XRT Point Spread Function in Slewing Mode
Off-Axis PSF

A few suitable off-axis sources are now appearing in the XMM archive…

Work ongoing…

Sources both on- and off-axis… moving sources…
EPIC PSFs For the Slew & Slow-Slew Survey, Incorporating New Modes

- Based on present understanding (from slew event files)
- Any arbitrary, straight, constant-speed path of a source through any EPIC detector
EPIC PSFs For the Slew & Slow-Slew Survey, Incorporating New Modes

- Based on present understanding (from slew event files)
- Any arbitrary, straight, constant-speed path of a source through any EPIC detector
SlewX = DETX
SlewY = DETY
SlewX = -DETX
SlewY = -DETY
2 Main Parameters
b – ‘impact parameter’
– ‘impact angle’

Also:
Slew speed
(90°/hr, 30°/hr)
Mode (FF, eFF, 3x3)
Energy …
Vignetting must be taken into account – central PSFs contribute more to final summed PSF – calculate vignetted-weighted sum.
Low vignetting

High vignetting

MOS1

MOS2

DETY

DETX

XMM

EPIC

MOS

Andy Read (amr30@star.le.ac.uk)

EPIC CAL/OPS Meeting

Mallorca, Spain 26-27/10/06
• RGAs cause azimuthal variations in off-axis vignetting in the MOSs

• MOS2 function is identical

• Implies, with exposure maps, detector positions of low/high vignetting
SlewX = -DETX
SlewY = -DETY

MOS2
DETX
DETY

SlewY
SlewX

RGS2
low vig.
high vig.

Source Direction

Slew Direction

RAWX
RAWY

1 2 3 4 5 6 7

XMM EPIC MOS

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EPIC CAL/OPS Meeting
Mallorca, Spain 26-27/10/06

University of Leicester
‘Frame-blurring’ – within a single frame the source can travel an appreciable distance

- PSF at each point is blurred (stretched) in the slew direction, depending on slew-speed & mode

pn extended full frame – ‘frameblur’ of 18 arcseconds
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<thead>
<tr>
<th>Instrument</th>
<th>Mode</th>
<th>Frame time (sec)</th>
<th>Slew speed (deg/hr)</th>
<th>‘Frameblur’ (arcsec)</th>
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PSFs that are used:

- 2-D PSFs – ‘medium’ CCF PSFs – Images – \( fn(\text{instr}, E, \theta, \phi) \) – used in SAS source-searching

- 1-D PSFs – ‘extended’ CCF PSFs – King profile \((r0, \alpha)\) – \( fn(\text{instr}, E, \theta) \) – used in ARF generation/spectral fitting
• 2-D PSFs – ‘medium’ CCF PSFs – Images – \( fn(\text{instr}, E, \theta, \phi) \) – used in SAS source-searching
Source path calculated (e.g. b=5500, \( \theta =25^\circ \), for MOS1, Full-Frame, slew-speed=90°/hr)

Step through n small intervals of source path – Is the source on the detector (Y/N)?

For each ‘Y’

- Interpolate and rotate appropriate PSF (position, energy, instrument, mode etc.) from CCF 2-D images (512 x 512, 1.1“)
- Obtain vignetting (pos, E, instr. etc.), and weight PSF image by vignetting
- Stretch PSF for ‘frameblurring’ (instrument, mode, slew-speed)

Add PSFs for whole source path and normalise 2D image (512 x 512, 1.1“) (sum over image = 1)

MOS1, Full-Frame, slew-speed=90°/hr - 4 PSF – unusable…

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EPIC CAL/OPS Meeting
Mallorca, Spain 26-27/10/06
- MOS1
- 3x3 mode
- slew-speed=30°/hr
- 12" PSF
  - very usable...
- Need for Vignetting:

- e.g. PN, $b=13500, = -45^\circ$, for PN, Full-Frame, slew-speed=30°/hr)

- Larger contribution from off-axis PSFs (elongation in perpendicular-to-slew direction) when vignetting not correctly taken into account
- Loss of CCD6
- MOS1
- 3x3 mode
- slew-speed=30°/hr
MOS2
3x3 mode
slew-speed=30°/hr
12° PSF blurring

Outer parts of PSF due to off-axis PSFs
Inner parts of PSF due to frameblurring
- pn
- e.g. $b = -17000 = 5^\circ$
- (zoom-in on PSF)

- All PSFs compact (short frame times)
- FF $30^\circ$/hr best
- eFF $30^\circ$/hr $\approx$ FF $90^\circ$/hr
CCF Files

- Possible CCF 2-D PSF images
- For each instrument, mode, energy...

2-D PSF as
Function of b (impact parameter)

- If (impact angle) not equal to ~0, then would need several times more images as function of b and
CCF Files

- Possible CCF 2-D PSF images
- For each instrument, mode, energy...
  2-D PSF as Function of b (impact parameter)

- If (impact angle) not equal to ~0, then would need several times more images as function of b and

- (note large ‘jump’ in PSF shape at edges of detector as path moves from 1 CCD to 3 CCDs)
• 1-D PSFs – ‘extended’ CCF PSFs – King profile (r0, alpha) – fn(instr, E, theta) – used in ARF generation/spectral fitting
• Source path calculated (e.g. \( b=0, \gamma=0^\circ \), for MOS2, 3x3 mode, slew-speed=30°/hr)
• Step through n small intervals of source path – Is the source on the detector (Y/N)?
• For each ‘Y’
  - Obtain 1-D King parameters \((r_0, \alpha)\) (position, energy, instrument) from CCF
  - Create a 2-D image of (circular) PSF
  - Obtain vignetting (pos, E, instr. etc.), and weight PSF image by vignetting
  - Stretch PSF image for ‘frameblurring’ (instrument, mode, slew-speed)
• Sum weighted PSFs for whole source path
• Fit 2D summed PSF image with a King profile to give \(r_0, \alpha\) for whole source path

• Vignetting – King parameters of final PSF are closer to those of central PSF than edge PSFs
• Frameblurred PSFs are wider (larger \(r_0\), flatter \(\alpha\)) than the non-FB PSFs

• Note: frameblurred PSFs are now non-circular (visible?) – Fitted King profiles look very good
- r0 and alpha as function of impact parameter
- impact angle=0, energy=2keV

**PN** | **MOS1** (r)
---|---
![Graph 1](image1.png) | ![Graph 2](image2.png)
![Graph 3](image3.png) | ![Graph 4](image4.png)
![Graph 5](image5.png) | ![Graph 6](image6.png)
- r₀ and alpha as function of impact parameter (zoom)
- impact angle=0, energy=2keV
- r0 and alpha as function of impact angle
- impact parameter=0, energy=2keV
• $r_0$ and $\alpha$ as function of impact angle (zoom)
• impact parameter=0, energy=2keV
- $r_0$ and alpha as function of energy
- impact parameter=0, impact angle=0
- r0 and alpha as function of energy
- impact parameter=10000, impact angle=0
Slew speed = 90°/hr : on-source time <~12 s (mean ~8 s)
Slew speed = 30°/hr : on-source time <~36 s (mean ~24 s)

Tangential projection not valid over whole slew. Long slews need to be subdivided to maintain astrometry.

Divide slew into ~1 deg² images and recalculate sky positions.

Source search using near-standard pipeline tuned for ~zero background + New CCF files
Slew sources searched for in sky co-ordinate images...
Slew source encircled energy & ARFs etc. calculated using sky co-ordinate images...
• Detector-Sky issues?
• For pointed observations, sky and detector images are closely related… for slews, this may not be the case…
• When the source-searching finds a candidate source, how does it know what PSF is appropriate (i.e. what $b$, )?
• Similarly for arfgen – how does it know what the appropriate PSF is?
Closing thoughts…

Azimuthal MOS-RGA vignetting variations not included
Will always be ~0? If not, may need a whole extra dimension of CCF entries (easy to produce)
- Slewing-mode PSFs (1-D & 2-D) calculated using current CCF pointed PSFs
- Improvements in pointed PSFs, especially off-axis (ongoing) lead easily & directly to improved slewing-mode PSFs

QSO 1308+326  7 arcmin off-axis

SLX 1744-299
~ 4 arcmin

SLX 1744-300
~ 1.5 arcmin

AX J1746.3-2843  5.5 arcmin off-axis

NGC7603  10 arcmin off-axis