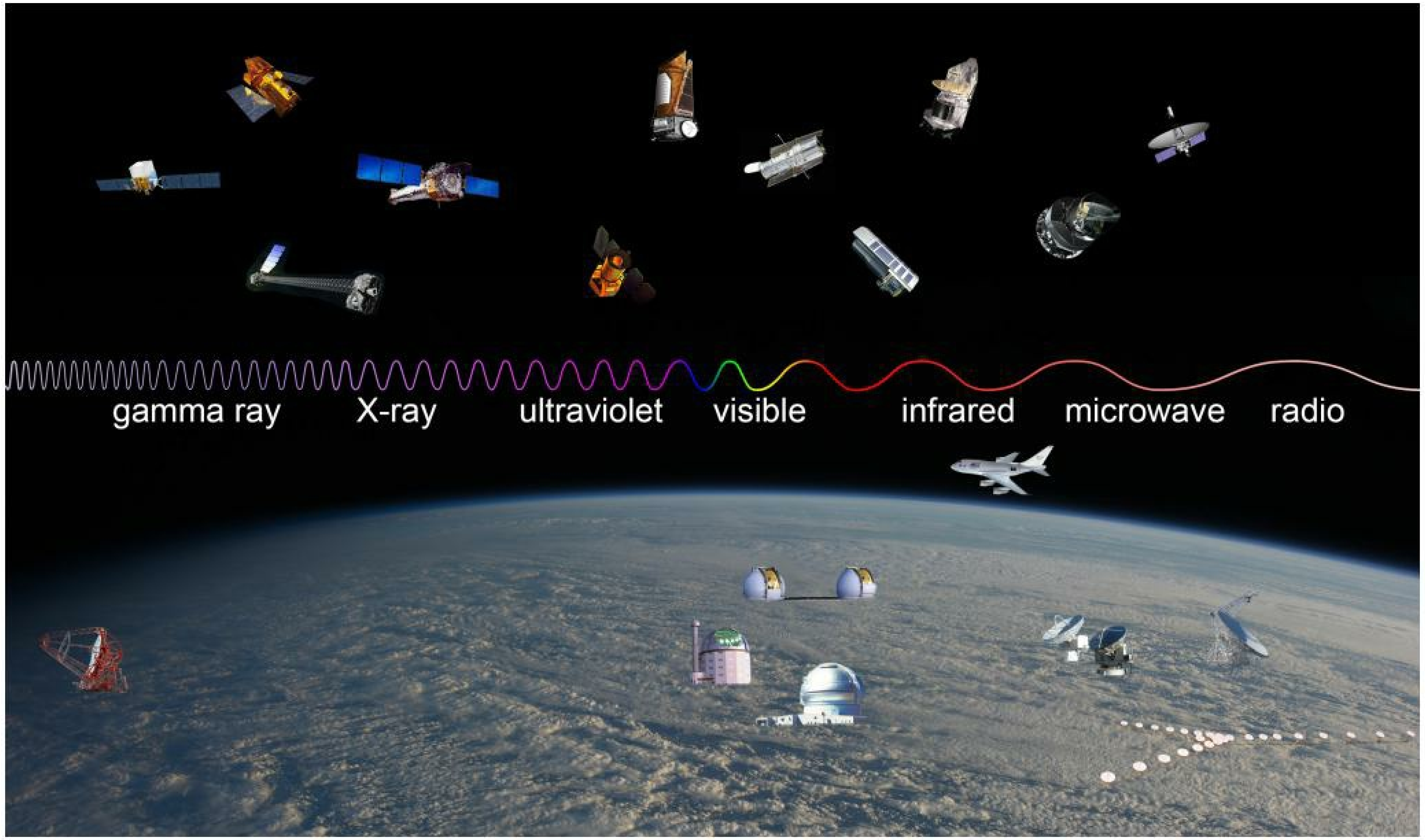
3ML

The Multi-Mission Maximum Likelihood framework

G.Vianello (Stanford University)

the problem

- Multi-wavelength data are necessary to get a complete physical picture
- How to combine data from instruments with completely different features, technology, issues?



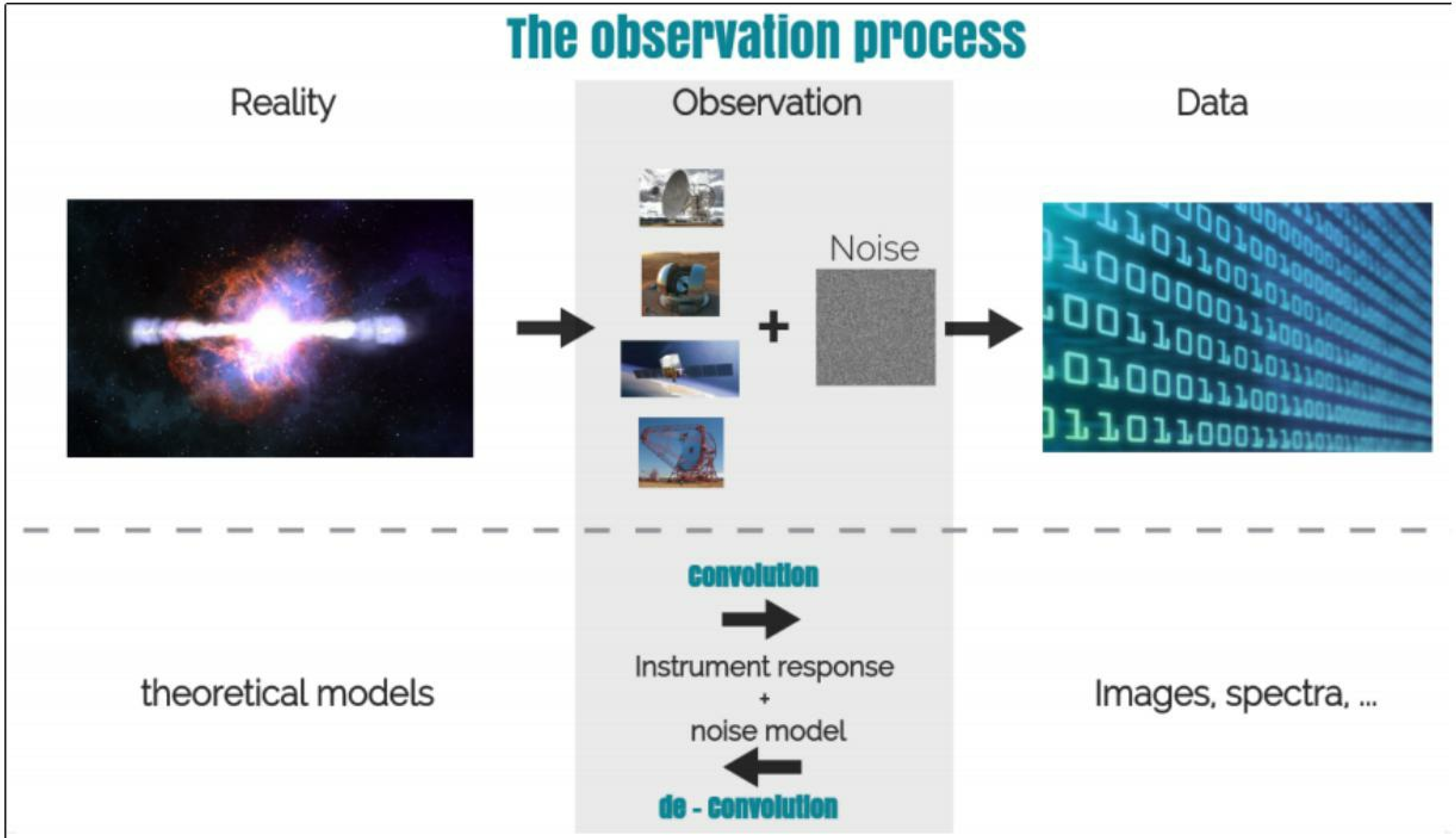
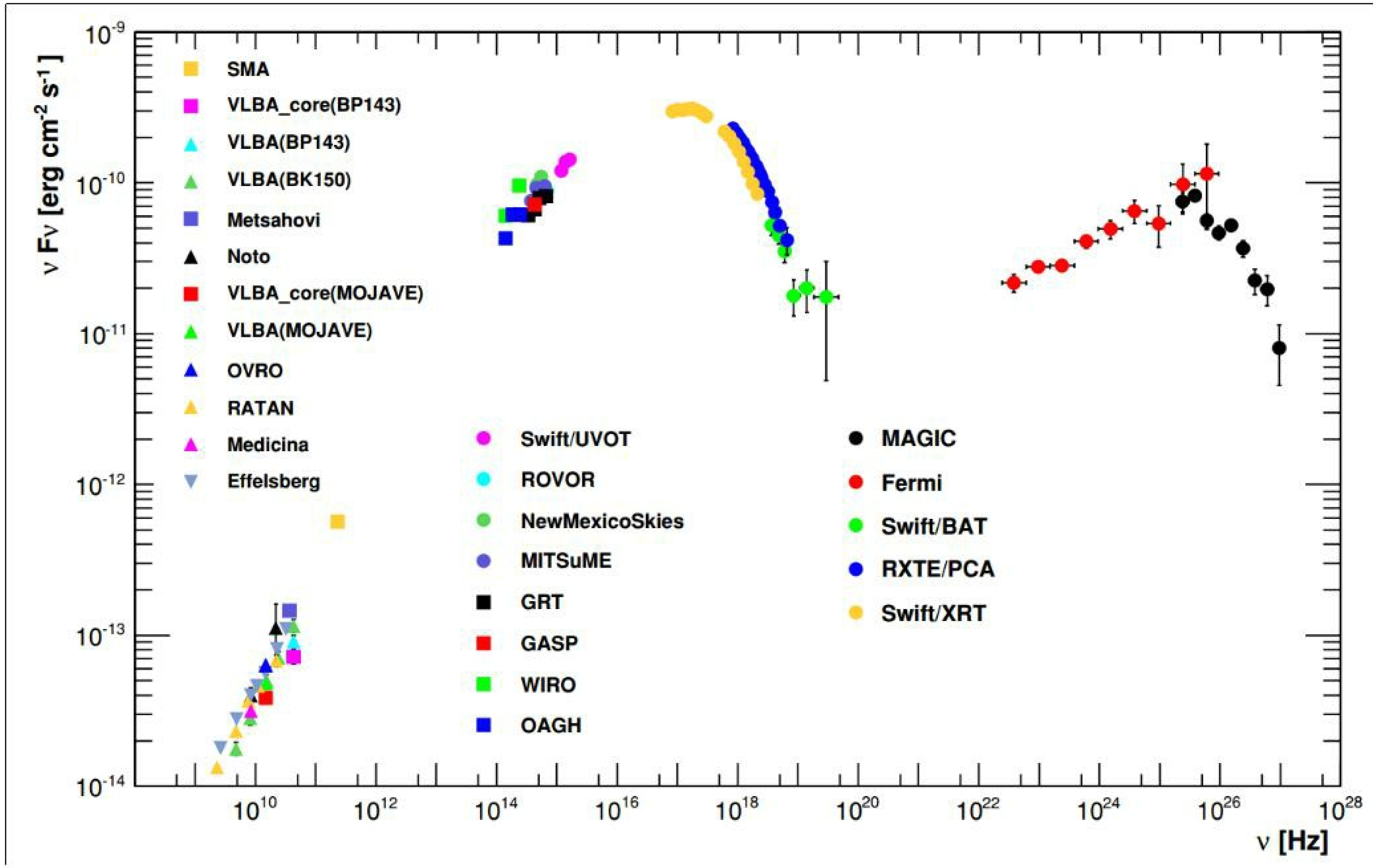


Figure 1: The observation process.

Vianello et al. 2015

Deconvolution: Spectral Energy Distribution

"bring the data to the model space"



Abdo et al. 2011

good if:

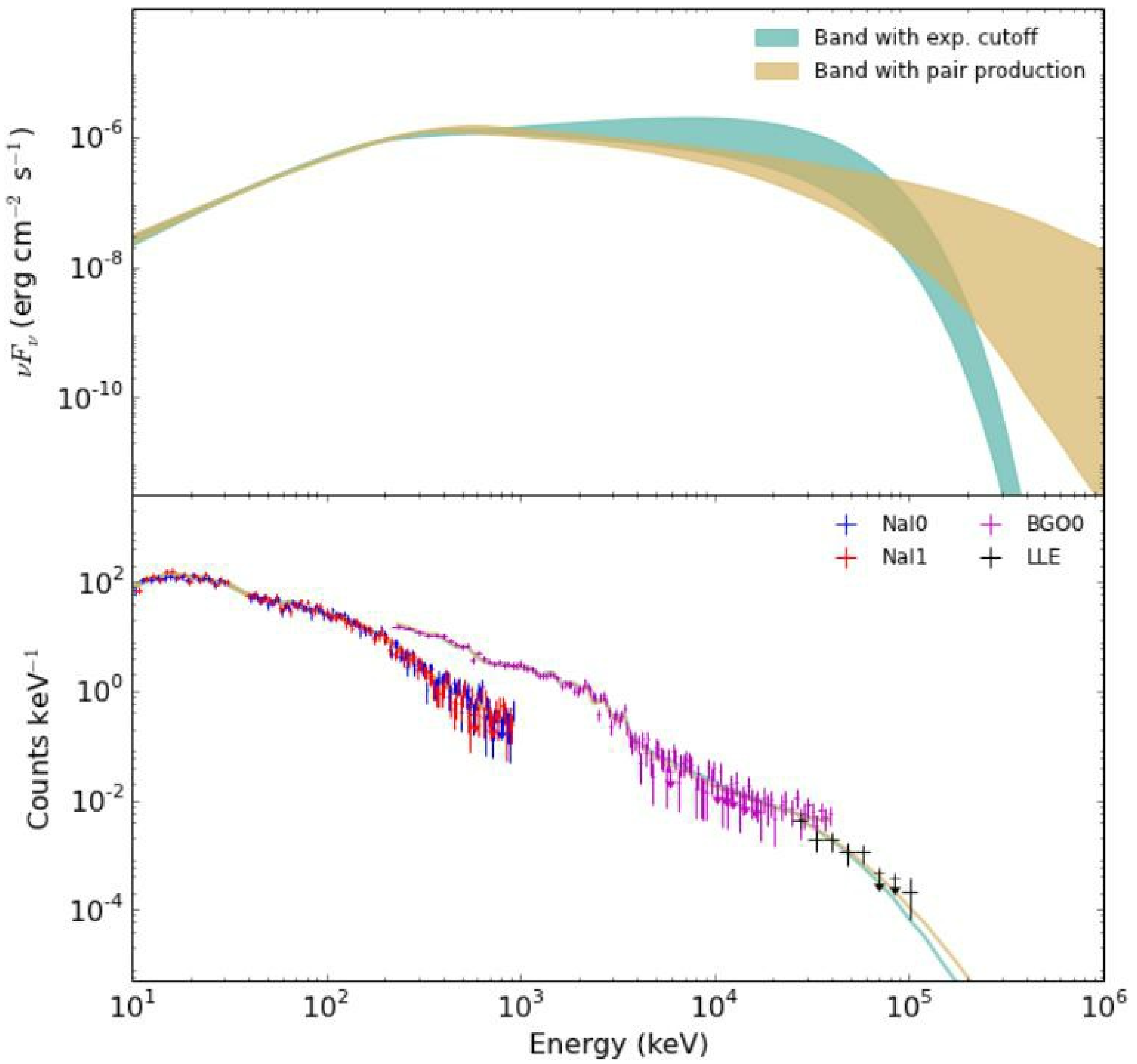
- Point source
- bright source
- negligible energy dispersion
- negligible energy biases

Problem with SED

$$n_{e_1,e_2} = \int_\omega d\omega \int_{e_1}^{e_2} de \int dE \int_\Omega d\Omega\, S(\vec{p}, E) * RSP(E, e, \vec{p}, \vec{P})$$

- S (the spectrum of the source) acts as a weight for the response
- under certain circumstances we can choose bins so that:
  - contributions from other energies are negligible
  - the choice of the functional form for S becomes irrelevant
- if the source is faint, difficult to divide too much
- if energy dispersion is big, it is impossible
- more than one model can give statistically equivalent description of the data
- no extended sources

Example of non-unique solution



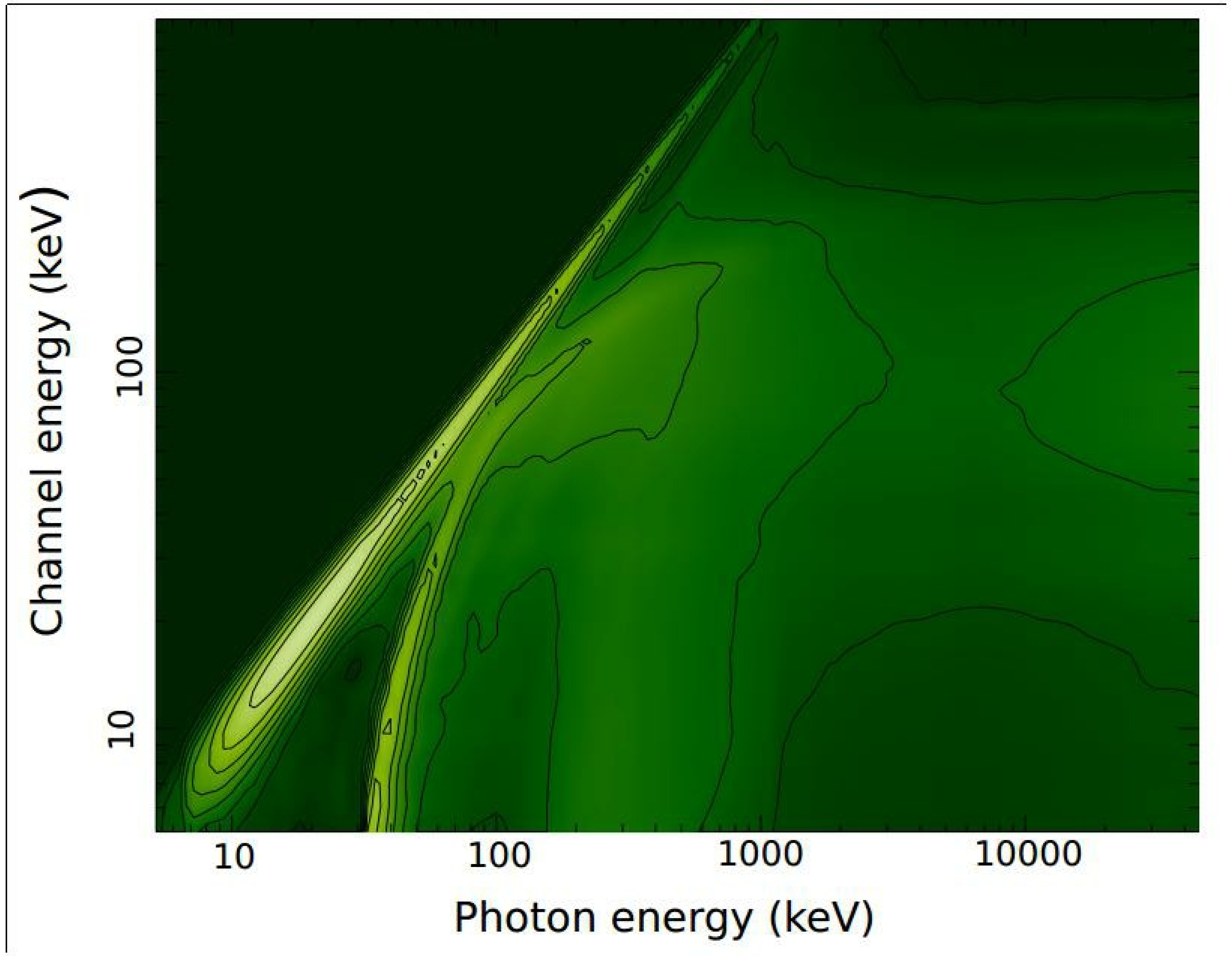
Vianello et al. in preparation

- Two different models can give an equivalent description of the data

Convolution: forward-folding

"bring the model to the data space"

- Adopt a model
- convolve with the response of instruments
- compare the prediction with the observation using a noise model (i.e., using a likelihood function)
- always possible
    - faint, bright, point-like, extended, multiple sources...

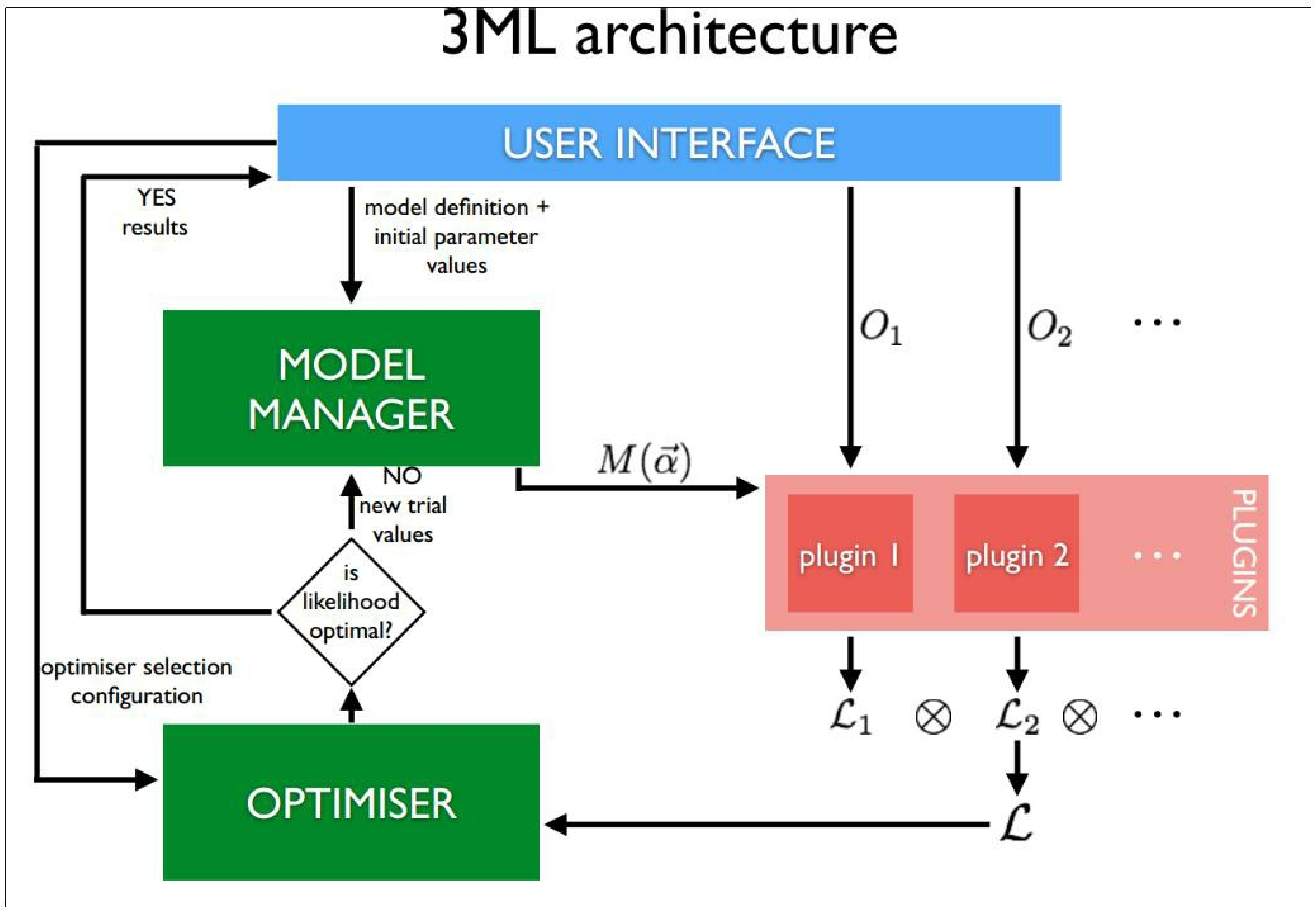


Response matrix of a GBM NaI detector

3ML

The Multi-Mission Maximum Likelihood framework

- provide a common framework for likelihood analysis
- what's different from other methods (xspec, sherpa, isis, rmfit...):
    - plugins: thin wrappers around instrument-specific software (ST for Fermi, LIFF for HAWC, xspec for Swift...)

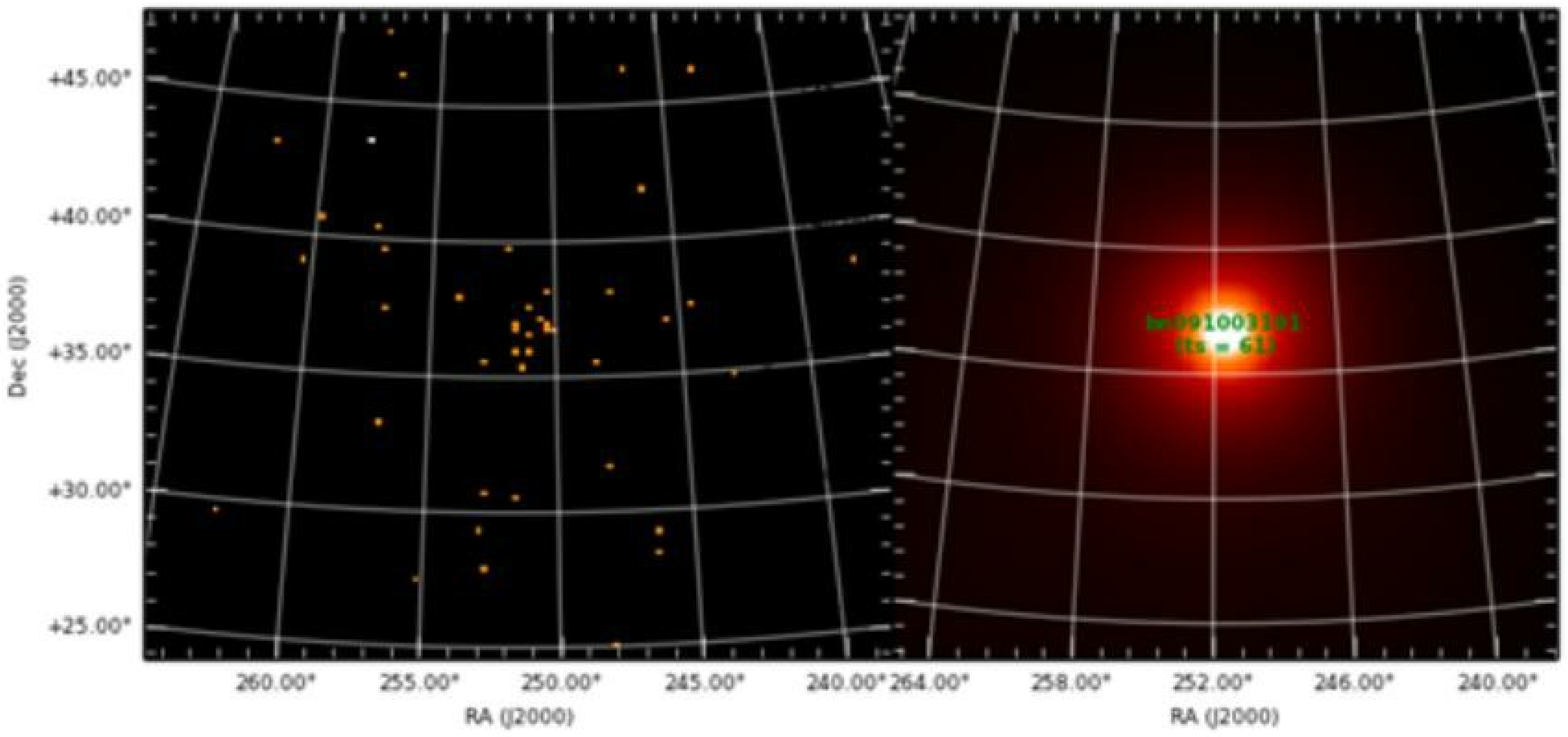


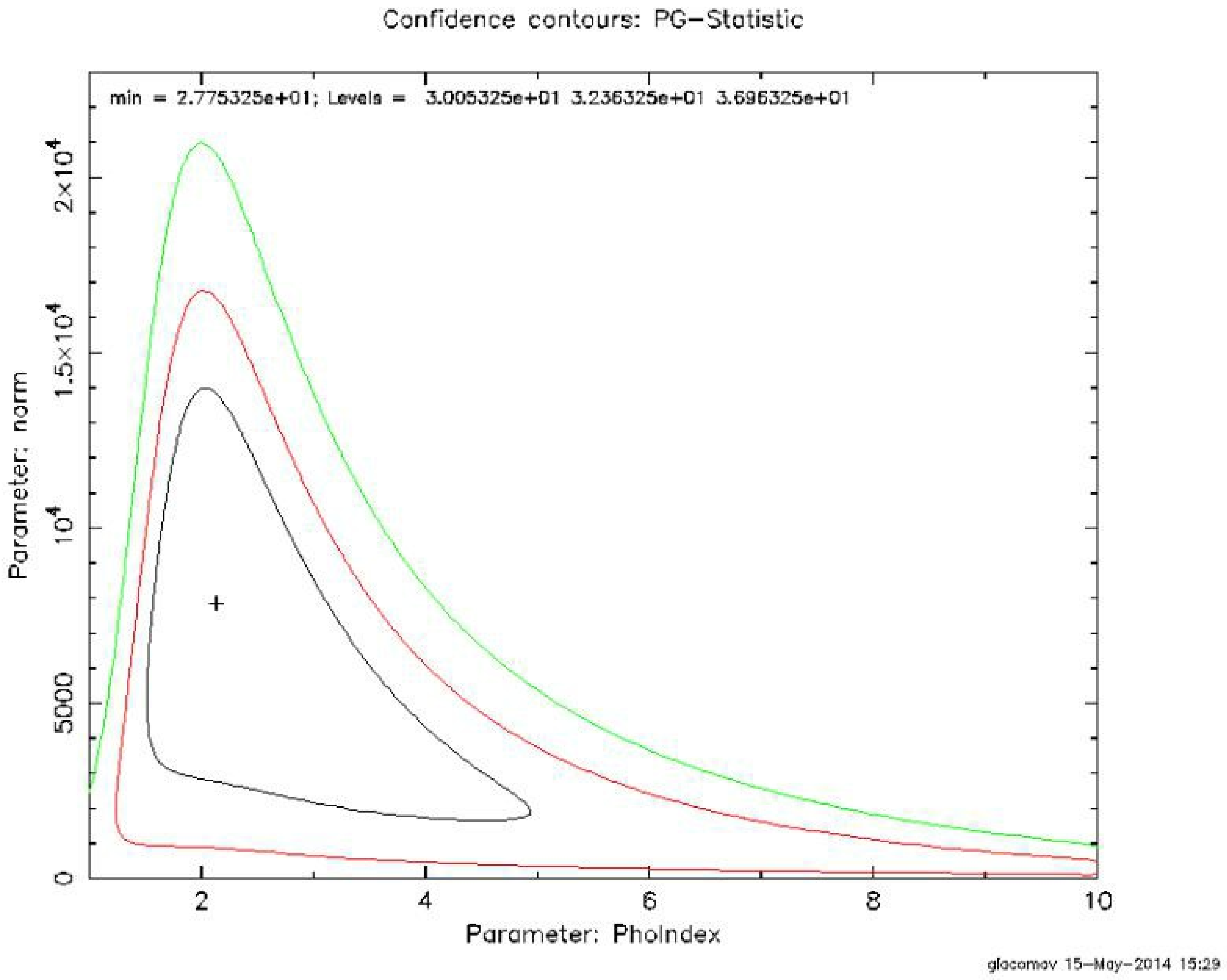
why plug-ins

- decouple framework and instrument-specific analysis
- guarantee the most optimal treatment of the data
- avoid placing any constraints on:
    - data formats
    - response specification
    - likelihood implementation
- use already-existing, official and tested software
- makes easy to handle instrument-specific background

Getting the most out of data

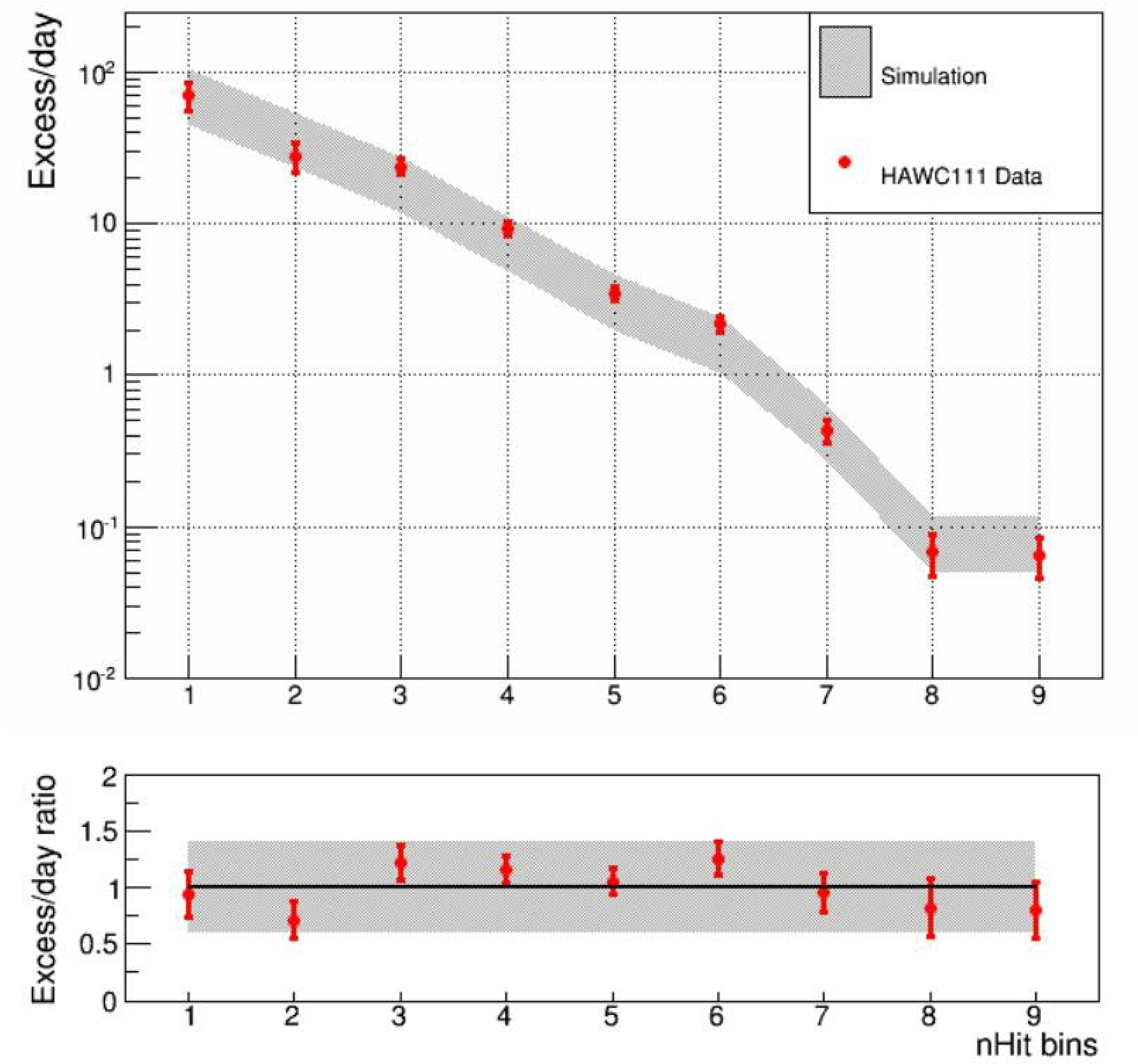
- existing software such as xspec, Rmfit or sherpa uses OGIP format
- OGIP format requires integrating over the space dimension
- Simulation: 45 bkg + 15 signal
  - Poisson probability of 60 when expecting 45 -> 2 sigma





Flexibility for heterogeneous data

- HAWC
  - no energy estimator yet
  - use instead nHit (number of PMTs hit)
    - strong dependence on core location, zenith...
  - Monte Carlo can predict nHit based on input model
  - 3ML makes possible to analyze Fermi data in energy space and HAWC data in nHit space in a joint analysis
- VERITAS: event display, 3d likelihood...
- Multi-messenger (future)
  - plugins not limited to e.m.
  - if we have physical models linking photons and other messengers (neutrinos), we can constrain them in a joint analysis



nHit "spectrum" of Crab Nebula, Smith et al. 2015

current status

- threeml.stanford.edu
- github.com/giacomov/3ML
  - open source, contributors very welcome!
- point source analysis ready for:
  - Fermi LAT (binned and unbinned)
  - HAWC (private)
  - OGIP-compliant (Fermi/GBM, Swift, Konus, XMM, Chandra...)
  - can use any spectral shape, built-in or custom
    - see my poster on GRB 100724B for a physical model
- Extended analysis in the work
- Expressed interest: VERITAS, HESS, MAGIC, Swift/UVOT...

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join us!

Example

afterglow of GRB 090510 with LAT and XRT