End-To-End Simulations with SIXTE: A Webinar

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What are End-to-End Simulations?

End-to-end (e2e) simulations: Simulation of the full detection chain for an astronomical instrument, from the astrophysical source through the imaging and detection process to the final data product.

$\Longrightarrow$ Full model of observational setup

E2e simulations have two major "customers":

Scientists:

- Gauge effect of design onto science: Can science goals be reached with the instrument?
  e.g., imaging quality, spectroscopy,...
- What other "observatory" science is possible?
- Plan future observations

Instrumentalists:

- Use science examples to study design: What is impact of design onto science goals?
- Translation of instrument parameters $\Longleftrightarrow$ Science goals
- Estimate instrument performance
  e.g., telemetry constraints, CPU constraints

$\Longrightarrow$ Core component of mission design and implementation!

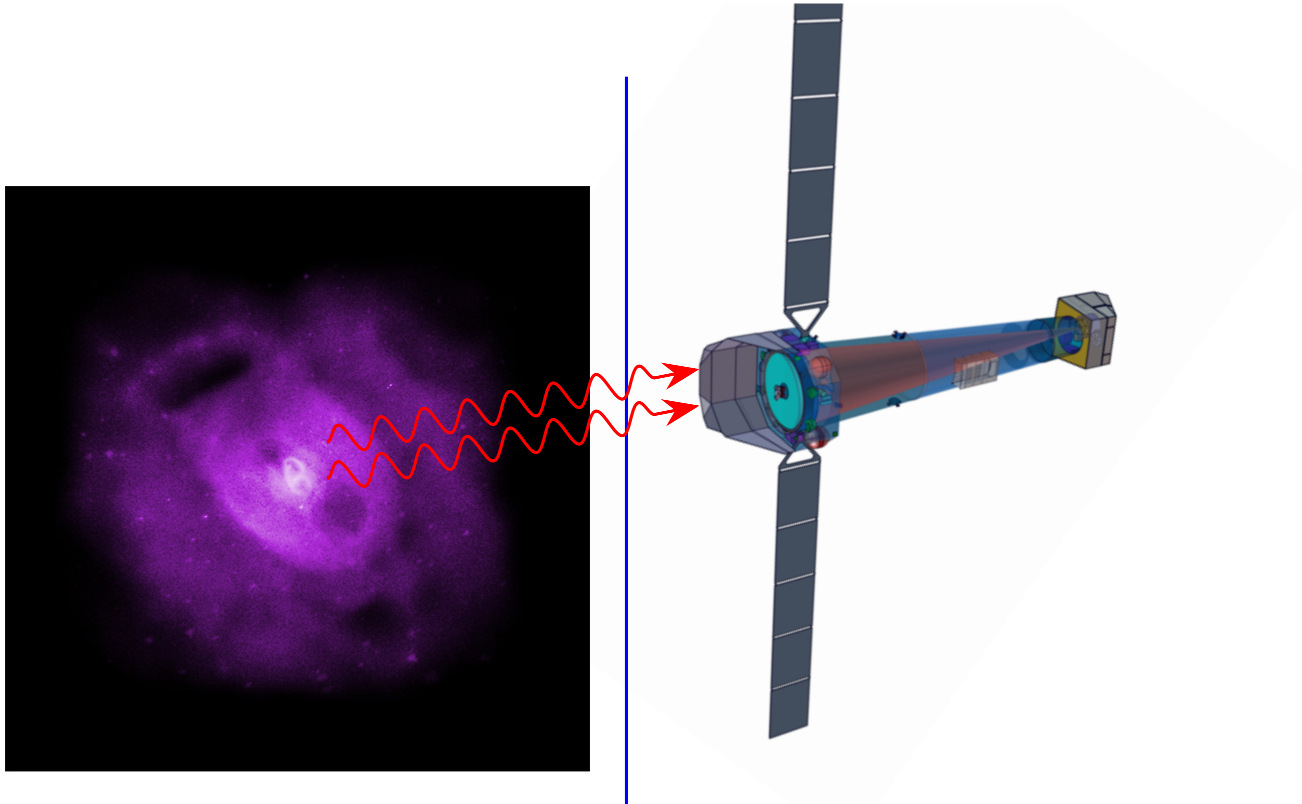
To be useful, e2e software should always represent best understanding of real instrumental performance.

Today's Webinar

1. What is SIXTE?
   - general overview
2. What is in SIXTE? – the models for the Athena WFI and X-IFU
   - detector model
   - the things you cannot do with ARFs and RMFs
     cross-talk, pile-up, DEPFET-readout, event grades, etc.
3. When to SIXTE?
   fakeit versus SIXTE
4. How to SIXTE?
   - demonstration of bright point source setup and simulation
   - extended source simulations
   - mosaicing, dithering, etc.
   - straylight
5. SIXTE? – questions (and answers?)

What is SIXTE?

Modeling



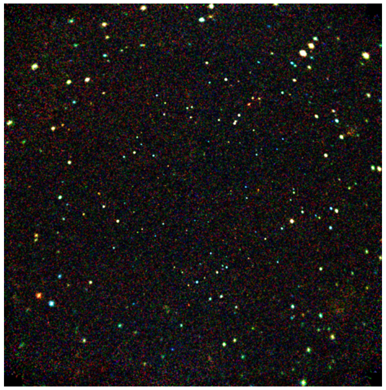
Source model – SIMPUT | Instrument model – SIXTE

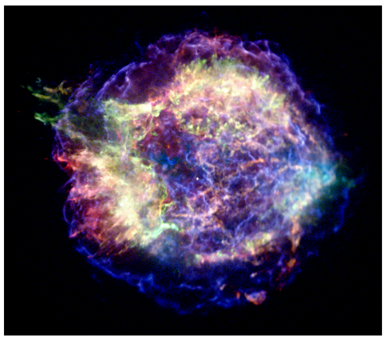
Source model: Define properties of the sources: Positions, Extended source/point source, spectral shape, variability,. . .

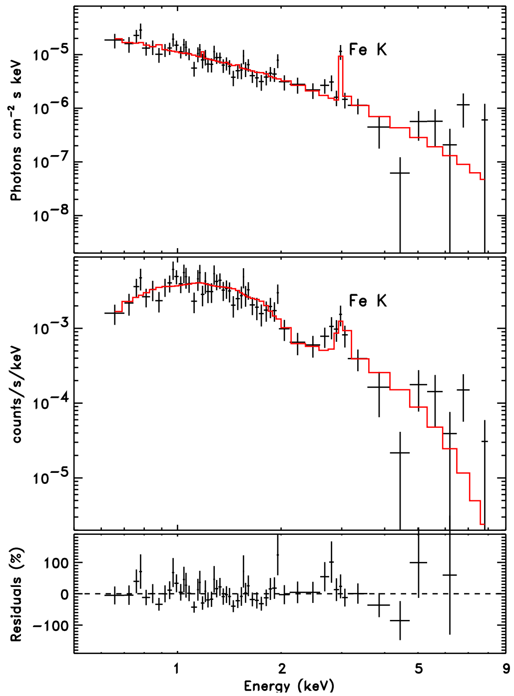
Instrument model: Define properties of the instrument: Imaging parameters, detection process, data processing chain

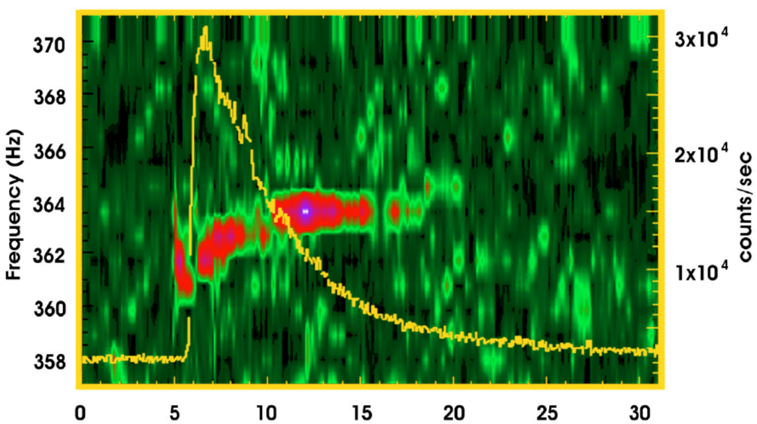
Output: Data that can be analyzed using standard astronomical analysis software (FTOOLS, XMM-SAS, XSPEC, ISIS,. . .)

Source Model: SIMPUT









sources are characterized by:

- source properties:
  - spectral shape
  - positions
  - light curves, pulse profiles, power spectra. . .
  - spatial extent
  - photon lists from MHD simulations
  - "data cubes" (e.g., cosmology)
- format allows reuse of common properties of sources

  e.g., reuse AGN spectra for multiple sources, reuse images of extended sources,. . .
- catalogs with arbitrary number of sources

  scales to millions of sources
- compatible w/other simulators

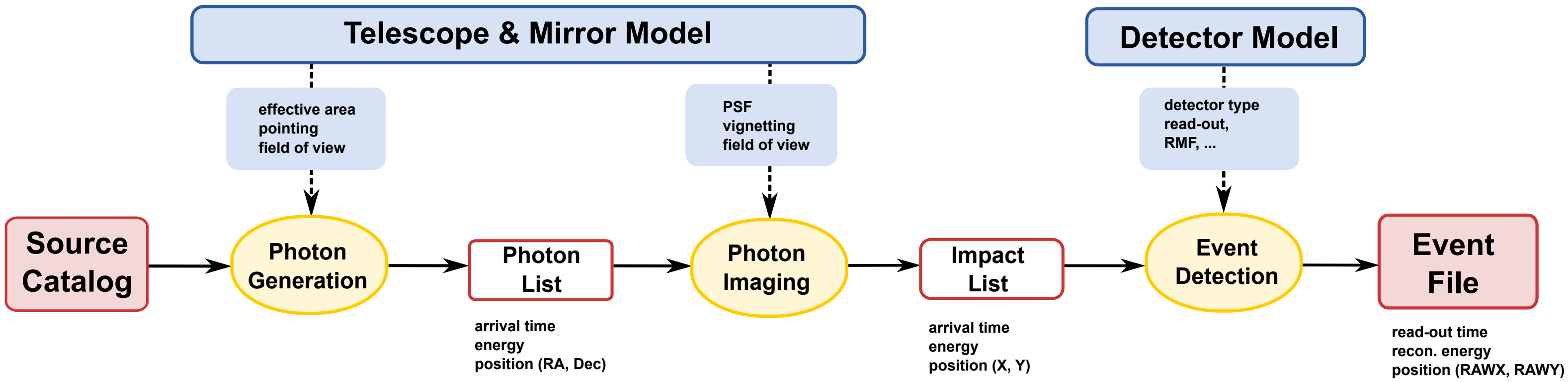
  `simx`, MARX

SIXTE

e2e environment: SIXTE, a generic Monte Carlo simulation framework for X-ray instruments
(Athena, eROSITA, ARCUS, XMM, LOFT, IXO, GRAVITAS,...)

http://www.sternwarte.uni-erlangen.de/research/sixte

- modular software → reuse existing algorithms for multiple instruments



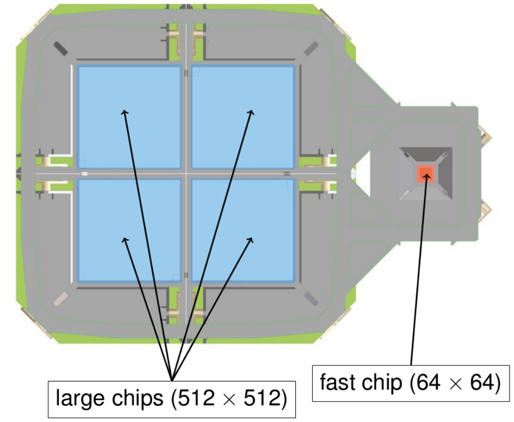
- uses calibration data (response files, PSF, ...) *or* physics-based instrument model
- output: FITS event list (time, energy, pixel)

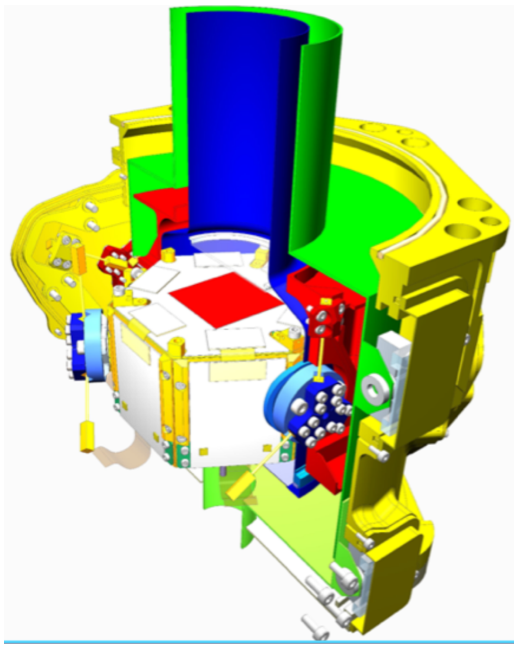
⟹ *one* simulator for science & technology development

Instrument model

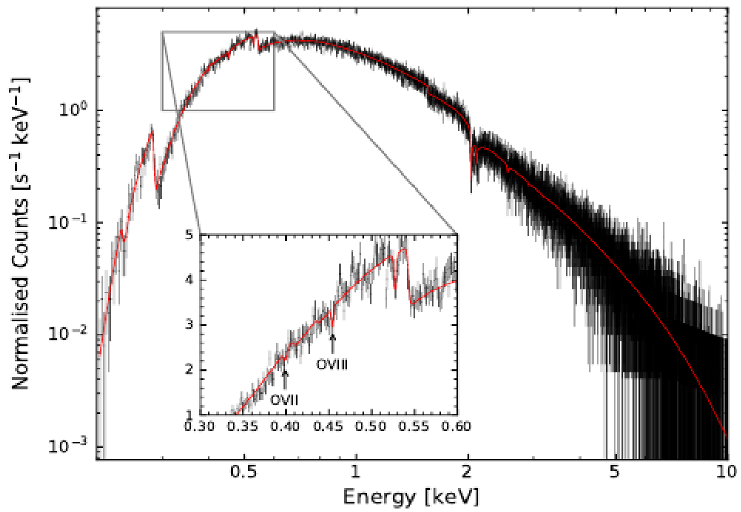
- Imaging module
  - pointing (attitude, e.g., for dithering)
  - ARF
  - vignetting
  - PSF
- Instrument module
  - device simulator:
    - simple/fast simulation: RMF sampling
    - advanced simulation: physics
      (e.g., $T(t)$ for X-IFU, photon effects in Si for WFI)

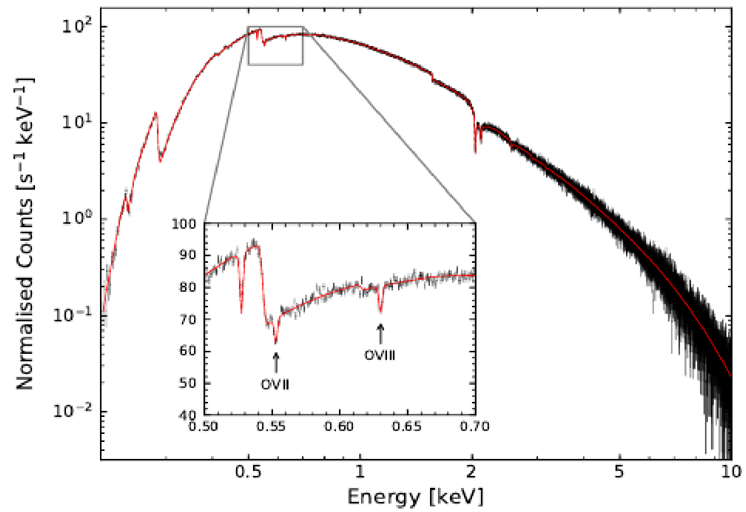
    flexible focal plane description (XML)
  - other effects considered: pile-up, crosstalk, background, readout
- Output: FITS event files



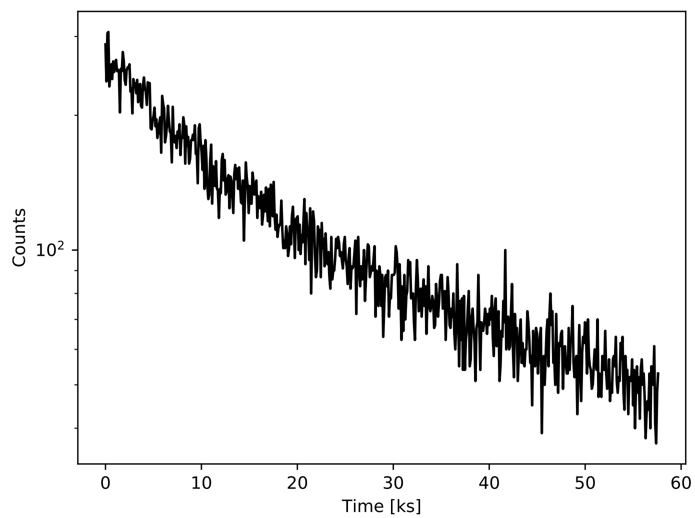


Example: GRBs and WHIM





$z_{\mathrm{WHIM}} = 0.4388$ Walsh et al. (2020, submitted; GRB is at $z = 2$) $z_{\mathrm{WHIM}} = 0.0382$

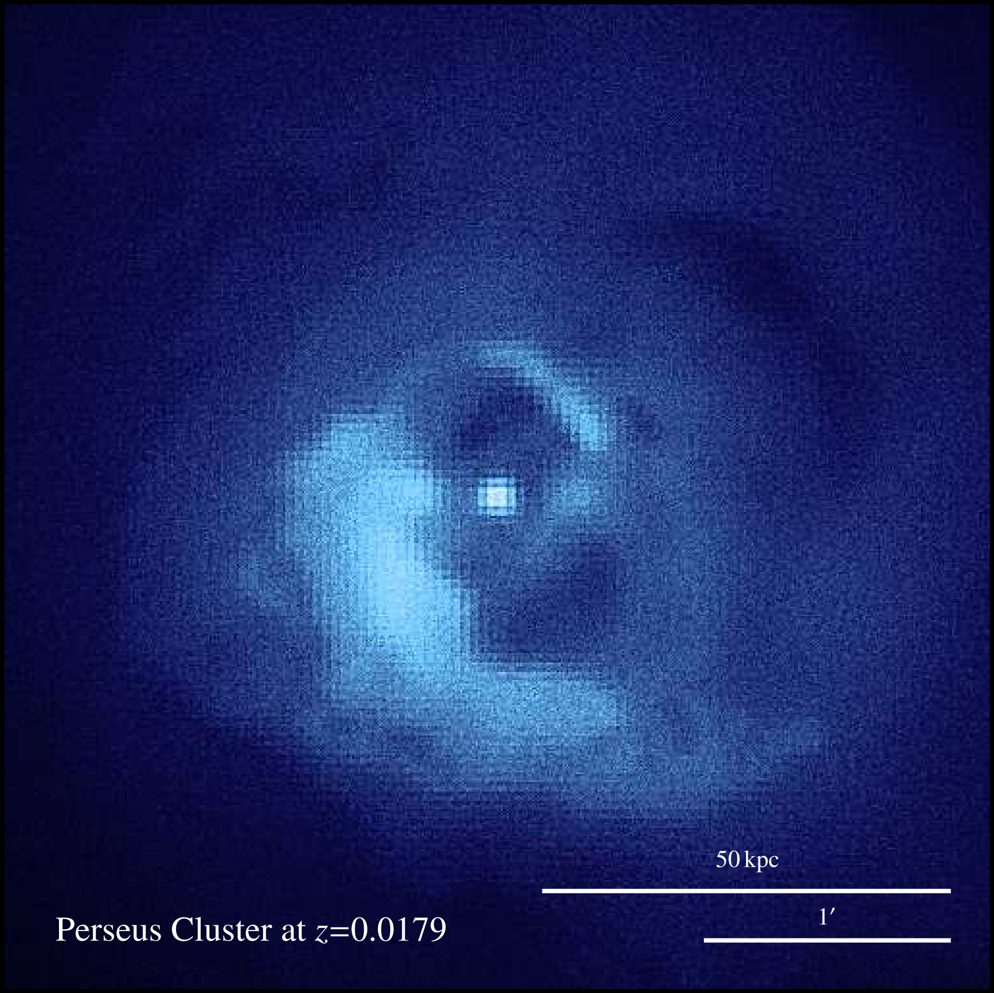


Example: Detection of Oxygen lines from WHIM in GRB spectra

Uses:

- realistic lightcurve
- realistic spectral shape

Simulation Output



50 ks, one chip

Now shift cluster to higher z:

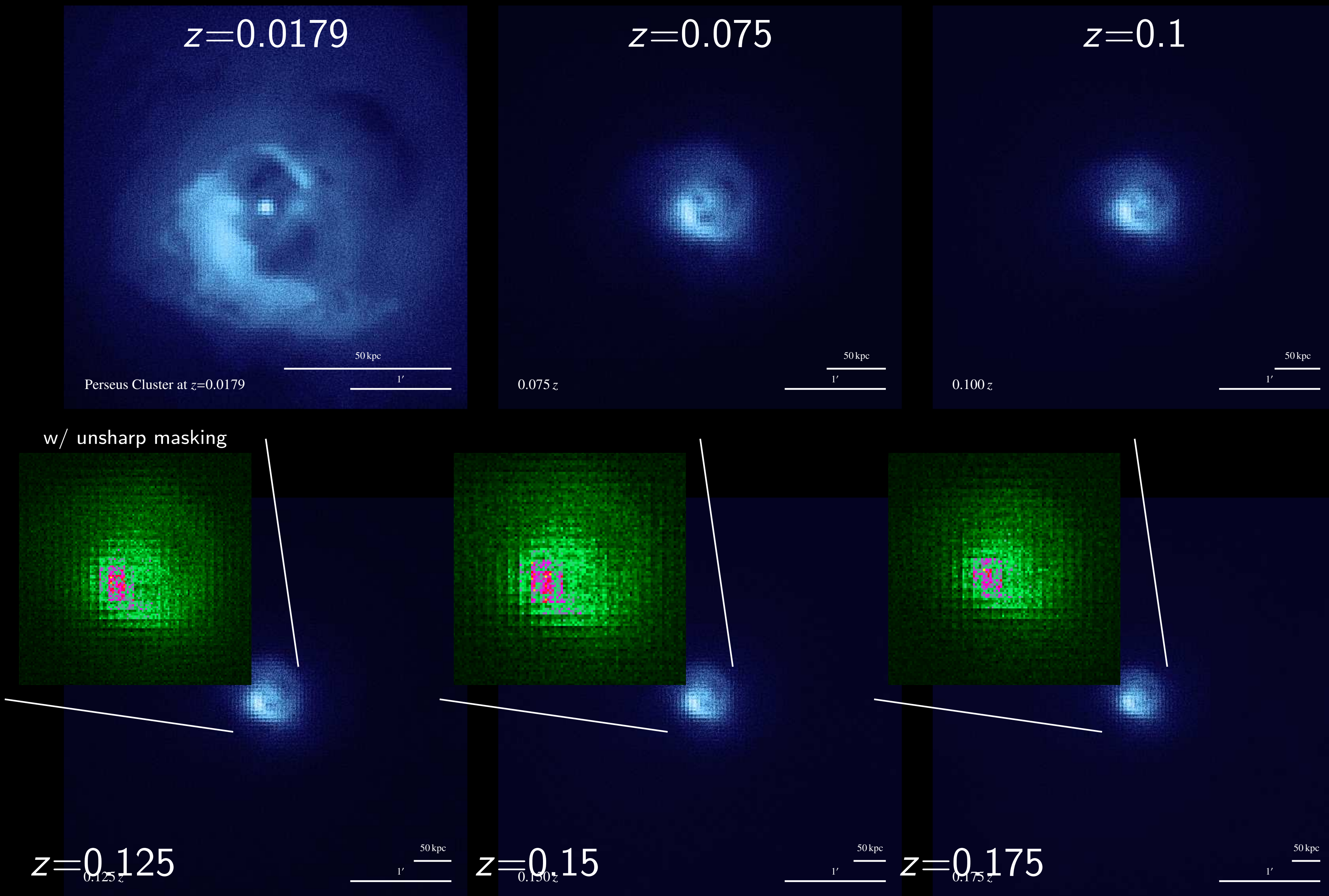
1) Scale cluster size scale via:

$$\phi(z) = \phi_{\mathrm{pers}} \cdot \frac{D_{\mathrm{pers}}/(1+z_{\mathrm{pers}})^2}{D(z)/(1+z)^2}$$

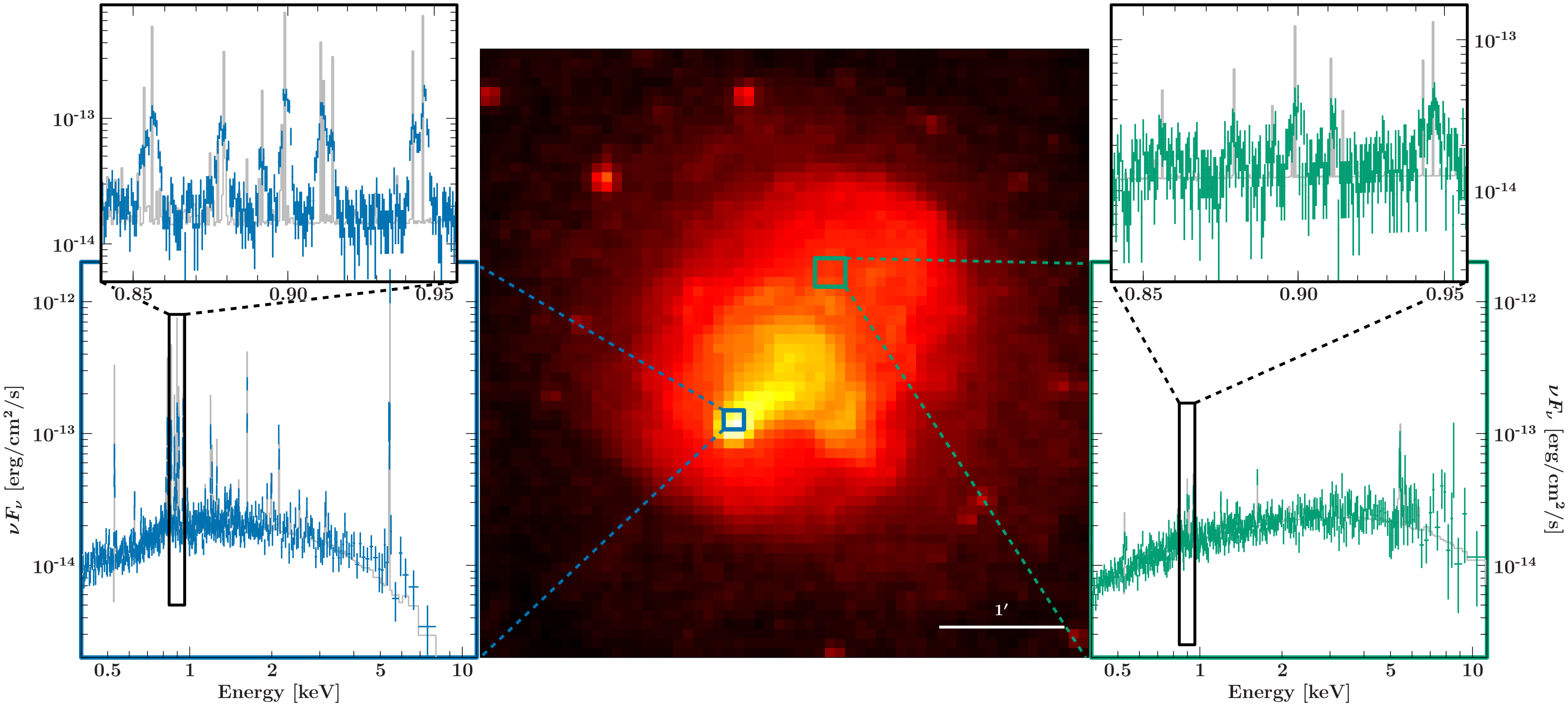
2) Scale flux with luminosity distance:

$$F(z) = F_{\mathrm{pers}} \cdot \left(\frac{D_{\mathrm{pers}}}{D(z)}\right)^2$$

Simulation Output

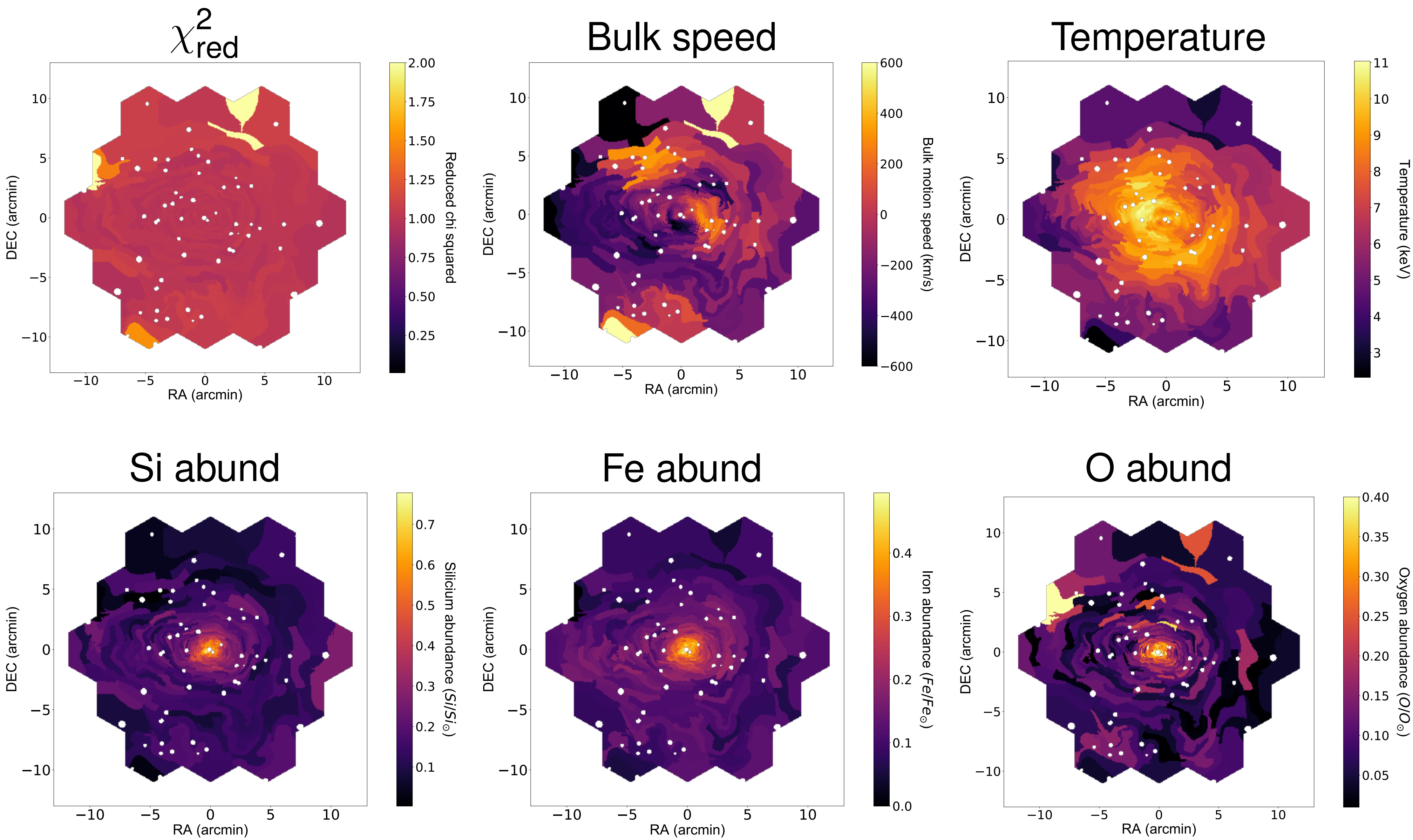


Example: Galaxy clusters



Abell 2146 with X-IFU (T. Dauser/E. Pointecouteau)

Example: Galaxy clusters



after E. Cucchetti et al. (2018, A&A 620, 173)

Summary

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SIXTE | Installation | Examples | Athena | SIMPUT | Contact

SIXTE - Simulation of X-ray Telescopes

SIXTE is a software package for X-ray telescope observation simulations developed at the Remeis Observatory (ECAP). It allows to undertake instrument performance analyses and to produce simulated event files for mission- and analysis studies.

The software strives to find a compromise between exactness of the simulation and speed. For many cases, by using calibration files such as the PSF, RMF and ARF, efficient simulations are possible at comparably high speed, even though they include nonlinear effects such as pileup. Setups for some current and future missions such as XMM-Newton or Athena are included in the package, others can be added by the user with relatively little effort through specifying the main instrument characteristics in a flexible, human-readable XML-based format.

For an overview of the SIXTE software package, see Dauser et al. (2019). If you use results obtained with SIXTE in a publication, please cite as: "This research has made use of the SIXTE software package (Dauser et al., 2019) provided by ECAP/Remeis observatory (https://github.com/thdauser/sixte)."

SIMPUT Format - Source Description

Properties of X-ray sources to be simulated are described in a detector-independent format, i.e., the same input can be used for simulating observations with all available instruments, and the same input can also be used for simulations with the SIMX simulator. The input files can be easily generated from standard data such as XSPEC spectral models or FITS images with tools provided with the SIXTE distribution. The input data scale well from single point sources up to very complicated setups. For example, for ATHENA we have simulated observations of the galactic center based on the Chandra input catalogues and images of the diffuse emission, while for eROSITA we regularly perform simulations of the whole sky using several million time-variable point sources.

More details on the SIMPUT format are described here. We also provide selected SIMPUT files for download, which can be readily used in a Sixte simulations.

SIXTE Simulator Manual

The first version of the SIXTE simulator manual is available for download below. It includes general description of SIXTE and the implementation of detectors such as the WFI, X-IFU, eROSITA and others. In addition, tutorials for Athena WFI and X-IFU simulations are included.

download: simulator_manual.pdf (v1.3.10, 2019-11-15)

supplementary files for the X-IFU tutorial (30MB!): X-IFU_clusters_tutorial.tgz

4 year eROSITA Attitude file for a launch in April 2019 (200MB!): eRASS_4yr_epc85_att.fits.bz2

4th SIXTE Workshop (19.-21. February 2019, IFCA)

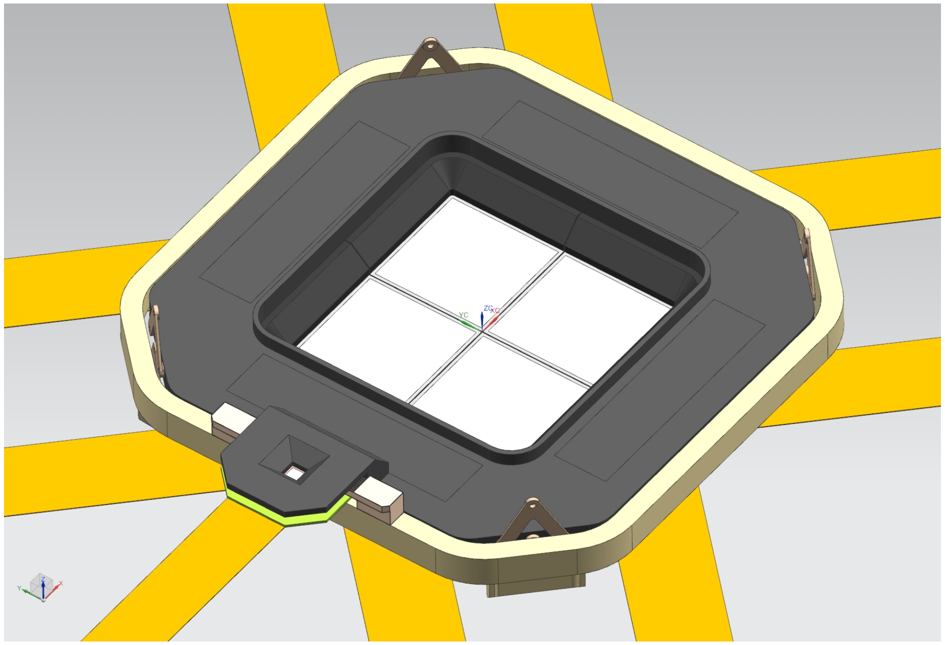
On the 19. until 21. February 2019 the fourth SIXTE workshop took place in Santander, with a focus on Athena WFI and X-IFU simulations. Below is a selection of the talks presented there.

Access:

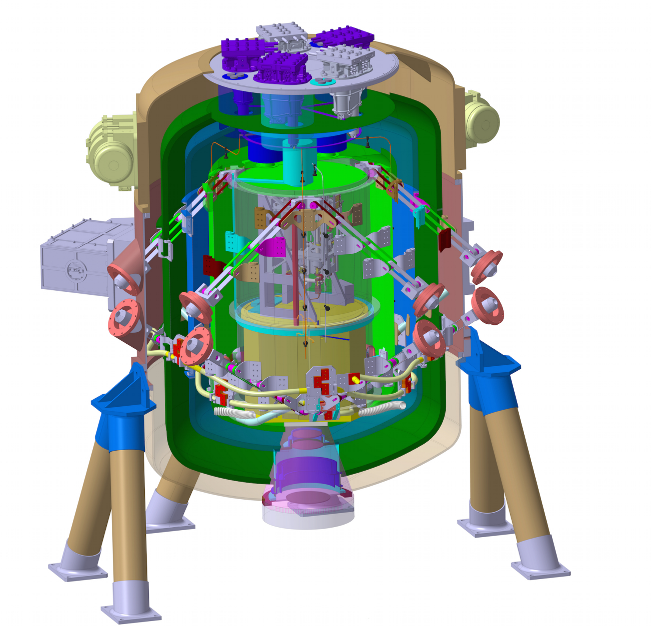
- documentation: 90 p. manual and Dauser et al. (2019, A&A 630, 66)
- help desk: sixte-support@lists.fau.de
- Source code: `http://www.sternwarte.uni-erlangen.de/research/sixte/index.php`.
  Works on Linux and Mac, git and release versions.

What is in SIXTE?

Athena's Instruments



MPE



CNES

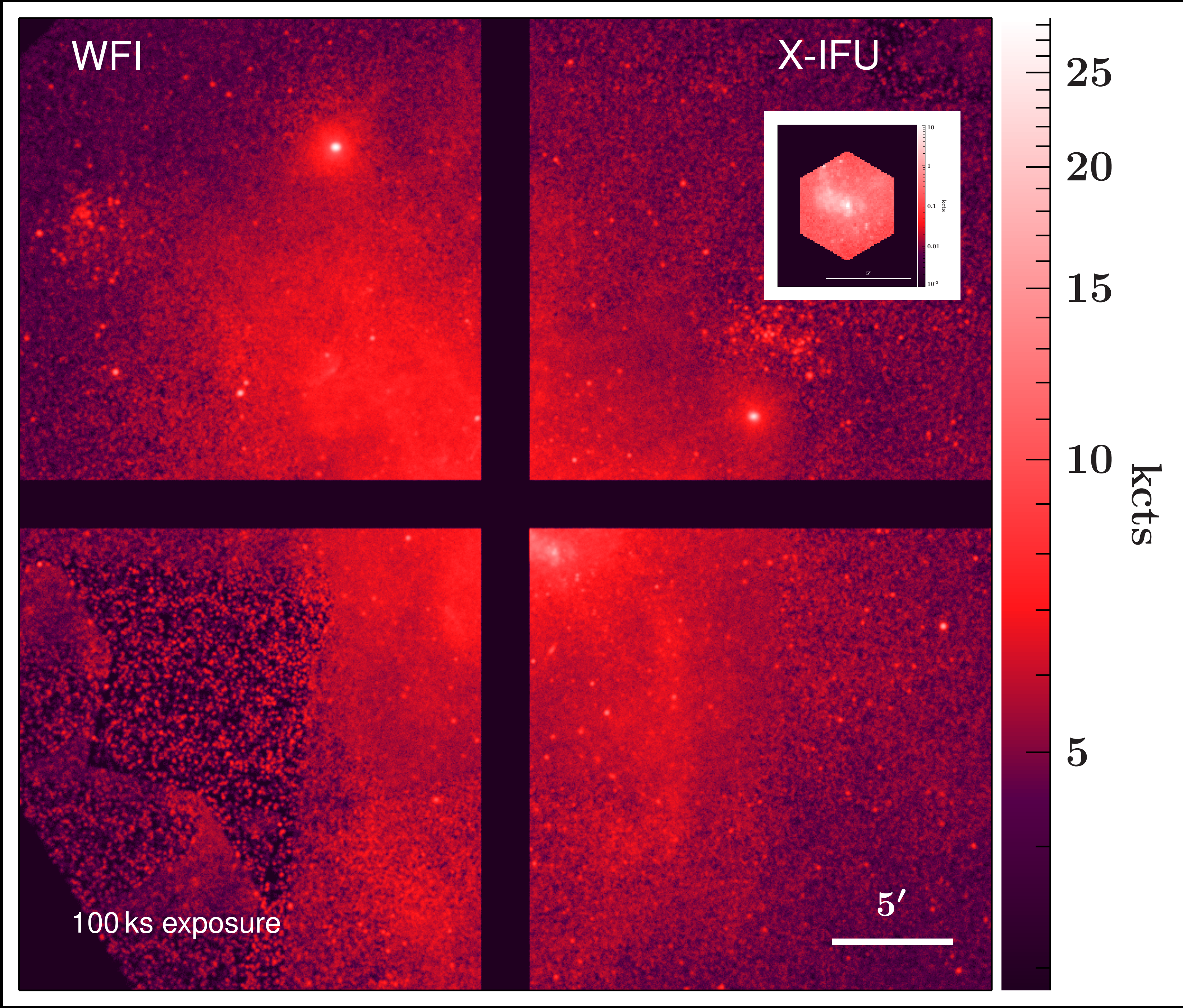
WFI (Imager):

- Si-based DEPFET
- large field of view
- moderate spectral resolution

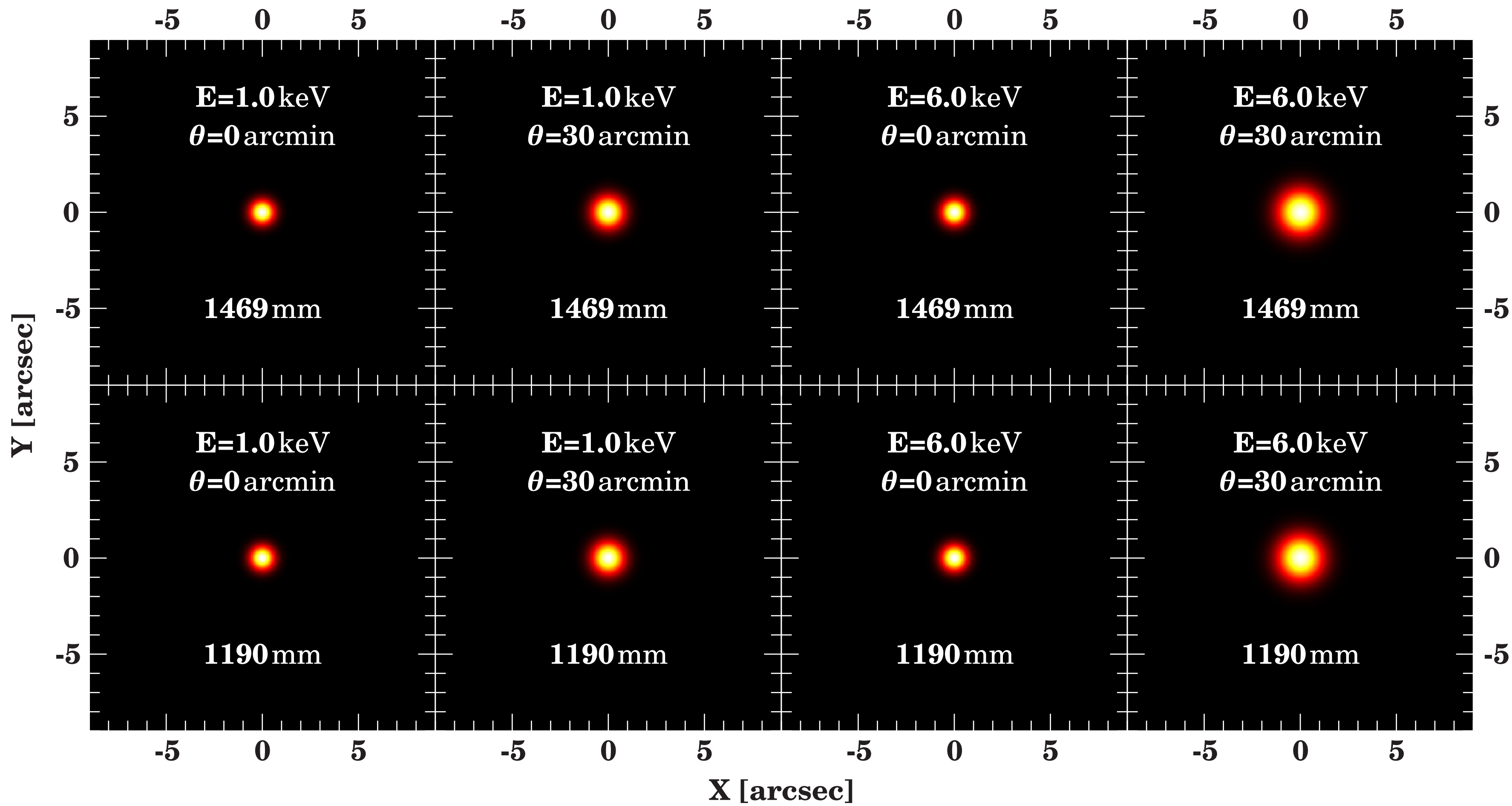
. . . behind silicon pore optics

X-IFU (Calorimeter):

- calorimeter (50 mK)
- smaller field of view
- high-spectral resolution imaging


WFI
X-IFU
100 ks exposure
5′
25
20
15
10
5
kcts

Optics – PSF

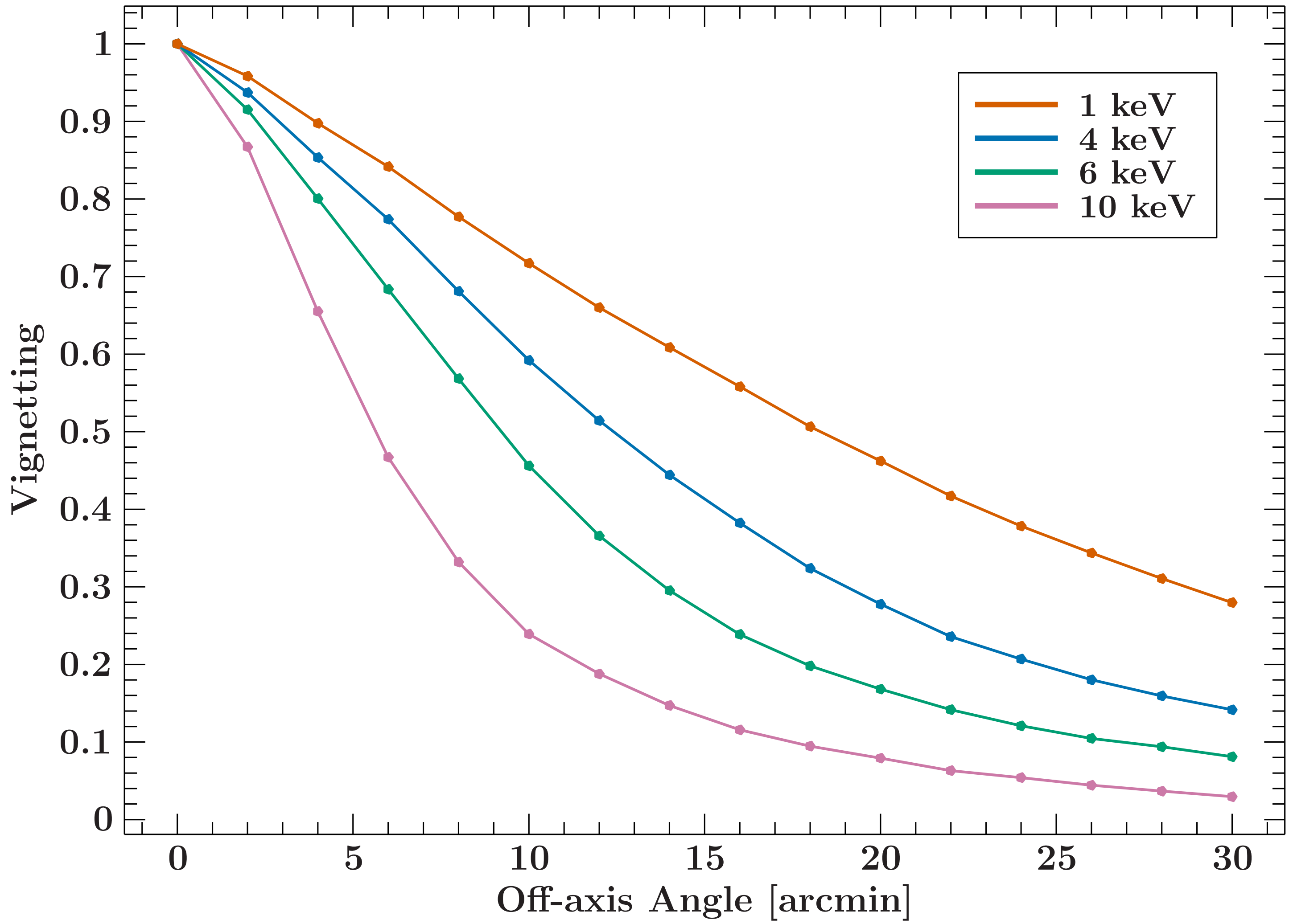


1469 mm is default

PSF: assume Gaussian shape (based on input from Dick Willingale)

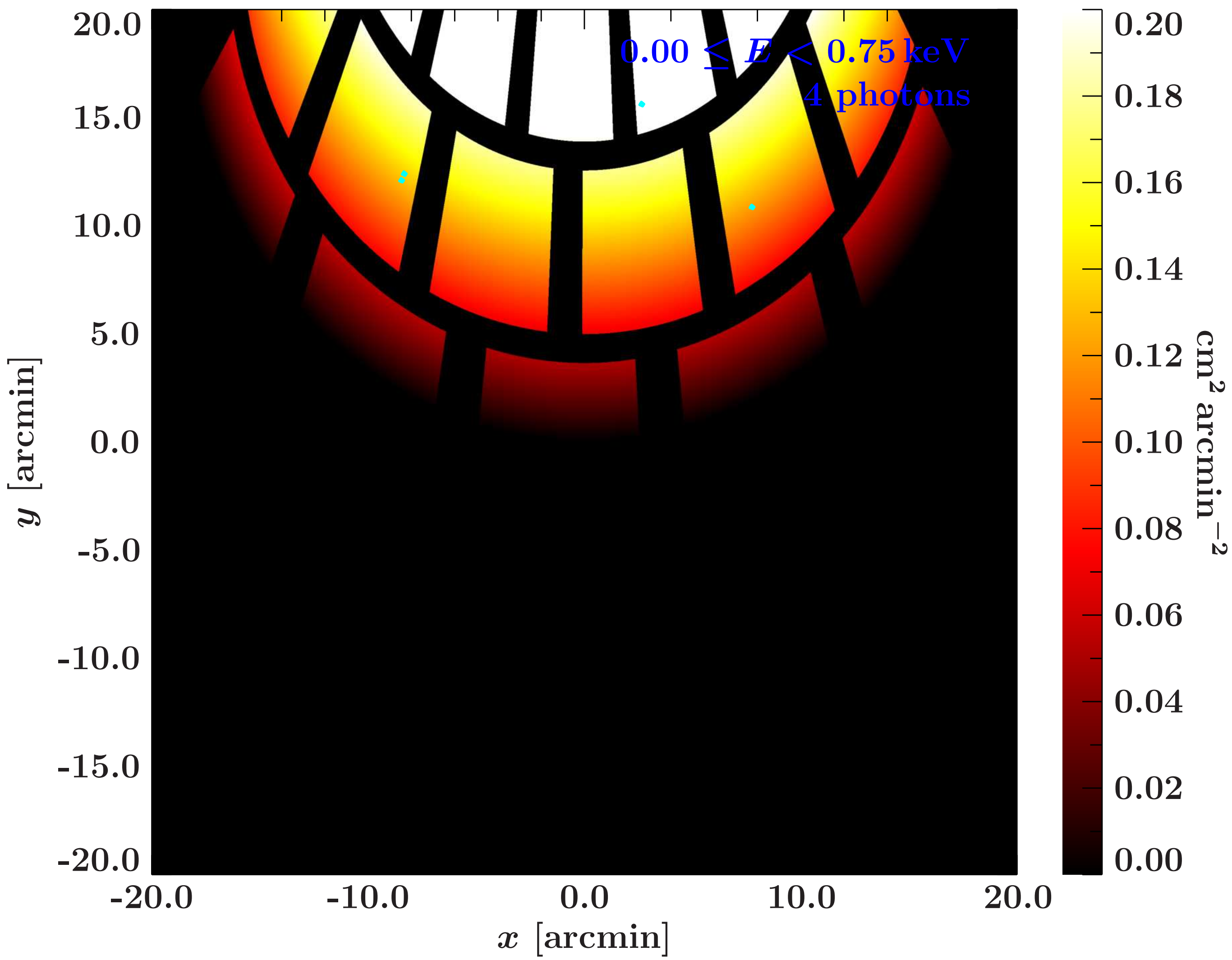
HEW: 4.9″ at 1 keV, 5.2″ at 6 keV; as optics design gets finalized, will be replaced by raytraced PSFs.

Optics – Vignetting



Vignetting function

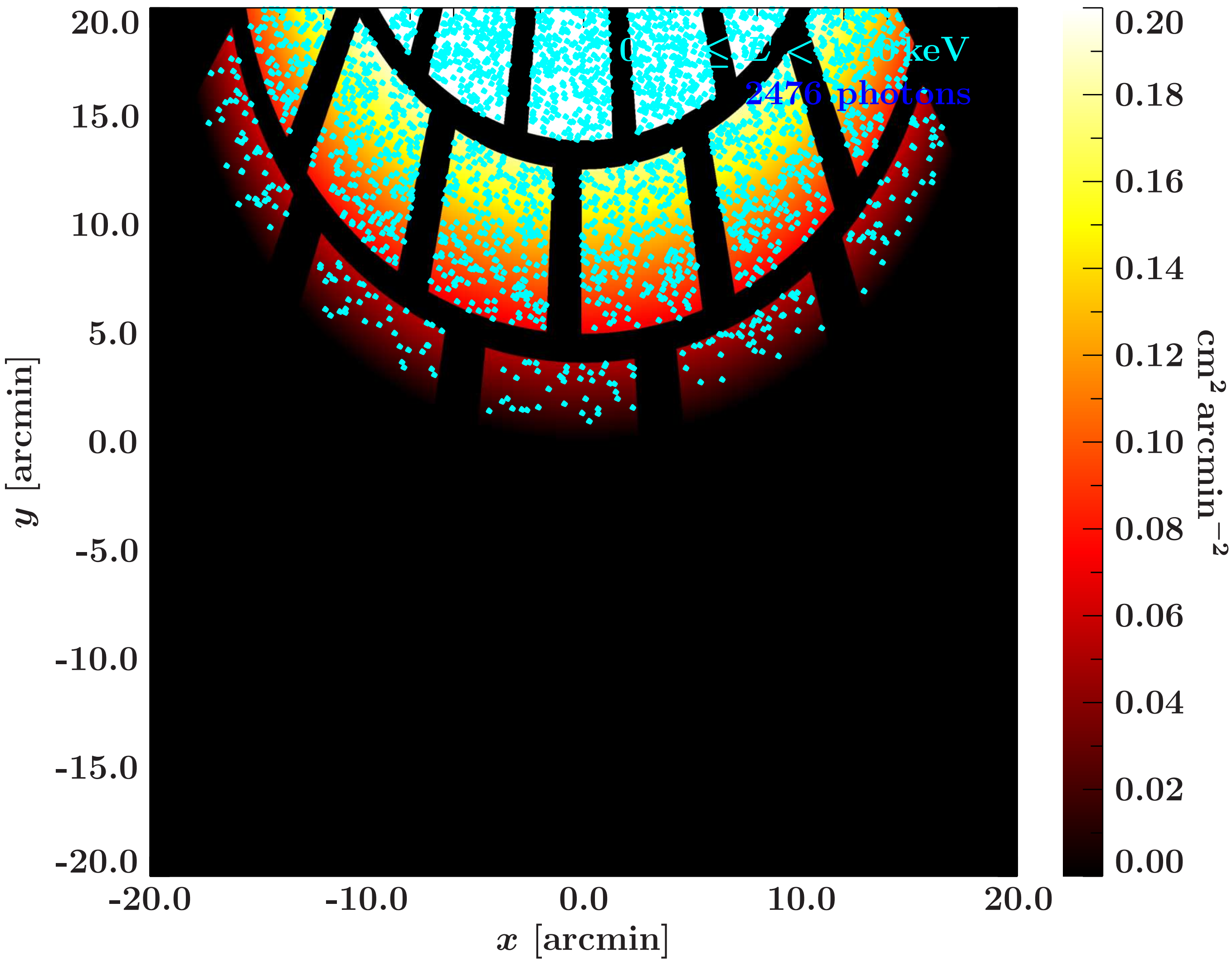
Optics – Straylight



PSF and photons from one source (*very* long exposure)

Now: Mirror 2.4, dated 2019 Jan 07 (Ir+SiC reflecting surface)

Optics – Straylight



PSF and photons from one source (*very* long exposure)

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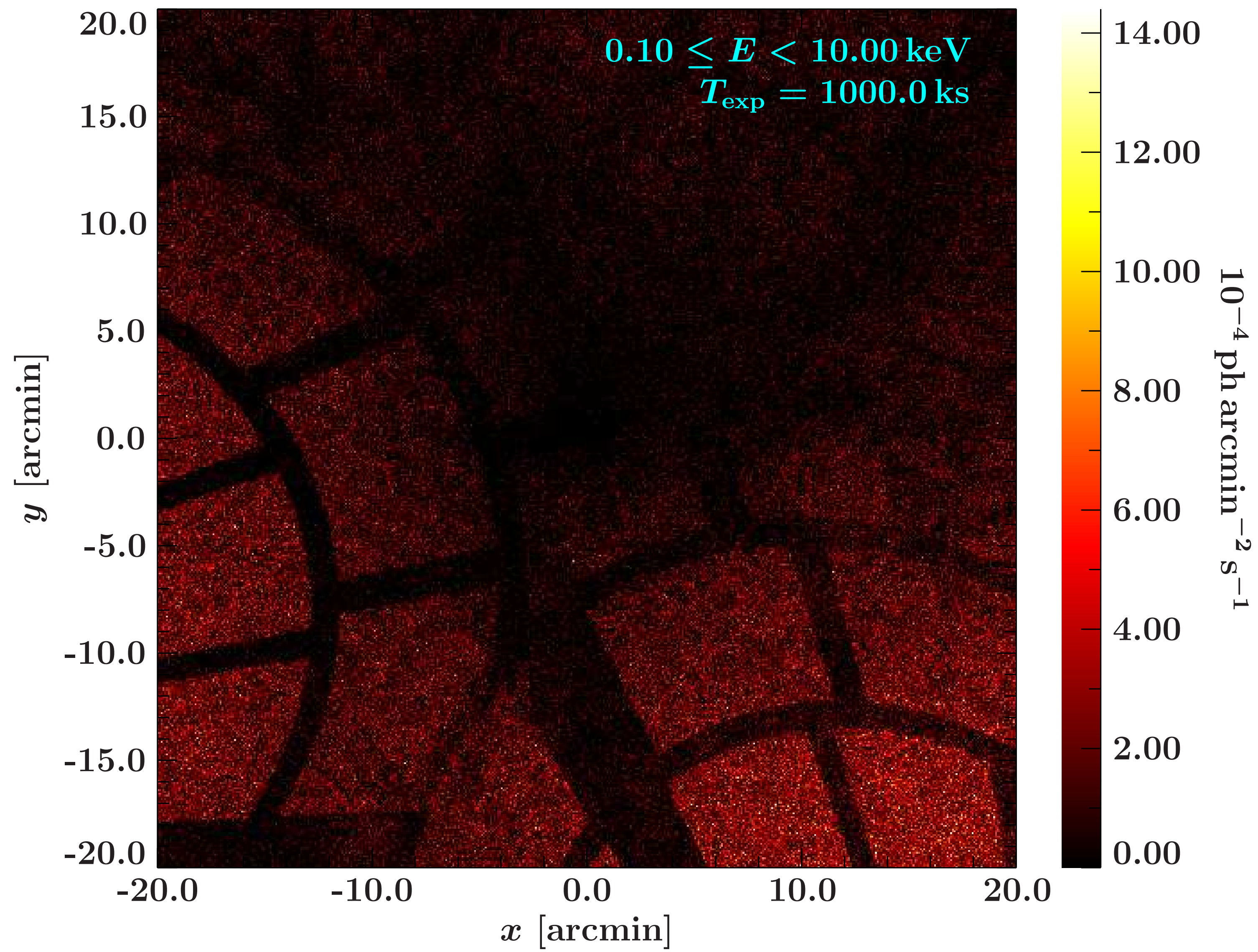
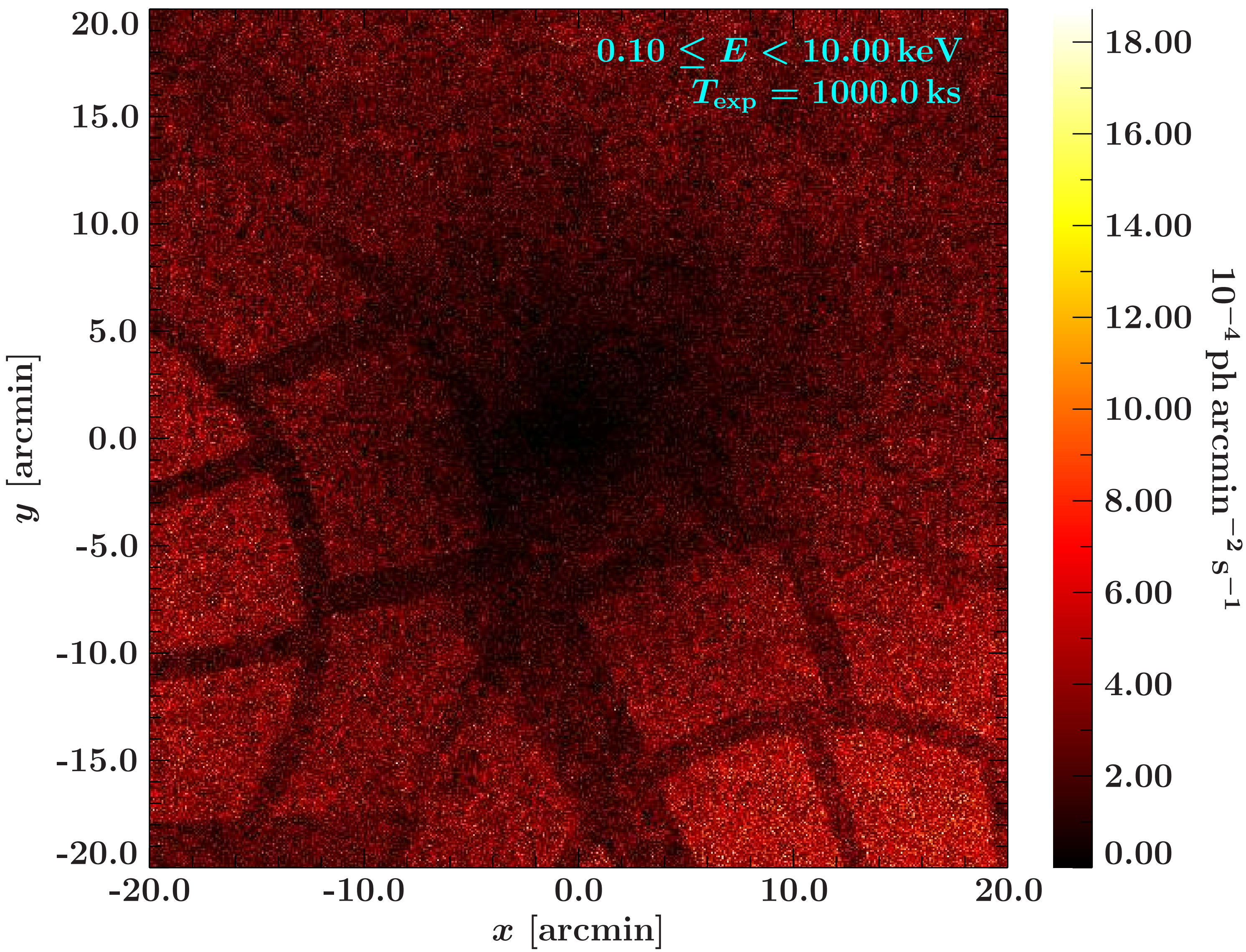
Optics – Straylight



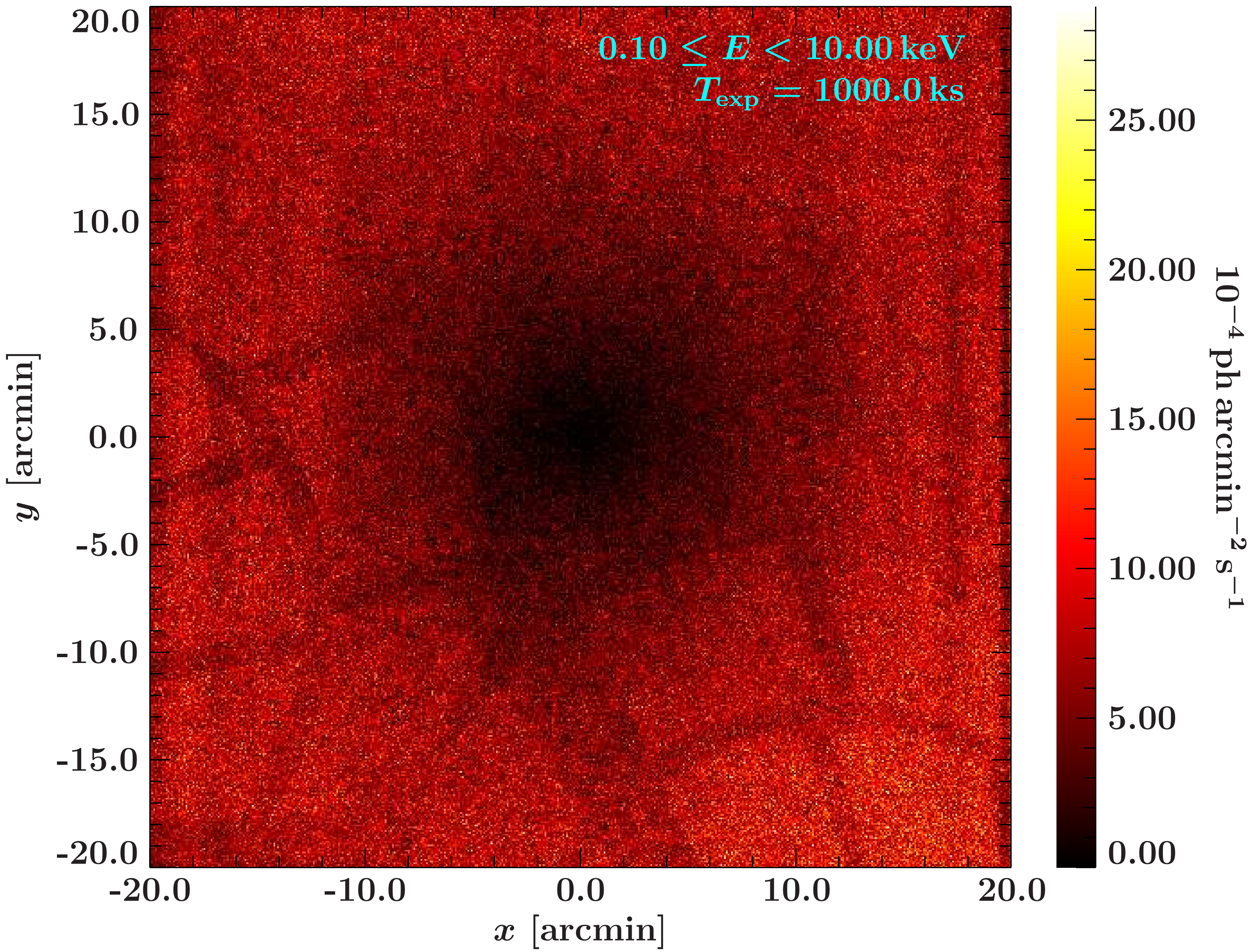
Straylight due to the 100 brightest sources ($T_{\text{exp}} = 10^6$ s)

Optics – Straylight



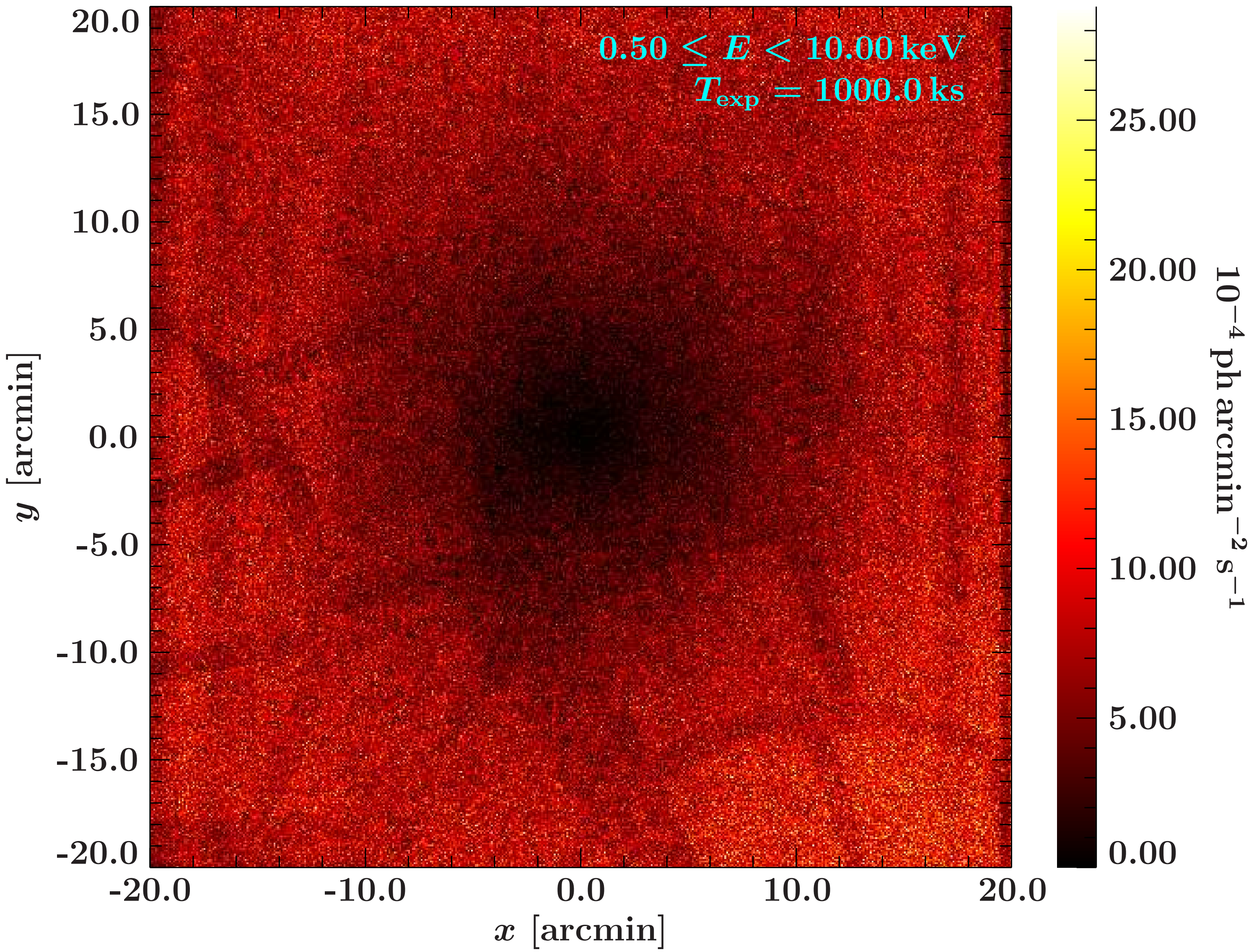
Straylight due to the 1000 brightest sources ($T_{\mathrm{exp}} = 10^6$ s)

Optics – Straylight



Straylight due to the 10000 brightest sources ($T_{exp} = 10^6$ s)

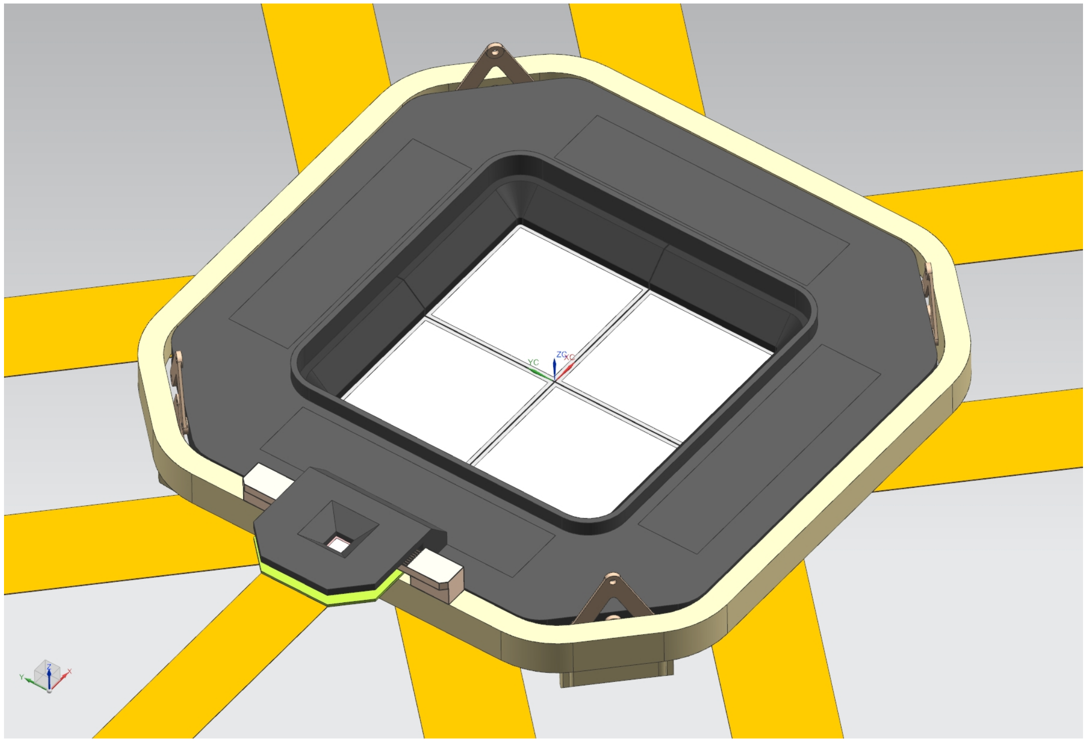
Optics – Straylight



Implementation in SIXTE: sample from image

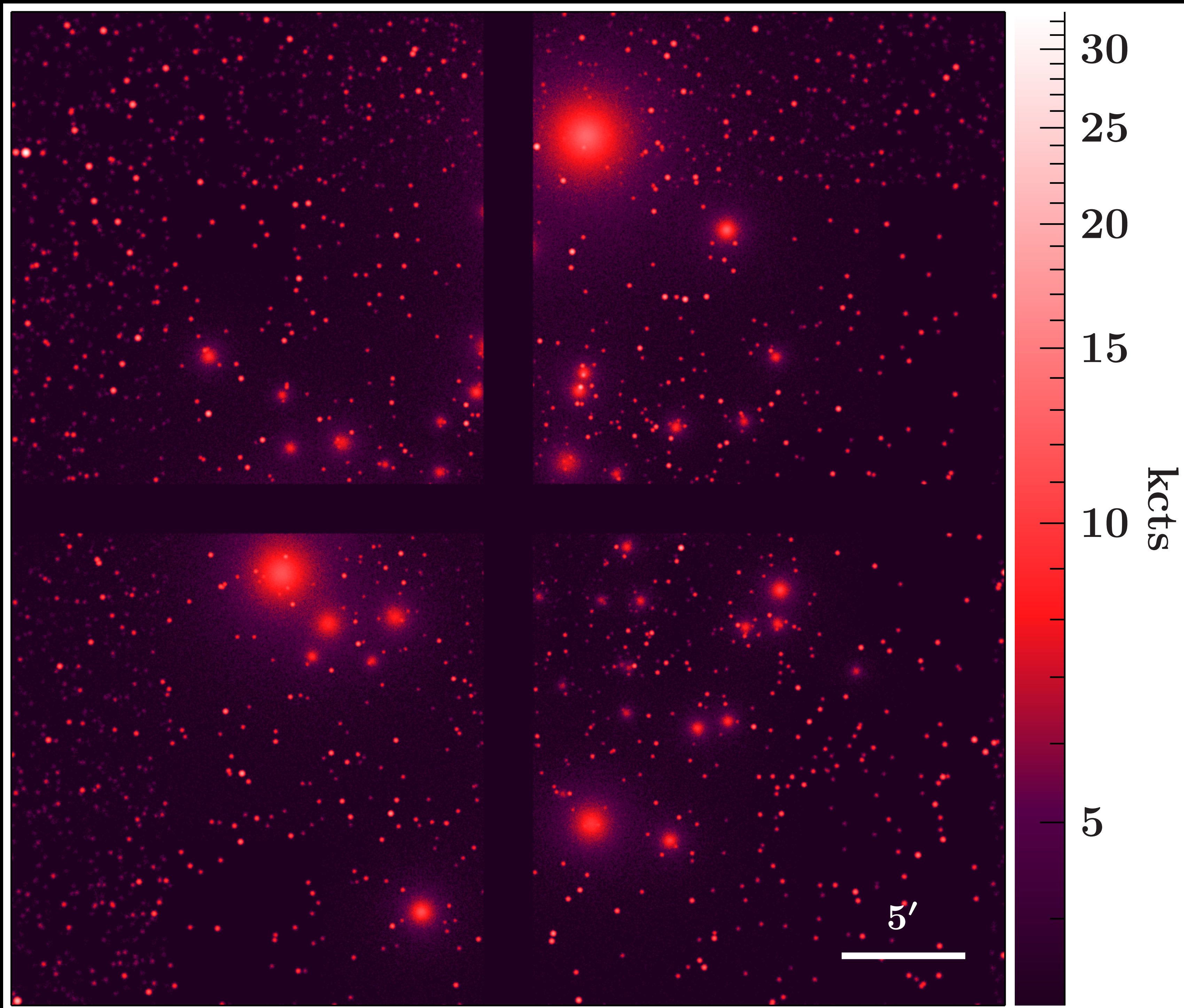
Available in next SIXTE release; due to dependency of surroundings, multiple realizations needed.

WFI

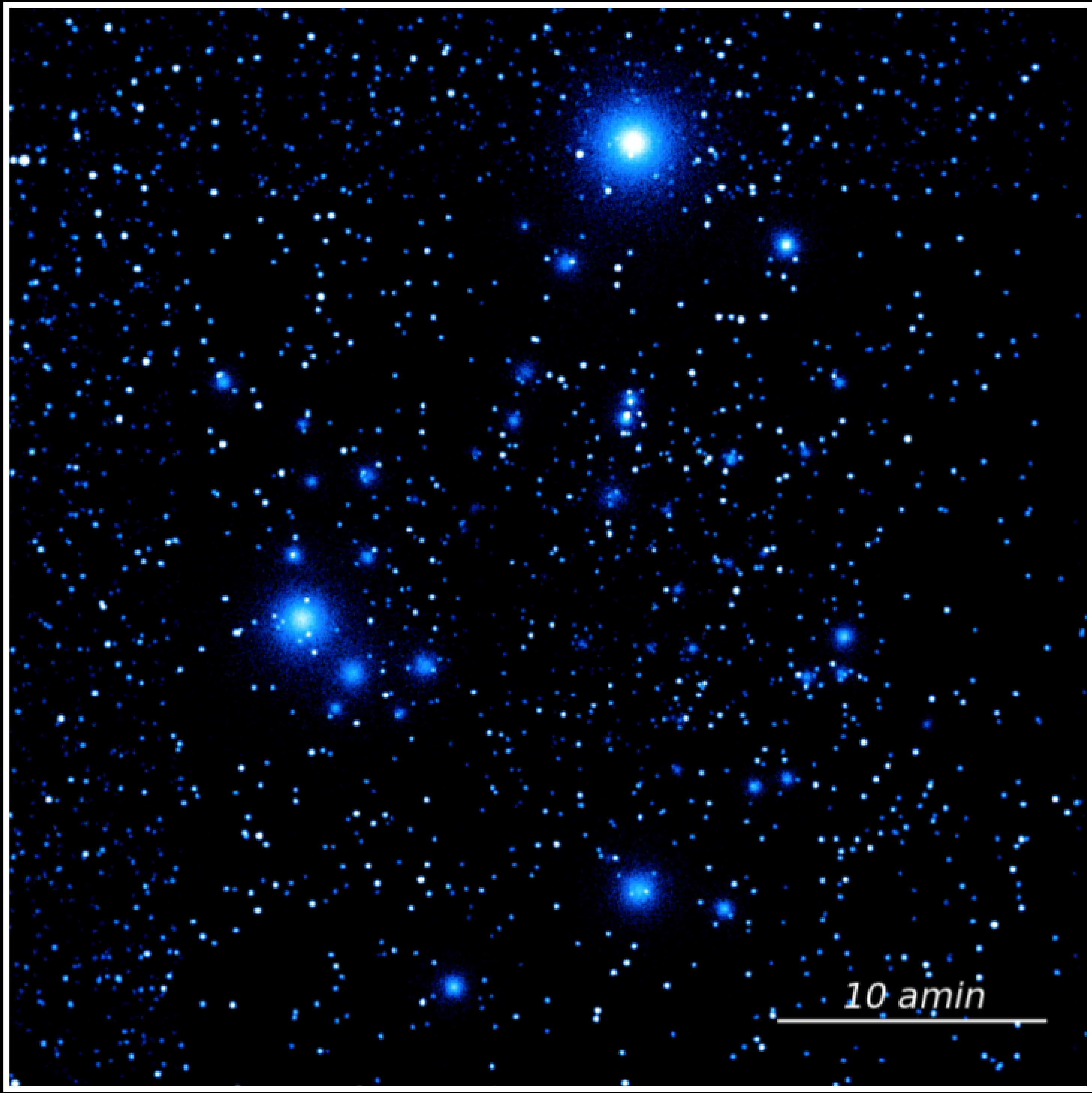


Wide Field Imager:

- Large Detector Array and Fast Detector (35 mm defocused)
- DePFET active pixel technology
- spectral resolution: $\leq$ 170 @ 7keV
- high count-rate capability (10 Crab)
- large FOV: $40' \times 40'$

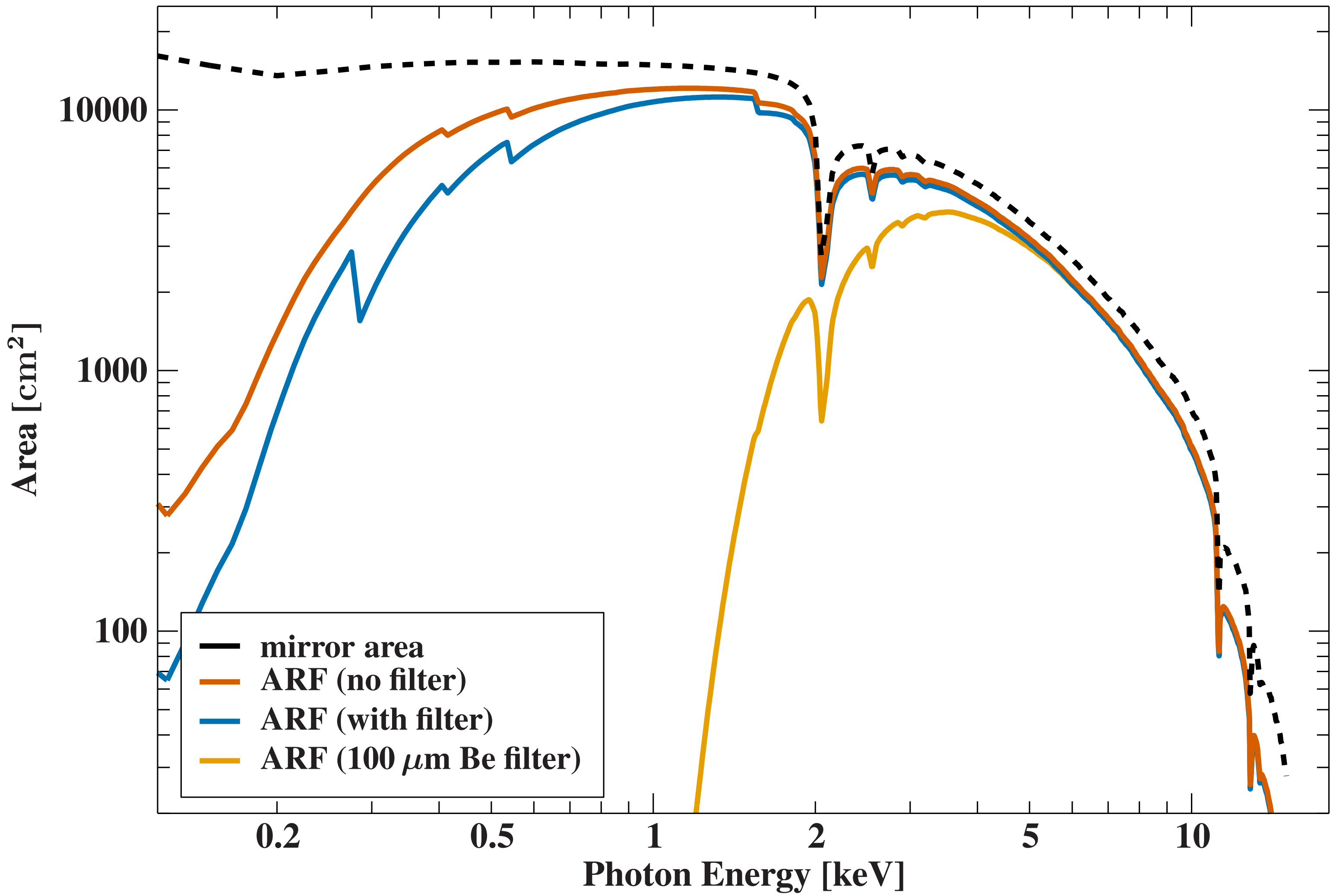


30
25
20
15
10
5
kcts
5′



Dithering efficiently removes the chip gaps

WFI – Effective Area

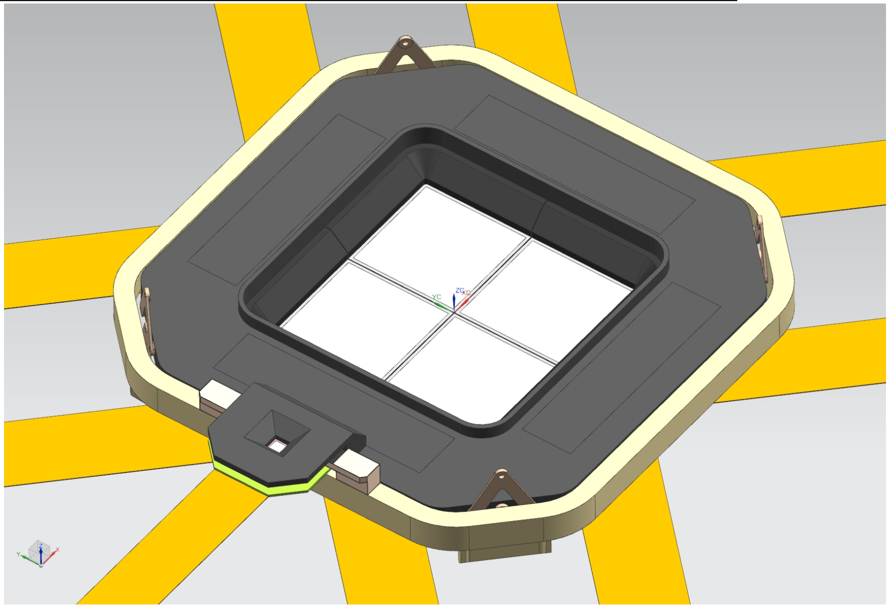


preliminary numbers – will be updated

Be-filter: removes photons below 2 keV

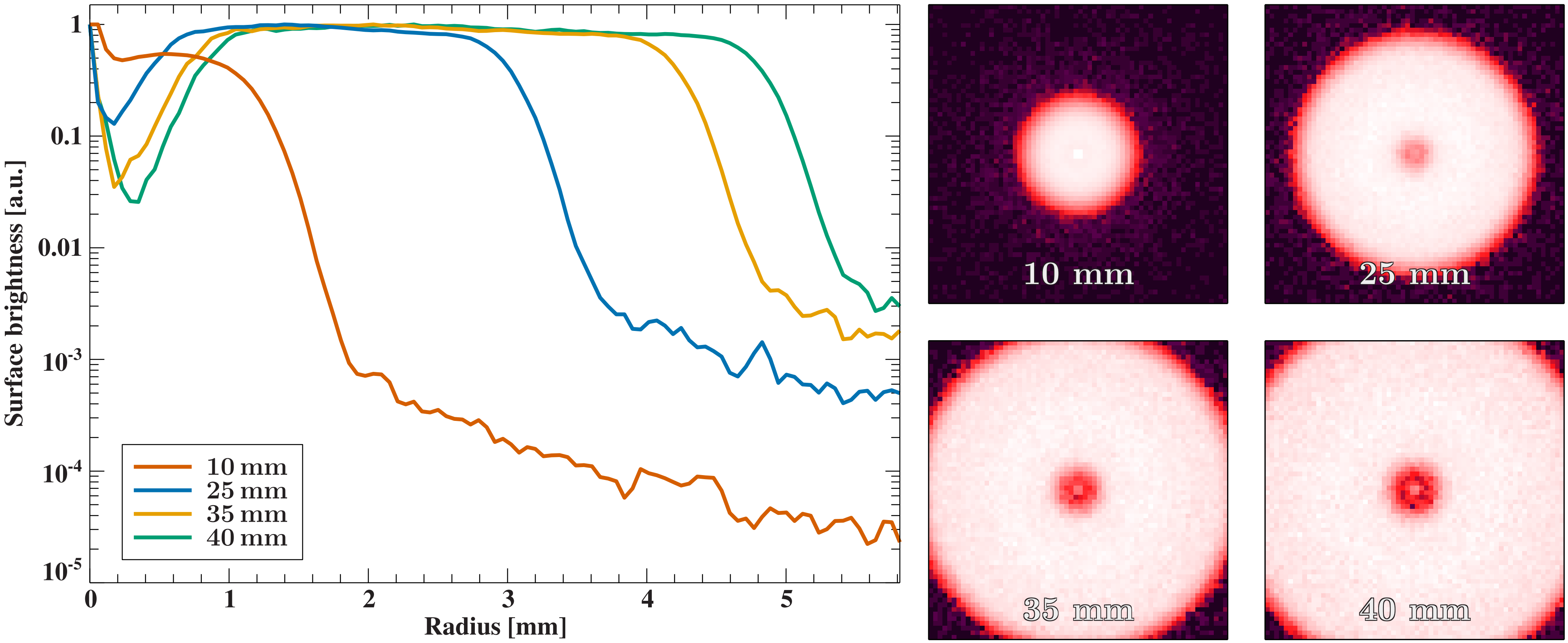
WFI – readout modi

Name	**Size** (rows × columns)	**time resolution**	**defocusing**
large	512 × 512	5018 μs	—
w64	64 × 512	627 μs	—
w32	32 × 512	314 μs	—
w16	16 × 512	157 μs	—
fast	64 × 64	80 μs	35 mm
fastBe	64 × 64	80 μs	35 mm



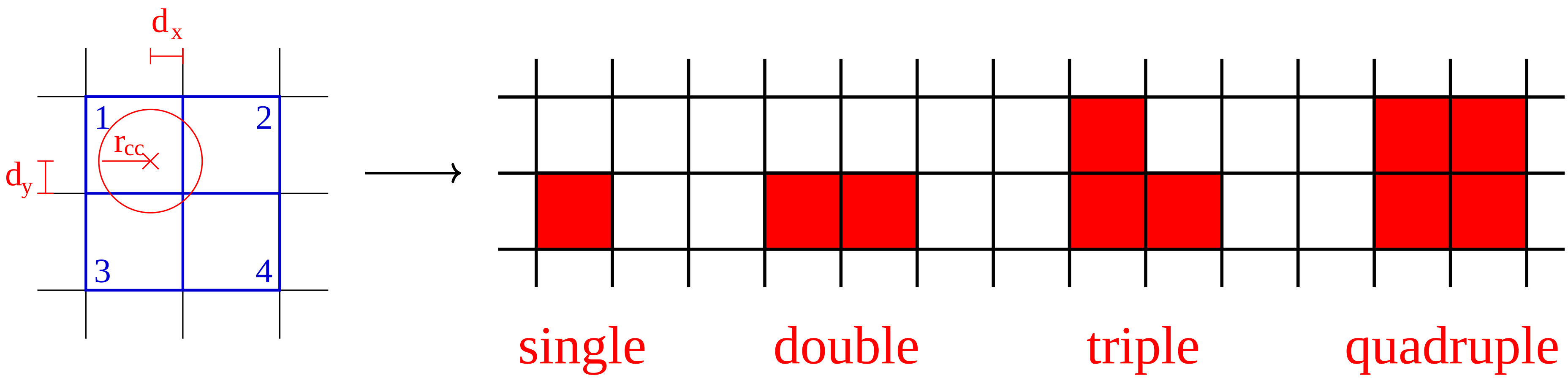
- Large Detector Array and Fast Detector
- Fast Detector defocused by default
- Option for a thick Be filter

WFI – Defocusing



⇒ defocusing distributes photons over larger area (**35 mm is optimal**)

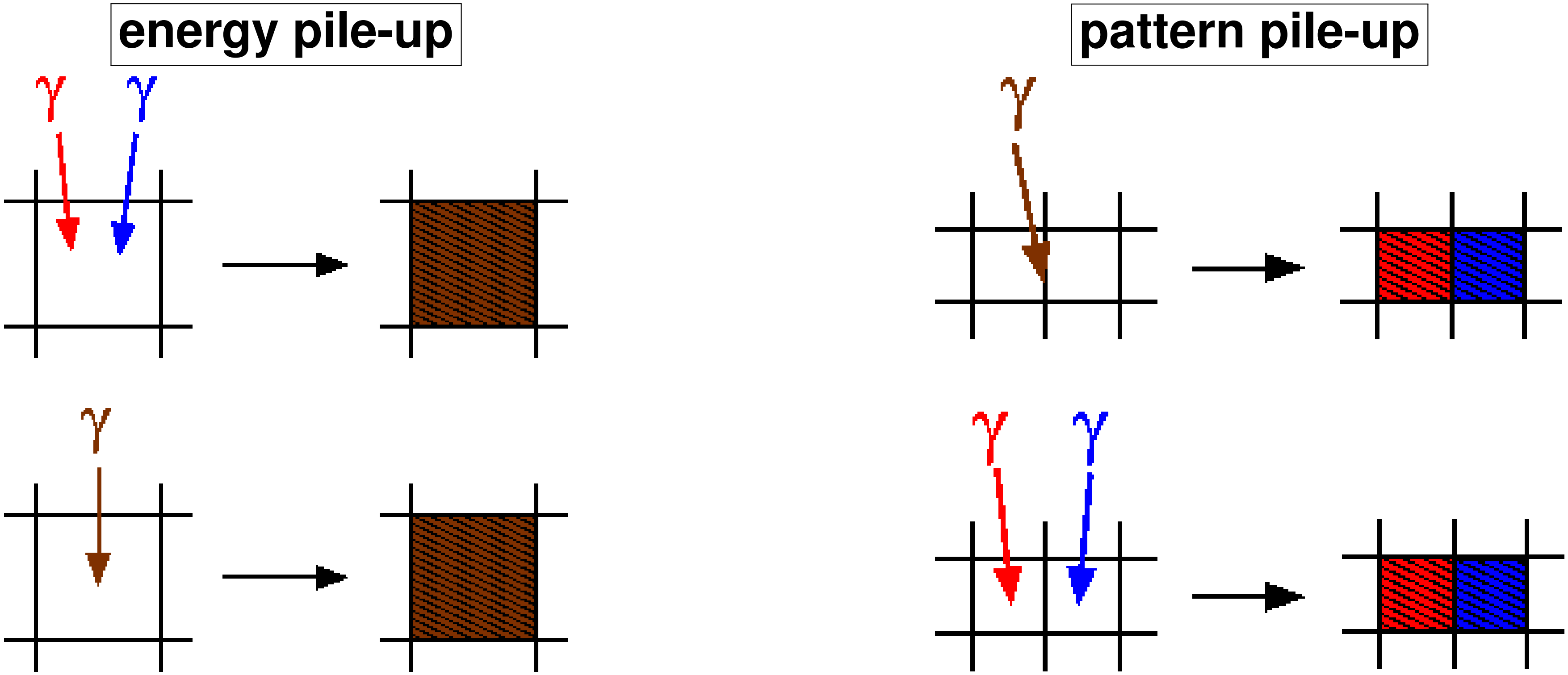
WFI – Event Detection



patterns are recombined in pattern analysis for each DEPFET frame

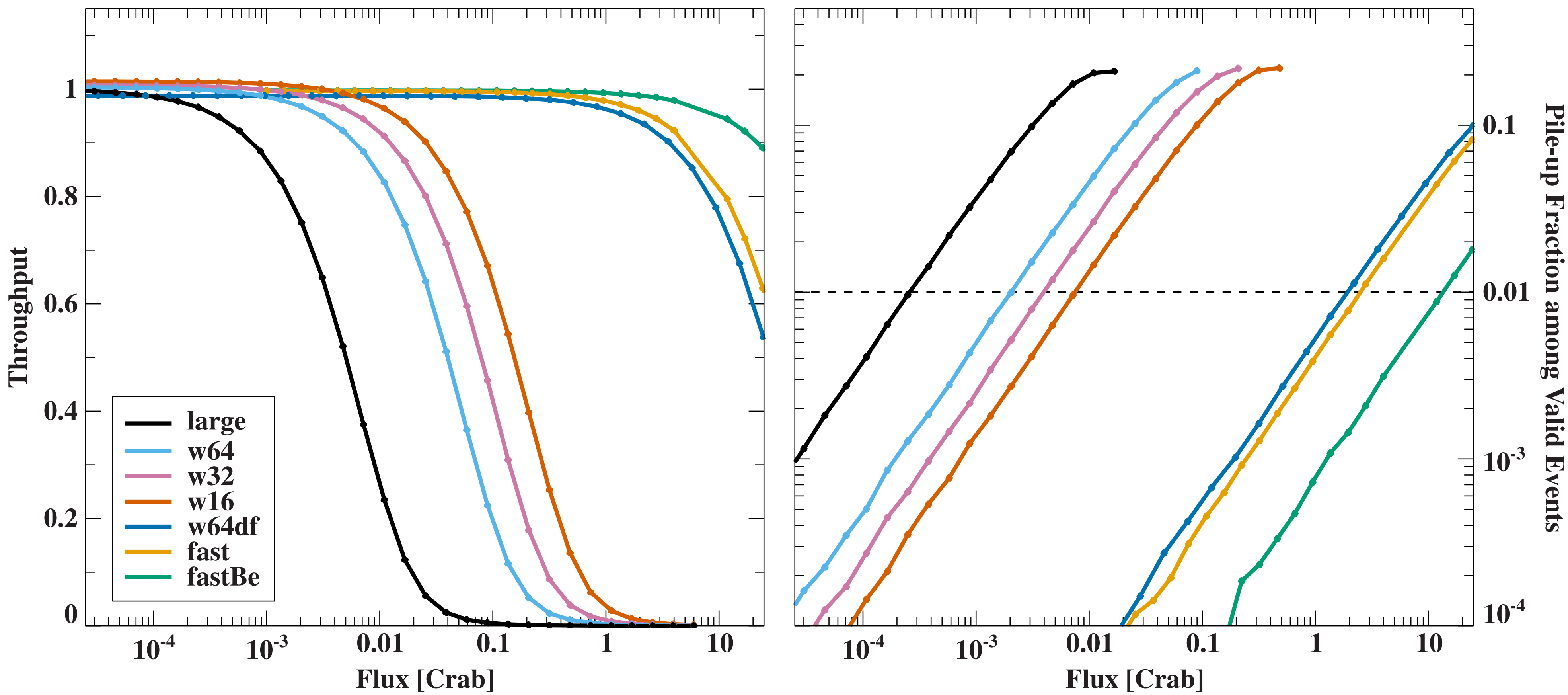
$\Rightarrow$ invalid patterns are rejected

WFI – Pile up



pile-up events distort spectral shape

WFI – Pile up

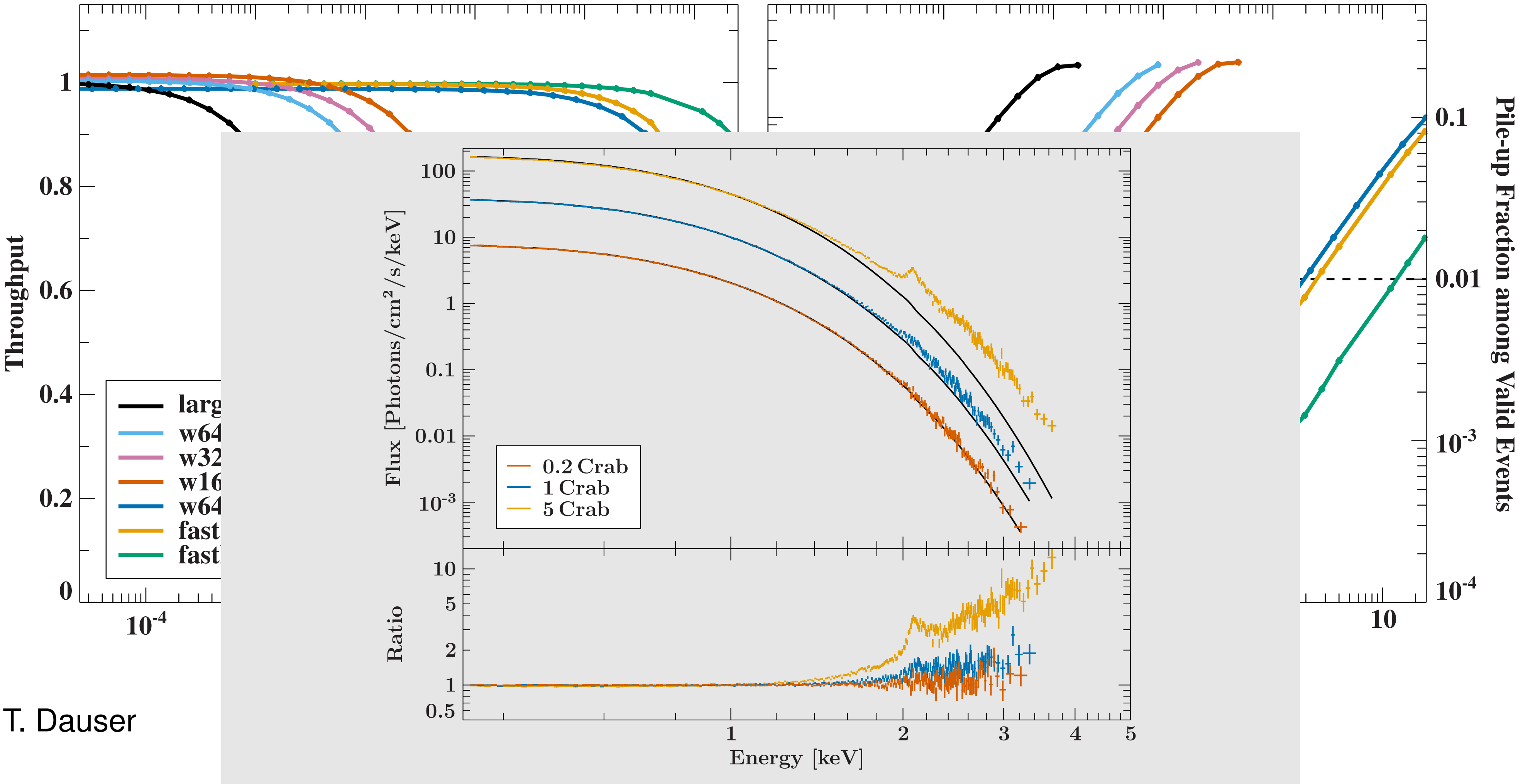


T. Dauser

pile up effects for bright sources in the WFI

Crab-like spectrum; simulation models readout effect for bright sources, as is important, e.g., for bright black hole transient outbursts. Up to 10 Crab possible with Be filter

WFI – Pile up



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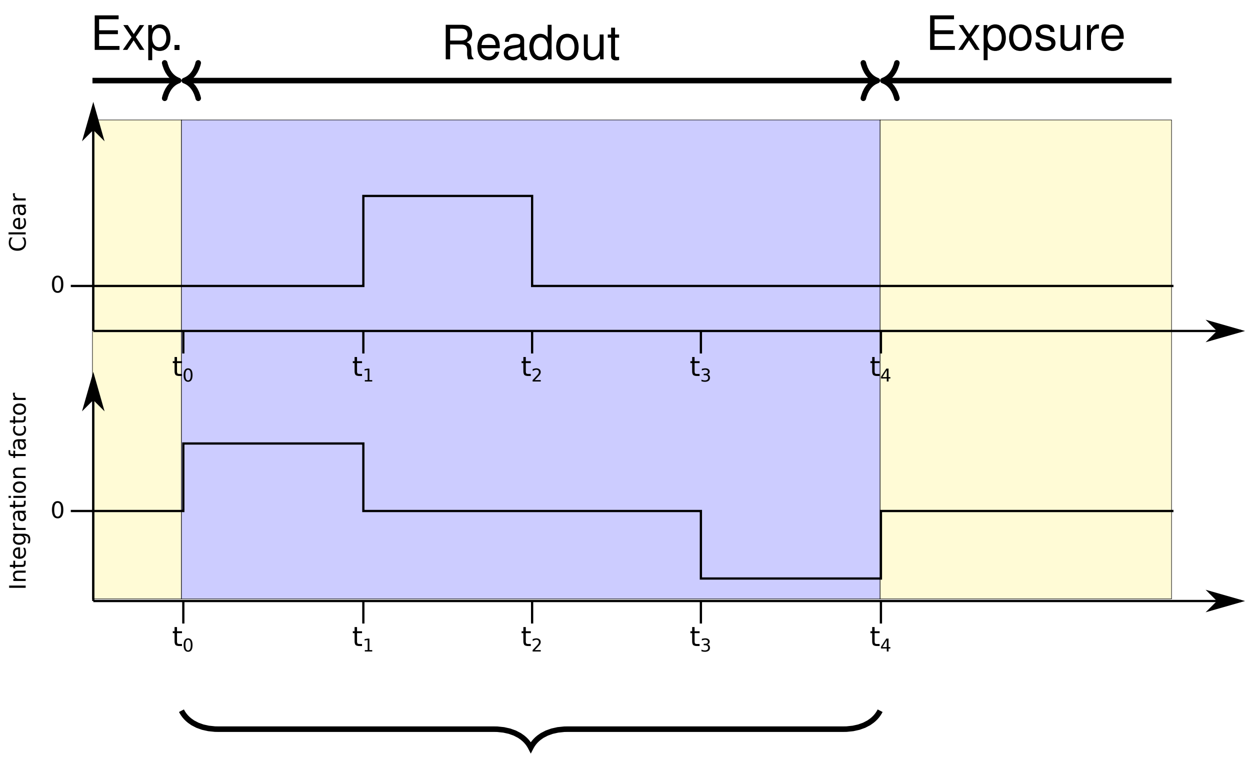
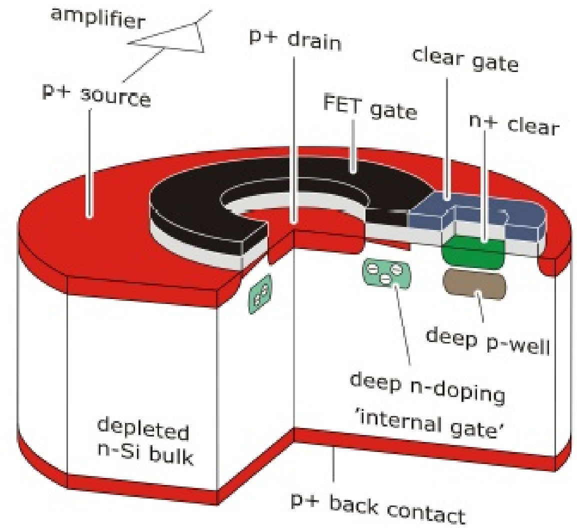
WFI – DEPFET read out implementation





Misfits

If photon arrives during read out: measured charge is affected

⇒ Energy E wrong ("Misfit")

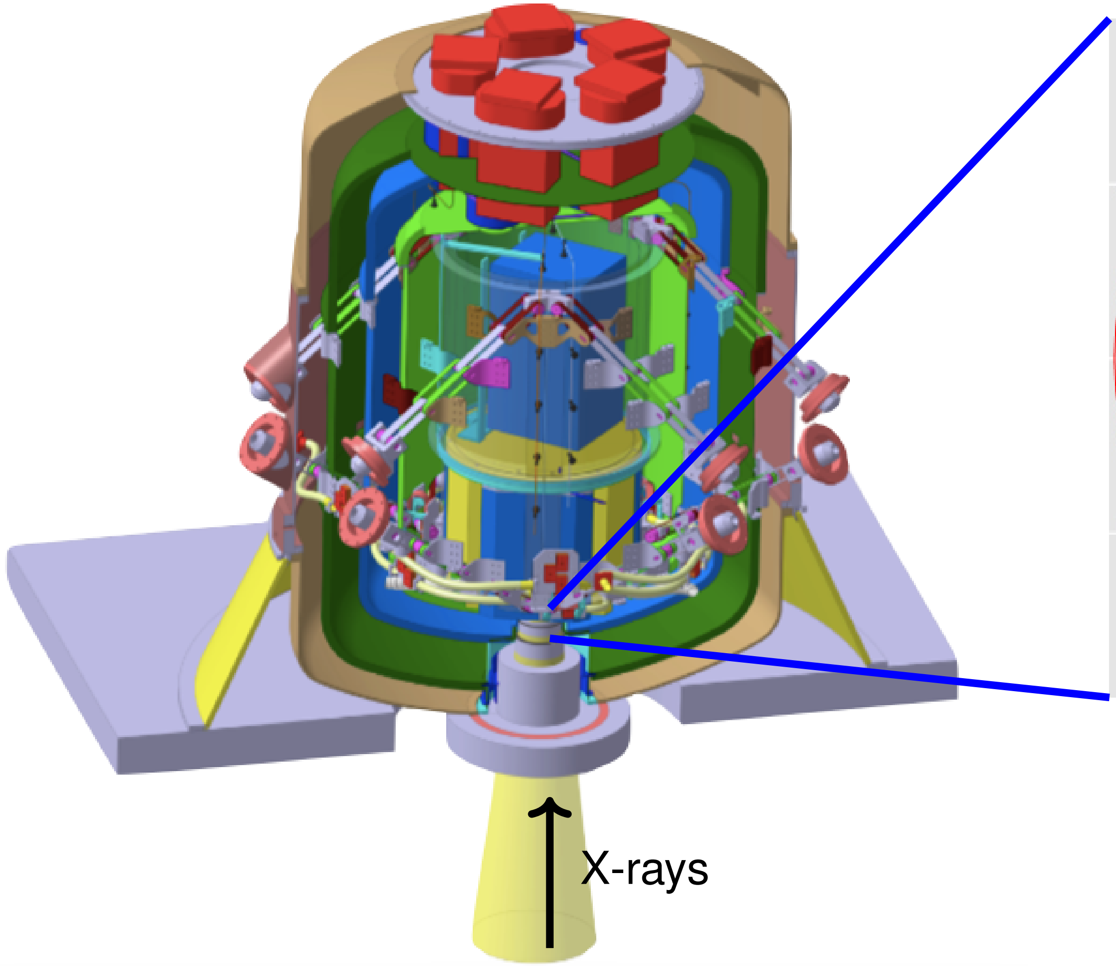
this is most relevant for window modes or the fast detector

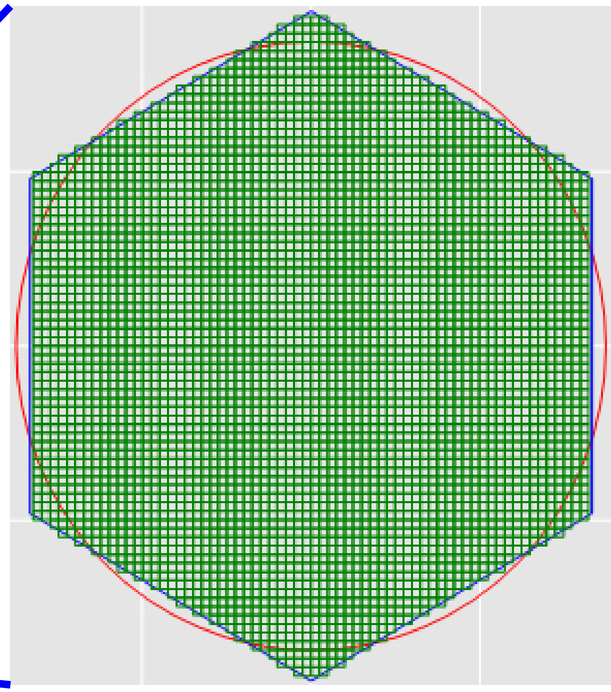
WFI – Summary

- DePFET technology: active pixels, no line shifts $\rightarrow$ misfits if pixel is hit during readout
- observations possible up to a few Crab, plus a thick filter for even brighter sources
- large 40' FoV, 4 chips $\rightarrow$ requires dithering
- SIXTE simulations:
  - `athenawfisim`: full 4 chip LDA
  - `runsixt`: single chip (LD, or the 35 mm defocused FD)
- Background:
  - particle background: right now assume nominal, flat background (0.5 cps per PHA channel)
    Option exists to sample CR tracks from GEANT simulation and to include track recognition
  - X-ray background: sample w/SIMPUT files containing a large number of AGN w/proper $\log N$-$\log S$ (available on SIXTE homepage)

X-IFU

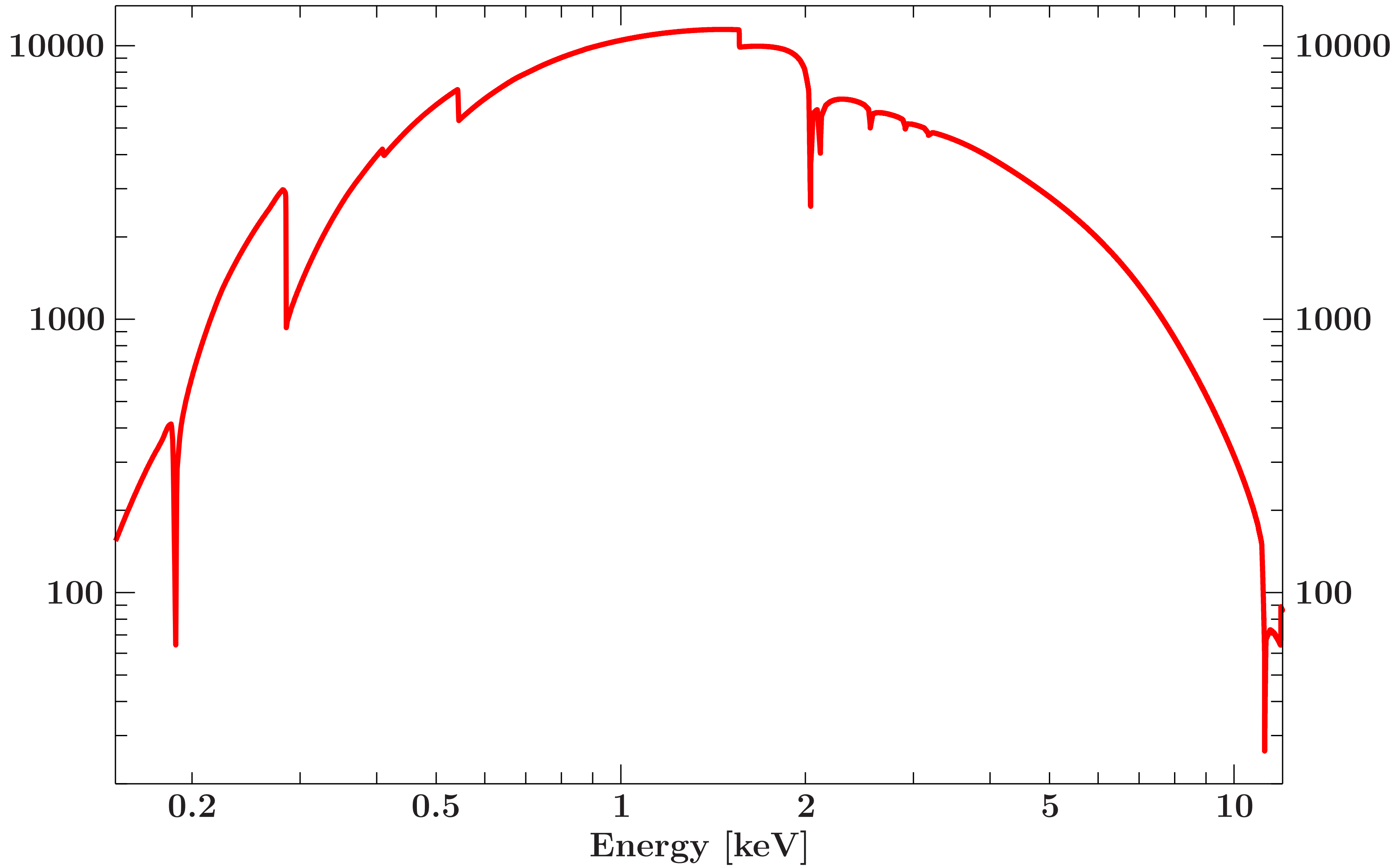
The X-ray Integral Field Unit (X-IFU):





- 3148 TES (Transition Edge Sensor) pixels
- very high spectral resolution imaging (2.5 eV FWHM and a $5'$ FoV)

X-IFU – Effective Area

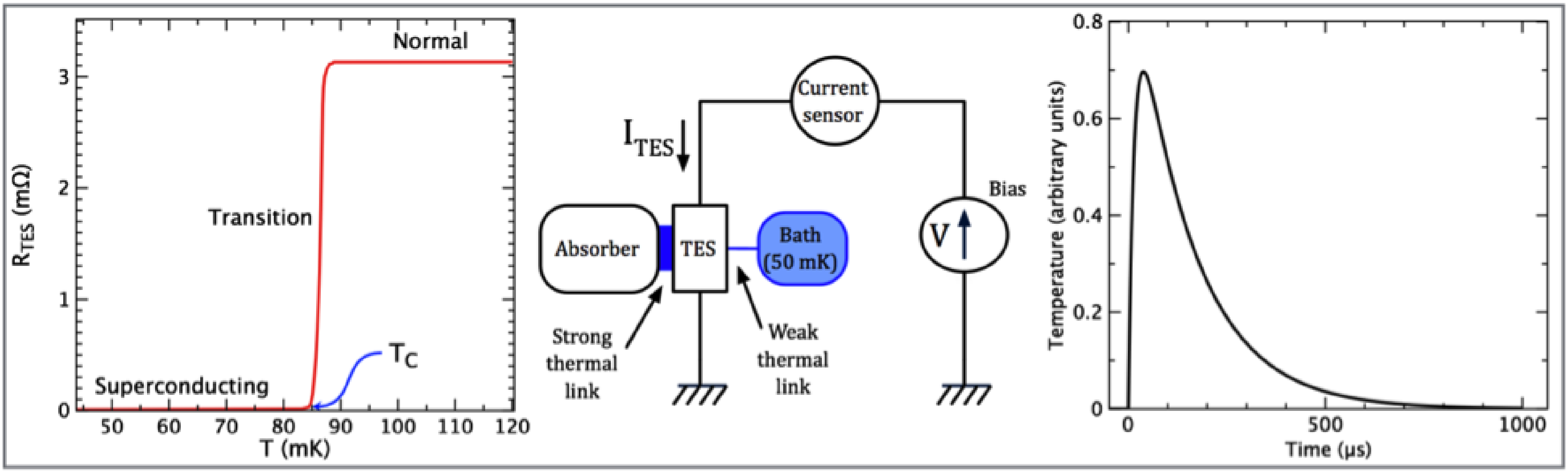


Effective area

a Be-filter is also discussed

X-IFU – Principle

X-IFU-pixels are single *Transition Edge Sensors*, operated at 50 mK
⇒ **measure temperature increase** of photon hitting the pixel



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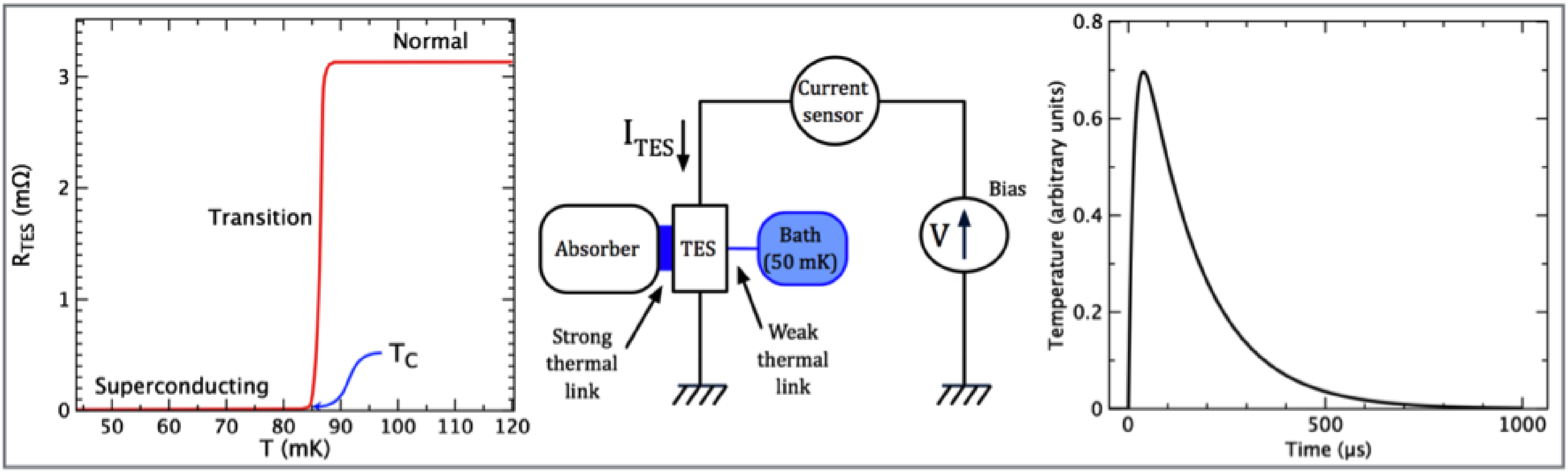


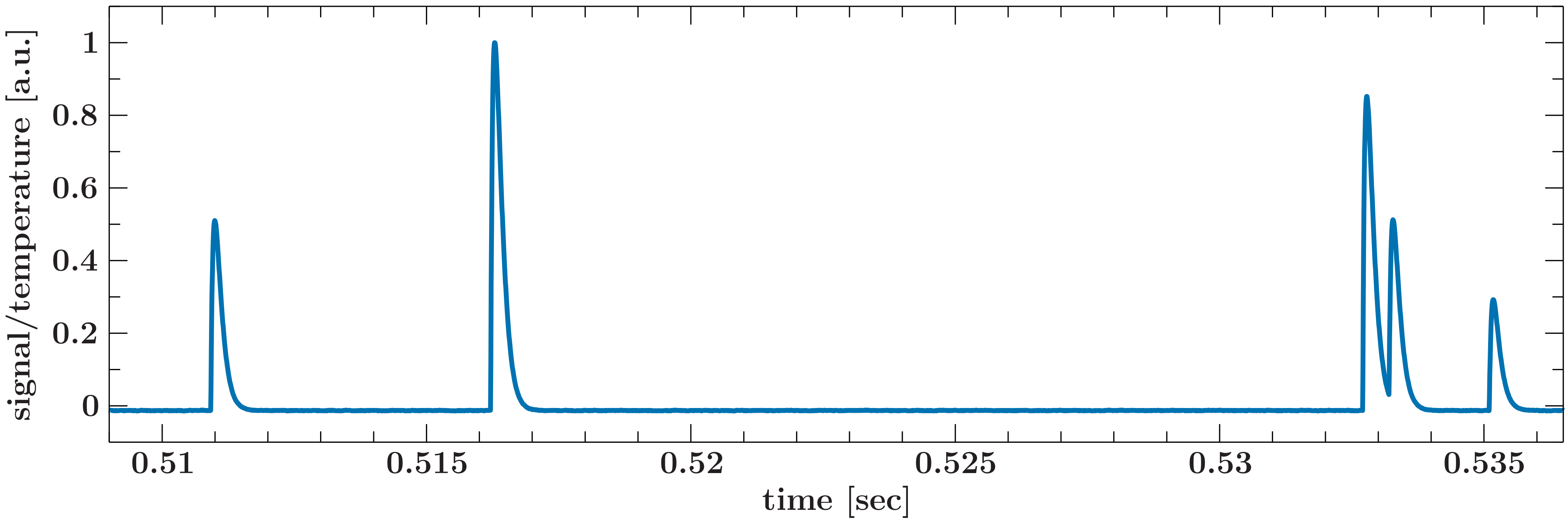
- basis of SIXTE model: numerical solution of differential equations for $T(t)$, $I(t)$ (Irwin & Hilton, 2005),

$$C\frac{dT}{dt} = -P_\mathrm{b} + P_\mathrm{J} + P + \mathrm{Noise} \qquad \text{and} \qquad L\frac{dI}{dt} = V - IR_\mathrm{L} - IR(T, I) + \mathrm{Noise}$$

- linear resistance, $R(T, I; \alpha, \beta)$; noise: Johnson of circuit, bath, excess noise
- input parameters: C, G_b, n, α, β, m, R_0, T_0, T_b, L_crit (or a full model for the transition edge)

X-IFU – Principle

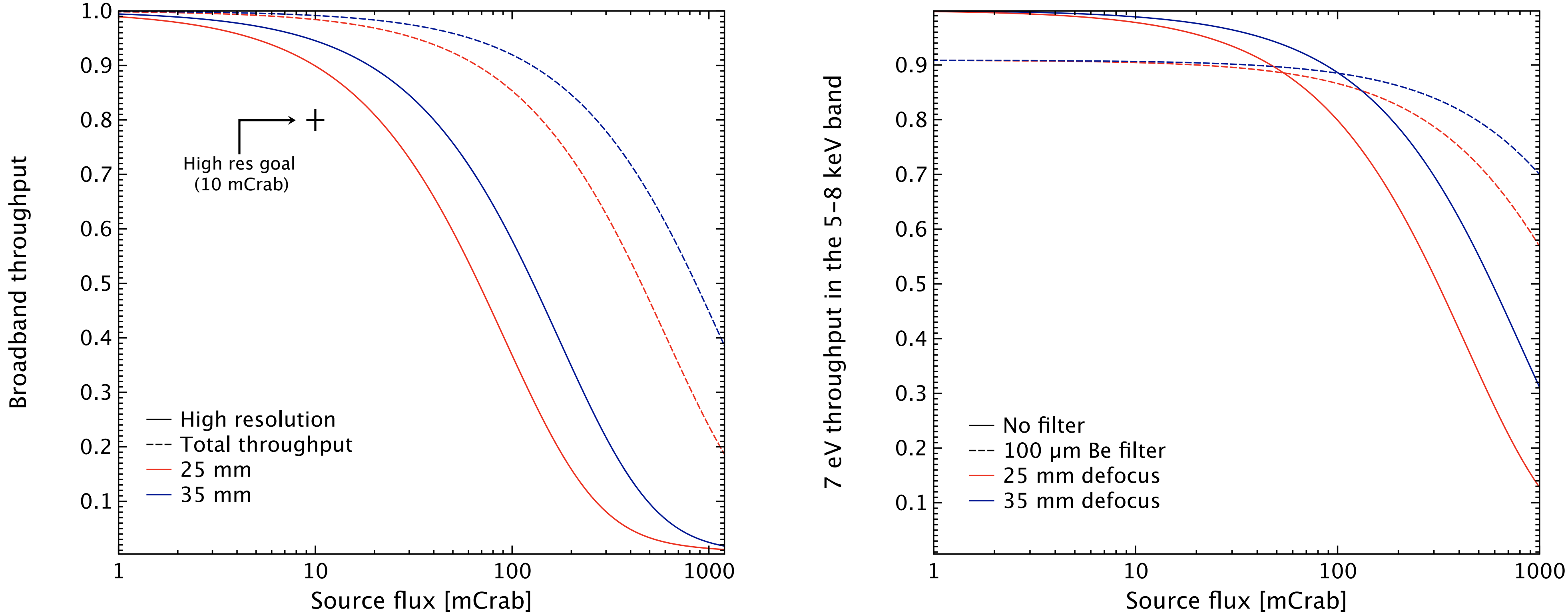
X-IFU-pixels are single *Transition Edge Sensors*, operated at 50 mK
⇒ **measure temperature increase** of photon hitting the pixel



- pulse area ∼ photon energy
- pulses with smaller separation yield lower energy resolution
  ⇒ **Event Grading** depending on the source flux

X-IFU – event grading

defocusing of the Athena optics allows observations up to 1 Crab



Grade	Δt since previous pulse	Δt until next pulse	Energy res.
(1) High res.	$\geqslant$ 7.9 ms	$\geqslant$ 45.3 ms	2.5 eV
(2) Medium res.	$\geqslant$ 7.9 ms	$\geqslant$ 2.3 ms	3 eV
(3) Limited res.	$\geqslant$ 7.9 ms	$\geqslant$ 1.0 ms	7 eV
(4) Low res.	$\geqslant$ 7.9 ms	–	$\sim$ 30 eV

X-IFU – Crosstalk

Crosstalk: unintended transmission of information between signal channels

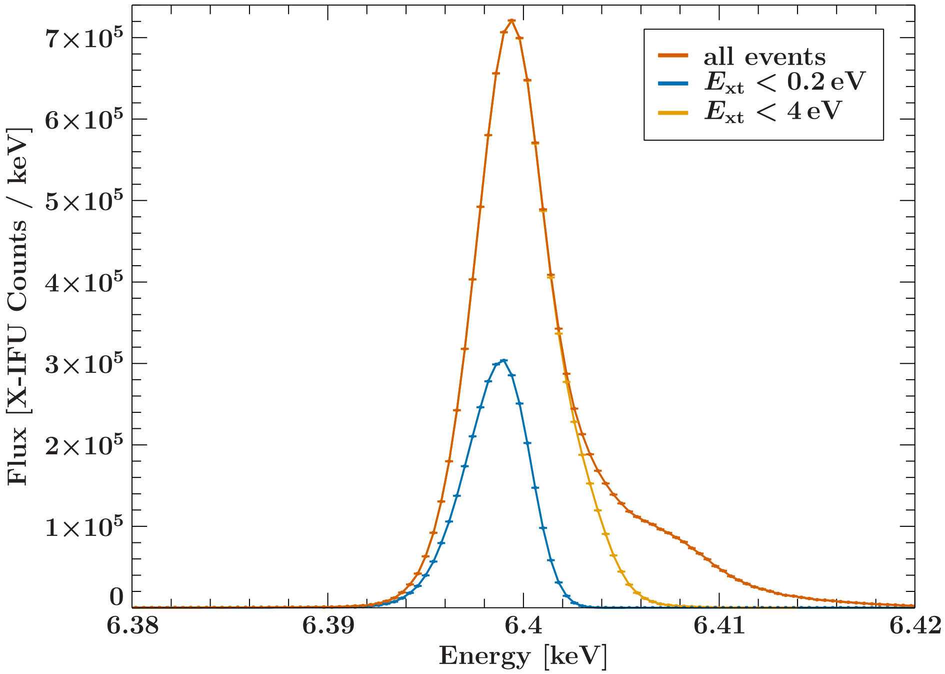
Different types of crosstalk:

- thermal coupling of two pixels (physical neighbors)
- electrical coupling due to SQUID switching, settling
- non-linear amplification of the read-out SQUID

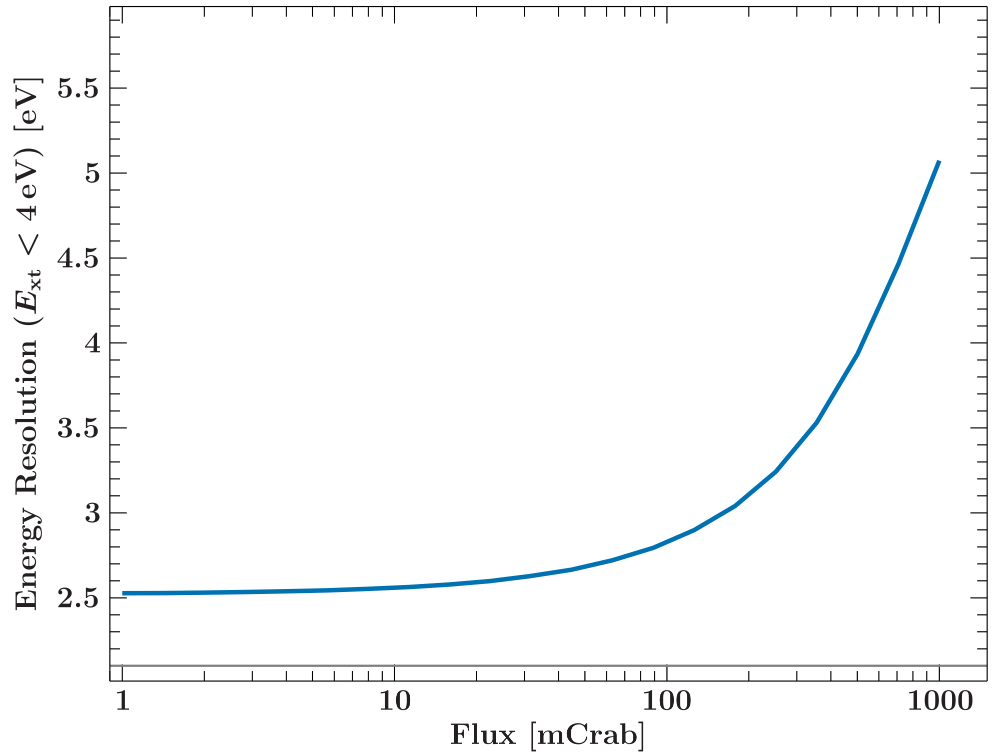
→ implemented in SIXTE

crosstalk effect on events is predictable

X-IFU – Crosstalk



simulation of a unphysically bright (1 Crab) narrow emission line



⇒ remove events which are *strongly* effected by crosstalk

> trade-off between energy resolution and throughput ⇒ 10 eV resolution with 50% throughput @ 1 Crab

X-IFU: SIXTE implementation

`xifupipeline`:

- full detector array
- full imaging implemented
- fast detection simulation using response matrices (works similar to CCD-type simulations)

⇒ **science simulations**

`tessim/xifusim` and `sirena`

- Simulation of TES physics and pulse reconstruction
- Slower than `xifupipeline`, but much better physics
- pixel interaction (crosstalk)

⇒ **Input for `xifupipeline`**

⟹ physics-based `tessimxifusim` results converted to be used in the fast and general `xifupipeline` simulation (event grading, crosstalk, . . .)

X-IFU – Summary

- 3148 TES pixels in a hexagonal shape
- 5′ FoV
- higher flux ($>$ 1mCrab): energy resolution and throughput slightly reduced

  but stil in the few eV range
- science simulations with `xifupipeline`, taking the most important TES physics effects into account
- physics input to the simulation pipeline by `tessim/xifusim`

When to SIXTE?

When to SIXTE?

When not to use SIXTE:

but `fakeit` or similar tools

- fainter point sources ($\lesssim$1 mCrab)

  1 mCrab: $F_{0.5-2\,\mathrm{keV}} = 10^{-11}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$,
  $F_{2-10\,\mathrm{keV}} = 2 \times 10^{-11}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$,

- quick estimates

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- quick estimates

When to use SIXTE:

and *not* fakeit

- bright sources ($\gtrsim$10 mCrab)

  i.e., many "famous" AGN

- faint sources if background behavior or exposure map matters
- imaging simulations:

  galaxy clusters, AGN evolution,...

  - point source detection sensitivity
  - point sources in crowded fields
  - extended sources

- variability simulations

  e.g., reverberation mapping, pulsations, QPOs,...

How to SIXTE?

Workflow

General workflow for SIXTE simulations:

(1) Preparation of the input of the simulation: Define what is to be observed and store it as a SIMPUT file. The input can be point sources, including time variability, extended sources, or the simulation of large catalogues of astronomical sources that can contain millions of X-ray sources on the whole sky.

(2) Running the simulation Run the simulation for a certain detector setup and exposure.

(3) Analyzing the simulation The output of the previous step are one or multiple standard FITS event files. SIXTE provides tools that prepare standard data products such as spectra and images from event files.

Point source simulation

Generate a simple SIMPUT-file:

1.1 `plist simputfile`

1.2 define model in xspec and save it with

```
XSPEC12>save model mcrab.xcm
```

1.3 `script01.bash`:

```
$SIMPUT/bin/simputfile Simput=mcrab.fits \
  RA=0.0 Dec=0.0 srcFlux=2.137e-11 Elow=0.1 Eup=15 \
  NBins=1000 logEgrid=yes Emin=2 Emax=10 \
  XSPECFile=mcrab.xcm
```

Point source simulation

Run the simulation

- All properties describing an instrument are defined in XML-files.
- The general simulator is called with `runsixt`, and can perform a simulation for any given SIXTE XML-file.

Recommendation: do this in a simple shell script (`script02.bash`):

```
#!/bin/bash

base=mcrab
xmldir=$SIXTE/share/sixte/instruments/athena-wfi/wfi_wo_filter_15row
xml=${xmldir}/ld_wfi_ff_large.xml

$SIXTE/bin/runsixt \
    XMLFile=${xml} \
    RA=0.000 Dec=0.000 \
    Prefix=sim_ \
    Simput=${base}.fits \
    EvtFile=evt_${base}.fits \
    Exposure=1000 \
    Mission=Athena \
    Instrument=WFI \
    Mode=large
```

Point source simulation

Analyze the simulation:

3.1 Use `fstruct`, `fv`, and `fdump` to take a look at the structure of the event file. How many events were simulated? Speculate on the meaning of the individual columns in the event file (see below for an explanation of their definition).

3.2 generate an image of the event file using `imgev`

3.3 generate a spectrum using `makespec`

Point source simulation

script03.bash: Prepare an image with imgev

```
#!/bin/bash

base=mcrab

$SIXTE/bin/imgev \
    EvtFile=sim_evt_${base}.fits \
    Image=img_${base}.fits \
    CoordinateSystem=0 Projection=TAN \
    NAXIS1=512 NAXIS2=512 CUNIT1=deg CUNIT2=deg \
    CRVAL1=0.0 CRVAL2=0.0 CRPIX1=256.5 CRPIX2=256.5 \
    CDELT1=-6.207043e-04 CDELT2=6.207043e-04 \
    history=true clobber=yes
```

Point source simulation

script04.bash: Prepare a spectrum with makespec

```
#!/bin/bash

base=mcrab
xmldir=./wfi_wo_filter_15row

$SIXTE/bin/makespec \
    EvtFile=sim_evt_${base}.fits \
    Spectrum=spec_${base}.pha \
    EventFilter="(RA>359.95 || RA<0.05) && Dec>-0.05 && Dec<+0.05" \
    RSPPath=${xmldir} clobber=yes

# fix an annoyance in the current SIXTE version
# (wll be fixed)
fparkey fitsfile=spec_${base}.pha keyword=CORRFILE value=none
fparkey fitsfile=spec_${base}.pha keyword=POISSERR value=T add=yes

# rebin
ftgrouppha infile=spec_mcrab.pha outfile=spec_mcrab_rebin.pha \
           grouptype=opt respfile=${xmldir}/athena_wfi_pirmf_v20190320.rmf
```

xml directory here is based on a soft link due to length limitations in FITS filenames

Point source simulation

`script01b.bash`/`script02b.bash`: Same for the X-IFU.

Simput: straightforward, but need to oversample the energy resolution!

```
#!/bin/bash

$SIMPUT/bin/simputfile Simput=apec.fits \
   RA=0.0 Dec=0.0 srcFlux=2.137e-12 Elow=0.1 Eup=15 \
   NBins=25000 logEgrid=yes Emin=2 Emax=10 \
   XSPECFile=apec.xcm
```

Point source simulation

`script01b.bash`/`script02b.bash`: Same for the X-IFU.

Simput: straightforward, but need to oversample the energy resolution!

```
#!/bin/bash

base=apec
xmldir=./athena-xifu
xml=${xmldir}/xifu_detector_lpa_75um_AR0.5_pixoffset_mux40_pitch275um.xml

xifupipeline XMLFile=${xmldir}/xifu_baseline.xml  \
   AdvXml=${xml} \
   Exposure=1000 \
   RA = 0. Dec=0. \
   EvtFile=apec_evt.fits \
   Simput=apec.fits \
_  clobber=yes
```

Extended source simulations

Example: η Car from Chandra (http://chandra.harvard.edu/photo/openFITS/xray_data.html)

- 3–8 keV Flux from literature: 10^{-11} erg cm^{-2} s^{-1}
- Describe spectrum with a constant (yes, I know that's wrong. . .)

Generate SIMPUT as before script05.bash:

```
#!/bin/bash

xmldir=$SIXTE/share/sixte/instruments/athena-wfi/wfi_wo_filter_15row

RA=161.267156643662
Dec=-59.684372315062

# fix bug in downloaded FITS file
fparkey fitsfile=etaCar_xray_hi.fits+0 keyword=WCSAXES value=2

simputfile Simput="etacar_high.fits" \
           RA=${RA} \
           Dec=${Dec} \
           srcFlux=1e-11 \
           Emin=3. \
           Emax=10. \
           Elow=2. \
           Eup=10. \
           XSPECFile=constflux \
           ImageFile=etaCar_xray_hi.fits \
           clobber=yes
```

Extended source simulations

Run simulation (note pointing direction!) `script05b.bash`:

```
#!/bin/bash

xmldir=./wfi_wo_filter_15row
xml=${xmldir}/ld_wfi_ff_large.xml

RA=161.267156643662
Dec=-59.684372315062

$SIXTE/bin/runsixt \
    XMLFile=${xml} \
    RA=${RA} Dec=${Dec} \
    Prefix=sim_ \
    Simput=etacar_high.fits \
    EvtFile=evt_etacar.fits \
    Exposure=1000 \
    Mission=Athena \
    Instrument=WFI \
    Mode=large \
    clobber=yes

$SIXTE/bin/imgev \
    EvtFile=sim_evt_etacar.fits \
    Image=img_etacar.fits \
    CoordinateSystem=0 Projection=TAN \
    NAXIS1=512 NAXIS2=512 CUNIT1=deg CUNIT2=deg \
    CRVAL1=${RA} CRVAL2=${Dec} CRPIX1=256.5 CRPIX2=256.5 \
    CDELT1=-6.207043e-04 CDELT2=6.207043e-04 \
    history=true clobber=yes
```

Mosaicing and dithering

Deep field simulations: build large SIMPUT catalogue of individual sources (Example: Chandra deep field south) (`script06.bash`):

for demonstration purpose, use `athenawfisim` and not `runsixt`

```
#!/bin/bash

xmldir=$SIXTE/share/sixte/instruments/athena-wfi/wfi_wo_filter_15row

xml0=${xmldir}/ld_wfi_ff_chip0.xml
xml1=${xmldir}/ld_wfi_ff_chip1.xml
xml2=${xmldir}/ld_wfi_ff_chip2.xml
xml3=${xmldir}/ld_wfi_ff_chip3.xml

${SIXTE}/bin/athenawfisim \
  RA=53.13 Dec=-27.8 \
  Prefix=cdfs_ \
  XMLFile0=${xml0} XMLFile1=${xml1} XMLFile2=${xml2} XMLFile3=${xml3} \
  Simput=CDFS_cat_lehmer.fits Simput2=CDFS_cat_galaxies.fits \
  Exposure=1000 \
  clobber=yes

ftmerge \
   cdfs_chip0_evt.fits,cdfs_chip1_evt.fits,cdfs_chip2_evt.fits,cdfs_chip3_evt.fi
ts \
   sim_combined_evt.fits clobber=yes
```

Inspect event file with fv $\Longrightarrow$ chip gaps

Mosaicing and dithering

Deep field simulations: build large SIMPUT catalogue of individual sources: Now add attitude file (`script07.bash`):

```
#!/bin/bash

xmldir=$SIXTE/share/sixte/instruments/athena-wfi/wfi_wo_filter_15row

xml0=${xmldir}/ld_wfi_ff_chip0.xml
xml1=${xmldir}/ld_wfi_ff_chip1.xml
xml2=${xmldir}/ld_wfi_ff_chip2.xml
xml3=${xmldir}/ld_wfi_ff_chip3.xml

${SIXTE}/bin/athenawfisim \
  RA=53.13 Dec=-27.8 \
  Prefix=cdfs_ \
  XMLFile0=${xml0} XMLFile1=${xml1} XMLFile2=${xml2} XMLFile3=${xml3} \
  Simput=CDFS_cat_lehmer.fits Simput2=CDFS_cat_galaxies.fits \
  Exposure=1000 \
  Attitude=CDFS_lissajous_80ksec.att \
  clobber=yes

ftmerge \
   cdfs_chip0_evt.fits,cdfs_chip1_evt.fits,cdfs_chip2_evt.fits,cdfs_chip3_evt.fi
ts \
   sim_combined_evt_lissajous.fits clobber=yes
```

Inspect event file with fv $\Longrightarrow$ life is good!

Mosaicing and dithering

For complex attitude: need exposure map (`script08.bash`):

```
#!/bin/bash

xmldir=$SIXTE/share/sixte/instruments/athena-wfi/wfi_wo_filter_15row

xml0=${xmldir}/ld_wfi_ff_chip0.xml
xml1=${xmldir}/ld_wfi_ff_chip1.xml
xml2=${xmldir}/ld_wfi_ff_chip2.xml
xml3=${xmldir}/ld_wfi_ff_chip3.xml

${SIXTE}/bin/exposure_map \
    Vignetting=${xmldir}/athena_vig_15row_20171016.fits \
    Attitude=CDFS_lissajous_80ksec.att \
    Exposuremap=expo_map.fits \
    XMLFile="${xml0};${xml1};${xml2};${xml3}" \
    fov_diameter=70 \
    CoordinateSystem=0 projection_type=TAN \
    NAXIS1=1078 NAXIS2=1078 CUNIT1=deg CUNIT2=deg \
    CRVAL1=53.13 CRVAL2=-27.8 CRPIX1=593.192308 CRPIX2=485.807692 \
    CDELT1=-6.207043e-04 CDELT2=6.207043e-04 \
    TSTART=0 timespan=5000.000000 dt=100. \
    chatter=3 clobber=true
```

Useful tools

Other useful tools to know about:

- `simputmultispec`: convert maps of model parameters into SIMPUT files
  e.g., image of abundance and temperature in a SNR or cluster
- `simputmerge`: merge SIMPUT files
- `xml2svg`: visualize detector setup from XML
- `sixteversion`: get installed SIXTE version
- `attgen_dither`: build Lissajous dither
- SOXS – `http://hea-www.cfa.harvard.edu/~jzuhone/soxs/index.html`
  generate SIMPUT from cosmological simulations and much more

What's still missing?

What is still missing:

- Straylight handling

  Code prepared, currently input into SIXTE $\Longrightarrow$ end of the month

- ARF generator

  right now use canned ARFs only, can not take into account extraction region, vignetting

  $\Longrightarrow$ code in development for circular extraction regions / annuli, should be done before August

- better treatment of optics

  Need to wait for mirror setup to finalize, then do fine PSF and vignetting grid

SIXTE? – Questions?