SIS gain numbers

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Abstract

We revised the gain numbers of the all chips of SIS. Relative gain to S0C1 is determined by combining the SNR data of Cas A, W49B, N132D together with the Ni line data in the background. Absolute gain of S0C1 is determined from the Ni line (1 ccd faint mode) in the background data. New gain numbers may be accurate to $\pm 0.3\%$.

1 Relative gain

Relative gain between chips can be measured by using stable sources with strong emission lines. We used the bright SNRs Cas A, W49B and N132D for this purpose. Ni line in the internal background is also used. Data used to calculate the relative gain are listed in table 1. In the analysis of relative gain, s0c1 is selected as a reference chip.

It is known that radiation damage of SIS changes the observed line energies systematically. Thus a careful data analysis is required. Two kinds of phenomena are known in relation to the radiation damage, *i.e.* RDD and CTI. RDD effect is largest in 4 ccd mode and is negligible in 1 ccd mode. The 4/2 ccd mode data used in the present analysis were all obtained just after the launch (within $\sim$4 months) when the radiation damage was not significant. Therefore, it may not be necessary to worry about the RDD very much. To minimize possible RDD effect, we used new dfe correction software (animaldfe5.41) in the present analysis. This new version of the dfe correction program uses RDD model function as a template, and hence artificial offset of the energy scale which might be brought into the data in the course of dfe correction should be minimum.

Table 1: Data used to calculate relative gain

Target	date	mode	Used line	Remark
W49B	April 24, 1993	4/2 ccd faint	Fe	s0c12/s1c30
	Nov 3, 1993	1 ccd faint	Fe	s0c30/s1c12
N132D	Sept 23, 1993	1 ccd faint	Si	
Cas A	July 27, 1994	1 ccd faint	Si	
	Aug 3, 1995	1 ccd faint	Si	
Ni (BGD)	April–June, 1993	4 ccd faint	Ni	Accumulated for 3 months

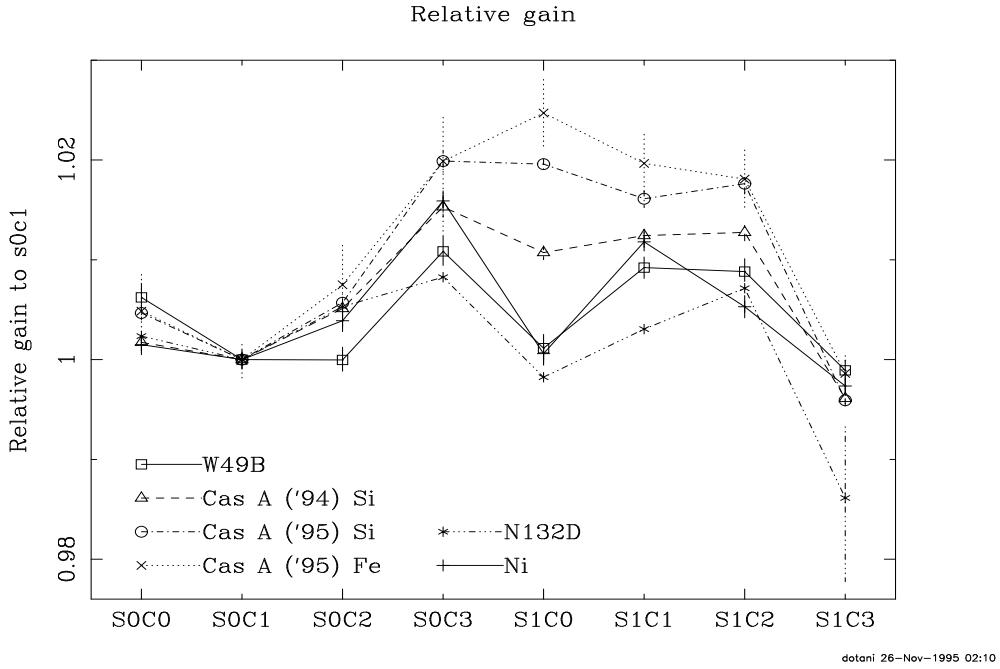

Figure 1: Relative gain of chips determined from W49B (Fe), N132D (Si), Cas A (Si,Fe), and Ni line in the background. N132D data have relatively poor statistics and the error bar is shown only for S1C3. Standard corrections to the data such as echo, dfe, and CTI corrections were applied to the data except for Ni line, which is not corrected for CTI. Note that the relative gain determined from Cas A data is significantly different from the other results, and the difference is larger in 1995 data.

CTI is supposed to increase with time after the launch. Thus CTI may not be important for Ni, N132D, W49B April data, which were acquired just after the launch. CTI correction is important only for Cas A and W49B November data. Although it may not be necessary, CTI correction was applied to N132D and both sets of W49B data. Note that we cannot apply CTI correction directly to Ni data because the number of transfer is not known for Ni events. It was recently found that CTI is significantly non-uniform over a chip (see the report on Nov 23 by Dotani et al), and the CTI values currently in use may not be correct. However, analysis of Ni line energy shows that CTI correction, even with the current values, reduces long-term changes of Ni line energy compared to the data not corrected for CTI. Thus we applied CTI correction to W49B November data as well as the April data using the current CTI values (determined by Cas A data in 1994). CTI correction to W49B November data may not be accurate enough. However, this is the best correction we can do with the current understanding of SIS.

In the case of Cas A data, we found that CTI correction did not work well. If we apply standard correction of echo, dfe and CTI to the data, relative gain of the chips determined by Cas A data was very different from that obtained from W49B, Ni and N132D data especially for S1C0. The results are shown in figure 1. It is clear from the figure that the relative gain determined from

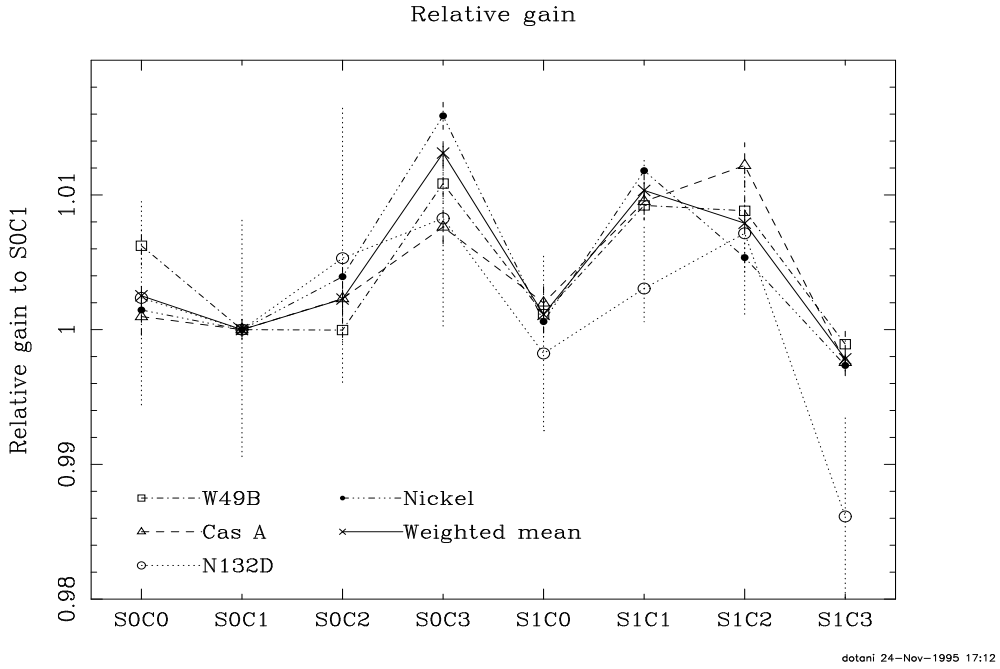

Figure 2: Relative gain of chips determined from W49B (Fe), N132D (Si), Cas A (Si), and Ni line in the background. Cas A line energies used to determine the relative gain are those extrapolated to the time at launch from the data in 1994 and 1995. Weighted mean of these results is used to determine the relative gain.

Cas A data is significantly different from the other results (especially for S1C0) and the difference is larger in later data. Because the difference increases with time, we interpret that the CTI values used to correct Cas A data are different from the true values. This is considered to be due to the non-uniformity of CTI.

Because it is difficult to estimate the CTI values appropriate to the Cas A data, we adopted an alternative method. Ni line analysis shows that CTI increases approximately linearly with time after the launch (see figure 3). Cas A data in 1994 and 1995 were obtained at exactly the same pointing positions. Thus we can assume that the decrease of the line energies of Cas A is proportional to the time after the launch. Using Cas A data in 1994 and 1995 (uncorrected for CTI), we can estimate the line energies of Cas A at the time of launch. The relative gain estimated using the extrapolated Cas A line energies is shown in figure 2 with other results. Cas A results are now almost consistent with other results and hence the extrapolation seems to work well.

Relative gain of the chips was determined by taking a weighted average of the data shown in figure 2. Results are listed in table 2.

Table 2: Relative gain to S0C1

S0C0	S0C1	S0C2	S0C3	S1C0	S1C1	S1C2	S1C3
1.0025	1.0000*	1.0023	1.0131	1.0011	1.0103	1.0079	0.9978

*Definition.

Table 3: New gain numbers

	S0C0	S0C1	S0C2	S0C3	S1C0	S1C1	S1C2	S1C3
New gain	3.5394	3.5622	3.2738	3.4636	3.1493	3.2540	3.4987	3.2347
Old gain	3.5564	3.5703	3.2887	3.5170	3.1600	3.2951	3.5344	3.2350

Unit of the gain number is eV/ADU.

2 Absolute gain

Because the relative gain is defined to S0C1, we need to determine the absolute gain of S0C1. For this purpose, we need to use an emission line at known energy. Only the Ni line in the background has enough flux necessary to determine the gain accurately. We accumulated background data every 3 months and then determined the Ni line energy. The data accumulated are 1 ccd fain mode and are corrected for dfe and echo. On-source data are also included to improve statistics if the source count rate is smaller than 0.1 counts/sec/SIS. We know empirically that such dim sources do not have significant flux around the Ni line.

We show in figure 3 the long-term history of the Ni line energy. Ni line energy show gradual decrease due to the CTI. As mentioned earlier, the decrease is monotonous and is almost proportional to the elapsed time after the launch. Thus, if a linear function is fit to the Ni line history and the function is extrapolated to the time at launch, it is expected to represent Ni line energy with no CTI. The best-fit linear function is also shown in figure 3. We found that the Ni line energy of S0C1 (1 ccd mode) at launch is 7.482 ± 0.010 keV.

Ni line Kα energy is 7.47234 keV. However, according to the Monte Carlo simulation, Ni events generated in the frame store region show systematically lower energy than those in the exposure region by about 20 eV due to the different pixel size. Analysis of the V-address and 1/2/4 mode dependence of Ni line flux shows that Ni line flux ratio between imaging and frame store regions is about $F^{\rm FS} : F^{\rm IM} \sim 7 : 3$. Therefore, Ni line in the background is expected to appear at 7.4648 keV. Comparison of the observed Ni line energy to the expected one shows that S0C1 gain should be lowered by 0.23%.

Using the absolute gain of S0C1 and the relative gain to S0C1, we can determine the gain numbers of each chip. New gain numbers are listed in table 3. We believe that accuracy of the gain numbers may be $\pm$0.3%.

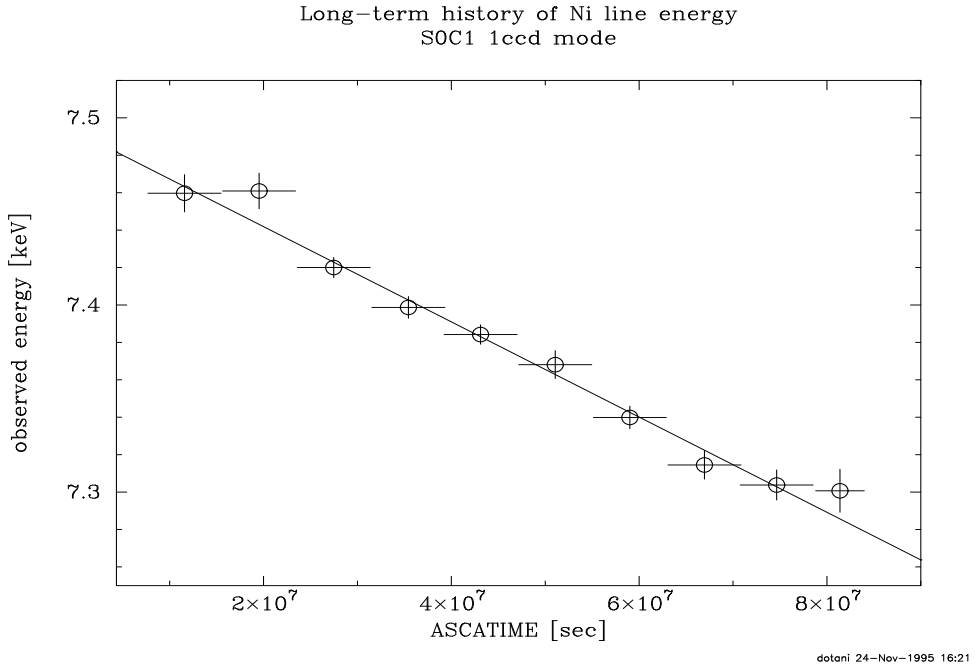

Figure 3: Long-term history of the Ni line energy obtained with S0C1. Ni line energy shows gradual decrease due to the CTI. Absolute gain was determined by extrapolating the Ni line energy to the time of launch (asca time = 4.3272×10^6).

3 Future work

We used Ni line data to determine the absolute gain of S0C1. However, Ni line data are available for all chips and hence gain numbers could be determined directly from Ni data. This should give consistent results with those listed in table 3. Such cross-check with the Ni line data is a future work.