Tools and Advancements towards Data Standardization of the MAGIC Collaboration

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Introduction

The gamma-ray astronomy community is keen on standardized data formats, because:

- Multi-experiment analysis yield interesting results while requiring **interoperability**
- Next-generation large-scale astrophysical experiments, like the Cherenkov Telescope Array (CTA), are build as **open observatories**
- **Large data volumes** require a community approach to be analyzed which requires open-source tools which work on standardized data formats
- Existing experiments reach the end of their lifetime and what to leave behind an **easily utilizable and accessible legacy**

magic_dl3

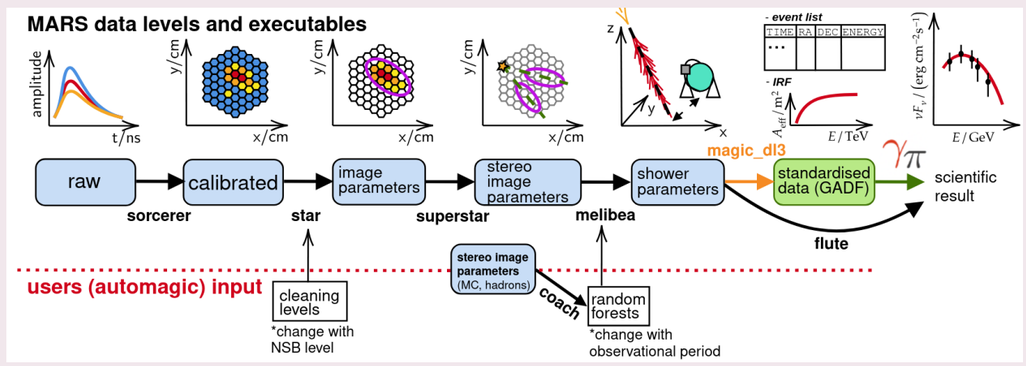

Figure 1. MAGIC data analysis chain with the green box being the DL3 and the blue boxes being MAGIC data levels.[1]

- **Data Level 3 (DL3)** contains the data to convert detector-specific information (event-counts) into experiment-independent information (gamma-ray flux)
- Since no proprietary MAGIC data level is GADF-compliant [2] *magic_dl3* **utilizes the melibea data level and produces DL3 data.**
- *magic_dl3* **applies a cut on the "gammaness"** to build gamma-ray event lists
- *magic_dl3* obtains the **Instrument Response Function from Monte Carlo simulations** with data-identical cuts

magic_dl3 Validation

To validate the *magic_dl3* tool, we compare the on and off region counts as well as the effective area and energy dispersion on a $0.4°$ offset, $[5°, 35°]$ zenith, $30\,\mathrm{h}$ Crab Nebula data set produced with the *magic_dl3* tool and analyzed with *Gammapy* and the MAGIC proprietary software *MARS*.

Moreover, we validated *magic_dl3* for a range of offset-distances from $0.2°$ to $1.4°$ by extending the data set with a $[5°, 50°]$ zenith, $20\,\mathrm{h}$ multi-offset Crab Nebula data set.

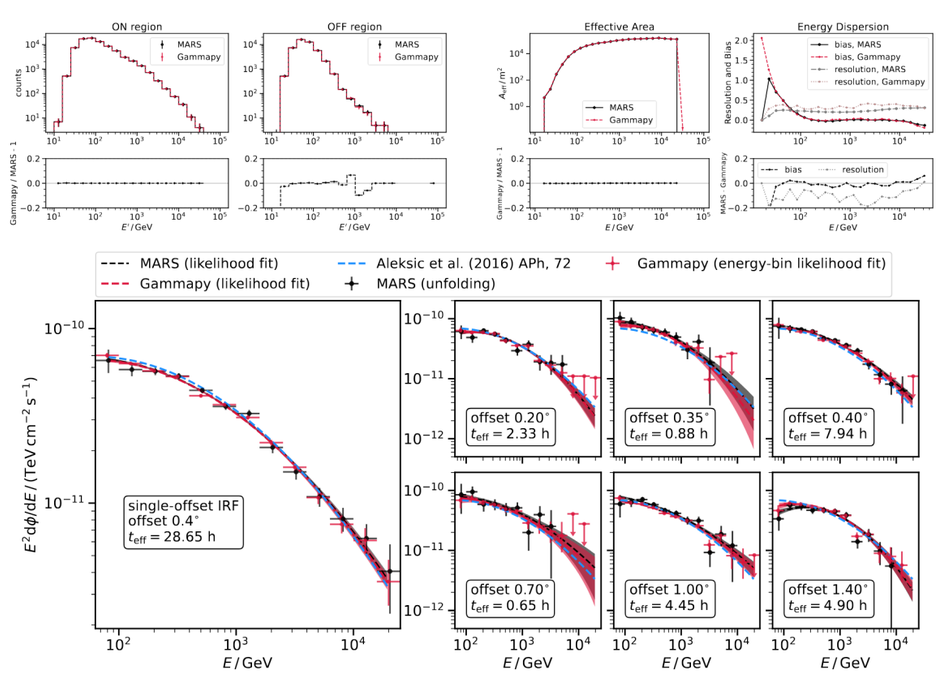

Figure 2. Above: DL3 feature comparison between *magic_dl3* in red and *MARS* in black. Below: SEDs obtained from different offset-distances with *magic_dl3* in red, *MARS* in black, and the reference in blue.[1, 3]

References & Acknowledgments

[1] MAGIC Collaboration. "Standardised formats and open-source analysis tools for the MAGIC telescopes data". In: *JHEAP* 44 (2024), pp. 266–278. DOI: 10.1016/j.jheap.2024.09.011.

[2] C. Nigro, T. Hassan, L. Olivera-Nieto. "Evolution of Data Formats in Very-High-Energy Gamma-Ray Astronomy". In: *Universe* 7 (2021), p. 374. DOI: 10.3390/universe7100374.

[3] J. Aleksić, et. al. "The major upgrade of the MAGIC telescopes, Part II: A performance study using observations of the Crab Nebula". In: *Astroparticle Physics* 72 (2016), pp. 76–94. DOI: 10.1016/j.astropartphys.2015.02.005.

[4] J. L. Schubert. "Pulsar analyses with the MAGIC experiment". In: (2024). DOI: 10.17877/DE290R-24588.

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autoMAGIC

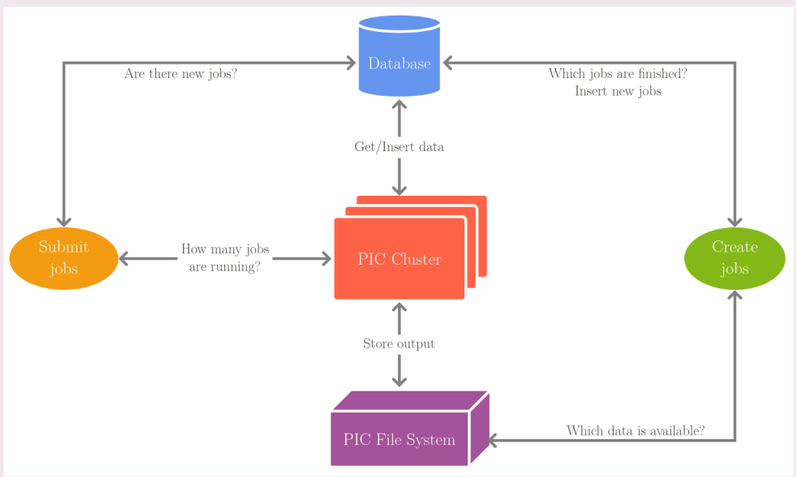

Figure 3. *autoMAGIC* operating procedure facilitating the automation of *MARS* analysis steps.[4]

autoMAGIC is an automated database-driven MAGIC data reduction tool, automatizing the preparation, execution, and storage of individual MAGIC data analysis steps.

1. *autoMAGIC* **automatically adapts analysis configurations** dependent on the observation conditions.
2. *autoMAGIC* **allows for consistent analysis** independent of the timescale while providing significant time-efficiency.
3. *autoMAGIC* **reduces human-dependent parameter choices** which are prone to errors.

autoMAGIC Validation

We validated *autoMAGIC* by testing its performance on a $0.4°$ offset, $[5°, 50°]$ zenith, $20\,\mathrm{h}$ Crab Nebula data set with varying moonlight conditions against a manual analysis as well as a reference.[3]

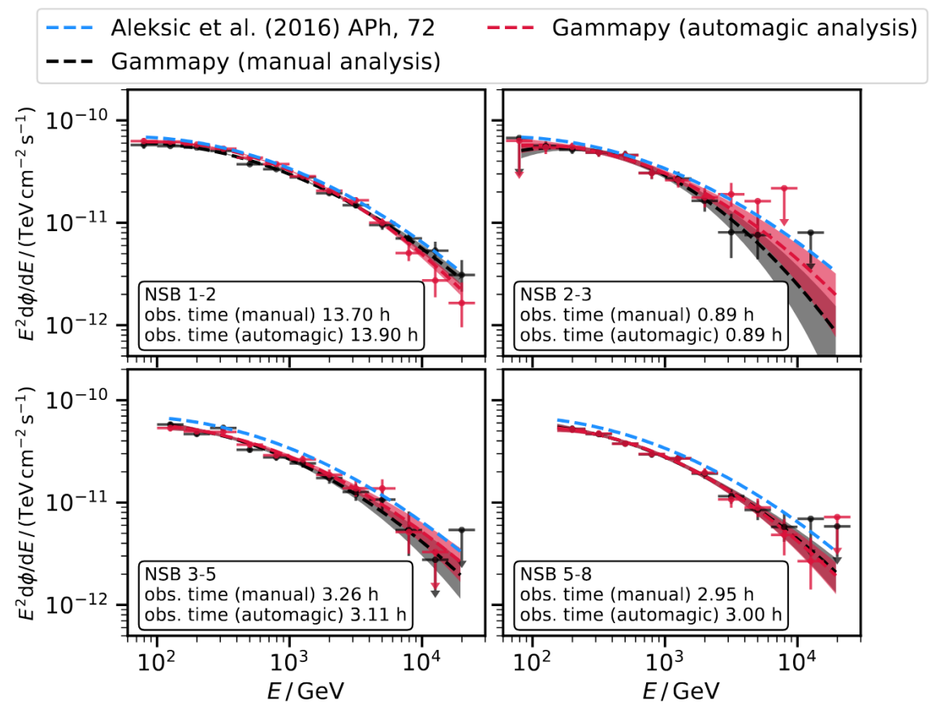

Figure 4. SEDs comparing the performance of autoMAGIC against a manual analyis on four different bins with increasing night-sky background.[1, 3]

Markarian 421 Variability Study

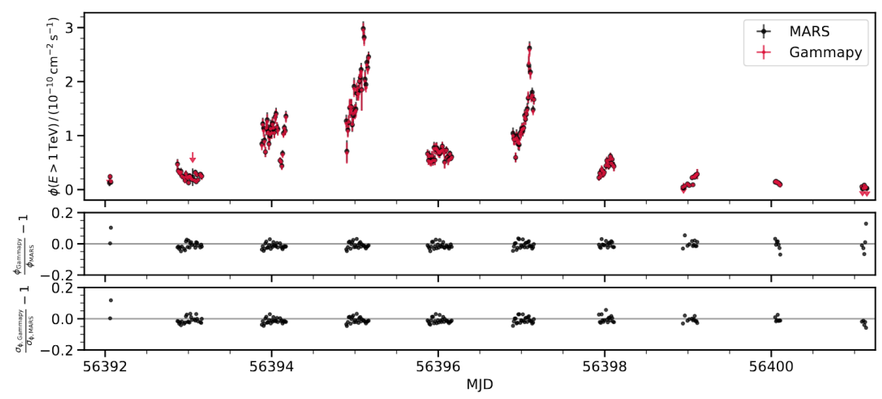

Figure 5. Lightcurve of Mrk421 with *magic_dl3* in red and *MARS* in black, below ratios of flux and signal.[1]

Besides DL3 features and offset-distances in Figures 2 and 1, we probed *magic_dl3* on Mrk421, a highly variable source, with a $0.4°$ offset, $[5°, 70°]$ zenith, $42\,\mathrm{h}$ data set showing the lightcurve in Figure 5.