Modeling the instrumental background in HaloSat

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Summary

Analysis of the instrumental background measured using a set of halo targets in the southern Galactic sky shows that the photon index in a power law model of the background spectrum depends on the count rate measured in the hard (3-7 keV) band as well as on the cut level on the hard-band count rate used to filter the data. There does not appear to be a significant dependence on the cut level on the VLE-band count rate used in filtering. A linear equation as given below with the appropriate slope and intercept selected from the table below for the cuts used is found to give a reasonable estimate of the photon index of the instrumental background.

Photon index = slope*(hard rate - hr0) + intercept, where hr0 = 0.05 c/s

Cut level		DPU14		DPU54		DPU38	
Hard	VLE	Slope	Intercept	Slope	Intercept	Slope	Intercept
0.12	0.75	-4.404±0.774	0.924±0.058	-6.138±0.892	0.890±0.049	-5.688±0.907	0.877±0.050
0.16	0.75	-4.642±0.445	0.885±0.059	-5.569±0.521	0.850±0.059	-5.443±0.534	0.837±0.062

The hard band count rate is calculated during generation of the cleaned event lists and is written into the header of the 'SPECTRUM' extension of the .pi files in the keyword 'HARDRATE'. The error on the count rate is written as 'HARDRERR'.

Analysis

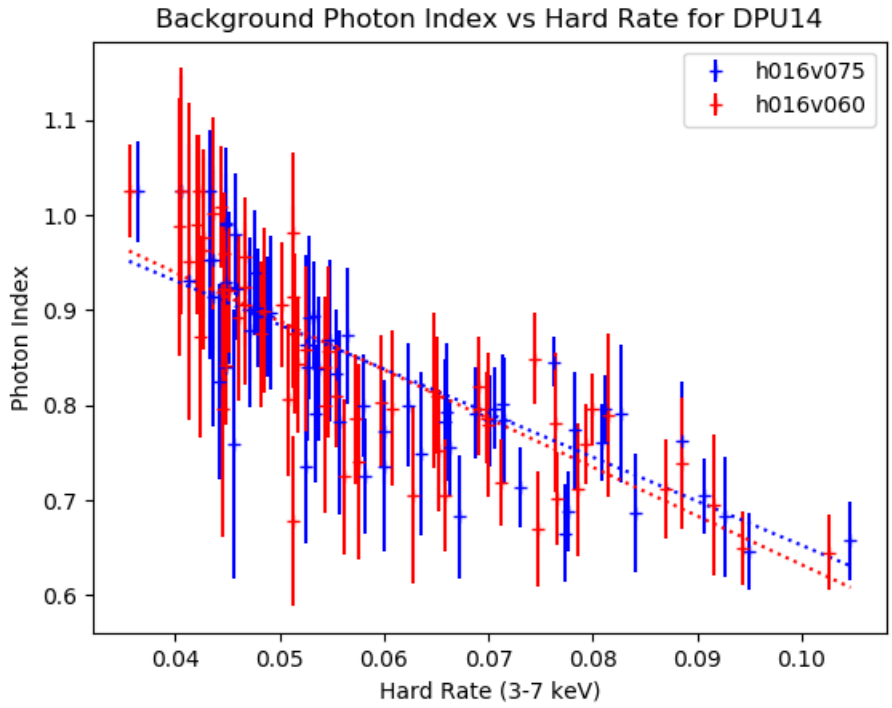
All HaloSat fields with Galactic latitude $b < -30$ and a source type of 'Halo' were used. Four sets of cuts were applied using 64 s bins with the hard cut being 0.12 c/s or 0.16 c/s and the VLE cut being 0.60 c/s or 0.75 c/s. Targets with an average exposure per detector of 8000 s or greater were retained for analysis. The spectra for each target were analyzed with a model consisting of a power law for the instrumental background with normalization and photon index as free parameters, an APEC component to model the local hot bubble component with fixed parameters calculated from Liu et al. (2017, ApJ, 834, 33), a cosmic X-ray background (CXB) component calculated from Capuletti et al. (2017, ApJ, 837, 19), and an APEC component to model the Galactic halo with the abundance fixed to 0.3 Solar and kT and normalization free. The CXB power law and halo APEC were subjected to absorption modeled with the TBabs model (Wilms et al. 2000, ApJ, 542, 914). The absorption column density was estimated using maps of optical extinction, E(B-V), measured with the Planck satellite based on the dust radiance with point sources removed (Planck Collaboration 2014, A&A, 571, A11). Total hydrogen column densities were

calculated from the E(B-V) values over a grid of points in each HaloSat field via a relation appropriate for the TBabs model (Zhu et al. 2017, MNRAS, 471, 3494). The curves of absorption versus energy were then weighted according the relative response within the HaloSat field and an equivalent total absorbing column density was found by fitting the weighted-average absorption curve.

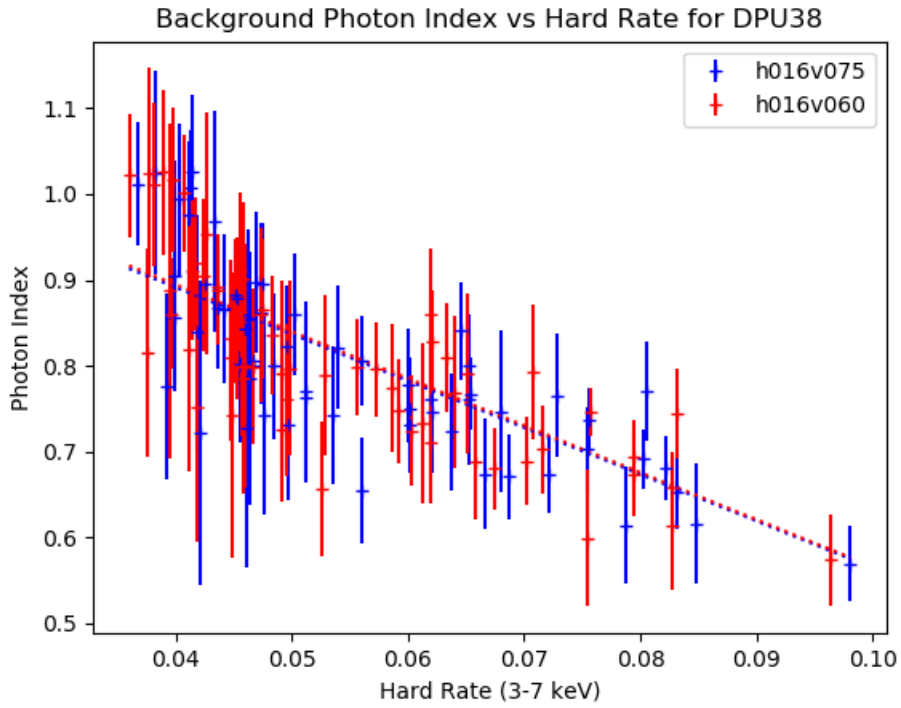
The figure below shows the background photon index versus the count rate in the hard (3-7 keV) band for DPU14 for two sets of filtering cuts, hard rate < 0.16 c/s for VLE rate < 0.75 c/s and < 0.60 c/s. Note the pronounced trend of photon index versus hard rate. The linear fit provides a significance improvement over the weighted average. For hard rate < 0.16 c/s and VLE rate < 0.60 c/s, the weighted average gives X^2/DoF = 162.7/61, while the linear fit gives X^2/DoF = 45.8/60.

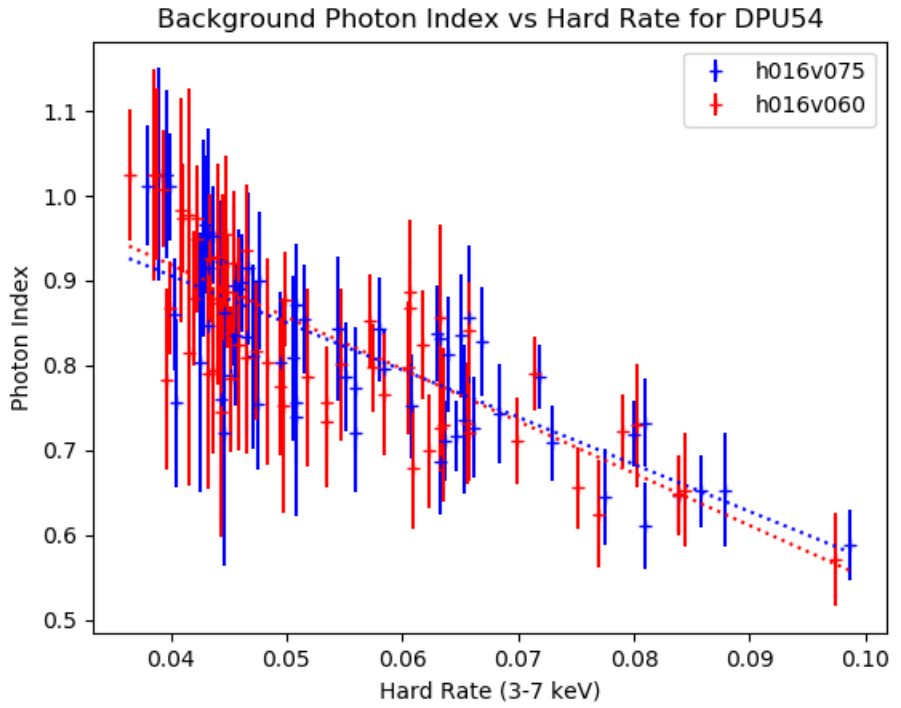
The parameters of linear fits for the two different VLE rate cuts are consistent within errors. The fit parameters for hard rate < 0.16 c/s and VLE rate < 0.75 c/s, give X^2 = 47.0 when applied to the data for hard rate < 0.16 c/s and VLE rate < 0.60 c/s. Similar behavior is found for the pair of cuts with hard rate < 0.12 c/s. Thus, the VLE rate cut does not appear to affect the background photon index for the limited range considered here.

The hard rate cut does have an effect on the relation. The fit parameters for hard rate < 0.12 c/s and VLE rate < 0.60 c/s, give X^2 = 70.2 when applied to the data for hard rate < 0.16 c/s and VLE rate < 0.60 c/s. Similar increases are seen for other pairs of cuts with differing hard rates.



The two figures below show similar results for DPUs 38 and 54.





As a consistency check, the figures below compare the Cash statistic and the fitted emission measure (EM) for data filtered with hard rate < 0.16 c/s for VLE rate < 0.75 c/s for fits with the background photon index free (f01) and with the background photon index calculated from the relations above (f02). The maximum increase in Cash statistic is 0.038. Only 2 (of 62) have a difference in EM larger than the 90% confidence error (by 1.03 and 1.21).