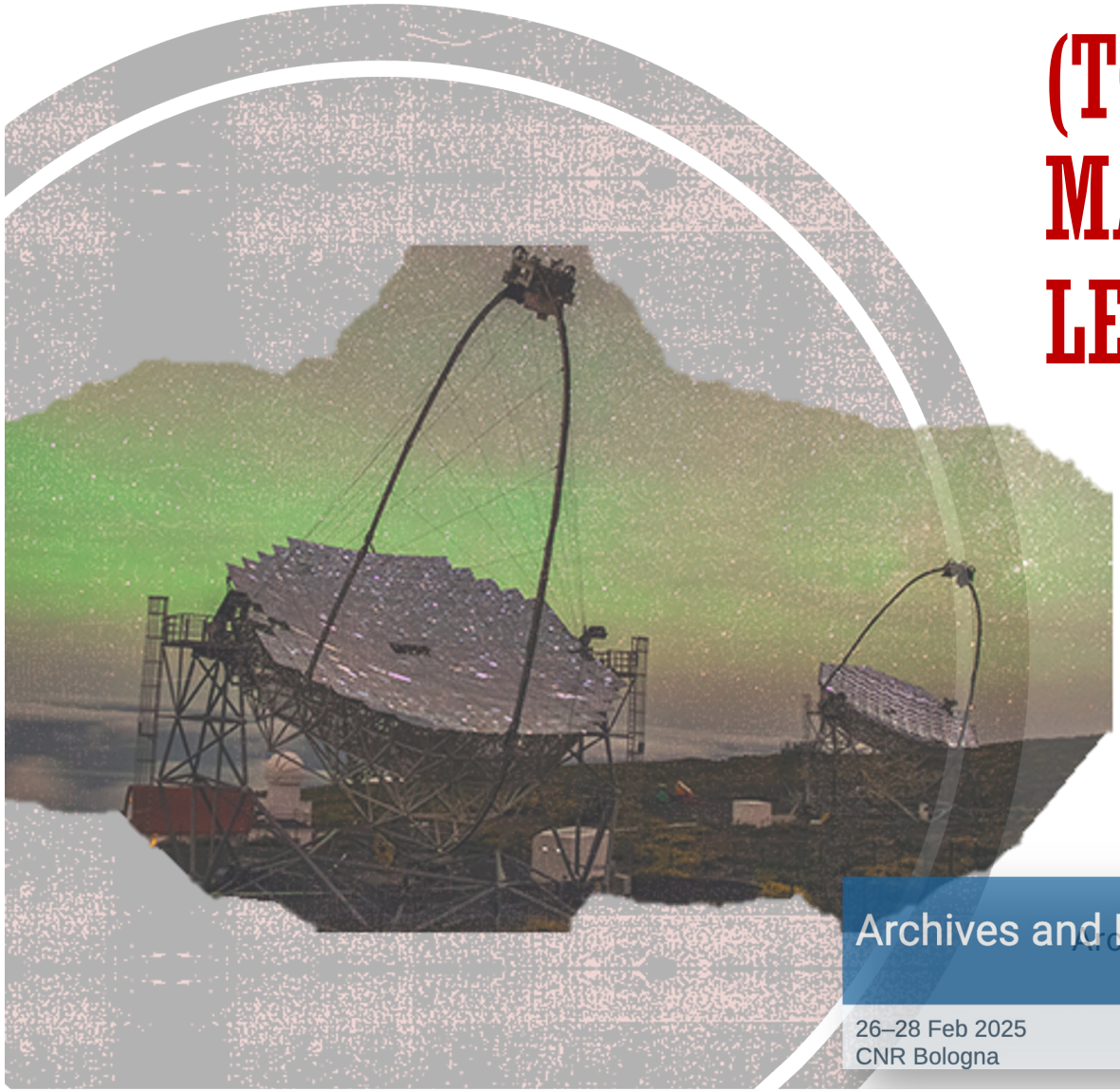


(TOWARD) A PUBLIC MAGIC G-RAY TELESCOPE LEGACY DATA PORTAL

Michele Doro, Elisa Prandini, Ilaria Viale (Uni Padova),

Stefano Marchesi (UniBo, INAF-OAS Bologna,Clemson Uni),

+ Roberta Zanin (CTAO)

Archives and Data Management Systems in the Big Data Era

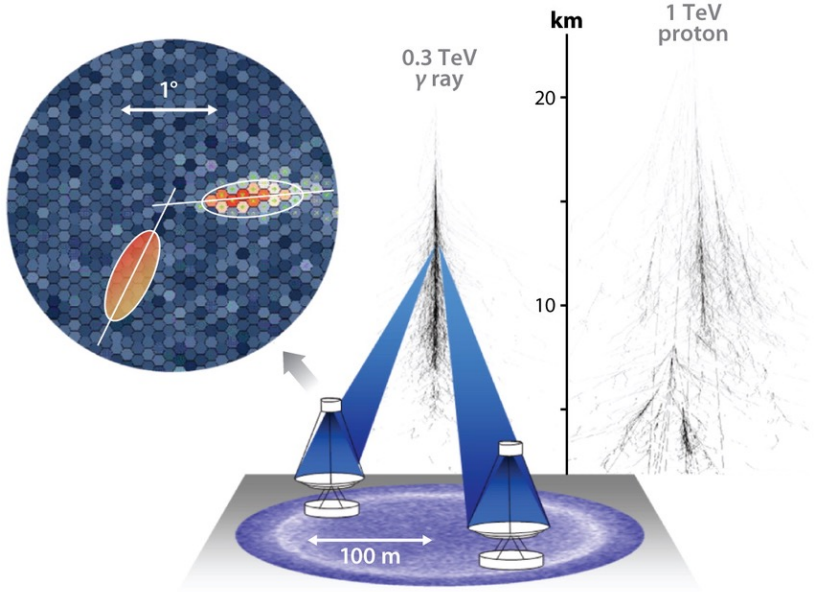
26–28 Feb 2025
CNR Bologna

IMAGING ATMOSPHERIC CHERENKOV TELESCOPES (IACTS)

Major Atmospheric Gamma-ray Imaging Cherenkov

← 17 m diameter tessellated+2k PMTs camera

← Range: 30 GeV – 50 TeV



Hinton JA, Hofmann W. 2009.
Annu. Rev. Astron. Astrophys. 47:523–65

- Cherenkov light (UV-Blue)→ observe at night!
- Field of view of ~5-10 deg
- Energy resolution ~10-20%
- Angular resoltution ~0.1 deg

CURRENT IACTS

IACT	Year	Nr. tels & diameter	Location
~~Whipple~~	~~1968~~	~~1×12 m~~	~~Arizona, USA~~
H.E.S.S.	2003	4×12 m+1×28 m	Gambserg, Namibia
MAGIC	2004	2×17 m	La Palma, Spain
VERITAS	2007	4×12 m	Arizona, USA

Table 1: Current major operating ground-based Cherenkov telescopes. Given are the starting year, the array multiplicity and dish diameter *in the latest configuration*, and the location.

MD NIMA742 (2014) 99-106

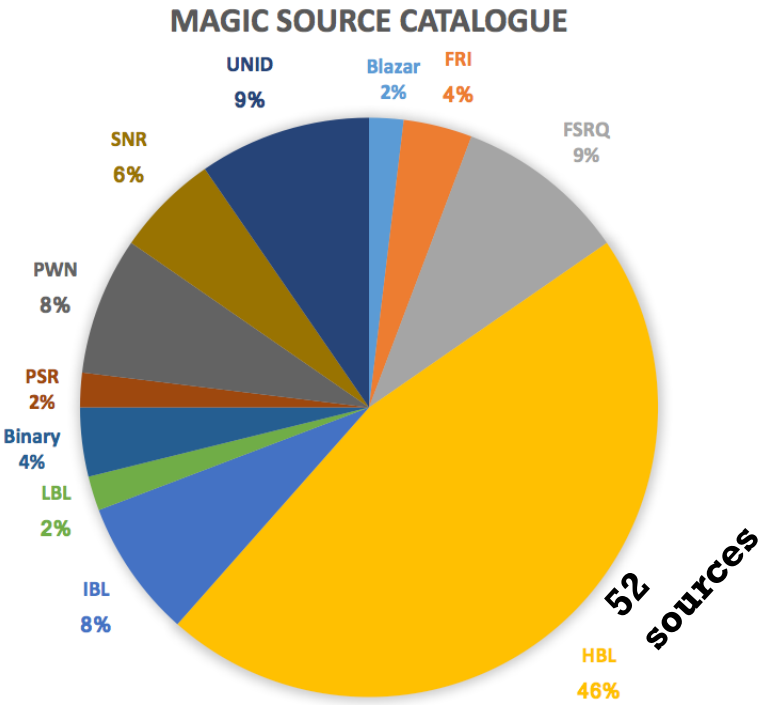
VERITAS

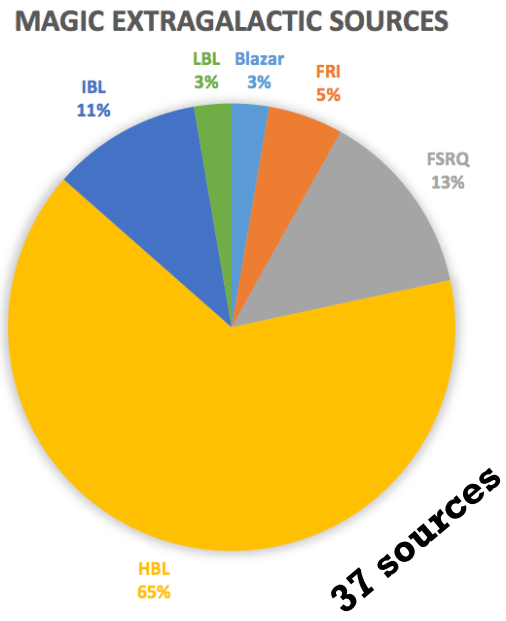
MAGIC

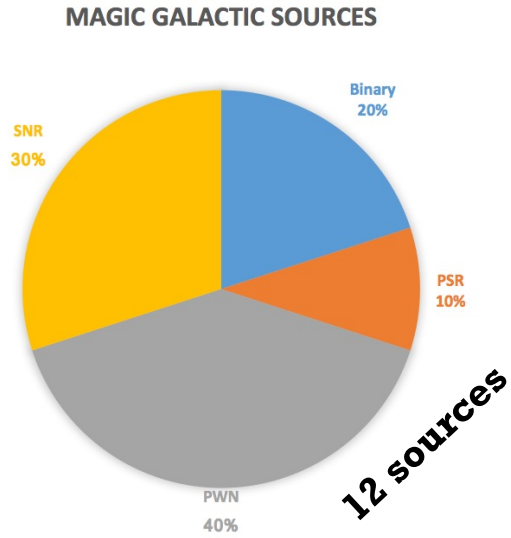
H.E.S.S.

THE MAGIC "CATALOGUES" (IN 2016)

From TeVCat 2.0 http://tevcat2.uchicago.



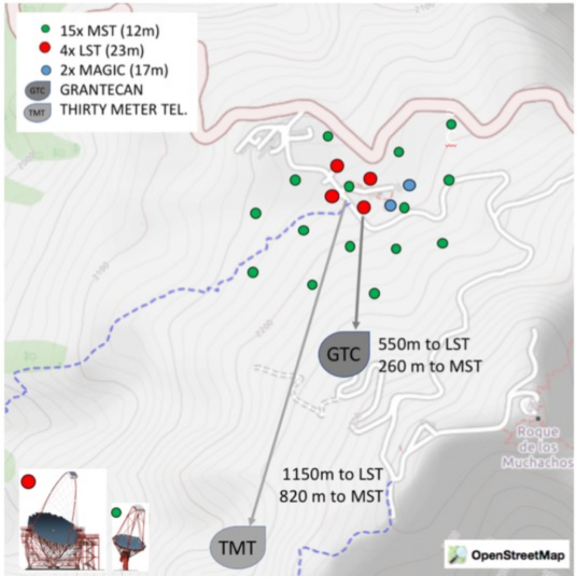


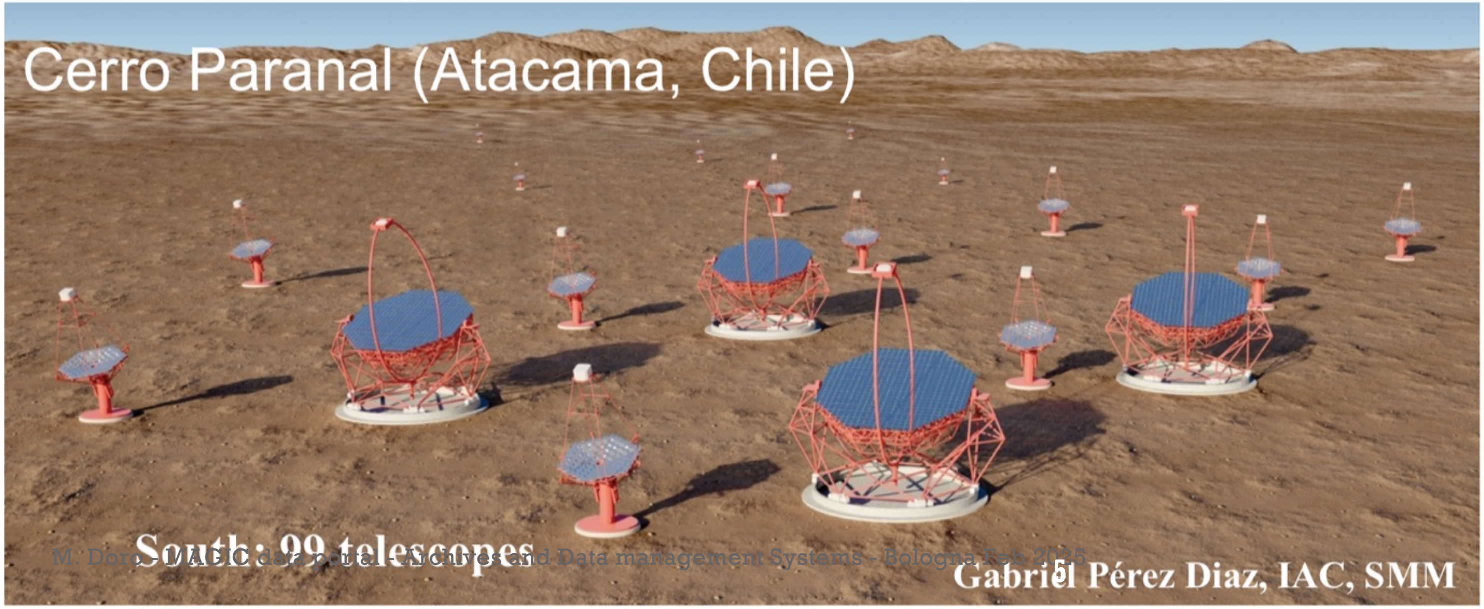


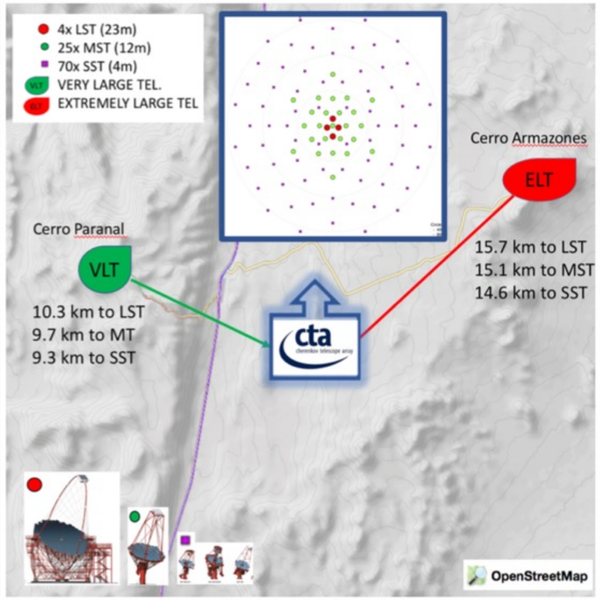
- MAGIC is in the N-hemisphere: optimized for extra-gal. physics
- MAGIC hunts the farthest objects due to lowest energy threshold

Dark Catalogue (many sources pointed and not detected)

CHERENKOV TELESCOPE ARRAY OBSERVATORY

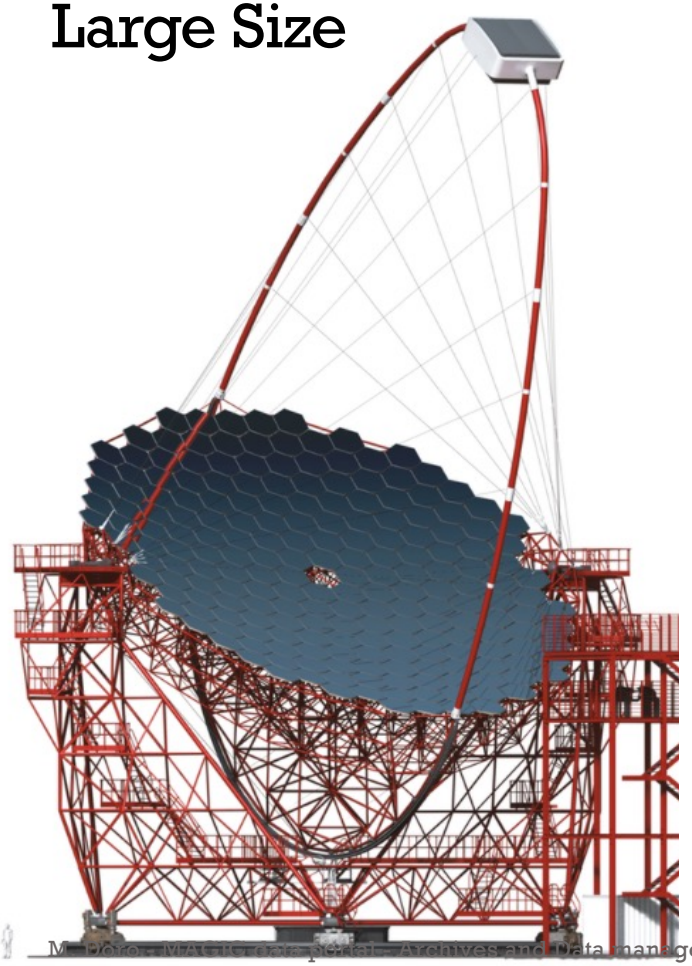




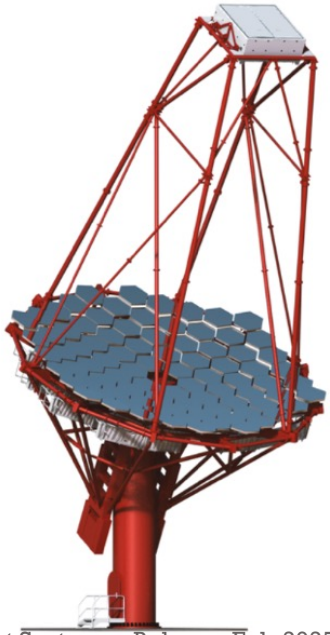


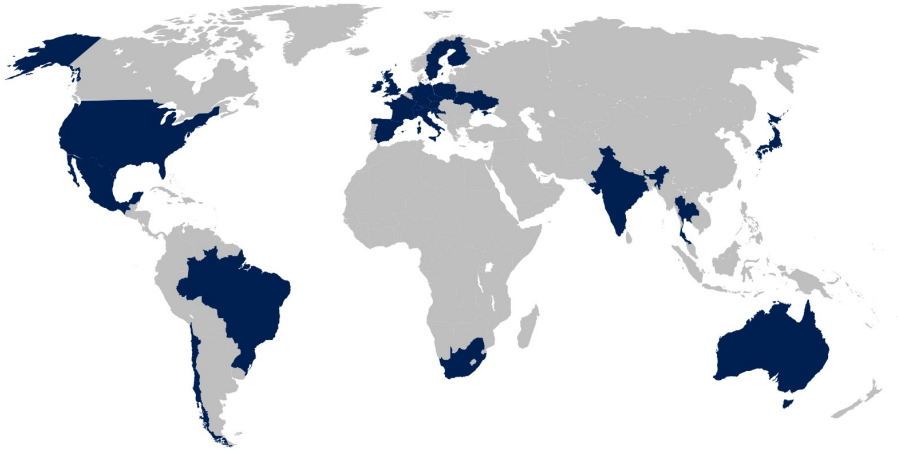
THREE TELESCOPE SIZES

Large Size



Medium Size



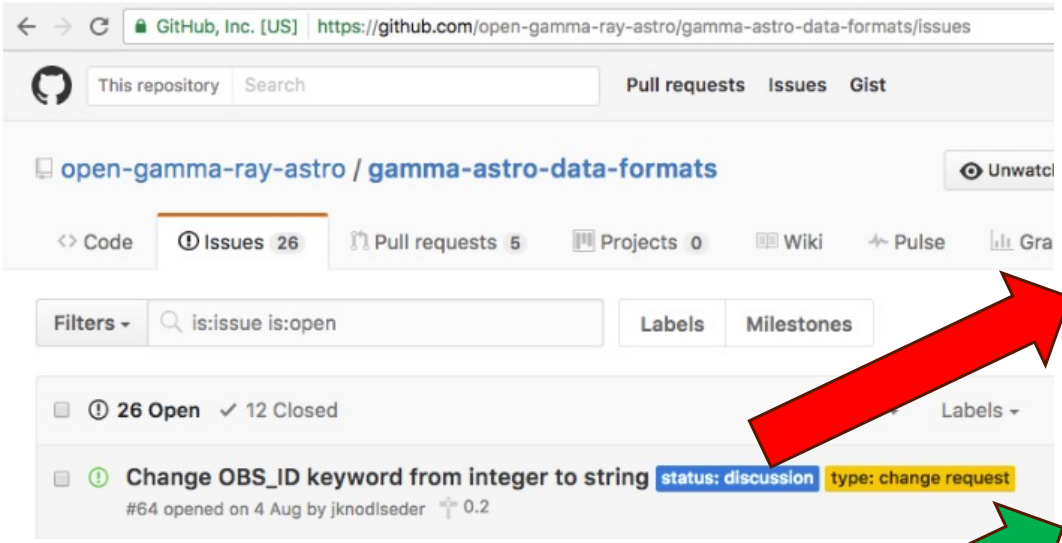


- 1500 scientists
- North array: 1 LST ready, 3 in construction, 9 MSTs starting 2025
- South-array: INAF LSTs in prep!

Small Size

DATA FORMAT FOR (HESS/MAGIC/VERITAS→CTAO)

GADF working group



Data Level	Short Name	Description	Reduction
Level 0 (DL0)	DAQ-RAW	Data from the Data Acquisition hardware/software.	
Level 1 (DL1)	CALIBRATED	Physical quantities measured in each separate camera: photons, arrival times, etc., and per-telescope parameters derived from those quantities.	1-0.2
Level 2 (DL2)	RECONSTRUCTED	Reconstructed shower parameters (per event, no longer per-telescope) such as energy, direction, particle ID, and related signal discrimination parameters.	10^{-1}
Level 3 (DL3)	REDUCED	Sets of selected (e.g. gamma-ray-candidate) events, along with associated instrumental response characterizations and any technical data needed for science analysis.	10^{-2}
Level 4 (DL4)	SCIENCE	High Level binned data products like spectra, sky maps, or light curves.	10^{-3}
Level 5 (DL5)	OBSERVATORY	Legacy observatory data, as survey sky maps or the CTA source catalog.	10^{-5} - 10^{-3}

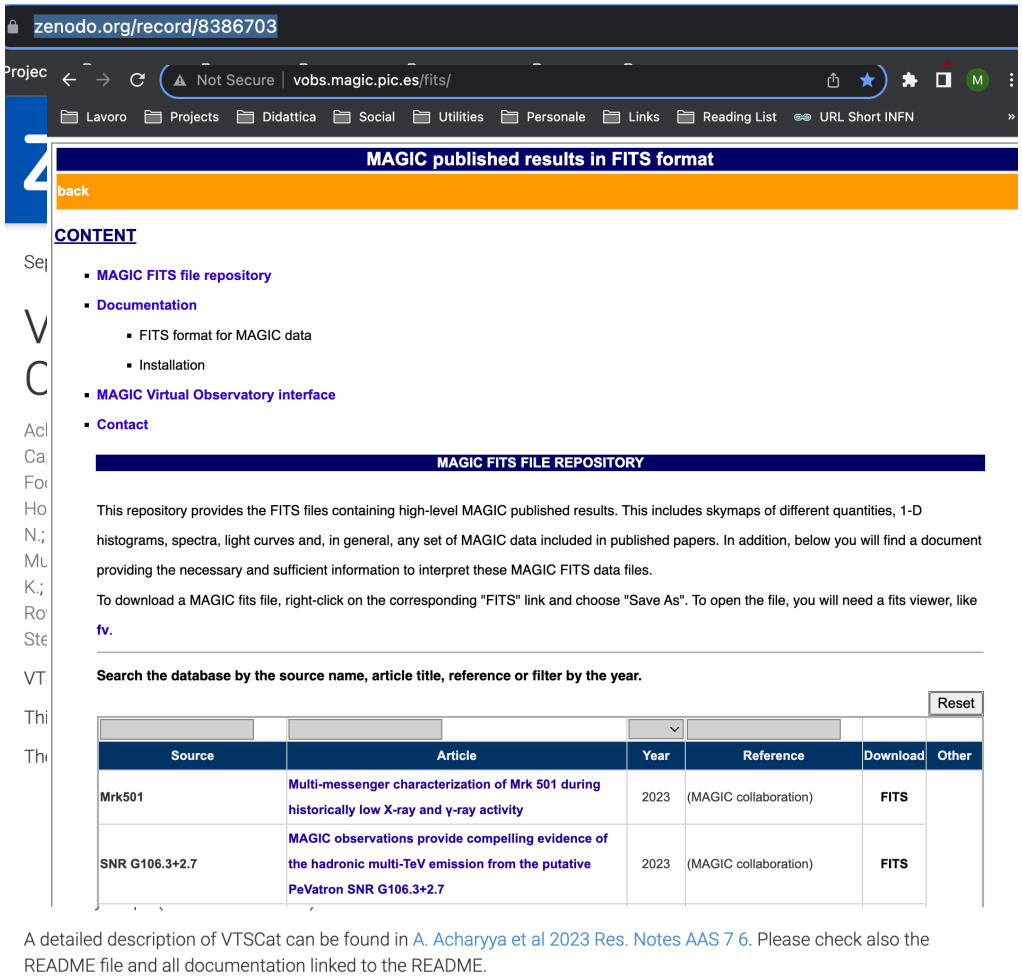
Table 1: Data levels foreseen in CTA.

Data model issues in the Cherenkov Telescope Array project

J.L. Contreras [a], K. Satalecka* [a], K. Bernlöhr [b], C. Boisson [c], J. Bregeon [d], A. Bulgarelli [e], G. de Cesare [e], R. de los Reyes [b], V. Fioretti [e], K. Kosack [f], C. Lavalley [d], E. Lyard [g], R. Marx [b], J. Rico [h], M. Sanguillot [d], M. Servillat [c], R. Walter [g], J.E. Ward [h] and A. Zoli [e] for the CTA consortium ‡

DATA SHARING

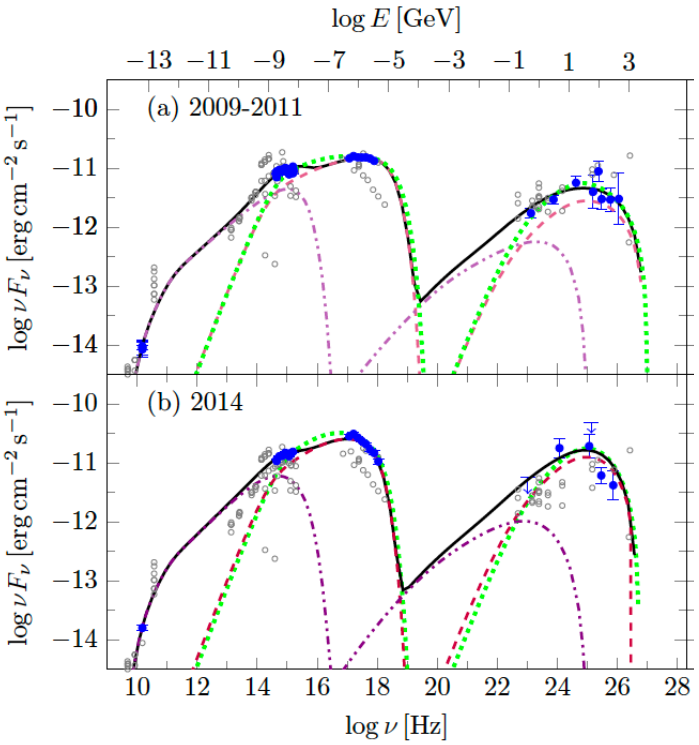
- IACTS are all late in sharing high-level science products to the wider community
  - VERITAS has archive and Zenodo: publicly accessible on HEASARC.
  - H.E.S.S.: built an online repository containing fits file and list of information in each paper.
- MAGIC
  - DL5-level (SED, LC, etc): .fits file in Barcelona server http://vobs.magic.pic.es/fits/ (in part incomplete)
  - DL3 files: a fraction of selected data in gammapy



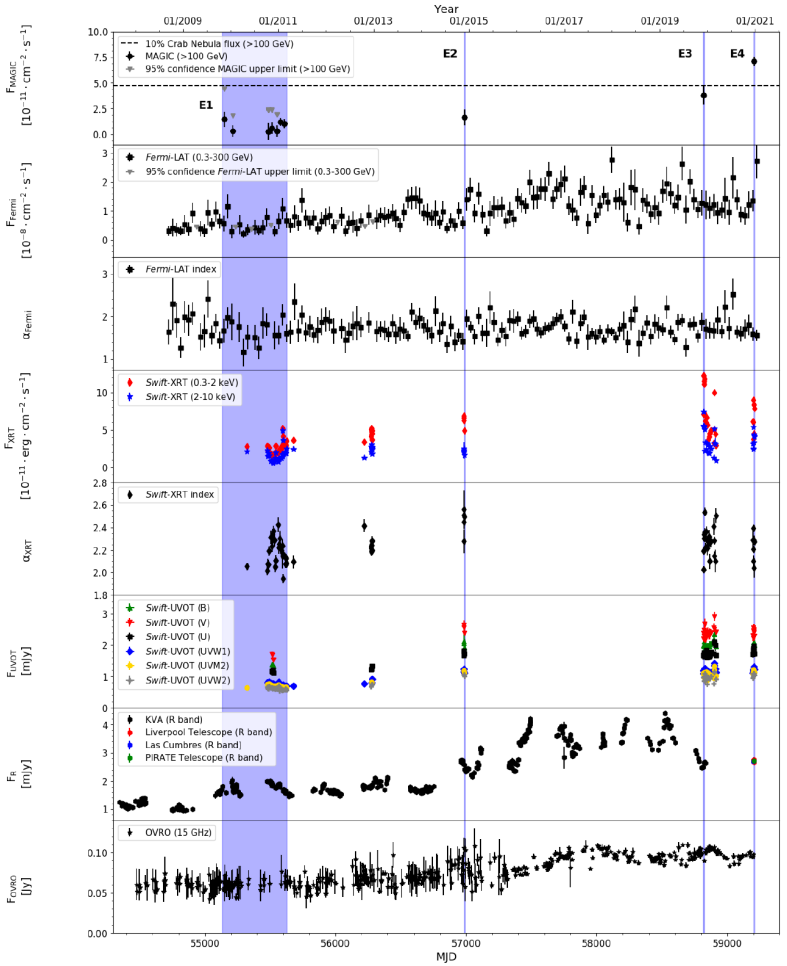
A detailed description of VTSCat can be found in A. Acharyya et al 2023 Res. Notes AAS 7 6. Please check also the README file and all documentation linked to the README.

MAGIC PRODUCTS

- During the years, MAGIC has studied a significant number (especially of) of extragalactic sources.
  - MAGIC data
  - Multi-w specific data
  - +historical data

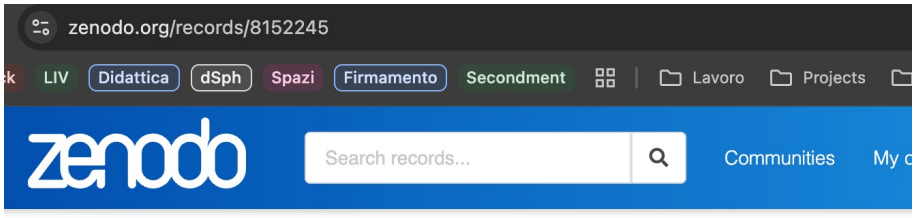


SED for specific states



Detailed MWL LC

A LARGE COLLECTION OF BLAZAR SED: STEVECAT



Published July 26, 2023 | Version version 1

STeVECat, the Spectral TeV Extragalactic Catalog

Gréaux, Lucas[1]; Biteau, Jonathan[1]; Hassan, Tarek[2]; Hervet, Olivier[3]; Nievas Rosillo, Mireia[4]; Williams, David A.[3]

```
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#    mid_start: 50545.0, mid_stop: 50956.0, observation_period: 1997-1998 - low, overlap_flag: 1,
reference: 1999A&A...350..757A, significance: 26.0,
#    source_id: 49, source_name: Mkn 421}
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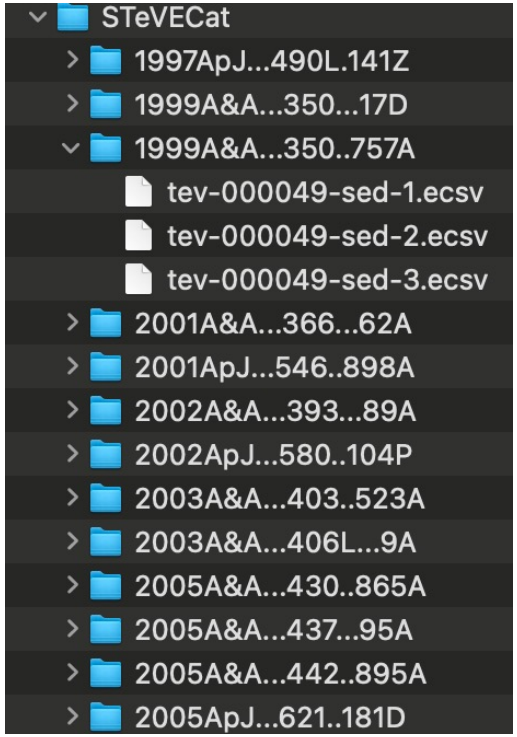


- Just VHE data
- Just data on files

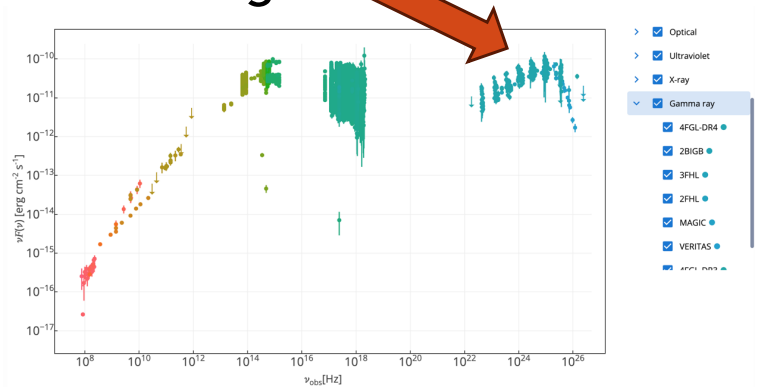
WHAT WE SET OUT TO DO

PROCEEDINGS OF SCIENCE

Toward a Public MAGIC Gamma-Ray Telescope Legacy Data Portal

M. Doro[a], C. Nigro[e], E.Prandini[a], A. Tramacere[b], M. Delfino[c,d], J. Delgado[c,d], E. do Souto[c], L. Jouvin[c], J. Rico[c] for the MAGIC Collaboration*

Missing!



- Collection of all SED/LC MAGIC+MWL data with as large a set of information as to be fully consistent → Legacy!
- DL5 products provided by authors and prepared by a group
  - Status: 2024 complete
- Dissemination plans:
  - Github astropy

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

  - VO

.ECSV FORMAT (FOR SED, LC + OTHER PROD: DM, ETC

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# - {Comments: "Datapoints from MAGIC light curves in the >100 GeV band. Four MAGIC Epochs: E1 (2009-2011); E2 (2014); E3 (2019); E4 (2020)."}
# - {Reference: "magic_2023a.yaml"}
# - {Status: "To be checked"}
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- Units defined (less errors)
- Added uncertaintes
- Format discussed with other iacts
  - Everyone has its format

.YAML HEADER

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 Pcoll:  magic, externals
 Pcauthor:  Jorge Otero-Santos; Daniel Morcuende; Vandad Fallah Ramazani; Daniela Dorner; David Paneque
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Other files:
 magic_2023a_fig1b_lc.ecsv
 magic_2023a_fig1d_lc.ecsv
```

- One per paper
- Contains list of files/figures of the paper

VO OBS CORE

- Discussion with IVOA High Energy Insterest Group (HEIG) and Marco Molinaro (INAF)

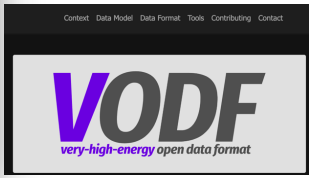
ObsCore column	Unit		Value or from `.ecsv,.yaml`	Comment
dataproduct_type	–	Y	sed	As defined in [11]
calib_level	–	Y	4	Level 4 is "analysis data products generated after some scientific data manipulation or interpretation".
obs_collection	–	Y	MAGIC/DL5	Because of possible other future collections e.g. 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. $1\,\mathrm{GeV}/c^2 \simeq 1.97 \times 10^{-16}$ 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.

- So far prepared the Obs. Core model to parse our data
- Still to make the TAP



CONCLUSIONS

Article

Dissemination of MAGIC High-Level Data - DL5 Data Portal

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1. We are testing an end-to-end service to share DL5 data via VO for legacy
2. Current IACT data for MWL context and for CTAO legacy
3. Start with year 2024, then continue with previous years
4. In the future, focus on DL3 (actual events for public analysis)

Thanks! Comments are very welcome, also offline! I really need suggestions!