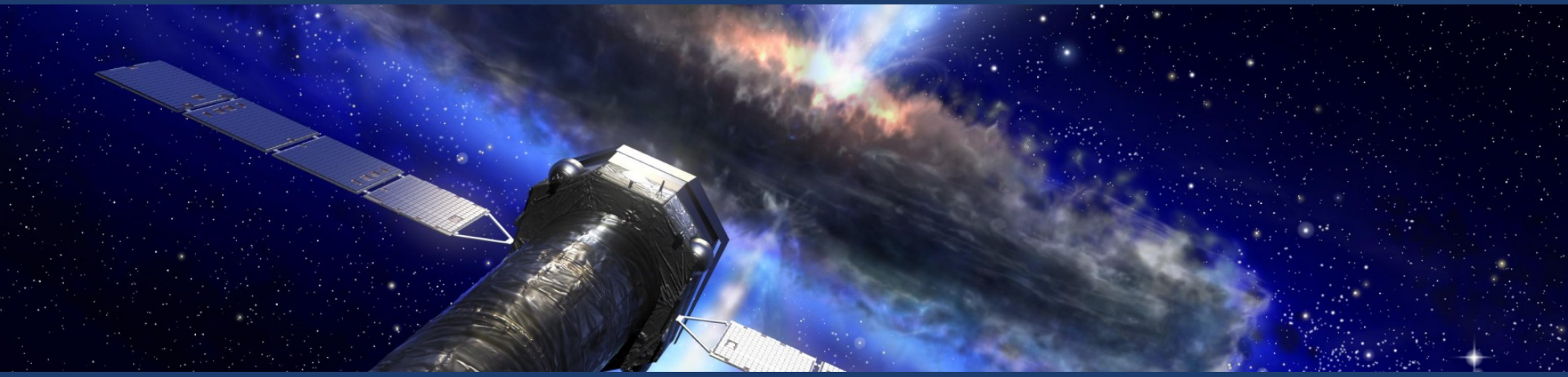


ATHENA End-To-End Simulations

J. Wilms, T. Dauser, P. Peille

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.

Purpose of this Meeting

What is the purpose of this meeting?

- Demonstrate current status of e2e design for ATHENA
  - same underlying engine
  - same inputs can be used for both instruments
  - similar outputs

  $\Longrightarrow$ What is already possible?
- Training in performing e2e simulations
  - basic simulations
  - advanced simulations
  - other missions
- Discuss future developments

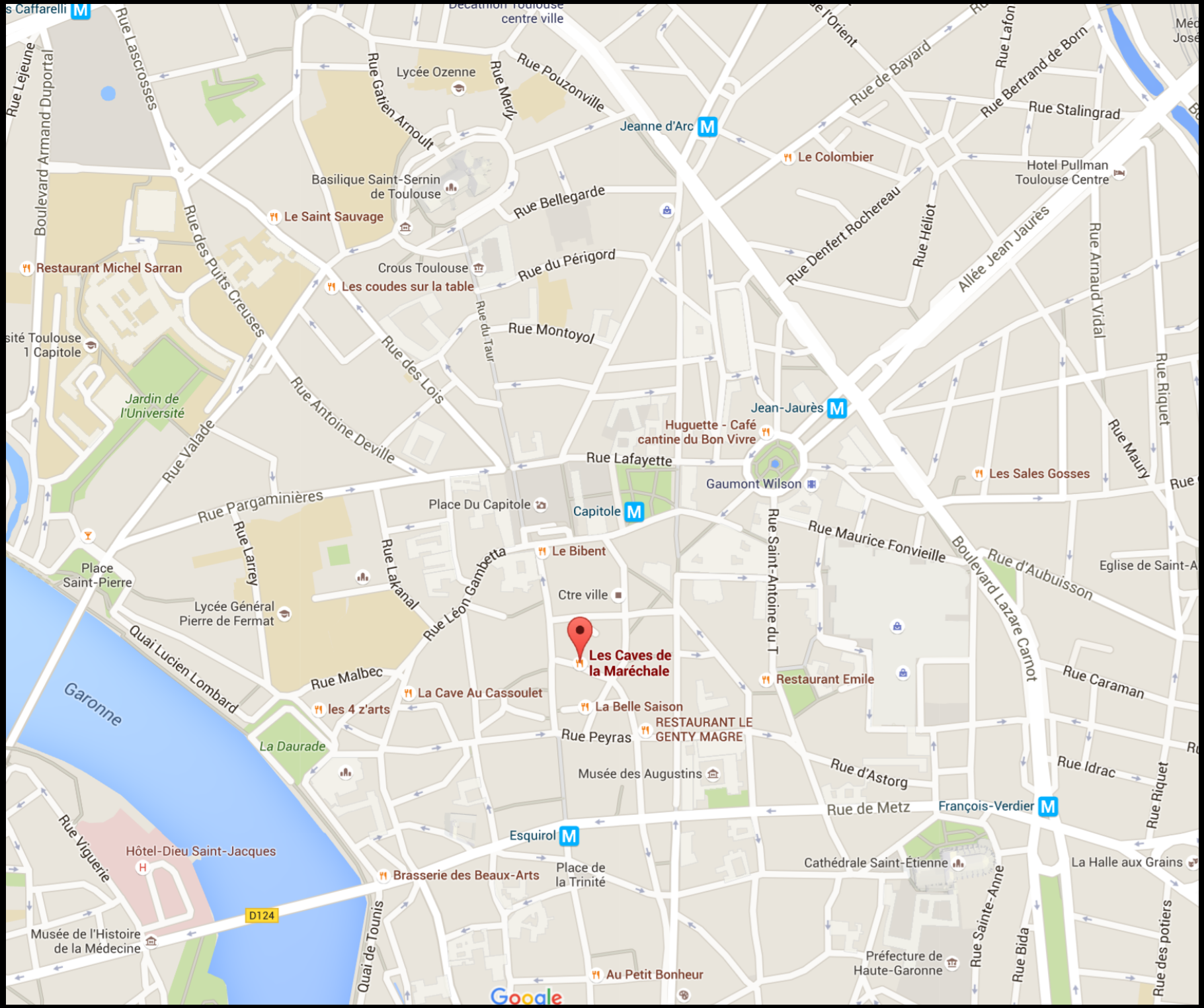
  $\Longrightarrow$ What do you need?

  $\Longrightarrow$ What is missing?

  $\Longrightarrow$ How can we meet?

Agenda

09:00–09:30	JW: Overview e2e simulations (SIXTE, Simput)
09:30–09:50	Brief introduction of everybody
09:50–10:10	TD: WFI
10:10–10:30	PP: X-IFU
10:30–11:00	**Coffee**
11:00–12:00	Session I: Basic Simulations
12:00–13:00	**Break for Lunch**
13:00–13:15	Carpano: Occultations
13:15–16:00	Session II: special topics
	PP: group I: clusters, extended sources
	TD: group II: wide field surveys
	JW: group III: variability, X-ray analysis
16:00–16:30	**Coffee**
16:30–17:30	Session II: continued
17:30–18:00	**Feedback**
20:00–	**conference dinner**: Les Caves de la Maréchales



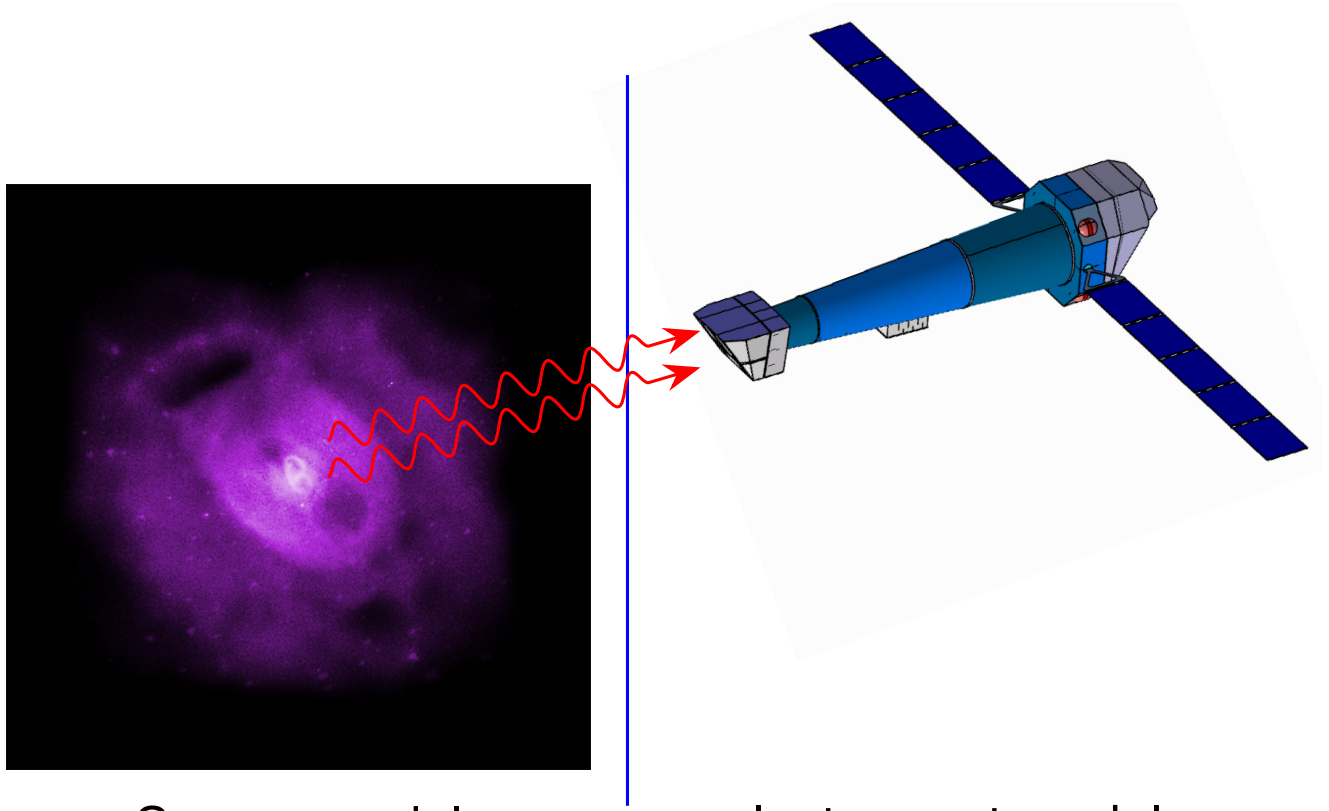
Les Caves de la Maréchale
Jeanne d'Arc
Le Colombier
Hotel Pullman Toulouse Centre
Lycée Ozenne
Basilique Saint-Sernin de Toulouse
Le Saint Sauvage
Restaurant Michel Sarran
Crous Toulouse
Les coudes sur la table
Jardin de l'Université
Jean-Jaurès
Huguette - Café cantine du Bon Vivre
Gaumont Wilson
Les Sales Gosses
Place Du Capitole
Capitole
Le Bibent
Place Saint-Pierre
Lycée Général Pierre de Fermat
Ctre ville
Restaurant Emile
La Cave Au Cassoulet
les 4 z'arts
La Belle Saison
RESTAURANT LE GENTY MAGRE
La Daurade
Musée des Augustins
François-Verdier
Esquirol
Hôtel-Dieu Saint-Jacques
Brasserie des Beaux-Arts
Place de la Trinité
Cathédrale Saint-Étienne
La Halle aux Grains
Musée de l'Histoire de la Médecine
Préfecture de Haute-Garonne
Au Petit Bonheur
Garonne
Rue Lascrosses
Rue Lejeune
Boulevard Armand Duportal
Rue Gatien Arnoult
Rue Merly
Rue Pouzonville
Rue de Bayard
Rue Bertrand de Born
Rue Stalingrad
Rue Bellegarde
Rue des Puits Creuses
Rue du Périgord
Rue Montoyol
Rue du Taur
Rue des Lois
Rue Antoine Deville
Rue Valade
Rue Pargaminières
Rue Larrey
Rue Lakanal
Rue Léon Gambetta
Rue Saint-Antoine du T
Rue Maurice Fonvieille
Boulevard Lazare Carnot
Rue d'Aubuisson
Rue Caraman
Rue Idrac
Rue Riquet
Rue Maury
Rue Arnaud Vidal
Allée Jean Jaurès
Rue Héliot
Rue Denfert Rochereau
Rue Lafayette
Rue Malbec
Quai Lucien Lombard
Rue Peyras
Rue d'Astorg
Rue de Metz
Rue Viguerie
Quai de Tounis
Rue Sainte-Anne
Rue Bida
Rue des potiers
D124
Google

Agenda

09:00–10:00	TD: Bright sources with the WFI
10:00–10:30	JW: TES simulations
10:30–11:00	**Coffee**
11:00–11:30	PP: Bright sources with X-IFU
11:30–12:00	JW/TD/PP: eROSITA, XMM-Newton, Suzaku,. . .
12:00–12:30	Suggestions for further developments
12:30–13:30	**Break for Lunch**
afternoon	possibility for further discussions, questions, simulations. . .

This is a workshop – please ask questions, voice your disagreements, express your praise. . .

Modeling



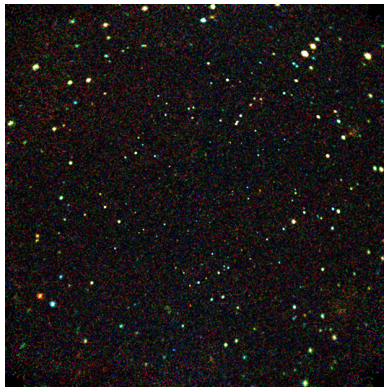
Source model | Instrument model

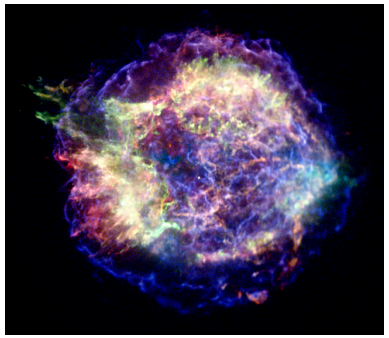
Source model: Define properties of the sources: Positions, Extended source/point source, spectral shape, variability,. . .

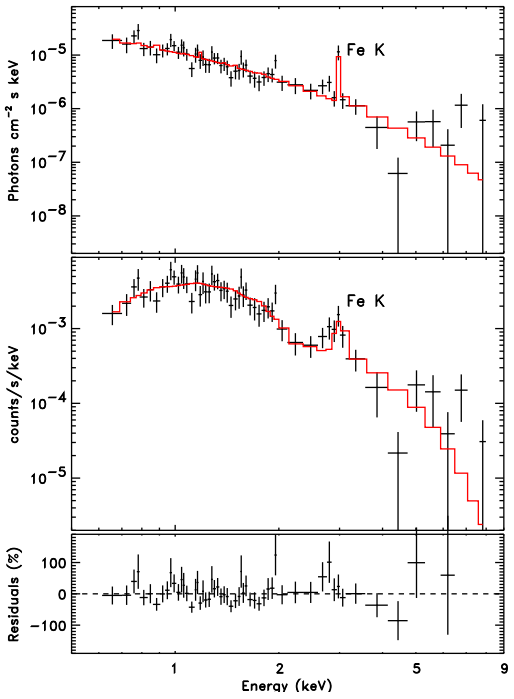
Instrument model Define properties of the instrument: Imaging parameters, detection process, data processing chain

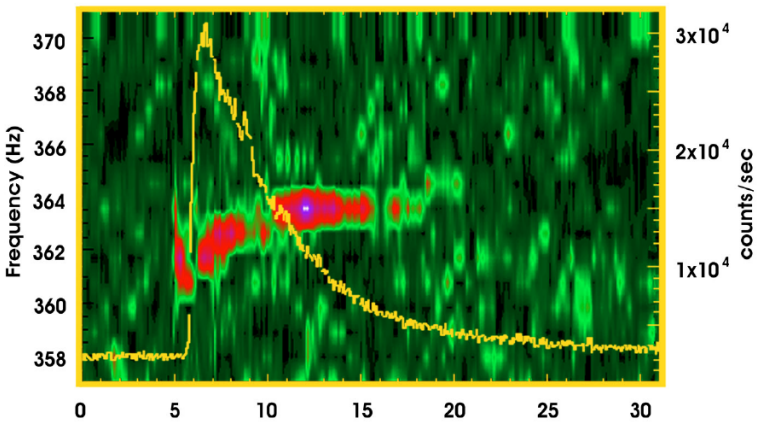
Output: Data that can be analyzed using standard astronomical analysis software (FTOOLS, XMM-SAS, XSPEC, ISIS,. . .)

Source description









Real sources are characterized by:

- position: (α, δ)
- spectral shape: $F(E)$
- flux distribution: $F(\alpha, \delta, E)$
- variability: $F(\alpha, \delta, t, E)$
- foreground absorption: $N_{\mathrm{H}}(\alpha, \delta)$

Aim for e2e:

- be as close as possible to reality

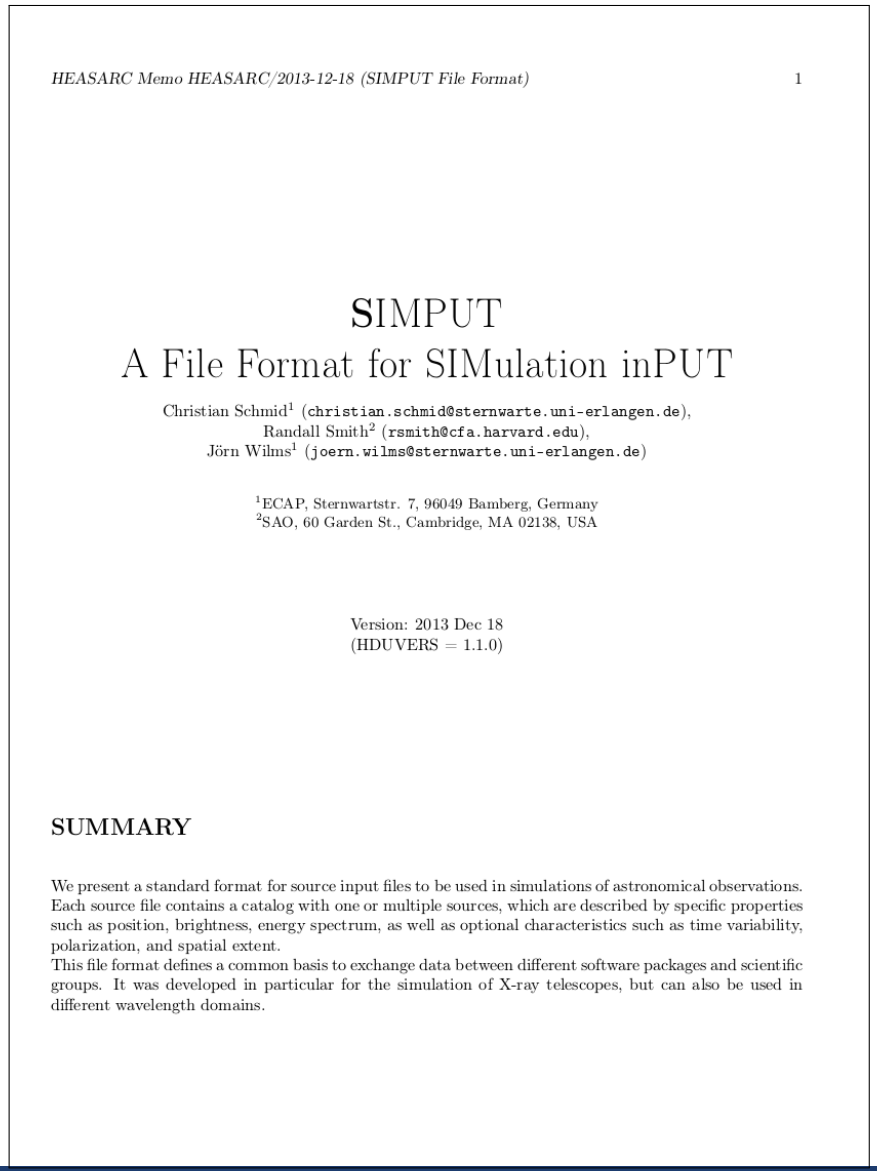
  no artificial limitations on source spectral shape, images, etc.

- be compatible w/other simulators

  reached with `simx` and `MARX`), unfortunately not with `heasim`.

$\Longrightarrow$ SIMPUT

Source description



HEASARC Memo HEASARC/2013-12-18 (SIMPUT File Format) 1

SIMPUT
A File Format for SIMulation inPUT

Christian Schmid[1] (christian.schmid@sternwarte.uni-erlangen.de),
Randall Smith[2] (rsmith@cfa.harvard.edu),
Jörn Wilms[1] (joern.wilms@sternwarte.uni-erlangen.de)

[1]ECAP, Sternwartstr. 7, 96049 Bamberg, Germany
[2]SAO, 60 Garden St., Cambridge, MA 02138, USA

Version: 2013 Dec 18
(HDUVERS = 1.1.0)

SUMMARY

We present a standard format for source input files to be used in simulations of astronomical observations. Each source file contains a catalog with one or multiple sources, which are described by specific properties such as position, brightness, energy spectrum, as well as optional characteristics such as time variability, polarization, and spatial extent.
This file format defines a common basis to exchange data between different software packages and scientific groups. It was developed in particular for the simulation of X-ray telescopes, but can also be used in different wavelength domains.

Data format describing source: SIMPUT

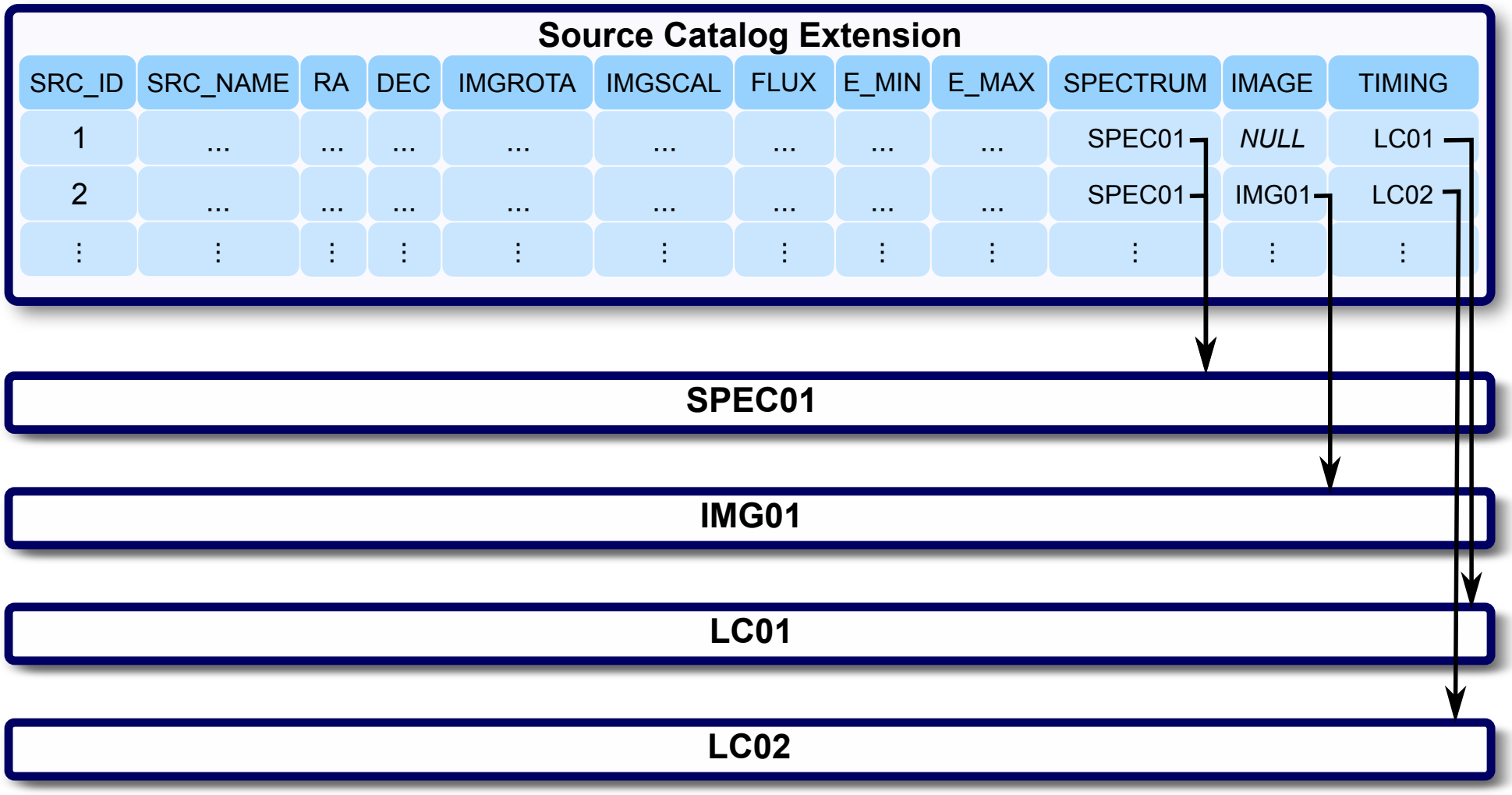
Formal description: FITS Standard Document:

`http://hea-www.harvard.edu/HEASARC/formats/simput-1.1.0.pdf`

- catalogs with arbitrary number of sources
- characterization of sources:
  - spectra
  - positions
  - light curves, pulse profiles, power spectra...
  - spatial extent
  - photon lists from MHD simulations
  - "data cubes"
- format allows reuse of common properties of sources

  e.g., reuse AGN spectra for multiple sources, reuse images of extended sources,...

Source description



Structure of source catalogue: reuse of common source properties possible

Source description

Library and tools to build SIMPUT files:

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

Library also contains tools to generate SIMPUT files:

- `simputfile`: generate SIMPUT file for one source

  Inputs are source position, flux spectral shape (XSPEC or ISIS par, ASCII), lightcurve, FITS image, PSD parameters, foreground absorption.

- `simputmultispec`, `simputmulticell`: powerful tools: generate SIMPUT for extended source w/spatial variation of spectral parameters
- `simputmerge`: Merge different SIMPUT catalogues

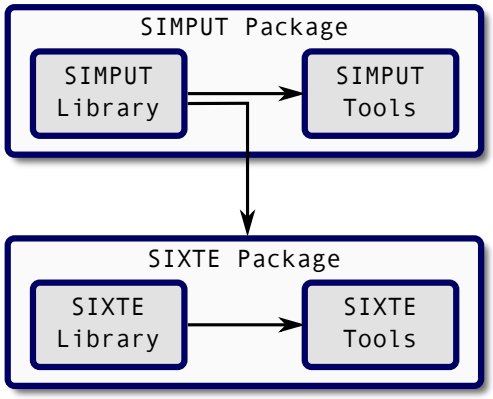
Helpers:

- `galabs`: Add galactic absorption from LAB-catalogue to SIMPUT catalogue
- `simputrotate`: rotate images in a SIMPUT file

  e.g., generate different sources from smaller source image catalogue

still to develop: `simputselect`

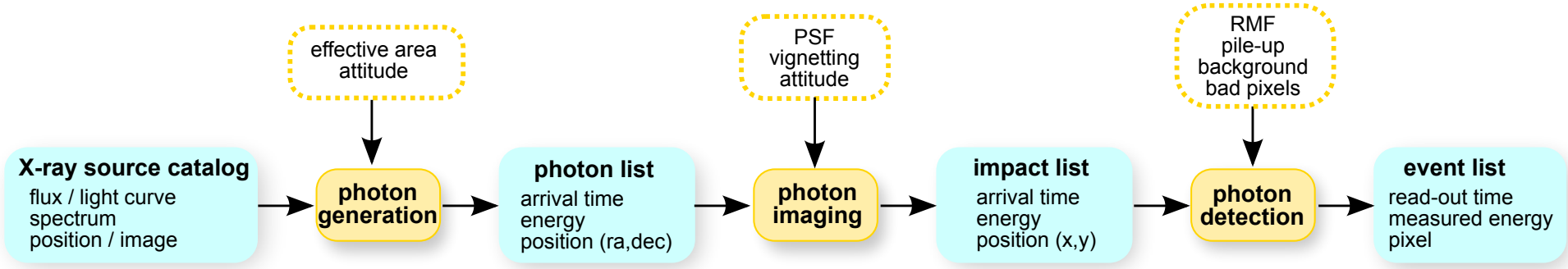
SIXTE



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

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

- modular software $\rightarrow$ reuse existing algorithms for multiple detectors



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

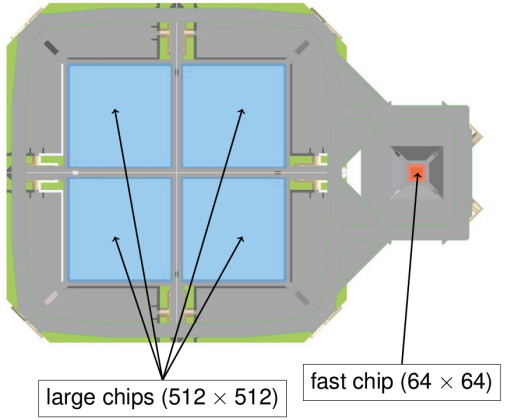
$\Longrightarrow$ *one* simulator for science & technology development

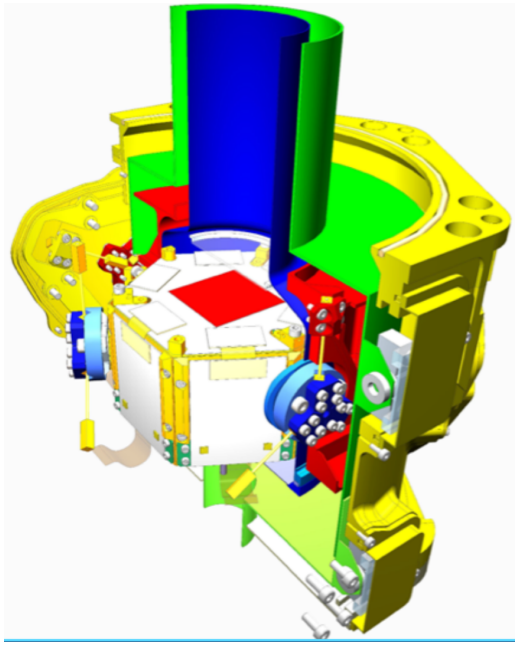
Instrument model

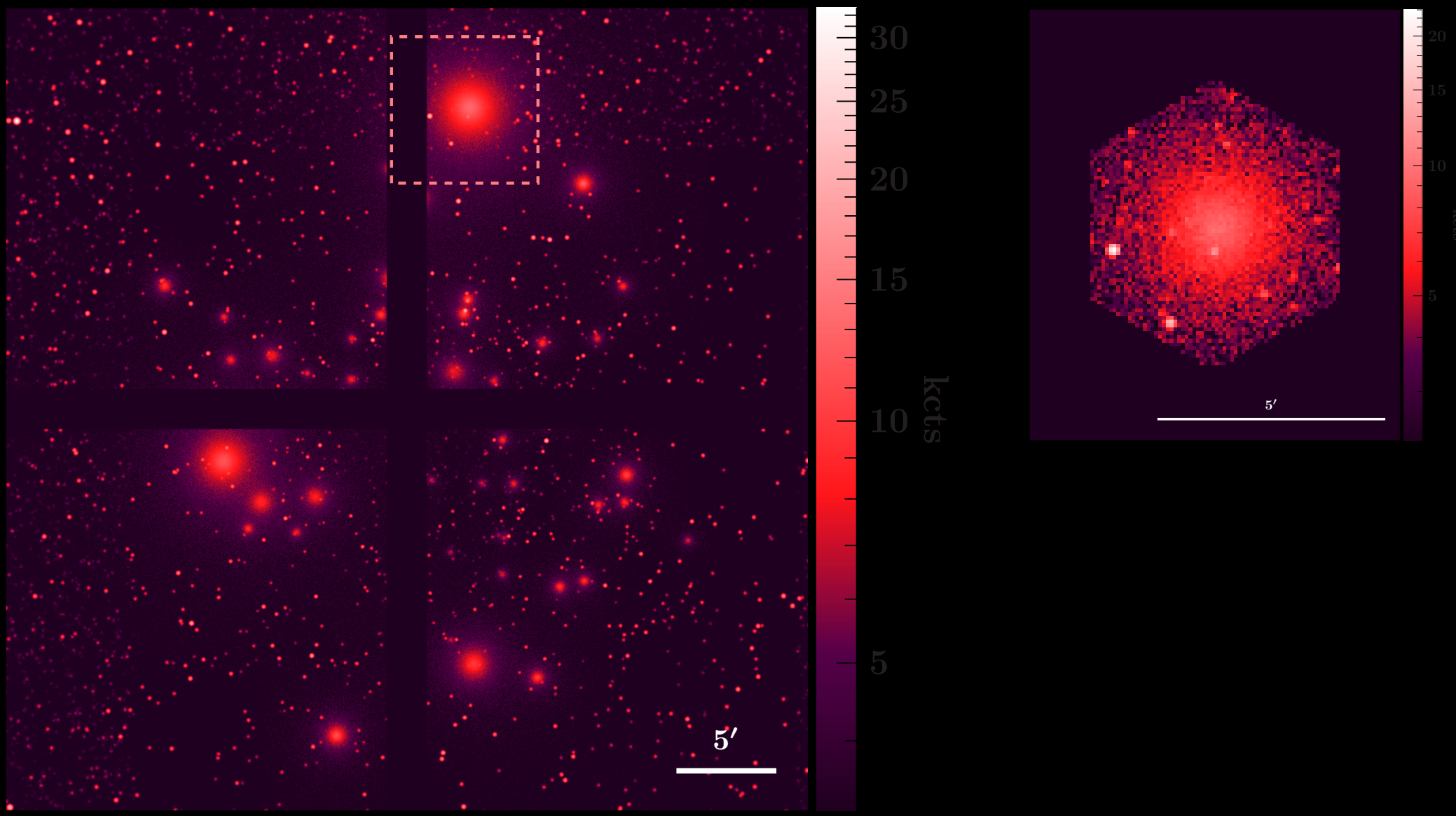
- Telescope model
  - pointing (attitude, e.g., for dithering)
  - ARF
  - vignetting
  - PSF
- Instrument model
  - device simulator:
    - simple/fast simulation: RMF sampling
    - advanced simulation: physics
      (e.g., $T(t)$ for X-IFU, photon effects in Si for WFI)

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

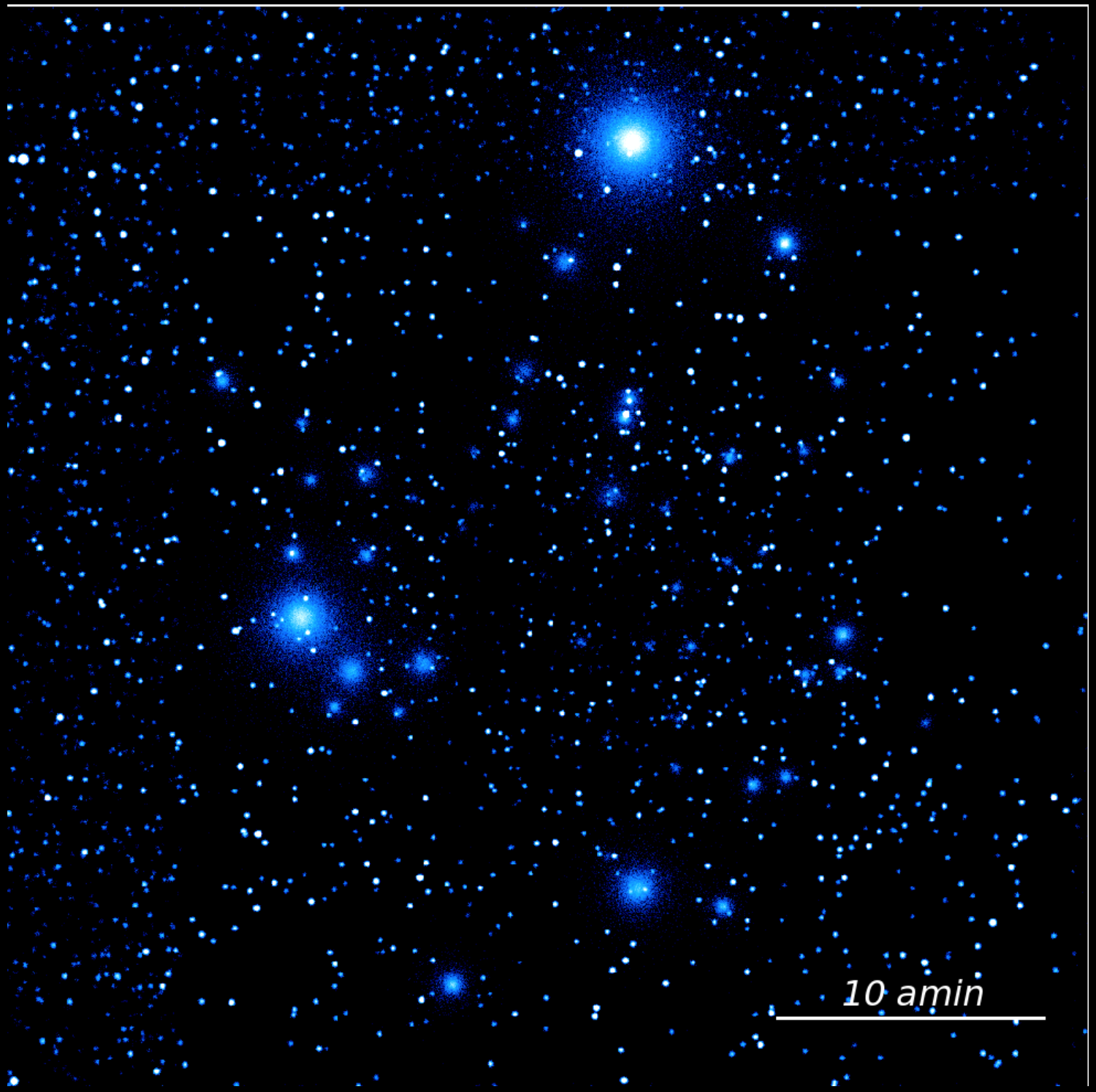
$\Longrightarrow$ Talks by T. Dauser and P. Peille



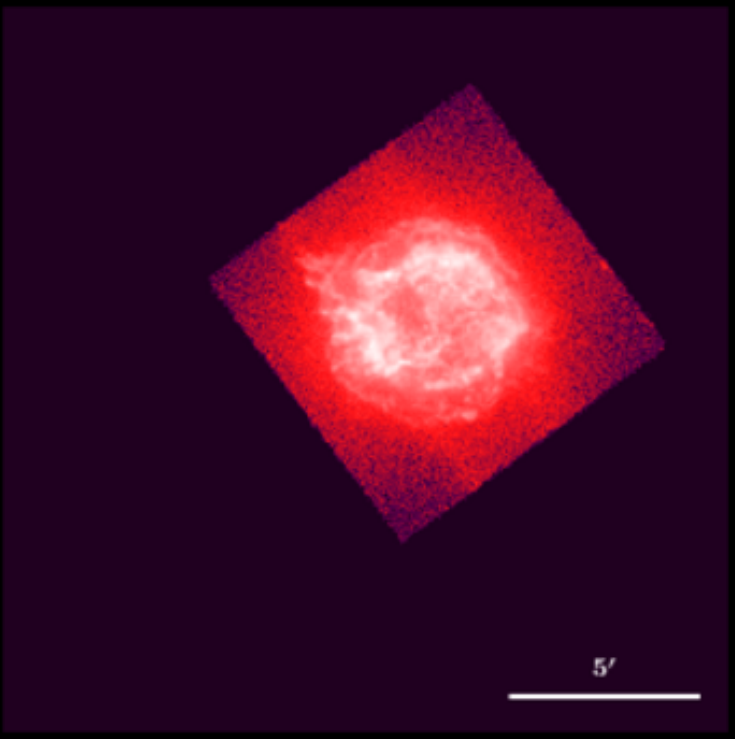




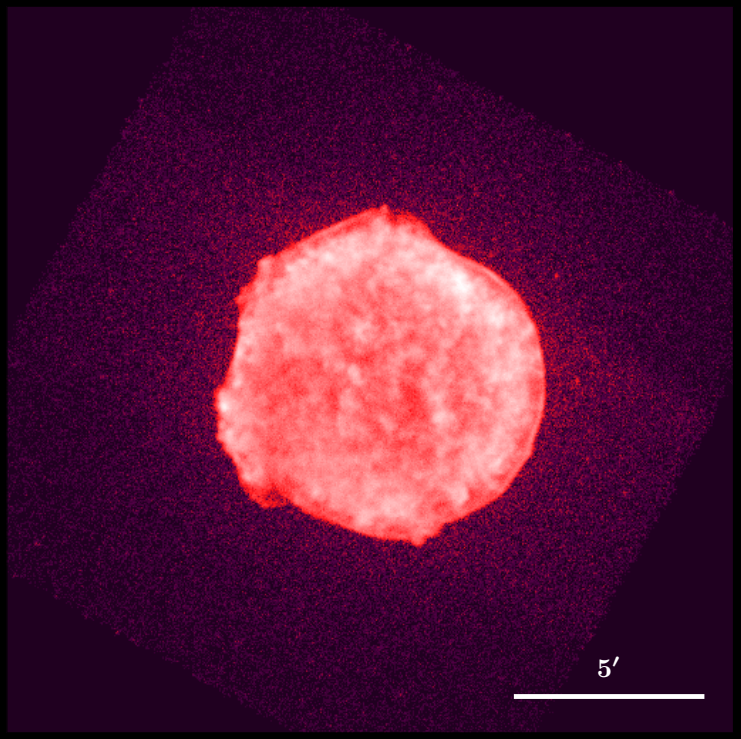
WFI and X-IFU simulations of the Chandra Deep Field South, based on the CDFS source catalogue (T. Brand/T. Dauser)



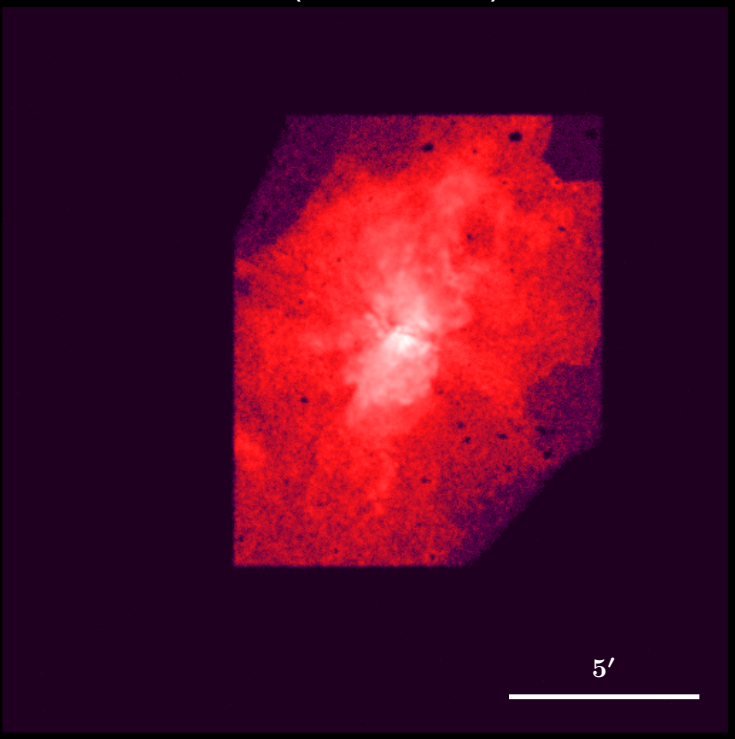
Chandra deep field south with the WFI w/dither (A. Rau/T. Dauser)



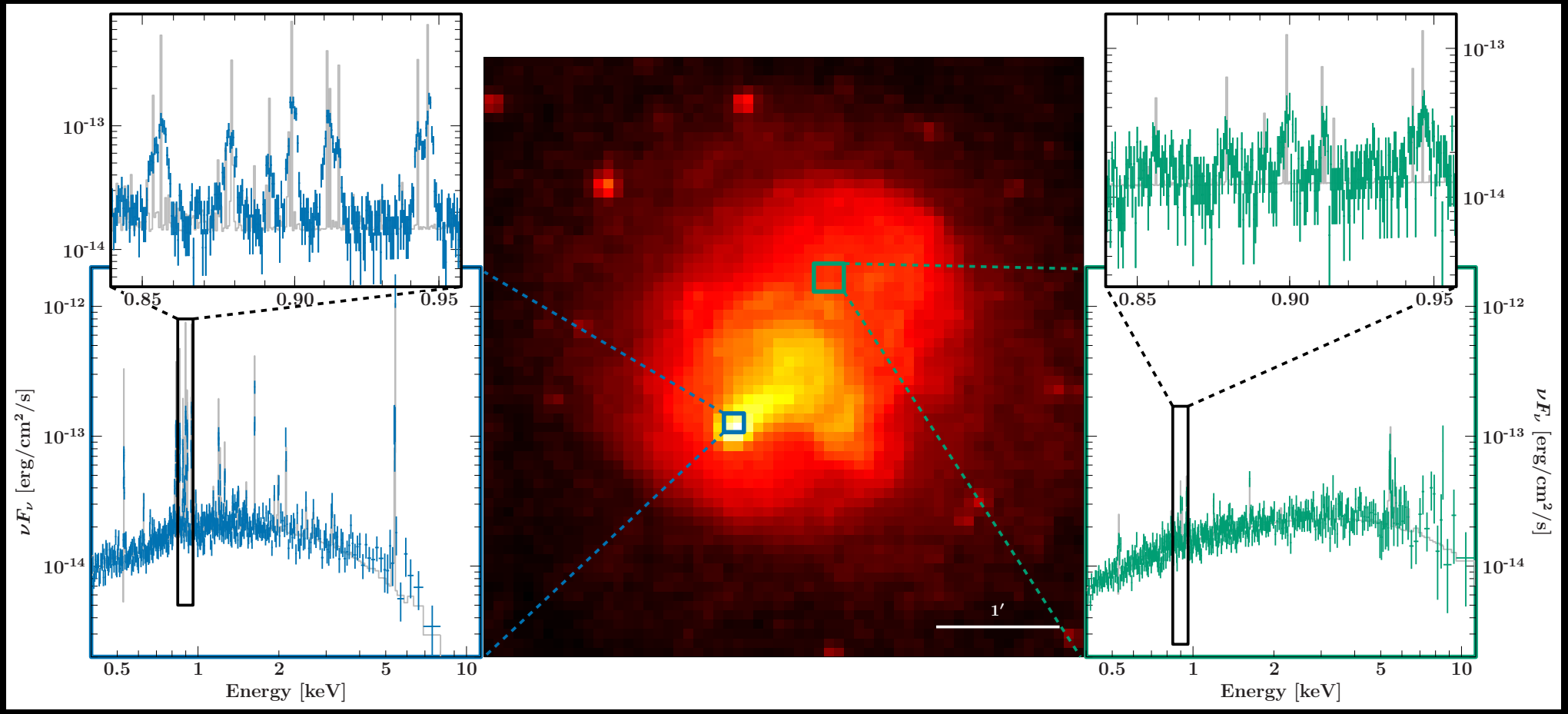
Cas A (WFI, 1 ks)



Tycho (WFI, 1 ks)

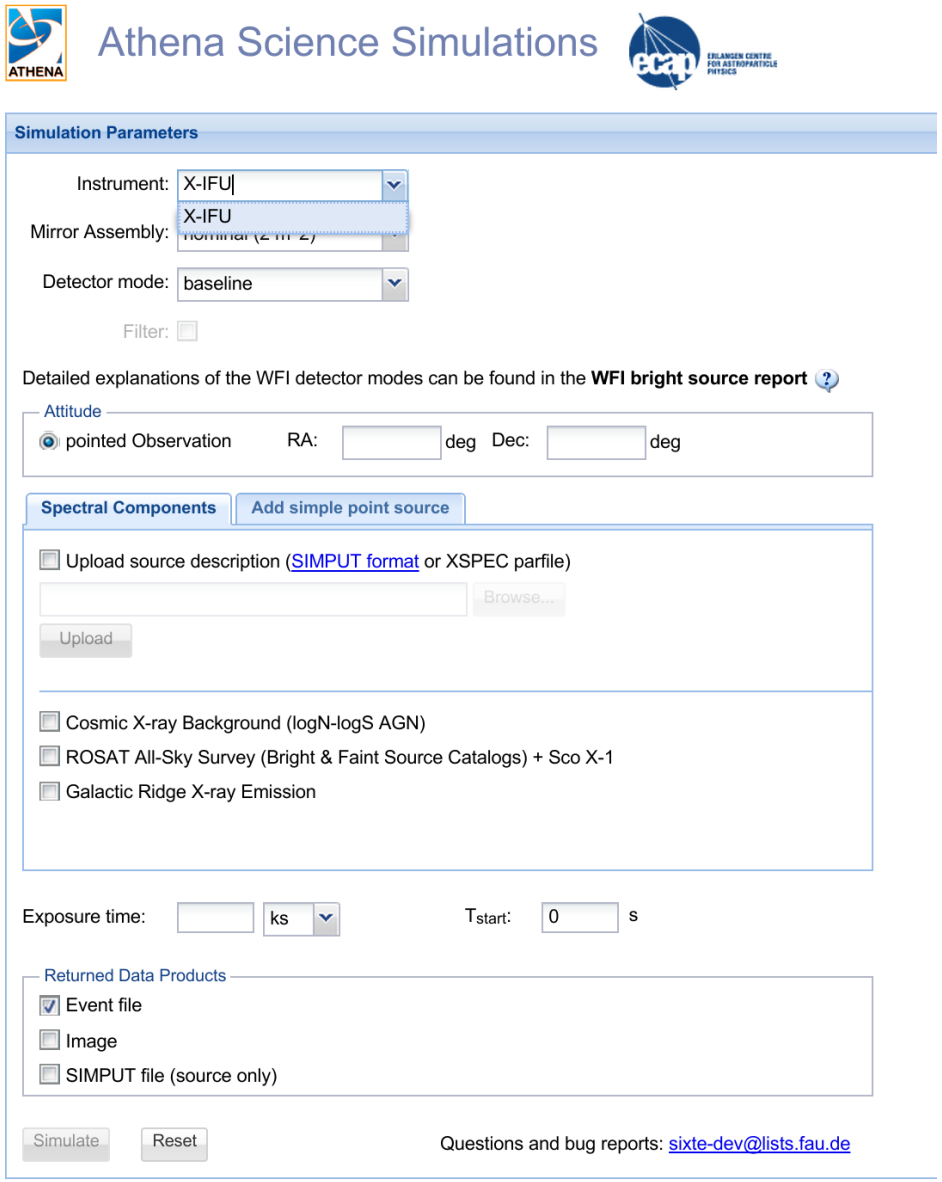


M 82 (WFI, 100 ks)



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

WWW



Access:

- Source code: `http://www.sternwarte.uni-erlangen.de/research/sixte/index.php`.
  Works on Linux and Mac, git and release versions.
- WWW interface: `http://hydrus.sternwarte.uni-erlangen.de/~athenasim/`.

Open Issues

Compared to other missions, we're already in an extremely good position!

- Finalize initial X-IFU and WFI models:
  - WFI: physics based model for photon interaction
  - X-IFU: finish physics based model
- Further SIMPUT, SIXTE tools
  - `simputselect`
  - particle background
  - ray tracer?
- documentation: first draft manual available
- Further improvements on WWW pages
- Develop higher level scripts for common tasks
- Tomorrow: brain storming session