Open high-level data formats and software for gamma-ray astronomy

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Abstract

In gamma-ray astronomy, a variety of data formats and proprietary software exist, often developed for one specific mission or experiment. Especially for ground-based imaging atmospheric Cherenkov telescopes (IACTs), data and software have been so far mostly private to the collaborations operating the telescopes.

However, there is a general movement in science towards open data and software and the next big IACT array, the Cherenkov Telescope Array (CTA), will be operated as an open observatory.

We have created a Github organisation where we are developing high-level data format specifications. A public mailing list was set up and a first face-to-face meeting on the IACT high-level data model and formats took place in April 2016.

The hope is that this open multi-mission effort will help to accelerate the development of open data formats and open-source software for gamma-ray astronomy, leading to synergies in the development of analysis codes and eventually better scientific results (reproducible, multi-mission).

Resources

- Mailing list for announcements and high-level discussions (75 members, including people from all major gamma-ray collaborations): lists.nasa.gov/mailman/listinfo/open-gamma-ray-astro
- Github issues and pull requests are used for detailed discussions: github.com/open-gamma-ray-astro
- Data format specifications in HTML and PDF format, including example files: gamma-astro-data-formats.readthedocs.io/

Notes

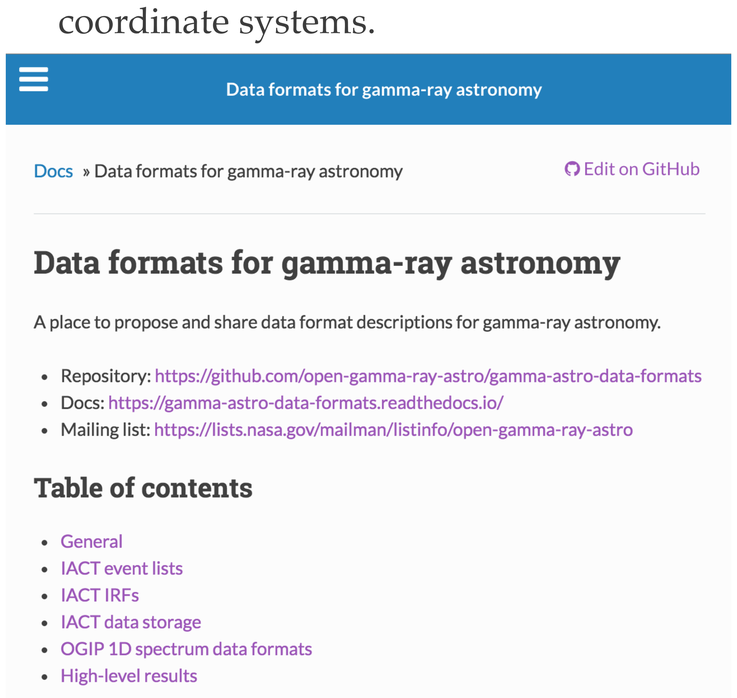
- The specification of a given format defines the names and semantics of data and header fields (mostly FITS is used).
- The spec should be easy to understand and useful. We include example files and some explanations, in addition to the detailed spec for a given format.
- The scope is high-level data, starting with event lists and instrument response functions (IRFs), what is called “data level 3” (DL3) in CTA.
- First stable release (archived on Zenodo, with a DOI) coming soon.

Contribute

- Use the existing formats.
  Give feedback!
  Propose additions and changes.
- Join the mailing list.
  Send an email with an idea or proposal.
- Create a Github account.
  File an issue with a correction or make a pull request proposing an addition.
- No formal approval process in place yet.
  This is a very recent effort.

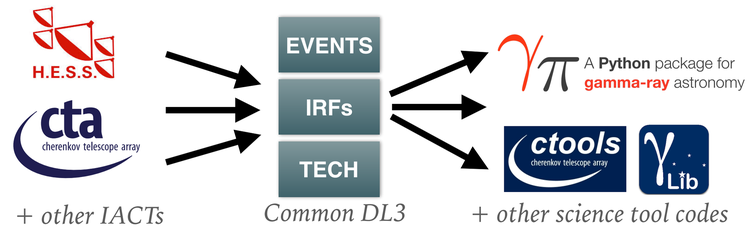
Content

- So far, the focus has been mainly on the definition of the IACT DL3 formats (see info in right column).
- Some work on higher-level formats for spectra and lightcurves, as well as HEALPIX images and cubes ongoing.
- A “general” section defining common things like details about time scales or coordinate systems.

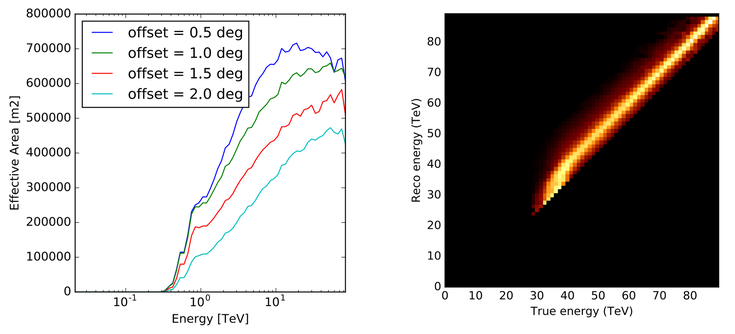


Example: IACT DL3

- Imaging atmospheric Cherenkov telescopes (IACTs) data level 3 (DL3): what is released to end users for analysis with science tool: EVENT, IRF, TECH
- First effort to develop an open common data model and format for IACT DL3.
- Prototyping by existing IACTs (H.E.S.S., MAGIC, VERITAS) and science tools (Gammapy, Gammalib/ctools) ongoing.
- Many points under discussion, e.g.
  — Observation modes, time intervals
  — EVENT and IRF linking
  — Pointing and livetime info
  — IRF axes and IRF validity ranges
  — Field of view coordinates



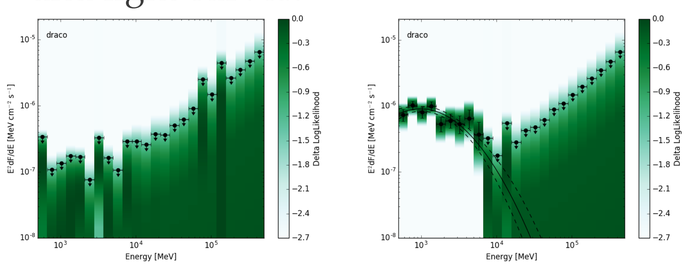
+ other IACTs *Common DL3* *+ other science tool codes*



Examples for IACT instrument response functions (IRFs): effective area (left) and energy dispersion (right)

Example: Likelihood SED

- A proposed format to store spectral analysis results for exchange and publication.
- Developed first in Fermipy and used for Fermi-LAT, now being adopted by other instruments and codes.
- “Flux points” and upper limits, but also a format for full likelihood profiles.
- Discussion on other high-level formats is ongoing, e.g. for global spectral models and light curves.



Examples for SEDs and likelihood profiles: a weak source (left) and a strong source (right)

Poster presented at Gamma 2016, Heidelberg in July 2016