REFERENCES

Dauser, T., Falkner, S., Lorenz, M., Kirsch, C., Peille, P., Cucchetti, E., et al. (2019). SIXTE: a generic X-ray instrument simulation toolkit. *AAP* 630, A66. doi:10.1051/0004-6361/201935978

Remillard, R. A. and McClintock, J. E. (2006). X-Ray Properties of Black-Hole Binaries. *ARAA* 44, 49–92. doi:10.1146/annurev.astro.44.051905.092532

APPENDIX

Since Galactic BH X-ray binaries in outburst can be among the brightest X-ray sources in the sky, mitigation of photon pileup will be necessary for the LET data. Photon pileup becomes significant ($\sim$1%) near 100 mCrab for the LET, yet many BH outbursts reach a peak luminosity of $\sim$1 Crab or more. In order to understand how our simulated results may be affected by the loss of signal due to the mitigation of this pileup, we performed a series of simulations with the SImulation of X-ray TElescopes (SIXTE) software (Dauser et al., 2019), provided by ECAP/Remeis observatory. SIXTE is able to model a telescope's performance and naturally takes into account detector effects such as pileup, and produces images, spectra, event lists, and light curves.

In order to mitigate pileup, typically the core of the source PSF is removed and an annular region is used to extract the source spectrum. We therefore simulated a series of observations from 1 mCrab to 10 Crab, for a typical hard and soft state BH spectrum (as defined by Remillard and McClintock 2006). For each of the two spectral states and at each flux level, pileup statistics were calculated from the SIXTE output event lists, as well as the surviving fraction of source counts necessary to drop below the 1% threshold when removing the core of the PSF. These results are given in Tables 1–3, where each table represents a different observing mode (full frame, 128w, and 64w). The surviving source count fraction in the LET after the pileup is mitigated can be used when simulating *HEX-P* spectra in XSPEC, since it gives a relative factor between the LET and the HETs, which are unaffected by pileup. Pileup mitigation can therefore be considered by applying a factor using the `constant` model in XSPEC.

The general trend, considering the results in Tables 1–3, is that for a brighter source, a smaller fraction of incoming photons will be useful. While some of this is due to photon pileup, many counts which register as a single photon in the detector can be thrown out as invalid due to either the shape or number of individual pixels involved in the detection. The interplay between the numbers of invalid and piled-up counts actually causes the pileup fraction to decrease above $\sim$ a few Crab, while the fraction of useful photons after mitigating pileup still follows the general trend.

Table 1. Summary of Pileup Results, Full Frame

Flux*	Flux*	Hard State		Soft State	
(erg cm^{-2} s^{-1})	(mCrab)	Pileup (%)	Fraction	Pileup (%)	Fraction
2.4×10^{-11}	1	0.06	1.0	0.09	1.0
7.2×10^{-11}	3	0.17	1.0	0.28	0.99
1.44×10^{-10}	6	0.33	1.0	0.55	0.99
2.4×10^{-10}	10	0.56	0.99	0.90	0.99
7.2×10^{-10}	30	1.6	0.71	2.5	0.63
1.44×10^{-9}	60	3.0	0.58	4.6	0.49
2.4×10^{-9}	100	4.6	0.50	6.7	0.46
7.2×10^{-9}	300	9.0	0.43	9.5	0.41
1.44×10^{-8}	600	8.7	0.40	5.9	0.42
2.4×10^{-8}	1 Crab	5.6	0.42	3.7	0.44
7.2×10^{-8}	3 Crab	3.5	0.49	3.9	0.50
1.44×10^{-7}	6 Crab	3.9	0.50	4.3	0.49
2.4×10^{-7}	10 Crab	4.2	0.48	4.7	0.49

*Here, flux is defined across the 2–10 keV energy band.

Table 2. Summary of Pileup Results, 128w

Flux*	Flux*	Hard State		Soft State	
(erg cm^{-2} s^{-1})	(mCrab)	Pileup (%)	Fraction	Pileup (%)	Fraction
2.4×10^{-11}	1	0.01	0.99	0.02	0.99
7.2×10^{-11}	3	0.04	0.99	0.07	0.99
1.44×10^{-10}	6	0.09	0.99	0.14	0.99
2.4×10^{-10}	10	0.14	0.99	0.23	0.99
7.2×10^{-10}	30	0.42	0.99	0.69	0.98
1.44×10^{-9}	60	0.83	0.98	1.35	0.80
2.4×10^{-9}	100	1.35	0.80	2.2	0.63
7.2×10^{-9}	300	3.7	0.54	5.5	0.47
1.44×10^{-8}	600	6.3	0.46	8.5	0.42
2.4×10^{-8}	1 Crab	8.5	0.42	9.7	0.41
7.2×10^{-8}	3 Crab	7.6	0.40	4.7	0.43
1.44×10^{-7}	6 Crab	3.8	0.44	3.5	0.47
2.4×10^{-7}	10 Crab	3.4	0.47	3.8	0.49

*Here, flux is defined across the 2–10 keV energy band.

Table 3. Summary of Pileup Results, 64w

Flux*	Flux*	Hard State		Soft State	
(erg cm^{-2} s^{-1})	(mCrab)	Pileup (%)	Fraction	Pileup (%)	Fraction
2.4×10^{-11}	1	0.01	0.98	0.01	0.99
7.2×10^{-11}	3	0.02	0.98	0.04	0.98
1.44×10^{-10}	6	0.04	0.98	0.07	0.98
2.4×10^{-10}	10	0.07	0.98	0.12	0.98
7.2×10^{-10}	30	0.22	0.98	0.36	0.98
1.44×10^{-9}	60	0.43	0.98	0.70	0.98
2.4×10^{-9}	100	0.71	0.98	1.15	0.87
7.2×10^{-9}	300	2.0	0.64	3.2	0.56
1.44×10^{-8}	600	3.7	0.53	5.6	0.46
2.4×10^{-8}	1 Crab	5.6	0.46	7.9	0.43
7.2×10^{-8}	3 Crab	9.7	0.39	9.0	0.39
1.44×10^{-7}	6 Crab	7.7	0.38	4.8	0.41
2.4×10^{-7}	10 Crab	4.6	0.42	3.6	0.44

*Here, flux is defined across the 2–10 keV energy band.