

Removing Electronic Row Noise in SHARP

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1 Introduction

This memo, in conjunction with a second one titled “Treating Correlated Noise in SHARP” covers versions of `sharpinteg` up to and including 3.1.3 (2012 Feb 21).

Some fraction of the SHARP data is plagued by electronic noise. This correlated noise affects two rows at a time and can be seen primarily in the Q and/or U maps, and sometimes I . Figure 1 is an example of this row noise. The file is #51194 from May 2010. The source is L483, with a $\tau_{225} = 0.045$. We will use this file throughout this memo.

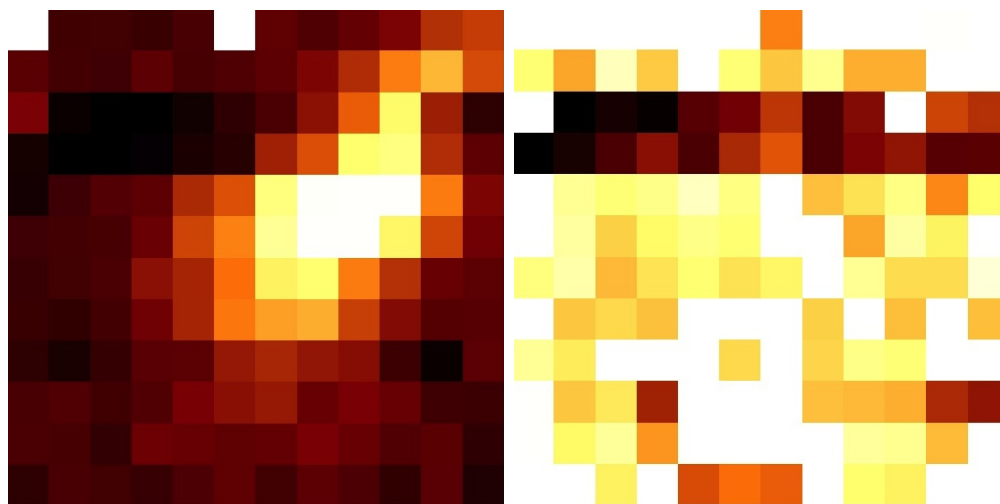


Figure 1: Example of electronic row noise and its effect on the data. Left panel is I and right panel is Q .

Because this row noise is intermittent, it should be possible to identify it and remove it from the data. Figure 2 shows the raw $H - V$ voltage for #51194. The four steps correspond to the four HWP angles. In addition, you can see several brief periods where the samples have significantly different values from their neighbors. These samples are what cause the row noise.

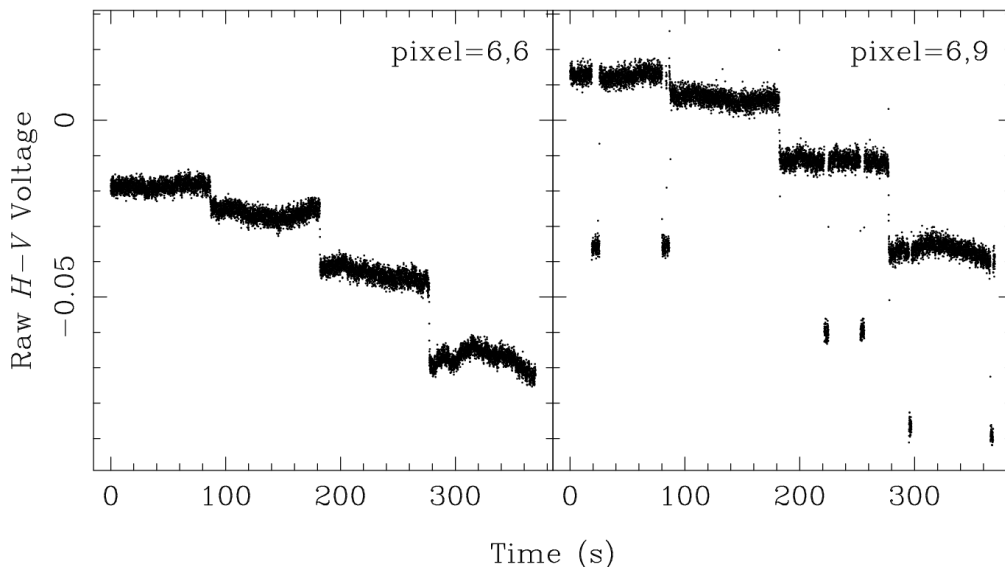


Figure 2: Electronic noise from the $H - V$ raw data. Left is a pixel in the center with no electronic noise, right is a pixel in row 9. The intermittent electronic noise is very evident.

2 Removing the Electronic Noise

To remove this electronic noise, I implemented Chauvenet's method in `sharpinteg`. Chauvenet's criterion is applied to the chopper demodulated data using the three steps below. A data set is defined as the frames in a single pixel, a single beam (either left or right), and single HWP angle. Chauvenet's criterion is then repeated for all pixels, beams, and HWP angles. As a final note, this procedure is only applied to the $H - V$ data. Treatment of the $H + V$ data is more complicated and will be discussed later. The three steps in Chauvenet's criterion are:

1. Compute the mean and standard deviation of a data set
2. throw out any points more than 3σ away from the mean
3. repeat until no points are rejected

Figure 3 shows the results of running Chauvenet's criterion for the same 2 pixels shown previously. All HWP angles and both the left and right beams are plotted. Red points are those rejected by Chauvenet's criterion. There are no points off the scale. Note that 2 samples are removed from pixel 6,6 even though there is no electronic noise in this pixel. Having 2 samples out of 294 or 0.68% of the data rejected is slightly more than expected by gaussian statistics (0.3% for 3σ), but not unreasonably so.

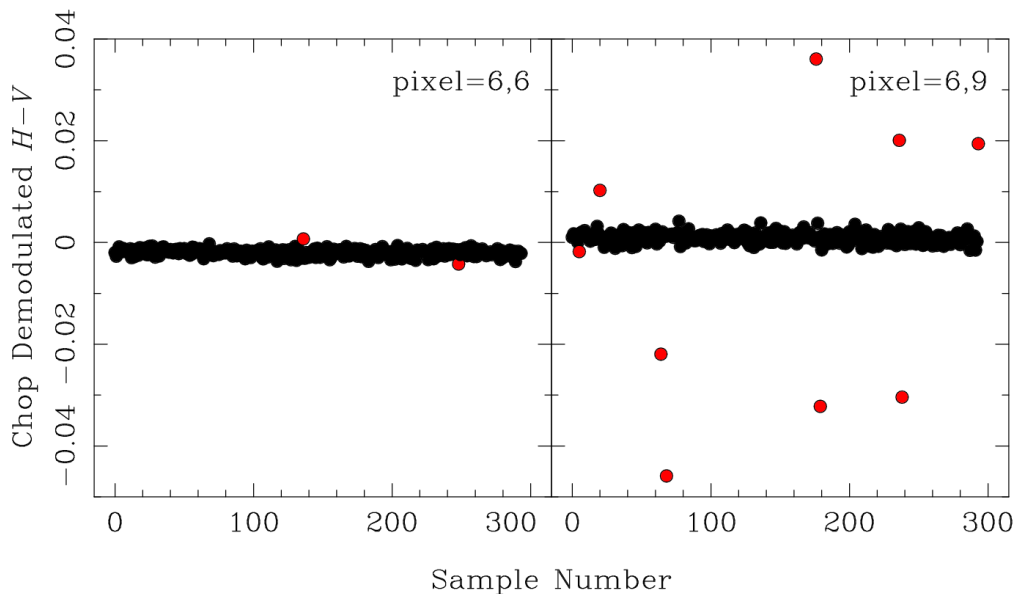


Figure 3: Demodulated $H - V$ data. Left is a pixel in the center with no electronic noise, right is a pixel in row 9. Red points are those excluded by Chauvenet's criterion.

2.1 $H + V$ Data

The $H + V$ data cannot have Chauvenet's criterion applied to them since the variability of the sky emission makes it impossible to reliably reject the electronic noise. I first attempted removing the same frames in each pixel that were flagged in $H - V$, but this leads to a biased I map (because of the variability of the sky emission). The key is to remove a frame in $H + V$ from *all* pixels if that frame is rejected by Chauvenet's criterion in $H - V$ in *any* pixel.

2.2 Old Chauvenet Criterion

Note, `sharpinteg` had a variant of Chauvenet's method already, but it was different in several respects from the new version. The old rejection criterion was based on the error function, Γ , rather than using 3σ . Also, it was only run once instead of iteratively. Finally, it was run on both the $H - V$ and $H + V$ data.

3 Final Results

The final result of applying this new Chauvenet's method to the data can be seen in Figure 4. Compare this to Figure 1 for a before-and-after picture. In my experience, row 9-10 electronic noise can be fixed by Chauvenet's criterion. The other pair of rows that frequently have electronic noise are 3-4. These rows do not seem to be fixed by

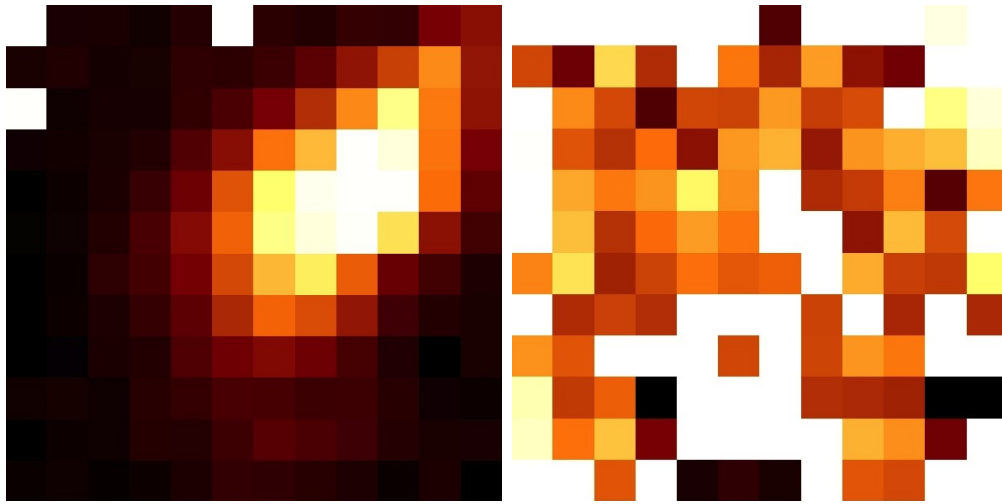


Figure 4: Same file as in Fig. 1, but with the electronic row noise removed by Chauvenet’s criterion. Left panel is I and right panel is Q .

Chauvenet’s criterion because the intermittent electronic noise occurs too frequently for it be rejected by a 3σ outlier routine.

4 Other Changes

In addition to the new Chauvenet’s method, I made a few other changes to `sharpinteg`.

I fixed a bug in `chop_demod()` so that completed chop cycles at the end of a nod would be counted. Before these were erroneously skipped. This means the number of frames (samples) in a file increased by up to 8 (up to 2 per HWP angle). Because there are ~ 300 frames (samples) in a file, this is only a couple of percent improvement.

I also moved the `checkNodLength()` function to after Chauvenet’s method. This check ensures that the number of frames (samples) in the first left, right, and second left are within some min/max range. By moving it to after Chauvenet, it is a better check on the amount of actual usable data. I also changed it so that `checkNodLength()` will check pixel-by-pixel and flag individual pixels that fail. Only if every pixel fails will `sharpinteg` abort and not create an output image. The output printed to the screen is the average number of frames computed over the good pixels. `checkNodLength()` is run on the $H - V$ data only since the $H + V$ is the union of all the bad frames and thus will be overly pessimistic. A future version of `sharpinteg` will add also check the $H + V$ data to ensure there are at least 2 samples for the first left, second left, and right beams for each HWP angle.

Lastly, `sharpinteg` now keeps track of the covariance between pixels and writes out a new FITS extension with this data. The purpose of this is described in a second memo, “Treating Correlated Noise in SHARP”.