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The Sliding-Cell Detection Program for Chandra X-ray Data

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Abstract. The Chandra X-ray Observatory provides unprecedented resolution over a large field of view with large collecting area. With these advancements, different and/or improved detection algorithms are a necessity for Chandra data analysis. We here present an overview of *Celldetect*, a source detection program for Chandra. *Celldetect* is descendent from *Einstein* and *ROSAT* data analysis programs (Harnden et al. 1984; DePonte & Primini 1993). It is part of the Chandra Interactive Analysis of Observations (CIAO) software package and is also used in automated processing of Chandra data.

1. Introduction

Celldetect identifies point sources in the presence of background. It can do so by three methods: estimating background locally, accepting a background map, or accepting a background value. The first approach is to examine the counts in a candidate source region and estimate the number of the counts in that region that are due to background. The candidate region is called the "detect cell" (Figure 1). The size of the cell is chosen to be some large fraction of the Point Spread Function (PSF) size. It is surrounded by a "background frame" of approximately equal area. For an isolated point source centered in the detect cell, the cell would contain source and background counts, while the frame would have only background counts. Using the counts in the frame, an estimate is computed for the number of counts in the cell which are due to background. These are subtracted from the cell counts. If the remaining detect cell counts are significantly higher than the estimated background counts, a source is detected.

When a background map or value is supplied to the tool, the background is not estimated and *celldetect* does not use a background frame.

Regardless of method, the cell is started in one corner of the dataset. It then "slides" repeatedly by one third its size, with a new source test made at each position. At the far end of the dataset, the cell slides down by one step and is repositioned horizontally, on the starting side.

This whole approach is essentially the "Local Detect" procedure described in DePonte & Primini (1993). The following sections outline advances built on that technique.

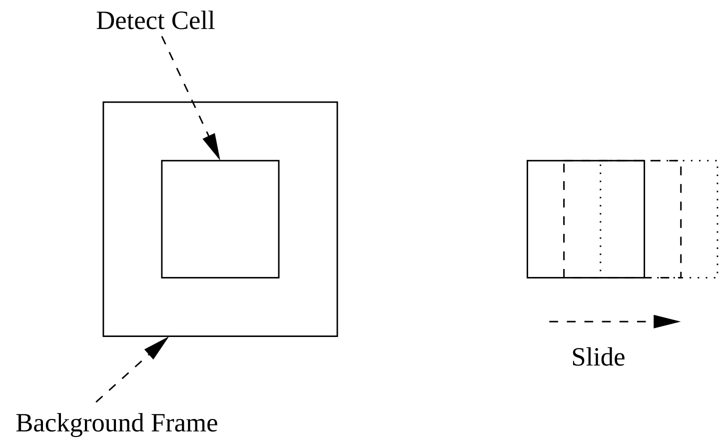

Figure 1. The sliding Detect Cell.

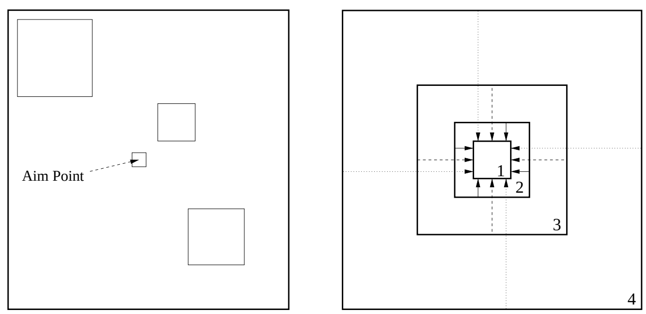

Figure 2. Varying cell sizes *(left)* and recursive blocking *(right)*.

2. Varying Detect Cell Size

As the size of the PSF varies with off-axis angle, the size of the detect cell should also vary (Figure 2). At each point where a detection is attempted, *celldetect* uses an appropriately sized cell. This size will typically be smallest at the aim point, and largest at the periphery of the dataset. *Celldetect* implements the cell size variation in an inelegant but practical manner. The tool does not attempt to switch between cell sizes as it slides the cell. It does a complete scan of the data at each cell size found in the dataset. A detection calculation at any cell placement point is only made when the PSF size at that point is appropriate for the size of the cell that is currently sliding. Correctly varying the cell size and placement during one scan is nontrivial.

3. Recursive Blocking

Modern X-ray detectors are large, and a spatially complete dataset can overwhelm the memory of a typical user's computer. However, the PSF usually grows with off-axis angle, and full resolution is not needed throughout the dataset. *Celldetect* starts analysis with a 2048 $\times$ 2048 unblocked "window" at the cen-

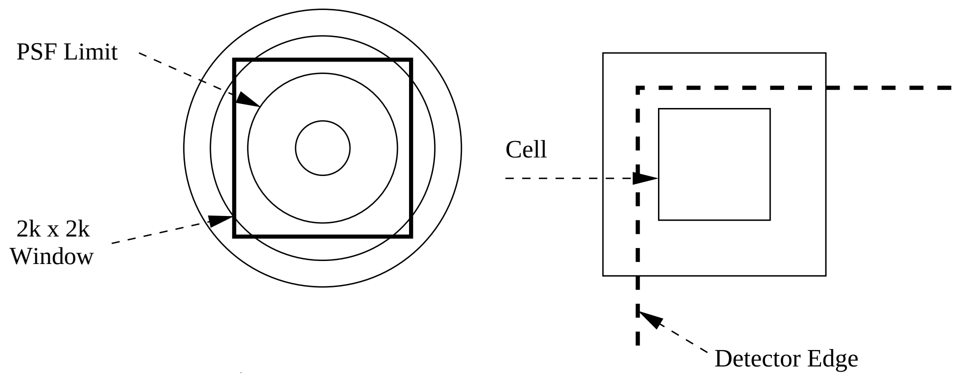

Figure 3. PSF limits *(left)* and detector edge effect *(right)*.

ter (aim point) of the dataset, then blocking down successively larger regions of the data into the same window (Figure 2). The analysis at each successive pass excludes the spatial extent of the previous pass. In each pass, the window is scanned at each of the cell sizes appropriate for that window. For a given instrument, the size of the window must be chosen large enough so that the blocked pixels still oversample the PSF size in later passes.

4. Consistent Analysis at Each PSF Size

When the pixels from a blocking pass are examined, there will be a range of PSF sizes in the analysis window. Some contours of constant PSF size will lie entirely within the window, others will lie only partially in the window (Figure 3). In each pass except the last, *celldetect* limits its analysis to the region of the largest PSF size which is completely contained within the window. This ensures that the data at any given PSF size are all examined at the same blocking factor.

5. Exposure Variation

When the background frame extends over an area of low exposure (relative to the detect cell), the background counts will be artificially reduced (Figure 3). This will make the detect counts appear artificially significant. The consequence is that *celldetect* is prone to declaring false sources near detector edges and other regions of low exposure. To assist the user, *celldetect* provides an "exposure ratio" calculation for each detection. This is a ratio of the average exposure (in either seconds or effective collecting area) for pixels in the background frame to the average exposure for pixels in the detect cell. Under-illuminated backgrounds will cause the ratio to be less than unity. The source list can then be filtered on this value to exclude questionable detections.

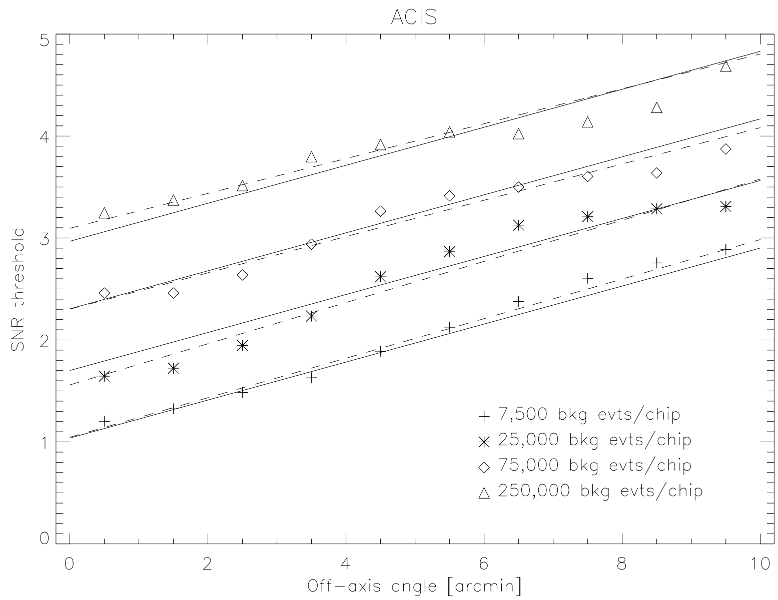

Figure 4. Graph of good SNR values for ACIS off-axis angles for 4 different densities of background events. Based on *celldetect* runs on MARX simulations containing only background events (in which *celldetect* should find no sources) (Dobrzycki et al. 2000).

6. Future Work

The background statistics in *celldetect* change as the cell size increases. This means that a fixed value of the SNR threshold is not appropriate for best source detection. A SNR varying with cell size (and hence off-axis angle) gives better results (Figure 4). A varying SNR is under consideration for a future release of *celldetect*.

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