

Pileup and the ACIS/HRMA Point Spread Function

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Introduction

Pileup and the HRMA/ACIS PSF

Introduction

Introduction

Introduction

ACIS Operation

Pileup

PSR J0437-4715

Spectral Pileup
Model Fits

Spectral Fits

Pileup Model Fit
Parameters

Pileup Grade Ratios

PSF Profile

PSF Profile

PSF Relative Profile

Pileup Losses

Pileup and ECF

Summary

- Overview of ACIS operation
- Effects of Pileup
- Pileup Observations (isolated pulsar PSR J0437-4715)
- Spectral fits: pileup “ α ” model
- PSF profile with pileup
 - depression of core
 - broadening of the PSF
- Summary

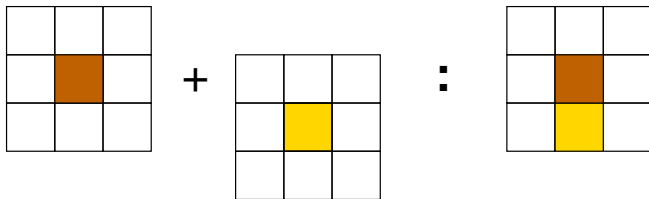
PSF Pileup

ACIS Operation (cartoon)

- frame exposed: τ_{frame} (typically ~ 3 s)
 - X-ray photons $\Rightarrow e^-$ charge clouds
- 3×3 detect island:
 - energy \propto charge in island
 - charge distribution: “grade”; good=0,2,3,4,6, bad=1,3,7
“good grade” \Rightarrow likely X-ray
“bad grade” \Rightarrow likely *not* X-ray
- frame rapidly transferred to frame store
 - parallel transfer rate $\equiv 40\mu\text{s}$ per parallel transfer
 - each pixel of column sees short exposure of all emission along the column \Rightarrow transfer streak or smear.
 - transfer \ll dither; “instantaneous smeared snapshot”

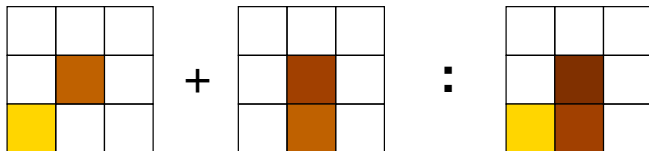
HRMA/ACIS PSF Pileup

- pileup: 2+ photons/detect island/frame (overlapping e^- clouds)
- Pileup has several effects:
 - Spectral distortion + photon loss:
 - 2 photons \Rightarrow 1 event with higher energy
 - Grade distortion:
 - merging of charge clouds; “good” (likely X-ray) events convert to “bad” (likely non-X-rays)
 - Spatial distortion:
 - merging of events and grade morphing \Rightarrow loss of events
 - most severe in PSF core, \Rightarrow PSF shape change



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PSF Pileup

Pileup Observations – PSR J0437-4715

Introduction

Introduction

Introduction

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Pileup

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Parameters

Pileup Grade Ratios

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PSF Profile

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- PSR J0437-4715: isolated pulsar; ~ 0.2 ct/s
- Aim: make data similar to data with different count rate.
- Use different frame times to sample pileup rates:
 - 0.2s, 0.4s, 1.5s, 3s, 6s, 10s
- scale dither periods inversely with $\tau_{\text{frame}}/3$ sec
 - max dither velocities comparable
 - reduce additional dither “blur”
 - Operational limits (dither rate) for shortest frame times

Upshot: observed ~ 16 – 24 ks for each frame time

PSF Pileup

Spectral Pileup Model Fits

Based on Davis (2001); see also *The Chandra ABC Guide to Pileup*.

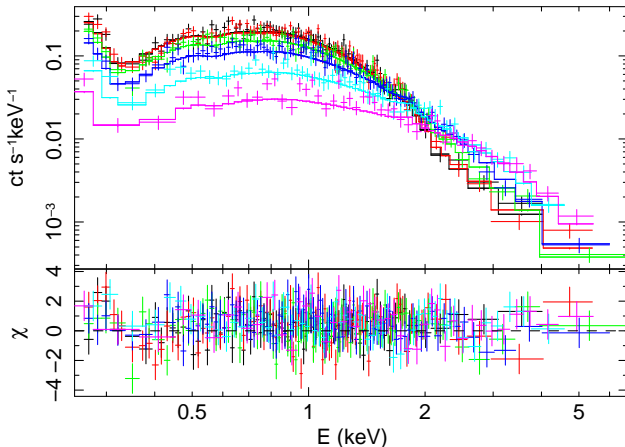
- spectral extraction $r \gtrsim 2''$: 95+% of point source flux
- α : probability that adding a photon to an event yields a valid X-ray event
- Approach: simultaneous fit of PSR J0437-4715 data
 - Fit “ α -model” using XSPEC. Parameters “tied”.
tframe parameter set according to observation τ_{frame} .
 - examined parameters vs. extraction radius,
2–20 pixel radius.
 - plausible parameters: $\alpha \approx 0.66$.

PSF Pileup

Pileup Model Spectral Fits

Simultaneous fit to pileup observations using pileup model

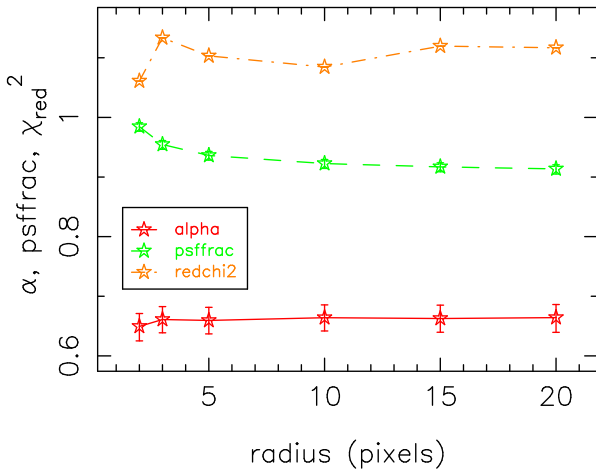
$\tau_{frame} = 0.2s, 0.4s, 1.5s, 3.0s, 6.0s, 10.0s$ $\chi^2_{red} \approx 1.1$ (477 dof)



PSF Pileup

Pile Model Spectral Fit Parameters

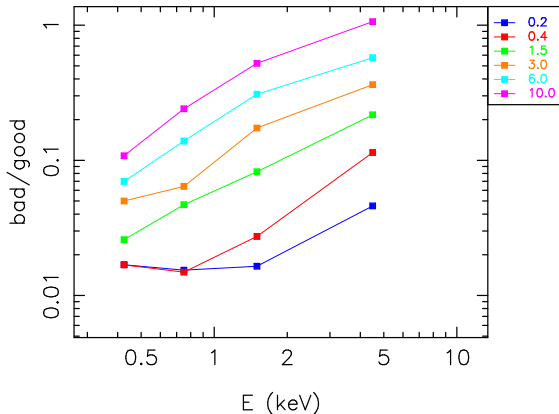
Variation of fit parameters with extraction region radius.



PSF Pileup

Bad/Good fraction vs. T_{frame}

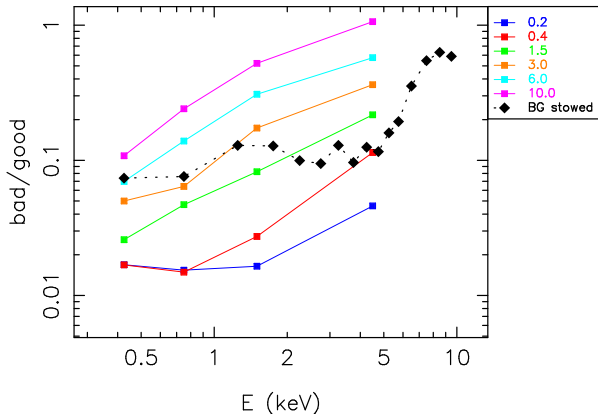
- Pileup causes grade morphing
- Examine grade ratios for PSF core
- Bad/Good grade fraction for central 1 pixel radius



PSF Pileup

Bad/Good fraction vs. T_{frame}

- Pileup causes grade morphing
- Examine grade ratios for PSF core
- Bad/Good grade fraction for central 1 pixel radius

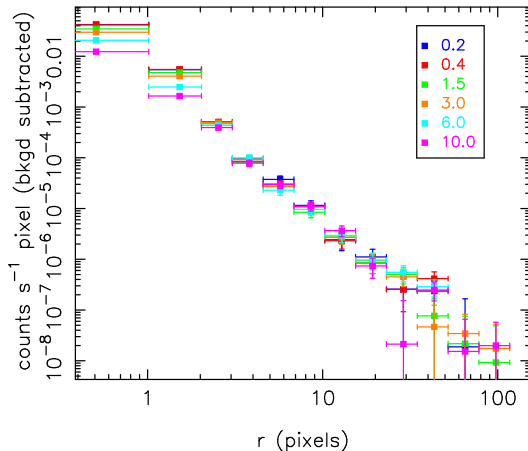


PSF Pileup

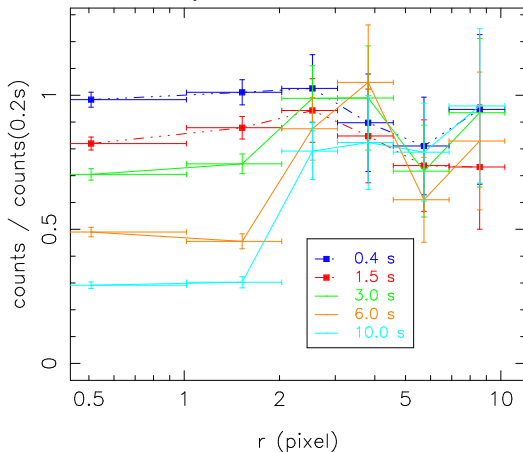
Effects of Pileup on PSF Profile

- Loss of events:
 - merging of events \Rightarrow event loss + spectral distortion
 - morphing of grades & event loss
- most severe in core \Rightarrow depression of core
- Pileup α -model for spectrum:
 - Λ = mean rate/frame (i.e., Poisson mean)
 - $\alpha \sim$ prob. adding photon to event
 \Rightarrow still have valid X-ray event
 - fraction of expected count rate lost due to pileup
 - $$f_r = 1 - \frac{[\exp(\alpha\Lambda) - 1] \exp(\Lambda)}{\alpha\Lambda} \approx 1 - \left(1 - \frac{\alpha}{2}\right) \Lambda$$
 - rate loss linear in Λ for small/modest pileup

PSF profile: 0.35–8 keV (background-subtracted)

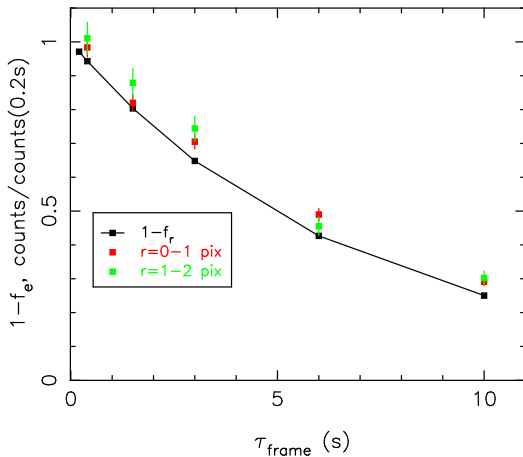


PSF profile: ratio to $\tau_{frame} = 0.2\text{s}$ (0.35–8 keV)
Pileup affect on PSF spatial structure



PSF profile: losses in the PSF core

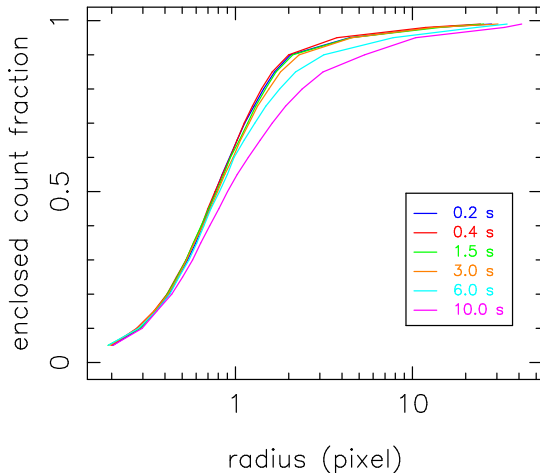
Pileup model: $\alpha = 0.662$, $\Lambda = 0.22 \tau_{\text{frame}}$



Enclosed Count Fractions

Profile Broadening

Pileup broadens ECF profile



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Introduction

Introduction

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- Examined a range of pileup conditions for a single source (PSR J0437-4715)
- compared to spectral “ α -model” for pileup
 $\alpha \approx 0.66$
- examined grade migration (“bad grades”/“good grades”) vs. rate and radius.
- examined PSF profile;
depression of PSF core due to pileup
 \Rightarrow broadening of PSF