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The Impact of the ACIS Readout Streak and Pileup on Chandra Source Detection

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Abstract. As part of the development of the Chandra Level 3 (L3) data products (Chandra Source catalog) the impacts of the ACIS *Readout Streak* and Pileup have been examined. A method has been developed which allows us to determine, for a given observation, which columns of the ACIS CCDs are impacted by *Readout Streaks* and may result in the detection of false sources. A discussion is given of how to identify and determine the characteristics of real sources located in the *Readout Streak*. The implications of this for the creation of L3 products is discussed. Additionally various methods of removing the *Readout Streak* from the image are examined.

1. Introduction

X-ray observations made with the Chandra Advanced CCD Imaging Spectrometer (ACIS) containing bright X-ray sources often contain a *Readout Streak* . This steak is a result of the finite amount of time (40 μsec per row) that it takes to read out the CCD after an integration time. As a result all points along a given readout channel are exposed to all points on the sky that lie along the given readout channel. The result is a streak along the channels which contain a bright source. This streak can cause problems when one is trying to detect and determine the properties of the X-ray sources in the data.

Currently under development is the Chandra Level 3 (L3) data products (Chandra Source Catalog). This project seeks to do source detection on all public Chandra data ($\sim$ 4200 observations) and create data products for all sources which are found. Due to the number of observations it is important to automate the source detection and minimize the number of spurious sources. A strong *Readout Streak* can easily cause on the order of 100 false sources being found.

Fig. 1a is an image of the S3 chip of an observation of M81 (OBSID: 735). Apparent is the *Readout Streak* of the central X-ray source and to a lesser extent the *Readout Streak* of the ultra-luminous object X6 (to the left edge of the image). Overlayed are the sources detected from a run of WAVDETECT (see Freeman et al. 2002). It is apparent that a large number of false source are caused by the *Readout Streak* with 60 of the 158 sources along the *Readout Streak*. We describe a simple algorithm to address this problem.

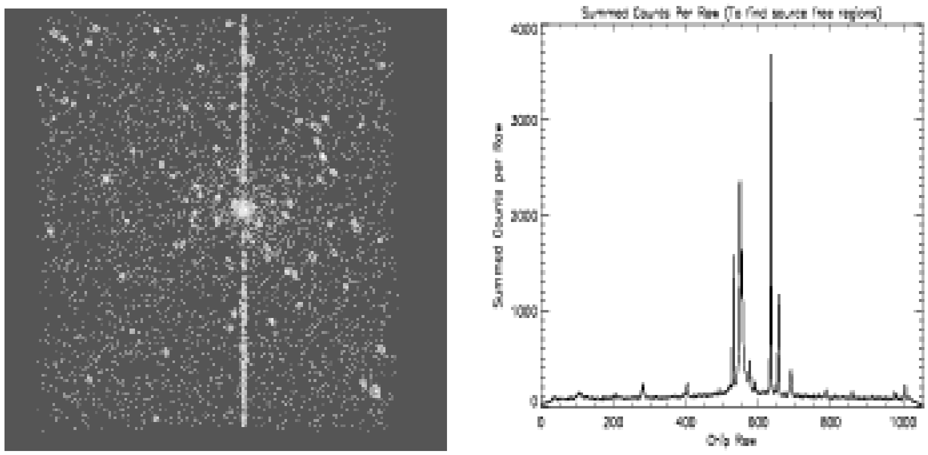

Figure 1. *a(left):* Image of the S3 chip of an ACIS observation of M81 with WAVDETECT source locations overlayed. *b(right):* Plot of the counts summed across readout channels vs. chip row. This is used to identify chips rows which do not contain counts from X-ray sources.

2. Background + Readout Streak

To address the problem of the *Readout Streak* in source detections we outline a technique in which from the data we create a background image containing the *Readout Streak*. The resulting background image can either be used to determine which sources are contained in the *Readout Streak* or it can be input into a source detection algorithm (such as WAVDETECT) as a background map.

- We first create a image for each chip. The resulting background images can be later merged to create an image to match the image being used by WAVDETECT.
- We rotate the image such that the X-axis will be along the chip rows (across readout channels) and Y-axis will be along the direction of the readout channel.
- We first sum along each X-axis (across readout channels) to make a plot of summed counts per row (see Fig. 1b) in order to determine which rows on the chip are source free.
- We find lowest summed value (excluding off chip and dither regions). This is represented by the dotted line in Fig. 2a. The square root of this value is used as a σ (standard deviation).
- We use as an upper bound the lowest value + $4 \times \sigma$ (dashed line in Fig. 2a). The rows whose summed values fall between the minimum value and this upper bound are considered the source free region. Note the number of σ is a parameter that one can vary.
- We then take the rows which are source free and sum along the direction of the readout channels and divide by the total number of rows. The result is a plot of counts/pixel vs. readout channel (see Fig. 2b). This represents the average background + *Readout Streak* contribution per readout channel.

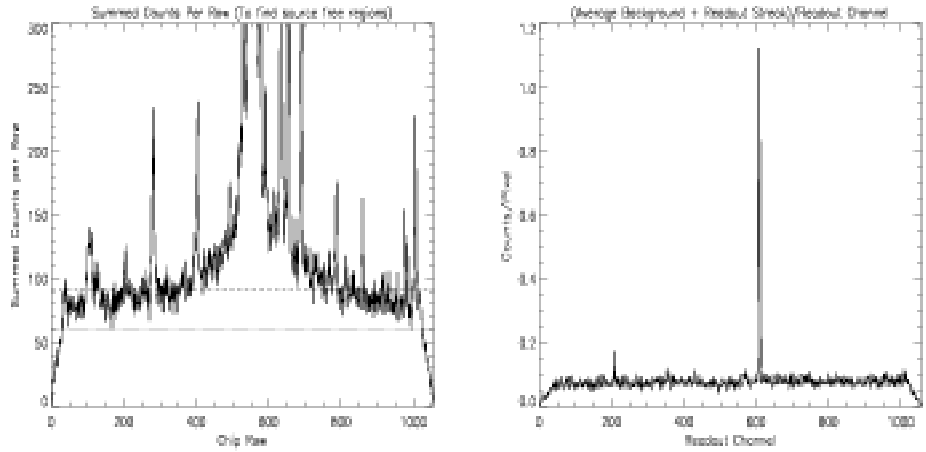

Figure 2. *a(left):* Same plot as Fig. 1b with limits used to determined which chip rows do not contain an X-ray source. *b(right):* The summed counts of the source free rows divided by the total number of source free rows vs. readout channel. This represents the background counts + *Readout Streak* counts as a function of readout channel.

- This can now be replicated (copied) for each row of the chip to create a background image which also contains the *Readout Streak* contribution (see Fig. 3a). Care needs to be taken in handling the edges of the chip.
- This background + *Readout Streak* image can now be input into the source detection algorithm (WAVDETECT) as a background map. Note that the use of this type of map is important since the *Readout Streak* affects the noise statistics significantly.

3. Results of this Approach

Using the background + *Readout Streak* image created in the manner described above for the S3 chip of the M81 observation we found the following:

- One can see the suppression of false sources caused by the background + *Readout Streak* as well as supplying a background to improve source detection. (see Fig. 3b).
- There are now 95 sources found instead of 158 sources. All of the "missing" sources were those previously found in the *Readout Streak*.
- Of the sources still found in the *Readout Streak* all appear, upon closer examination, to be real sources.
- Near the edge of the chip and near the center of M81 (where there is extended emission) there are a few additional sources found (not found in the initial run of WAVDETECT).
- The *Readout Streak* from the background image can also be used to "clean" the image and remove the *Readout Streak* from the image (see Fig. 4). But one should be careful of using this image for source detection since the noise statistics are significantly different for the *Readout Streak* than

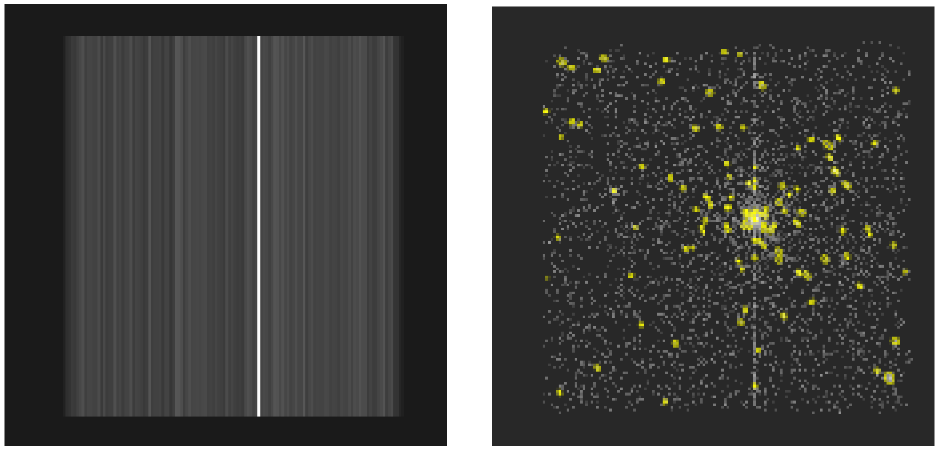

Figure 3. *a(left):* A background + *Readout Streak* image created by taking the background + *Readout Streak* (shown in Fig. 2b) and replicating it for each chip row.*b(right):* Image of the S3 chip observation of M81 with source locations (WAVDETECT) found using the background map shown in Fig. 3a. Note the lack of false source found in the *Readout Streak*

for the rest of the background. This a cosmetic operation that has little scientific meaning.

4. Future Work

This method holds great promise in terms of identifying and removing spurious *Readout Streaks* sources. Some additional areas of study and work we are pursuing are:

- **Two-dimensional Background Images**: From the source free rows there should be additional two-dimensional information about the background. Thus in principle we should be able to create a two-dimensional background image containing *Readout Streaks*.
- **Pileup Information**: In general, sources which are bright enough to have a noticeable *Readout Streak* also suffer from Pileup (multiple photons per pixel during integration). The exposure to the bright source of the pixels in the *Readout Streak* is so short that they in general should not have this problem. Thus an examination of the *Readout Streak* should give one information on how much Pileup a source is experiencing.
- **Different X-Ray Missions**: This technique can be applied to any X-ray mission which is using a CCD detector and may experience *Readout Streak* problems. The use of this method for other X-ray missions (Current: XMM, Past: ASCA, Future: ASTRO-E2) is being investigated.
- **L3 and CIAO**: We are working to make this tool able to be run in the L3 pipeline environment and also release a version as a CIAO tool for the general user.

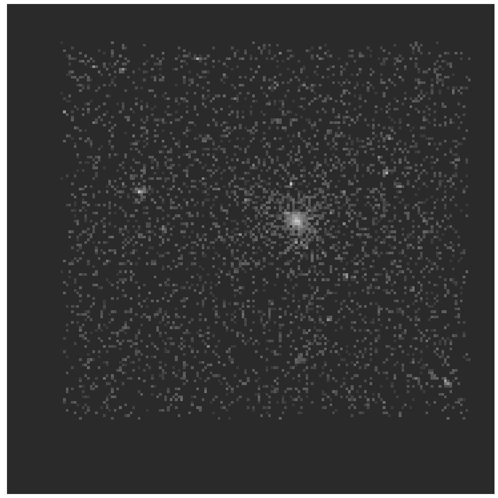

Figure 4. Image of the S3 chip observation of M81 "cleaned" using the *Readout Streak* information shown in Fig. 3a.

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References

Freeman, P. E., Kashyap, V., Rosner, R., & Lamb, D. Q., 2002, ApJS, 138, 185