MINIS spectrometer gain

The x-ray spectrometer converts each x-ray into a 12 bit digital word which indexes into a 208 channel spectrum where the corresponding bin is incremented. The electronics is linear, but the scintillator crystal isn't. Its light output varies with temperature, and also droops at higher energy.

We require a relation between channel number and energy deposited within the crystal. For instance, the center energy of a spectrum bin, $E_c = f_c(i, T)$, is a function of bin number $i \in \{0, 207\}$ and temperature T. To a good approximation, $f_c(i, T) = g_c(i)H(T)$ factors into a term approximately proportional to the bin number and a term which depends on temperature.

If $j \in \{0, 4095\}$ denotes a raw spectrometer bin, then the center energy is $(j + 1/2)H(T)$. Since the MINIS flight computer rebins spectrometer output words into a 208 channel spectrum, we need to recover an approximate raw bin from the rebinned spectrum. The binning scheme is as follows:

Raw range	group size	new range
0–59	2	0–29
60–247	4	30–76
248–479	8	77–105
480–959	16	106–135
960–2431	32	136–181
2432–4095	64	182–207.

From this table, one finds $g_c(5) = 11$ or $g_c(183) = 2528$.

By observing how the 511 keV line varies with time, we can effectively isolate the temperature dependent part of the function, $h(t) = H(T(t))$ (where t is time), without having to know the crystal temperature. This works because there is a unique temperature at every time. I tracked the 511 keV peak through each flight and then found an approximating function for $h(t)$ (keV/raw bin), where t is the tick counter.

$$h_{1\mathrm{N}}(t) = \begin{cases} 2.247 & \text{if } t < 255000; \\ -1.57423 \times 10^{-12} t^2 + 1.12949 \times 10^{-6} t + 2.06087 & \text{if } 255000 \leq t < 555000; \\ -1.79218 \times 10^{-12} t^2 + 2.50972 \times 10^{-6} t + 1.42568 & \text{if } 555000 \leq t < 1005000; \\ -324593/t - 2.25527 \times 10^{-8} t + 2.50031 & \text{if } 1005000 \leq t < 3675000; \\ 2.329 & \text{if } 3675000 \leq t. \end{cases}$$

$$h_{2\mathrm{N}}(t) = \begin{cases} 1.997 & \text{if } t \leq 660000; \\ -1.89415 \times 10^{-14} t^2 + 1.67503 \times 10^{-7} t + 1.93895 & \text{if } 660000 < t < 3500000; \\ -8.92314 \times 10^{-14} t^2 + 8.03179 \times 10^{-7} t + 0.585892 & \text{if } 3500000 \leq t < 5500000; \\ 3.52973 \times 10^{-14} t^2 - 5.19149 \times 10^{-7} t + 4.10544 & \text{if } 5500000 \leq t < 7000000; \\ 2.201 & \text{if } 7000000 \leq t. \end{cases}$$

$$h_{1\mathrm{S}}(t) = \begin{cases} 2.144 & \text{if } t \leq 510000; \\ -7.82826 \times 10^{-17} t^3 + 2.19636 \times 10^{-10} t^2 - 2.2793 \times 10^{-4} t & \\ \quad +105.401 - 1.72244 \times 10^{7}/t & \text{if } 510000 < t \leq 930000; \\ 1.9249 - 1.2059 \times 10^{-7} t & \text{if } 930000 < t < 1440000; \\ 2.42476 \times 10^{-20} t^3 - 2.77349 \times 10^{-13} t^2 + 1.11251 \times 10^{-6} t & \\ \quad +0.607299 & \text{if } 1440000 \leq t < 5000000; \\ 2.264 & \text{if } 5000000 \leq t. \end{cases}$$

$$h_{2\mathrm{S}}(t) = \begin{cases} -4.34771 \times 10^{-16} t^2 + 2.13959 \times 10^{-8} t + 2.22583 & \text{if } t \leq 18000000; \\ 1.26874 \times 10^{-17} t^2 - 2.33722 \times 10^{-9} t + 2.53212 & \text{if } 18000000 < t. \end{cases}$$

$$h_{3\mathrm{S}}(t) = \begin{cases} -3.65812 \times 10^{-13} t^2 + 1.95382 \times 10^{-7} t + 2.2257 & \text{if } t \leq 1400000; \\ 6.40846 \times 10^{-8} t + 1.9573 & \text{if } 1400000 < t \leq 8600000; \\ 0.0413276 \sin(7.272 \times 10^{-7} t + 1.56519) - 4.59543 \times 10^{-9} t & \\ \quad +2.48827 & \text{if } 8600000 < t. \end{cases}$$

$$h_{4\mathrm{S}}(t) = \begin{cases} -2.66554 \times 10^{-2} \sin(7.272 \times 10^{-7} t + 19.6335) \\ \qquad -2.69042 \times 10^{-16} t^2 + 8.62646 \times 10^{-9} t + 2.09771 \end{cases}$$