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SUMAMPS−based Gain Maps and RMF for the HRC−I

Jennifer Posson−Brown, Vinay Kashyap (SAO)

For both the HRC-I and HRC-S, the scaled sum of amplifier signals (SUMAMPS) is a better proxy for spectral response than the PHA. Here we discuss the creation of a set of time-dependent gain maps and an RMF for the HRC-I based on and for use with scaled SUMAMPS. Using observations of AR Lac, G21.5-0.9 and HZ 43 taken regularly since launch, we model the time dependence of the gain decline with an exponential plus linear function. The resulting time-dependent gain maps convert scaled SUMAMPS into "SUMAMPS pulse invariant" (SPI), allowing for comparison of source profiles taken at different epochs or locations on the detector. We apply these gain corrections to HRC-I/LETG observations of HR 1099, PKS 2155-304, and Cygnus X-2 and use this data to create a redistribution matrix (RMF). The RMF is derived by modeling the SPI profiles at given wavelength bins with two Gaussians. The RMF captures the gross energy resolution of the HRC-I and can be used to interpret hardness ratios or quantile plots.

I. Scaled SUMAMPS

- SUMAMPS: sum of signals from 3 amplifiers nearest event signal on each axis
- SAMP: scaled SUMAMPS = $\frac{SUMAMPS \times 2^{AMP\_SF-1}}{C}$. C=148; chosen to match PHA values (see Figures 1 and 2)
- SPI: pulse invariant (gain-corrected) SAMP
- SPI will replace PI in HRC event lists

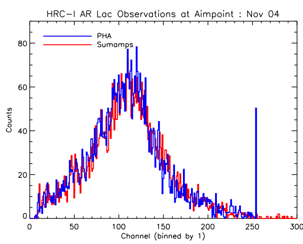

Figure 1 A comparison of PHA and SAMP profiles for HRC-I AR Lac ObsID 4292. Note that the profiles are very similar, except for PHA piling up at channel 255.

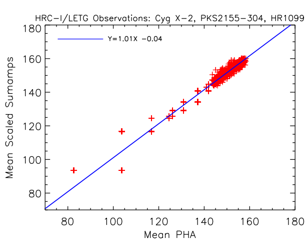

Figure 2 Mean PHA vs mean SAMP for several sources (HR1099, PKS2155-304, and Cygnus X-2) observed with HRC-I/LETG. Each point represents the background-subtracted mean of the combined PHA or scaled SUMAMPS (SAMP) profile in a given wavelength bin. The solid blue line shows a linear fit to the data between PHA=140:160. Note that the best-fit slope ≈ 1 and the best-fit offset ≈ 0 indicating that mean SAMP tracks mean PHA over a range of energies.

II. Gain Maps

- Like PHA, scaled SUMAMPS reflect the gain decline over time (Figure 3)
- Observations of AR Lac at 21 locations on detector and HZ 43 and G21.5-0.9 at aimpoint used to make set of time-dependent gain correction maps
- Gain correction maps defined as $g(\vec{x}|t) = g_{LAB}(\vec{x}) \times \gamma(\vec{x}|t) \times TC(t)$ where
  - $g_{LAB}(\vec{x})$ = preflight gain correction map, based on lab flat field maps
  - $\gamma(\vec{x}|t)$ = spatial correction surface, extrapolated for each epoch from set of 20 spatial correction factors. These correction factors are determined by matching profiles of 20 offset AR Lac observations per epoch to aimpoint profile (e.g. Figure 4).
  - $TC(t) = \frac{a_0+a_3}{a_0 e^{-a_1 t}+a_2 t+a_3}$. This time-dependent correction function is fit to temporal correction factors (Figure 5). The correction factors are determined by matching profile of aimpoint observation at given time to profile at initial time for AR Lac, G21.5-0.9 and HZ 43.
- Final gain correction maps shown in Figure 6. They correct for the temporal and spatial variation in scaled SUMAMPS (Figures 7 and 8).

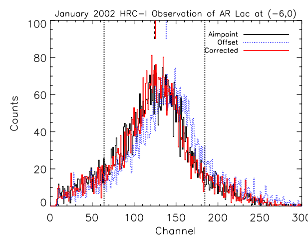

Figure 4 Example of profile matching to determine spatial correction factor. The black histogram shows the aimpoint SAMP profile and the blue dotted histogram shows the offset SAMP profile (6′ off-axis in this case). The red histogram shows the offset profile corrected by a factor of γ=0.906. The dotted black lines show the region where the matching was performed. The short bars at the top of the plot indicate the profile means.

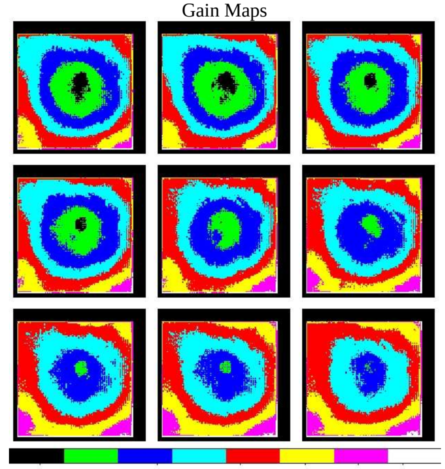

Figure 6 The final gain correction maps, shown on a log scale from 0.9 to 4.0. They proceed in chronological order from top to bottom, left to right.

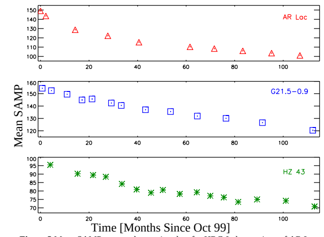

Figure 3 Mean SAMP versus observation date for HRC-I observations of AR Lac (top), G21.5-0.9 (middle) and HZ 43 (bottom) taken regularly since launch. All three sources show the gain decline.

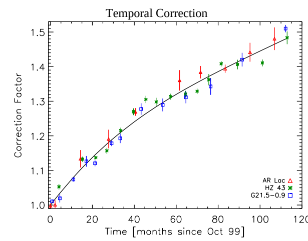

Figure 5 The temporal correction function $TC(t) = \frac{a_0+a_3}{a_0 e^{-a_1 t}+a_2 t+a_3}$ fit to correction factors derived from AR Lac, G21.5-0.9 and HZ 43 observations at the aimpoint by matching the profile of observations at time > 0 (measured in months since Oct 1999) to the profile of the initial observation.

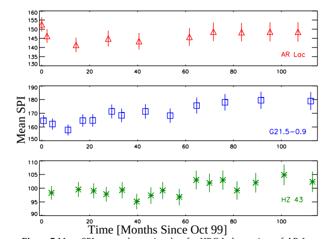

Figure 7 Mean SPI versus observation date for HRC-I observations of AR Lac (top), G21.5-0.9 (middle) and HZ 43 (bottom) taken regularly since launch. The gain correction maps have removed the downward trend with time seen in Figure 3.

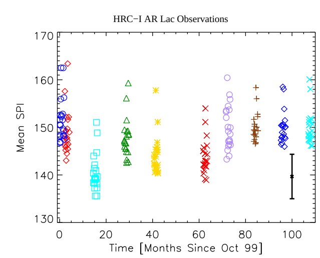

Figure 8 Mean SPI versus observation date for HRC-I observations of AR Lac, with 21 observations per epoch (one at the aimpoint and 20 at offset locations). The black bar in the lower right corner shows the typical 2-sigma error.

III. RMF

- We apply gain maps to HRC-I/LETG observations of Cygnus X-2, PKS 2155-304 and HR 1099.
- Spectra are combined and background subtracted, using the continuum regions for each source (Table 1). We group the data into wavelength slices with at least 4000 counts per slice.
- We fit the SPI profile for each wavelength slice with two Gaussians (Figure 9).
- Fit results (Gaussian mean, sigma, normalization and reduced Chi-square) shown in Figure 10.
- Loess-smoothed fit results used to construct RMF. See Poster C.14 (Kashyap & Posson-Brown) for RMF images and applications.

Source	ObsID	Exposure Time s	Date	Wavelength Range Å
Cygnus X-2	87	29653.09	2000-04-24	1 - 12
PKS 2155-304	1801	13726.06	2000-08-10	1 - 20
	3716	7328.56	2002-11-30	
HR 1099	1388	2259.95	1999-10-27	11.5 - 12.5, 17 - 50
	1389	2259.01	1999-10-27	
	1392	2260.08	1999-10-27	
	1393	2259.02	1999-10-27	

Table 1 HRC-I/LETG observations used to create RMF.

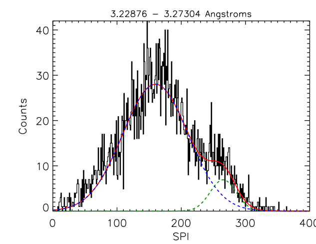

Figure 9 Example of 2-Gaussian fit to SPI profile of combined Cygnus X-2 and PKS 2155-304 data between 3.2876 - 3.27304 Å. One Gaussian (dashed blue line) fits the primary peak and the second (dashed green line) fits the high-energy shoulder.

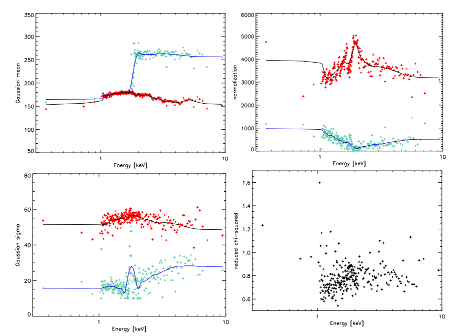

Figure 10 Results of 2-Gaussian fits: mean (top left), sigma (top right), normalization (bottom left), and reduced Chi-square (bottom right). The red points show the fit parameters for the primary (central) Gaussian and the cyan points show the fit parameters for the secondary (high-energy shoulder) Gaussian. The black and blue lines show the Loess smoothing of the data.