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Defining the data legacy of the MAGIC telescopes: adopting a standardised data format and open-source analysis tools

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Very-high-energy (VHE, $E > 100\,\mathrm{GeV}$) gamma-ray telescopes have traditionally conducted science with proprietary data and software. After two decades of operations, they have accumulated thousands of hours of observations whose full scientific exploitation cannot be accomplished by the restricted group of scientists operating these instruments. The advent of a new generation of open gamma-ray observatories and, at the same time, the forthcoming end of their scientific operations, call for the realisation of public archives of their observations. With the objective to facilitate the exchange and dissemination of data from current- and next-generation gamma-ray instruments, the "Data formats for gamma-ray astronomy" (`GADF`) initiative was formed to provide an open and standardised format for gamma-ray astronomical data. In this contribution, we present the effort to produce data of the Major Atmospheric Gamma-ray Imaging Cherenkov (MAGIC) telescopes in this standardised format. A total of 150 hours of observations of different sources were converted to the `GADF` format and then validated by analysing them with the open-source software `Gammapy` and comparing the results obtained against those produced with the MAGIC proprietary software, `MARS`. The effort to standardise and validate the MAGIC data in an open and shared format constitute the first fundamental milestone towards the realisation of its public data legacy.

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1. Introduction

The usage of standardised data and open-source analysis tools emerged as relevant topics in gamma-ray astronomy as the next-generation of VHE instrument, represented by the Cherenkov Telescope Array (CTA) [1], decided to open its observations to the astronomical community. The community-driven standardisation initiative known as "Data formats for gamma-ray astronomy" (GADF) [2, 3] and the open-source software `Gammapy` [4] were conceived to address these requirements. VHE astronomers started to test the newly-available open data format and analysis tools with current-generation instruments. As a result, the High Energy Stereoscopic System (H.E.S.S.) realised the first public release of `GADF`-compliant data [5], while [6] and [7] demonstrated that small samples of standardised data from different gamma-ray instruments (space- and ground-based) could be easily combined with open-source tools producing fully-reproducible results.

While only two 20-min observations of MAGIC were released for the demonstrative project in [6], the Collaboration undertook the effort to produce larger samples of standardised data and to perform extensive tests on the agreement of `MARS`- and `Gammapy`-based analyses. In this contribution we summarise those efforts, that were also presented in [8].

2. Data sets and validation

For the process of validation we selected three different sources illustrating different scientific and analysis cases:

- 50 h of Crab Nebula observations from [9] were used to validate the spectrum and light curve estimation in case of a bright and steady VHE gamma-ray emitter;
- 42 h of Mrk421 observations from [10] were used to validate the light curve estimation in case of a bright and highly variable VHE gamma-ray emitter;
- 57 h of M15 observations from [11] were used to validate the upper limit estimation on the flux in case of a source too dim in gamma rays to provide a significant detection.

For the production of the `GADF`-compliant data, the standard data reduction was performed with the `MARS` software [12]. A newly-developed MAGIC proprietary library was then used to extract the high-level information expected by the `GADF` specifications (list of events with their reconstructed energy, direction, and arrival times, and a parametrisation of the response of the system) and store it in the `GADF`-compliant data.

3. Results

For all the sources in considerations, for all the flux estimation performed, we observed an excellent agreement between the results obtained with `MARS` and with the standardised data analysed with `Gammapy`.

4. Conclusion

For all the high-level analyses performed, a good agreement was observed between the two data formats and software. The validation of this first standardised data production represent a milestone in the definition of the future MAGIC data legacy.

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PoS(ICRC2023)827