Infrared Spectrograph
Technical Report Series

IRS-TR 04001: Photoresponse and Read Noise Trends through IRS Campaign 5

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Abstract

We have analyzed of the anneal sequences obtained at the beginning and end of each IRS campaign and in the middle of longer campaigns. The read noise in SRS mode is particularly well behaved, rarely exceeding the pre-launch limit and never varying by more than 6% in a campaign since the Solar flare event which preceded Campaign N2 in 2003 October. The read noise in raw mode is generally well-behaved, but in SL tends to be near the limit and occasionally over. We recommend modifying the noise limits to account for what we have learned about the noise behavior since launch. The photoresponsivity of all modules has changed, but only because of change to the operating parameters of the detector arrays (Campaign K2) and the Solar flare event. From Campaign N2 to Campaign 5, the photoresponsivity has been stable to better than 1% for all modules. Analysis of photoresponsivity images reveals no new bad pixels.

1 Introduction

Through in-orbit checkout (IOC), science verification, and normal operations, a series of photoresponsivity and noise measurements have been conducted as part

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of the standard startup and shutdown anneal sequences. The longer campaigns in normal operations have led to an additional anneal sequence conducted in the middle of each campaign.

These measurements provide information on how the read noise and photoresponse of each detector have behaved during a campaign and also from one campaign to the next. In this report, we present the trends in read noise and photoresponse as a function of time and relate some of the changes in these properties to events in the mission of the Spitzer Space Telescope.

2 Data

The anneal sequences obtain data from the IRS in both standard modes: raw (or SUR for sample-up-the-ramp) and sample-reset-sample (SRS). Raw mode consists of 4 to 16 nondestructive reads of the array while charge accumulates on the multiplexor. The anneal sequences obtain raw data in 16-sample ramps with 2-second intervals between samples, producing a 128×128×16 data cube. In SRS mode, each pixel is sampled, reset, and sampled again, giving the charge on the array before and after an integration. A given sample-reset-sample sequence results in a 256×128 image, and in the anneal sequence, this is repeated 16 times, resulting in a 256×128×16 data cube.

The anneal sequences for startup, mid-campaign, and shutdown all follow a standard pattern of 32 exposures. Each of the modules are checked (in the sequence SL, SH, LL, LH), then the four detector arrays are annealed, then each module is checked again. Thus the exposures come in eight sets of four, one set for each module before annealing, and one after. Each set of exposures follows the same sequence: an exposure in SUR mode with the stimulator off, a similar exposure in SRS mode, an SUR exposure with the stimulator on, and a similar SRS exposure.

The 16 SRS reads in SRS mode are transferred from the spacecraft as a single data collection event (DCE). In SUR mode, the 16-sample ramp is repeated three times, resulting in three DCEs per SUR exposure. Thus the 32 exposures for a given anneal sequence produce 64 DCEs (16 SRS and 48 SUR). Each DCE is treated as a separate data file.

3 Analysis

We analyzed all data using the Pipeline Interactive Reduction and Analysis Tool (PIRAT) developed at Cornell. PIRAT first modifies the header information for the data files.

For SUR data, PIRAT then fits slopes to the ramps to collapse the cubes to 128×128 two-dimensional images, correcting the slopes for cosmic ray signatures and non-linearities in the response functions. It calculates a SUR read noise (SURN) map by comparing the slopes obtained for the 3 DCEs for each exposure obtained in raw mode with the stimulator lamps off. This comparison produced three difference maps, and the map with the smallest standard deviation is the basis for the final read noise map. The SURN values quoted below are the standard deviation of the read noise map, masking pixels illuminated by the orders or peak-up fields and pixels affected by cosmic rays. The cosmic ray masks include all pixels identified with cosmic rays in the slope-fitting stage and all pixels which exceed a median filter test when the read noise map is produced. In addition, all pixels either vertically or horizontally adjacent to any pixel affected by a cosmic ray is also masked.

For SRS data, PIRAT differences the sample and reset values for each pixel and determines a standard deviation of the second through ninth differences (out of 16) to produce a 128×128 SRS read noise (SRSRN) map. The SRSRN values quoted below are the median of each SRSRN map.

For each campaign, the SURN and SRSRN results are compared with the noise limits in Table 1. In addition, several stability measurements are determined by comparing the post-anneal results at the beginning of a campaign with the pre-anneal results at the end. For longer campaigns with a mid-campaign anneal sequence, we treat the two halves of the campaign separately.

The analysis of the anneal sequences from a given campaign includes tests of system stability from the beginning of the campaign to the end. The SURN and SRSRN values are compared from measurements made after the anneal in the startup sequence to the measurements made in the final shutdown sequence. The photoresponsivity of the arrays with the stimulator lamp on (stimhi) are also compared in a similar manner, and individual pixels which have changed significantly are noted. Table 2 gives the limits for how much the SURN, SRSRN, and stimhi responses can change. For longer campaigns with a mid-campaign anneal sequence, the two halves of the campaign are treated independently by comparing post-anneal startup to pre-anneal mid-campaign and post-anneal mid-campaign to pre-anneal shutdown.

TABLE 1
NOISE LIMITS FOR IRS ANNEAL SEQUENCES

Module	SURN		SRSRN
	Campaign A–J	Campaign K2 on	All campaigns
Short-Low	7.6	8.8	15.0
Short-High	7.6	8.8	15.0
Long-Low	10.6	14.5	15.0
Long-High	10.6	17.6	15.0

TABLE 2
STABILITY LIMITS FOR IRS ANNEAL SEQUENCES

Measured quantity	Yellow limit	Red limit
SURN	20%	40%
SRSRN	5%	10%
Stimhi response	5%	10%

TABLE 3
DETECTOR SETTINGS FOR IRS MODULES

Module	Campaign A–J		Campaign K2 on	
	V_{detsub} (V)	T (K)	V_{detsub} (V)	T (K)
Short-Low	3.49	5.52	3.00	6.20
Short-High	3.49	5.52	3.00	6.20
Long-Low	3.41	4.51	3.20	4.40
Long-High	3.41	4.51	3.00	4.40

Before Campaign K2, the bias voltages and operating temperatures of the detectors were modified to maximize the ratio of responsivity to read noise as measured in a series of tests in early IOC. Table 3 presents the detector substrate voltage and temperature of the detecotrs before and after Campaign K2. The bias voltage across the detectors $V_{bias} = 5.0 - V_{detsub}$. These changes necessitated the changes in the noise limits given in Table 1.

PIRAT also generates stimhi images of each module. These are obtained by differencing images in SRS mode with the stimulator lamps on and off. To analyze the stability of the photoresponsivity of the detectors, we measure the mean photoresponsivity on an unilluminated portion of each array in each campaign.

4 Trends

4.1 Read Noise

Figure 1 plots the read noise in SRS mode (SRSRN) as a function of time. The SRSRN results are well behaved and consistently under the 15.0 DN limit for each module. If these limits were lowered to values closer to the actual data, it would be easier to spot and flag troublesome SRSRN measurements. We would recommend new limits of 13.0 DN for SL and 13.5 DN for the other modules.

Figure 2 shows how the read noise in raw mode (SURN) for the four modules varies in time. Except for the response to the Solar flare event on 2003 October 28, LH has behaved well and generally stayed below the noise limit. SH shows occasional jumps in SURN, but since Campaign P has also behaved well. While

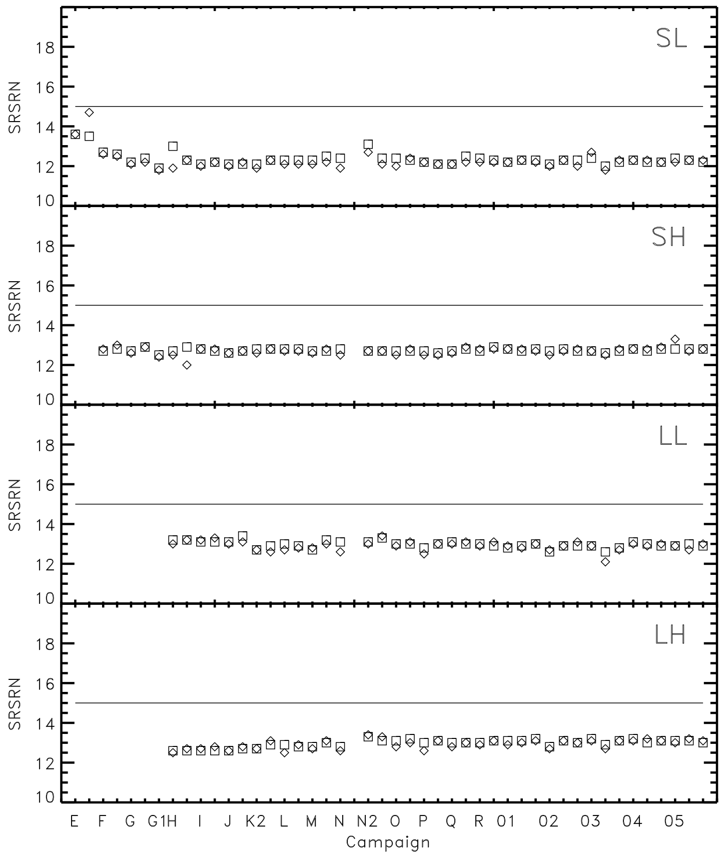

Figure 1 — SRS read noise (SRSRN) for all startup, mid-campaign, and shutdown anneal sequences in each campaign from launch through Campaign 3 in normal operations. The pre-anneal data are plotted with diamonds, and post-anneal data are plotted with squares. The 15.0 DN limit for each module is shows as a horizontal line. The SRSRN results are consistently within the required limit.

the scatter in SURN for LL has been larger than the other modules, it has stayed within the noise limit since Campaign N2.

The SURN in SL has been more of a problem. Early in IOC the noise clearly exceeded the limit, and while it steadily decreased as the telescope cooled, it was not until Campaign P that it had settled to a relatively stable value. Despite the increase in the noise limit from 7.6 DN before Campaign K2 to 8.8 DN after, SL still frequently exceeds this limit.

The best explanation for the poor behavior of SL is a combination of the peak-up subarrays on the detector, droop effects, and jailbarring. The red peak-up array has its peak sensitivity at 22 μm, which explains the early temperature-dependent difficulties. Even with a cold telescope, the peak-up subarrays are illuminated by background radiation at all times, and this increase the susceptibility of SL to the droop effect, which in turn increases the jailbarring apparent in raw images. The jailbarring increases the measured SURN, and for this reason SL remains near the noise limit most of the time. Whatever the origin of the apparent noise in SL, it does not appear in the SRS data nor does it appear to impact the quality of science observations with SL. The increased noise levels, as we measure the SURN in SL, seems to be an unavoidable property of the IRS in orbit.

We recommend increasing the SURN limit to 10.0 DN for SL, and decreasing it to 8.0 for SH and 14.0 for LL. The current 17.6 DN limit for LH should remain unchanged.

4.2 Photoresponse

Figure 3 shows how the relative photoresponse has varied in each module since launch. For each module, all data are normalized to the photoresponse in Campaign N2. Two events stand out. First, the change in operating parameters of the detectors prior to Campaign K2 significantly improved the photoreponsivity of the detectors. Second, the Solar flare event which began on 2003 October 28 occurred during Campaign N. This was one of the most powerful Solar events in the past three decades, and as a result, the measured photoresponse of all four arrays dropped noticeably.

From Campaign N2 to Campaign 5, the photoresponsivity has been stable, showing standard deviations of 0.3% in SL and SH, and 0.5% in LL and LH.

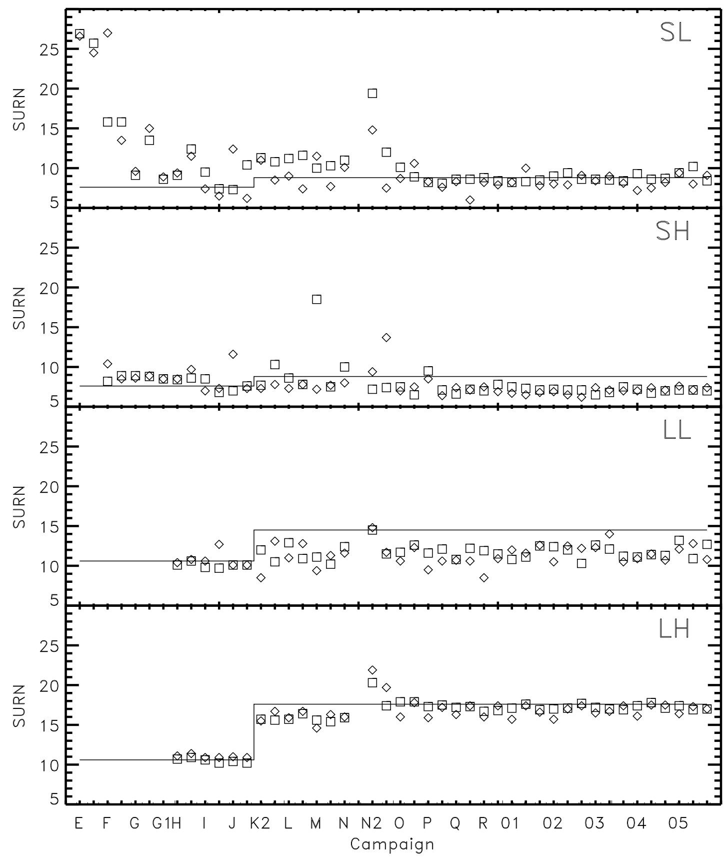

Figure 2 — SUR read noise (SURN) for all startup, mid-campaign, and shutdown anneal sequences, as in Fig. 1. Symbols are as defined in Fig. 1. The SURN limits changed at the beginning of Campaign K2 to reflect modified detector operating voltages and temperatures. In general, only SL exceeds the SURN limit, and after Campaign N2 only occasionally.

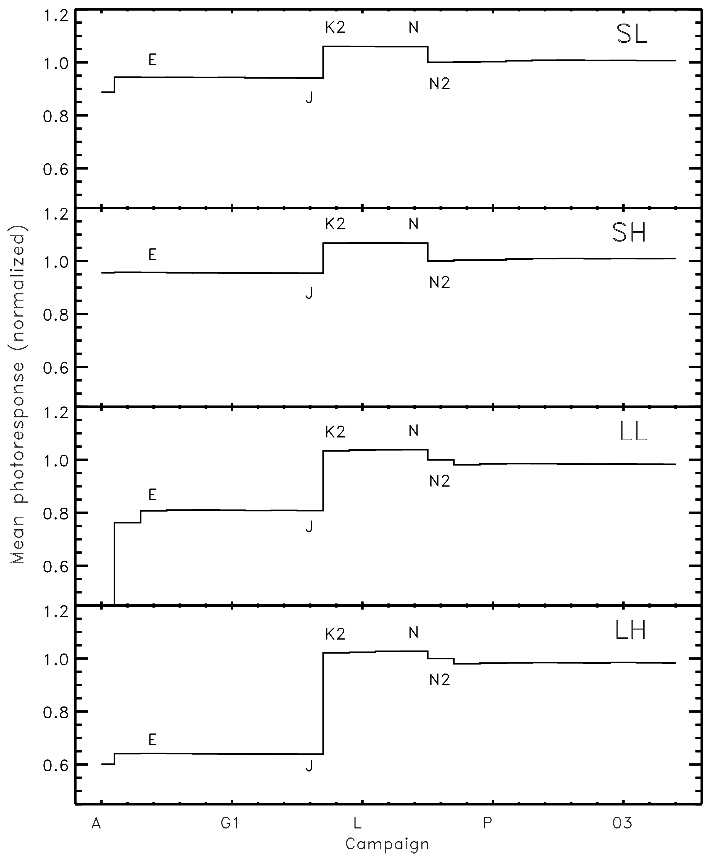

Figure 3 — Relative photoresponse as a function of time. The photoresponse plotted here is measured in the startup activity in each campaign. All data for each module have been normalized to the photoresponsivity in Campaign N2. The jump in photoresponse with Campaign K2 reflects the modified operating voltages and temperatures for each module. The drop between Campaigns N and N2 resulted from the Solar flare event of 2003 October 28.

4.3 Stability during a campaign

Several factors invalidated the stability measurements of the IRS early in the mission, including the cooling of the telescope, the changes in operating parameters of the detectors, and the Solar flare event of 2003 October 28. Campaign N2, the first campaign after the flare, also showed some instability, but from Campaign O onward, the read noise and photoresponsivity have generally been well behaved.

The IRS has only exceeded the yellow SRSRN stability limit of 5% after Campaign N2. This occurred in the first half of Campaign 3, when LL became 6% less noisy between anneals. The maximum deviations for the other modules have been 5% (SL), 2% (SH), and 4% (LH).

From Campaign O on, the IRS has only exceeded the yellow SURN stability limit on three occasions. SL exceeded the limit twice, once in Campaign Q, when the read noise dropped 30%, and once in the first half of Campaign 1, when it increased 22%. SH dropped 33% in Campaign P. The maximum deviations in SURN for the other modules have been 14% (LL) and 6% (LH). In general, the variations in SURN observed appear to be due more to the method of annealing and measuring the SURN than to the dectector noise itself.

Changes in measured stimhi photoresponse tend to be dominated by transient effects. Usually, when a number of pixels change enough to exceed the yellow limit for a given module, the orders are readily visible, indicating a change in background level between anneal sequences. In Campaigns 3 and 4, the change in SL photoreponse was dominated by latent images on the peak-up arrays.

Excluding these transient effects, no previously masked pixels appear to be misbehaving consistently.

5 Conclusion

Comparing the read noise from the anneal sequences from one campaign to the next revels that the SRS read noise (SRSRN) is very stable. The read noise in raw mode (SURN) has generally been stable since Campaign N2, but SL is still exceeding its 8.8 DN noise limit frequently enough to be a problem. Given that the higher SL SURN values in orbit do not seem to be impacting the quality of science observations, the noise limit should be raised to a value which would only be exceeded when the system is not behaving normally. We recommend that the SURN limit be raised to 10.0 DN for SL.

The SRSRN limits should be lowered to a value closer to the range of observed noise, namely 13.0 DN for SL and 13.5 DN for the other modules. Similarly, the SURN limits could be lowerd to 8.0 DN for SH and 14.0 DN.

The photoresponsivity from Campaign N2 through Campaign 5 has varied by less than 1% in all modules.

Analysis of photoresponse and noise stability within a campaign reveals that the noise level rarely varies by 5% or more. The SURN measurements are not as stable, but the limit of 20% variation has only been exceeded three times since Campaign N2. The comparison of stimulator photoresponse images reveals no new bad pixels.