DETECT Tools in CIAO

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CONTRIBUTORS

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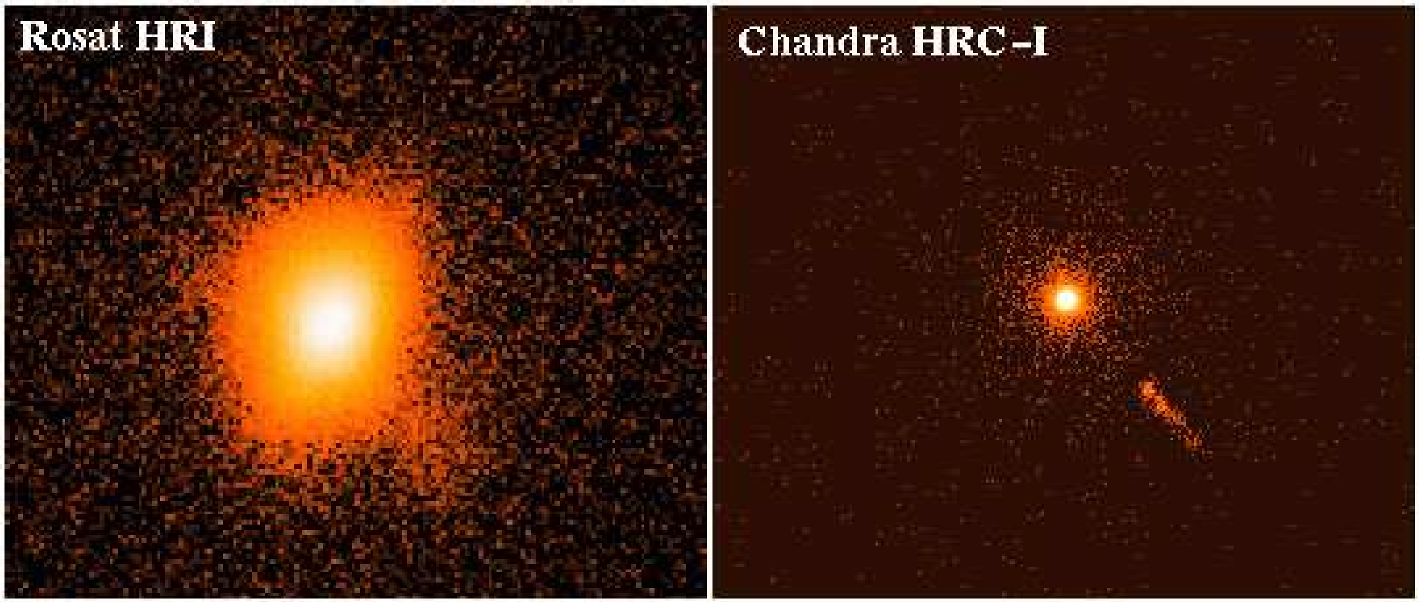
OUTLINE

- Chandra challenges for source detection tools
- CXC Detect tools:
  - CELLDETECT
  - VTPDETECT
  - WAVDETECT
- Sample runs: Chandra/ACIS observation of 3C295

Chandra challenges for source detection tools

- Chandra mirrors have an angular resolution ~10 finer than any previous X–ray telescope:
  - Complex source structures are commonly seen; point sources and blobs in Rosat often turn out to be source complexes in Chandra
  - Extended sources have low surface brightness
- PSF changes dramatically with position
- No single method for detection of X–ray sources is adequate

3C273 in Rosat and Chandra



CIAO Detect Tools

- CELLDETECT:
  - sliding cell: like Rosat, plus:
    - variable cell size, calculated automatically based on PSF size
    - "recursive blocking", automatic handling of spatially large data sets
    - exposure map–based rejection of spurious sources at detector edges
- VTPDETECT:
  - Voronoi Tesselation and Percolation; good for low surface brightness, irregular/extended sources
- WAVDETECT:
  - wavelet convolution, with iterative background determination; good for crowded regions

CELLDETECT: PROS and CONS

- Fast and robust
- Works well for point sources
- PSF shape not important; only approximate size needed
- Familiar to community
- Can swallow entire Chandra observation with one gulp

- Problems with extended sources; requires proper cell size and background
- Gets confused in crowded fields if background calculated locally

VTPDETECT: PROS and CONS

- Does not assume anything about source size/shape (works well when sources are extended/irregular)
- Photon–based, thus can work on large areas in full resolution
- Works well on low surface brightness extended sources

- Does not assume anything about source size/shape (gets confused in crowded fields)
- Very slow if number of photons is large and if there is low contrast between background and sources

WAVDETECT: PROS and CONS

- Works well in crowded fields; background determination is iterative
- Works well for point sources on top of extended emission
- Shape of PSF not important, only approximate size needed
- Edge–of–field and vignetting effects handled correctly

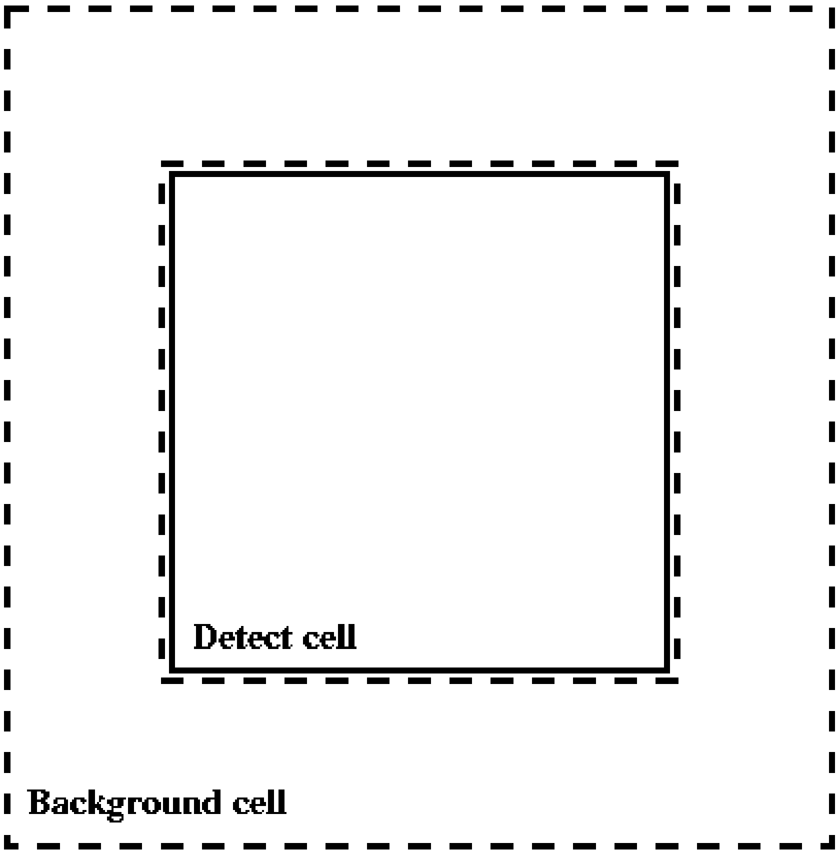
- Much slower than sliding cell, especially if many wavelet scales are analyzed
- Currently limited to small chunks of data (1k x 1k – OK, 2k x 2k – pushing it)
- Requires tricks (like binning) for large areas, thus in principle losing resolution

CELLDETECT

- Concept borrowed from PROS detect package, with enhancements.
- Scanning an X–ray image with a square "detect cell." The signal to noise ratio is calculated by comparing the counts in the cell and counts in the background.
- References:
  - CXC Detect Manual
  - Calderwood et al. 2001, ADASS X, ASP Conf. Ser. 10, 443
  - Dobrzycki et al. 2000, AAS/HEAD, 32, 2708

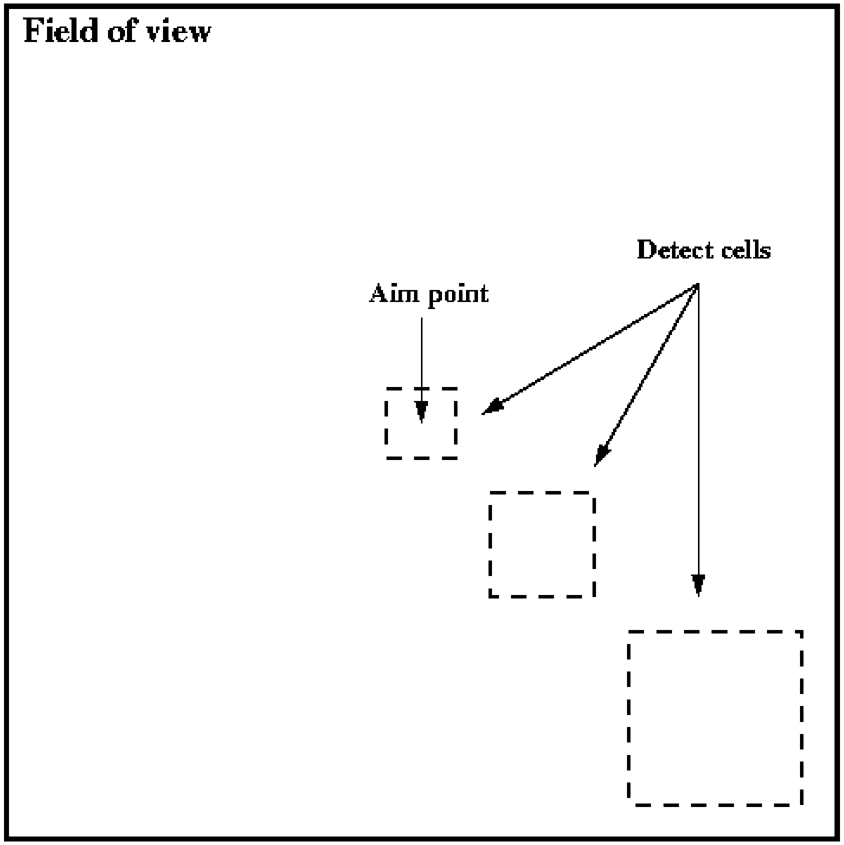
CELLDETECT: background

1. Local background (default, pictured): square "annulus" surrounding the detect cell
2. Map background: provided by the user (bkgfile)
3. Fixed numerical value: provided by the user (bkgvalue)

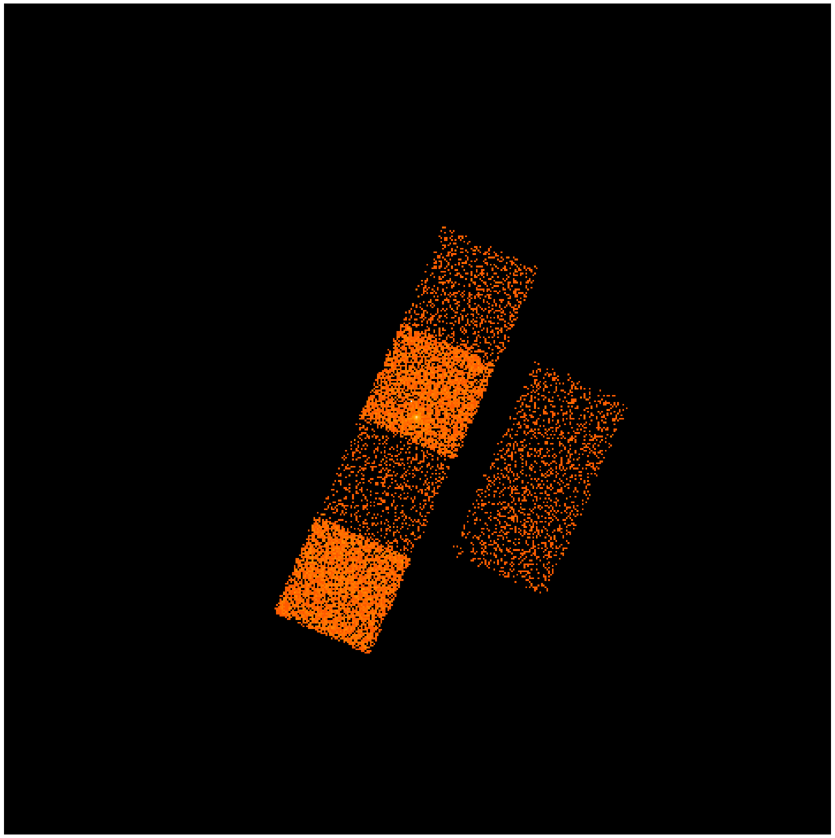


CELLDETECT: variable cell

- The size of the detect cell is based on the PSF size. The user can select what fraction of the source counts should fall into the cell (eenergy), and at what energy this is specified (eband).
- Can be overriden with fixedcell

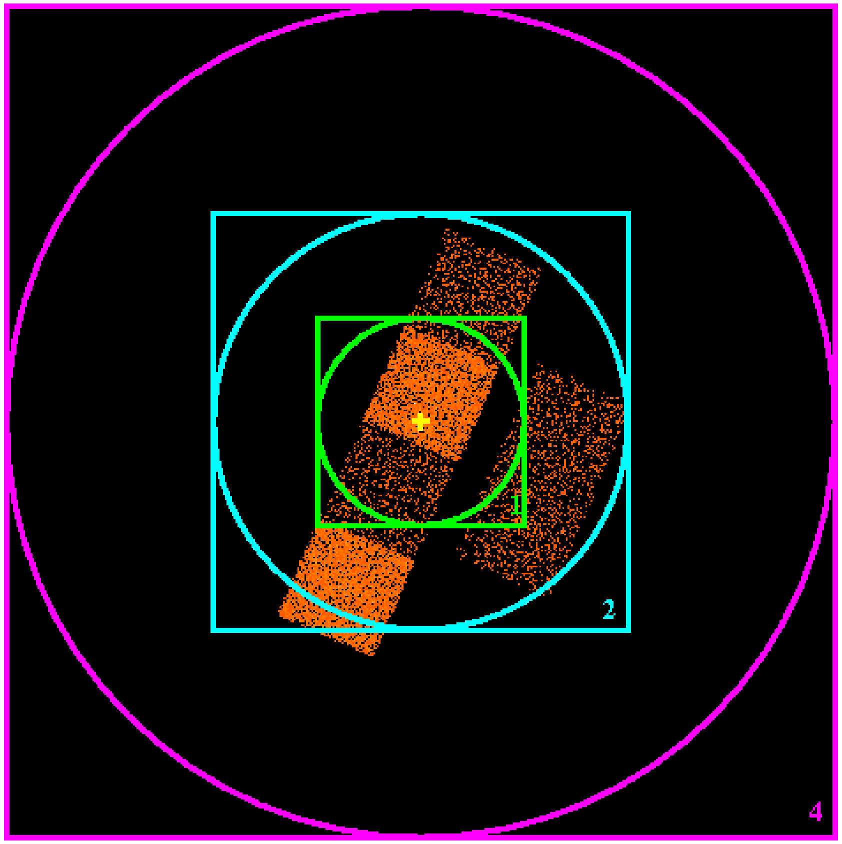


CELLDETECT: recursive blocking



- Chandra datasets are large: ACIS (pictured) is 8k x 8k, HRC–I is 32k x 32k.

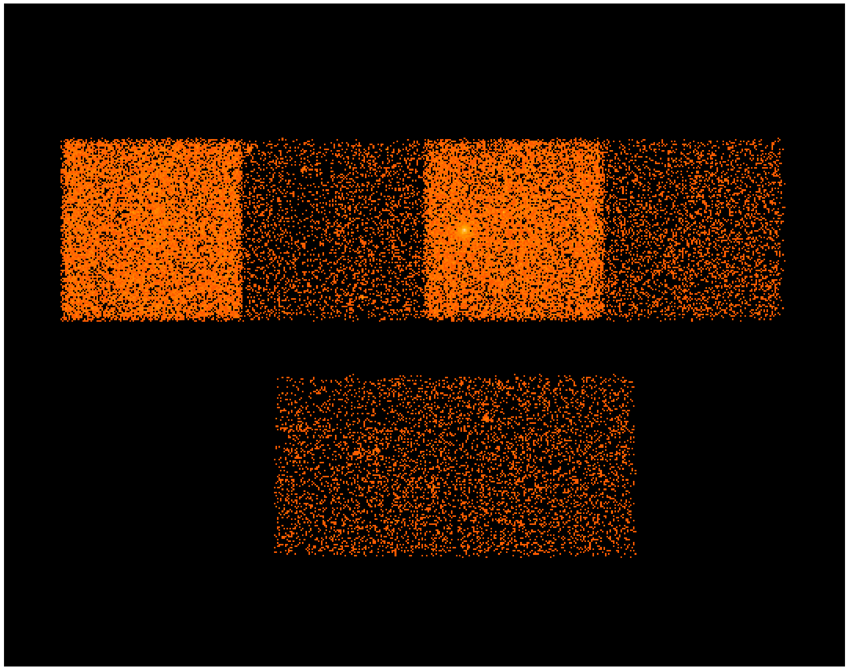
CELLDETECT: recursive blocking



- "Recursive blocking":
  1. Center 2k x 2k scanned for sources in full resolution, only selecting sources inside the circle totally enclosed in the selected data set,
  2. Center 4k x 4k blocked by 2, excluding region analyzed in step 1,
  3. Etc.

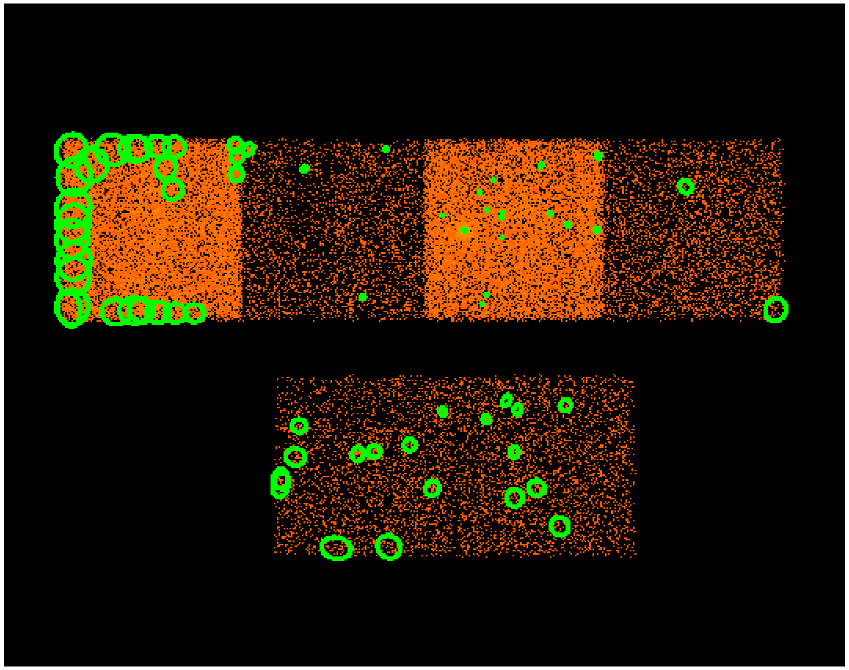
CELLDETECT: edge effects

- Chandra data have several edge effects:
  - field of view boundaries,
  - jumps in background between BI and FI chips in ACIS,
  - node boundaries inside ACIS chips.



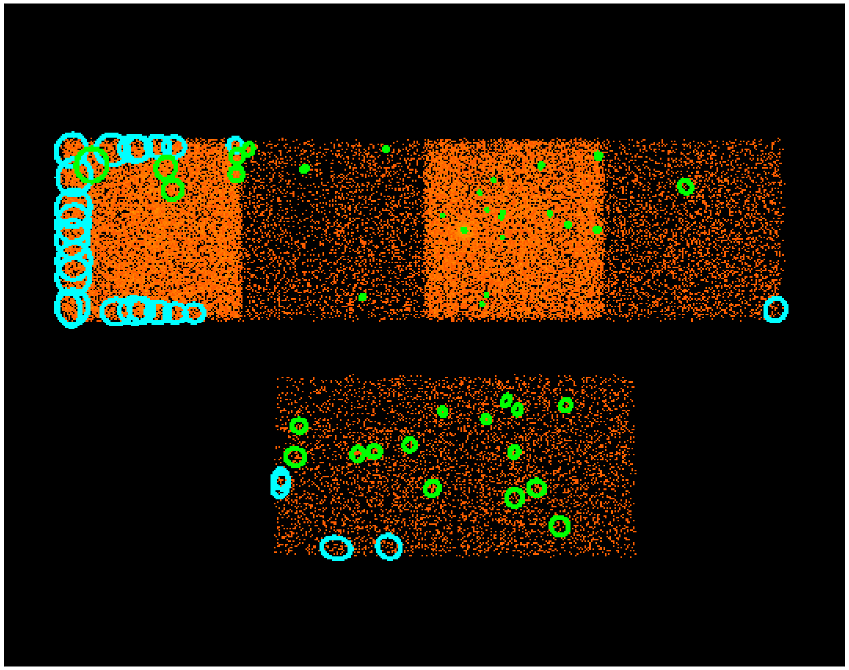
CELLDETECT: edge effects

- "Vanilla" CELLDETECT run leads to several spurious detections at detector edges.



CELLDETECT: edge effects

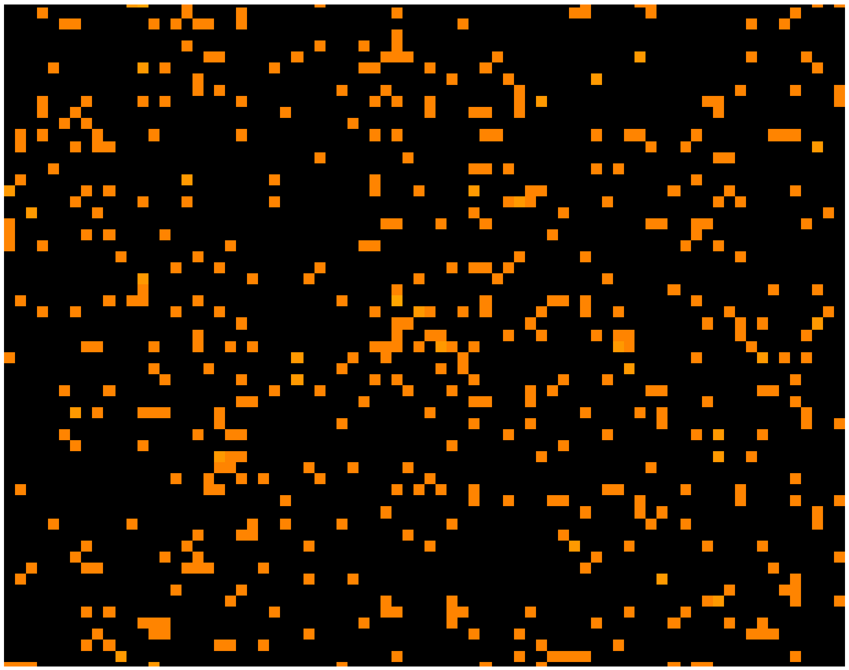
- The user may provide a stack of exposure maps (expstk) and select only sources for which the ratio of exposures in the detect and background cells is higher than user–defined value (expratio).



VTPDETECT

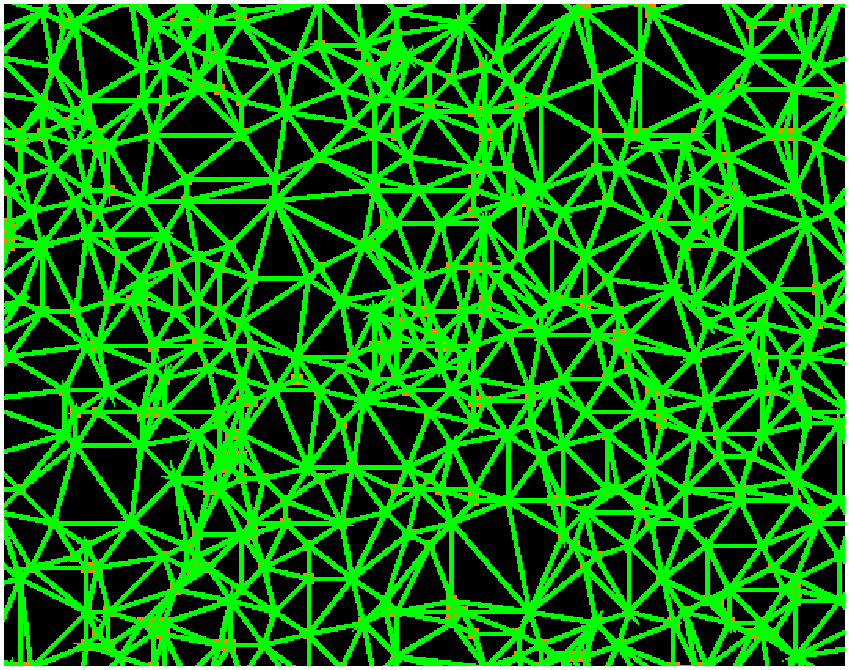
- A "friend–of–friend–of–friend" algorithm.
- Scale–independent: good for extended/irregular sources, but encounters problems in crowded fields.
- References:
  - CXC Detect Manual
  - Ebeling & Wiedenmann 1993, Phys.Rev.E, 47, 704
  - Ebeling et al. 1996, MNRAS, 281, 799
  - Jones et al. 1998, ApJ, 495, 100

VTPDETECT: how it works



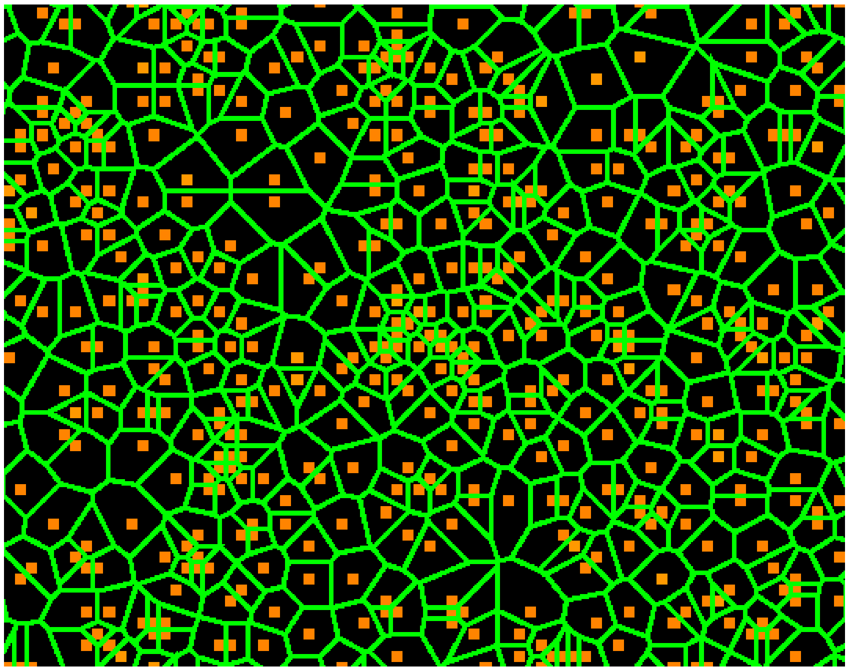
- Small (ca. 75 x 50 pixels) fragment of Chandra/ACIS observation of 3C295

VTPDETECT: how it works



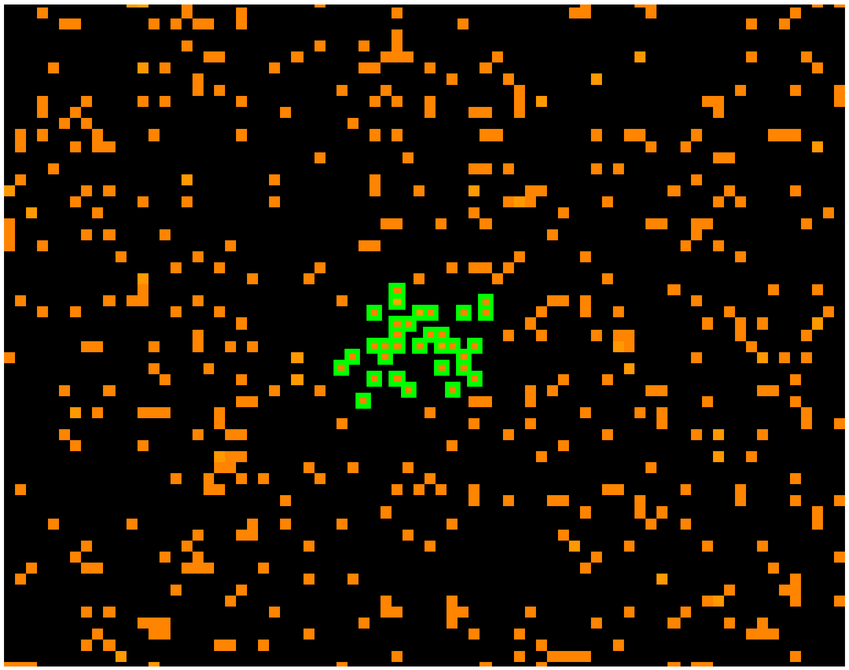
- A triangulation network is built on all events in the considered region.

VTPDETECT: how it works



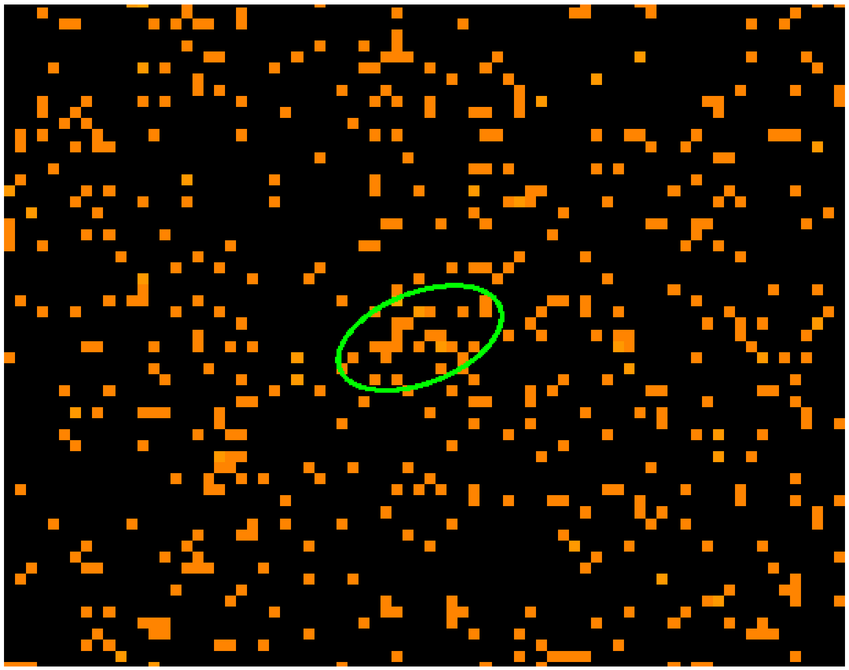
- The triangulation network is used to construct Voronoi tesselation. Cumulative distribution of the inverese areas of the Voronoi cells is compared with Poisson distribution.

VTPDETECT: how it works



- Cutoff value for photon density wrt. background is determined; the user can influence it by providing scale value. Percolation is run on the individual cells, grouping cells (i.e. photons) exceeding the cutoff into source candidates.

VTPDETECT: how it works



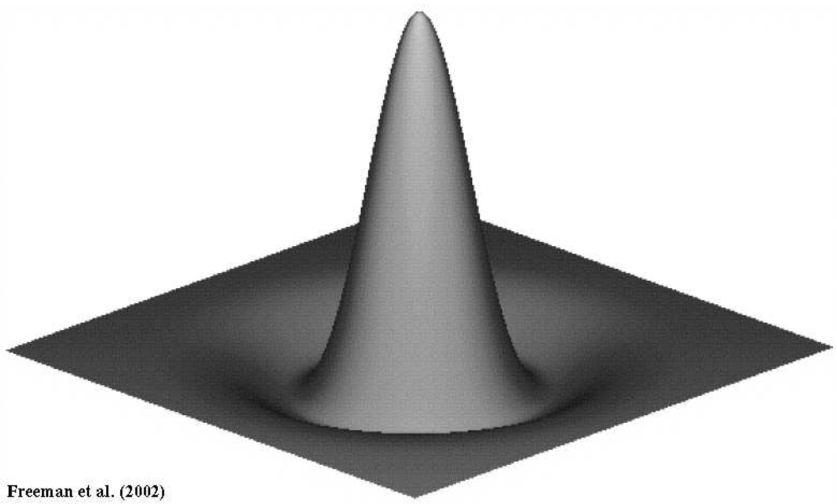
- The source is listed on output if the number of events in the candidate exceeds user–defined minimum (coarse).

WAVDETECT

- The data image is convolved with a wavelet (which spatially integrates to zero) for a set of wavelet scales.
- The tool consists of two separate parts:
  - WTRANSFORM: produces correlation map at each scale and generates lists of candidate positions
  - WRECON: uses WTRANSFORM outputs to define a source cell and obtain source parameters
- References:
  - CXC Detect Manual
  - Freeman et al. 2002, ApJS, 138, 185

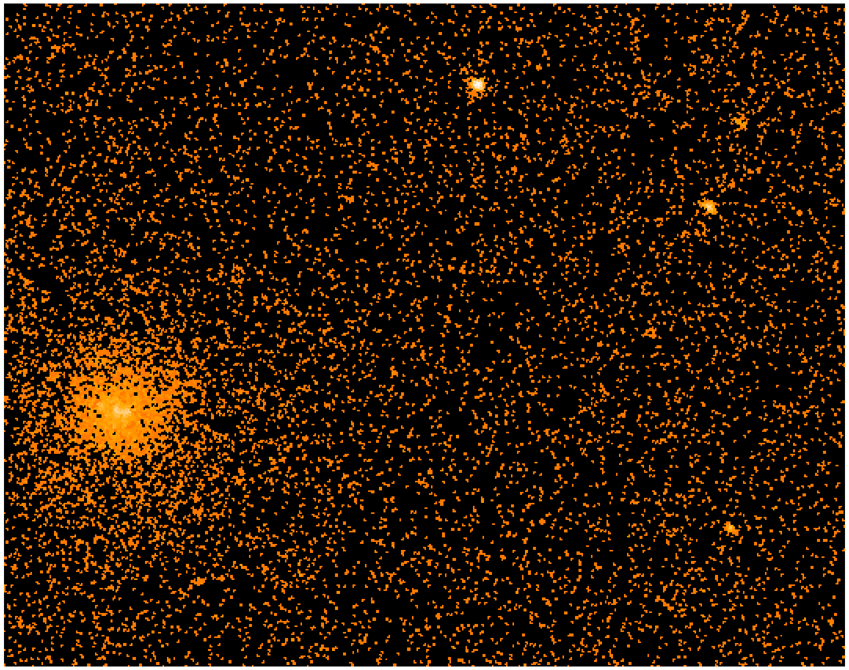
WAVDETECT

- The tool uses "Mexican Hat" wavelet.
- The detection process is repeated for a set of wavelet scales, usually separated by a factor of sqrt(2) or 2.
- CAVEAT: both a large number of scales and large sized scales affect machine memory and run time.



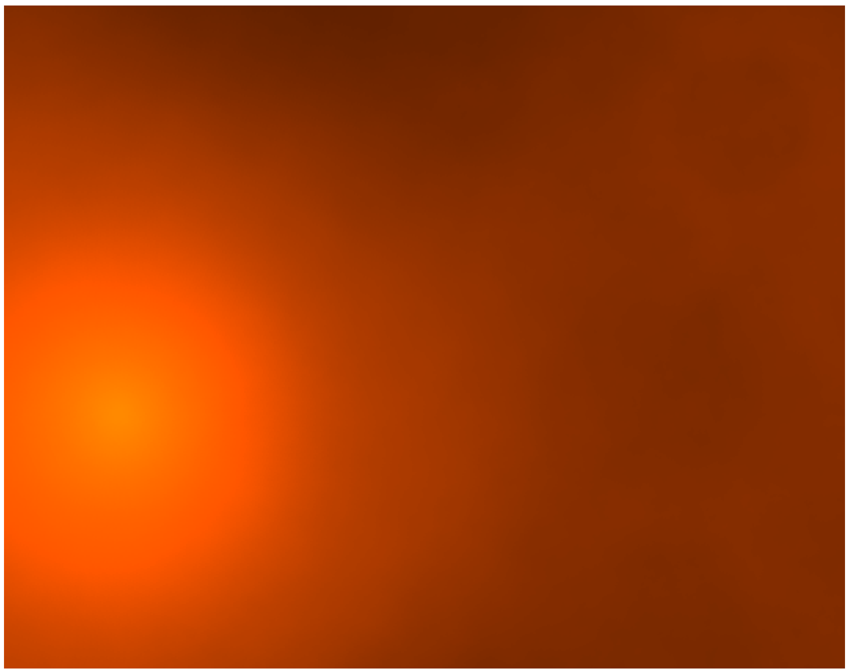
Freeman et al. (2002)

WAVDETECT: test run



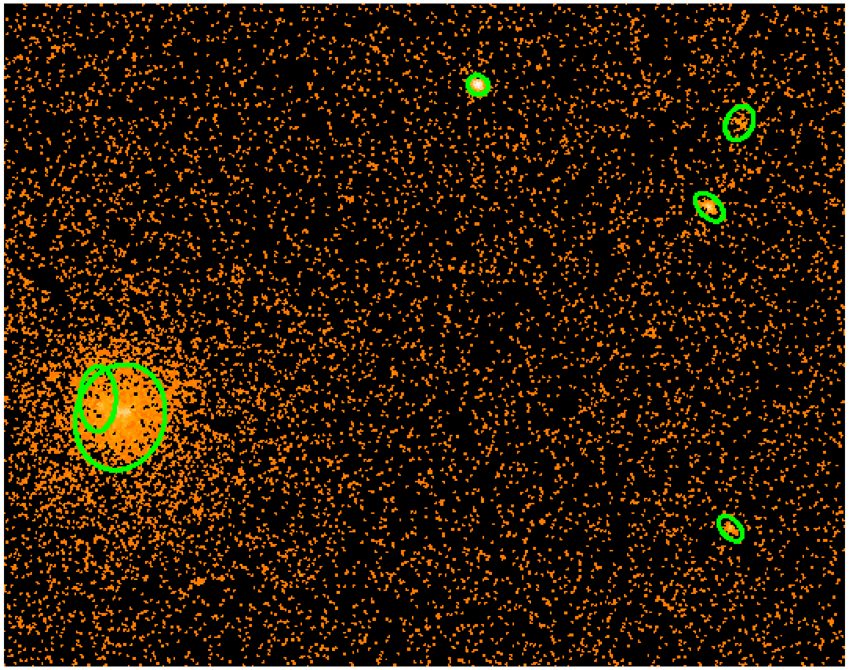
- Chandra/ACIS observation of 3C295. WAVDETECT was run with five scales: 2, 4, 8, 16, and 32 pixels. Image shown is ca. 120 x 85 pixels.

WAVDETECT: background



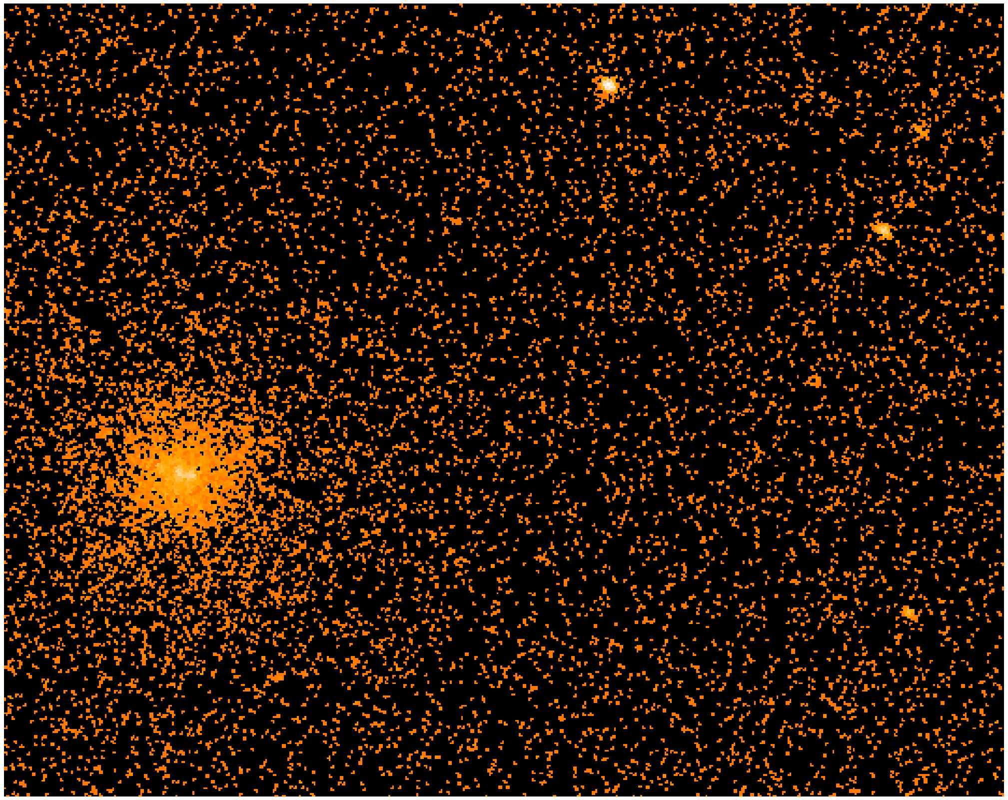
- Background map is determined iteratively; the user can specify how hard the tool is to work on that (bkgsigthresh, maxiter, iterstop).
- The user can provide own background map (bkginput, bkgerrinput).

WAVDETECT: outcome

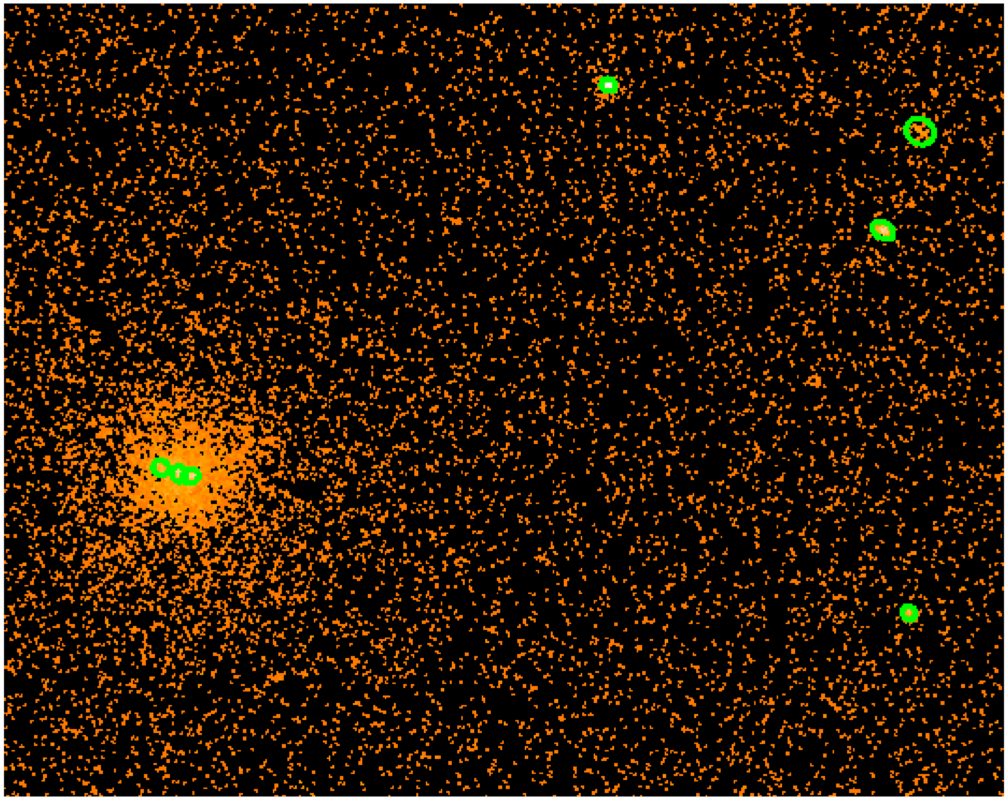


- For each candidate, detection with highest correlation maximum from all WTRANSFORM runs is selected. The user can affect the outcome by modifying detection threshold (sigthresh).

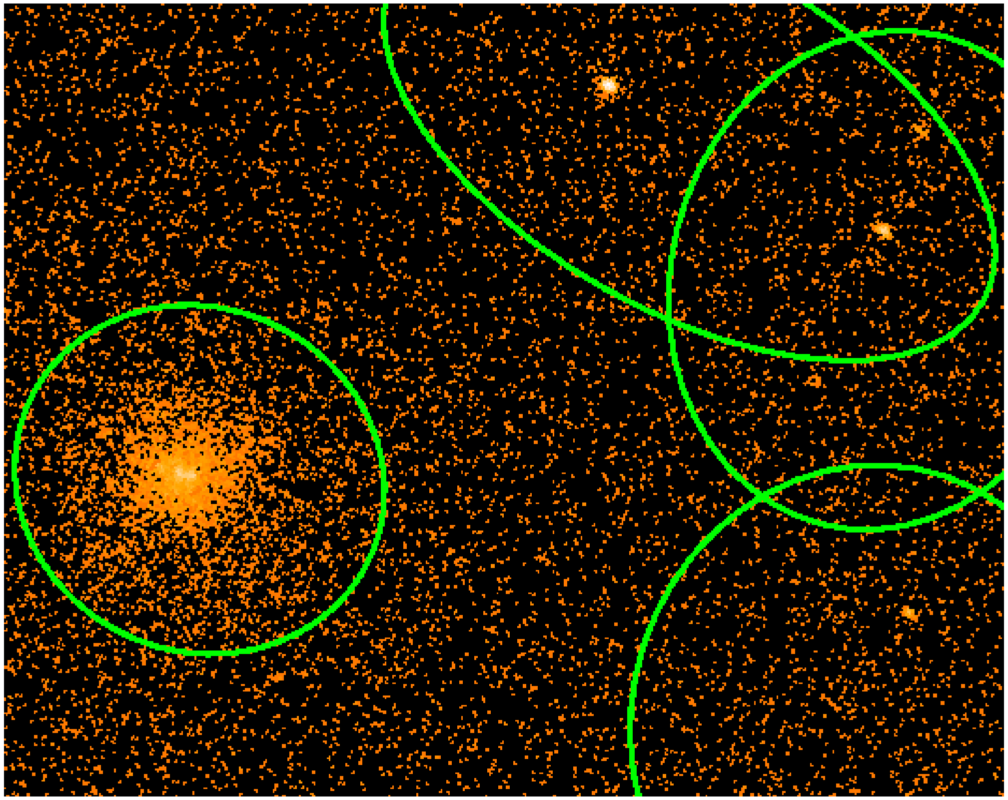
Tool Comparison



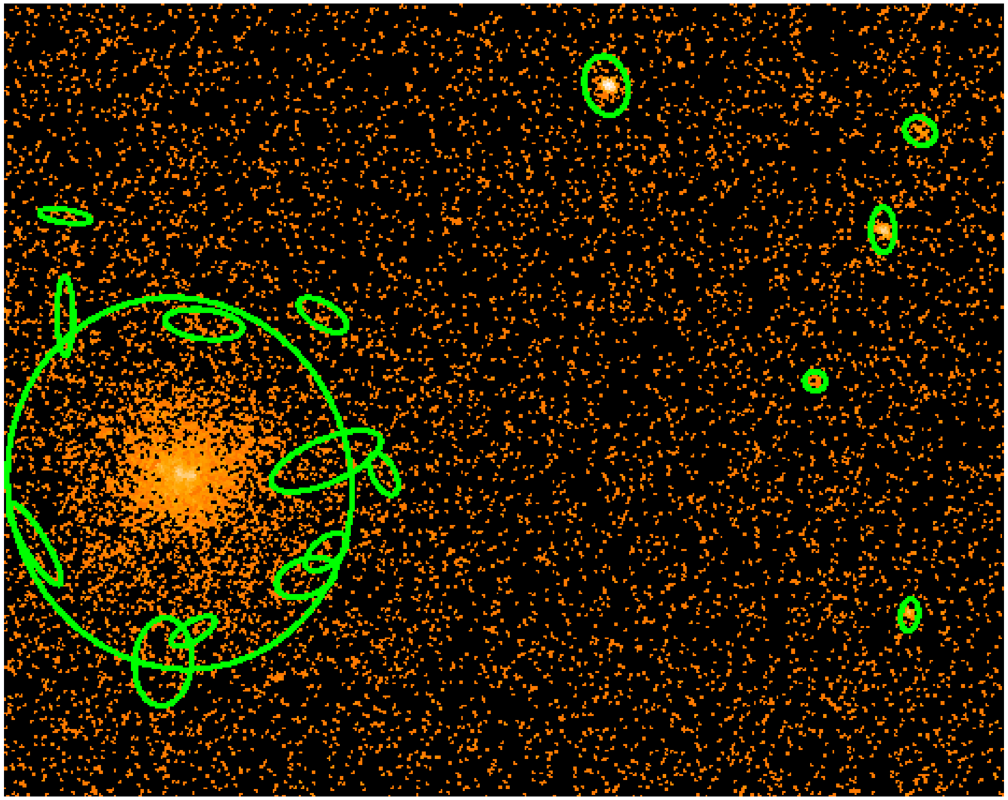
CELLDETECT: variable cell



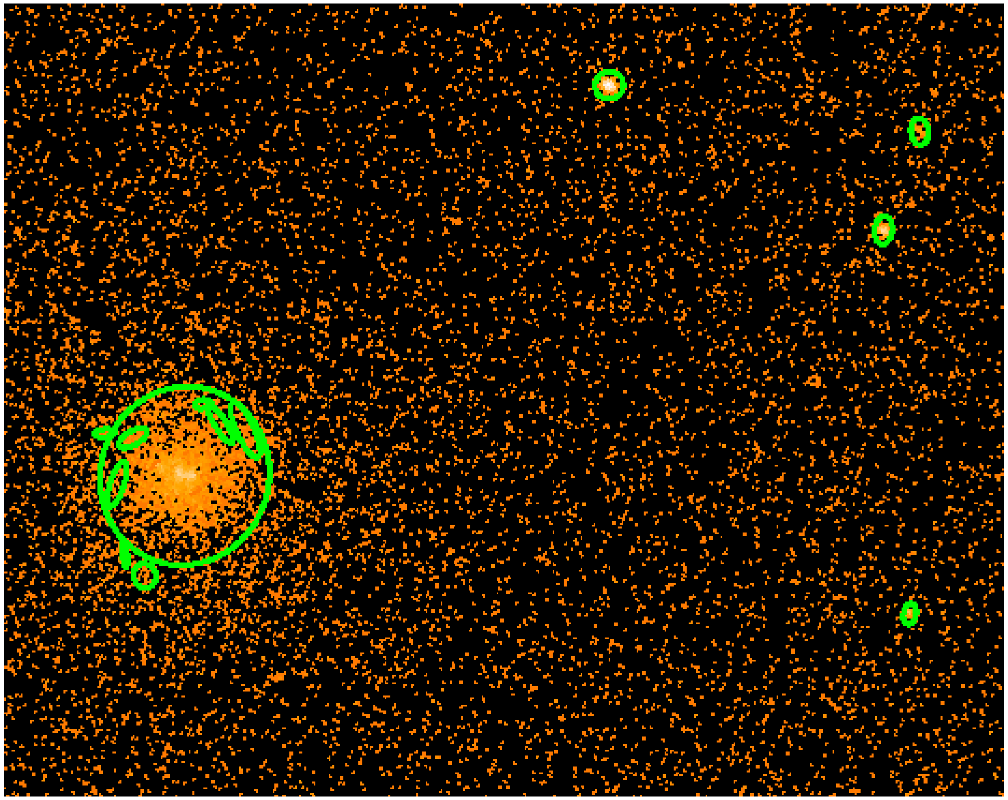
CELLDETECT: large fixed cell



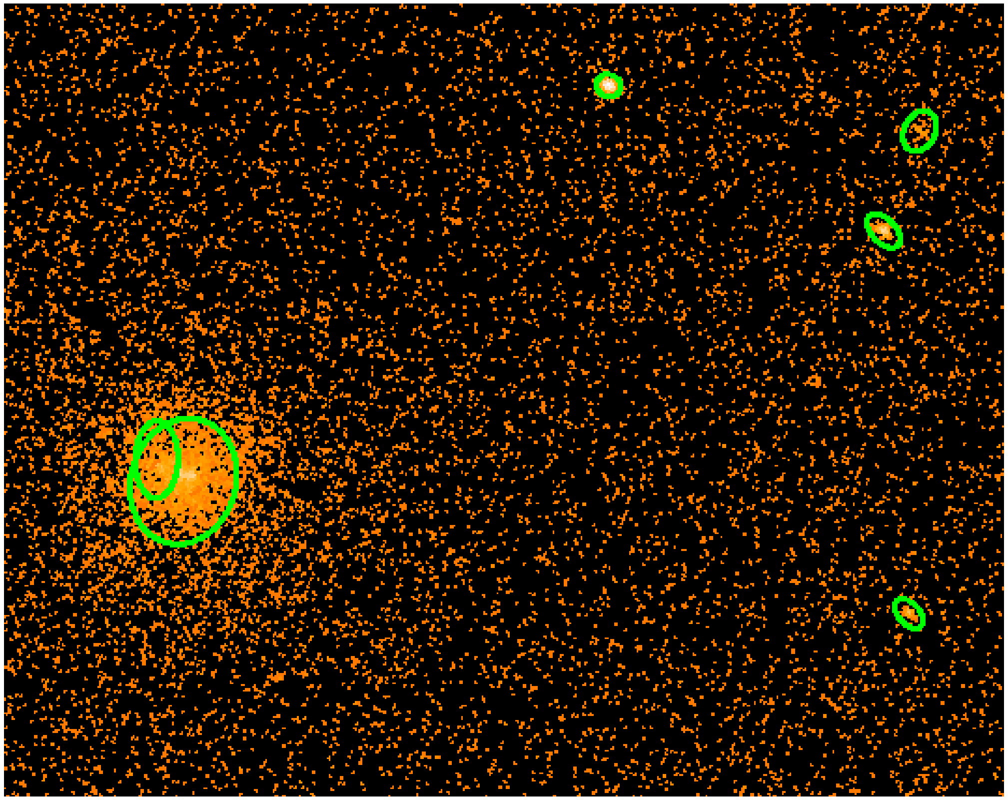
VTPDETECT: scale=1



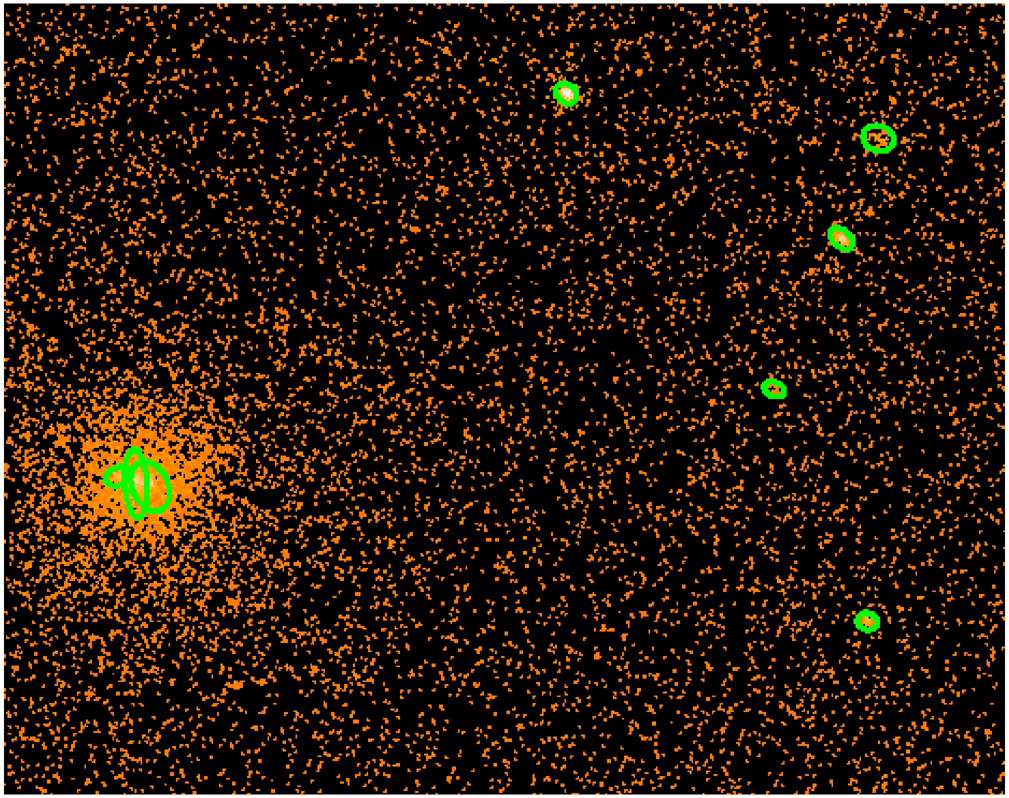
VTPDETECT: scale=3



WAVDETECT: five scales



WAVDETECT: seven scales



FUTURE

- Calibrating tools. Necessary for survey−type applications (e.g. CXC "Level 3" processing). For example: false source probability, resolving power as a function of source strength, separation, energy, off−axis angle, etc. NOTE: CELLDETECT false source probability stuff in the CXC Detect Manual needs to be treated with caution, since it was done with now−obsolete PSF size table.
- Simultaneous detection in multiple observations of the same region with different detectors, detector configurations, off−axis angles, etc.
- General cell profiles, e.g. PSF−shaped, astrophysically−shaped (shells, King profile, etc.).
- Speeding WAVDETECT up.