Article

Dissemination of MAGIC High-Level Data - DL5 Data Portal

Michele Doro [1,2†], Stefano Marchesi [3,4,5‡], Elisa Prandini [1,2] and Ilaria Viale [1,2]

1 Department of Physics and Astronomy, University of Padova, via Marzolo 8, 35131 Padova (Italy);
2 INFN sez. Padova, via Marzolo 8, 35131 Padova (Italy);
3 Dipartimento di Fisica e Astronomia (DIFA) Augusto Righi, Università di Bologna, via Gobetti 93/2, I-40129 Bologna, Italy;
4 INAF-Osservatorio di Astrofisica e Scienza dello Spazio (OAS), via Gobetti 93/3, I-40129 Bologna, Italy;
5 Department of Physics and Astronomy, Clemson University, Kinard Lab of Physics, Clemson, SC 29634, USA
* Correspondence: michele.doro@unipd.it
‡ These authors contributed equally to this work.

Abstract: TBD

Keywords: keyword 1; keyword 2; keyword 3 (List three to ten pertinent keywords specific to the article; yet reasonably common within the subject discipline.)

1. Project aims

The MAGIC collaboration [1] has published more than 200 peered-reviewed papers from its first light. The largest fraction of them reports detection or upper limits on very-high-energy gamma-ray emission from astrophysical targets, normally expressed as photon flux or spectral energy distribution (SEDs). Because several astrophysical sources are varying in intensity they are monitored, and intranight or longer-term variability is appreciated, therefore Light Curves (LCs) are also reported in such publications. Furthermore, for close-enough objects, normally within the Milky Way, an extension can be appreciated with respect to the telescope angular resolution, also skymaps of the signal are reported. Finally, in case the signal model is connected to some physical parameters, such a the dark matter annihilation cross-section, the observation reports estimation or limits on such parameters.

All such data are normally simply published in plots within a paper. In line with the FAIR principles (Findable, Accessible, Interoperable and Reusable) for astronomical data [2], in order to increase the data dissemination and provide a stable and controlled legacy of such numerical results, we have developed a project for the creation of a portal of high-level (SEDs, LC, skymaps, etc) results from MAGIC publications. Data are transcript in `ascii` files readable by human eyes and machines and containing a selection of relevant information for those data, including units and provenance.

In this work, we describe the portal, the structure of the files and their content, and the way these are disseminated to virtual observatories.

2. Portal Overview

The portal is structured as follows:

1. For each publication, an header file and a set of files (normally one or more for each figure of the paper) is created, containing MAGIC-related data
2. Additional data (MWL data or other data) are possibly prepared
3. The files are saved in a `gitlab` repository accessible to only MAGIC members[1]
4. TODO: in a dedicated server, the above files are copied. In the server, a descriptor connects the fields and metadata of the portal files into VO compliants data
5. TODO: a system runs on the VO webserver that reads MAGIC portal data

[1] https://gitlab.pic.es/magic/magic_dl5_dataportal

Citation: M. Doro and others. MAGIC DL5 portal. *Journal Not Specified* **2024**, *1*, 0. https://doi.org/

Received:
Revised:
Accepted:
Published:

For the header and content file, we borrowed an idea from the gamma-cat collection[2]. This would allow us, in addition to the VO, to distribute data through gitlab with commands such as (TO BE DONE):

```
from gammapy.sourcelist.MAGIC import srclistMAGIC
```

and obtain data quickly e.g. in python notebooks.

2.1. Virtual Observatory

The Virtual Observatory (VO) is a general term for a collection of federated resources that can be used to conduct astronomical research, education, and outreach. The International Virtual Observatory Alliance (IVOA) is a global collaboration of separately funded projects to develop standards and infrastructure that enable VO applications. Data collection must be registered in the VO via a table access protocol (TAP) service.

The GADF [3] is a community-led effort to create an open, unified data format for gamma-ray instruments, focusing on data at the reconstructed event level [4]. Built partly on the OGIP standards, GADF is specifically tailored for very-high-energy (VHE) data. It was first designed in 2011 for CTAO during its prototyping phase. Now, it serves as the standard for VHE gamma-ray data and, since becoming open-source in 2016, has also been adopted as the primary format for the gammapy software [5]. The Very-high-energy Open Data Format (VODF) [6,7] is planned as an evolution of GADF. It aims to address some limitations of the GADF format by providing a well-documented and consistent data model that caters to both VHE gamma-ray and neutrino astronomy needs, while also enhancing support for validation and version management. VODF will standardize a set of file formats for reconstructed event-level data (event lists), higher-level products like sky images, light curves, spectra, and source catalogs, as well as N-dimensional binned data cubes. This standardization will allow common scientific tools to be used across multiple high-energy instruments, enabling combined likelihood model fitting over wide energy ranges from either event or binned data. VODF aims to be compatible with existing IVOA standards wherever possible.

3. MAGIC Data Structure

For each publication we generate a set of files as follows, depending on the topics of the paper and the material contained in it:

1. A header file containing general information on the publication, along with the list of files attached. This is a .yaml file
2. A data file in .ecsv format for Spectral Energy Distribution or in general spectral flux data
3. A data file in .ecsv format for Light Curves
4. Other data files in .ecsv format for parameters estimation or constraints, e.g. dark matter annihilation cross-section upper limits or decay lifetime lower limits, limits on interaction strength of axion-like particles fields, and so on.

3.1. Template header file

The header files just contains metadata which are of support to the each paper to define the attached files but also add basic information such as the journal reference, and the credit to the authors of the papers. The template reads as follows:

```
File_info:
 Fdate   : #date of last modification
 Fvers   : #version of files (after publication), default v1.0
 Fgen    : Michele Doro michele.doro@unipd.it
 Fmail   : contact.magic@mpp.mpg.de, magic_legacy@mpp.mpg.de
```

[2] https://docs.gammapy.org/0.7/catalog/gammacat.html, now a discontinued project within the gammapy open software.

```
 Flink   : <link_to_thisfile_repository>
 Fstatus : "Commments"
Paper info:
 Ptitle   : "Paper Title"
 Pref     : Journal
 Pdoi     : DOI link
 Parxiv   : arxiv link
 Pcoll    : magic
 Pcauthor : full names of corresponding authors
 Pfauthor : full author list
 Pads     : reference as in ADS
 Pinspire : reference as in inspirehep
Targets in file:
 Tpname01: short name as in the paper
 Taname01: alternative name used by other instruments/collaborators on the paper
File list MAGIC:
 magic_20xxa_fig1_sed.ecsv
 magic_20xxa_fig2_lc.ecsv
Other Files:
 magic_20xxa_fig3.dat
```

It starts with information over the header files itself such as `Fdate` containing the last date in which the file was modified, `Fvers` containing information over the version. This can be useful in case the file is already distributed but then modified. `Fgen` contains name and email address of the person that generated the file (for credit and contact); `Fmail` is the contact mail for further information which normally is contact.magic@mpp.mpg.de or magic_legacy@mpp.mpg.de for this activity; `Flink` is aimed to contain the actual link to the file in case the file is directly accessible from a webpage so that if one scientist receives it by other means s/he can find its permament location online; `Fstatus` is just an internal tag. Normally we used tags such as: in preparation, completed, checked, etc.

Then follows information on the paper such as the paper title `Ptitle`, journal reference `Pref`, the DOI and arXiv links `Pdoi, Parxiv`, the list of collaborations that are authors of the paper in `Pcoll`. Here we use e.g. `magic, hess, external` for MAGIC, H.E.S.S. or external members. In `Pcauthor` we report the full names of the corresponding authors of the paper, both for credit and so that in case a user can report to them for further questions on the data. We then report the paper full list of authors in `Pfauthor` also for credit. This can be easily copied-paste from the NASA ADS webpage of that reference because it does not add affiliation numbers. Finally, we provide the bibliographic references in `Pads,Pinspire` as reported by the NASA ADS [8] or InspireHEP [9] webpages.

A new section lists the targeets in the file. `Tpname01` is the name of the first source as used in the MAGIC publication. `Taname01` is the alternative name of this first sources. One can add several lines if there are more sources, e.g. `Tpname02,Tpname03`.

Finally, the list of attached files is reported. We start with the figures containing MAGIC original data. As naming convention we used a structure like `magic_20xxa_fig1_sed.ecsv`, `magic_20xxa_fig2_lc.ecsv` which contains the year, the figure number from the paper, and the general type of data (SED, LC, etc). Whenever applicable and possible, we also provide other data from the manuscript, e.g. from tables or plots, also referring to data from other instruments, but originally analyzed in the MAGIC manuscript.

3.2. Spectral Energy Distribution Files

The template of a file reporting SED data is as follows:

```
# %ECSV 0.9
# ---
# datatype:
# - {name: srcname   , unit: latex   , datatype: str     , description: Source name          }
# - {name: en        , unit: TeV     , datatype: float32 , description: Energy               }
# - {name: en_wlo    , unit: TeV     , datatype: float32 , description: Energy bin width low }
# - {name: en_wup    , unit: TeV     , datatype: float32 , description: Energy bin width up  }
# - {name: nufnu     , unit: erg cm-2 s-1, datatype: float32 ,
    description: Differential photon flux at energy  }
# - {name: nufnu_elo , unit: erg cm-2 s-1, datatype: float32 ,
```

```
    description: Lower uncertainty in nufnu          }
# - {name: nufnu_eup , unit: erg cm-2 s-1, datatype: float32 ,
    description: Upper uncertainty in nufnu          }
# - {name: tstart    , unit: mjd     , datatype: float32 , description: MJD start            }
# - {name: tstop     , unit: mjd     , datatype: float32 , description: MJD stop             }
# - {name: texpo     , unit: h       , datatype: float32 , description: Observation time     }
# - {name: instrument, unit: latex   , datatype: str     , description: Instrument           }
# - {name: dataformat, unit: latex   , datatype: str     , description: Data Format          }
# - {name: comments  , unit: latex   , datatype: str     , description: Comments             }
# meta: !!omap
# - {Filename: magic_20xx_figx_sed.1ecsv}
# - {Source: "Put target name here"}
# - {Figure: "Description"}
# - {Title: "Title of the paper"}
# - {Comments: "Add comments"}
# - {Reference: "magic_2020o.yaml"}
# - {Status: "Status of file"}
# schema : astropy -2.0

srcname; en; en_wlo; en_wup; nufnu; nufnu_elo; nufnu_eup; tstart; tstop; texpo;
instrument; dataformat; comments
M15;   59.44692;  47.22056 ; 74.83894; 2.8759e-11; nan; nan; 57174; 57632; 173;
MAGIC; ul; ""
```

where `srcname` reports the source name, normally in the way it's reported in the paper or a shorter version, `en` is the energy of the point which is best expressed in TeV units but can be expressed in any other equivalent units (e.g. frequency or other multiple of eV), `en_wlo, en_wup` are the values of energy at which the energy bin starts and ends, they are not therefore the left and right bin width, which can be easily computed. `nufnu` is the differential photon flux and can be expressed in any units of flux. Preferred is erg cm-2 s-1 but also (ph) cm-2 s-1 can be used. `nufnu_elo, nufnu_eup` are now the lower and upper uncertainty from the flux point. `tstart, tstop` are the MJD dates of the begin and end of observation as reported in the paper. If the SED reports several periods these can be specified one after the other. `texpo` reports the total observation time, regardless the start/end. `instrument` reports single or multiple instruments and externals. `dataformat` is used in case of upper limits, where `ul` is written and finally a `comments` field is left for remarks.

Among the metadata we report `Filename` that is the actual file name for easier recovery. `Source` for quick view. `Figure` in which we described the origin of data as a figure in the publication. `Title` the title of the paper. `Comments` for further comments.`Reference` is the corresponding `.yaml` header file. Finally `Status` tell us about the status of the file.

3.3. Light Curve Files

The template of a file reporting LC data is the following:

```
# %ECSV 0.9
# ---
# datatype:
# - {name: srcname, unit: latex  , datatype: str     , description: Source name            }
# - {name: t      , unit: mjd    , datatype: float32 , description: Time of measurement    }
# - {name: t_wlo  , unit: d      , datatype: float32 , description: Lower width of time bin}
# - {name: t_wup  , unit: d      , datatype: float32 , description: Upper width of time bin}
# - {name: t_exp  , unit: h      , datatype: float32 , description: Exposure time          }
# - {name: flux   , unit: cm-2 s-1, datatype: float32 , description: Flux measured above the
    energy threshold             }
# - {name: flux_elo , unit: cm-2 s-1, datatype: float32 , description: Lower uncertainty
    of flux  }
# - {name: flux_eup , unit: cm-2 s-1, datatype: float32 , description: Upper uncertainty
    of flux  }
# - {name: eth_lo  , unit: GeV,    datatype: float32 , description: Assumed lower energy
    threshold for integral flux calculation}
# - {name: eth_up  , unit: GeV,    datatype: float32 , description: Assumed upper energy
    threshold for integral flux calculation}
# - {name: instrument, unit: latex  , datatype: str  , description: Instrument     }
# - {name: dataformat, unit: latex  , datatype: str  , description: Data Format    }
```

```
# - {name: comments  , unit: latex  , datatype: str  , description: Comments      }
# meta: !!omap
# - {Filename: magic_template_lc.ecsv}
# - {Source: ""}
# - {Figure: ""}
# - {Title: ""}
# - {Comments: ""}
# - {Reference: ""}
# - {Status: ""}
# schema : astropy -2.0

srcname; t; t_wlo; t_wup; t_exp; flux; flux_elo; flux_eup; eth_lo; eth_up; instrument;
dataformat; comments
```

where `srcname` reports the name of the source of interest as in the SED template, `t` is the time of the LC point, usually expressed in MJD units, although other units are possible; `t_wlo` and `t_wup` are respectively the lower and upper width of the time bin; `t_exp` is the exposure time; `flux` is the integrated flux computed above the energy threshold and usually expressed in (ph) $\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. `flux_elo` and `flux_eup` are the lower and upper uncertainties of the flux point. `eth_lo` and `eth_up` are the lower and upper energy thresholds used for the integral flux calculation. Finally, similarly to the SED template, `Instrument` reports the observing instrument, `dataformat` is used to indicate if the reported flux is an upper limit, and `comments` is used for remarks. The reported metadata are the same as in the SED template.

3.4. Skymap Files

For the moment we do not produce skymaps. We have plans to have them in .fits format.

3.5. Other Files

In cases where data are not reported as flux limits but according to a parameter of interest, these can be extracted in less standard way. However, because several portals are found online that collect such limits, one can try and agree on the format with such portals, so that limits and measurements can be shared more efficiently. Here we mention some.

Axion-like Particles limits

The template of a file reporting limits on the axion-like particles parameter space is as follows. This was generate in order to be compliant with the online AxionLimits repository [3].

```
# %ECSV 0.9
# ---
# datatype:
# - {name: srcname   , unit: latex  , datatype: str     , description: Source name             }
# - {name: ma        , unit: eV    , datatype: float32 , description: axion-like particle mass  }
# - {name: gagamma   , unit: GeV-1 , datatype: float32 , description: ALPs to photons coupling  }
# - {name: tstart    , unit: mjd   , datatype: float32 , description: MJD start                 }
# - {name: tstop     , unit: mjd   , datatype: float32 , description: MJD stop                  }
# - {name: texpo     , unit: h     , datatype: float32 , description: Observation time          }
# - {name: instrument, unit: latex , datatype: str     , description: Instrument                }
# - {name: dataformat, unit: latex , datatype: str     , description: Data Format               }
# - {name: comments  , unit: latex , datatype: str     , description: Comments                  }
# meta: !!omap
# - {Filename: magic_template_alp_constraints.ecsv}
# - {Source: ""}
# - {Figure: ""}
# - {Title: ""}
# - {Comments: ""}
# - {Reference: ""}
# - {Status: ""}
# schema : astropy -2.0
```

[3] https://github.com/cajohare/AxionLimits

```
srcname; ma; gagamma; tstart; tstop; texpo; instrument; dataformat; comments
```

where `srcname` reports the name of the source used to obtain the constraints, m_a is the mass of the axion-like particle, $g_{a\gamma}$ is the coupling of the axion-like particle to photons, `tstart` and `tstop` represent MJD dates of the begin and end of observations used to obtain the limits, while `texpo` is the total observation time used. Finally, columns `instrument`, `data format` and `comments`, are used to mark the instrument whose data is used in the study, data format reported in the table, most often being the 95% and/or 99% confidence levels and comments as any additional remarks, respectively. The reported metadata are the same as in the SED and LC templates.

This format was used for reporting the first constraints on axion-like parameter space obtained with MAGIC [10] which were timely added to the remaining limits on ALPs coupling with photons collected in the AxionLimits repository.

Dark Matter Limits

Similarly to the ALP portal described above, the `gDMbounds` project[4] aims at collecting, displaying and perform operation with experimental limits on dark matter (DM) annihiltion or decay. This portal accepts files in a specific format. For the case of annihilating DM:

```
# %ECSV 0.9
# ---
# datatype:
# - {name: mass   , unit: TeV    , datatype: float32 , description: DM mass  }
# - {name: sigmav , unit: cm3s-1 , datatype: float32 , description: <sigmav> }
# meta: !!omap
# - {reference:       "Title of the paper"}
# - {authors:         "List of authors (in case First Author plus 'and others'"}
# - {journalref:      "Journal reference"}
# - {doi:             "DOI of the paper"}
# - {arxiv:           "arXiv ID of the paper"}
# - {instrument:      "Instrument name"}
# - {year:            "Year of publication"}
# - {source:          "Target name"}
# - {channel:         "Channel name"}
# - {confidence       "Confidence level as fraction" }
# - {dmfraction:      "branching channel fraction"}
# - {obs_time:        "Observation time with unit h, d, or y"}
# - {figure:          "Description"}
# - {comment:         "Any comments on the result"}
# - {status:          "Status of file"}
# schema : astropy -2.0

mass sigmav
```

and for decaying DM with few modified fields:

```
# ---
# datatype:
# - {name: mass , unit: TeV , datatype: float32 , description: DM mass  }
# - {name: tau  , unit: s   , datatype: float32 , description: lifetime }
# meta: !!omap
[...]

mass tau
```

When data are formatted in this way, the inclusion in the portal and the data distribution is very quick and efficient.

4. Multi-wavelength Data

Multi-wavelength data are very often included in MAGIC papers to complement and enrich the physics information and interpretation. These data are in the same form as the

[4] https://github.com/micheledoro/gDMbounds

MAGIC data described above, namely: SED points, light curves, skymaps, and other less common data files. In some cases, multi-wavelength data are the result of a collaboration with other telescopes/observatories and teams, and the data dissemination through a public data portal is not granted. In other cases, the multi-wavelength data are the result of an analysis done by MAGIC members on publicly available data (e.g., *Swift*-XRT or UVOT). Therefore, depending on the paper and the specific campaign, some multi-wavelength data will be shared through the data portal, but the completeness of the multi-wavelength dataset is not granted in any paper. Nevertheless, the multi-wavelength data availability and information on how to retrieve the missing data is shared through the portal in the header file.

Therefore, the multi-wavelength data-sharing information and the data themselves are organised as follows:

- The header file summarizes the files shared in the paper, and reports any contact address that can be used to retrieve multi-frequency data.
- Specific files (e.g., SED, light curve, ...) sharing the data shown in the paper, following the same file structure presented in Sections 3.2 and 3.3.

5. Proposed ObsCore Data Model

The ObsCore Data Model is a standardized schema defined by the IVOA to describe and organize astronomical observations in a consistent way across different archives and databases. It forms part of the VO framework and is widely used to support data discovery and interoperability. The main purposes od the ObsCore Data Model are 1. Data Discovery, that is to enable users to perform uniform queries to find observations across diverse datasets and archives, regardless of the original data structure; 2. Interoperability, to facilitate combining and comparing data from different sources by enforcing a common metadata structure and 3. Search Efficiency, to provide a standard way to describe key metadata elements for fast and effective searches (e.g., by time, wavelength, instrument). A reference document can found in Ref. [11].

There are several Data Product Type in the ObsCore which require specific field to be added. Some are compulsory some are not. The general idea is that a Table Access Protocol (TAP) will read through our `.ecsv` files and create a table with data and metadata matching the ObsCore Data Model vocabulary. Is therefore fundamental to define a one to one match between the MAGIC `.ecsv` files and the ObsCore Data Model together with some explanation of the meaning of the fields. This is done for the different data product below.

5.1. ObsCore Data Model for SED

In this section, we present example of ObsCore Data Products for the MAGIC products, with the goal of making them Table Access Protocol (TAP)-compliant. In Table 1 we report the model for a spectral energy distribution (SED). In Table 2 we instead report the Obscure Data Product structure we developed for a light curve.

ObsCore column	Unit		Value or from `.ecsv`,`.yaml`	Comment
dataproduct_type	–	Y	sed	As defined in [11]
calib_level	–	Y	4	Level 4 is "analysis data products generated after some scientific data manipulation or interpretation".
obs_collection	–	Y	MAGIC/DL5	Because of possible other future collections e.g. MAGIC/DL3, etc.
obs_id	–	Y	{magic_2024a}	From YAML file
obs_publisher_did	–	Y	ivo://magictelescope/dataset?magic/2024a/sed/1	
access_url	–		https://gitlab.pic.es/magic/magic_dl5_dataportal	
access_format	–		ecsv	Format of the data product if downloaded as a file
access_estsize	kb	Y	10	Approximate size (in kilobytes) of the file
facility_name	–	Y	{instrument}	From ECSV SED file
instrument_name	–	Y	NULL	**Note: in principle we can define MAGIC-single, MAGIC-stereo, etc.**
target_name	–	Y	{srcname}	From ECSV SED file
s_ra	deg	Y	{Tra01}	From YAML file
s_dec	deg	Y	{Tdec01}	From YAML file
s_fov	deg	Y	3.5	Approximate size of the region covered by the data product
s_region	–	Y	0.1 deg	Precisely specify the covered spatial region of a data product.
s_resolution	arcsec	Y	360	Estimated spatial resolution of the data product in arcseconds
s_xel1	–	Y	-1	Number of elements along the first spatial axis
s_xel2	–	Y	-1	Number of elements along the second spatial axis
t_min	d	Y	{tstart}	Start time in MJD. From ECSV SED file
t_max	d	Y	{tstop}	End time in MJD. From ECSV SED file
t_exptime	s	Y	{texpo}	Exposure times in seconds. From ECSV SED file
t_resolution	s	Y	-1	Minimal interpretable interval between two points along the time axis
t_xel	–	Y	-1	Number of elements along the time axis
em_min	m	Y	2e-16	Start in spectral coordinates. Should be proxy of energy threshold. $1\,\mathrm{GeV}/c^2 \simeq 1.97 \times 10^{-16}$ m.
em_max	m	Y	2e-21	End in spectral coordinates
em_res_power	–	Y	10	Spectral resolving power defined as $\lambda/\Delta\lambda$
em_xel	–	Y	-1	Number of values spanned for the spectral axis
o_ucd	–	Y	phot.flux.density	UCD of observable
pol_xel	–	Y	-1	Number of elements along the polarization axis
target_class	–	N	NULL	**Note: We can define the target class, but do we want it?**
obs_creation_date	–	N	{Fdate}	Date when the dataset was created. From YAML file
obs_creator_name	–	N	{Fgen}	Name of the creator of the data. From YAML file
bib_reference	–	N	{Pref}	Service bibliographic reference. From YAML file
data_rights	–	N	Public	Public/Secure/Proprietary/

Table 1. ObsCode Data Model for a spectral energy distribution.

ObsCore column	Unit		Value or from `.ecsv,.yaml`	Comment
dataproduct_type	–	Y	timeseries	As defined in [11]
calib_level	–	Y	4	Level 4 is "analysis data products generated after some scientific data manipulation or interpretation".
obs_collection	–	Y	MAGIC/DL5	Because of possible other future collections e.g. MAGIC/DL3, etc.
obs_id	–	Y	{magic_2024a}	From YAML file
obs_publisher_did	–	Y	ivo://magictelescope/dataset?magic/2024a/timeseries/1	
access_url	–		https://gitlab.pic.es/magic/magic_dl5_dataportal	
access_format	–		ecsv	Format of the data product if downloaded as a file
access_estsize	kb	Y	10	Approximate size (in kilobytes) of the file
facility_name	–	Y	{instrument}	From ECSV light curve file
instrument_name	–	Y	NULL	**Note: in principle we can define MAGIC-single, MAGIC-stereo, etc.**
target_name	–	Y	{srcname}	From ECSV light curve file
s_ra	deg	Y	{Tra01}	From YAML file
s_dec	deg	Y	{Tdec01}	From YAML file
s_fov	deg	Y	3.5	Approximate size of the region covered by the data product
s_region	–	Y	0.1 deg	Precisely specify the covered spatial region of a data product.
s_resolution	arcsec	Y	360	Estimated spatial resolution of the data product in arcseconds
s_xel1	–	Y	-1	Number of elements along the first spatial axis
s_xel2	–	Y	-1	Number of elements along the second spatial axis
t_min	d	Y	{tstart}	Start time in MJD. From ECSV light curve file (time of the first bin?)
t_max	d	Y	{tstop}	End time in MJD. From ECSV light curve file (time of the last bin?)
t_exptime	s	Y	-1	Exposure times in seconds.
t_resolution	s	Y	{t_wlo} or {t_wup}	Minimal interpretable interval between two points along the time axis. From the ECSV light curve file
t_xel	–	Y	{n_lines}	Number of elements along the time axis. This is the number of lines in the ECSV file.
em_min	m	Y	{eth_lo}	Start in spectral coordinates. We treat it as a proxy of the energy range lower boundary, from the ECSV light curve file. $1\,\mathrm{GeV}/c^2 \simeq 1.97 \times 10^{-16}\,\mathrm{m}$.
em_max	m	Y	{eth_up}	End in spectral coordinates. Upper boundary of the energy range, from the ECSV light curve file.
em_res_power	–	Y	10	Spectral resolving power defined as $\lambda/\Delta\lambda$
em_xel	–	Y	-1	Number of values spanned for the spectral axis
o_ucd	–	Y	phot.flux.density	UCD of observable
pol_xel	–	Y	-1	Number of elements along the polarization axis
target_class	–	N	NULL	**Note: We can define the target class, but do we want it?**
obs_creation_date	–	N	{Fdate}	Date when the dataset was created. From YAML file
obs_creator_name	–	N	{Fgen}	Name of the creator of the data. From YAML file
bib_reference	–	N	{Pref}	Service bibliographic reference. From YAML file
data_rights	–	N	Public	Public/Secure/Proprietary/

Table 2. ObsCode Data Model for a light curve.

Author Contributions: Conceptualization, X.X. and Y.Y.; methodology, X.X.; software, X.X.; validation, X.X., Y.Y. and Z.Z.; formal analysis, X.X.; investigation, X.X.; resources, X.X.; data curation, X.X.; writing—original draft preparation, X.X.; writing—review and editing, X.X.; visualization, X.X.; supervision, X.X.; project administration, X.X.; funding acquisition, Y.Y. All authors have read and agreed to the published version of the manuscript.

Funding: We acknowledge contribution from the Next Generation EU funds within the National Recovery and Resilience Plan (PNRR), Mission 4 - Education and Research, Component 2 - From Research to Business (M4C2), Investment Line 3.1 - Strengthening and creation of Research Infrastructures, Project IR0000012 – "CTA+ - Cherenkov Telescope Array Plus"

Data Availability Statement: We encourage all authors of articles published in MDPI journals to share their research data. In this section, please provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study. Where no new data were created, or where data is unavailable due to privacy or ethical restrictions, a statement is still required. Suggested Data Availability Statements are available in section "MDPI Research Data Policies" at https://www.mdpi.com/ethics.

Acknowledgments: We acknowledge contribution in populating the portal from I. Batkovic, M. Manganaro, M. Morrone, ... We gratefully acknowledge discussion with J. Delgado and H. Kormayer. We acknowledge the support of the MAGIC collaboration.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

SED	Spectral Energy Distribution
LC	Light Curve
`.ecsv`	Encapsulated Comma Separated Values file format
`.yaml`	Ain't Markup Language file format

References

1. MAGIC homepage. www.magic.mpp.mpg.de.
2. Wilkinson, M.D.; Dumontier, M.; Aalbersberg, I.J.; Appleton, G.; Axton, M.; Baak, A.; Blomberg, N.; Boiten, J.W.; da Silva Santos, L.B.; Bourne, P.E.; et al. The FAIR Guiding Principles for scientific data management and stewardship. *Scientific Data* **2016**, *3*, 160018. https://doi.org/10.1038/sdata.2016.18.
3. Gamma Astro Data Formats (GADF) homepage. https://gamma-astro-data-formats.readthedocs.io/.
4. Deil, C.; et al. Open high-level data formats and software for gamma-ray astronomy. *AIP Conf. Proc.* **2017**, *1792*, 070006, [arXiv:astro-ph.IM/1610.01884]. https://doi.org/10.1063/1.4969003.
5. Donath, A.; Terrier, R.; Remy, Q.; Sinha, A.; Nigro, C.; Pintore, F.; Khélifi, B.; Olivera-Nieto, L.; Ruiz, J.E.; Brügge, K.; et al. Gammapy: A Python package for gamma-ray astronomy. *A&A* **2023**, *678*, A157. https://doi.org/10.1051/0004-6361/202346488.
6. Very-high-energy Open Data Format (VODF) homepage. https://vodf.readthedocs.io/.
7. Khélifi, B.; Zanin, R.; Kosack, K.; Olivera-Nieto, L.; Schnabel, J. The Very-high-energy Open Data Format: towards a shared, open data format in very-high-energy astronomy. *PoS* **2023**, *ICRC2023*, 1510, [arXiv:astro-ph.IM/2308.13385]. https://doi.org/10.22323/1.444.1510.
8. NASA astrophysics data system. https://ui.adsabs.harvard.edu/.
9. INSpire astrophysics data system. https://inspirehep.net/.
10. Abe H. et al. (MAGIC Collaboration). Constraints on axion-like particles with the Perseus Galaxy Cluster with MAGIC, 2024. https://doi.org/https://doi.org/10.1016/j.dark.2024.101425.
11. International Virtual Observatory Alliance (IVOA). Observation Core Components, Version 1.1, 2017. Accessed: 2024-12-11.