Open data and tools for very high energy gamma-ray astronomy

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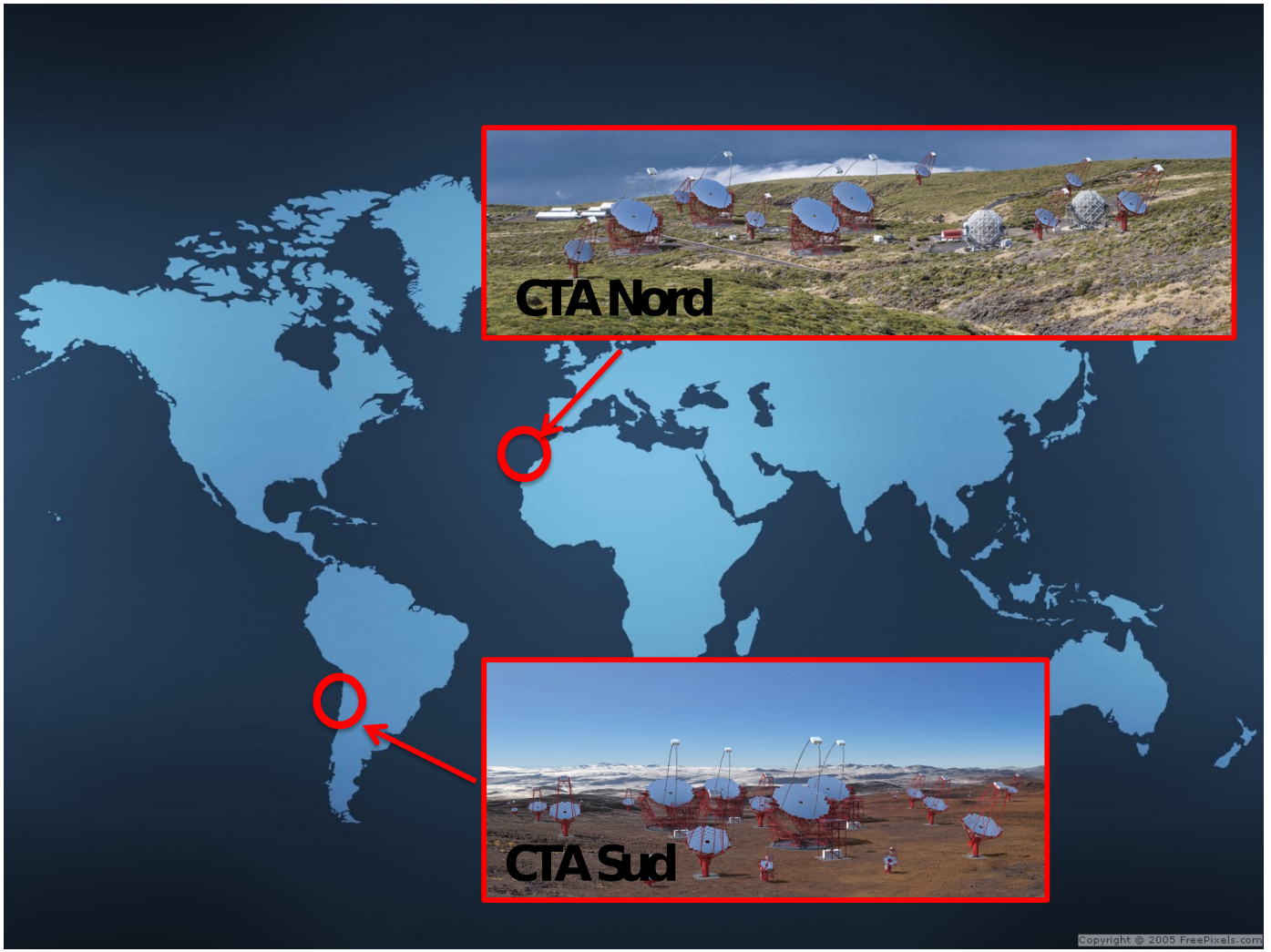
Asterics
Astronomy ESFRI & Research Infrastructure Cluster

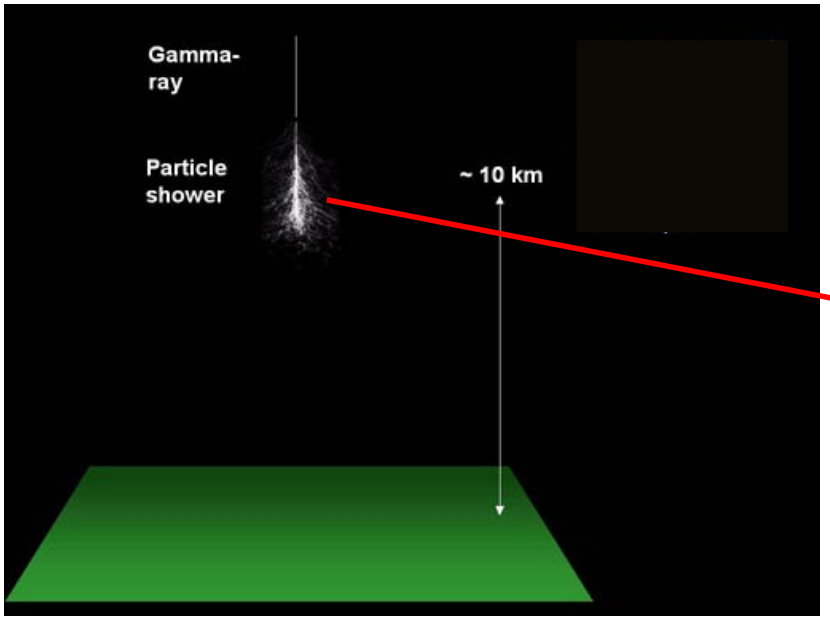
Obelics
OBservatory E-environments Linked by common ChallengeS

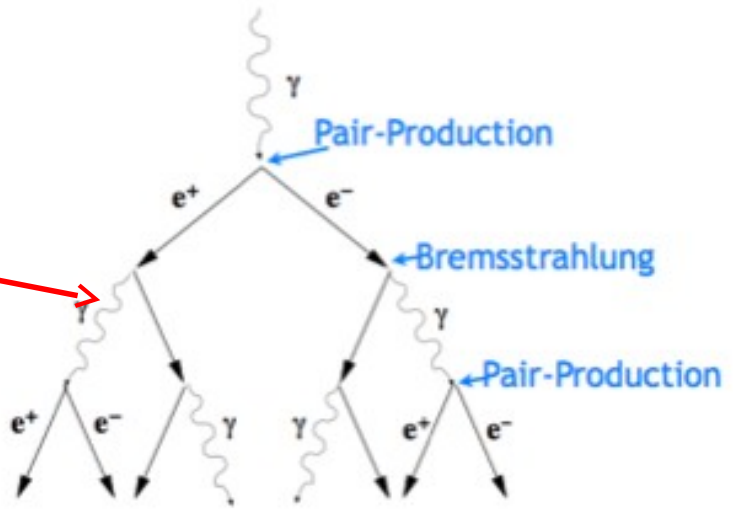
Imaging Air Atmospheric Cherenkov (IACT)

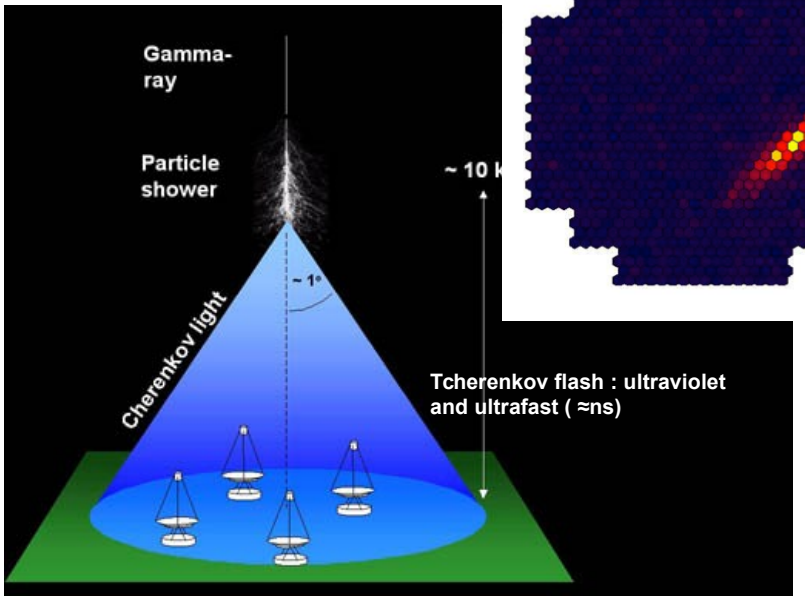
Cherenkov Telescope Array (CTA)



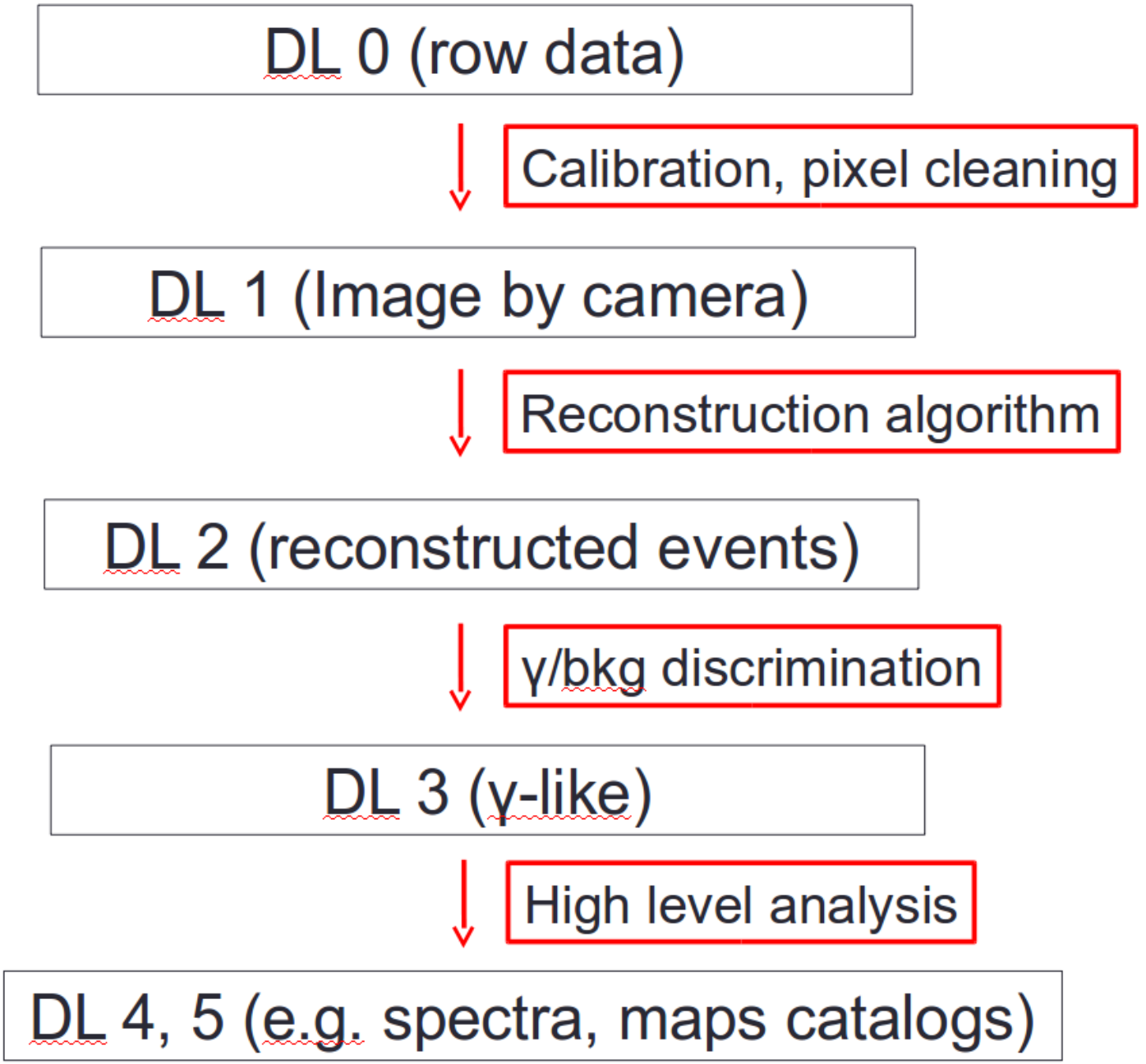
Imaging Air Cherenkov Technique







Data Level for CTA



Open data format for CTA

- Current IACT: data and software are **mostly private** to the collaborations operating the telescopes.

- CTA: first ground-based gamma-ray telescope array operated as an **open observatory with public observer access**

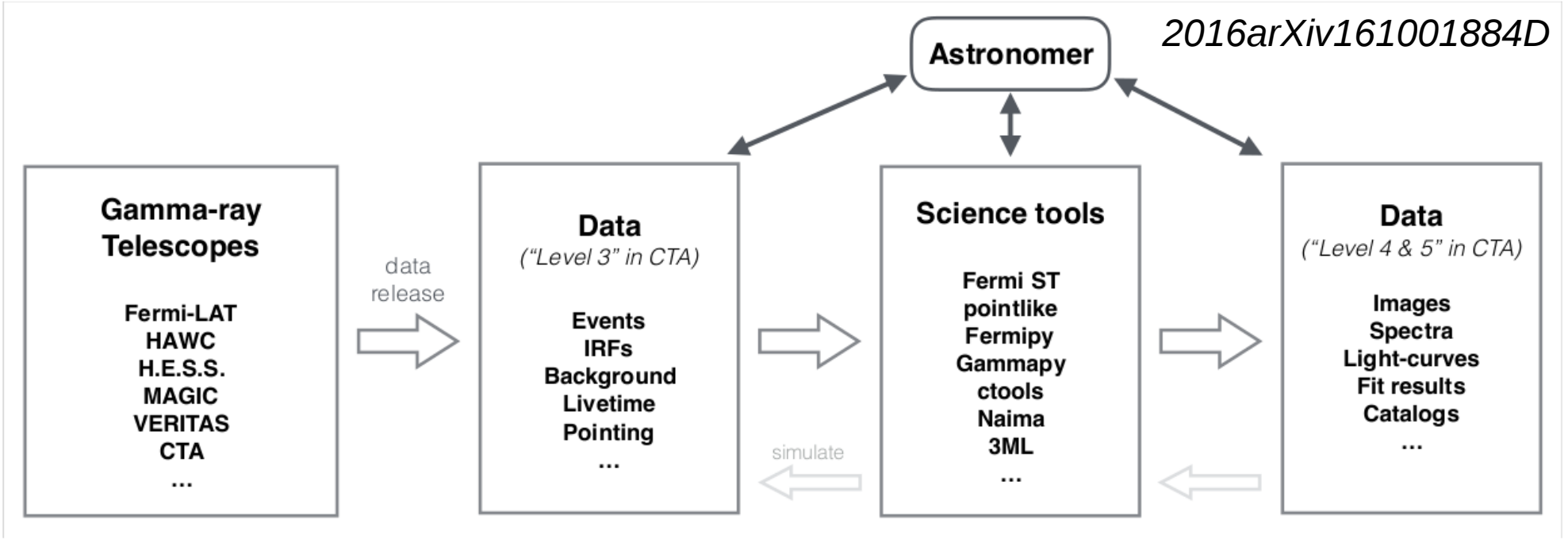
  → requirements for the data formats and software tools

- Space telescopes have public high-level data and tools

- In FITS (widespread in the astronomy community)

Have a common DL3 public format

- Github organisation:
  https://gamma-astro-data-formats.readthedocs.io/



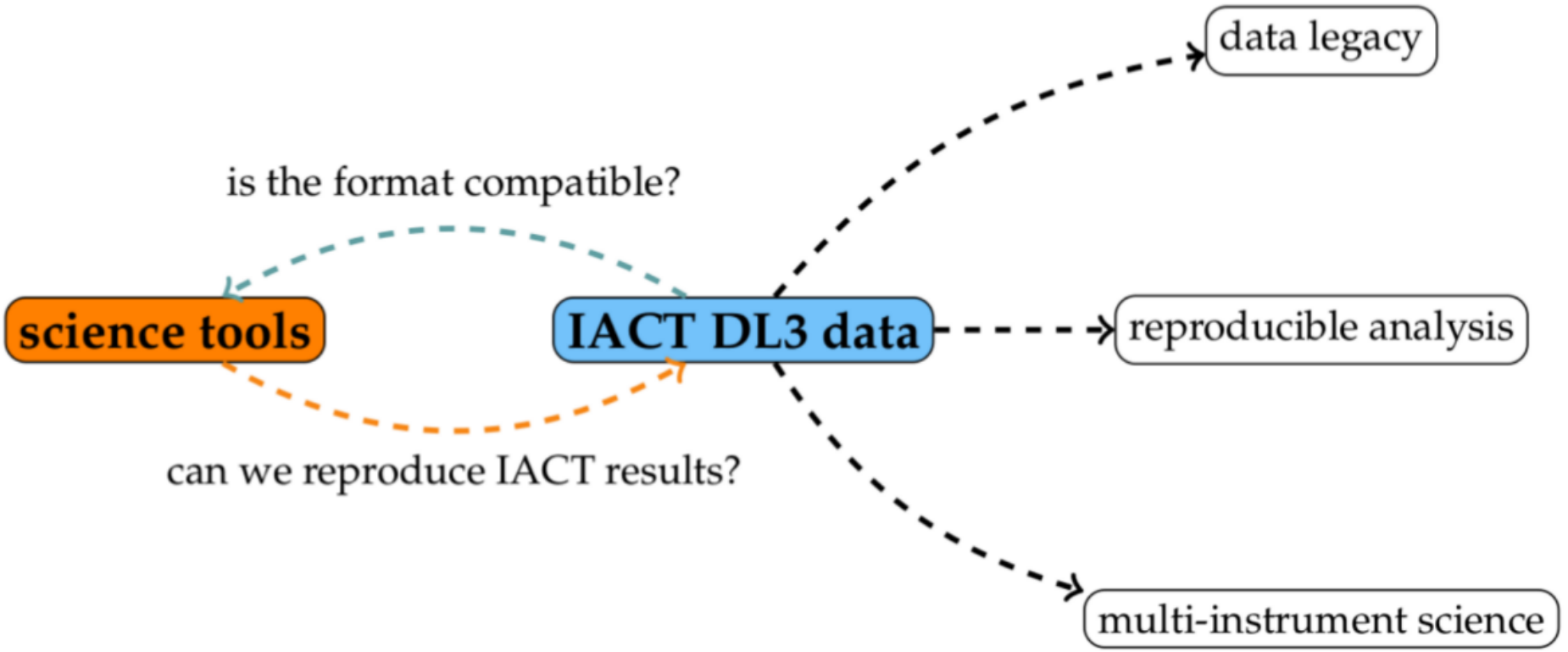
- High-level gamma-ray data (after calib, reco, g/h-separation) is pretty much always the same and given by:
  - **Event list (TIME, RA, DEC, ENERGY)**
  - **Instrument response (AREA, PSF, EDISP, BKG)**

- Current IACTs have started to "export" their data

DL3 format validation – Current IACTs

The DL3 files generated by current IACTs are necessary for:

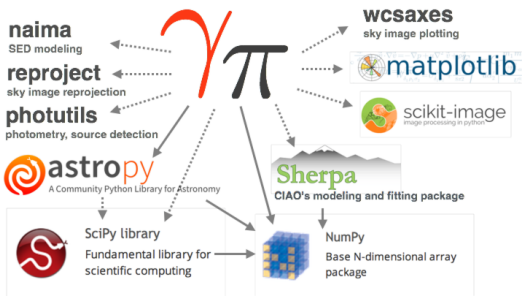
- CTA science tools validation
- legacy data that allow reproducible and multi-instrument analysis



Open source analysis tool for CTA

- Traditionally in gamma-ray astronomy: C++ & ROOT
- CTA science tool prototypes *Gammapy and Gammalib/ctools* based on the DL3 format

build on Python, Numpy and Astropy



"no dependencies"
C++ package, SWIG Python

GammaLib

ctools
cherenkov telescope array

- 3ML: interface to existing codes (HAWC, VERITAS, GBM, LAT)
- No agreement! (except ROOT seems to have fallen out of fashion!!)

3D likelihood analysis

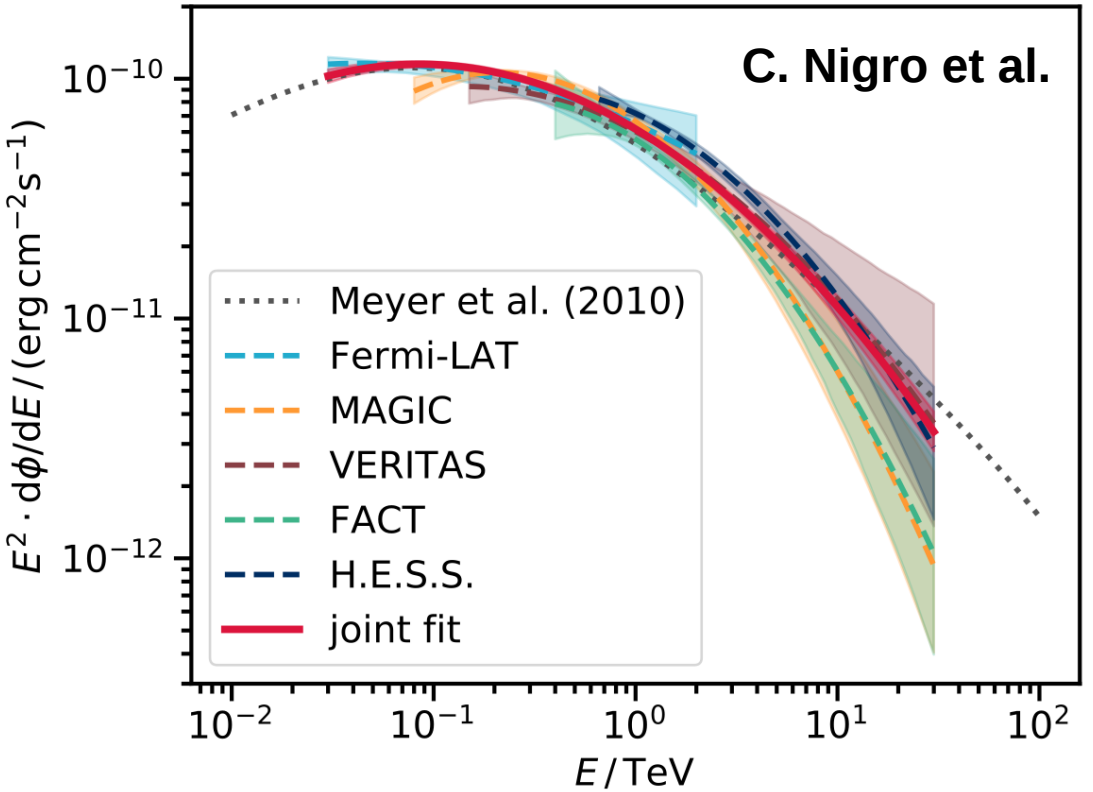
- Sources morphology: more and more precise and complex
- This complexity will increase with CTA observation
- 3D analysis or cube analysis: *fit simultaneously the morphology and the spectrum on a cube dataset* → required to separate the different components of a same region of the sky
- This is the challenge of the science tool developed for CTA

IACT FITS data

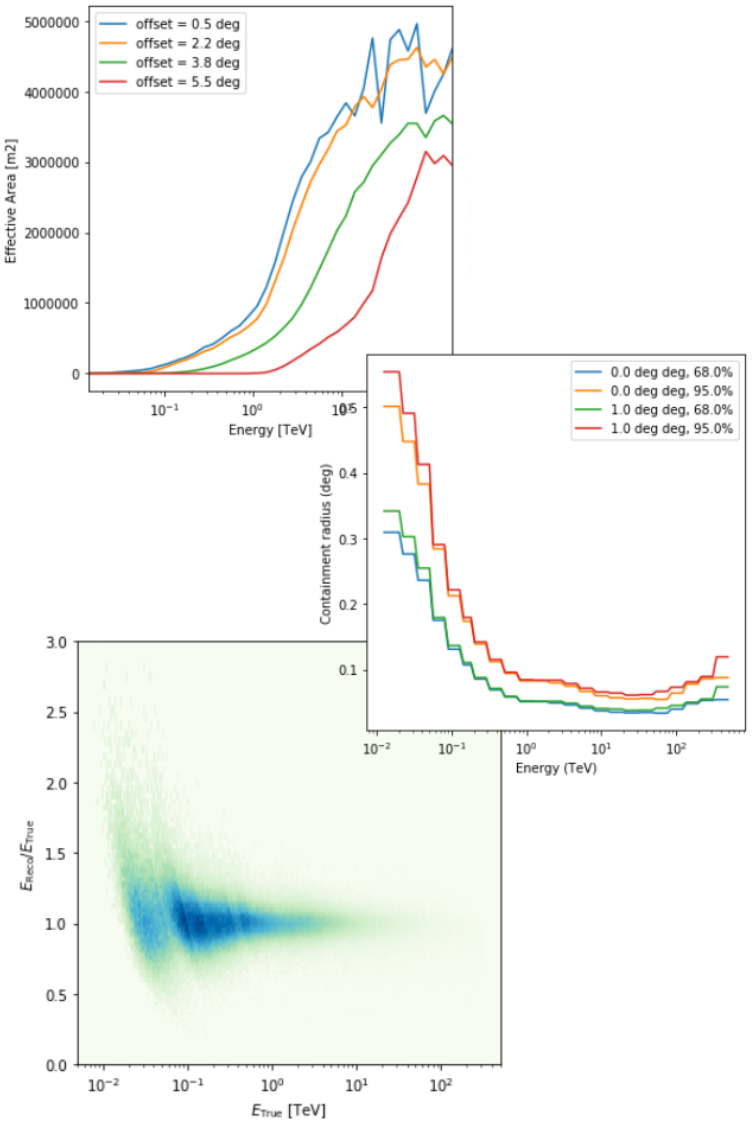
- H.E.S.S. periodically converts their data to DL3
  - first released of a significant open DL3 dataset (2018)
  - test open data and tools. Not for science studies
  - 30 hours: point, extended and variable source observations
  - Data available for download: https://www.mpi-hd.mpg.de/hfm/HESS/pages/dl3-dr1/
  - Analysis tutorial with *Gammapy*: https://docs.gammapy.org/0.10/notebooks/hess.html
  - You can play around with Aladin
- VERITAS and MAGIC: working DL3 converter

Joint Likelihood analysis of the Crab Nebula

- Crab Nebula data from each IACT in the DL3 format
- **Spectrum joint likelihood fit using *Gammapy***
- DL3 samples released to the public together with the required tools
  → Reproducible using Python, Jupyter, conda, Docker
- Accepted in A&A: Data & code open: https://github.com/open-gamma-ray-astro/joint-crab



CTA data challenge



- CTA IRFs in FITS format: *www.cta-observatory.org/science/cta-performance/*
- Used in CTA-internal first data challenge in 2017/2018
- Could extend and refine formats for CTA. Or develop something new and better, based on lessons learnt.

Conclusions and Perspectives

- Space telescopes have public high-level data and tools
- Ground-based telescopes so far private data and codes
- Effort started to collaborate more on data and codes
- It’s time for open data and open source tool but still a lot to be done, interesting time ahead!