The Development and Use of a Background Map for the Chandra Source Catalog

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I. Introduction:

Early in the development of the Chandra Source Catalog (CSC) it was recognized that a background map was necessary to perform critical CSC tasks such as source detection, photometry, and source characterization. We present a discussion of how such maps can be created directly from the Chandra data.

The background maps for Chandra ACIS data consist of two components. One is a high spatial frequency component due to read-out streaks and the other is a low spatial frequency component. The discussion of the algorithm used for the high frequency maps has been covered in McCollough & Rots (2005). Here we focus on generating the low spatial frequency maps and on combining them with the high frequency ones to produce the final background maps. We present source detection results with and without use of background maps which illustrates the reduction in false source detections. We also discuss what future development might be necessary.

Finally, we turn to generating similar background maps for Chandra HRC data. These are dominated by the low spatial frequency maps for the HRC since this detector does not suffer from the read-out streak problem found in Chandra ACIS data.

II. High Spatial Frequency Maps (Streak Map):

X-Ray sources observed with ACIS will produce high spatial frequency structure in the background caused by readout frame transfer (readout streak). This steak is the result of the finite amount of time (40 μsec per row) that it takes to read out the CCD after an integration period. Consequently, all pixels along a given readout channel are exposed to all points on the sky that lie along that readout channel. The result is that for readout channels which containing bright sources there will be a streak along the length of the readout channel.

A discussion of the algorithm used for the CSC to create high spatial frequency maps which address the readout streak problem is given in McCollough & Rots (2005). It should be noted that these maps also contain a 1-dimensional low frequency component. This must be accounted for when creating the low spatial frequency map. Figure 1 shows the streak map created for broad band (0.5-7.0 keV) image of M81 (obsid 735).

III. Low Spatial Frequency Maps (Modified Poisson Mean):

As noted noted above the streak map contains a 1-dimensional low frequency component which represents an average of the low frequency background over the rows used to create the streak map. What is needed is a 2-dimensional low frequency map which accounts for variation of the low frequency component across the image. We create that low frequency map using the following steps:

- From the event data create an image at the appropriate energy band binning.
- For the image create the appropriate streak map.
- Subtract the streak map from the image. This removes the high frequency component from the image as well as the low frequency component that is contained in the streak map.
- For each point in the streak map subtracted image we define a box of *nsize* by *nsize* pixels centered on the point. Thus the edges of the box are *nsize*/2 away from the point. This defines the sampling area. *nsize* represents the low frequency filter size (sizes smaller than this being filtered out and attenuated). Near the edges of the maps the area is truncated and some higher frequency information may propagate into the map. But this is currently not viewed as a major issue.
- For the sampling area of each point a histogram (h) is created of the count distribution. Since the readout streak has been subtracted there will be some negative count pixels. As a result bin 0 will be typically represented by ≤ 0.5 to $< +0.5$.
- From the histogram the highest bin (a) and its higher neighbor (b) are identified.
- The background is calculated as:

  $b_{lf} = \mathrm{mean}(h[a] \cup h[b])$

  This is a modified form of a Poisson Mean. That is to say the mean value of all of the pixels contained in the histogram columns of h[a] and h[b] . It is expected that there will be negative values in this map. This map serves to modify the low spatial frequency component that is contained in the high spatial frequency map (streak map).
- This process is done for each point in the maps.
- For the ACIS observations we used an *nsize* of 129 pixels. This corresponds to a scale size of ~ 1 arcminute.

In Figure 1 is the low frequency map created for broad band (0.5-7.0 keV) image of M81 (obsid 735).

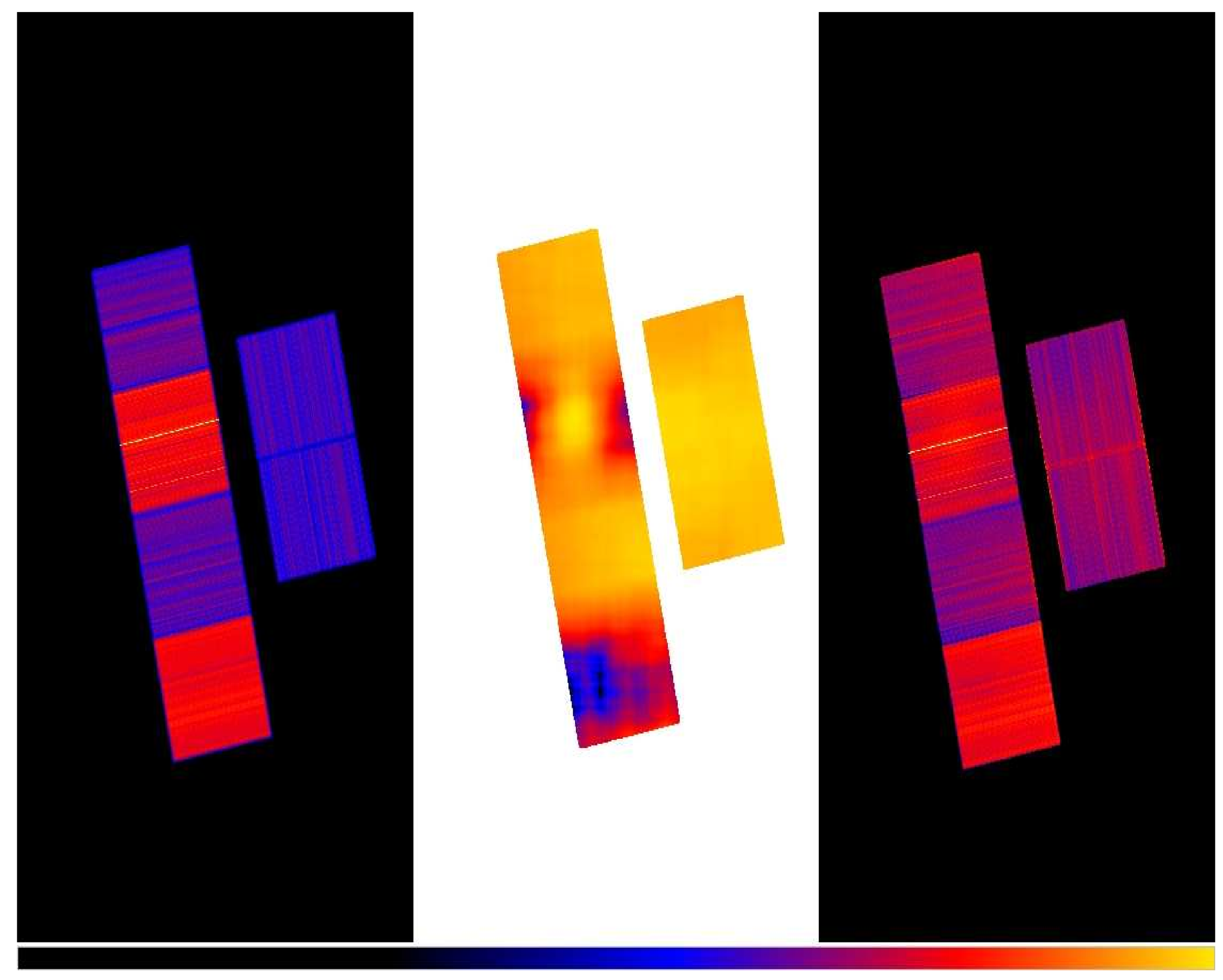

Figure 1: The CSC broad band (0.5-7.0 keV) background map for the Chandra observations of M81 (obsid 735) and its various components are given above. *(right)* Streak map; *(center)* Low spatial frequency map; and *(left)* Final exposure corrected background map.

IV. Total Background Map and Source Detection:

The final background map is created by:

- Add the streak map to the low frequency map.
- Create an exposure map for image and normalize it so that its maximum value is one.
- Finally divide the combined map from first step by the normalized exposure map. This last step is to make exposure adjustments to the edge of the background where the effects of dither come into play.

Figure 1 also shows the background map created for broad band (0.5-7.0 keV) image of M81 (obsid 735).

Figure 2 presents the broad band images of M81 (obsid 735) with the results of WAVDETECT runs without *(left)* and with *(right)* a background. WAVDETECT is wavelet-based source detection algorithm designed for the spatial analysis of Poisson data (Freeman, et al. 2002). Note that using the background results in the elimination of the readout streak sources and spurious sources near the the front/back illuminated chips.

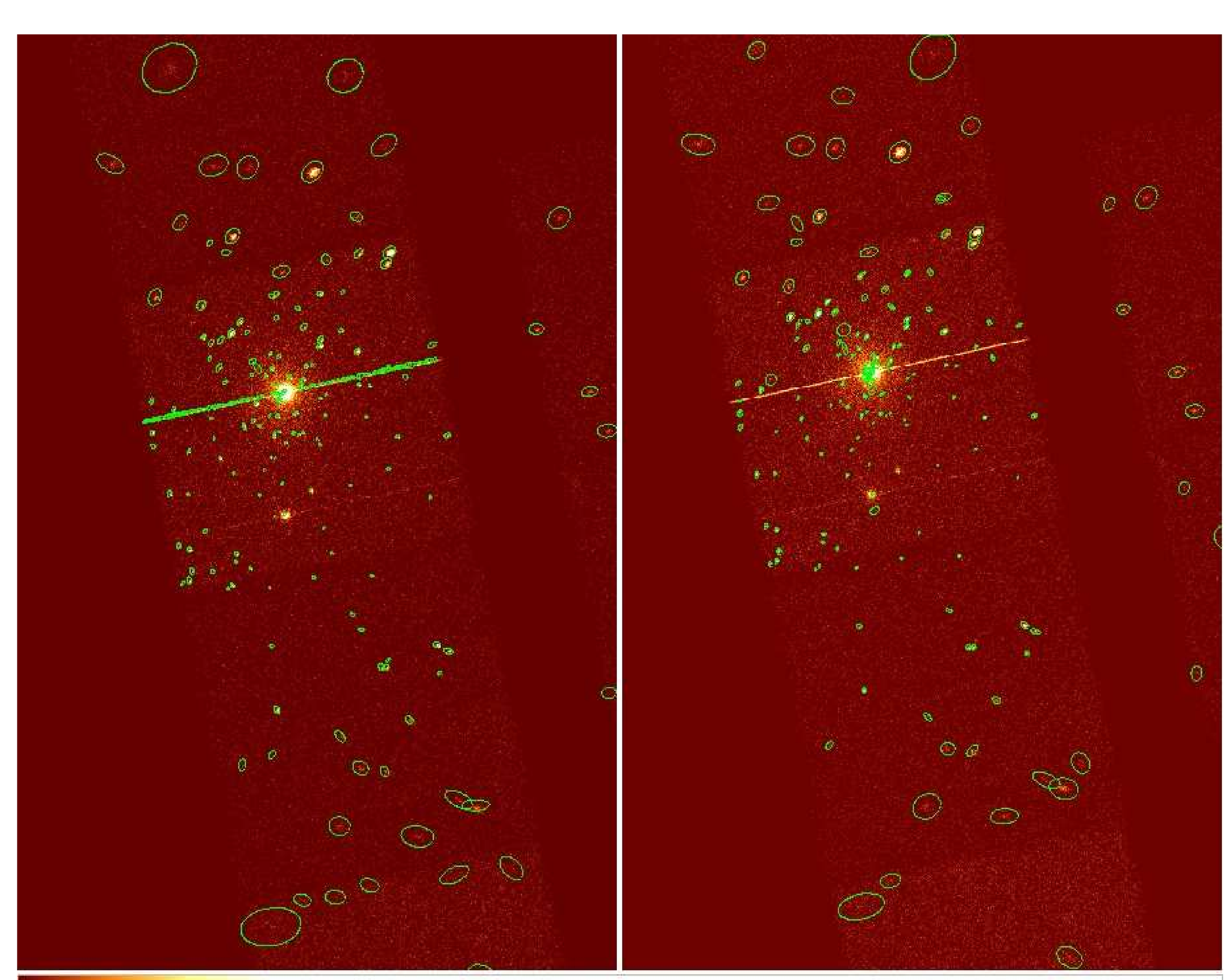

Figure 2: *(right)* The source detections as a result of a WAVDETECT run on a broad band (0.5-7.0 keV) image of M81 (obsid 735) without the CSC background map; *(left)* The source detections for same image using a CSC background map. Note the elimination of false sources in the readout streak and near the front/back illuminated chip boundary (bottom of the image).

V. HRC Background Maps:

There is also a need for a background map for the Chandra HRC observations. For the HRC there are really two instruments, the HRC-I and the HRC-S. Imaging with the HRC-S is problematic and since there are only a limited number of imaging observations with this instrument background map creation has been deferred.

The HRC-I is a microchannel plate device and as such does not suffer from the problem of readout streaks. Thus all that is necessary is a low spatial frequency map to represent the background. What we use is the same algorithm that was used for the ACIS background maps without the use of a readout streak map.

In Figures 3 are images of the HRC-I background map and image with detections of an HRC-I observation of M31 (obsid: 7283). One important thing to note is that the background increases toward the edges of the map giving rise to a bowl shaped appearance to the map. This is a result of the HRC-I's background being dominated of cosmic rays.

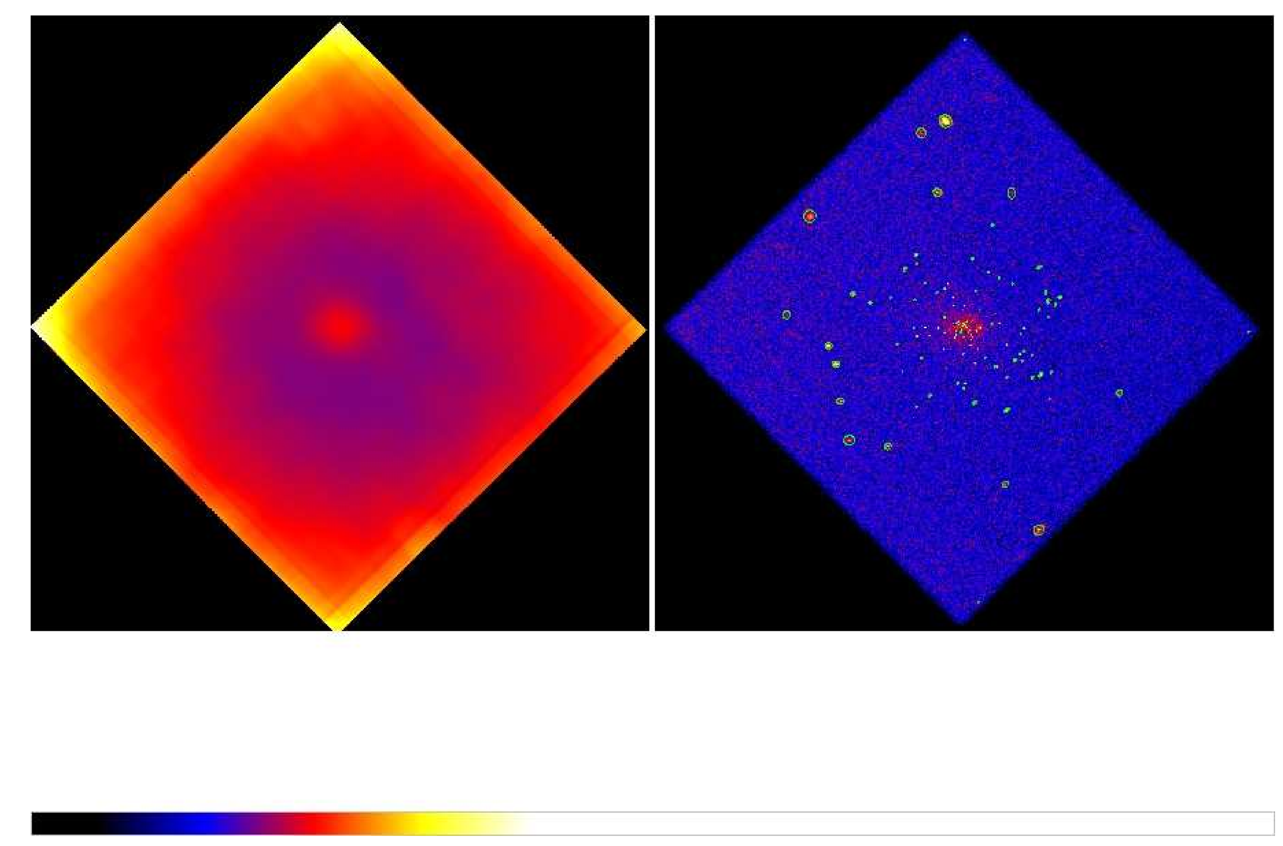

Figure 3: *(right)* The background map for an HRC-I observation of M31 (obsid 7283); *(left)* The source detection of the M31 using the CSC background map. The image has been blocked by a factor of 10 and smooth to highlight the sources.

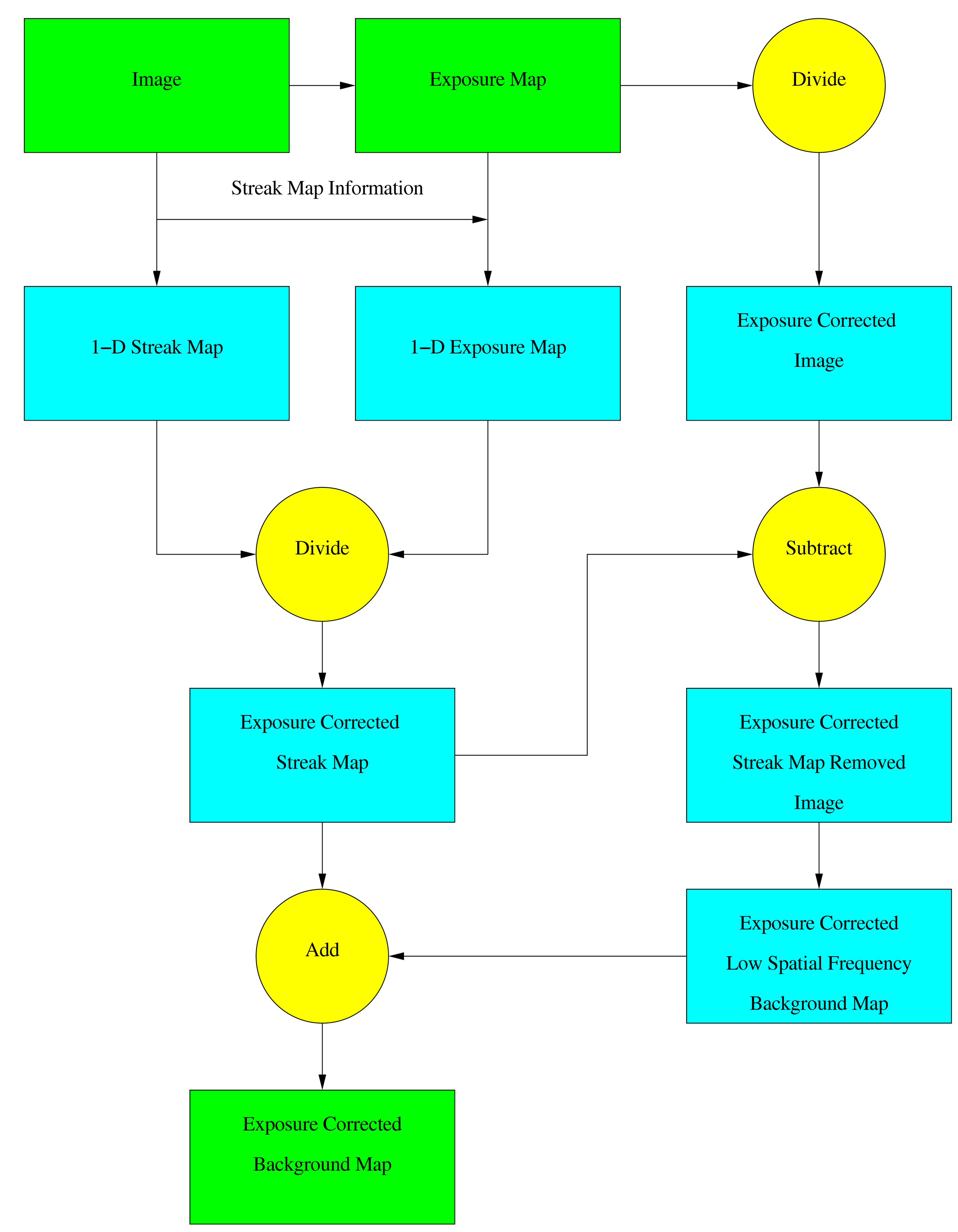

Figure 4: A flow chart which reflects the current implementation along with planned enhancements (improved streak maps and exposure maps) for the CSC background map.

VI. Future Work:

In addition to creating a background map for HRC-S we are also working on the following:

- ACIS Background Map Enhancements: We are seeking to improve the background map by more accurately creating the streak maps and the exposure maps that are used to correct the background map. The steps for this enhanced version of the background map creation are graphically outline in the Figure 4.
- HRC Background Map Enhancements: For the HRC a dominate component of the background are the cosmic rays which have a relatively uniform contribution across the detector. From various calibration observations we should be able to estimate the contribution due to the cosmic rays and subtract them from the images before the background map is created.

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