energy ranges (see the CXC memo "A New Flight Model of the HRC-I MCP Quantum Efficiency" by K. T. Hole, R. H. Donnelly, and J. Posson-Brown, August 2002). However, prior to the PKS 2155-304 observations, we had no flight data in the energy range 0.2-0.7 keV. The PKS 2155-304 observations were done to test the QE model in this range.

For each of the two PKS 2155-304 observations taken with the HRC-S/LETG, we extracted a spectrum and fit a power-law model. The parameters for the fits are shown in Table 1. The fit parameters for the "before" and "after" observations agree within errors. By convolving the source model (using the average value of the power-law index, $\Gamma = 2.375$) with the v2.1 HRC-I QE model, and current HRMA effective area, UVIS transmission, and LETG efficiency models, we derive a predicted count rate of 1.58 cts/s.

Our observed rates are taken from Level 1 event lists which have been filtered on the good time intervals (GTIs) provided in the standard filter files. For the HRC-I PKS 2155-304 observation, we find an observed count rate of 1.70 ± 0.01 cts/s. This is 7% higher than the predicted rate. For the other calibration sources, the observed and predicted count rates agree to within 4% or less.

We increased the QE model in the range 0.277 to 1.0 keV with a smooth quadratic scale factor (see Figure 1) to avoid introducing artificial features. With this increase, the predicted rate for PKS 2155-304 agrees with the observed rate to within $\sim$1%. For the other three sources, the rates predicted by the updated model agree with observed rates to within 3% or less. Table 2 shows the observed rates and predicted rates with QE model v2.1 and with the updated QE model. The percent difference between the observed and predicted rates for each source is shown in parenthesis after the predicted rate.

The updated QE model is shown in Figure 1 with its error envelope in blue. The v2.1 QE model and associated error are overplotted, and the scale factor (minus one) is shown below the model. An updated effective area (EA) model was made by convolving the updated QE model with the most recent UVIS-I transmission and HRMA effective area models. This updated EA model for the HRC-I is shown in Figure 2, with its associated error envelope. The v2.1 EA model and error are overplotted.

The updated QE model has the same relative errors as the v2.1 QE model - 6% overall, with higher uncertainties below the carbon edge ($\sim$20%) and lower uncertainties at higher energies.

ObsID	nH (atoms/cm^2)	Γ	normalization
3709 (before HRC-I)	1.36e20	2.35 $\pm$ 0.05	0.027 $\pm$ 0.002
4406 (after HRC-I)	1.36e20	2.40 $\pm$ 0.05	0.027 $\pm$ 0.002

Table 1: Parameters from power law models fit to HRC-S/LETG PKS 2155-304 observations done before and after the HRC-I PKS 2155-304 observation

Source	Energy Range	Observed Rate	Pred w/ QE v2.1	New Pred
	keV	cts/s	cts/s	cts/s
HZ 43	$\leq$ 0.2	4.35 $\pm$ 0.05	4.29 (1.38%)	4.29 (1.38%)
PKS 2155-304	0.2 - 2.5	1.70 $\pm$ 0.01	1.58 (7.06%)	1.68 (1.18%)
Cas A	0.7 - 2.5	89.19 $\pm$ 1.60	85.77 (3.83%)	86.58 (2.93%)
G21.5-0.9	$\geq$ 1.0	0.61 $\pm$ 0.02	0.62 (1.64%)	0.62 (1.64%)

Table 2: Observed, current (v2.1), and new predicted count rates. The percentages in parenthesis after the predicted rates are the differences from the observed rates.

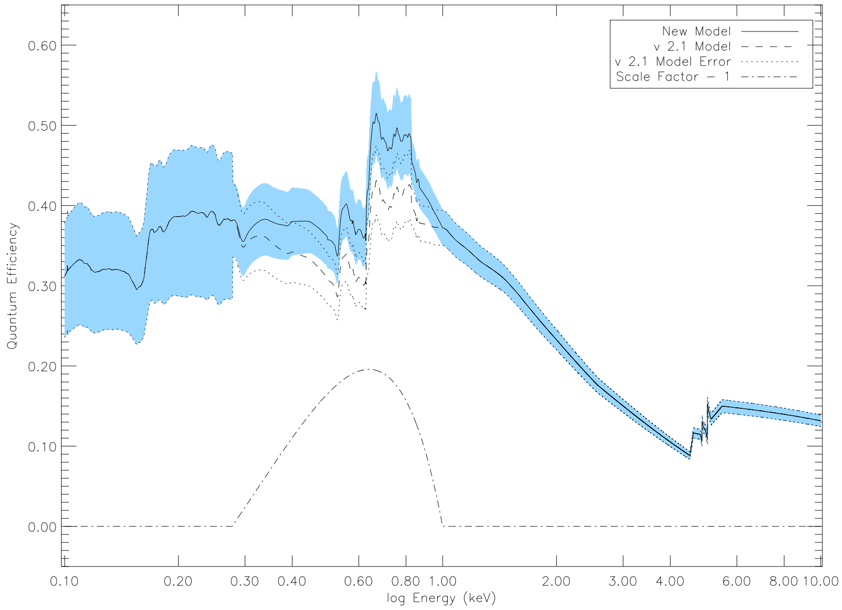

Figure 1: The new QE model and error envelope. The current QE model (v2.1) and error are overplotted, and the scale factor (minus 1) is shown below.

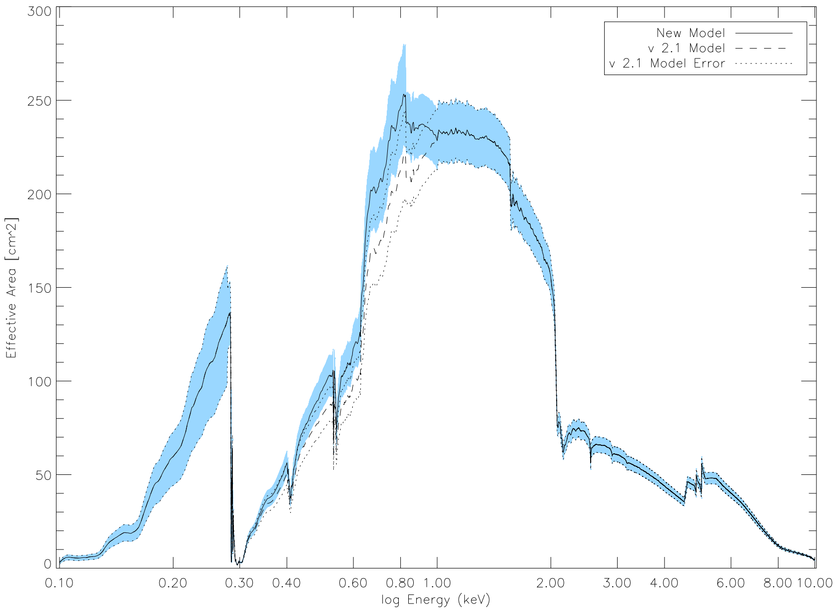

Figure 2: The updated EA model and error envelope. The current model (v2.1) and error are overplotted.