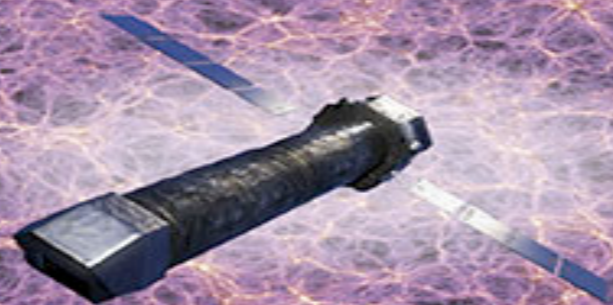


ATHENA

THE ASTROPHYSICS OF THE
HOT AND ENERGETIC
UNIVERSE



HOW DOES ORDINARY MATTER
ASSEMBLE INTO THE LARGE SCALE
STRUCTURES THAT WE SEE TODAY?

HOW DO BLACK HOLES GROW
AND SHAPE THE UNIVERSE?

Europe's next generation **X-RAY OBSERVATORY**

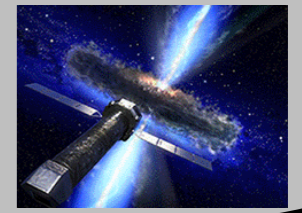
SIXTE implementation of the X-IFU

Philippe Peille

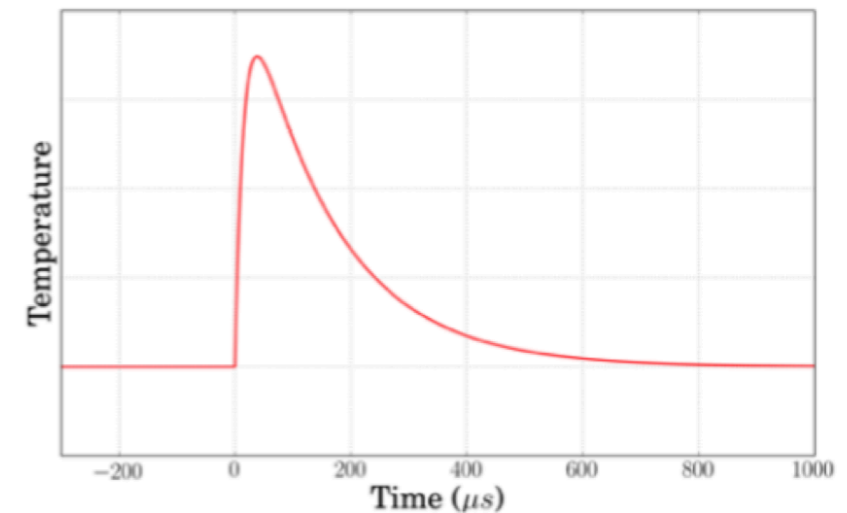
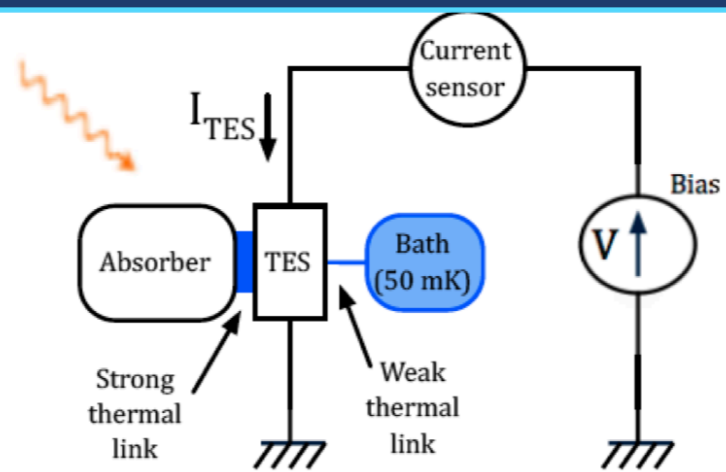
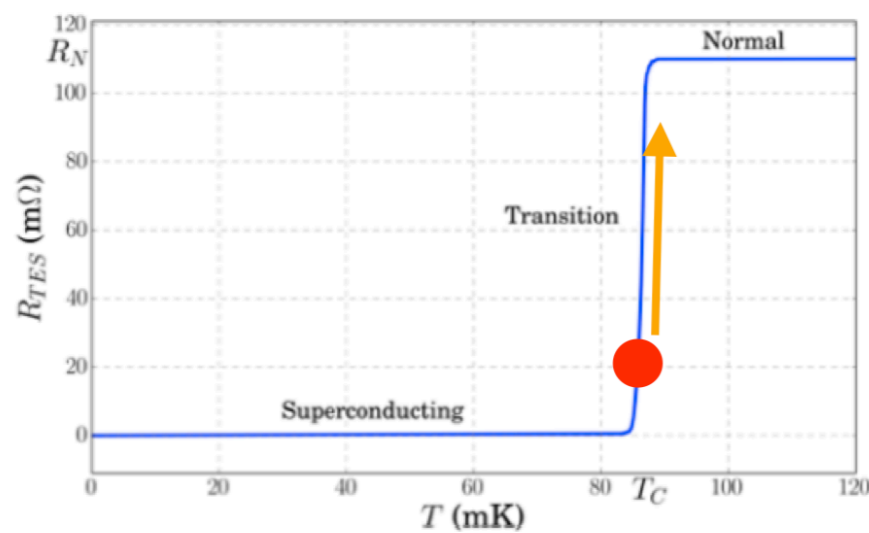
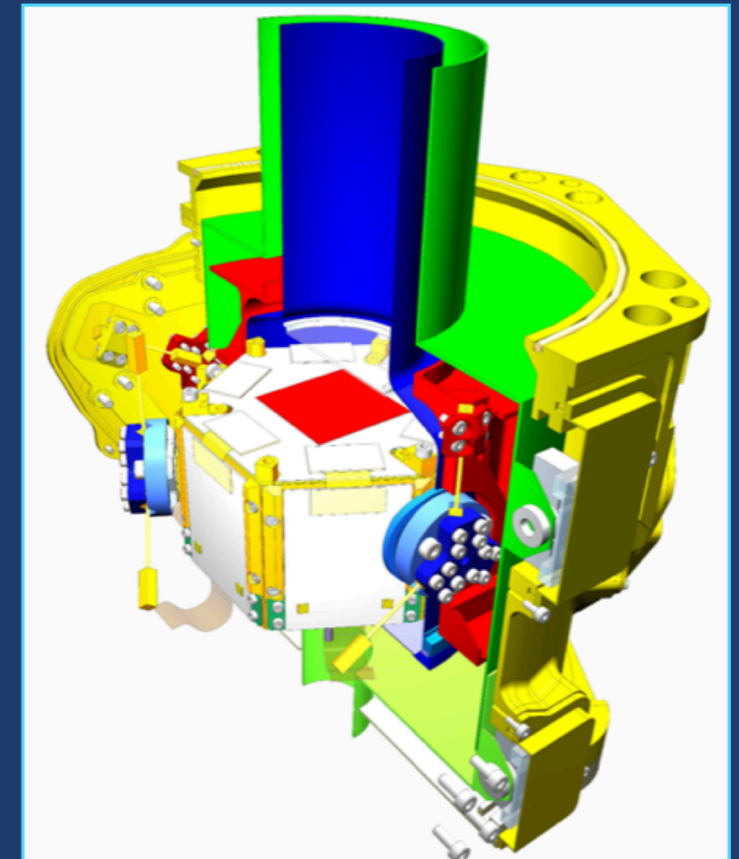
on behalf of the X-IFU E2E simulations team
ECAP, IRAP, IFCA & GSFC

SXTE WORKSHOP, IRAP, APRIL 20 2016

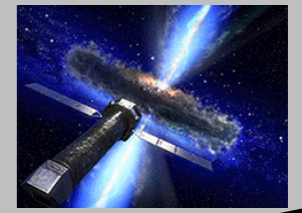
THE X-IFU



- The X-IFU is an X-ray micro-calorimeter
 - Detection plane populated by TESs cooled to their transition phase temperature
 - Sensitive to heat increases induced by impacting X-rays

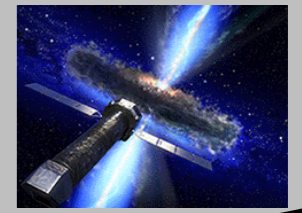


THE X-IFU: A FEW NUMBERS

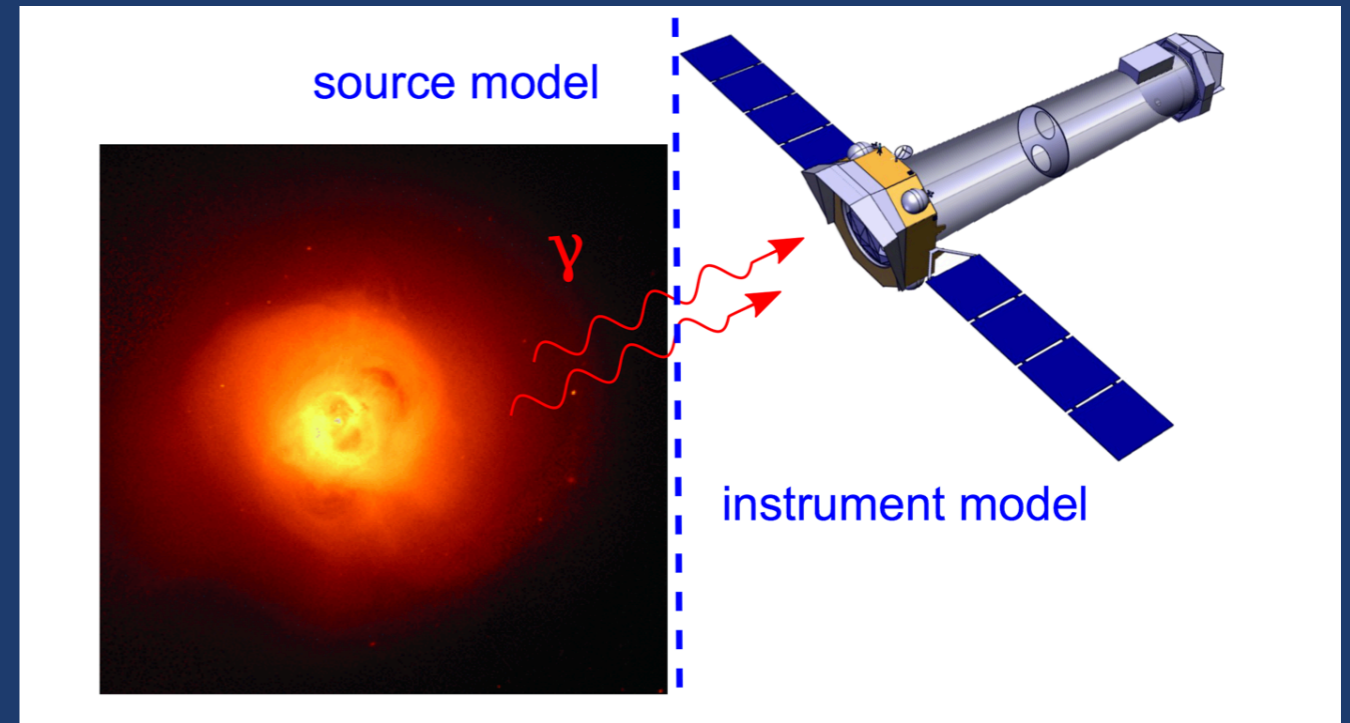


Parameter	Baseline requirement
Spectral resolution	2.5 eV
Field of view	5' (equivalent diameter)
Pixel size	< 5'' (mirror PSF HEW)
Instrumental bkg level	< $5 \cdot 10^{-3}$ count/s/cm ² /keV
Energy range	0.2-12 keV
Count rate capability	80 % high res events @ 1 mCrab
Bright source throughput	30 % @ 1 Crab
Detection quantum efficiency	> 75% @ 1 keV / > 83 % @ 6 keV
Time resolution	10 μ s

X-IFU E2E SIMULATIONS IN A NUTSHELL

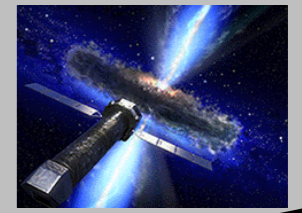


- Athena telescope model
 - pointing (attitude)
 - ARF
 - vignetting
 - PSF
- X-IFU instrument model
 - background
 - X-IFU focal plane geometry
 - TES physics and event-reconstruction
 - pile-up
 - crosstalk (soon)
- Source model
 - SIMPUT source



Outputs an event file with energy, time
and pixel position
with additional information for performance
analysis

DESCRIBING THE X-IFU: OVERALL SET-UP



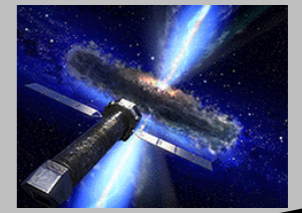
- The overall X-IFU set-up is described by a standard SIXTE XML file
 - Similar to the WFI
 - Allows easy changes of the optical properties of the ATHENA optics

```
<?xml version="1.0"?>
<instrument telescop="Athena" instrume="XIFU">
<telescope>
<focallength value="12.0"/>
<fov diameter="0.5"/>
<arf filename="athena_xifu_sixte_1469_onaxis_v20150402.arf"/>
<psf filename="athena_psf_onaxis_20150602.fits"/>
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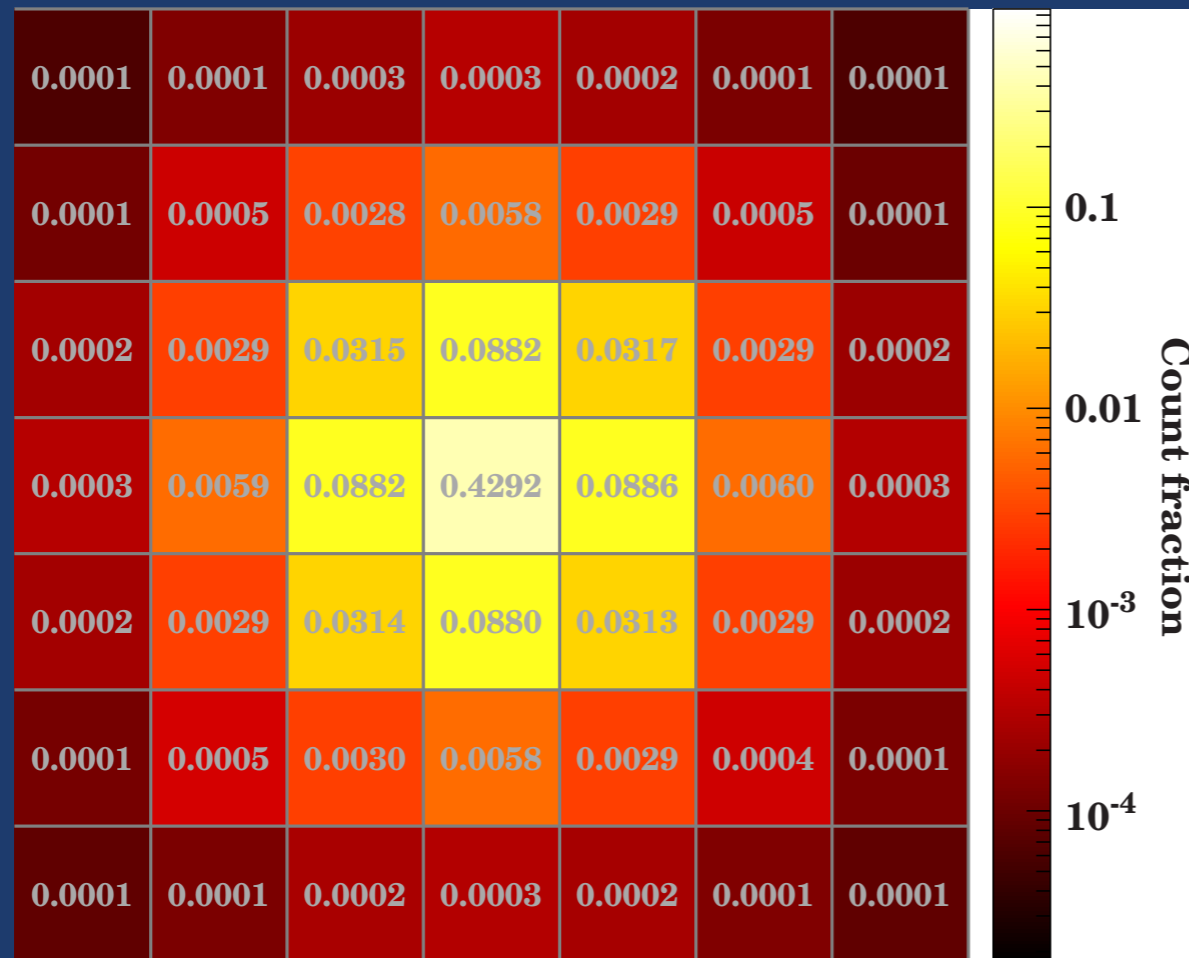
<detector>
<dimensions xwidth="64" ywidth="60"/>
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  ydelt="265.e-6"/>
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<threshold_event_lo_keV value="200.e-3"/>
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</detector>
</instrument>
```

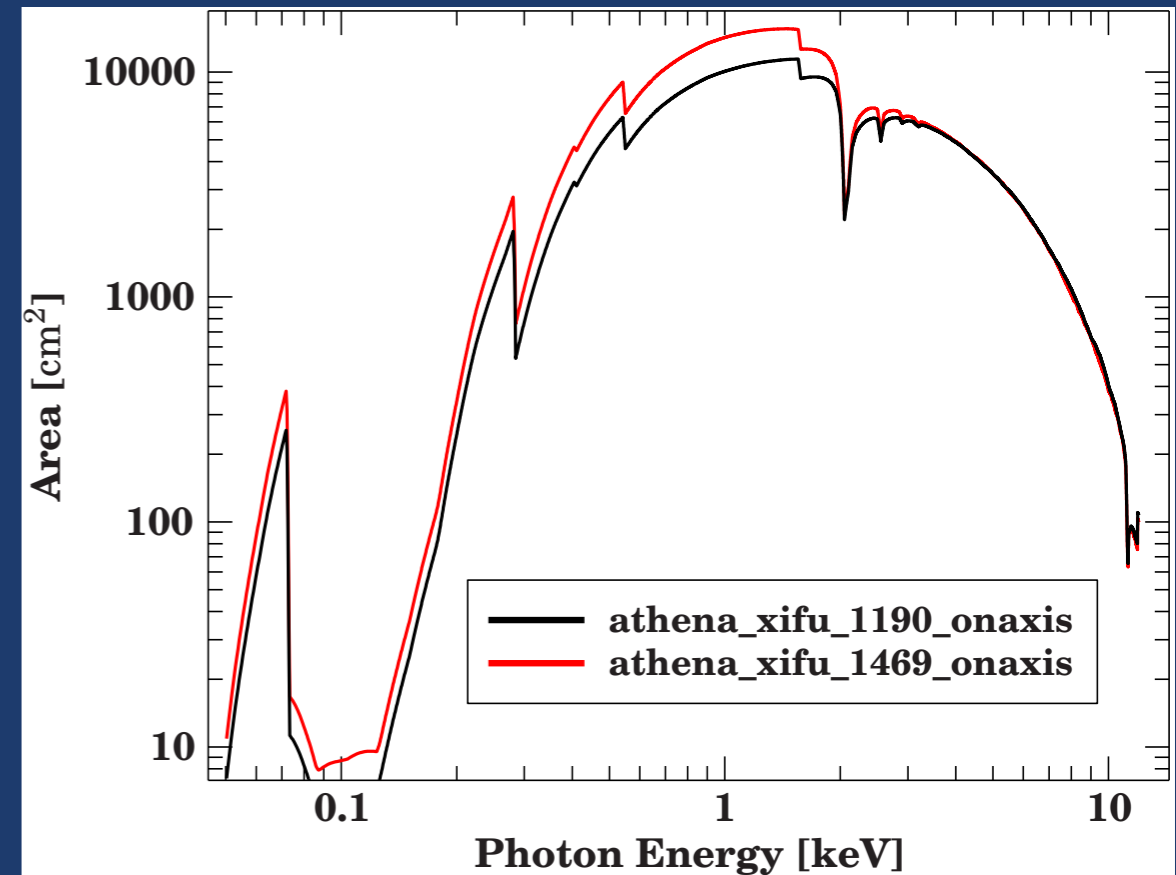
THE ATHENA OPTICS AND THE X-IFU



- The ATHENA PSF and X-IFU ARF are described through calibration files

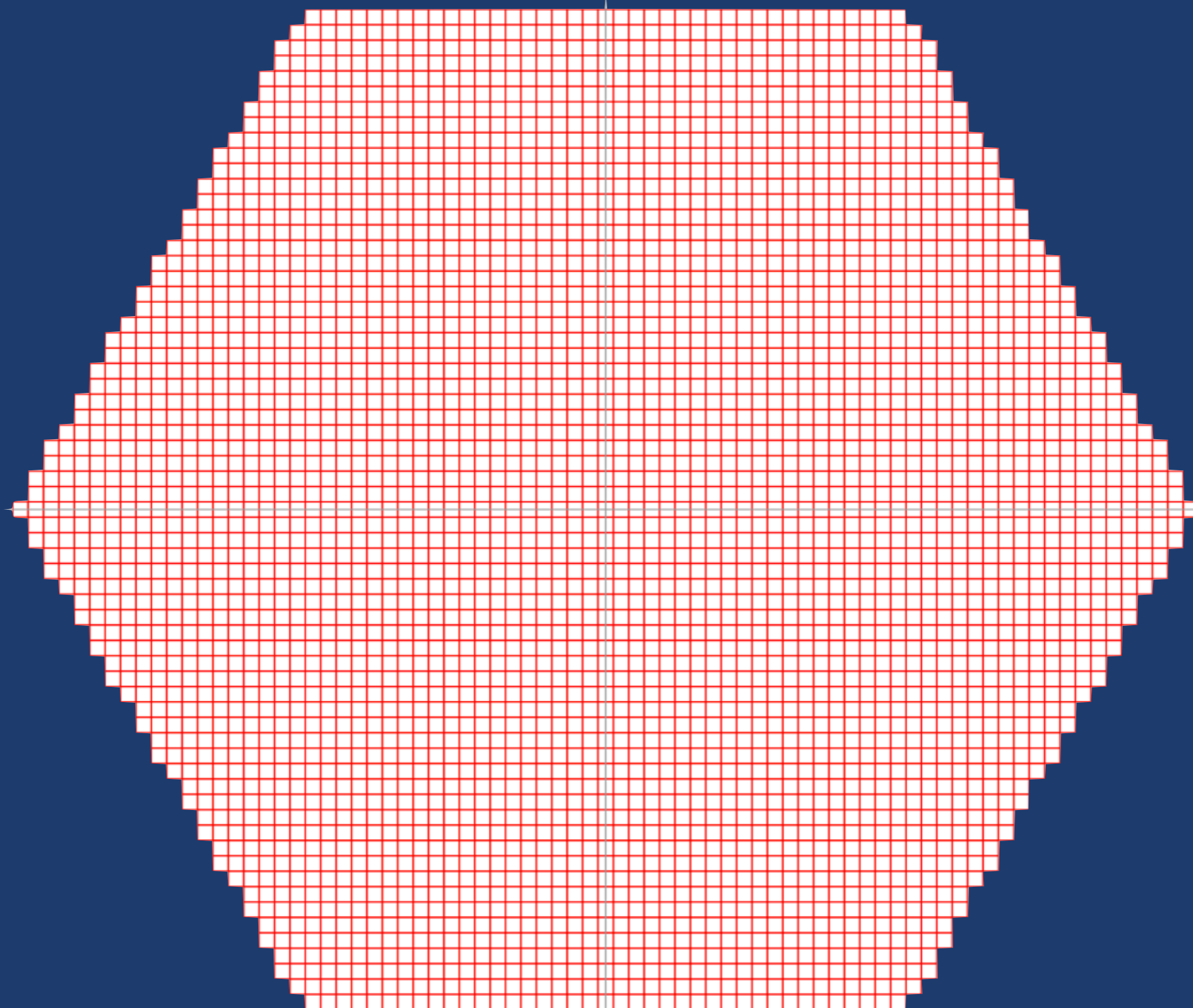
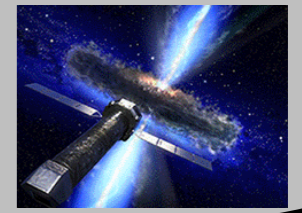


PSF spread on the baseline X-IFU pixels

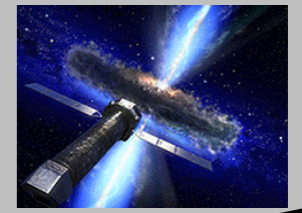


X-IFU ARF depending on the mirror are

DESCRIBING THE X-IFU FOCAL PLANE (BASELINE)



DESCRIBING THE X-IFU FOCAL PLANE



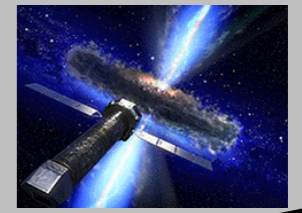
- The standard SIXTE XML file is not well suited to describe the X-IFU focal plane
- An advanced detector XML file format was developed

```
<?xml version="1.0"?>
<instrument telescop="Athena" instrume="XIFU">
<telescope>
<focallength value="12.0"/>
<fov diameter="0.5"/>
<arf filename="athena_xifu_sixte_1469_onaxis_v20150402.arf"/>
<psf filename="athena_psf_onaxis_20150602.fits"/>
<vignetting filename="athena_1469_2.3_irb4c_vig.fits"/>
</telescope>

<detector>
<dimensions xwidth="64" ywidth="60"/>
<wcs xrpix="32.5" yrpix="32.5" xrval="0." yrval="0." xdelt="265.e-6"
  ydelt="265.e-6"/>
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<phabackground filename="sixte_XIFU_tot_extended.pha"/>
<threshold_readout_lo_keV value="200.e-3"/>
<threshold_event_lo_keV value="200.e-3"/>
<readout mode="event"/>

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DESCRIBING THE X-IFU FOCAL PLANE



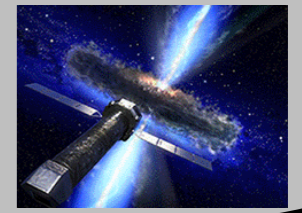
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```
<?xml version="1.0"?>
<pixdetector type="x-ifu" npix="3832" xoff="0" yoff="0">
  <samplefreq value="156.25e+3"/>

  <grading num="1" name="high" pre="400" post="1024" rmf="athena_xifu_rmf_highres_v20150609.rmf"/>
  <grading num="2" name="mid" pre="400" post="256" rmf="athena_xifu_rmf_midres_v20150609.rmf"/>
  <grading num="3" name="low" pre="400" post="0" rmf="athena_xifu_rmf_lowres_v20150609.rmf"/>

  <hexagonloop radius="0.0095961370452" pixelpitch="249e-6" cross="1">
    <pixel>
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    </pixel>
  </hexagonloop>
</pixdetector>
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DESCRIBING THE X-IFU FOCAL PLANE



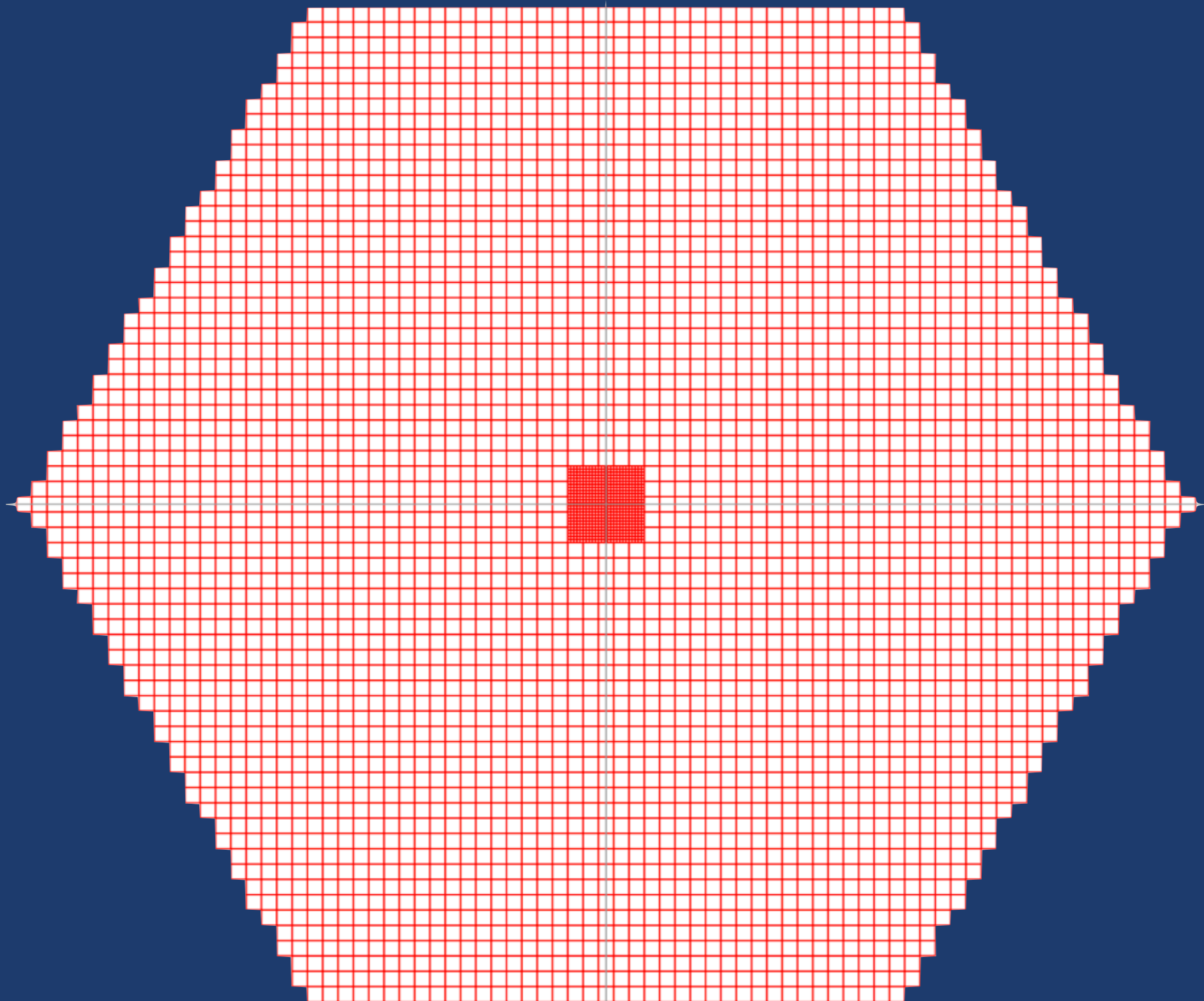
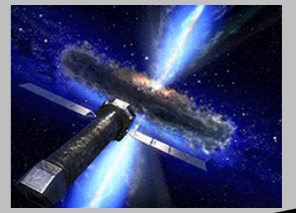
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```
<?xml version="1.0"?>
<pixdetector type="x-ifu" npix="3832" xoff="0" yoff="0">
  <samplefreq value="156.25e+3"/>

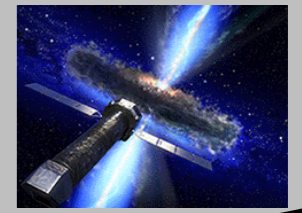
  <grading num="1" name="high" pre="400" post="1024" rmf="athena_xifu_rmf_highres_v20150609.rmf"/>
  <grading num="2" name="mid" pre="400" post="256" rmf="athena_xifu_rmf_midres_v20150609.rmf"/>
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  <hexagonloop radius="0.0095961370452" pixelpitch="249e-6" cross="1">
    <pixel>
      <shape posx="$x" delx="$p" posy="$y" dely="$p" width="245e-6" height="245e-6"/>
    </pixel>
  </hexagonloop>
</pixdetector>
```

DESCRIBING THE X-IFU FOCAL PLANE (WITH SPA)



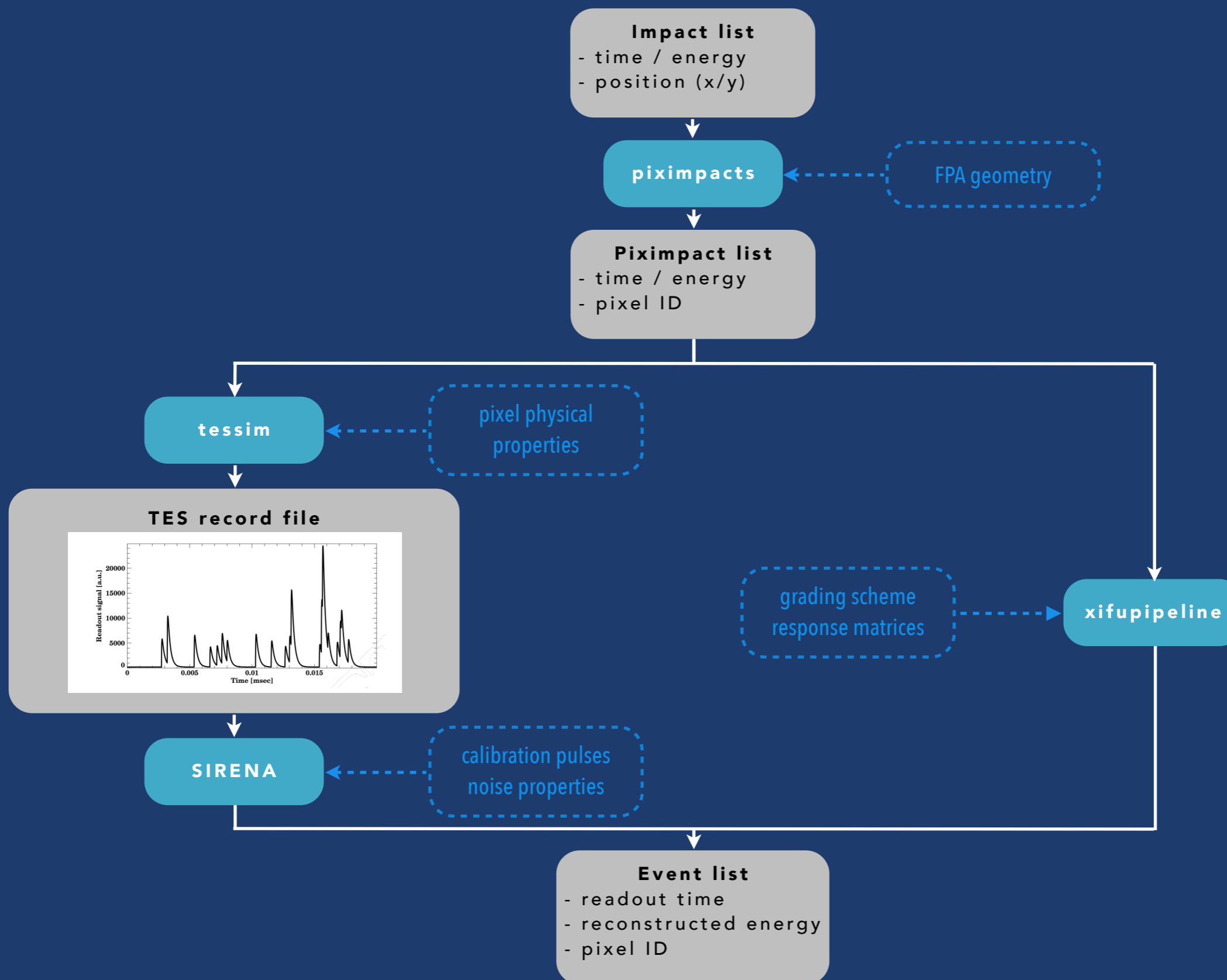
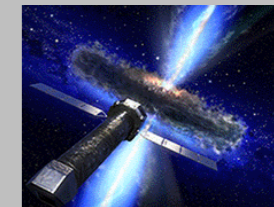
DESCRIBING THE X-IFU FOCAL PLANE



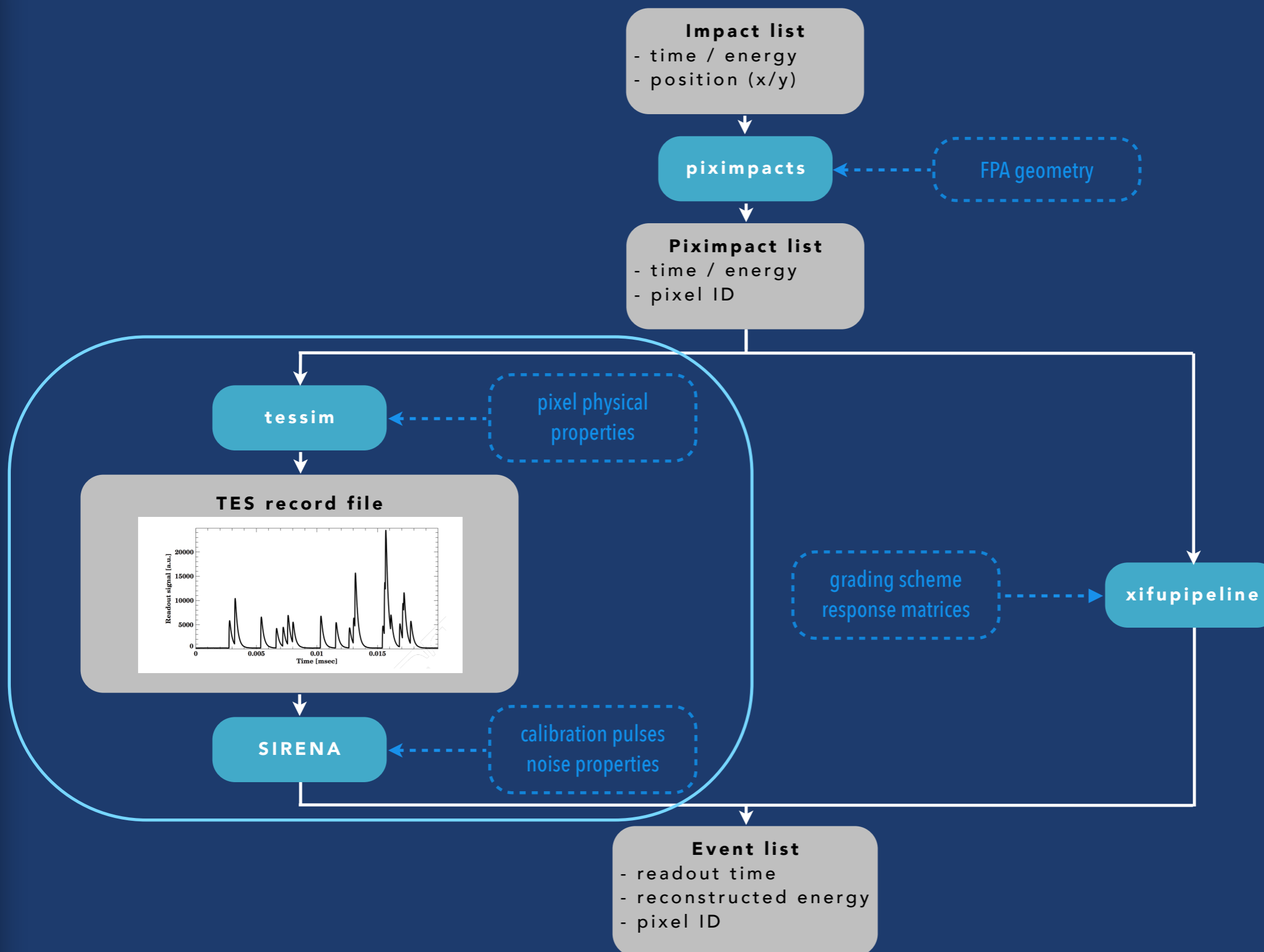
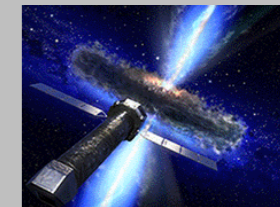
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```
<?xml version="1.0"?>
<pixdetector type="x-ifu" npix="3832" xoff="0" yoff="0">
  <samplefreq value="156.25e+3"/>
  <grading num="1" name="high" pre="400" post="1024" rmf="athena_xifu_rmf_highres_v20150609.rmf"/>
  <grading num="2" name="mid" pre="400" post="256" rmf="athena_xifu_rmf_midres_v20150609.rmf"/>
  <grading num="3" name="low" pre="400" post="0" rmf="athena_xifu_rmf_lowres_v20150609.rmf"/>
  <hexagonloop radius="0.0095961370452" pixelpitch="249e-6" cross="1">
    <pixel>
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    </pixel>
  </hexagonloop>
</pixdetector>
```

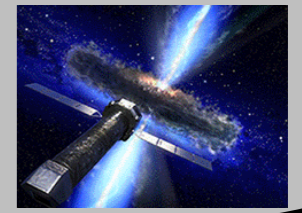
TWO SIMULATION APPROACHES



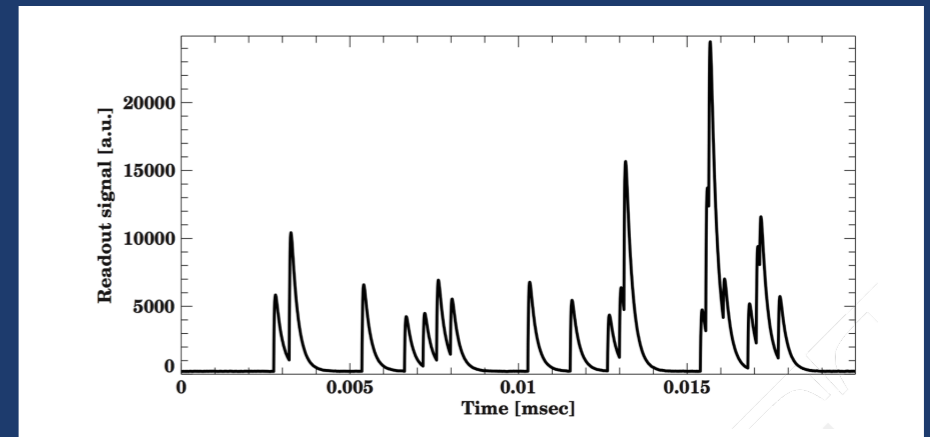
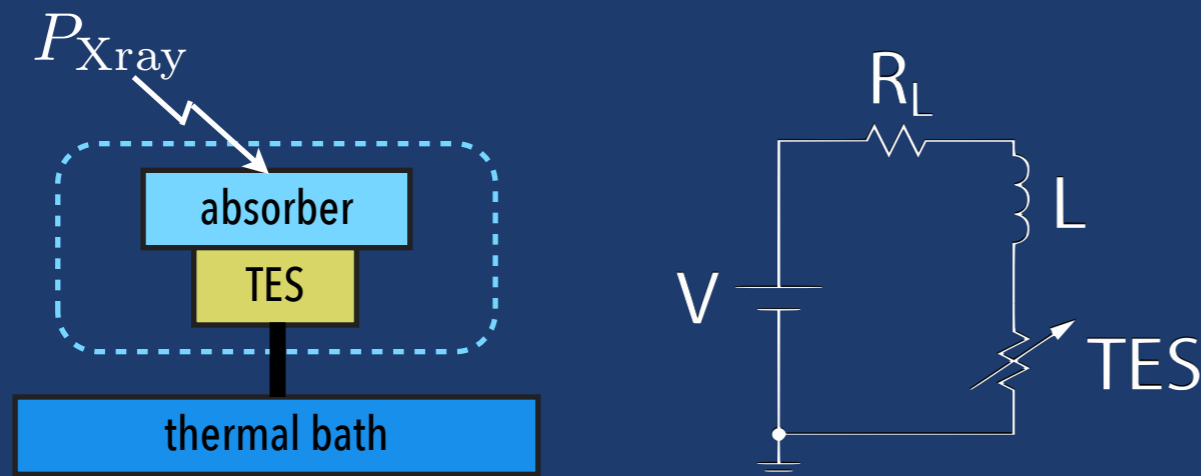
TWO SIMULATION APPROACHES



TESSIM AND SIRENA

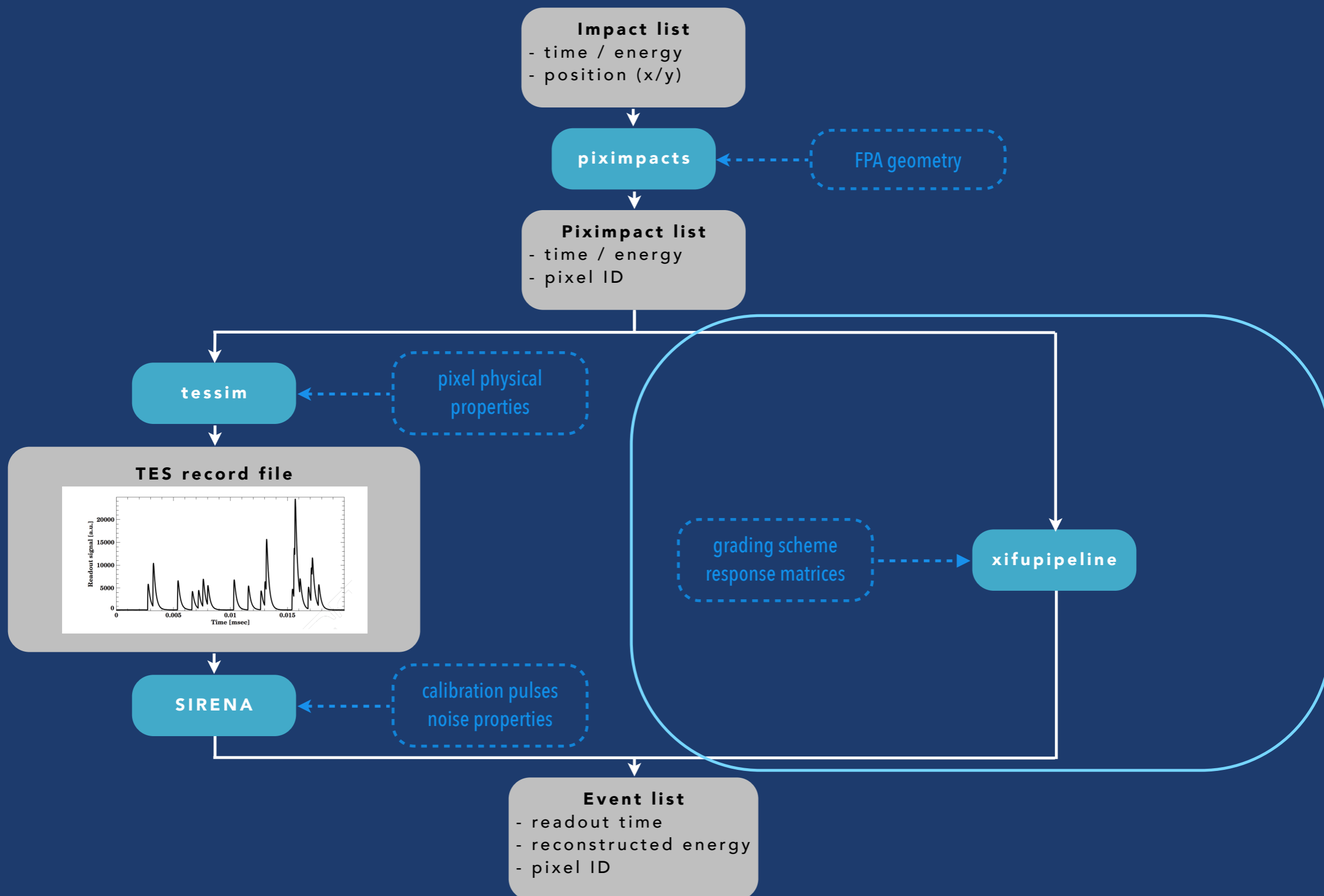
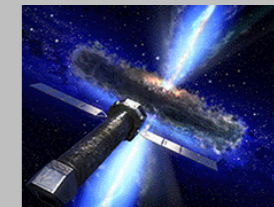


- TESSIM is a TES physical model creating representative data streams coming out of the future X-IFU pixels
- Allows the precise testing of the future X-IFU performance at the pixel level
- See Joern's talk tomorrow

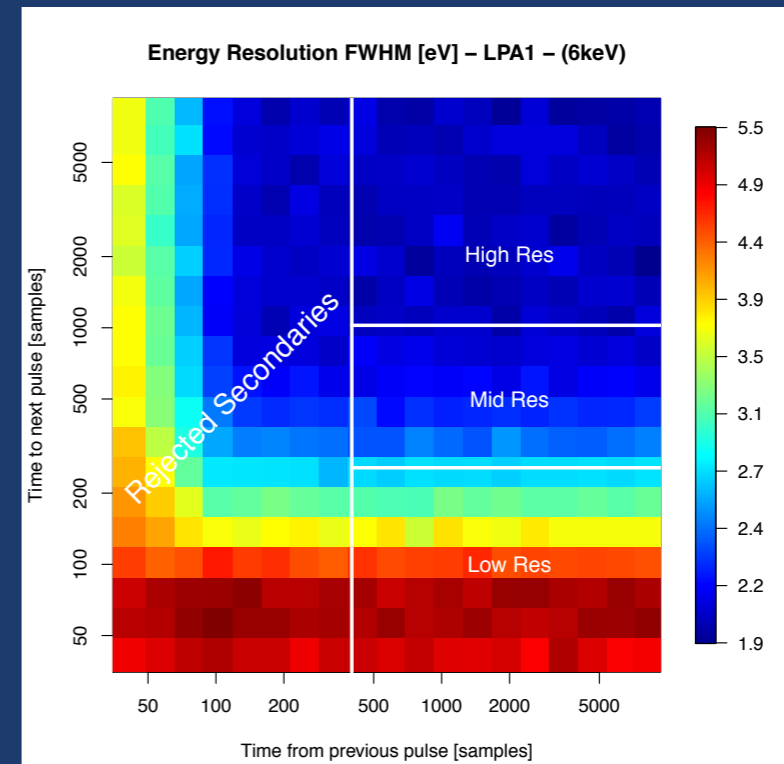
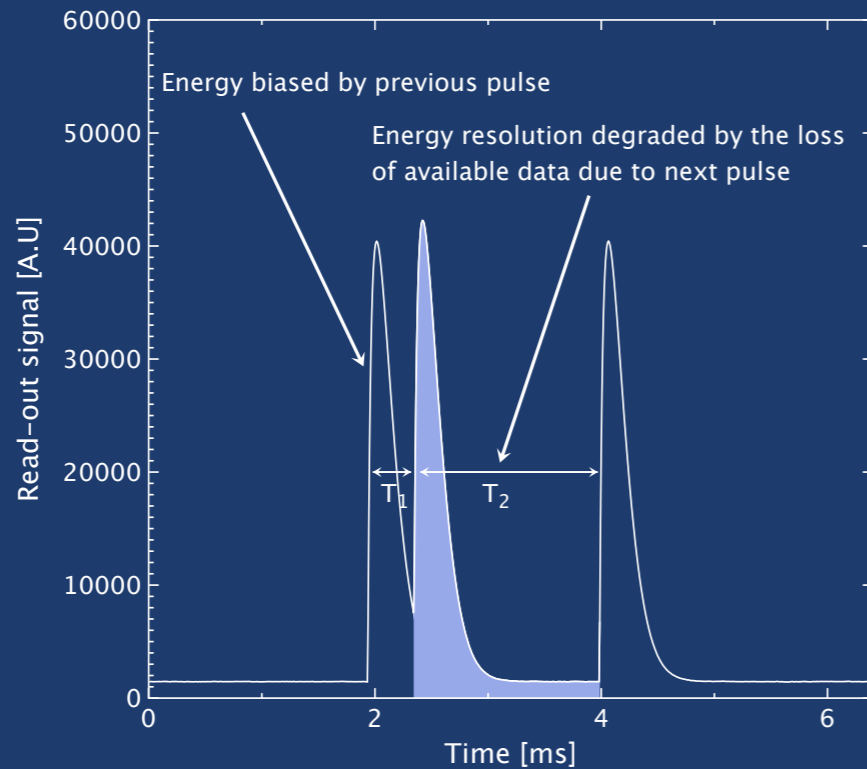
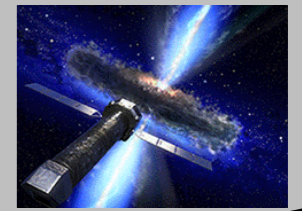


- The future pulse reconstruction on-board software SIRENA has been fully integrated into the SIXTE software
- Responsible for extracting the time and energy of each impacting photon from the pulses train
- Its future performance can be tested and parametrized using SIXTE

TWO SIMULATION APPROACHES

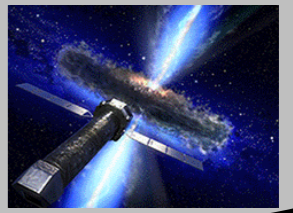


EVENT GRADING



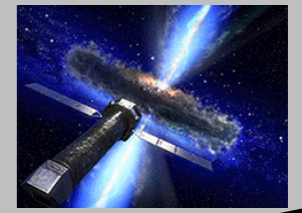
- Event grades depending on pulse separation defined from TESSIM/SIRENA studies

Grade	T_1	T_2	ΔE
High res	≥ 2.6 ms	≥ 6.6 ms	2.5 eV
Medium res	≥ 2.6 ms	≥ 1.6 ms	3.0 eV
Low res	≥ 2.6 ms	≥ 6.4 μ s	15 eV
Secondary	-	-	N/A



- Tessim is a realistic but expensive tool
 - Well suited to study fine effects as well as degradations happening at very high count rates
 - Cannot be used with laptop-like resources to conduct ~ 100 ks observations on the whole detector array
- Xifupipeline fills in this gap
 - Full imaging implemented
 - Fast simulation based on response matrices
 - Each event gets its energy randomised according to its grade
 - Pile-up effects also simulated
 - Crosstalk will soon be simulated
 - Does not replace the physics based simulation, but good for spectro-imaging studies of faint sources

DESCRIBING THE X-IFU FOCAL PLANE



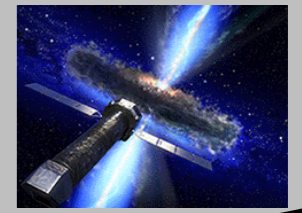
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  <samplefreq value="156.25e+3"/>

  <grading num="1" name="high" pre="400" post="1024" rmf="athena_xifu_rmf_highres_v20150609.rmf"/>
  <grading num="2" name="mid" pre="400" post="256" rmf="athena_xifu_rmf_midres_v20150609.rmf"/>
  <grading num="3" name="low" pre="400" post="0" rmf="athena_xifu_rmf_lowres_v20150609.rmf"/>

  <hexagonloop radius="0.0095961370452" pixelpitch="249e-6" cross="1">
    <pixel>
      <shape posx="$x" delx="$p" posy="$y" dely="$p" width="245e-6" height="245e-6"/>
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</pixdetector>
```

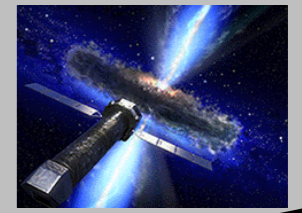
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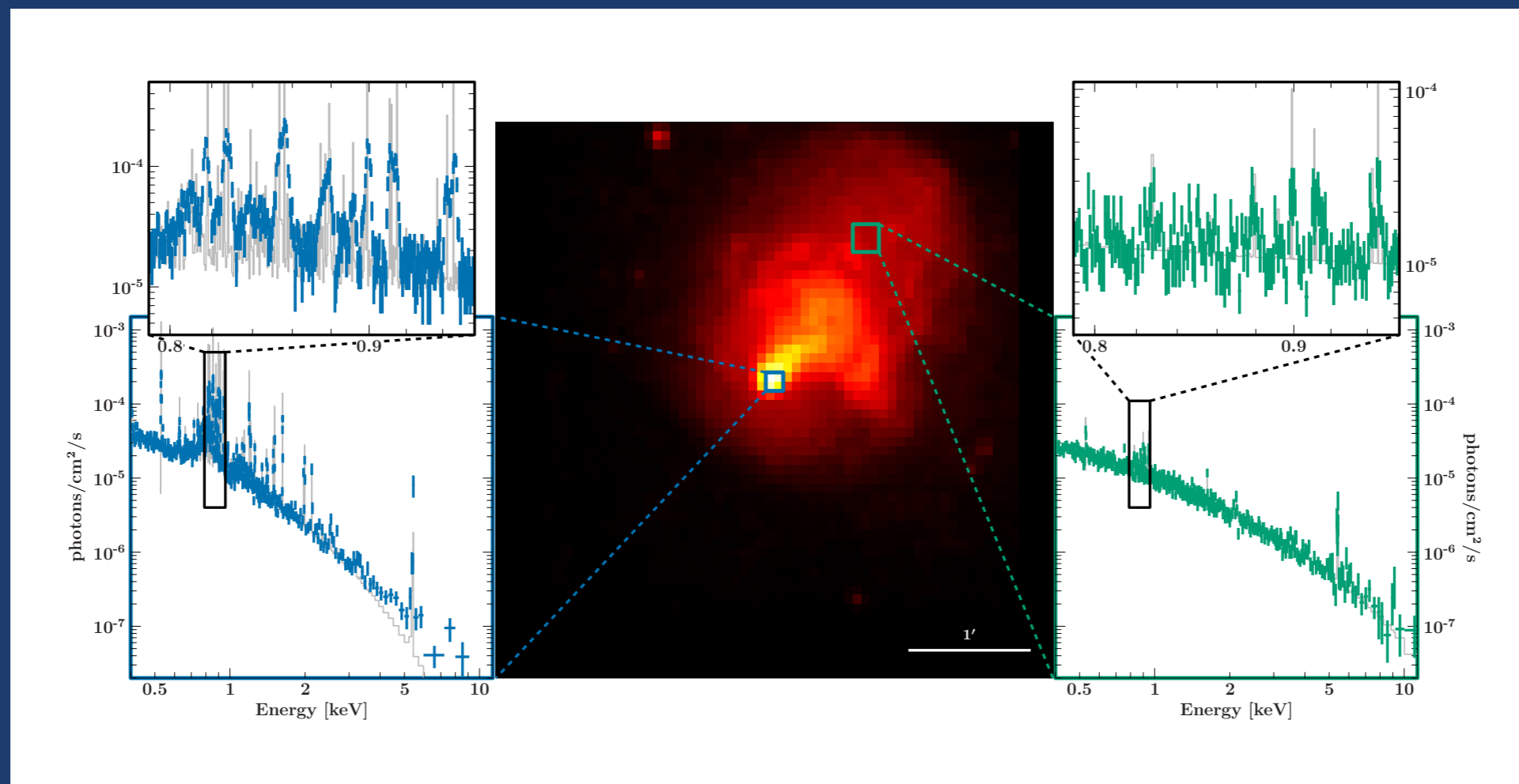
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</pixdetector>
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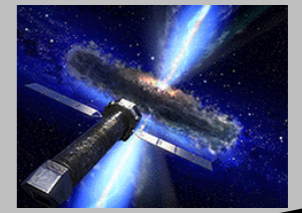
CONCLUSION



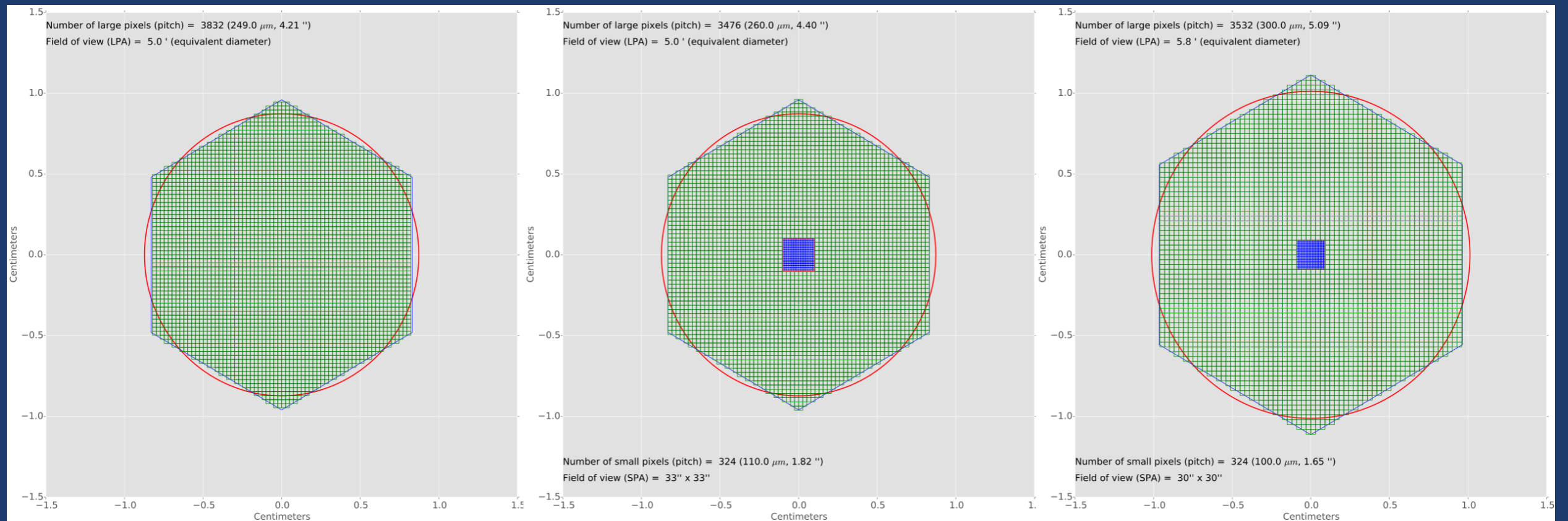
- A very flexible setup allowing both high and low level simulations
- Advanced studies already done with this simulator
 - Estimating the pulse reconstruction performances
 - Data cube simulations



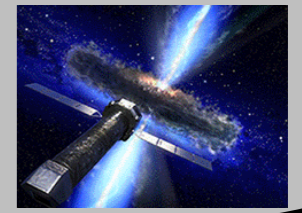
CONCLUSION



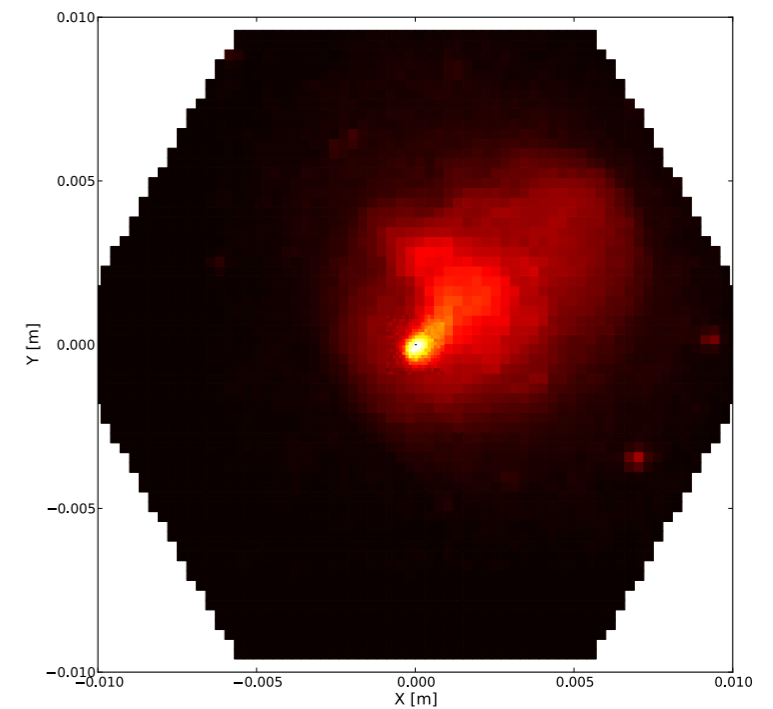
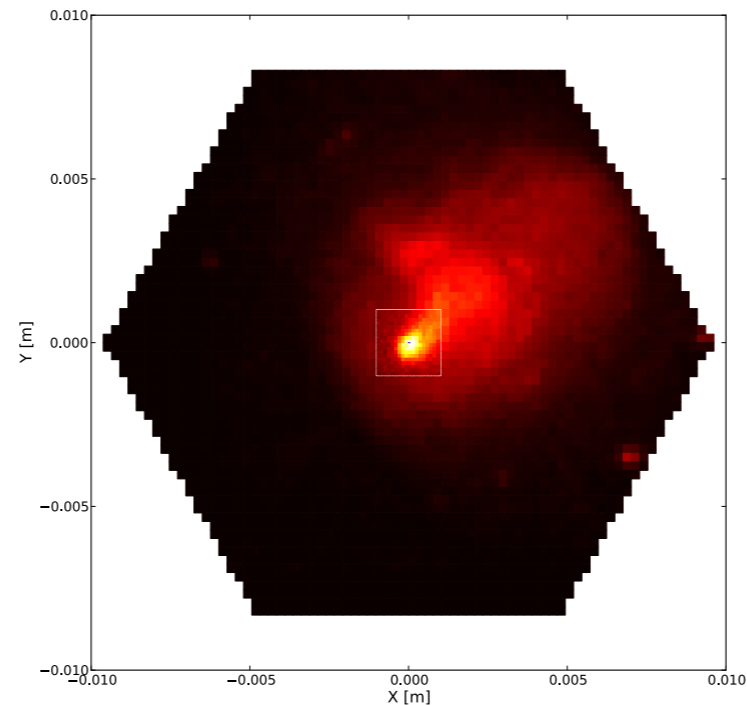
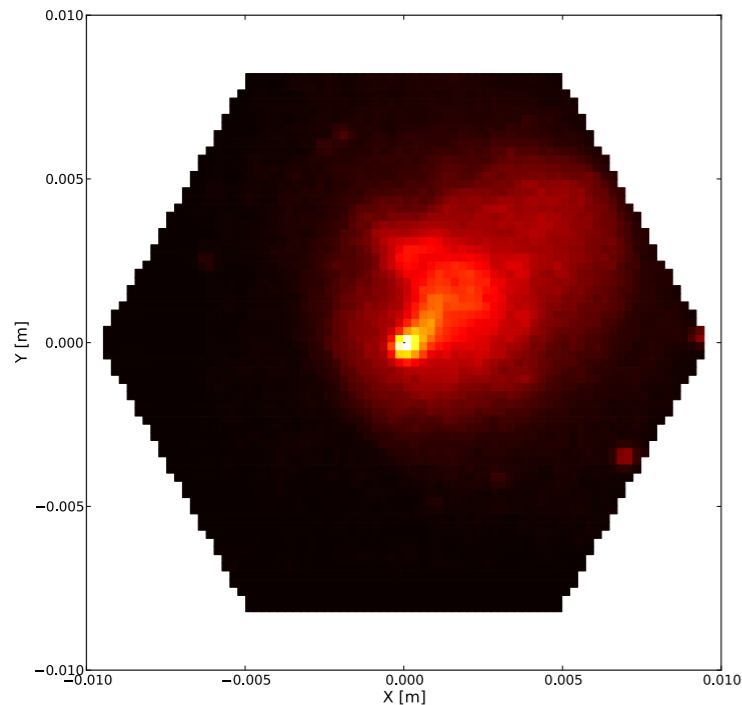
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 - Study of different array configurations



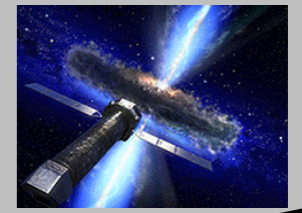
CONCLUSION



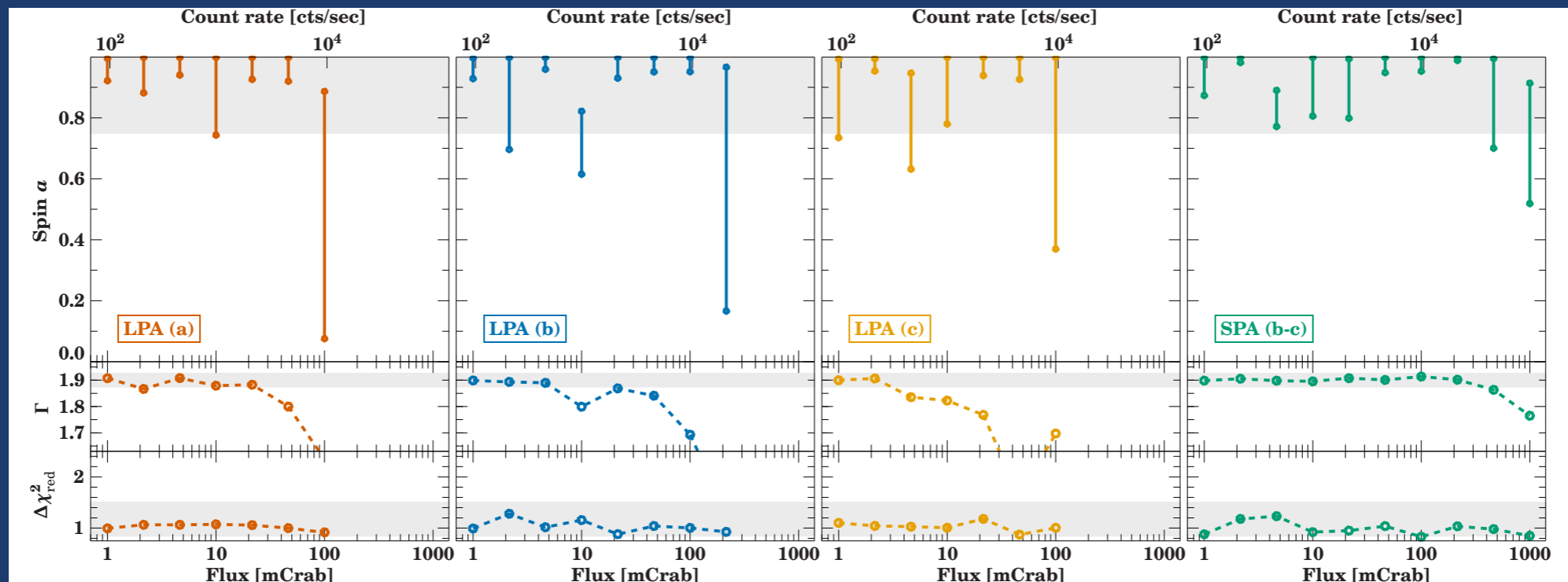
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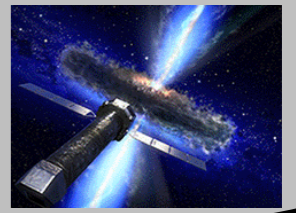
CONCLUSION



- A very flexible setup allowing both high and low level simulations
- Advanced studies already done with this simulator
 - Estimating the pulse reconstruction performances
 - Data cube simulations
 - Study of different array configurations
 - Science performance studies

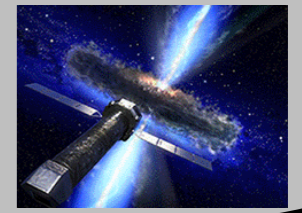


CONCLUSION



- A very flexible setup allowing both high and low level simulations
- Advanced studies already done with this simulator
 - Estimating the pulse reconstruction performances
 - Data cube simulations
 - Study of different array configurations
 - Science performance studies
- Next steps
 - Simulate calibration uncertainties (ARF, RMF, ...)
 - Finalize crosstalk study
- Papers and communications at upcoming Conferences
 - *SPIE*: 3 papers on TESSIM, Event reconstruction and Crosstalk
 - *High-resolution X-ray spectroscopic software and tools*: Tutorial session on X-IFU simulations
 - *EWASS 2016*: Talk on simulations of galaxy clusters outskirts with X-IFU

ACCESS TO THE SIMULATOR



- The simulator is accessible via
 - a web page interface at <http://hydrus.sternwarte.uni-erlangen.de/~athenasim/>
 - limited configurations only, RMF based simulations
 - the SIXTE download page at <http://www.sternwarte.uni-erlangen.de/research/sixte/>
 - gives access to both official tar.gz releases and the git repository

Simulation Parameters

Instrument: X-IFU
Mirror Assembly: X-IFU
Detector mode: baseline

Filter:

Detailed explanations of the WFI detector modes can be found in the **WFI bright source report** ?

Attitude
 pointed Observation RA: deg Dec: deg

Spectral Components Add simple point source

Upload source description ([SIMPUP format](#) or XSPEC parfile)
 Browse...
Upload

Cosmic X-ray Background (logN-logS AGN)
 ROSAT All-Sky Survey (Bright & Faint Source Catalogs) + Sco X-1
 Galactic Ridge X-ray Emission

Exposure time: ks Tstart: s

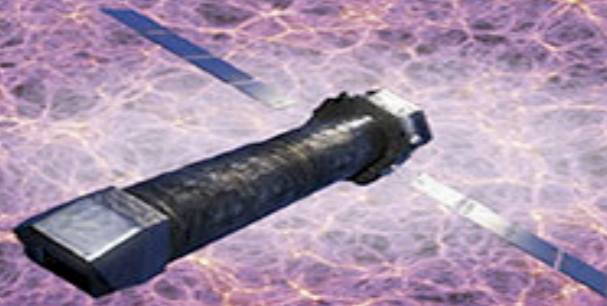
Returned Data Products
 Event file
 Image
 SIMPUT file (source only)

Simulate Reset

Questions and bug reports: sixte-dev@lists.fau.de

ATHENA

THE ASTROPHYSICS OF THE
HOT AND ENERGETIC
UNIVERSE



HOW DOES ORDINARY MATTER
ASSEMBLE INTO THE LARGE SCALE
STRUCTURES THAT WE SEE TODAY?

HOW DO BLACK HOLES GROW
AND SHAPE THE UNIVERSE?

Europe's next generation **X-RAY OBSERVATORY**

SIXTE implementation of the X-IFU

Philippe Peille

on behalf of the X-IFU E2E simulations team

SXTE WORKSHOP, IRAP, APRIL 20 2016