Analysis of the ACIS Particle Background and Generation of Model Spectra

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Chandra ACIS particle background

- Cosmic-ray particles are a significant contributor to the X-ray background.
- No public tool exists to estimate the paricle-induced background for Chandra.
- Previous work (Bartalucci et al. 2014) studied average spectral shape and spatial variation for ACIS-I chips in VFAINT mode.
- We aim to understand the time and spatial variation of the ACIS-I & S background in VFAINT & FAINT mode in order to provide spectral models.

Data reduction

- Used “ACIS stowed” and blank-sky observations (Table 1).
- Data range from 2002 to 2016 with total exposure of ~940 ks (stowed), and from 2007 to 2010 with total exposure of ~2930 ks (blank-sky).
- Obtained ”merged data” for both the stowed and blank-sky observations by taking sum over all the observations.

Stowed

OBSID	DATE	EXPOSURE (ks)
62664	2016-12-08	9.11
62665	2016-11-03	9.10
62666	2016-10-14	9.00
62667	2016-09-26	10.64
62668	2015-12-09	47.38
62678	2012-06-15	47.38
62802	2011-11-09	50.56
62804	2011-07-12	47.45
62809	2010-03-06	45.60
62810	2009-11-04	49.86
62811	2009-06-19	12.38
62812	2009-06-18	33.15
62813	2008-11-03	49.02
62814	2008-07-26	48.72
62815	2007-11-08	46.45
62816	2007-05-28	46.28
62819	2006-11-18	47.29
62823	2006-06-01	44.11
62824	2005-11-13	47.17
62831	2005-06-10	47.20
62836	2004-11-04	46.62
62846	2003-12-08	45.86
62848	2003-05-04	47.46
62850	2002-09-03	52.49

Blank-sky

OBSID	DATE	EXPOSURE (ks)
12043	2010-03-18	129.58
12044	2010-03-23	99.53
12045	2010-03-28	99.72
12046	2010-04-08	78.02
12047	2010-04-12	10.14
12048	2010-05-23	138.10
12049	2010-05-28	86.94
12050	2010-06-03	29.66
12051	2010-06-10	57.29
12052	2010-06-15	110.41
12053	2010-07-05	68.11
12054	2010-07-09	61.00
12055	2010-05-15	80.68
12123	2010-03-21	24.79
12128	2010-03-27	22.80
12129	2010-04-03	77.14
12135	2010-04-06	62.53
12137	2010-04-16	92.78
12138	2010-04-18	38.53
12213	2010-05-17	61.29
12218	2010-06-11	87.98
12219	2010-06-06	33.66
12220	2010-06-18	48.13
12222	2010-06-05	30.64

Blank-sky (continued)

OBSID	DATE	EXPOSURE (ks)
12223	2010-06-13	100.71
12227	2010-07-14	54.32
12230	2010-07-11	33.81
12231	2010-07-12	24.72
12232	2010-07-18	32.89
12233	2010-07-16	35.57
12234	2010-07-22	49.15
8591	2007-09-20	45.43
8592	2007-10-22	86.64
8593	2007-10-06	49.49
8594	2007-11-01	141.40
8595	2007-10-19	115.42
8596	2007-10-24	115.12
8597	2007-10-17	59.28
9575	2007-10-27	108.69
9578	2007-10-30	38.57
9593	2007-09-22	46.43
9596	2007-11-04	111.89
9718	2007-10-03	49.38

Table 1: Observation logs.

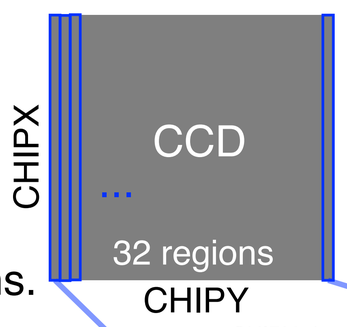
Modeling the background spectra

- Spectral model includes:
  - Al, Si, Ni and Au fluorescence lines as zero-width Gaussians (Table 2).
  - “frame store lines” (produced by inappropriate correction of CTI for events that convert in the frame store region) as broad Gaussians with flat top.
  - continuum as powerlaw, broken powerlaw, exponential and broad Gaussians.
- Spatial variation:
  - used the merged data.
  - flux and spectral shape (mainly frame store lines and continua (< ~1 keV)) vary along CHIPY axis.
  - each chip divided into 32 regions along CHIPY, and modeled (Figure 1).
- Time variation:
  - used the individual stowed spectra extracted from the whole chip regions.
  - stowed data flux showed a negative correlation with the solar activities (Figure 2).
  - < ~10% variation in spectral shapes (difference in low- and high-E flux ratio), parametrized by fitting the individual stowed spectra (Figure 2).

(Mizuno et al. 2004)

Origin		Line centroid (keV)	
Al	Kα	1.48656	+frame store line
	Kβ	1.55745	+frame store line
Si	Kα	1.73978	
Au	Mα2	2.11800	+frame store line
	Mα1	2.12290	+frame store line
	Mβ	2.20500	+frame store line
	Mγ	2.41000	+frame store line
Ni	Kα1	7.46090	
	Kα2	7.47820	
	Kβ1,3	8.26470	
Au	L1	8.49390	+frame store line
	Lα1	9.71330	+frame store line
	Lα2	9.62800	+frame store line
	Lβ2	11.5847	+frame store line
	Lβ1	11.4423	+frame store line

Table 2: Line emissions included in our study.



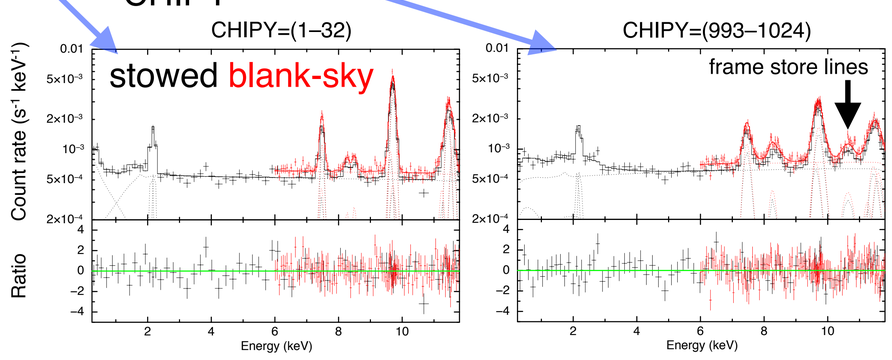


Figure 1: Spectral variation along CHIPY axis (I0, VFAINT mode).

The tool to generate particle background model

- We have developed software to generate a model spectrum for the particle-induced X-ray background given **an input events file and extraction region**.
- Compare the output spectral model to the merged data extracted from the whole chip regions (scaled to fit 9.0–11.5 keV range; Figure 3).
- Applied to an observation of an extended source on the ACIS-I array (fitted using 9.0–11.5 keV; Figure 4).
- Issues to be addressed: - evaluate the uncertainty of the tool quantitatively.
  - check the software bugs to publish it.

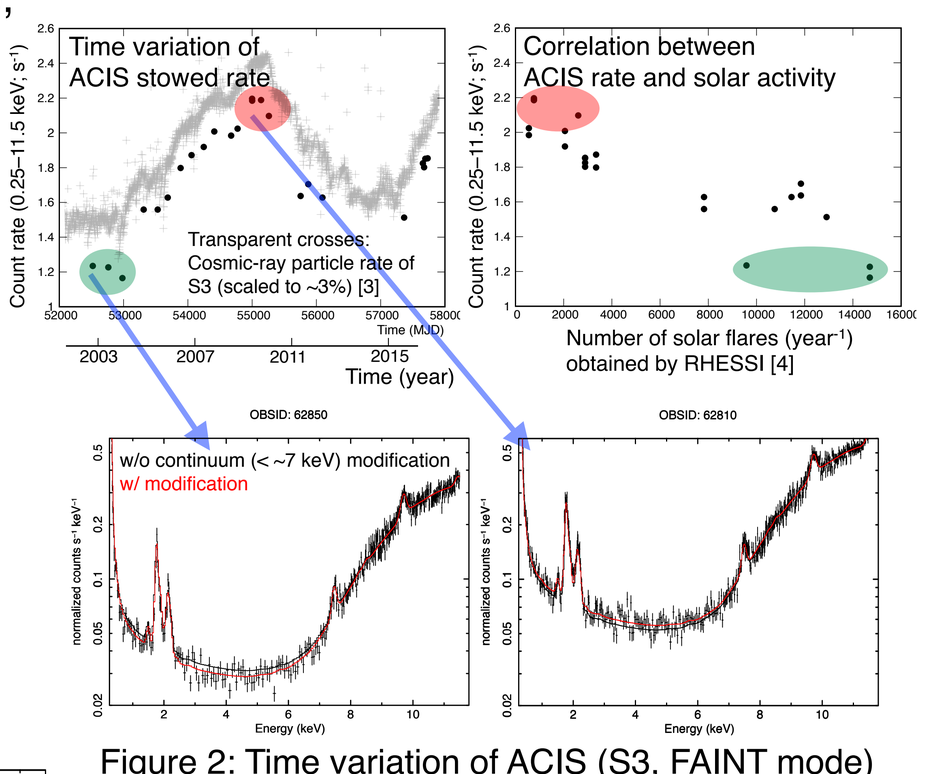


Figure 2: Time variation of ACIS (S3, FAINT mode) paricle background rate and spectral shape.

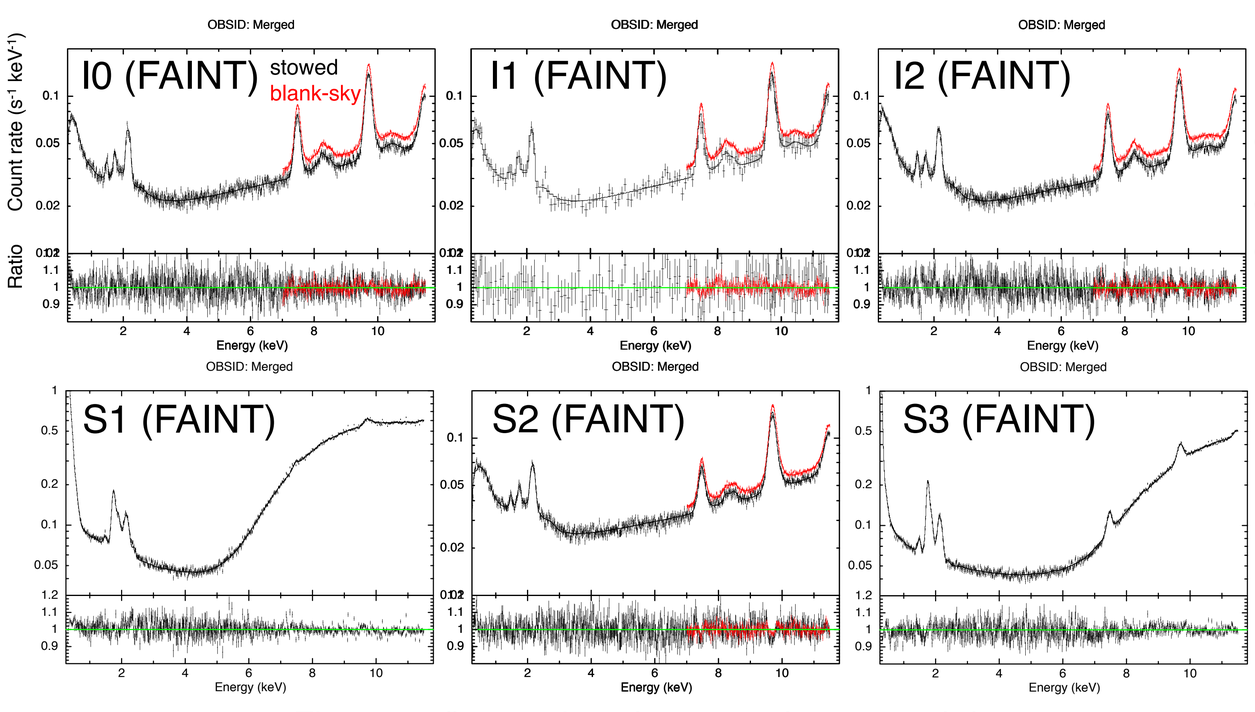
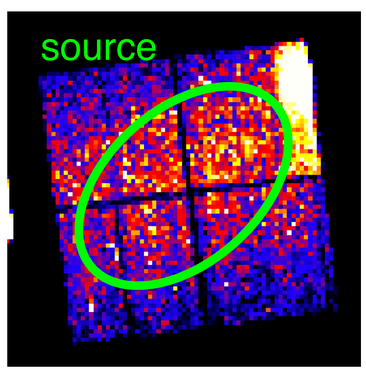


Figure 3: Comparison between the merged data and the output spectral models of the tool.



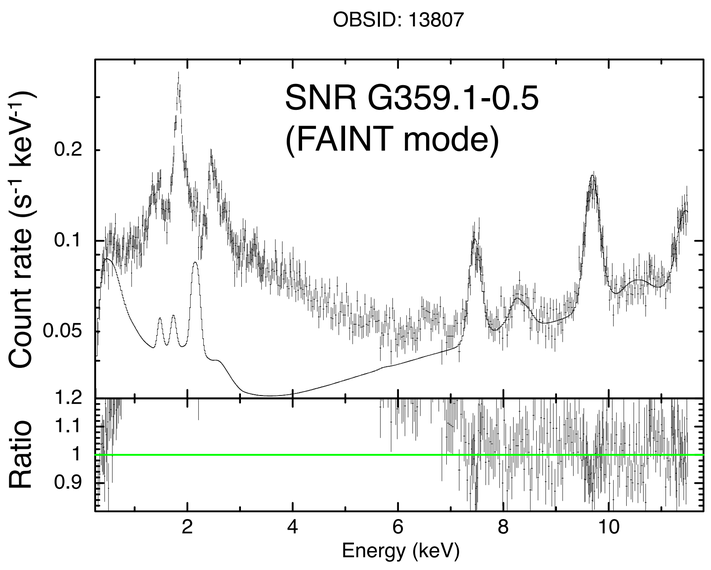


Figure 4: Application of the tool to the SNR G359.1-0.5. The source region covers all the four ACIS-I chips.

References

1. Bartalucci, I., Mazzotta, P., Bourdin, H., et al. 2014, AAP, 566, A25
2. Mizuno, T., Kamae, T., Godfrey, G., et al. 2004, ApJ, 614, 1113
3. ACIS CTI monitoring: https://space.mit.edu/~cgrant/cti/cti120.html
4. RHESSI solar flare list: https://hesperia.gsfc.nasa.gov/rhessi3/data-access/rhessi-data/flare-list/index.html