Distribution and Identification of ACIS-S4 Streak Events

Version 1.0

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John C. Houck

Center for Space Research, Massachusetts Institute of Technology, Cambridge MA, 02139

houck@space.mit.edu

Streak events are identified primarily on the basis of coincidence of $> \nu$ events occurring in a single *chipy* row of a single node within a single frame (Figure 1). The *grade* and *fltgrade* distributions of the streak events are similar to those of "good" events (Figure 2). The energy spectrum peaks at $E \approx 0.5$ keV and shows weak line emission features, the strongest of which lies at 1.8 keV and is probably associated with silicon (Figure 3). Over the course of a long observation in which many frames are read out, only a small fraction of rows ($q \lesssim 10^{-4}$) have streaks; they occur at about the same rate on each node. In *chipx*, the streaks are correlated with the readout nodes, but they appear uniformly distributed in *chipy* (Figure 4).

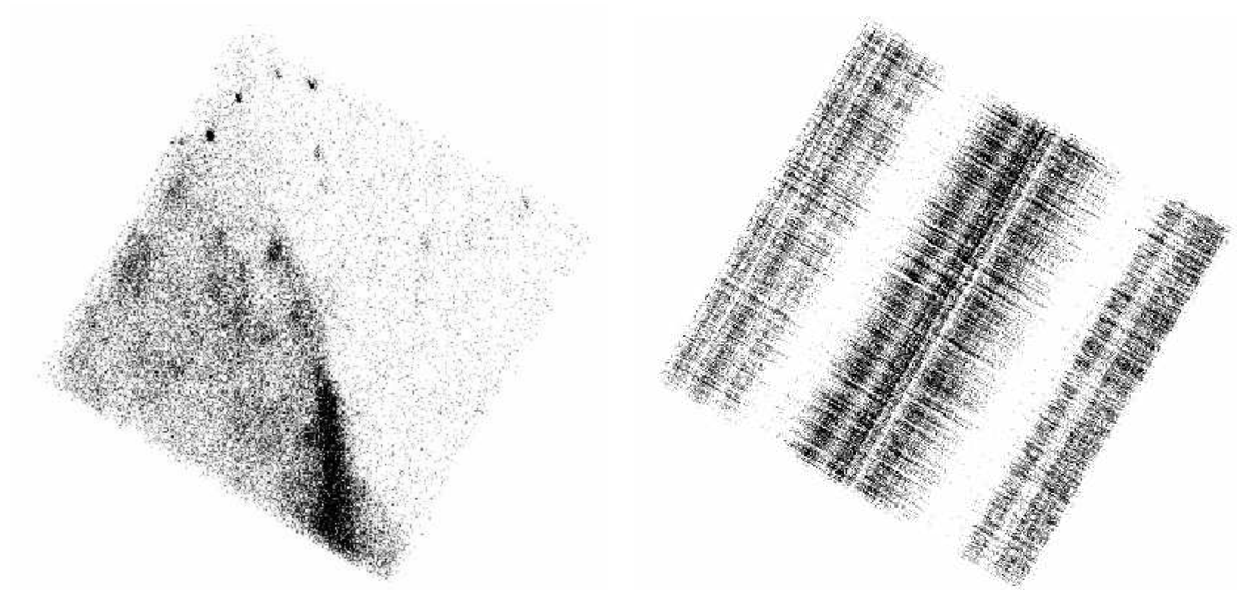

Fig. 1.— Effect of the destreak filter on obsid 1959. The *left* image shows non-streak events and the *right* image shows the streak events. Because of the high streak rate in this dataset, the filter enforced a maximum row-loss fraction of $q = 2 \times 10^{-4}$.

Although the probability, q, of having a streak in a given row is normally in the range $q \approx (0.3-1) \times 10^{-4}$, it has been observed to increase by a factor of four or more within a single observation. The streak rate may be correlated with the quiescent S3 amplitude reject rates (`amp_rej`) which correspond to events with $pha > 15$ keV[1]. The quiescent S3 `amp_rej` rates are known to correlate

[1]See `http://space.mit.edu/~cgrant/s4.html`

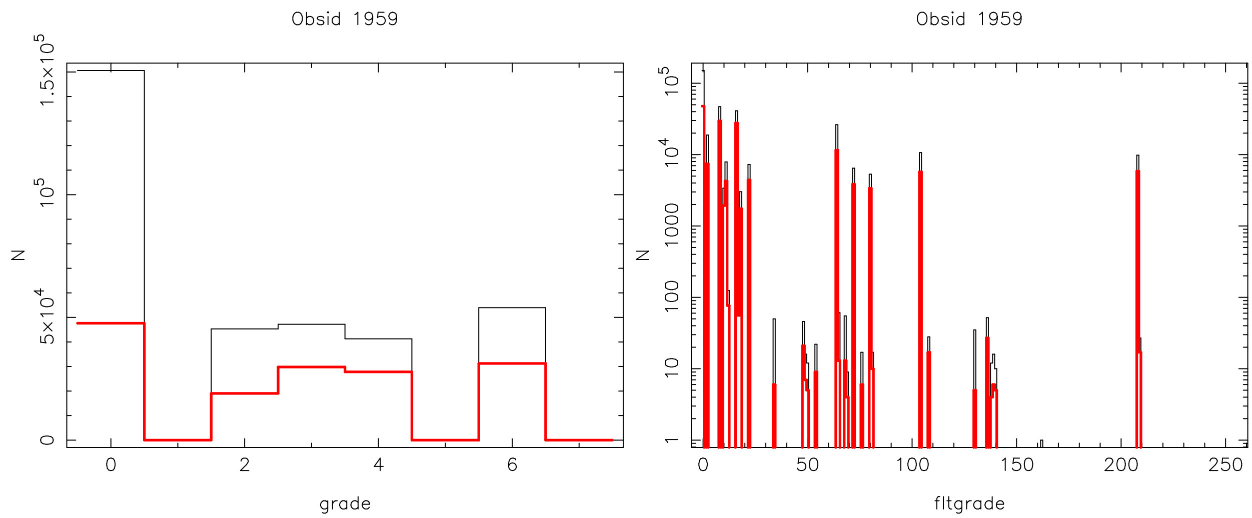

Fig. 2.— Distribution of *grade* (*left*) and *fltgrade* (*right*) for streak events (thick, red line) and "good" events (narrow, black line).

well with the cosmic ray rate measured by the Advanced Composition Explorer (ACE) SIS[2]. The streak rate is apparently uncorrelated with the presence of background flares (Figure 5).

To minimize the coincidence rate due to other processes (e.g. high particle background), the input event list should be prefiltered to remove as many "bad" events as possible. In this context, "bad" refers to all events which will eventually be discarded for other reasons. Alternatively, the destreak implementation may include code which ensures that "bad" events are ignored.

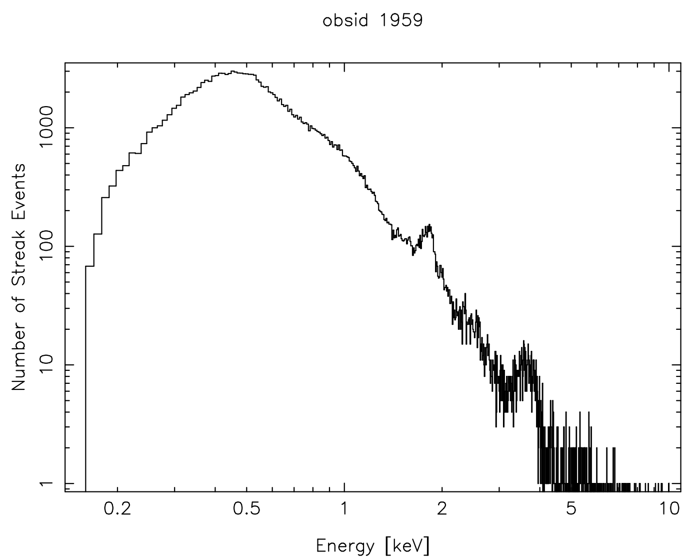

Fig. 3.— Distribution of streak events with *energy* for obsid 1959.

It has been empirically determined that the probability of a streak having N events is

$$P(N) = \frac{e^{-N/a}}{a} \tag{1}$$

where typically, $a \approx 8.5$. The value of the constant a appears weakly dependent on the rate of occurrence of streaks. Given the distribution function, $P(N)$, it follows that the set of streaks with $> N$ events contains a fraction $f(> N)$ of all streak events where

$$\begin{aligned} f(> N) &\equiv 1 - \frac{\sum_0^N n\ P(n)}{\sum_0^\infty n\ P(n)} \\ &= \left[1 + N\left(1 - e^{-1/a}\right)\right] e^{-N/a} \\ &\approx \left(1 + \frac{N}{a}\right) e^{-N/a} \end{aligned} \tag{2}$$

[2]Grant, C.E., Bautz, M.W., & Virani, S.N., 2002, "The Temporal Characteristics of the Chandra X-ray Observatory High Energy Particle Background", in *X-rays at Sharp Focus: Chandra Science Symposium*, ASP Conference Series, Vol. 262, Schlegel and Vrtilek, Eds.

where the approximation requires $a^{-2} \ll 1$. Note that most streak events occur in streaks with $> a$ events. If streaks appear with probability q, then the probability of generating N streak events in a given row within a given frame is

$$P_q(N) \equiv qP(N) = \frac{q}{a} e^{-N/a}. \tag{3}$$

When source events are detected at a rate r within a given row, the probability of having s source events in that row within a given frame of duration τ is

$$P_x(s) = \frac{x^s e^{-x}}{s!}, \qquad x \equiv r\tau. \tag{4}$$

The mean number of source events expected in a given row is x.

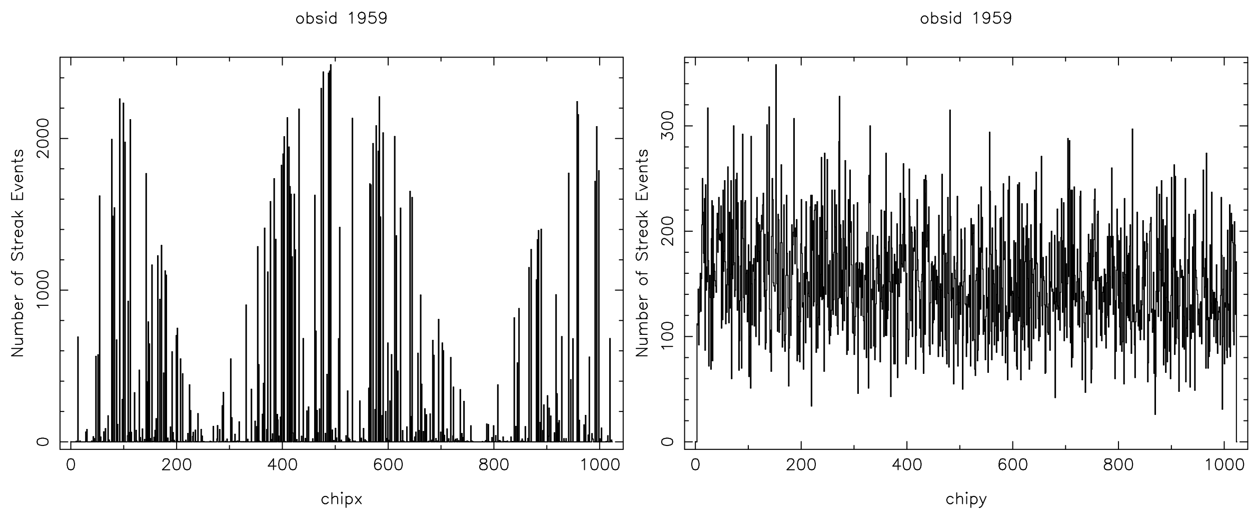

Fig. 4.— Distribution of streak events with *chipx* and *chipy* for obsid 1959.

Given a streak identification threshold ν, streak events can be efficiently separated from source events to the extent that $x \ll \nu \ll a$. When $\nu \gtrsim a$, the fraction of streak events identified falls below $f(> a) = 0.71$. When $x \approx \nu$, a significant fraction of source events will be misidentified as streak events. Therefore, the maximum "safe" source event rate within a single row is $r \approx a/\tau \approx 2.7$ counts s^{-1}, for $\tau = 3.2$ sec. Point sources which exceed this event rate are likely to suffer from significant photon pile-up. High surface brightness extended sources and dispersed spectra of bright point sources may exceed this threshold with less photon pile-up because they can deposit source events along the length of a row rather than at a single point.

In automated processing, the incident source event rate, x, may be unknown. In this case, an iterative algorithm may be the simplest way to ensure that the streak identification threshold is not set too low (e.g. to better satisfy the condition $x \ll \nu \ll a$). First, identify the streaks using a given threshold value, ν, and then examine the fraction, σ, of rows identified as having streaks. If the $\sigma > q$, it is likely that the threshold was set too low and that a significant number of source events have been incorrectly labeled as streak events. To correct this, simply increase the threshold, ν, and apply the algorithm again, iterating until $\sigma < q$. Because the majority of streak events occur in rows with $> a$ events, the streak identification threshold may rise as high as $\nu \approx a$, yet still identify most of the streak events.

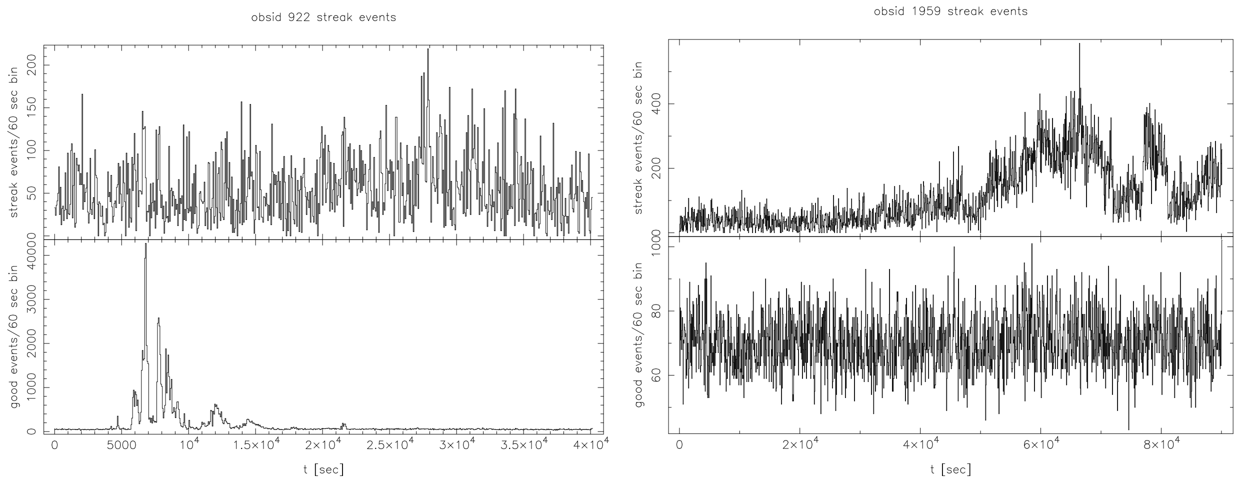

Fig. 5.— Rate of occurrence of streak events and "good" events ($status = 0$, $grade \neq 1, 5, 7$) versus time. Although obsid 922 shows very strong background flares, the streak rate remains steady. In contrast, obsid 1959 shows significant variation in the streak rate even though the background event rate remains constant.

For example, Figure 6 shows the exposure time lost in obsid 2741 (Cyg X-1) as a function of *chipy* by application of streak thresholds ν = 1-7. In this observation, the total livetime for ACIS-S4 is 1812 sec; because this observation used a narrow sub-array, only 512 rows were read out. The peaks in the lost-time distribution correspond to the location of the HEG and MEG dispersed spectra from this bright point source. Low values of ν cause many rows containing source events to be misidentified as streaks and discarded, resulting in the loss of as much as 55% of the exposure time in rows with high incident (dispersed) source flux. Increasing the streak threshold to $\nu = 7$ reduces the streak rate to $\sigma < 10^{-4}$. This reduces the exposure time loss-rate to negligible levels (<0.5%), yet still identifies 78% of the streak events. Figure 6 shows that the row-loss fraction, σ, on each node drops exponentially as the streak identification threshold, ν, increases. Although this observation contains a negligible number of streak events, this example illustrates that even when the incident source flux is high, the streak filter can work efficiently.

This iterative approach should work effectively up to a maximum source event rate of about $r_{\rm max} \approx a/\tau$. At higher source event rates, there is little point in applying the streak filter because many streak events will be missed and because the streak event rate is likely to be a negligible fraction of the source event rate.

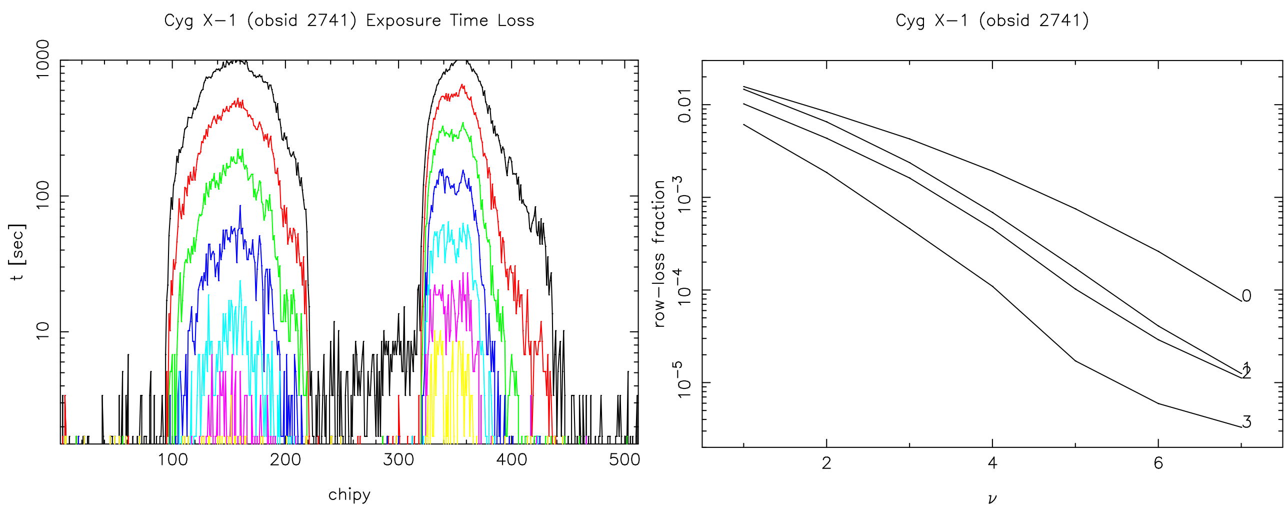

Fig. 6.— *left:* Exposure time lost as a function of *chipy* due to identification of streaks using streak thresholds ν = 1-7. Note that the fraction of misidentified source events drops by a constant factor for each increment in the streak identification threshold. *right:* Row-loss fraction versus streak identification threshold, ν, for nodes 0,1,2,3 of ACIS-S4.