ACIS Memo #204
Massachusetts Institute of Technology
Center for Space Research
Cambridge, MA 02139
Room NE80-6053/37-518A
cgrant@space.mit.edu

To: ACIS Team
From: Catherine Grant
Subject: Dependence of ACIS performance on small temperature changes
Date: 13 June 2003

This memo investigates the dependence of CTI, detector gain, pulseheight and line width on small (few degree) changes in focal plane temperature. These temperature excursions occur with some regularity during the CTI pad time observations and are sometimes seen during science observations as well. It has already been established that the performance of both FI and BI CCDs changes dramatically between a temperature of -110C and -120C. The dependence of CTI on much smaller temperature changes has been reported anecdotally, but never systematically studied. Since there is interest in utilizing portions of the CTI pad time for science observations, it may become more important to identify how large a temperature excursion needs to be to effect calibration accuracy.

1 Data

In order to minimize the effect of changes in background and radiation damage, the analysis is limited to a small number of consecutive orbits. The details of the observations utilized are shown in Table 1. Identical analysis is shown for two time periods; one in which ingress is warm and one in which egress is warm.

To investigate whether the temperature during the bias frames has any effect on the results, identical analysis was done for the same data subtracting two different biases. The first bias was that taken as part of the observation, so the bias temperature is similar to that of the data. The second bias was from a single observation with the nominal focal plane temperature. After correcting for the different initial overclock values for each observation, the results were very consistent. Since the general practice for the pipeline has always been to use the bias that comes with the data, all the analysis presented here will do the same. If there are small variations in the bias structure due to temperature, they would be present in both the bias and the data so this practice seems sensible.

The background (s3 amp_rej) is reasonably stable during both time periods with small day to day fluctuations but no significant trends. Using the CTI background relation used in CTI monitoring, the resulting change in measured CTI induced by the background fluctuations is no more than 5×10^{-7} or a few tenths of a percent. In addition the background rate shows no significant correlation with focal plane temperature. While changes in the background should not skew the overall results, the data errors will be increased accordingly. The S3 observations should be unaffected by background changes.

Table 1: Data

ObsID	Date	Mean T	Max T	Min T	Orbit
61026	2002:264:0834	-119.21	-118.74	-119.54	Egress
61022	2002:267:0021	-116.32	-115.51	-117.12	Egress
61021	2002:269:0636	-119.70	-119.70	-119.70	Ingress
61019	2002:269:1452	-117.15	-116.96	-117.61	Egress
61017	2002:271:2028	-119.74	-119.70	-119.87	Ingress
61015	2002:272:0645	-116.73	-116.48	-117.12	Egress
61012	2002:274:2235	-118.32	-118.09	-118.58	Egress
61011	2002:277:0403	-119.76	-119.70	-119.87	Ingress
61009	2002:277:1318	-115.99	-115.83	-116.32	Egress
61007	2002:279:1846	-119.71	-119.70	-119.87	Ingress
60898	2003:002:1148	-119.12	-118.90	-119.54	Egress
60896	2003:004:1640	-118.12	-117.93	-118.25	Ingress
60892	2003:005:0242	-119.68	-119.54	-119.70	Egress
60888	2003:007:1857	-119.70	-119.70	-119.70	Egress
60886	2003:010:0140	-117.64	-117.45	-118.09	Ingress
60884	2003:010:0947	-119.70	-119.70	-119.70	Egress
60883	2003:012:1503	-118.35	-118.09	-118.74	Ingress
60882	2003:013:0051	-119.69	-119.54	-119.70	Egress
60881	2003:015:0824	-117.68	-117.28	-118.09	Ingress
60880	2003:015:1717	-119.71	-119.70	-119.87	Egress
60878	2003:018:0751	-119.70	-119.70	-119.70	Egress
60877	2003:020:1327	-118.47	-118.09	-118.74	Ingress

Only the I3, S2 and S3 CCDs are including in this analysis. Because S2 and S3 are part of both the I-array and S-array configurations, there are twice as many measurements in each time period as there are for I3. Since S2 has a higher CTI than the I-array CCDs which in turn have higher CTI than S3, the magnitude of any change with temperature due to charge trapping will likely be largest on S2 and smallest on S3.

2 CTI

Figure 1 shows the parallel CTI at Mn-Kα (5.9 keV) for I3, S2, and S3 as a function of focal plane temperature. Since the CTI change between the two time periods is very small, both time periods are analyzed together. A simple linear fit to the data yields a CTI change of $(3.6 \pm 0.2) \times 10^{-6}$ and $(4.5 \pm 0.1) \times 10^{-6}$ per degree for I3 and S2, or $2.5 \pm 0.1\%$ and $2.6 \pm 0.1\%$ per degree. No significant change with temperature is seen for S3.

The statistical error on a typical FI CCD CTI measurement is of order a few 10^{-7}, so the need for a strict temperature criterion for CTI monitoring is clear. In fact, temperature variations within our currently accepted limits (~ 0.5C) may cause some of the excess scatter seen in CTI monitoring plots (see `http://space.mit.edu/~cgrant/cti` for example plots).

3 Detector Gain

The detector gain is defined as a linear fit to the Al-K, Ti-Kα and Mn-Kα lines for data in the bottom 20 rows closest to the readout. There is no significant dependence of either the slope or offset of this fit as a function of temperature for any CCD.

4 Pulseheight and Line Width

From the user's perspective, the important calibration metrics are the change in line pulseheight and width as a function of focal plane temperature. The next two plots, figures 2 and 3, show the dependence of 5.9 and 1.5 keV pulseheight on temperature for the top 200 rows of the CCD. Table 2 lists the results of a linear fit to the data.

Table 2: Pulseheight Change

CCD	5.9 keV Peak Change		1.5 keV Peak Change	
	ADU / degree	Percent / degree	ADU / degree	Percent / degree
I3	-4.3 ± 1.3	-0.33 ± 0.10	-1.9 ± 0.3	-0.67 ± 0.10
S2	-5.2 ± 0.7	-0.41 ± 0.05	-2.6 ± 0.1	-0.97 ± 0.05
S3	$+1.1 \pm 0.2$	$+0.09 \pm 0.02$	$+0.49 \pm 0.05$	$+0.17 \pm 0.02$

Currently, the published accuracy of ACIS gain calibration is 0.3%. Both of the FI CCDs will grossly violate this beyond a degree from the nominal temperature. The gain change is much smaller for S3, so three degrees is marginally acceptable. Temperatures more than a degree from nominal have been seen during science observations, but only a subset - those which require CCD spectroscopy on an FI CCD - are strongly affected.

The final two plots, figures 4 and 5, show the dependence of 5.9 and 1.5 keV line width on temperature for the top 200 rows of the CCD. The measurement errors are much higher and consequently only the S2 data has a significant (99%) dependence on temperature. At both energies, a linear fit to the data yields a change in line width of $\sim 4\%$ per degree. I am uncertain if there is a published specification for line width calibration, but for most data it is doubtful that this is measurable.

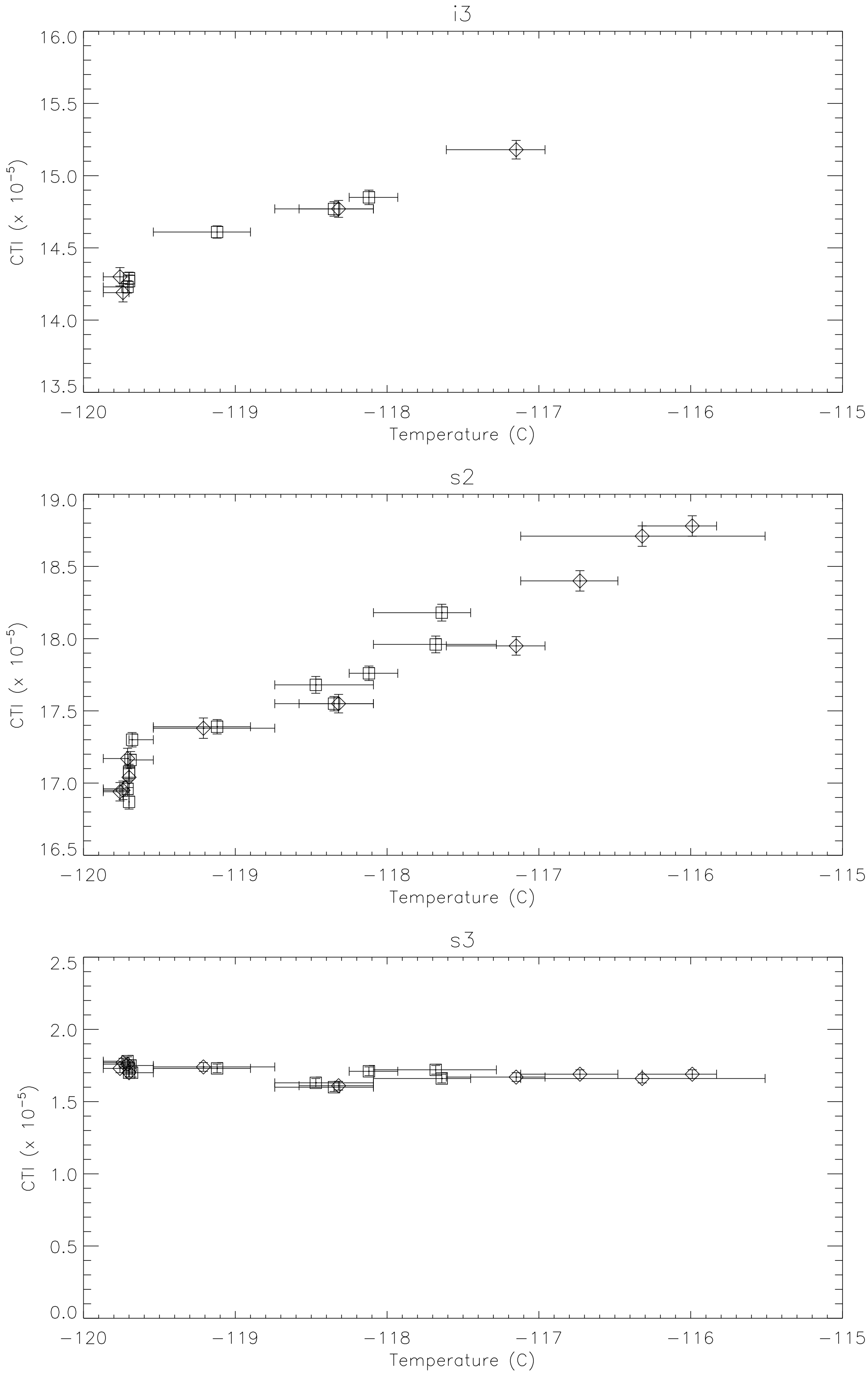
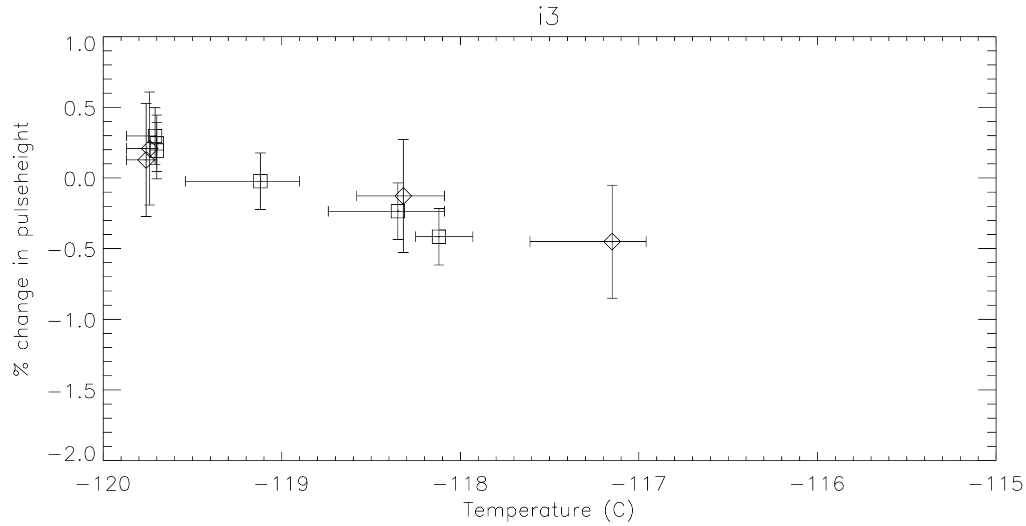
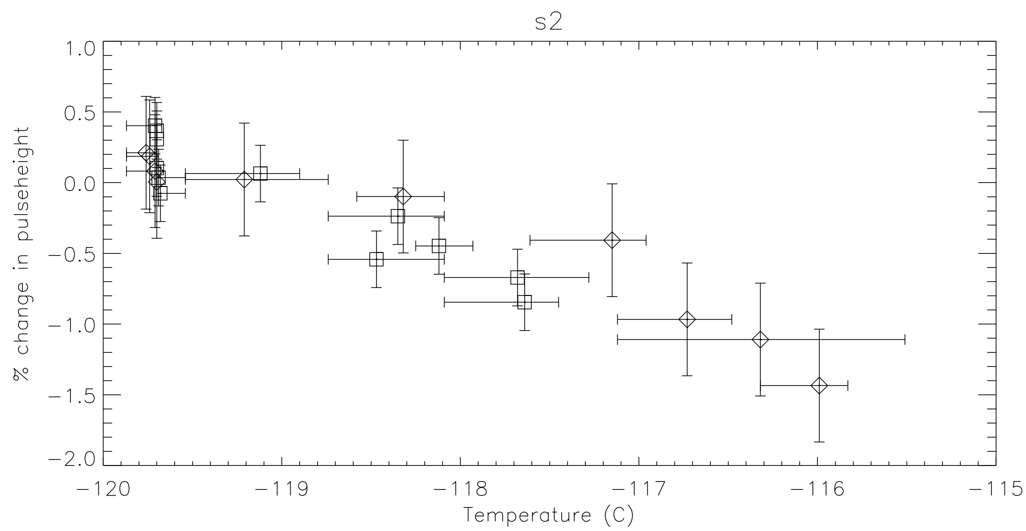


Figure 1: CTI at Mn-Kα (5.9 keV) for I3, S2, and S3 as a function of temperature. The "error bars" in the temperature axis correspond to the minimum and maximum temperature reached during the observation. The first time period, in which egress is warmer, are shown as diamonds. The second time period are squares.





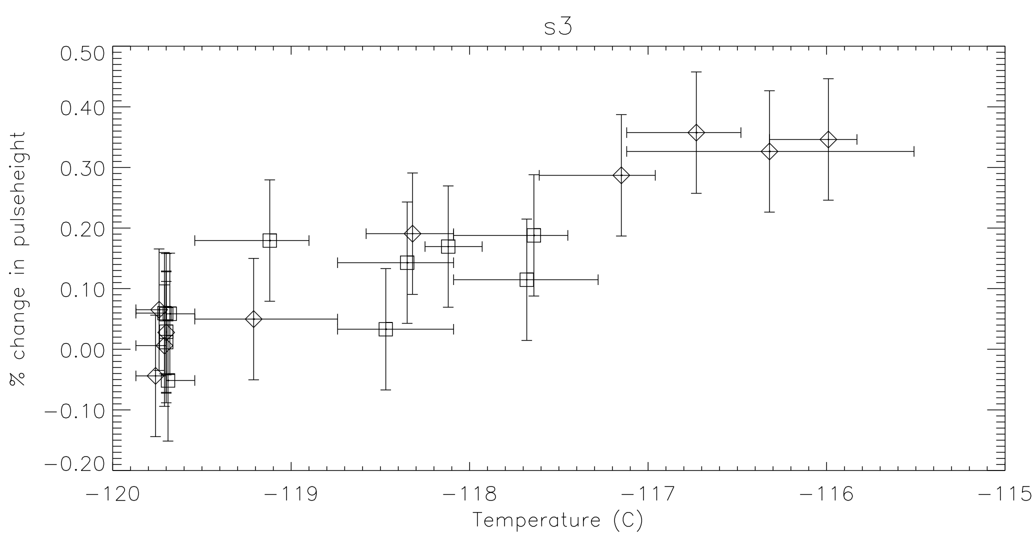


Figure 2: Mn-Kα (5.9 keV) peak for I3, S2, and S3 as a function of temperature. The "error bars" in the temperature axis correspond to the minimum and maximum temperature reached during the observation. The first time period, in which egress is warmer, are shown as diamonds. The second time period are squares.

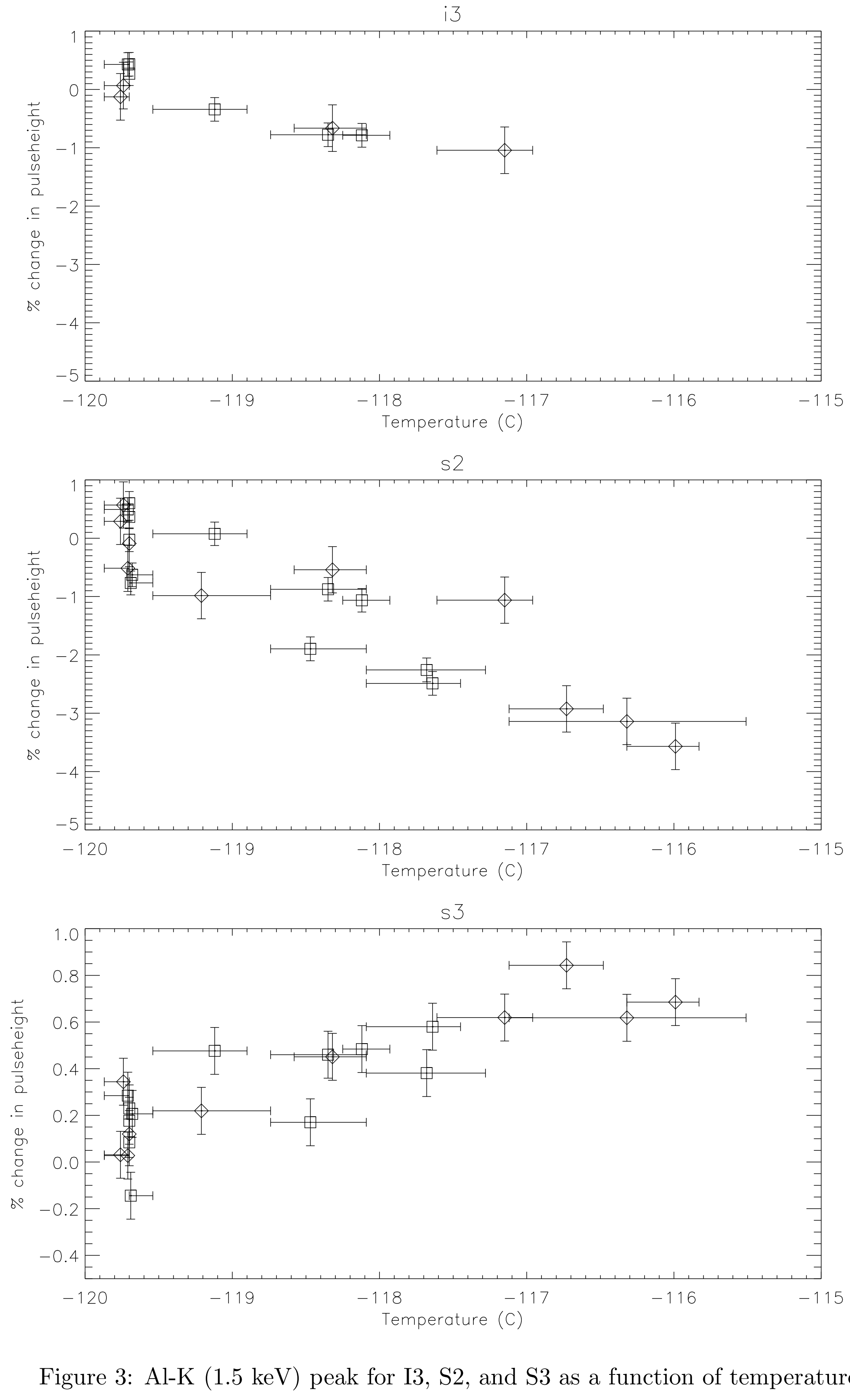


Figure 3: Al-K (1.5 keV) peak for I3, S2, and S3 as a function of temperature.

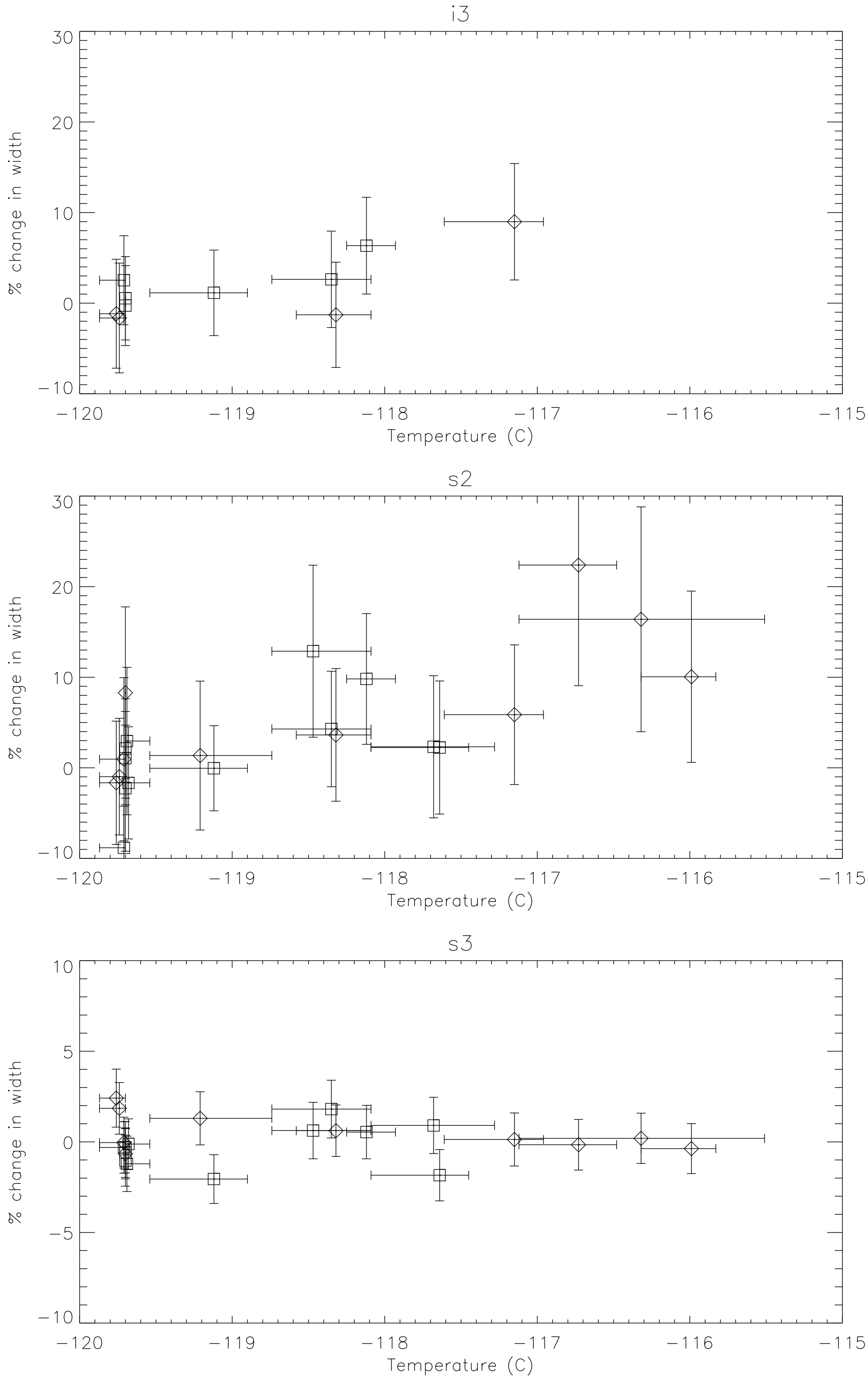


Figure 4: Mn-Kα (5.9 keV) linewidth for I3, S2, and S3 as a function of temperature. The "error bars" in the temperature axis correspond to the minimum and maximum temperature reached during the observation. The first time period, in which egress is warmer, are shown as diamonds. The second time period are squares.

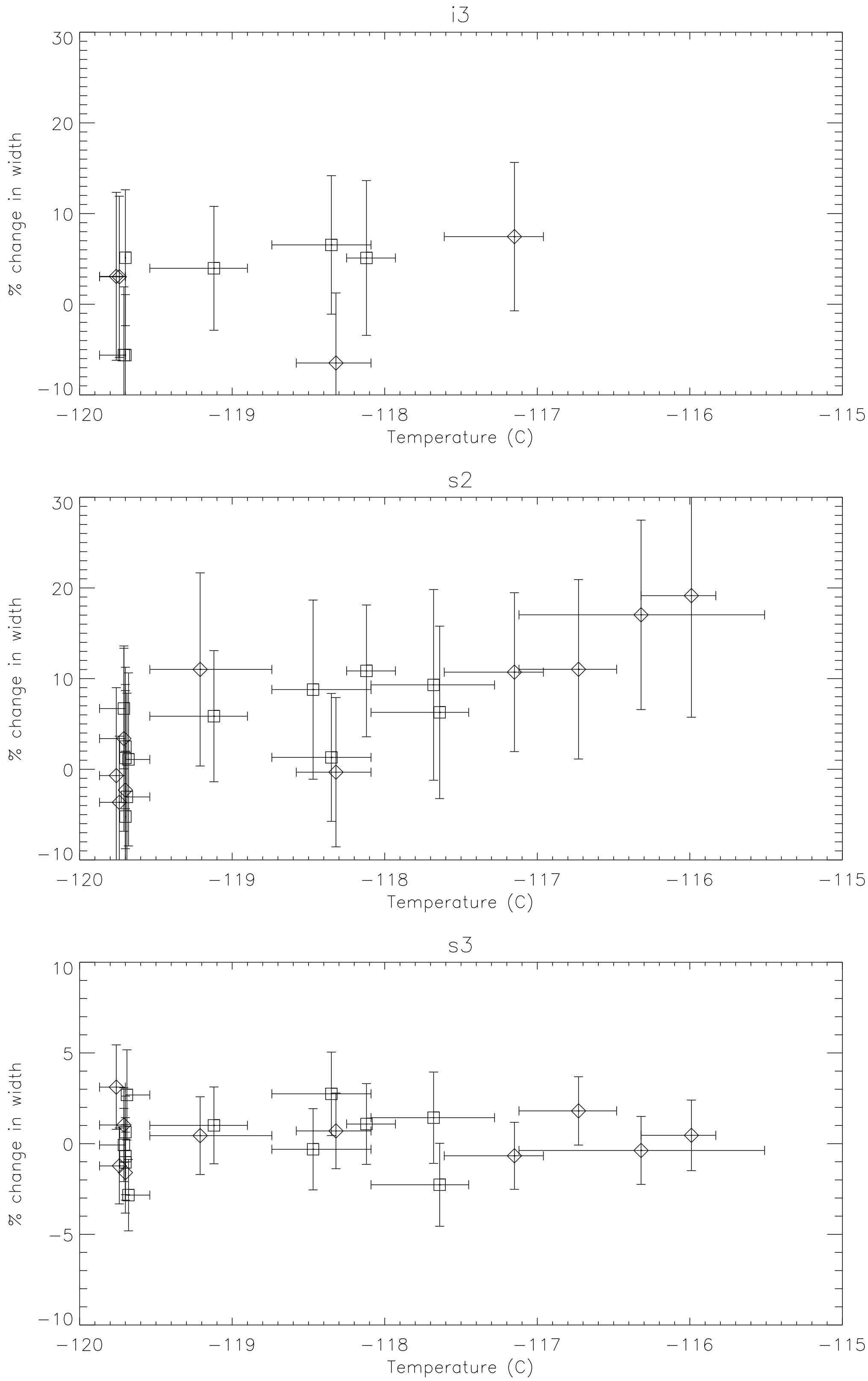


Figure 5: Al-K (1.5 keV) line width for I3, S2, and S3 as a function of temperature.