Practical 3 – Observatory Science

Athena School — June 2022, Toulouse

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

WFI ATHENA

X-IFU ATHENA X-ray Integral Field Unit

Introduction

The simulations in this session will cover a small subset of sources in the Observatory Science theme.
This session will not show any dramatically new observation techniques, but will rather focus on building more complex SIMPUT files.

We will be looking at the supernova remnant Cas A and at Jupiter, as well as a photon list SIMPUT.

As a general note: in each folder, there are also instructions in a `README.txt` file.

Part 1: Cas A

You can find the scripts in the `day3_CasA` folder in the simulation package.

In this example, the SIMPUT has already been generated, as running the script takes a long time.

It is generated from a 3D parameter map of Cas A, provided by Fabio Acero from CEA Saclay.

RA	DEC	nH	T	Z	TAU	Abundanc	FLUX
E	E	E	E	E	E	E	E
degrees	degrees	cm-2	keV		s/cm3		ergs/cm2/keV/s
Modify	Modify	Modify	Modify	Modify	Modify	Modify	Modify
3.509506E+02	5.883988E+01	1.300000E+00	1.393851E-01	-3.377486E-03	1.810712E+08	2.000000E+00	3.629959E-21
3.509602E+02	5.881832E+01	1.300000E+00	1.076827E-01	-1.564921E-03	6.031767E+08	2.000000E+00	5.351583E-22
3.509602E+02	5.881832E+01	1.300000E+00	4.213666E-01	-4.760067E-03	4.733534E+09	2.000000E+00	1.282365E-17
3.509555E+02	5.882523E+01	1.300000E+00	1.886990E-01	-6.135592E-03	1.406432E+08	2.000000E+00	6.185347E-20
3.509555E+02	5.882523E+01	1.300000E+00	3.251365E-01	-7.435357E-03	8.696628E+08	2.000000E+00	1.716798E-18
3.509555E+02	5.882523E+01	1.300000E+00	3.397128E-01	-8.585960E-03	1.118034E+09	2.000000E+00	2.778826E-18
3.509555E+02	5.882523E+01	1.300000E+00	1.968089E-01	-6.756530E-03	1.105729E+08	2.000000E+00	8.083437E-20
3.509539E+02	5.882754E+01	1.300000E+00	2.441042E-01	-7.867521E-03	2.123915E+08	2.000000E+00	3.337707E-19
3.509539E+02	5.882754E+01	1.300000E+00	4.051426E-01	-9.803275E-03	1.127202E+09	2.000000E+00	6.481635E-18
3.509539E+02	5.882754E+01	1.300000E+00	1.026066E+00	-1.892889E-02	7.991647E+09	2.000000E+00	1.268505E-15
3.509539E+02	5.882754E+01	1.300000E+00	7.935182E-01	-1.693629E-02	4.307802E+09	2.000000E+00	2.629390E-16
3.509539E+02	5.882754E+01	1.300000E+00	3.682517E-01	-9.430836E-03	6.039309E+08	2.000000E+00	3.110976E-18
3.509539E+02	5.882754E+01	1.300000E+00	2.709764E-01	-7.892492E-03	3.398940E+08	2.000000E+00	4.803484E-19
3.509524E+02	5.882985E+01	1.300000E+00	3.246770E-01	-9.113534E-03	4.086700E+08	2.000000E+00	1.472619E-18
3.509524E+02	5.882985E+01	1.300000E+00	4.802680E-01	-1.090742E-02	1.420144E+09	2.000000E+00	1.546444E-17
3.509524E+02	5.882985E+01	1.300000E+00	9.933510E-01	-1.963743E-02	7.604997E+09	2.000000E+00	1.193320E-15
3.509524E+02	5.882985E+01	1.300000E+00	9.482511E-01	-1.866863E-02	6.414952E+09	2.000000E+00	7.651323E-16
3.509524E+02	5.882985E+01	1.300000E+00	4.801316E-01	-1.033269E-02	1.487593E+09	2.000000E+00	1.408454E-17
3.509524E+02	5.882985E+01	1.300000E+00	3.016959E-01	-8.323169E-03	4.305431E+08	2.000000E+00	9.201402E-19
3.509524E+02	5.882985E+01	1.300000E+00	1.696204E-01	-4.953873E-03	2.009179E+08	2.000000E+00	2.063451E-20

Part 1: Cas A

To see how it is generated, look at the `simput` subdirectory. Here, we make use of the tool `simputmulticell`.

This tool takes as input a list of sky positions and associated parameter values, which the user must map to parameters in a spectral model (in this case, xcm) file.

The tool then generates spectra on a parameter grid and creates one SIMPUT source for each sky cell, assigning the closest matching spectrum to it.

In this particular case, we vary the plasma temperature, ionization timescale and redshift.

Part 1: Cas A

You can then observe the source and extract spectra using the provided bash scripts.
The procedure is the same as for the galaxy cluster on day 1 – you can also select your own regions.

One thing you might see, especially when observing with the WFI, is that the source is spatially undersampled – it does not look like one extended source, but a collection of point sources.
This SIMPUT is still in development – the grid sampling still needs to be optimized.

Part 1: Cas A

Optional simulation: The exposure time chosen above is rather short (because Cas A is very bright - otherwise the simulations will take very long).

While you can see a lot of detail in the soft band, one interesting component we miss this way is the iron line at 6.4 keV – we would need longer exposures for this, but we would get a lot of low energy counts we don't care about.

However, you can use the Be filter to ignore those! Rerun a longer simulation with it, and examine the iron line.

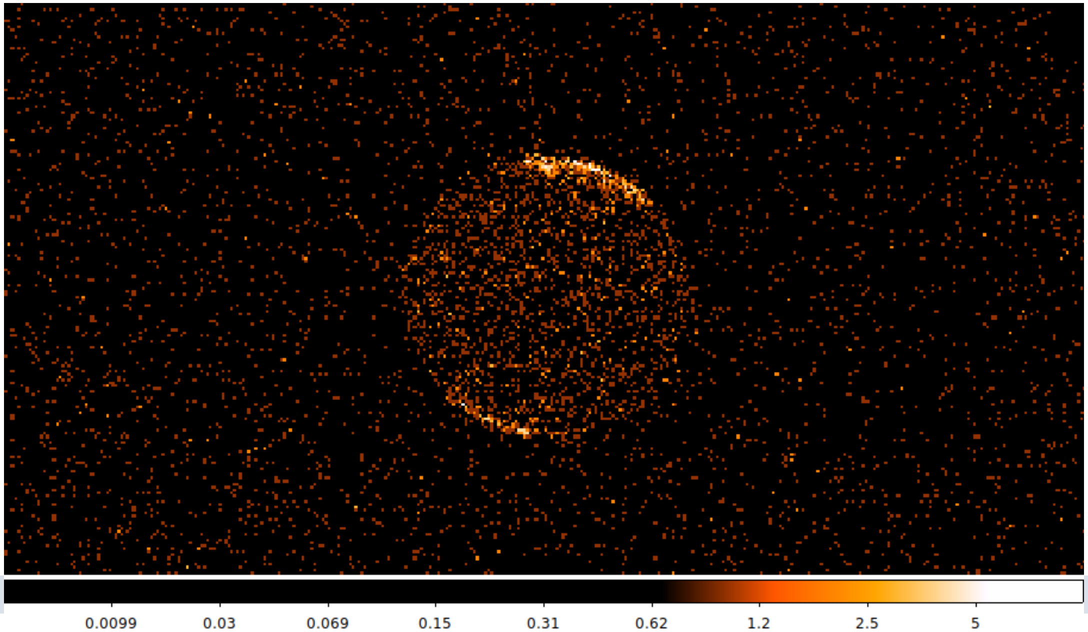
Part 2: Jupiter

You can find the scripts in the `day3_jupiter` folder in the simulation package.

In this exercise, we look at a multi-component extended source, namely Jupiter with auroral emission.

The image data is based on a 2011 Chandra observation, models were fit to XMM-Newton RGS data from 2003.

Input data was provided by Graziella Branduardi Raymont, University College London



Part 2: Jupiter

The source generation works in two steps, both in the `simput` subfolder:

First, we need to define our emission regions. This is done in the interactive Python notebook `1_emission_regions.ipynb`. We will look at it live.

Once the emission regions are defined, we use `2_make_catalog.sh` to create two individual SIMPUT files and merge them.

Once this is done, you can observe the source and extract the spectra as before.
Unlike the RGS, the X-IFU can actually resolve the emission components spatially! The WFI can better separate those regions than the X-IFU on account of its smaller pixels.

Part 3: Photon lists

See Edoardo's live demo

Setting up your own simulations

You have now seen several example simulations related to Athena.

To run your own simulations, you need to build your own SIMPUTs.
Some resources for this and SIXTE in general are:

- The SIXTE manual under
  `https://www.sternwarte.uni-erlangen.de/sixte/`
- The last SIXTE workshop, with recordings and slides under
  `https://indico.ifca.es/event/2552/`
- The `sixte-support` mailing list

Additionally, you can use the scripts provided to you in this school as a base to create your own SIMPUTs.

Note: If you want to keep using SIXTE, you should subscribe to the SIXTE users mailing list for information about updates and bugfixes. See `https://www.sternwarte.uni-erlangen.de/sixte/contact/`

When to use SIXTE

There are some cases where you won't need to use SIXTE for your science case, but most of the time it is worth it:

When not to use SIXTE

but `fakeit` or similar tools

- fainter point sources ($\lesssim 1\,\mathrm{mCrab}$)
  $F_{0.5-2\,\mathrm{keV}} = 10^{-11}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$,
  $F_{2-10\,\mathrm{keV}} = 2 \cdot 10^{-11}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$
  unless background starts to become important
- quick estimates

When to use SIXTE

and *not* `fakeit` or similar tools

- bright sources ($\gtrsim 10\,\mathrm{mCrab}$)
  i.e. many "famous" AGN
- faint sources if background or exposure map matters
- imaging simulations
  - point source detections sensitivity
  - point sources in crowded fields
  - extended sources
- variability simulations
  e.g., reverberation mapping, pulsations, QPOs,. . .