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A Test for Weak Cosmic Ray Events on CCD Exposures

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Abstract. It is notoriously difficult to identify weak cosmic ray events in long exposure observations. The majority of "de-glitch" programs have little difficulty in identifying the bright events. The faint events—either individual or "splatter" around bright events—are rather more problematic. We propose a simple test to evaluate the effectiveness of a de-glitch program in removing weak events. The method is to compare the probability distribution function (PDF) of cosmic ray events between an observation and a dark frame matched in exposure time. We illustrate the basic idea using dark exposures from a Tek 1024×1024 CCD with varying exposure lengths and read-out times.

1. Observations

We have obtained dark frames using the Tek 1024×1024 CCD at the AAT 3.9 m with varying exposure lengths (15, 30, 60, and 120 min) and read-out times (FAST, SLOW, XTRASLOW). The histogram of each frame shows the contribution from the bias, read and dark noise. A millisecond exposure was used to remove the bias and read noise contribution to each histogram. The additional contribution from the dark noise is well calibrated at 0.11 counts pix^{-1} ksec^{-1}. It is assumed that the remaining events are related to cosmic rays. Only half the CCD frame was used because long exposures revealed a weak intensity gradient in the dark response on the other half.

2. Method

We define $n(E)\ dE$ to be the number of cosmic ray events with energies (expressed in counts) in the range $(E, E + dE)$. The cumulative distribution is

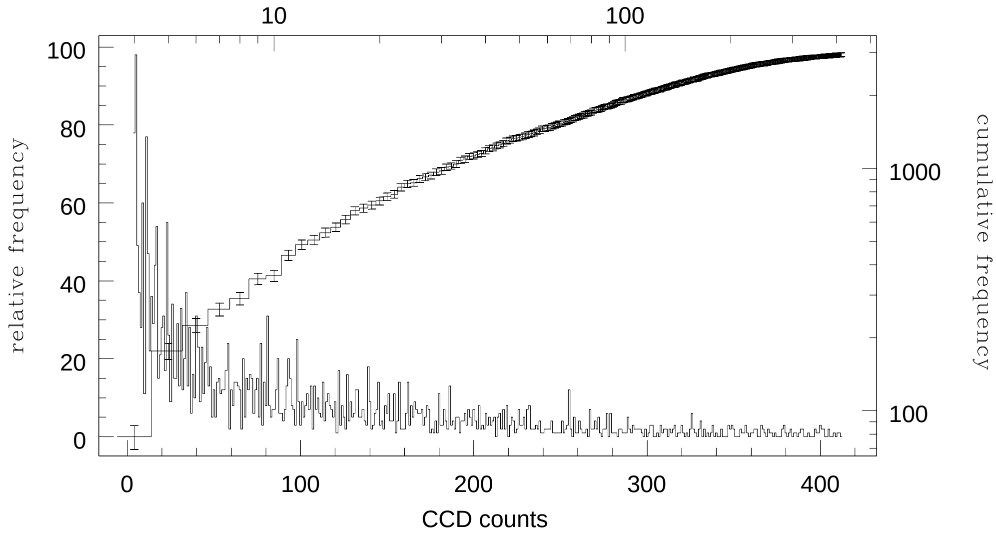

Figure 1. Histogram of cosmic ray events in a two hour dark frame. The monotonic curve is the cumulative histogram of these events. The error bars are Poissonian and not independent.

then

$$P(E) = \int_0^E n(E)\, dE \tag{1}$$

When $n(E) \propto E^\beta$, the slope of the plot $\log P$ vs $\log E$ is proportional to $\beta + 1$. In Figure 1, the noisy histogram is the bias/dark/read noise subtracted dark frame. The monotonic curve is a plot of $\log P$ vs. $\log E$ which is found to be rather well defined and reproducible over the different exposures. We propose that de-glitch programs should compute the PDF in this way for both the data and a matched dark frame (same exposure, same read-out time). The PDF for the data is determined from all events identified by the de-glitch algorithm. Since the energetic events are easier to find, the bright end of both PDFs will be well matched. In Figure 2, where the de-glitch PDF turns over at low energy—presumably but not necessarily at an energy greater than or equal to the turnover in the dark PDF—gives some idea as to how effective the algorithm has been in removing the weaker events.

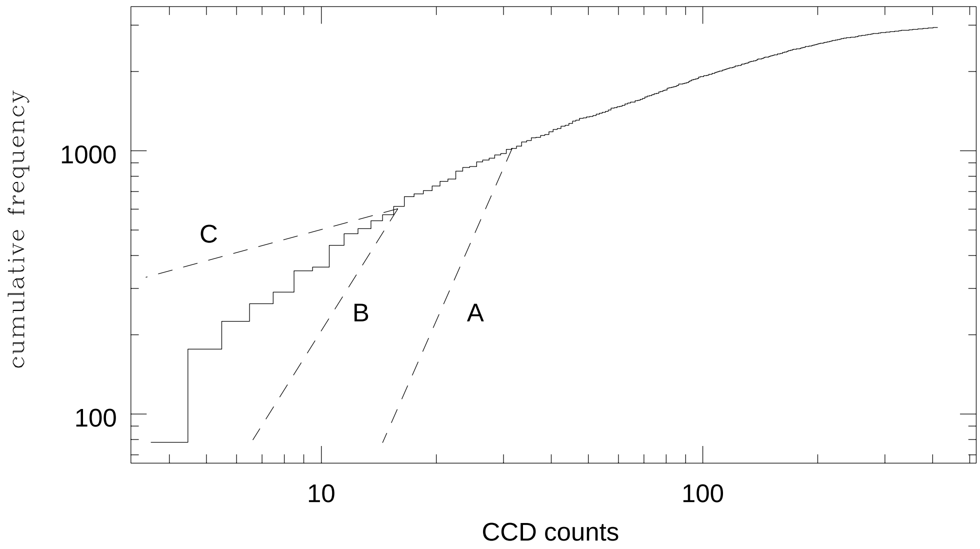

Figure 2. The cumulative histogram from Figure 1 with which to compare the performance of a de-glitch algorithm. Three cases are illustrated: algorithm A is too conservative, algorithm B more reliable, and algorithm C has mistaken real data with faint cosmic rays.