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

Cosimo Nigro\textsuperscript{a,*} on behalf of the MAGIC Collaboration

\textsuperscript{a}Institut de Física d’Altes Energies (IFAE), The Barcelona Institute of Science and Technology, Campus UAB, Bellaterra, 08193 Barcelona, Spain

E-mail: cosimo.nigro@ifae.es

Very-high-energy (VHE, $E > 100$ 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.
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.

5. Acknowledgements

C.N. acknowledges support by the Spanish Ministerio de Ciencia e Innovación (MICINN), the European Union – NextGenerationEU and PRTR through the programme Juan de la Cierva (grant FJC2020-046063-I), by the the MICINN (grant PID2019-107847RB-C41), and from the CERCA program of the Generalitat de Catalunya.

References


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Cosimo Nigro

30 Croatian MAGIC Group: University of Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture (FESB), 21000 Split, Croatia
31 Croatian MAGIC Group: Josip Juraj Strossmayer University of Osijek, Department of Physics, 31000 Osijek, Croatia
32 Finnish MAGIC Group: Finnish Centre for Astronomy with ESO, University of Turku, FI-20014 Turku, Finland
33 Japanese MAGIC Group: Department of Physics, Tokai University, Hiratsuka, 259-1292 Kanagawa, Japan
34 Università di Siena and INFN Pisa, I-53100 Siena, Italy
35 Saha Institute of Nuclear Physics, A CI of Homi Bhabha National Institute, Kolkata 700064, West Bengal, India
36 Inst. for Nucl. Research and Nucl. Energy, Bulgarian Academy of Sciences, BG-1784 Sofia, Bulgaria
37 Japanese MAGIC Group: Department of Physics, Yamagata University, Yamagata 990-8560, Japan
38 Finnish MAGIC Group: Space Physics and Astronomy Research Unit, University of Oulu, FI-90014 Oulu, Finland
39 Japanese MAGIC Group: Chiba University, ICEHAP, 263-8522 Chiba, Japan
40 Japanese MAGIC Group: Department of Physics, Kyoto University, 606-8502 Kyoto, Japan
41 Japanese MAGIC Group: Institute for Space-Earth Environmental Research and Kobayashi-Maskawa Institute for the Origin of Particles and the Universe, Nagoya University, 464-8001 Nagoya, Japan
42 Croatian MAGIC Group: Ruđer Bošković Institute, 10000 Zagreb, Croatia
43 INFN MAGIC Group: INFN Sezione di Perugia, I-06123 Perugia, Italy
44 INFN MAGIC Group: INFN Roma Tor Vergata, I-00133 Roma, Italy
45 Japanese MAGIC Group: Department of Physics, Konan University, Kobe, Hyogo 658-8501, Japan
46 also at International Center for Relativistic Astrophysics (ICRA), Rome, Italy
47 now at Institute for Astro- and Particle Physics, University of Innsbruck, A-6020 Innsbruck, Austria
48 also at Port d’Informació Científica (PIC), E-08193 Bellaterra (Barcelona), Spain
49 also at Institute for Astro- and Particle Physics, University of Innsbruck, A-6020 Innsbruck, Austria
50 also at Department of Physics, University of Oslo, Norway
51 also at Dipartimento di Fisica, Università di Trieste, I-34127 Trieste, Italy
52 Max-Planck-Institut für Physik, D-80805 München, Germany
53 also at INAF Padova
54 Japanese MAGIC Group: Institute for Cosmic Ray Research (ICRR), The University of Tokyo, Kashiwa, 277-8582 Chiba, Japan