Analyzing (and proposing) extended sources with XRISM

François Mernier
fmernier@umd.edu
The basics of analyzing extended sources

✓ The emission is extended... but (often) faint!
  ✓ If not properly accounted for, background may bias the results

✓ Background subtraction is good...
✓ ...Background **modelling** is (much) better!

---

![Suzaku/XIS spectrum](image)

Miller et al. (2007)

- Your favorite (extended) source
- Local Hot Bubble (LHB)
- Galactic Halo (GH)
- Extragalactic Background (EB)

- Hard particle background (e.g. XMM-Newton)
- Soft proton background (e.g. XMM-Newton)

---

**Not an issue with Gate Valve closed...**
The problem
Point spread function (PSF) and field of view

Field of view
(25’ x 25’ total equivalent)

XMM-Newton
Point spread function (PSF) and field of view

Field of view
(25’ x 25’ total equivalent)

\[
\frac{6''}{25'} = 0.4\%
\]

PSF
(6’’ FWHM, on axis)

XMM-Newton
Point spread function (PSF) and field of view

Field of view
(25’ x 25’ total equivalent)

\[
\frac{6''}{25'} = 0.4\%
\]

Field of view
(8.5’ x 8.5’ per chip)

XMM-Newton

Chandra
Point spread function (PSF) and field of view

**Field of view**
(25' x 25' total equivalent)

\[
\frac{6''}{25'} = 0.4\%
\]

**XMM-Newton**

**Field of view**
(8.5' x 8.5' per chip)

\[
\frac{0.5''}{8.5'} = 0.1\%
\]

**Chandra**

**PSF**
(6'' FWHM, on axis)

**PSF**
(0.5'' FWHM, on axis)
Point spread function (PSF) and field of view

Field of view
(38’ x 38’)

\[
\frac{1.7’}{38’} = 4%
\]

XRISM / Xtend
Point spread function (PSF) and field of view

Field of view
(38’ x 38’)

\[
\frac{1.7'}{38'} = 4\%
\]

XRISM / Xtend

Field of view
(3’ x 3’)

\[
\frac{1.7'}{3'} = 57\% (!)
\]

XRISM / Resolve
Point spread function (PSF) and field of view

Field of view (30’ x 30’)

\[
\frac{1.7'}{38'} = 4\%
\]

XRISM / Xtend

Field of view (3’ x 3’)

\[
\frac{1.7'}{3'} = 57\% (!)
\]

XRISM / Resolve
A bit of nomenclature...

✓ “Contamination”?
  ✓ Need to specify what contaminates what… Moreover, it sounds quite negative (whereas substantial “contamination” is not necessarily bad… see further)

✓ “Photon leak”?
  ✓ Can a large PSF stricto sensu considered as a “leak”?

✓ “Mixing”?
  ✓ More accurate term (and takes multi-directionality into account)

✓ XRISM PSF will mix the data spatially… but also spectrally!
  ➡ Spatial-spectral Mixing (SSM)

✓ The SSM will affect mostly Resolve (…but it may be also substantial in Xtend, depending on the science case / observing strategy)
Spatial-Spectral Mixing: internal vs. external

Internal SSM:
✓ When the emission within the same field of view mixes across pixels and “contaminate” other regions within the same field of view
✓ Examples: supernova remnants, complex star-forming regions, clusters with cavities, etc.
Spatial-Spectral Mixing: internal vs. external

Internal SSM:
✓ When the emission within the same field of view mixes across pixels and “contaminate” other regions within the same field of view
✓ Examples: supernova remnants, complex star-forming regions, clusters with cavities, etc.
Internal SSM:
✓ When the emission within the same field of view mixes across pixels and “contaminate” other regions within the same field of view
✓ Examples: supernova remnants, complex star-forming regions, clusters with cavities, etc.

Spatial-Spectral Mixing: internal vs. external
Spatial-Spectral Mixing: internal vs. external

Internal SSM:
✓ When the emission within the same field of view mixes across pixels and “contaminate” other regions within the same field of view
✓ Examples: supernova remnants, complex star-forming regions, clusters with cavities, etc.
Spatial-Spectral Mixing: internal vs. external

External SSM:
✓ When sources outside the detector contaminate the detector region itself
✓ Examples: outskirts of a cool-core cluster, bright AGN nearby an extended source, etc.
A (very) simple example…

**V1** (redshifted photons)
+235 km s\(^{-1}\)

**V2** (blueshifted photons)
-235 km s\(^{-1}\)

5 arcmin
A (very) simple example...

**V1** (redshifted photons)  
+235 km s\(^{-1}\)

**V2** (blueshifted photons)  
-235 km s\(^{-1}\)

5 arcmin

Cross-contamination of V1
A (very) simple example...

**V1** (redshifted photons)
+235 km s\(^{-1}\)

**V2** (blueshifted photons)
-235 km s\(^{-1}\)

5 arcmin

Cross-contamination of V1

Distance (X) from center (arcmin)
A (very) simple example...

V1 (redshifted photons) +235 km s\(^{-1}\)

V2 (blueshifted photons) -235 km s\(^{-1}\)

5 arcmin

Cross-contamination of V1

Fractional number of photinos per 0.05 arcmin/Bin

Distance (X) from center (arcmin)
A (very) simple example...

**V1** (redshifted photons)  
+235 km s\(^{-1}\)

**V2** (blueshifted photons)  
-235 km s\(^{-1}\)

Cross-contamination of V1

Cross-contamination of V2

Fractional number of photos per 0.05 arcmin/Bin

Distance (X) from center (arcmin)

X (arcmin)

Y (arcmin)
A (very) simple example...

**V1** (redshifted photons)  
+235 km s\(^{-1}\)

**V2** (blueshifted photons)  
-235 km s\(^{-1}\)

---

Cross-contamination of V1

Cross-contamination of V2

**Fractional number of photons per 0.05 arcmin Bin**

**Distance (X) from center (arcmin)**
A (very) simple example...

**V1** (redshifted photons) +235 km s\(^{-1}\)

**V2** (blueshifted photons) -235 km s\(^{-1}\)

5 arcmin

Cross-contamination of V1

Cross-contamination of V2

Distance (X) from center (arcmin)

Fractional number of photons per 0.05 arcmin/Bin

redimg.fits

blueimg.fits
A (very) simple example…

**V1** (redshifted photons)  
+235 km s\(^{-1}\)

**V2** (blueshifted photons)  
-235 km s\(^{-1}\)

5 arcmin

Spatial mixing...

- Fraction of V2 photons mixing into the V1 region: 15%
- Fraction of V1 photons mixing into the V2 region: 17%
A (very) simple example...

\[ \sigma = 1 \text{ eV} \]
\[ (110 \text{ km s}^{-1}) \]

\[ \sigma = 3 \text{ eV} \]
\[ (330 \text{ km s}^{-1}) \]
A (very) simple example...

\[ \sigma = 1 \text{ eV} \quad (110 \text{ km s}^{-1}) \]

Cross-contamination fraction = 0.16

model

RMF-convolved
A (very) simple example…

\[ \sigma = 1 \text{ eV} \quad (110 \text{ km s}^{-1}) \]

\[ \sigma = 3 \text{ eV} \quad (330 \text{ km s}^{-1}) \]
A (very) simple example...

\[ \sigma = 1 \text{ eV} \quad (110 \text{ km s}^{-1}) \]

\[ \sigma = 3 \text{ eV} \quad (330 \text{ km s}^{-1}) \]
Addressing the problem
Ready to fall into the rabbit hole...?
A concrete case (Virgo cluster)

RA/DEC region X: Area not overlapping with any overlaid detector region
A concrete case (Virgo cluster)

✓ **CAPITAL** letter (C, E, NW, SW): **sky** region
(“true” regions you want to investigate, spectral models, etc.)

✓ **small** letter (c, e, nw, sw): **detector** region
(“output” counts and spectra)

RA/DEC region X: *Area not over-lapping with any overlaid detector region*
A concrete case (Virgo cluster)

✓ **CAPITAL** letter (C, E, NW, SW): **sky** region

("true" regions you want to investigate, spectral models, etc.)

✓ **small** letter (c, e, nw, sw): **detector** region

("output" counts and spectra)

✓ $S_i =$ observed **spectrum** of detector region i

✓ $M_J =$ **spectral model** of sky region J

✓ $R_i =$ **response matrix** (RMF) of detector region i

✓ $A_i =$ **effective area** (ARF) of detector region i
A concrete case (Virgo cluster)

✓ **CAPITAL** letter (C, E, NW, SW): sky region
  ("true" regions you want to investigate, spectral models, etc.)

✓ **small** letter (c, e, nw, sw): detector region
  ("output" counts and spectra)

✓ $S_i = \text{observed spectrum}$ of detector region $i$

✓ $M_J = \text{spectral model}$ of sky region $J$

✓ $R_i = \text{response matrix}$ (RMF) of detector region $i$

✓ $A_i = \text{effective area}$ (ARF) of detector region $i$
A concrete case (Virgo cluster)

✓ **CAPITAL** letter (C, E, NW, SW): sky region
   (“true” regions you want to investigate, spectral models, etc.)

✓ **small** letter (c, e, nw, sw): detector region
   (“output” counts and spectra)

✓ $S_i =$ observed *spectrum* of detector region $i$

✓ $M_J =$ *spectral model* of sky region $J$

✓ $R_i =$ *response matrix* (RMF) of detector region $i$

✓ $A_i =$ *effective area* (ARF) of detector region $i$
A concrete case (Virgo cluster)

✓ **CAPITAL** letter (C, E, NW, SW): **sky** region
  ("true" regions you want to investigate, spectral models, etc.)

✓ **small** letter (c, e, nw, sw): **detector** region
  ("output" counts and spectra)

✓ $S_i = \text{observed spectrum}$ of detector region $i$
✓ $M_J = \text{spectral model}$ of sky region $J$
✓ $R_i = \text{response matrix}$ (RMF) of detector region $i$
✓ $A_i = \text{effective area}$ (ARF) of detector region $i$
A concrete case (Virgo cluster)

\[ S_c = \text{[Diagram description]} \]
A concrete case (Virgo cluster)

\[ S_c = \]
A concrete case (Virgo cluster)

$S_c = A_c R_c$  \[ M_c \]
A concrete case (Virgo cluster)

\[ S_c = A_c R_c \]

\[ M_C \]
A concrete case (Virgo cluster)

\[ S_c = A_c \cdot R_c \quad M_C \]
A concrete case (Virgo cluster)

\[ S_c = A_c R_c \left[ \mathbf{P}_{C \rightarrow c} \mathbf{M}_C + \mathbf{P}_{E \rightarrow c} \mathbf{M}_E \right] \]
A concrete case (Virgo cluster)

\[ S_c = A_c R_c \left[ P_{C \rightarrow c} M_C + P_{E \rightarrow c} M_E + P_{NW \rightarrow c} M_{NW} \right] \]
A concrete case (Virgo cluster)

\[ S_c = A_c R_c [P_{C \rightarrow c} M_C + P_{E \rightarrow c} M_E + P_{NW \rightarrow c} M_{NW} + P_{SW \rightarrow c} M_{SW}] \]
A concrete case (Virgo cluster)

\[ S_e = A_e R_e \left[ P_{C \rightarrow e} M_C + P_{E \rightarrow e} M_E + P_{NW \rightarrow e} M_{NW} + P_{SW \rightarrow e} M_{SW} \right] \]
A concrete case (Virgo cluster)

\[ S_{nw} = A_{nw} R_{nw} \left[ P_{C \rightarrow nw} M_{C} + P_{E \rightarrow nw} M_{E} + P_{NW \rightarrow nw} M_{NW} + P_{SW \rightarrow nw} M_{SW} \right] \]
A concrete case (Virgo cluster)

\[ S_{sw} = A_{sw} R_{sw} \left[ P_{C\rightarrow sw} M_C + P_{E\rightarrow sw} M_E + P_{NW\rightarrow sw} M_{NW} + P_{SW\rightarrow sw} M_{SW} \right] \]
A concrete case (Virgo cluster)

\[ S_c = A_c R_c \left[ P_{C \rightarrow c} M_{C} + P_{E \rightarrow c} M_{E} + P_{NW \rightarrow c} M_{NW} + P_{SW \rightarrow c} M_{SW} \right] \]

\[ S_e = A_e R_e \left[ P_{C \rightarrow e} M_{C} + P_{E \rightarrow e} M_{E} + P_{NW \rightarrow e} M_{NW} + P_{SW \rightarrow e} M_{SW} \right] \]

\[ S_{nw} = A_{nw} R_{nw} \left[ P_{C \rightarrow nw} M_{C} + P_{E \rightarrow nw} M_{E} + P_{NW \rightarrow nw} M_{NW} + P_{SW \rightarrow nw} M_{SW} \right] \]

\[ S_{sw} = A_{sw} R_{sw} \left[ P_{C \rightarrow sw} M_{C} + P_{E \rightarrow sw} M_{E} + P_{NW \rightarrow sw} M_{NW} + P_{SW \rightarrow sw} M_{SW} \right] \]

Observed spectra of detector region \( i \)

Response matrices of detector region \( i \)

Effective areas of detector region \( i \)

Spectral models of sky region \( J \)

\[ S_i = A_i R_i \sum_J P_{J \rightarrow i} M_J \]
A concrete case (Virgo cluster)

\[ S_c = A_c R_c \begin{bmatrix} P_{C\rightarrow c} \\ M_c + P_{E\rightarrow c} \\ M_e + P_{N\rightarrow c} \\ M_{NW} + P_{SW\rightarrow c} \end{bmatrix} \]

\[ S_e = A_e R_e \begin{bmatrix} P_{C\rightarrow e} \\ M_c + P_{E\rightarrow e} \\ M_e + P_{N\rightarrow e} \\ M_{NW} + P_{SW\rightarrow e} \end{bmatrix} \]

\[ S_{nw} = A_{nw} R_{nw} \begin{bmatrix} P_{C\rightarrow nw} \\ M_c + P_{E\rightarrow nw} \\ M_e + P_{N\rightarrow nw} \\ M_{NW} + P_{SW\rightarrow nw} \end{bmatrix} \]

\[ S_{sw} = A_{sw} R_{sw} \begin{bmatrix} P_{C\rightarrow sw} \\ M_c + P_{E\rightarrow sw} \\ M_e + P_{N\rightarrow sw} \\ M_{NW} + P_{SW\rightarrow sw} \end{bmatrix} \]

Coefficients of photon mixing from sky region \( J \) into detector region \( i \)

\[ S_i = A_i R_i \sum_{J} P_{J\rightarrow i} M_J \]

4 x 4 = 16 models fitted simultaneously to 4 observed spectra
A concrete case (Virgo cluster)

How to obtain the $P_{j \rightarrow i}$ coefficients?

- **Method 1**: leave normalizations of the 16 models free
  - …Bad idea! (Empirical, black box, too many free params, degeneracies, etc.)

- **Method 2**: estimate coefficients from ray-tracing simulations
  - …Via ARF generator (part of the future XRISM data reduction software)
A concrete case (Virgo cluster)

- **Method 2**: estimate coefficients from ray-tracing simulations
  - …Via ARF generator (part of the future XRISM data reduction software)

---

![Diagram](image.png)

**Input “source type” options**
- point source
- flat circle
- $\beta$-model

**Input image (e.g. Chandra, sim., etc.)**

**Output ARF**

1) `xrtraytrace`

2) `xaxmaarfgen`

*(name might still change)*

Credits: T. Yaqoob
A concrete case (Virgo cluster)

**Method 2**: estimate coefficients from ray-tracing simulations

...Via ARF generator (part of the future XRISM data reduction software)

Credits: T. Yaqoob
A concrete case (Virgo cluster)

**Method 2**: estimate coefficients from ray-tracing simulations

...Via ARF generator (part of the future XRISM data reduction software)

Input "source type" options:
- point source
- flat circle
- \( \beta \)-model

Input image (e.g., Chandra, simulation)

1) `xrtraytrace`

2) `xaarfgen`

\( (A_j \times P_{J \rightarrow i}) \)

e.g. 5%
**Method 2**: estimate coefficients from ray-tracing simulations

- Via ARF generator (part of the future XRISM data reduction software)

Diagram showing steps:
1. Input "source type" options
   - point source
   - flat circle
   - \(\beta\)-model
2. Input image (e.g., Chandra, sim)
3. \(\text{xrtraytrace}\)
4. \(\text{xaarfgen}\)
5. Output ARF

Equation:
\[
(A_i \times P_{J \rightarrow i}) \rightarrow A_{J \rightarrow i}
\]

Example:
- \(E_{\text{cm}^2} \leq 5\%\)
A concrete case (Virgo cluster)

\[ S_c = A_c R_c \] \[ S_e = A_e R_e \] \[ S_{nw} = A_{nw} R_{nw} \] \[ S_{sw} = A_{sw} R_{sw} \]

\[ [P_{c \rightarrow c}] M_C + P_{E \rightarrow c} ] \] \[ [P_{c \rightarrow e}] M_C + P_{E \rightarrow e} ] \]

\[ [P_{c \rightarrow nw}] M_C + P_{E \rightarrow nw} ] \]

\[ [P_{c \rightarrow sw}] M_C + P_{E \rightarrow sw} ] \]

\[ M_E + P_{NW \rightarrow c} \] \[ M_E + P_{NW \rightarrow e} \] \[ M_E + P_{NW \rightarrow nw} \] \[ M_E + P_{NW \rightarrow sw} \]

\[ M_{NW} + P_{SW \rightarrow c} \] \[ M_{NW} + P_{SW \rightarrow e} \] \[ M_{NW} + P_{SW \rightarrow nw} \] \[ M_{NW} + P_{SW \rightarrow sw} \]

Effective areas of detector region i

Observed spectra of detector region i

Response matrices of detector region i

Spectral models of sky region J

\[ S_i = A_i R_i \sum_{J} P_{J \rightarrow i} M_J \]
A concrete case (Virgo cluster)

\[
\begin{align*}
S_c &= R_c [A_{C \rightarrow c} M_c + A_{E \rightarrow c} M_c + A_{NW \rightarrow c} M_c + A_{SW \rightarrow c} M_c] \\
S_e &= R_e [A_{C \rightarrow e} M_e + A_{E \rightarrow e} M_e + A_{NW \rightarrow e} M_e + A_{SW \rightarrow e} M_e] \\
S_{nw} &= R_{nw} [A_{C \rightarrow nw} M_{nw} + A_{E \rightarrow nw} M_{nw} + A_{NW \rightarrow nw} M_{nw} + A_{SW \rightarrow nw} M_{nw}] \\
S_{sw} &= R_{sw} [A_{C \rightarrow sw} M_{sw} + A_{E \rightarrow sw} M_{sw} + A_{NW \rightarrow sw} M_{sw} + A_{SW \rightarrow sw} M_{sw}]
\end{align*}
\]

Observed spectra of detector region i

Response matrices of detector region i

Spectral models of sky region J

\[
S_i = R_i \sum_j A_{j \rightarrow i} M_j
\]

4 x 4 = 16 models fitted simultaneously to 4 observed spectra
A concrete case (Virgo cluster)

\[ S_c = R_c \begin{bmatrix} A_{C \rightarrow c} & M_C + A_{E \rightarrow c} & M_E + A_{NW \rightarrow c} & M_{NW} + A_{SW \rightarrow c} \\ \end{bmatrix} M_{SW} \]

\[ S_e = R_e \begin{bmatrix} A_{C \rightarrow e} & M_C + A_{E \rightarrow e} & M_E + A_{NW \rightarrow e} & M_{NW} + A_{SW \rightarrow e} \\ \end{bmatrix} M_{SW} \]

\[ S_{nw} = R_{nw} \begin{bmatrix} A_{C \rightarrow nw} & M_C + A_{E \rightarrow nw} & M_E + A_{NW \rightarrow nw} & M_{NW} + A_{SW \rightarrow nw} \\ \end{bmatrix} M_{SW} \]

\[ S_{sw} = R_{sw} \begin{bmatrix} A_{C \rightarrow sw} & M_C + A_{E \rightarrow sw} & M_E + A_{NW \rightarrow sw} & M_{NW} + A_{SW \rightarrow sw} \\ \end{bmatrix} M_{SW} \]

\[ S_i = R_i \sum_{j} A_{j \rightarrow i} M_j \]

4 x 4 = 16 models fitted simultaneously to 4 observed spectra
Even more concretely…

$$S_c = R_c [(...) + A_{E\rightarrow c} M_E + (...) ]$$
Even more concretely...

$ \text{xaarfgen} \text{ telescop="XRISM" instrume="RESOLVE" (...) regionfile="/path/to/my_detector_region_c.reg" sourcetype="IMAGE" imgfile="/path/to/my_image_of_sky_region_E.fits$}

\[ S_c = R_c [(\ldots) + A_{E \rightarrow c} M_E + (\ldots)] \]
Even more concretely...

```bash
$ xaarfgen telescop="XRISM" instrume="RESOLVE" (...) regionfile="/path/to/my_detector_region_c.reg" sourcetype="IMAGE" imgfile="/path/to/my_image_of_sky_region_E.fits"
```

\[
S_c = R_c [(\ldots) + A_{E \rightarrow c} M_E + (\ldots)]
\]
Even more concretely...

```
$ xaarfgen telecop="XRISM" instrume="RESOLVE" (...)
regionfile="/path/to/my_detector_region_c.reg"
sourcetype="IMAGE"
imgfile="/path/to/my_image_of_sky_region_E.fits"
```

\[ S_c = R_c [(...) + A_{E \rightarrow c} M_E + (...) \]
Another concrete case (Perseus cluster)

**Hitomi Collaboration et al. (2018)**

12 detector regions
(obs1: 2 regions - obs2: 5 regions - obs3: 5 regions)

\[ J = 0, 1, \ldots, 12 \]

6 sky regions
(Larger than detector regions to account for external SSM)

\[ i = 0, 1, \ldots, 6 \]

\[ S_i = R_i \sum_j A_{j \rightarrow i} M_j \]

12 x 6 = 72 models fitted simultaneously to 12 observed spectra (!)
Another concrete case (Sagittarius A*)

35 detector regions
\[ J = 0,1,\ldots,35 \]

35 sky regions
\[ i = 0,1,\ldots,35 \]

\[ S_i = R_i \sum_j A_{J \rightarrow i} M_J \]

35 x 35 = 1225 models fitted simultaneously to 35 observed spectra !!

Problem: XRISM ARFs are very heavy to generate (>1-1.5 hour per ARF)!
→ > 51 days on a single-core machine!
Mitigating the long ARF generation times

1. Divide a few regions of interest in a smart way (e.g. regions with similar special features, “optimize” the SSM, etc.)…

2. Treat each pixel separately vs “the rest” (modelled as a block)

3. Ignore regions with virtually inexistent SSM

4. A library of pre-computed PSFs may be made available some time soon (PSFlib)

5. ARFs can be computed over narrow energy ranges too…

6. …other options with your host institute? (Grid computing, computing clusters, etc.)
Mitigating the long ARF generation times

1. Divide a few regions of interest in a smart way (e.g. regions with similar special features, “optimize” the SSM, etc.)…

2. Treat each pixel separately vs “the rest” (modelled as a block)

3. Ignore regions with virtually inexistent SSM

4. A library of pre-computed PSFs may be made available some time soon (PSFlib)

5. ARFs can be computed over narrow energy ranges too…

6. …other options with your host institute? (Grid computing, computing clusters, etc.)
Mitigating the long ARF generation times

1. Divide a few regions of interest in a smart way (e.g. regions with similar special features, “optimize” the SSM, etc.)…

2. Treat each pixel separately vs “the rest” (modelled as a block)

3. Ignore regions with virtually inexistent SSM

4. A library of pre-computed PSFs may be made available some time soon (PSFlib)

5. ARFs can be computed over narrow energy ranges too…

6. …other options with your host institute? (Grid computing, computing clusters, etc.)
Mitigating the long ARF generation times

1. Divide a few regions of interest in a smart way (e.g. regions with similar special features, “optimize” the SSM, etc.)…

2. Treat each pixel separately vs “the rest” (modelled as a block)

3. Ignore regions with virtually inexistent SSM

4. A library of pre-computed PSFs may be made available some time soon (PSFlib)

5. ARFs can be computed over narrow energy ranges too…

6. …other options with your host institute? (Grid computing, computing clusters, etc.)
Mitigating the long ARF generation times

1. Divide a few regions of interest in a smart way (e.g. regions with similar special features, “optimize” the SSM, etc.)...

2. Treat each pixel separately vs “the rest” (modelled as a block)

3. Ignore regions with virtually inexistent SSM

4. A library of pre-computed PSFs may be made available some time soon (PSFlib)

5. ARFs can be computed over narrow energy ranges too...

6. ...other options with your host institute? (Grid computing, computing clusters, etc.)
Advice and recommendations
If you plan to analyze a source...

✓ **Your favorite extended source will (very) likely be affected by SSM!**

✓ **Systematic uncertainties** (SSM, background, effective areas, calibration, etc.)

✓ Substantial SSM is **not necessarily “bad”** (see above example with ~50% purity)

✓ Data analysis will **NOT be a simple XSPEC fit!** (e.g. investigation of spectral signatures of SSM before fitting - see Anna’s talk on Friday)

✓ Recommended to plan a coherent **tiling of regions** to investigate

✓ “Brute-force” multi-pixel array spectroscopy is challenging…
If you plan to propose a source...

1. What is the **spatial (and spectral) structure** of the extended source? (clues from Chandra / XMM, previous literature, etc.)

2. How is SSM likely to impact the **analysis** of the proposed source?

3. How is SSM expected to impact the **proposed science goals**?

4. Will the source be analyzed over several **spatial regions**? If so, which tiling strategy (and why)?
If you plan to propose a source...

5. What **method(s)** is/are thought to be the most appropriate to tackle internal SSM effects? (e.g. computing precise ARFs directly, using PSFlib, using an alternative or hybrid method, etc.)

6. Is **external SSM** expected to impact the analysis (and output science) of the source?

7. **Other properties** of the source expected to further complicate the analysis? (e.g. pile-up effects, uncertainties in atomic databases impacting spectral features relevant to the science goals, etc.)
✓ We are entering a **new era**… lots of challenges and **lessons to learn** (exciting on this aspect too!)
✓ We are entering a **new era**... lots of challenges and **lessons to learn** (exciting on this aspect too!)

**WITH GREAT (RESOLVING) POWER**

**COMES GREAT (ANALYSIS) RESPONSIBILITY**