VODF
very-high-energy open data format

Introducing VODF

The Very High Energy Data Format

Bruno Khélifi, Karl Kosack, Laura Olivera-Nieto, Jutta Schnabel, Roberta Zanin

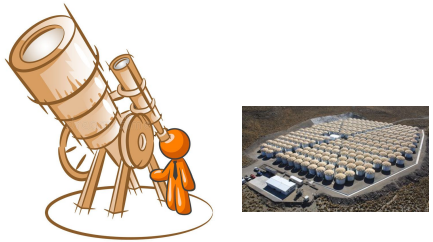
IVOA May 2023 Interoperability Meeting

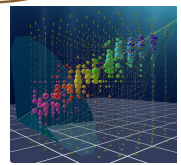
08 - 12 May 2023, Bologna, Italy

Outline: From gamma rays to high energies

GADF
Data Formats for
Gamma-Ray Astronomy

VODF
Very-high-energy
Open Data Format





A Python package for gamma-ray astronomy

Some history: GADF

A (short History of GADF)

2011 Prototypes for the CTA data format and science tools

2016
- Establishment of the Gamma-ray Astronomy Data Formats (GADF) initiative
- First preliminary release version (0.1), mainly focused on IACTs

2018
- Version 0.2 released
- Support implemented in the science tools Gammapy and ctools
- H.E.S.S. releases ≈ 50 h of observations of different sources using the format

2019
- FACT, Fermi-LAT, H.E.S.S. MAGIC and VERITAS observations of the Crab Nebula are used to perform the first multi-instrument analysis
  [doi:10.1051/0004-6361/201834938]
  `https://github.com/open-gamma-ray-astro/joint-crab`
- `ctools` based analysis of the H.E.S.S. data release
  [doi:10.1051/0004-6361/201936010]
- Comparison of Gammapy and ctools using the H.E.S.S. data release
  [doi:10.1051/0004-6361/201936452]

from Maximilian Linhoff

From gamma rays to very high energy

ASTRI - Astronomia a Specchi a Technologica Replicante Italiana, (IACT telescope)

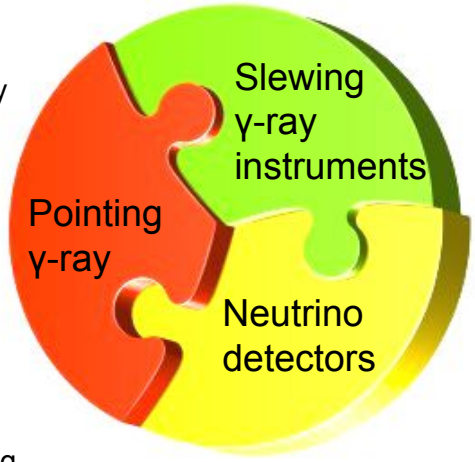
CTAO - Cherenkov Telescope Array Observatory (IACT observatory)

FACT - First APD Cherenkov Telescope (IACT telescope)

H.E.S.S. - High Energy Stereoscopic System (IACT Array)

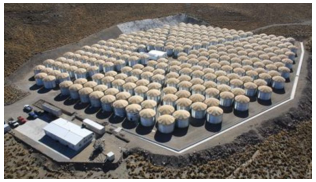
MAGIC - Major Atmospheric Gamma-ray Imaging Cherenkov telescope (IACT array)

VERITAS - Very High Energy Radiation Telescope Array System (IACT array)



Fermi-LAT - Large Area Telescope on the Fermi Space Telescope (High-energy Space Observatory)

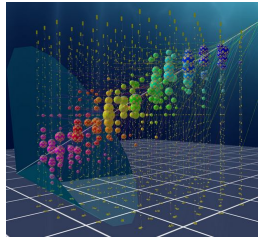
HAWC - High-Energy Water Cherenkov telescope (WCT)



SWGO - Southern Wide-Field Gamma-Ray Observatory (WCT)

IceCube - Neutrino Observatory

KM3NeT - The Cubic Kilometre Neutrino Telescope (neutrino telescope)



New structure & new science: VODF

established 2022

VODF Steering committee

one representative per experiment, defining roadmap & goals

VODF Lead Editors

Format development

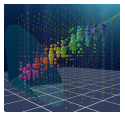
Conveners

Organization & Coordination of work

Documentation:
https://vodf.readthedocs.io
Source & Community:
https://github.com/VODF/

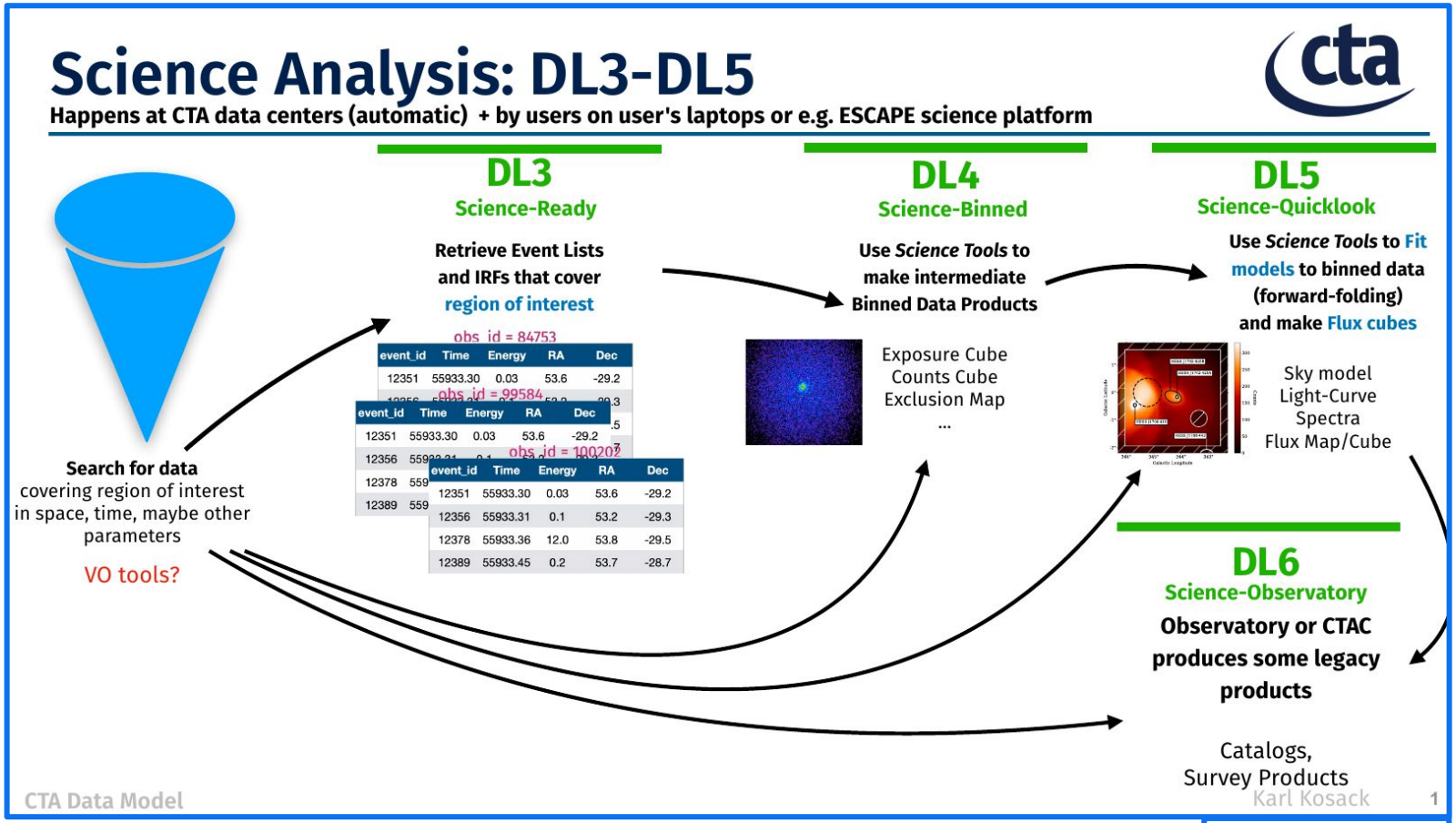
Validation of standardized data formats and tools for ground-level particle-based gamma-ray observatories
doi:10.1051/0004-6361/202243527

GADF @gammapy



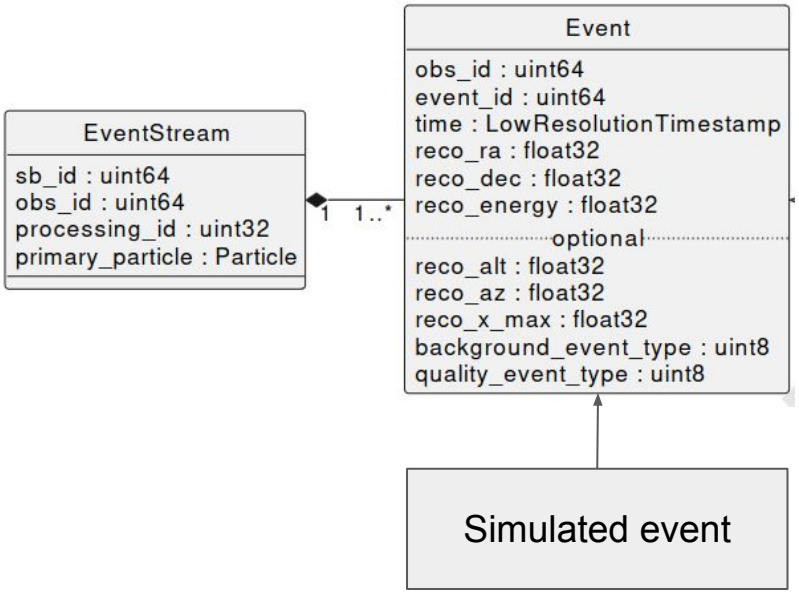
Models of Galactic Source Emissions with CTA and KM3NeT (in preparation)

What it is about: Data levels



Basic data format: “Events” and “service data”

event = particle detection (gamma, neutrino)



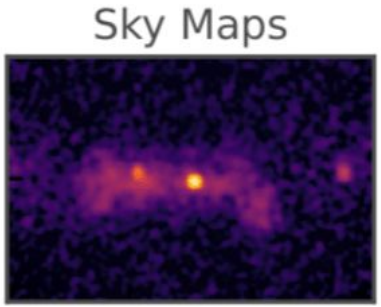
Information derived from simulation: Instrument Response Functions (IRFs)

- Stable Time Interval
- Effective Area
- Energy Dispersion
- Point Spread Function
- Background
- Radius of On-Region for Point-Like IRFs

Higher levels: Science results

DL4 (Science binned)

- exposure maps
- counts maps
- exclusion maps
- significance maps
- excess maps



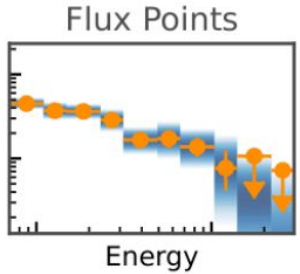
DL5/6 (Science products)

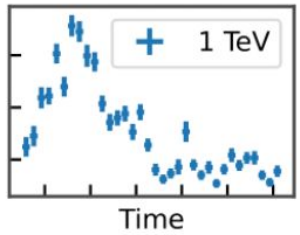
- Flux maps & fit models
  - data cube (3D,4D)
  - 2D sky map
  - light curve
  - spectrum
  - spatio-spectral cube
  - …

Potential future developments with VODF

Source Catalogs

Name	Flux	Size
SNR	1e-12	1 deg
PWN	1e-11	0.2 deg
GRB	1e-10	0 deg





Next steps & open questions

- Starting with a format definition
  - Allow for multiple IRFs
  - Including different event categories (event types)
  - Choose standard (OGIP vs. FITS)
- Ensuring interoperability (especially with IVOA)
  - Make data discoverable via VO (ObsCore?)
  - Could contribute to an interest group if it happens
  - Current considerations see contribution by Mathieu Servillat (DM II in parallel)
    - CTAO Data Model group & DM for High Energy astrophysics
  - Further workshop prepared for June 28/29 (French VO, extending WP4 ESCAPE)

VODF

very-high-energy open data format

Thank you for your attention

and looking forward to modelling!

In very-high-energy (VHE) gamma-ray astronomy, the community has converged to use a common open data format (GADF) for the high-level data products. With the arrival of open observatories like CTA or KM3NeT and the increasing number of multi-wavelength and multi-messenger studies, a new initiative has been created to specify formats of high-level data from very and ultra high energy gamma-ray facilities and from VHE neutrino ones. This contribution will present the Very-high-energy Open Data Format (VODF) project that has been settled by 11 VHE astroparticle facilities and how it aims to better respect the FAIR principles and the IVOA recommendations.

Apps II, Thursday 11, 11-12:30

Bruno Khelifi: Very-high-energy Open Data Format

Presentation of VODF (Very high energy Open Data Format) (11+3)

Outline

- History
  - Motivation - GADF (learning from OGIP standard)
    - OGIP: https://heasarc.gsfc.nasa.gov/docs/heasarc/ofwg/docs/spectra/ogip_92_007/node5.html
    - Common analyses & papers - gammapy used but missing extensions to GADF: https://arxiv.org/abs/1903.06621
    - https://arxiv.org/abs/2203.05937
  - Organization - Structure
  - Contributors - Observatories: Commonalities (analyses overlap, more complicated events, ground based)
- Content
  - Data levels: example plot from Axel (@Laura) (https://vodf.readthedocs.io/en/latest/data_format/index.html)
    - Perhaps example for events & IRF
  - Data model based on CTA data model - include picture
- Goal: interoperability with IVOA
  - Domain-specific data looking for interoperability
    - Discoverable via IVOA (Obscore -> DM) - minor change for data level
      - Could contribute to an interest group if it happens
    - Description of data format & further access
      - Point to Mathieu's discussion
      - Further workshop prepared for June 28/29 (French VO, extending WP4 ESCAPE)

Summary: Initiative to preserve & continue access