3ML

The Multi-Mission Maximum Likelihood framework

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Docker

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  1. **Install Docker for your platform.**
     1. **https://docs.docker.com/install/**
     2. **Installers for OsX and Windows provided in the USB pen**
  2. **Install the threeml docker file**
     1. **Due to slow network there is a threeML-docker.zip in the USB pen containing the docker image and all the files you need to run this tutorials. Expand the archive, and go into the threeML-docker directory:**

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```
To access the notebook, open this file in a browser:
        file:///root/.local/share/jupyter/runtime/nbserver-64-open.html
    Or copy and paste one of these URLs:
        http://(10728d6cdbaa or 127.0.0.1):8888/?token=12f470d746a0c90ed5f78f7f1047bc8c6ed3397517d6c0c8
```

```
> open http://127.0.0.1:8888/?token=12f470d746a0c90ed5f78f7f1047bc8c6ed3397517d6c0c8
```

Agenda

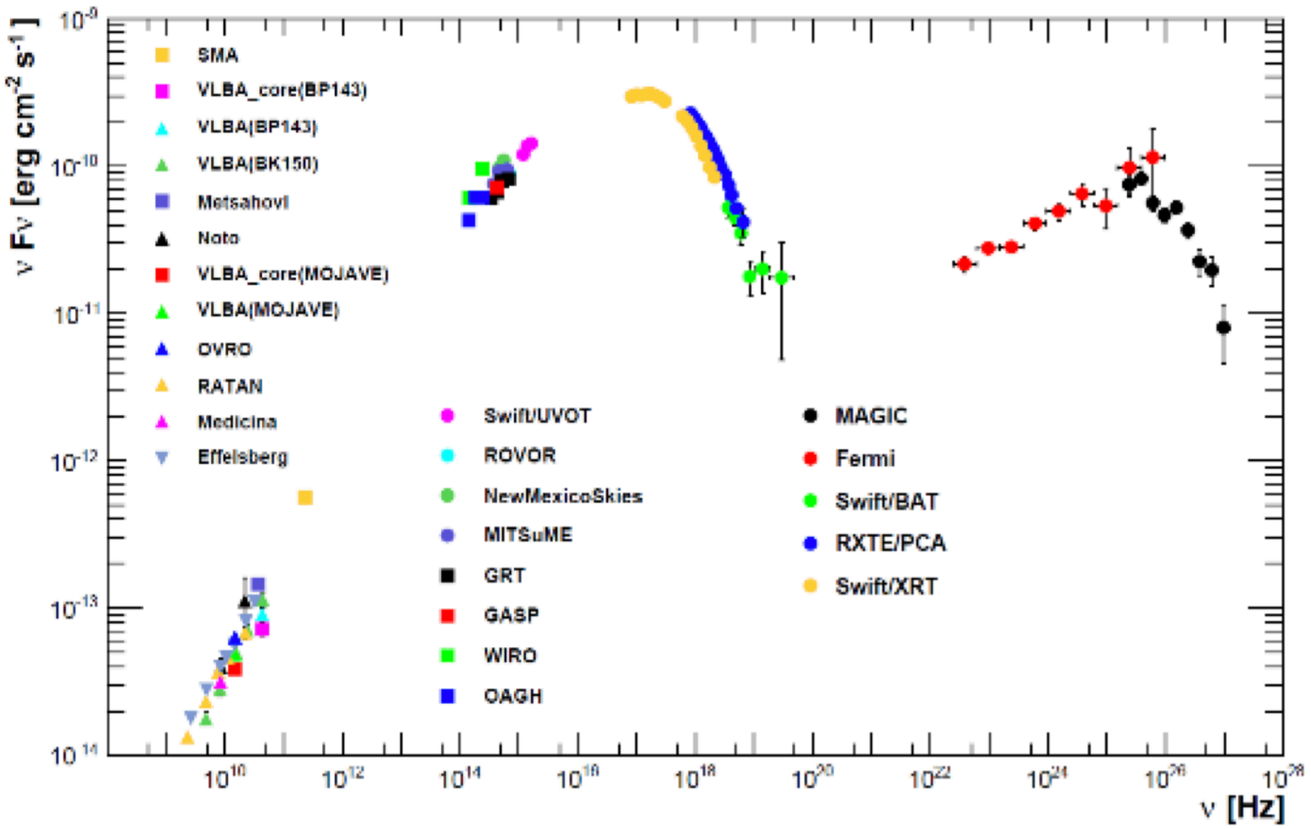
- **Introduction to 3ML**
  - General idea
  - Installation
- **Tutorials**
  - LAT Only analysis (interface to fermipy)
  - GRB080916C: LAT+LLE+GBM
  - GRB190114C: LAT+GBM+LLE+XRT

What's on the market

- **Existing multi-instrument solutions:**
  - **XSPEC, GSPEC, RMFIT, ISIS, SHERPA, gammapy, gammalib,…**
    - **Good for instruments that share the same analysis and with data in the same data-format (OGIP)**
    - **They re-implement analysis tools (missing the opportunity to use up-to-date software developed by various instrument teams)**
  - **Not all instrument can be reconnected to the same analysis (One size does not fit all!)**

Spectral Energy Distribution

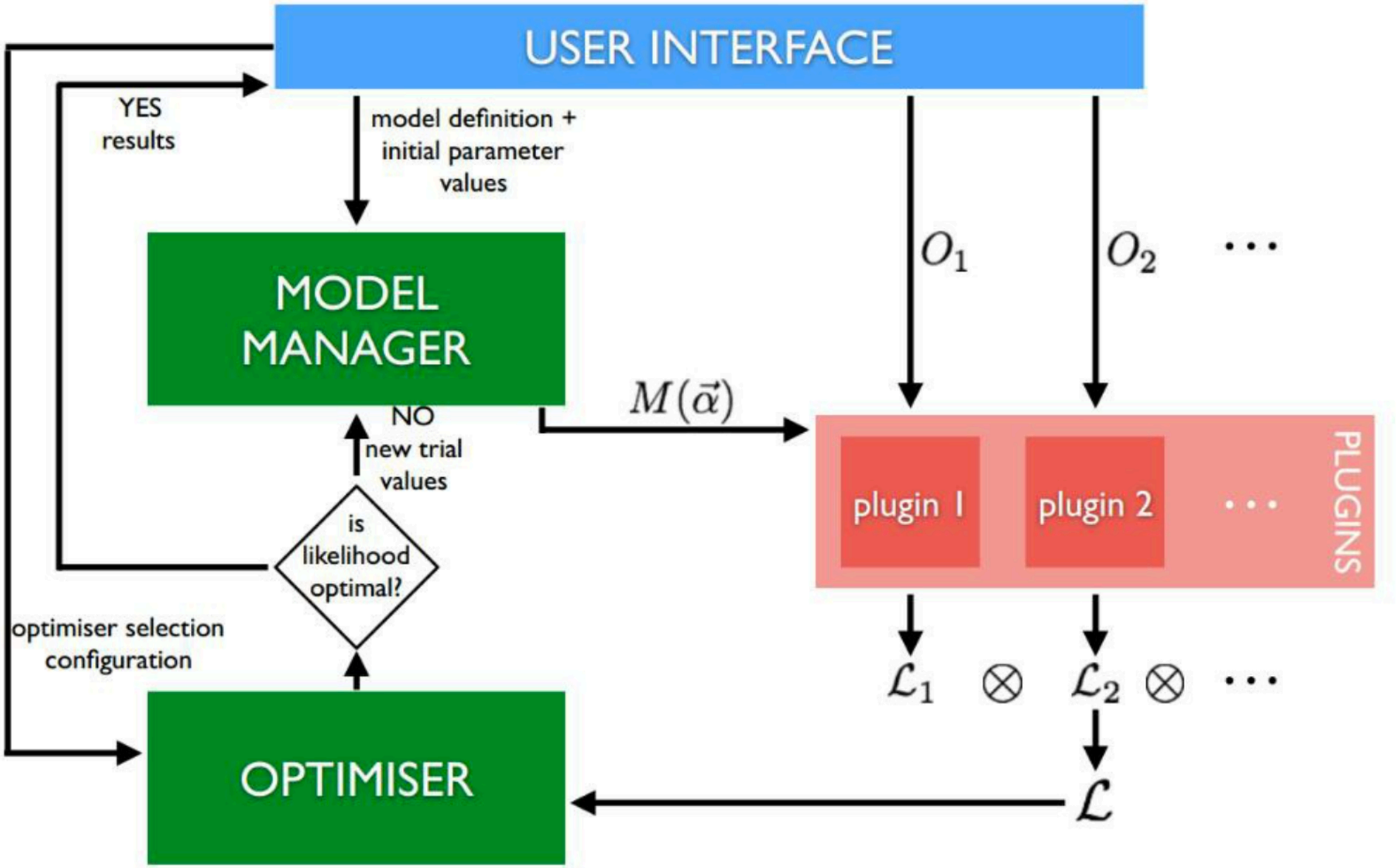
- **Each instrument makes its own analysis, optimizing the model (often different) and provide a "butterfly" or flux points**
  - **The spectrum of the source is independently fit by every instrument, and not globally fitted**
  - **A chi^2 fit is done on the resulting flux points (or butterflies). Now the source model is not the same that was used to fit the data in the first place…**
- **Not really rigorous way to analyze the data.**
  - **unfortunately widely used in our community…**



3ML is different

- **Better solution for multi-instrument fits**
  - The parameters of the models are globally marginalized (each instrument participate with its strength)
  - There are instrument specific background (instruments have different backgrounds) that are fitted independently
  - One definition of the model (parameters of the source are fitted taking the likelihood values from every dataset in the fit).
- **The software provides an interface to the model manager, which interacts, using plugins, with the existing software developed by the various instrument teams**
  - Receive input the model, return the value of the likelihood…
- **Extreme flexible:**
  - No limitation on the analysis implemented, language used, messenger, IRFS, background.
  - python plugins interface with any type of code developed by the instrument team
  - Existing solutions (Science Tools, XSPEC, sherpa,…) can be used as plugin.

3ML architecture

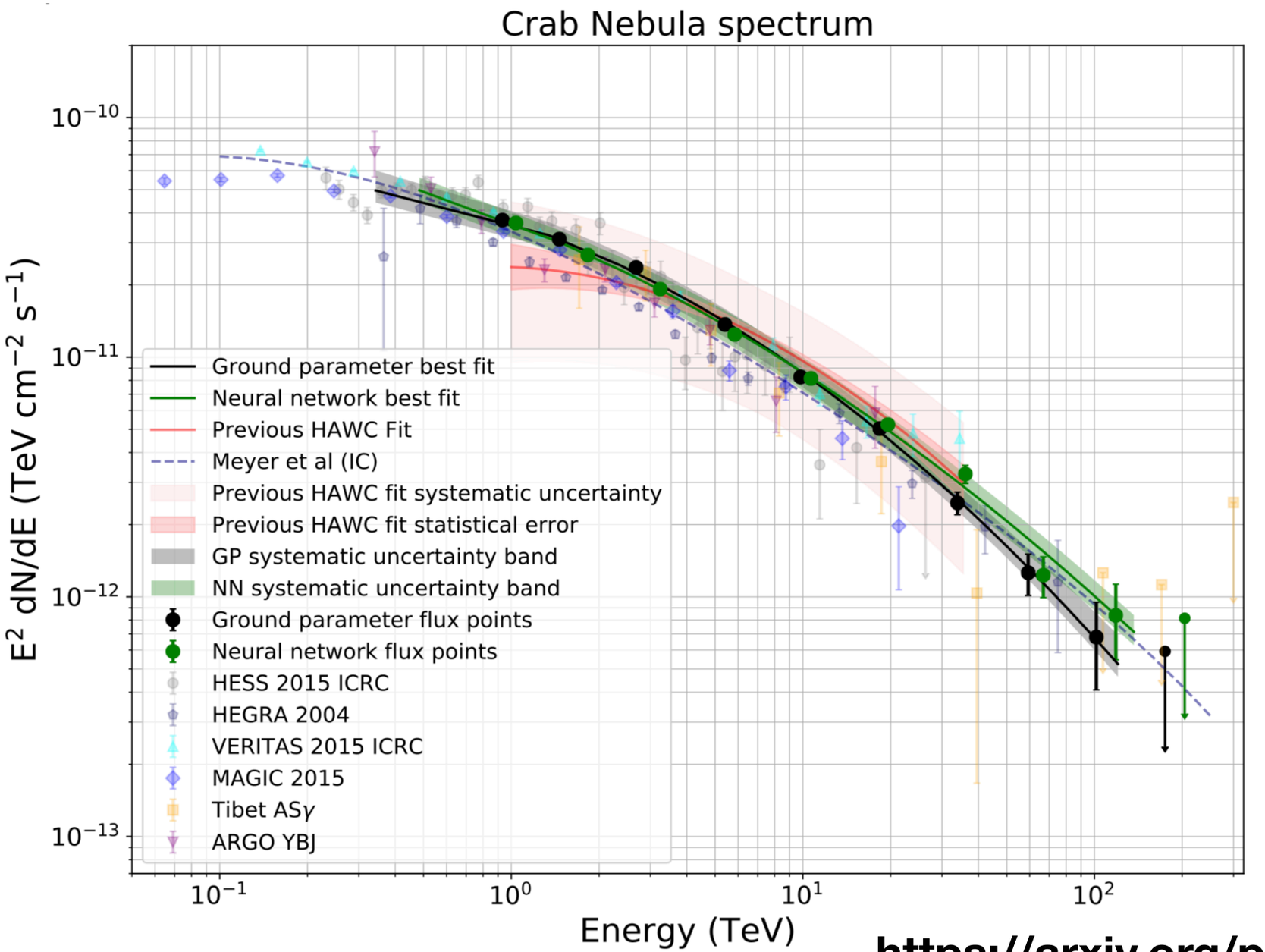


Existing plugins

- **Fermi LAT:**
  - Fermipy
  - Unbinned analysis using gtburst products (for GRB, solar flares,…)
- **Fermi GBM, LLE for GRB and (solar flares).**
  - spec, time and tte data
- **OGIP "XSPEC type": anything that can be fit in XSPEC**
- **HAWC both point and extended sources (for HAWC collaboration members)**
  - Probably will be the standard package for HAWC analysis.
  - Several analysis already published using 3ML.
- **VERITAS: only point sources (internal)**
- **Optical: with ~2000 optical filters (thanks to the Spanish Virtual Observatory Filter profile service)**
- **Many other groups showed interests in 3ML.**
- **CTA joint analysis developing ctools plugin (Luigi: "straightforward!")**

Fermi-LAT - HAWC

- **3ML is considered as HAWC baseline analysis tool**
- **Possible that HAWC data will be public**



3ML based fit

https://arxiv.org/pdf/1905.12518.pdf

Distribution

- **Documentation:**
  - https://threeml.readthedocs.io/en/latest/index.html
- **If you want to install with conda fermiST, fermipy, and threeML:**

```
#!/bin/bash
conda create --name fermi3ML -c conda-forge -c fermi -c threeML
source activate fermi3ML
conda install -c conda-forge -c threeml -c fermi threeml xspec-modelsonly fermipy
fermitools
```

- **This creates an environment (fermi3ML) with everything in it!**
- **Few things to remember:**
  - **Conda environment is in: $CONDA_PREFIX (mine is: /Users/omodei/anaconda/envs/fermi3ML)**
  - **python code of threeML & astromdodels in:**

```
$CONDA_PREFIX/lib/python2.7/site-packages/threeML
$CONDA_PREFIXlib/python2.7/site-packages/astromodels

To start the notebook: jupyter notebook
```

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For the heads on…

jupyter

Quit Logout

Files Running IPython Clusters Nbextensions

Select items to perform actions on them.

Upload New

0 /	Name	Last Modified	File size
bn080916009		21 days ago	
bn190114873		3 days ago	
Crab		4 minutes ago	
GRB080916C		4 minutes ago	
GRB190114C		4 minutes ago	
Trials.ipynb		3 days ago	170 kB
TS_distribution.ipynb		3 days ago	250 kB
Dockerfile		a month ago	2.13 kB
gtburst.log		3 days ago	420 B
run.sh		a month ago	90 B
threeml.tar		20 hours ago	8.91 GB

Notebooks and Tutorials

Crab/Crab.ipynb
- Crab fit with 3ML interface tp fermipy
- Make a fit from a 4FGL catalog source (Crab) modeling the source with synchrotron and IC emission (from 4FGL)
- Plot spectra
- Run Bayesian inference analysis

GRB080916C/GRB080916C.ipynb
- GBM+LAT+LLE time-resolved analysis, like the one in the Science paper!

GRB190114C/GRB190114C.ipynb
- LAT+XRT joint analysis

TS_distribution.ipynb
- Obtaining the distribution of the null hypothesis and show that it is distributed as a chi^2

Trials.ipynb
- Showing how the TS distribution is affected by the number of trials (in the context of GRB and GW followup)

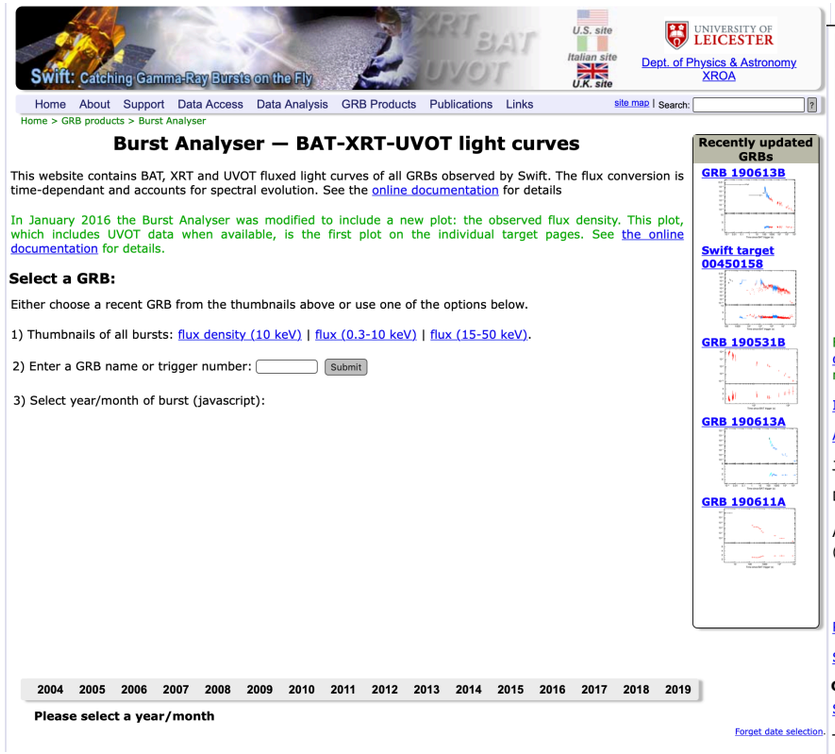
gtburst

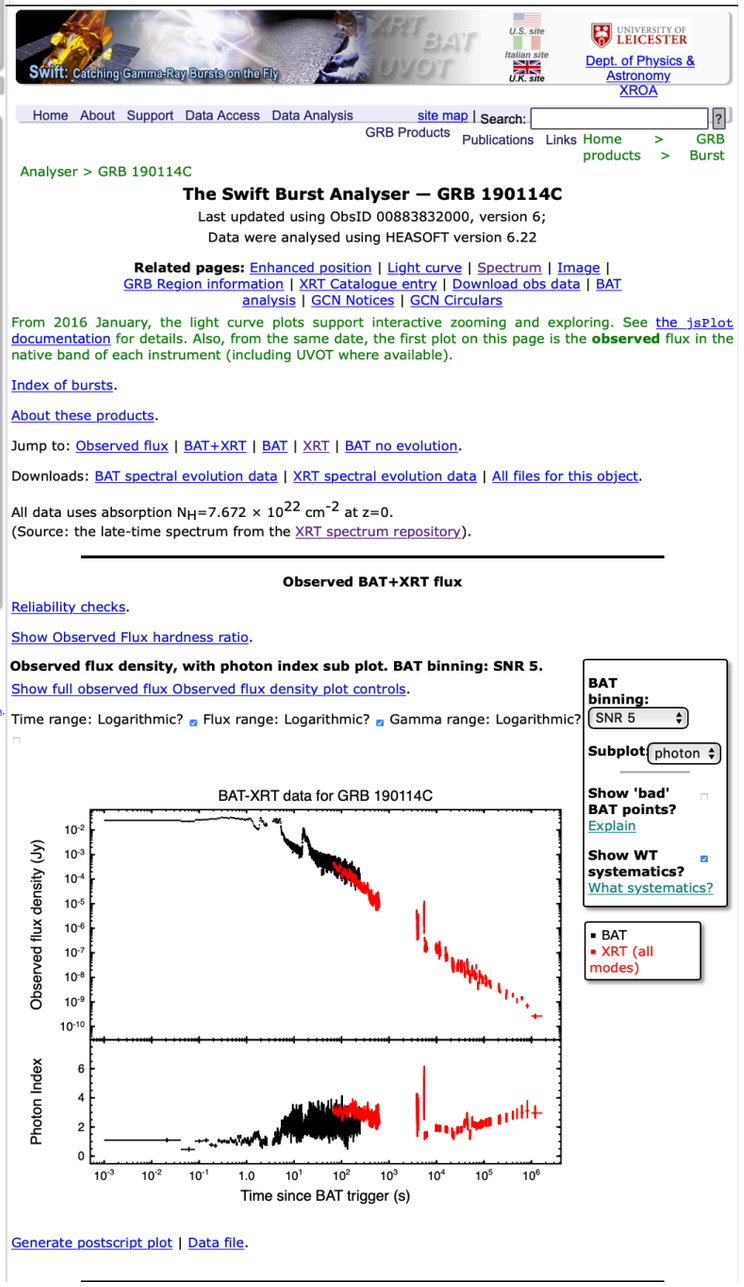
- **gtburst is a graphical user interface (GUI) we wrote a while back to analyze Fermi LAT GRB.**
  - **Download GBM, LAT and LLE data for GBM trigger catalog bursts**
  - **Make likelihood analysis (binned or unbinned) of LAT data**
  - **Prepare PHA file to be analyzed in XSPEC**
  - **Locate GRB with gttsmap**

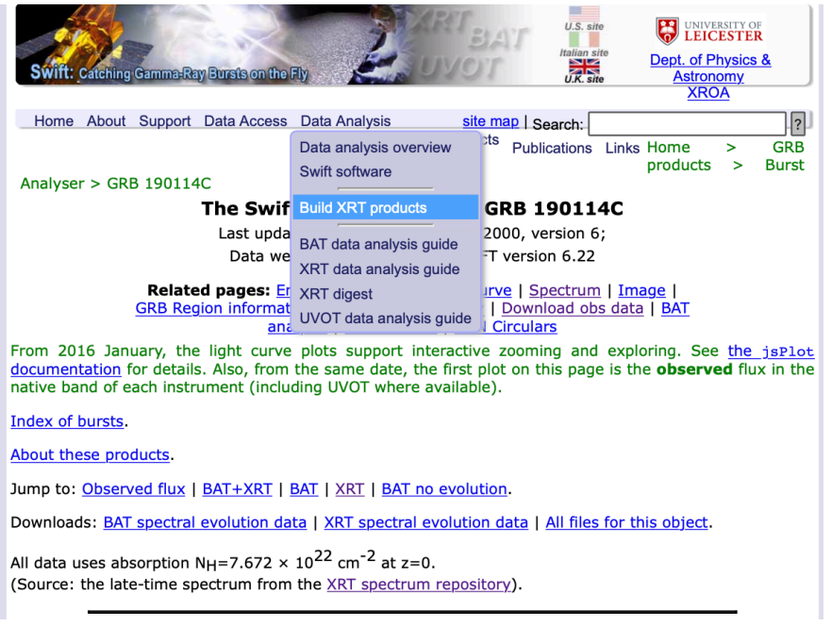
```
gtburst is distributed with Fermi ScienceTools
In the conda environment with fermitools:

> gtburst
```

Swift Burst Analyzer

- **http://www.swift.ac.uk/burst_analyser/**







Processing will be performed using HEASOFT v6.22.

Select products

To reduce the load on our servers, please select only the independent products you require.

Light curve: ☐ Spectrum? ☑ Position? ☐ Image? ☐

Build prod

Object details

*Name: 190114C Find

*Target ID: 883832

Start time: 569191162

All input times since this? ☑

*Coordinates: 54.516868, -26.

NOTE: You have changed the object name. The position, start time and target ID columns may be invalid.

Global options

*Try to centroid? Yes

*Centroid method: Single pass

*Max attempts: 10

*Search radius (arcmin): 3

Super-soft source? ☐

Show advanced pile-up controls?

*Use 1SXPS source lists: Yes

(if available) E-mail address:

Spectral details

*Use redshift? No

*Redshift:

*Use which observations?

All ○

Those covering times: ○

Those within 12 hrs of the first ○

Grade range: Default

*Time for spectrum: User defined

*You can specify up to 4 time regions below:

#1: Name
Times:

#2: Name
Times:

#3: Name
Times:

#4: Name
Times:

GRB name

Input time since this

User defined time intervals