

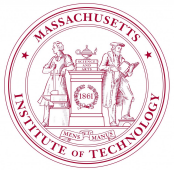


Penn State MIT SAO Stanford

Reducing the Athena WFI Background with the Science Products Module: Lessons from Chandra ACIS

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SPM – Science Products Module

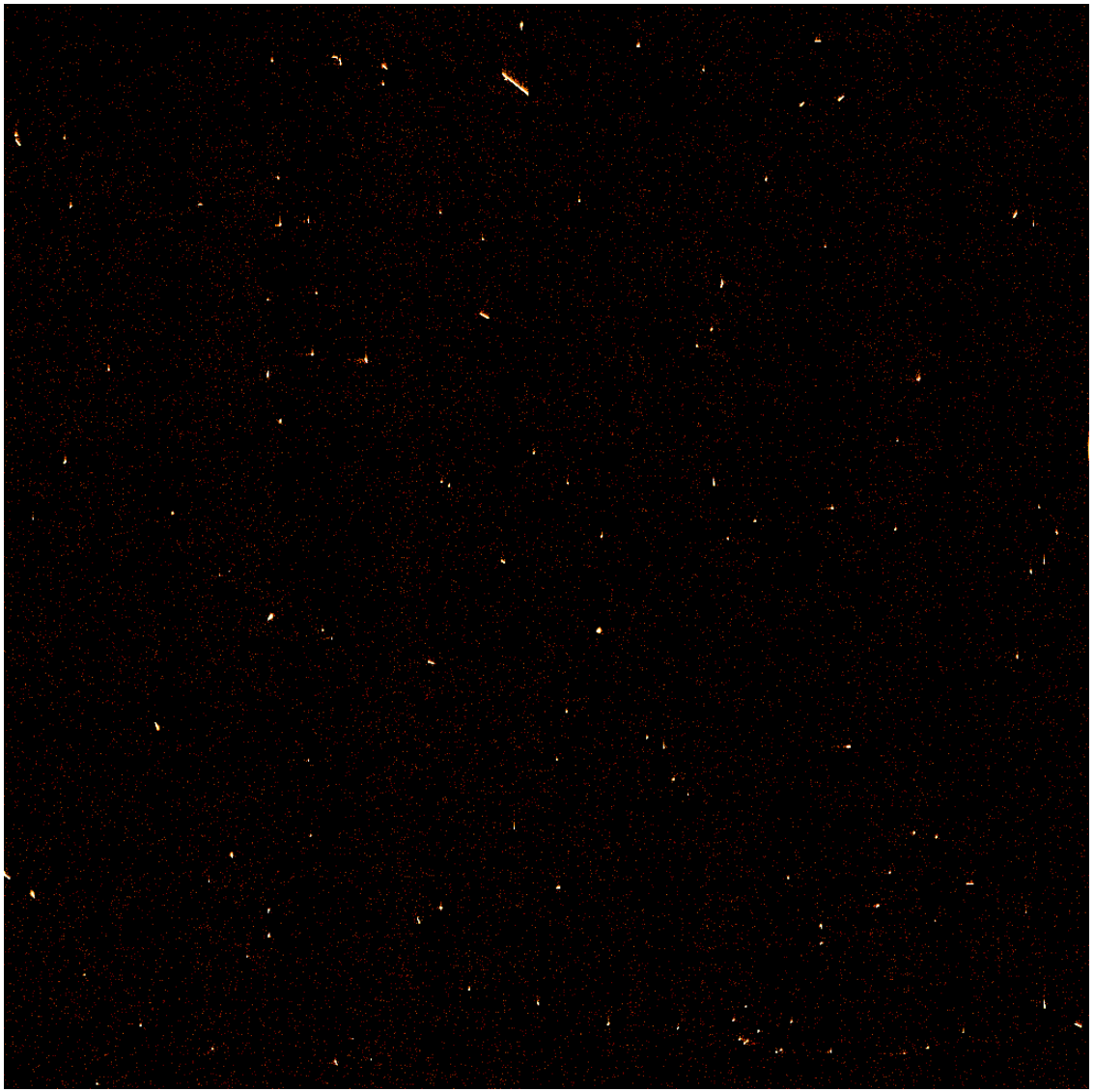
- Proposed US contribution to the WFI (MIT, SAO, PSU, Stanford)
- Secondary CPU that can perform special processing on the on-board science data stream
- MIT & SAO: Identify on-board processing algorithms that reduce and improve knowledge of the WFI particle background
  - Telemetry limitations require discarding most pixels on-board, keeping just potential X-ray event candidates
  - Additional information in the discarded full frame data may be helpful in identifying background events that are masquerading as X-ray signal events

MIT Approach: Examine On-Orbit ACIS Data

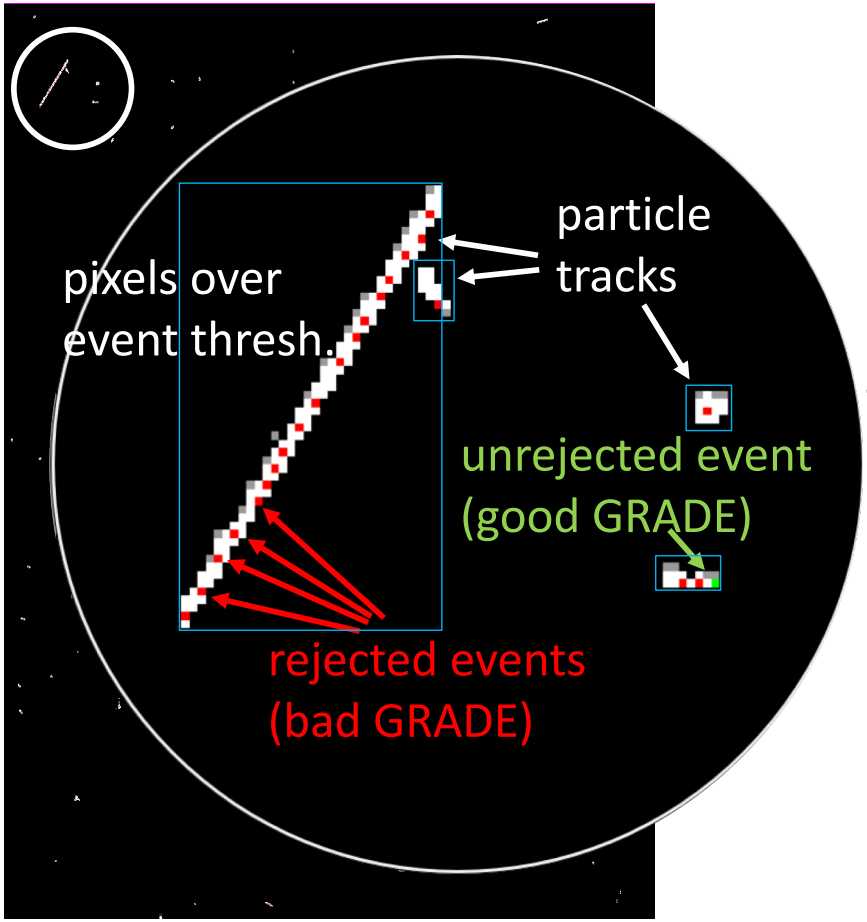
- Use unprocessed, full CCD frames from Chandra on-orbit
  - Back-Illuminated ACIS-S3 is most relevant to WFI
  - Chandra orbit samples similar environment to L2
  - 24 µm pixels, fully depleted, 45 µm deep
  - Detector in stowed position
- Find and categorize events using on-orbit algorithms.
  - Distinguish events that would be flagged as background by standard filtering from events that are masquerading as acceptable X-ray events
- Find particle tracks (blobs) using image segmentation algorithm
- Search for phenomenological correlations that may improve background rejection

Sample Chandra data
Back-illuminated CCD
3.3 sec full frame
91 observations
562 total frames
2003-2016

68025 total events



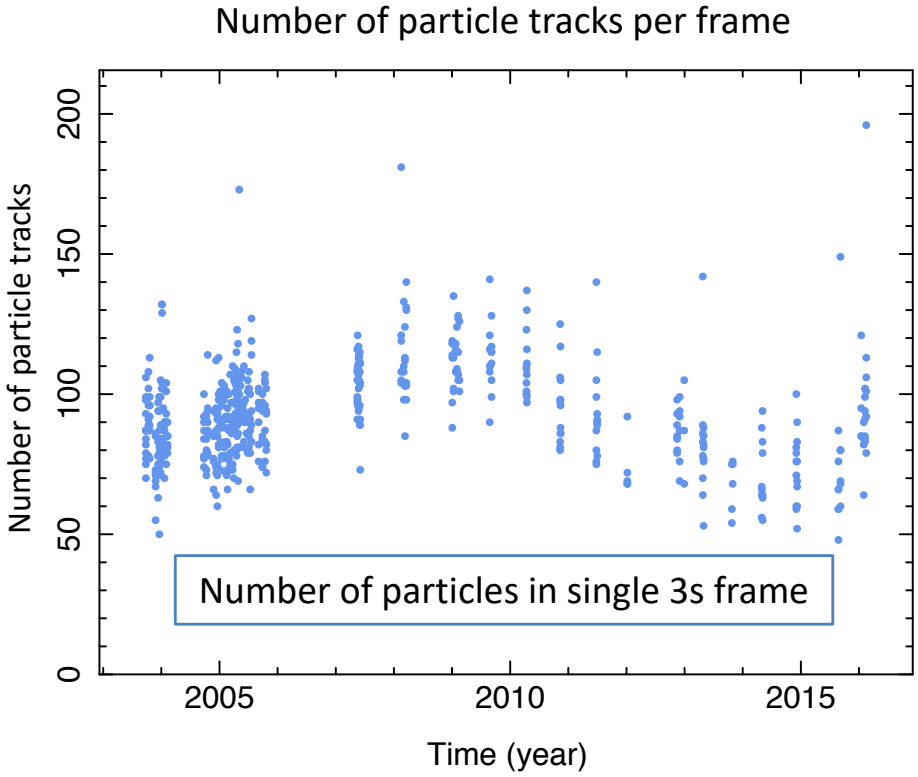
Processing Frame Data

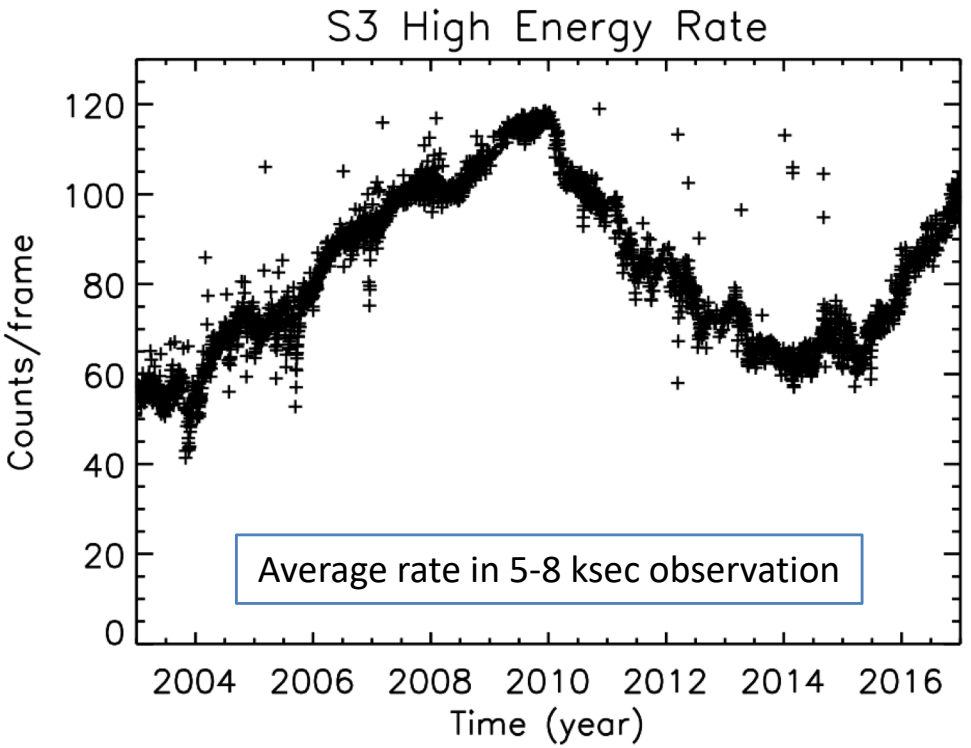


- Find particle tracks with image segmentation
  - Any contiguous set of > 4 pixels above the event threshold
  - Includes connected corners
- Perform event finding, grading, and filtering identical to ACIS on-board processing
  - No upper energy filter
  - Filter around calibration source lines of Al K, Ti K, Mn K (real X-rays)

Particle Background Time Dependence

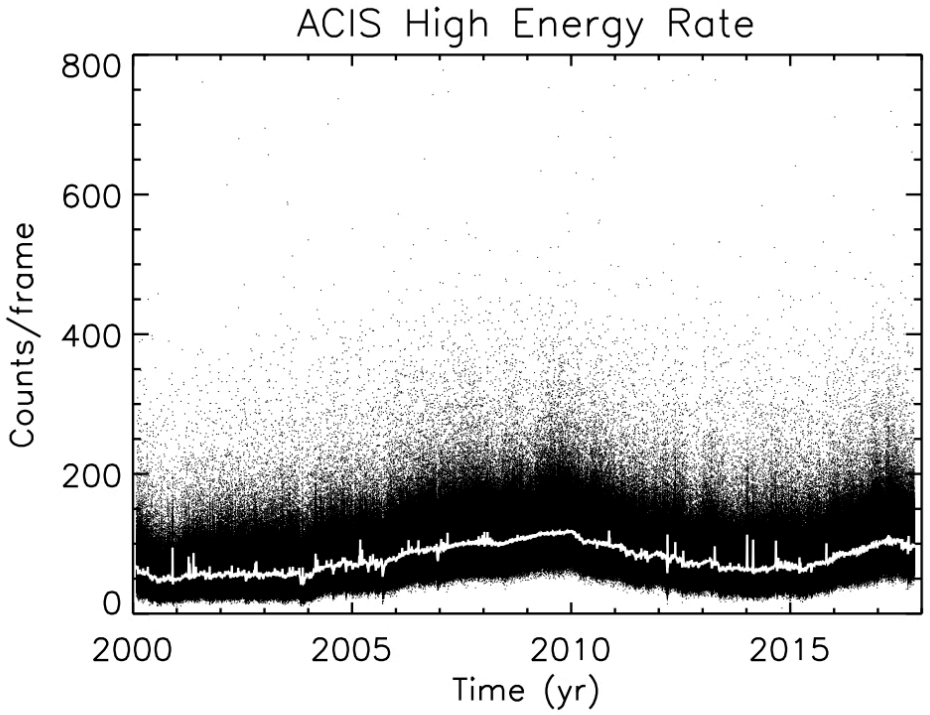
- # of particle tracks follows secular change in solar cycle
- Variations on timescales of a day and longer

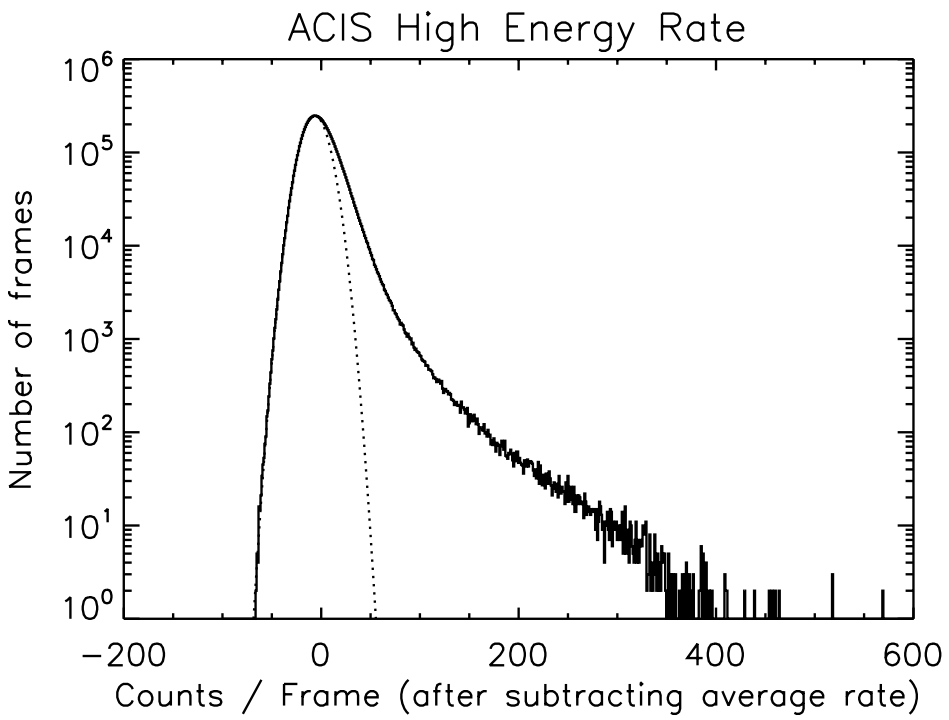




Particle Background Time Correlation

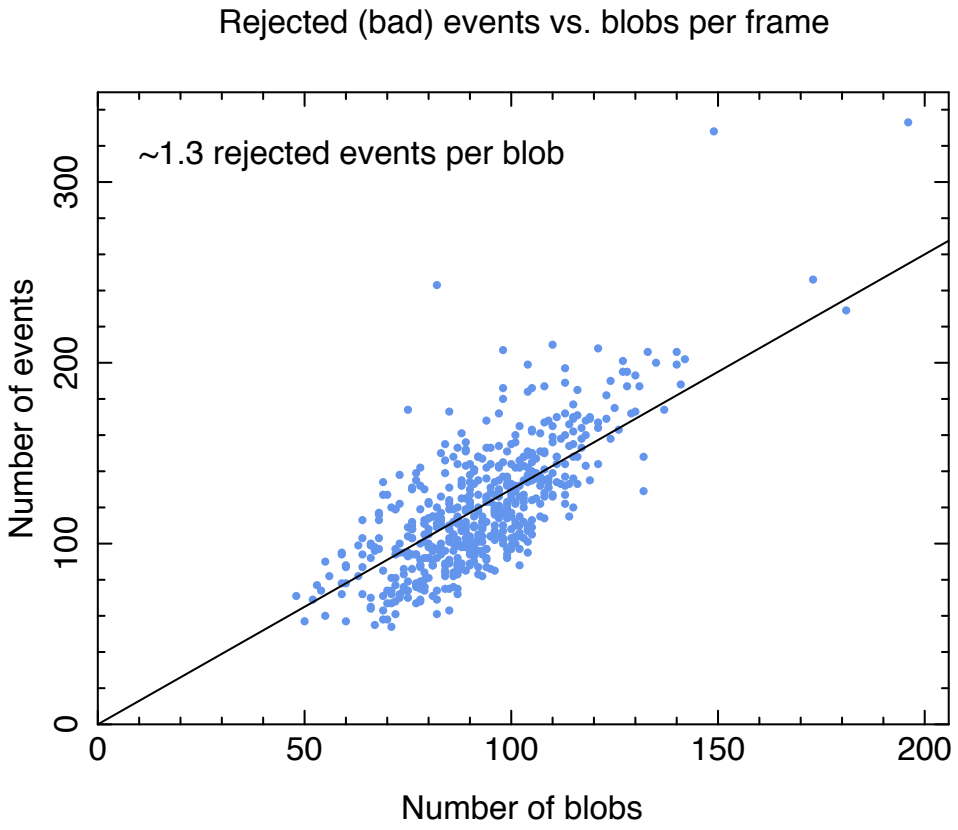
- Variations of particle rate at timescale of 3 sec frame
- ~ 20% of frames in the high count rate tail

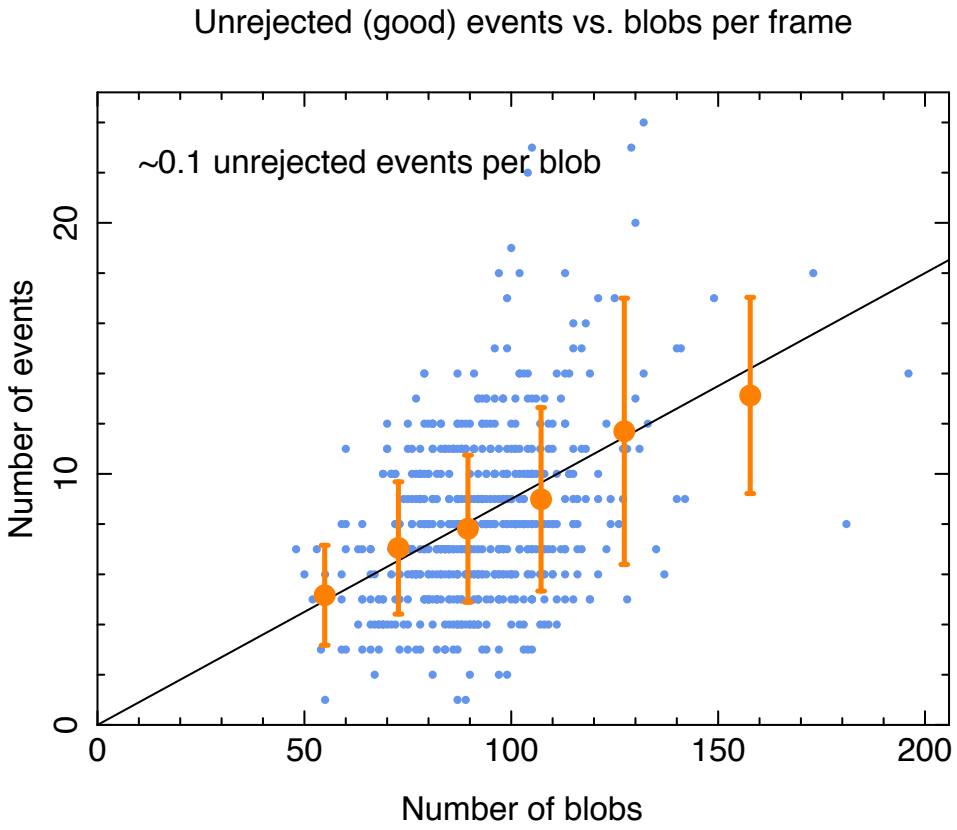




Events and Particle Tracks Correlation

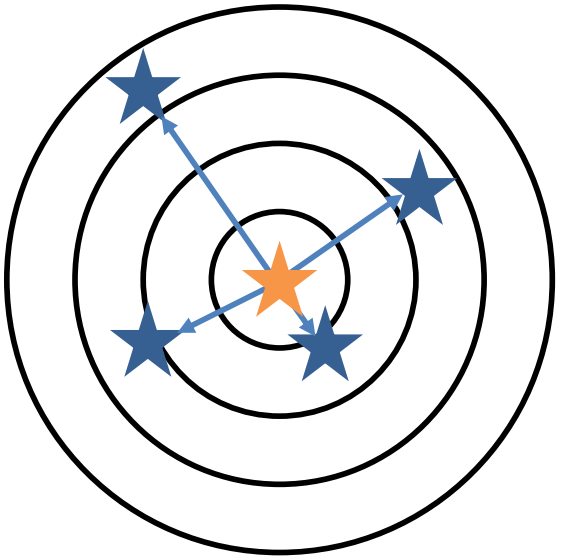
- # of rejected and ***unrejected*** events scales with # of particle tracks





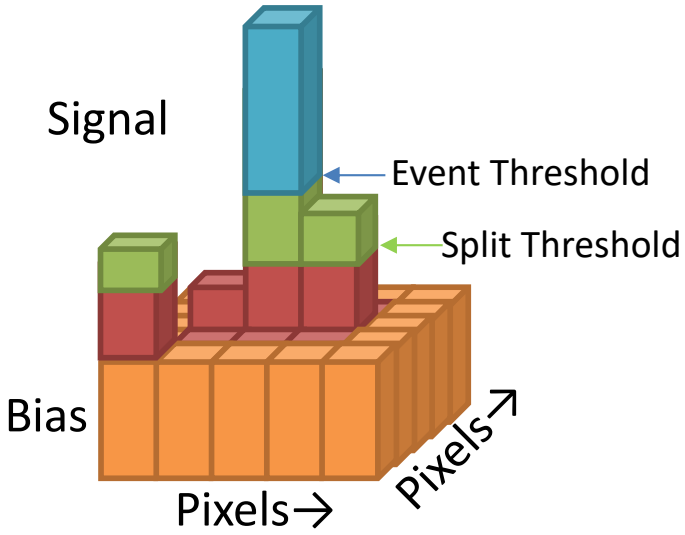
MIT Activities: Spatial Correlation

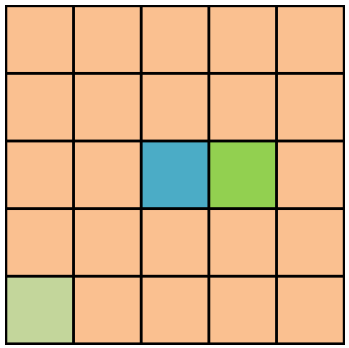
- Are valid (unrejected) events associated with particle tracks in a single frame?
- Correlate particle tracks with rejected events, valid events, and X-ray events
- Perform analysis for unbinned ACIS pixels (24 x 24 µm) and binned approximation of WFI pixels (120 x 120 µm)
  - ACIS CCD thickness is 45 µm, not 350-450 µm
  - Particle tracks in WFI will be larger!
  - WFI event processing may be different



MIT Activities: ACIS Grade Filtering

- ACIS (ASCA) grades are based on the 3x3 pixel island, and the pattern of pixels above the split threshold
- Optional filtering can be applied on ground based on any pixel in the outer 5x5 above split threshold
  - "VFAINT" filtering
  - Requires individual 5x5 pulse heights or a flag indicating which are high
  - Reduces BG by 4x at 0.3 keV, 1.25x above 6 keV (ACIS BI)

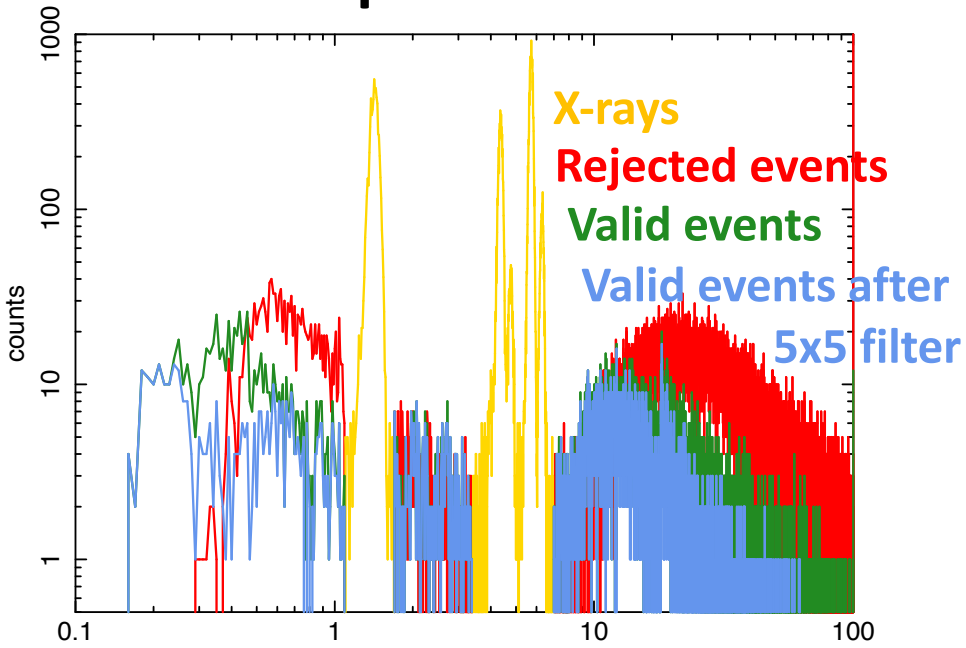




MIT Activities: Correlations with Particle Tracks 24 µm pixels (ACIS)

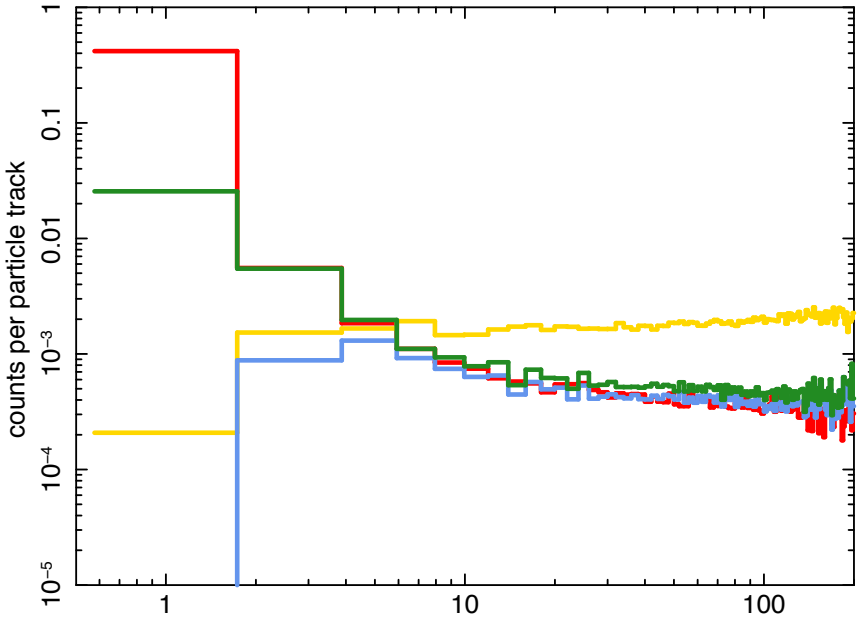
From combined 562 ACIS BI frames (**55685 rejected**; **12340 valid**; **33192 X-rays**)

Spectrum



Energy (keV)

Correlation with particles

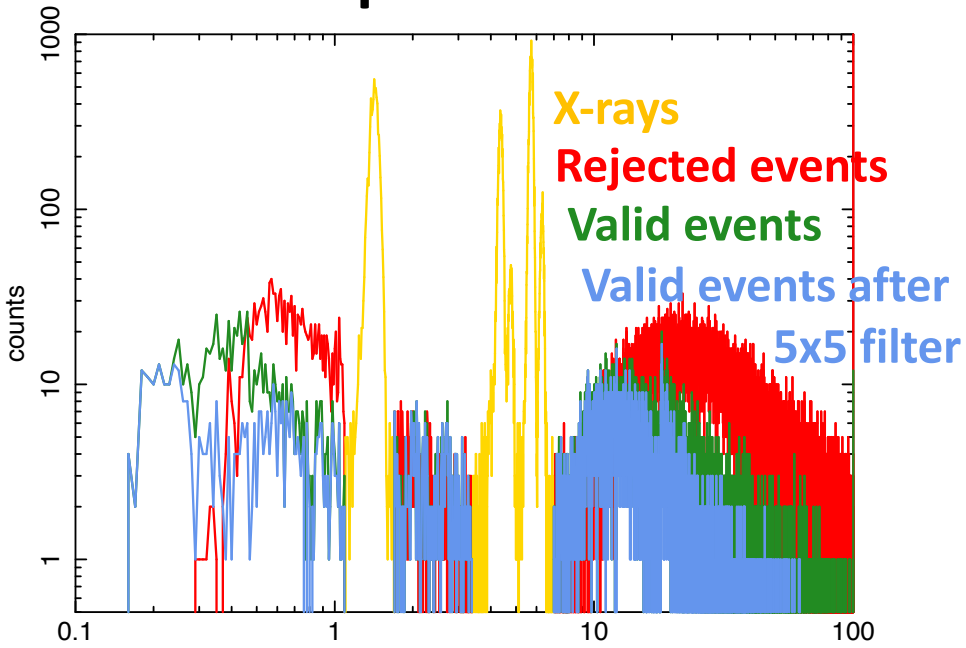


Distance from nearest particle track (24 µm pixels)

MIT Activities: Correlations with Particle Tracks 24 µm pixels (ACIS)

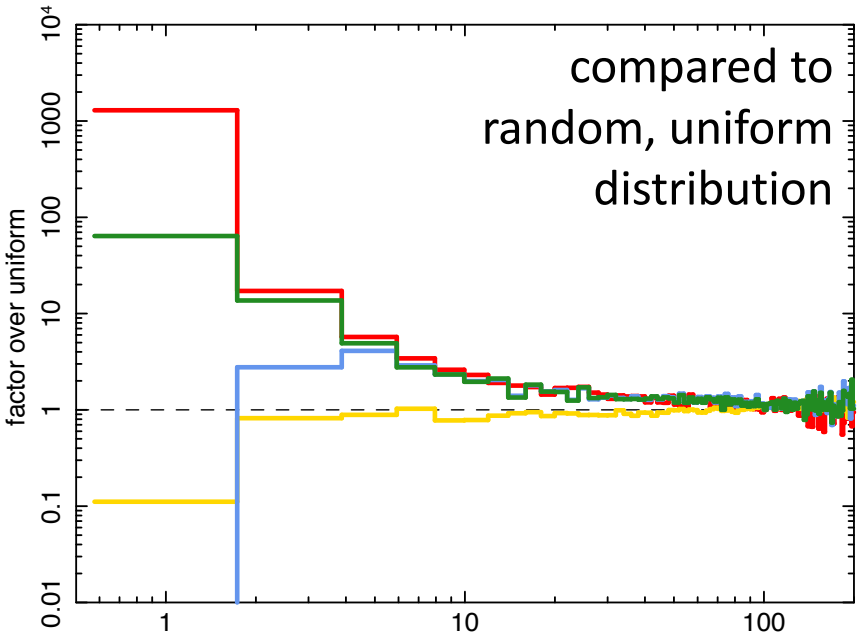
From combined 562 ACIS BI frames

Spectrum



Energy (keV)

Correlation with particles

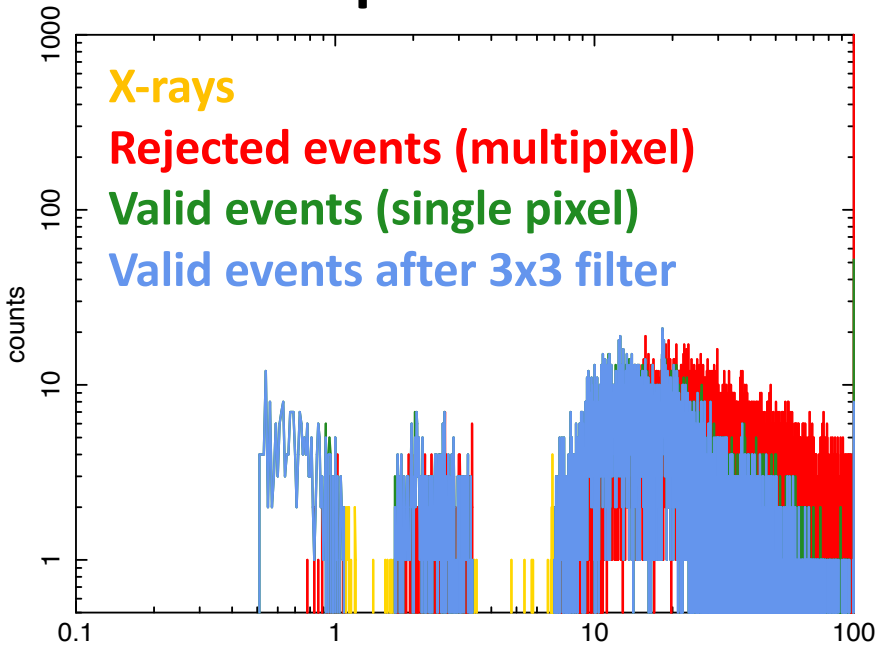


Distance from nearest particle track (24 µm pixels)

MIT Activities: Correlations with Particle Tracks 120 µm pixels (~WFI)

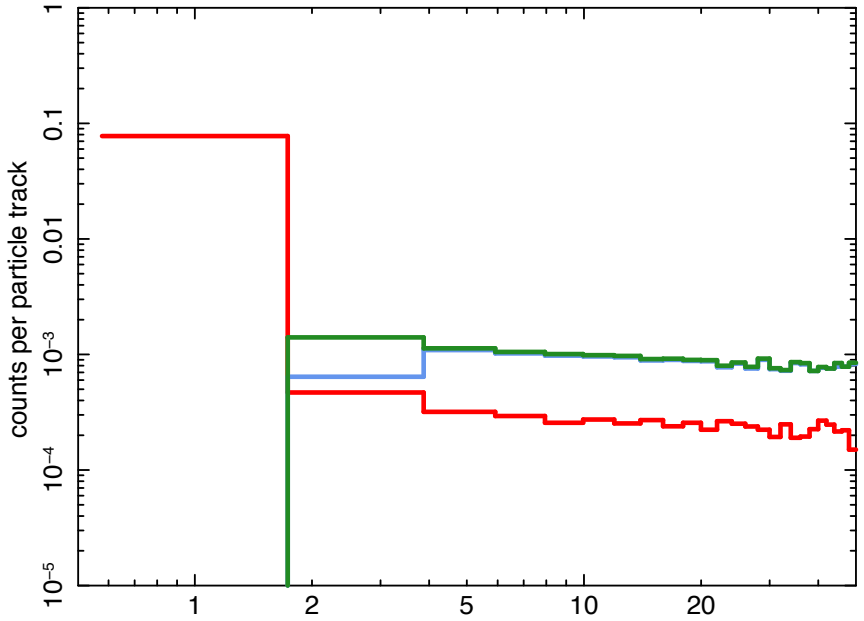
From combined 562 ACIS BI frames

Spectrum



Energy (keV)

Correlation with particles

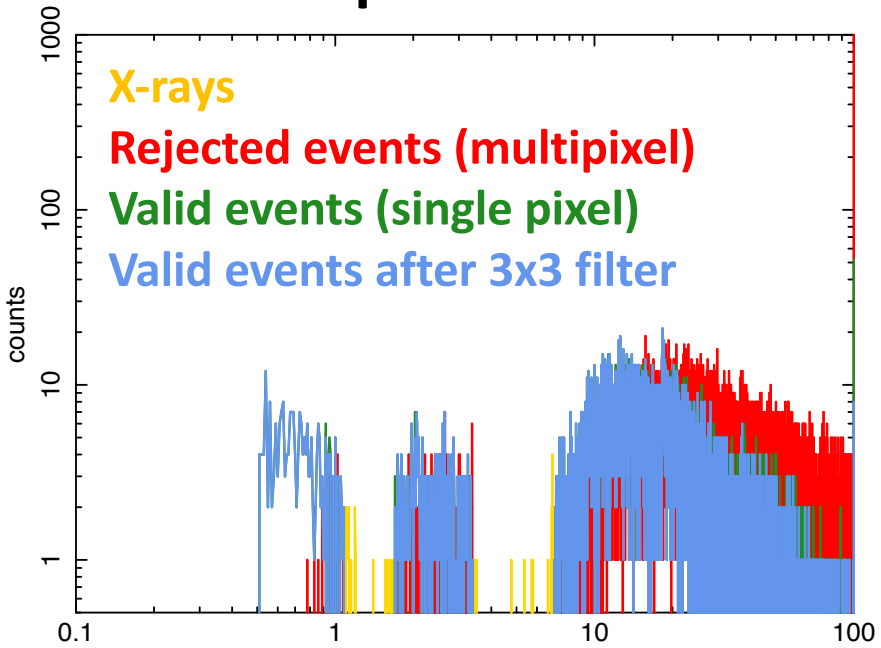


Distance from nearest particle track (120 µm pixels)

MIT Activities: Correlations with Particle Tracks 120 µm pixels (~WFI)

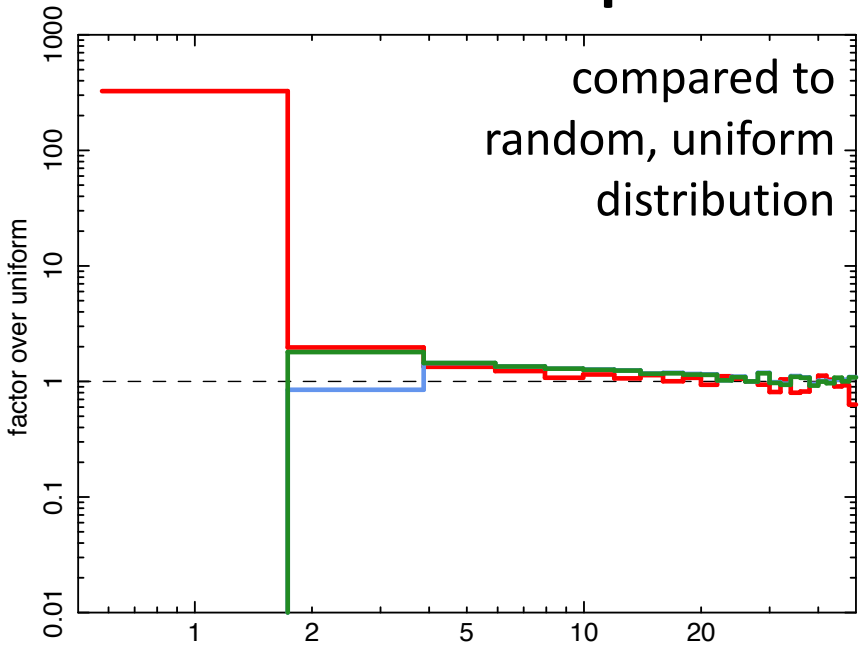
From combined 562 ACIS BI frames

Spectrum



Energy (keV)

Correlation with particles



Distance from nearest particle track (120 µm pixels)

Preliminary Conclusions and Future Plans

- Clear spatial correlation between particle tracks and unrejected background events in ACIS data
- On-board particle track identification may allow reduction of WFI background
- Further work is required
  - SAO is doing a similar analysis on EPIC-pn small window mode, better analog to WFI than ACIS
  - MIT is examining Geant4 simulations of WFI particle background
  - Continue to further characterize particle tracks (image segmentation, detached secondaries)