ESCAPE

European Science Cluster of Astronomy & Particle physics ESFRI research Infrastructures

g-Like : likelihood maximisation and profiling for astrophysical (and beyond) applications

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E-OSSR Onboarding Presentation

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What is gLike?

- **Framework for numerical maximisation of joint (e.g. multi-instrument) likelihood functions**;
- likelihood of **one free parameter** (g) and **as many nuisance parameters as wanted**, profiled over in the maximisation process;
- C++ code built on ROOT;
- **Use cases** (in order of increasing complexity):
  - estimating the intensity of an astronomical source of signal particles in the presence of background particles from datasets obtained with different instrument and in different data formats;
  - estimating the dark matter annihilation cross-section combining observations of dwarf spheroidal gamma-ray and neutrino telescopes;
  - estimating the energy scale of quantum gravity by combining observations of recently measured GRBs (work in progress);
- already used for several publications, **highlights**:
  - Fermi-LAT + MAGIC DM searches in dSphs,
  - gloryduck project (check Tjark's presentation @Fermi Symposium).

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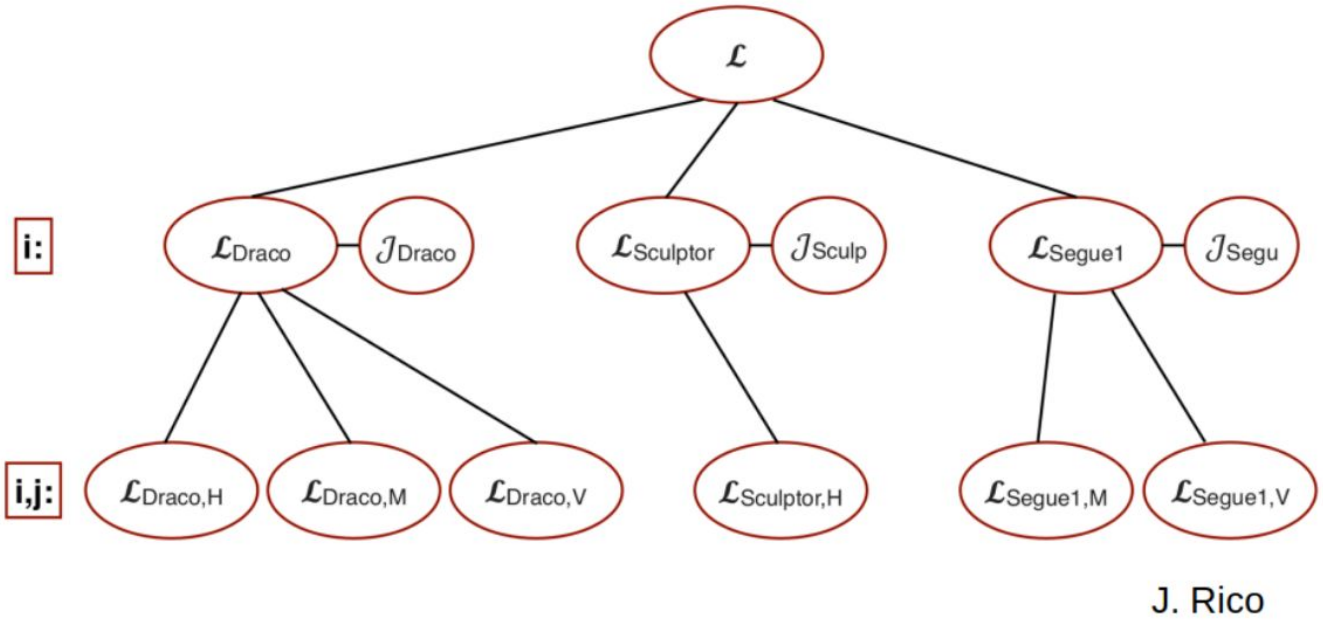
What is gLike?

Likelihood formula:

$$\mathcal{L}\left(\langle\sigma v\rangle; \nu \mid \mathcal{D}_{\mathrm{dSphs}}\right) = \prod_{l=1}^{N_{\mathrm{dSphs}}} \mathcal{L}_{\mathrm{dSph},l}\left(\langle\sigma v\rangle; J_l, \nu_l \mid \mathcal{D}_{l,\mathrm{measured}}\right) \times \mathcal{J}_l\left(J_l \mid J_{l,\mathrm{obs}}, \sigma_{\log J_l}\right)$$



J. Rico

- gLike can create complex likelihood functions from simpler likelihood terms;
- nuisance parameters **can selectively affect in the same way an arbitrary number of these terms**.

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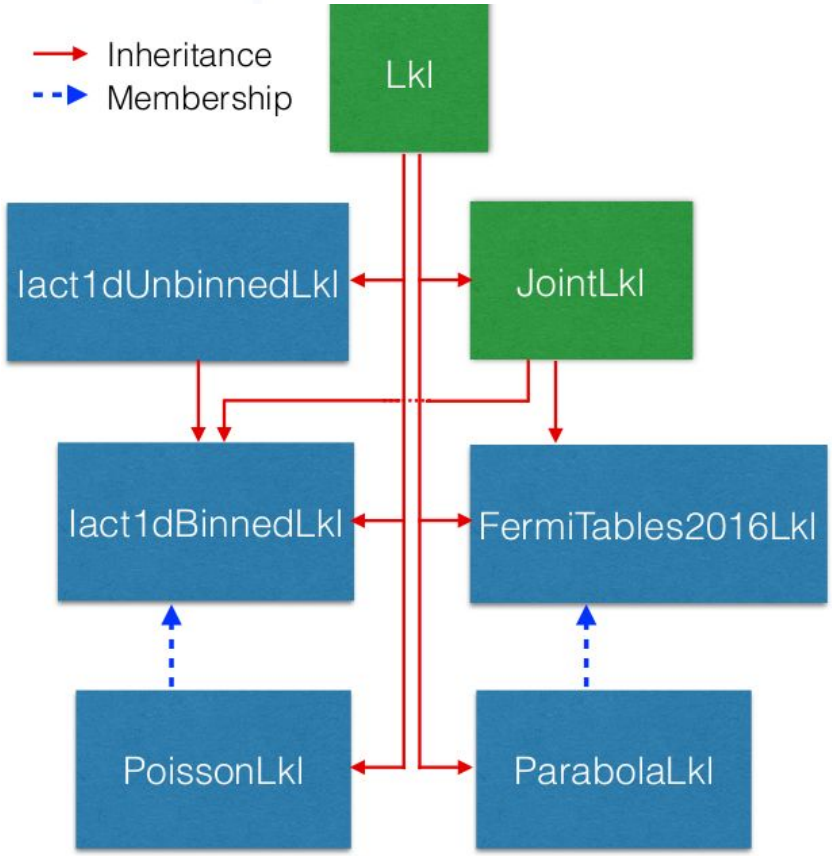
What is gLike?



CODE:

- Lkl: abstract linked to TMinuit, performing the minimisation of *-2 log L* vs *g*;
- JointLkl: combines several Lkl objects in a joint likelihood;
- the remaining classes implement a particular likelihood function:
  - Iact1dUnbinnedLkl: energy-dependent unbinned likelihood for energy spectra measured with IACTs,
  - Iact1dBinnedLkl: binned version of Iact1dUnbinnedLkl;
  - FermiTables2016Lkl: total *L* values according to Fermi tables (*L* vs flux for bins in Energy);
  - PoissonLkl: On/Off double Poisson likelihood (LiMa, Rolke,...);
  - ParabolaLkl: holds values of *L* vs g;
  - TemplateLkl: template for new likelihood classes;
- IactEventListIRF: simple data class for IACT ON and OFF data and IRF components.

DATA:

- Data directory with gamma-ray spectra from DM annihilation and decay in different channels (from Cirelli 2011), used for **<σ*v*>** estimation;
- Test IACT unbinned / binned spectral data in ROOT and FITS format.

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Software Development

- **Software development on github:** https://github.com/javierrico/gLike
- **Documentation:**
  - github wiki;
  - .html documentation can be generated with one of the scripts or at compilation with cmake;
- **License:** GNU General Public License v3.0.
- **Test and CI / CD:**
  - only a small test unit available at the moment, not integrated in a workflow;
  - no workflow for CI / CD set up at the moment.

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Software Development

- **Operating System, compilation environment:**
  - ROOT (sole dependency);
  - cmake build;
- **hardware requirements:**
  - no particular hardware requirement;
- **containerisation and portability requirements:**
  - containers available for two root versions;
- **workflow/interface requirements to other software/services:**
  - compatibility with gammapy, interface at the data level.

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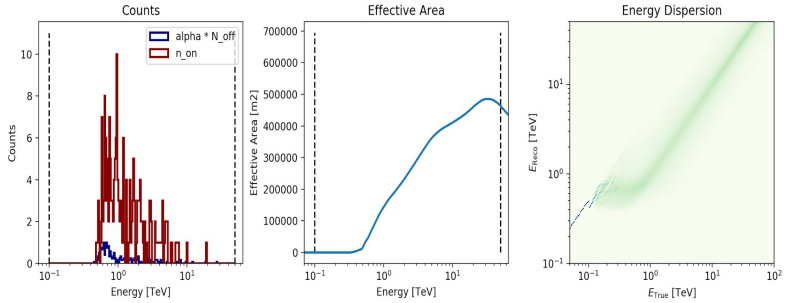
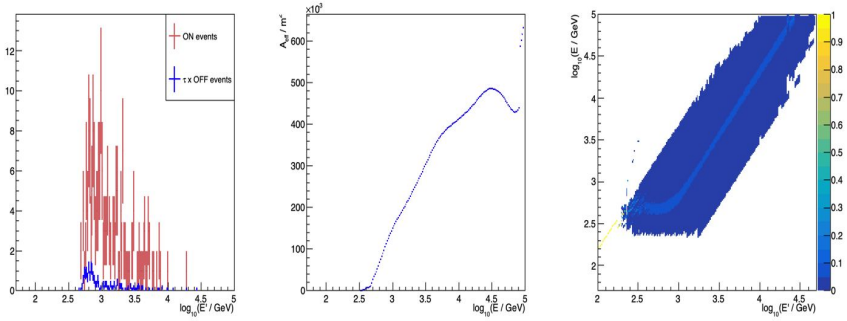
Software Development

- Decided to make gLike **interfaceable with gammapy at the data level**;
- user reduces data with gammapy, **DL3 -> unbinned spectral data** (list of ON - OFF events + IRF);
- the **unbinned spectral data** are then feeded to gLike for likelihood minimisation / profiling;
- script to produce unbinned spectral data with gammapy in gammapy-extra;
- added interface to FITS data in gLike (via ROOT);
- to read the OGIP format (in which the spectral data are stored) a patch in ROOT was needed. The ROOT version including this patch is > v6.20;
- we maintained compatibility with old ROOT versions (used by most of the analysers).

Gammapy output (from data reduction)



gLike input (to likelihood analysis)



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OSSR Integration

- **What is available?**
  - source code;
  - singularity containers, two root versions:
    - v5-34-36, used by analysers,
    - v6-22-06, ROOT patched to read IRF in .fits data.
- **What will be onboarded (source code, container, test workflow incl. data)?**
  - source code;
  - containers;
- **Are there open points and requirements?**
  - expand the test unit (already working on this);
  - include the tests and the container generation in a git automatic workflow;
  - add interface to binned spectral data (OGIP) obtainable with gammapy - and produced by many high-energy instruments (X-ray telescopes...).

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OSSR Integration

- **What is the “user story” of a EOSC user taking on the software?**
- a user can reduce gamma-ray data with gammapy and analyse them with gLike;
- a user can combine **data from different instruments** (gamma-ray and neutrino observatories) **and in different formats** (ROOT and FITS) in the same likelihood framework with gLike;
- it will be extremely relevant for the **Dark Matter Test Science Project:**
  - flexible likelihood template can be used to add likelihood terms for particle physics data.

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Time for a short demo (~10 min)

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