

Experience on building an ObsCore service for HE event-lists

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*IVOA Sydney
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A long way

It's a Long Way... from Private Ground-based Gamma-ray Data to Public Release: Open-data, Open-source Tools, First Real TeV Data Release from H.E.S.S.

[C. Boisson et al. 2020, ADASS XXVII Santiago, ASPC 522 497B]

- Imaging Atmospheric Cherenkov Telescopes
- Gamma **data format** initiative
- **Open tools** for analysis

→ A story of the relations between Cherenkov observatories and the IVOA



2012-2014

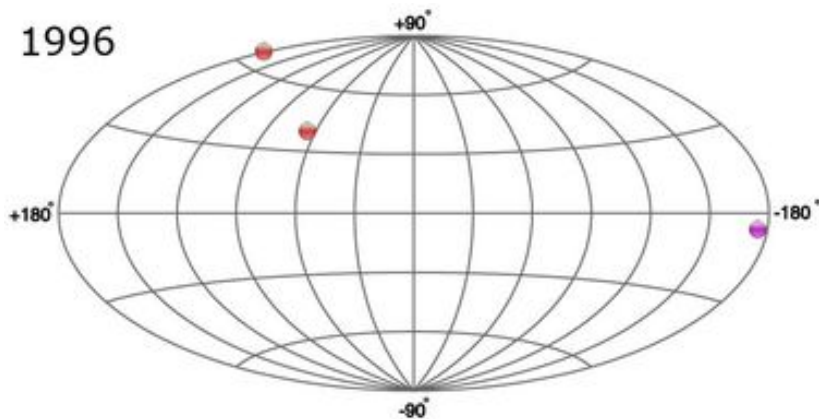


2015-2019

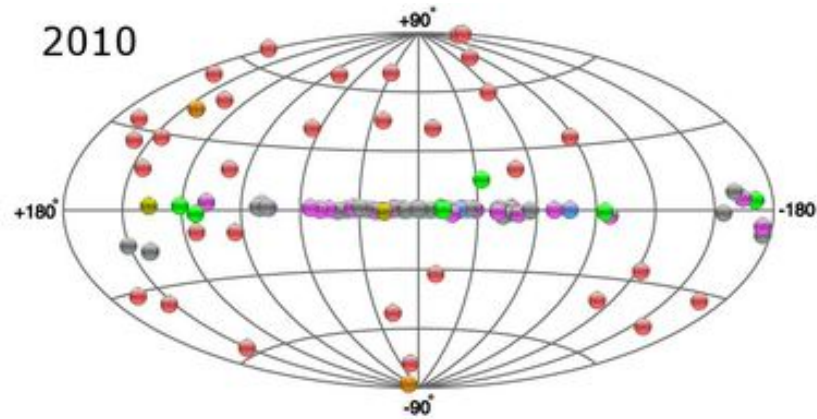


2019-2023

1996



2010



Source Types

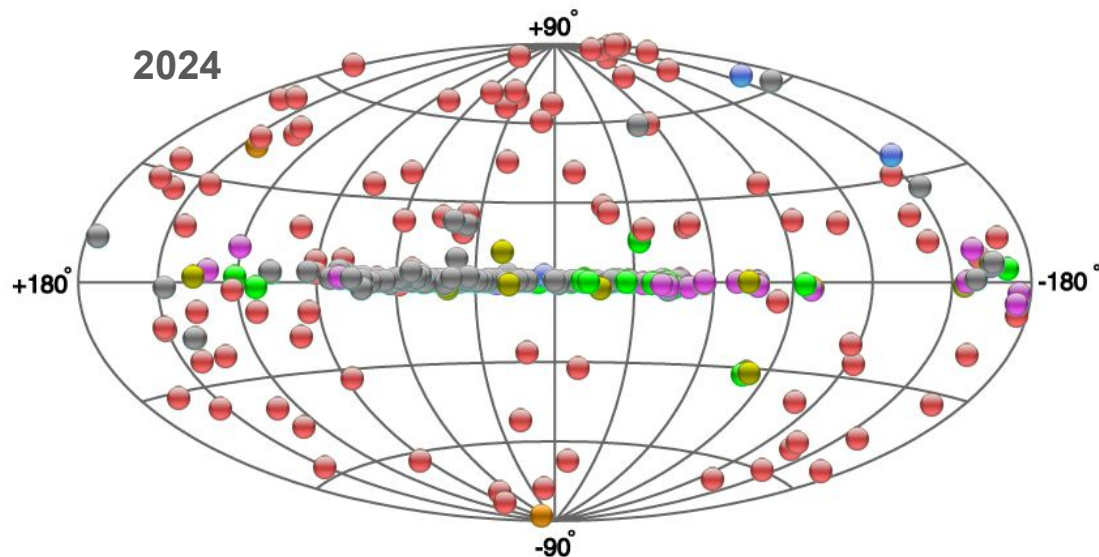
- PWN
- XRB PSR Gamma BIN
- HBL IBL FIR FSRO LBL
- Shell
- Starburst
- DARK UNID Other
- uQuasar Cat. Var. BIN

TeVCat2

<http://tevcat2.uchicago.edu/>

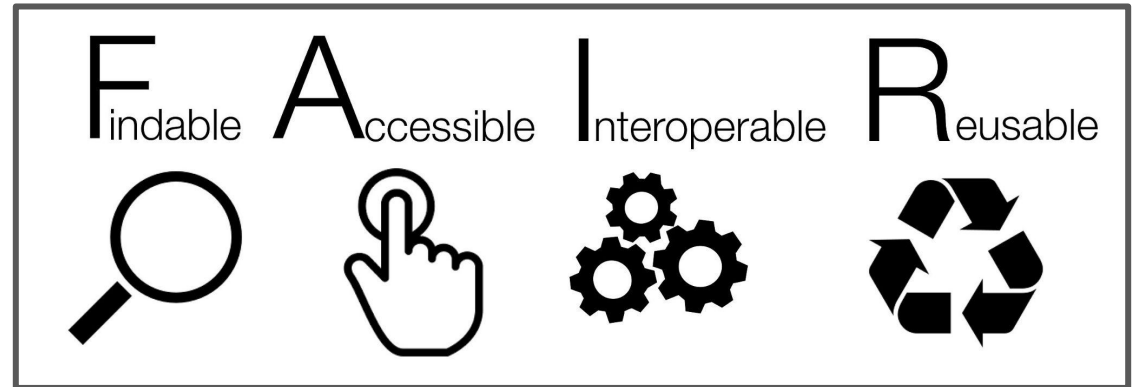
H.E.S.S., MAGIC, VERITAS
> 200 sources
energy > 100 GeV

2024



Open Observatory and Open Science

CTA will operate as an **open observatory** and will provide data to the scientific community. In the context of **Open Science**, the data provided by CTA must follow the **FAIR Guiding Principles** for scientific data management:



See e.g. Servillat et al. 2022, ADASS XXXI, ASP Conference Series
"FAIR high level data for Cherenkov astronomy"
<https://hal-obspm.ccsd.cnrs.fr/obspm-03516688>

F = Findable



International Virtual Observatory Alliance (IVOA) standards tailored to make data findable:

- IVOA Observation Data Model Core Components (**ObsCore**)

[\[link to IVOA REC\]](#) → adapted to Cherenkov data

- IVOA Table Access Protocole (**TAP**)

[\[link to IVOA REC\]](#)

- Deployed service at ObsParis

<https://hess-dr.obspm.fr>

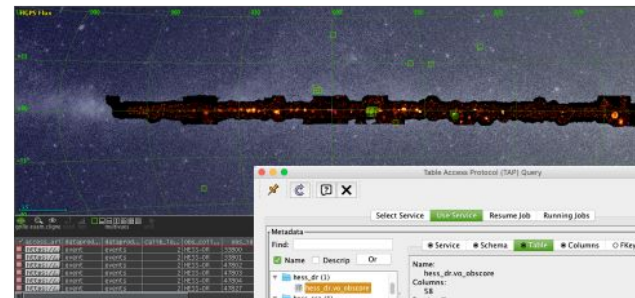
- Registered to the VO **Registry** via PADC (Paris Astronomical Data Centre)

→ **Data widely findable**

e.g. Aladin, TOPCAT, TapHandle, PyVO...

+ dedicated web pages

TapHandle



Aladin



TOPCAT

F = Findable : generation of an ObsCore Table

Module `ivoa.py` now included in **GammaPy**

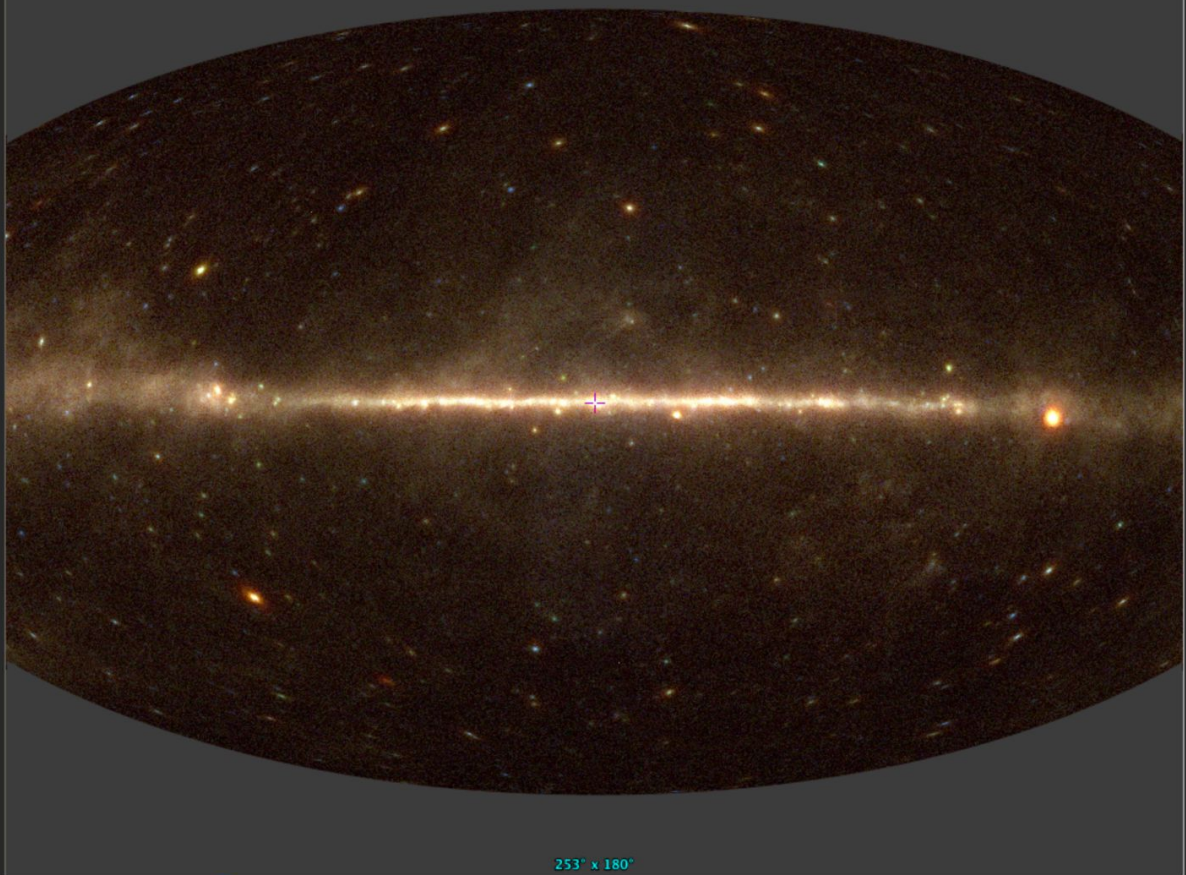
Export of the DataStore into an IVOA ObsCore table with proper metadata to build an IVOA TAP service



<code>dataproduct_type</code>	<code>calib_level</code>	<code>target_name</code>	<code>obs_id</code>	<code>obs_collection</code>	<code>obs_publisher_id</code>	<code>access_url</code>	<code>access_format</code>	<code>access_estsize</code>	<code>s_ra</code>	<code>s_dec</code>	<code>s_fov</code>
								kbyte	deg	deg	deg
str10	int32	str25	str10	str10	str30	str30	str30	int32	float64	float64	float64
EVENTS	2	AGN monitoring	513837	DL3	ivo://ctao#<internal_id>	URL<internal_id>	application/fits	1797	327.5722	-14.7231	0.0
EVENTS	2	AGN monitoring	513839	DL3	ivo://ctao#<internal_id>	URL<internal_id>	application/fits	1785	356.2607	-16.4372	0.0
EVENTS	2	AGN monitoring	513833	DL3	ivo://ctao#<internal_id>	URL<internal_id>	application/fits	1664	262.7	-0.2026	0.0

Collections → 35132

Fermi color



- select
- pan
- dist
- phot
- draw
- tag
- moc
- spect
- filter
- cross
- x-y
- rgb
- assoc
- crop
- cont
- pixel
- prop
- del

CDS/P/Fermi

epoch -

size -

dens. -

opac. -

zoom -

sky

253° x 180°

select
from -- all collections --

- ▼ Collections → 26 / 35132
 - ▼ Image → 2 / 620
 - ▼ Gamma-ray → 2 / 24
 - ▼ HESS → 2
 - HGPS significance
 - HGPS integral flux
 - ▼ Catalog → 20 / 33068
 - ▼ Others → 4 / 1262
 - ▼ SSA (spectrum) → 2 / 159
 - ▼ padc.obspm.astro → 1 /
 - hess_ssa
 - ▼ vopdc.obspm → 1 / 3
 - High Energy Stereosc
 - ▼ TAP (table) → 2 / 220
 - nasa.heasarc → 1 / 35
 - RHESSI Gamma-Ray B
 - ▼ padc.obspm.he → 1 / 2
 - H.E.S.S. DL3 public te:

HGPS Flux



360° x 180°

select

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CDS / P / HGPS

CDS / P / Fermi

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dens. -

opac. -

zoom -

359.94023 = 00.04

360° x 180°

no time filter sky

select

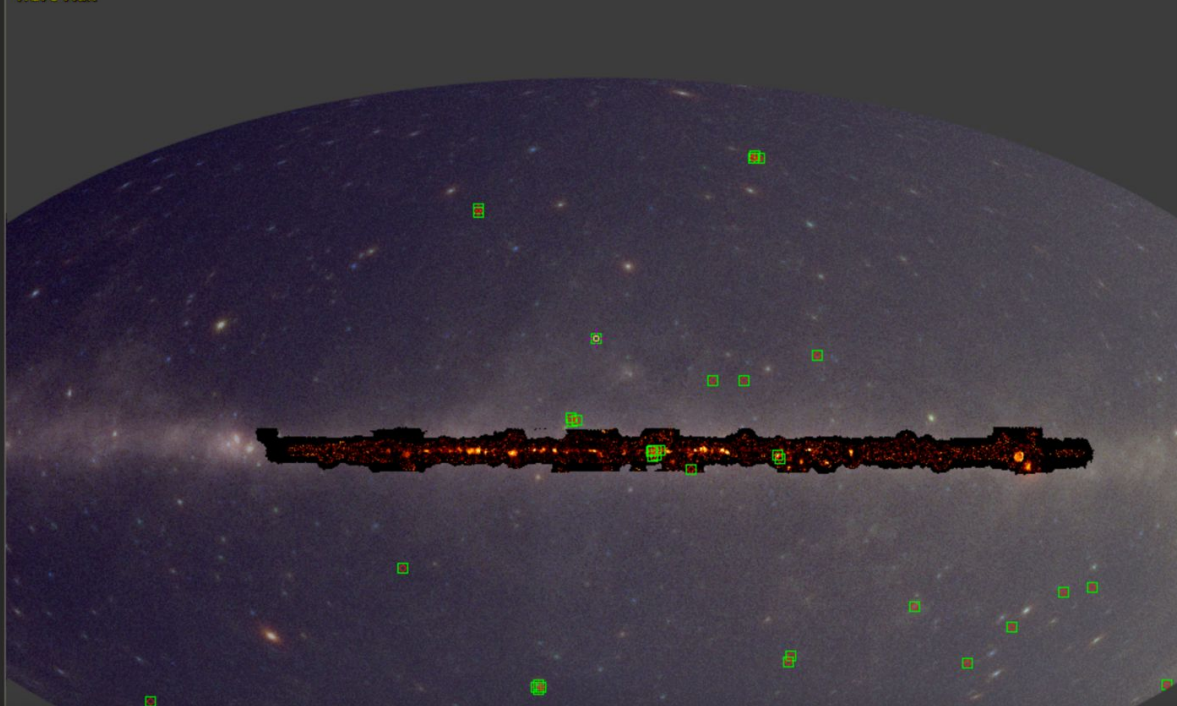
from -- all collections --

coll. sort view scan filter

grid study wink redonorth hdr multiview match

- ▼ Collections → 26 / 35132
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 - H.E.S.S. DL3 public te

HGFS Flux



obscore ⓘ

- Field: target_name
- Value: Sco X-1
- UCD: meta.id;src

name of target

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padc.obspm.he /
CDS / P / HGFS

Aladin Java measurements frame

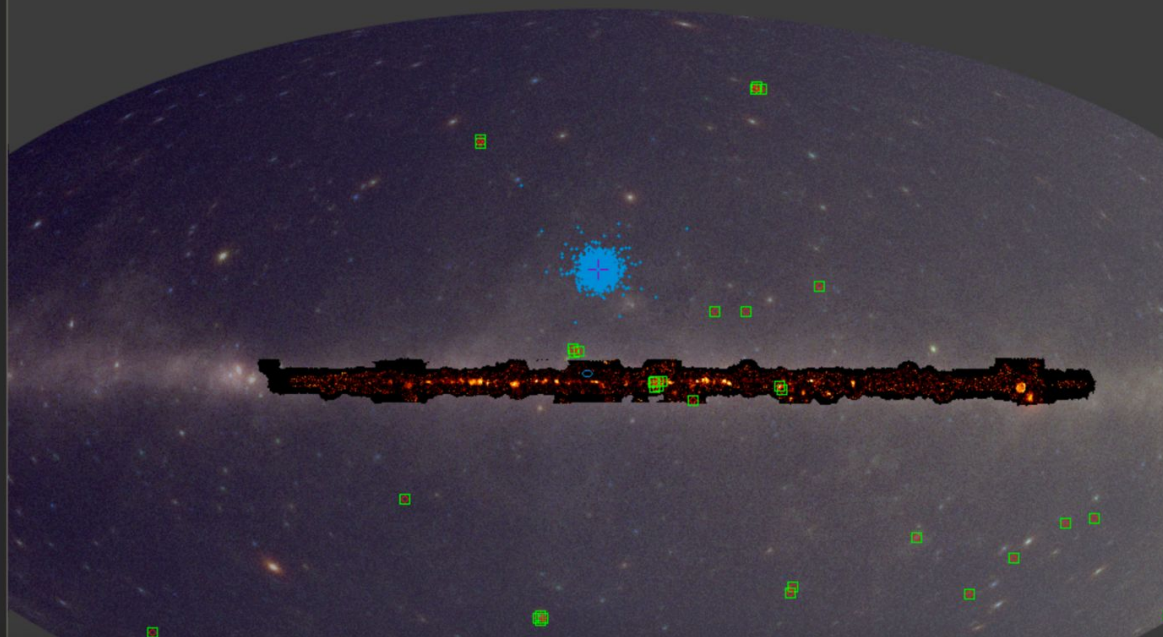
obscore - target_name: name of target

Search

access_url	dataproduct_type	dataproduct_sub...	calib_level	obs_collection	obs_id	obs_publisher_did	access_format	access_estsi	target_name	s_ra
https://hess-dr.obspm.fr/	event-list	events	2	HESS-DR	26827	ivo://padc.obspm/hess#...	application/fits	241920	Arp 220	234.5016784667..
https://hess-dr.obspm.fr/	event-list	events	2	HESS-DR	26791	ivo://padc.obspm/hess#...	application/fits	172800	Arp 220	233.7383728027..
https://hess-dr.obspm.fr/	event-list	events	2	HESS-DR	26077	ivo://padc.obspm/hess#...	application/fits	239040	Sco X-1	244.9916687011..
https://hess-dr.obspm.fr/	event-list	events	2	HESS-DR	25511	ivo://padc.obspm/hess#...	application/fits	233280	3C 273	187.77819824218
https://hess-dr.obspm.fr/	event-list	events	2	HESS-DR	25443	ivo://padc.obspm/hess#...	application/fits	325440	3C 273	187.2778930664..
https://hess-dr.obspm.fr/	event-list	events	2	HESS-DR	25345	ivo://padc.obspm/hess#...	application/fits	334080	3C 273	187.2778930664..
https://hess-dr.obspm.fr/	event-list	events	2	HESS-DR	23736	ivo://padc.obspm/hess#...	application/fits	259200	SN 1987A	83.86775207519..

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 - H.E.S.S. DL3 public te

HGSPS Flux



obscore ⓘ

- Field: access_url
- Value:
- https://hess-dr.obspm.fr
- UCD: meta.ref.url

URL used to access dataset

select
pan
dist
phot
draw
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https://hess-dr.o
https://hess-
https://hess-
https://hess-d
padc.obspm.he/
CDS/P/HGSPS

Aladin Java measurements frame

obscore - access_url: URL used to access dataset

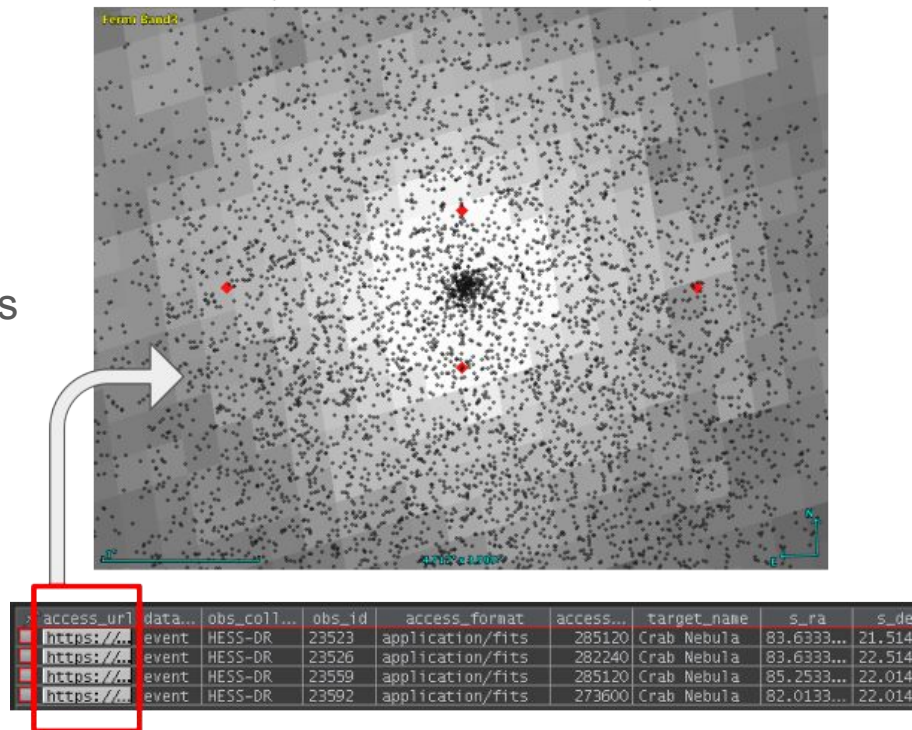
Search

access_url	dataprodu	dataprodu	calib	obs	obs	obs	access	access	target	s
https://hess-dr.obspm.fr/	event-list	events	2	HESS-DR	26827	ivo://padc.obspm/hess#..	application/fits	241920	Arp 220	234.5016784667..
https://hess-dr.obspm.fr/	event-list	events	2	HESS-DR	26791	ivo://padc.obspm/hess#..	application/fits	172800	Arp 220	233.7383728027..
https://hess-dr.obspm.fr/retrieve/hess_dl3_dr1_obs_id_026077.fits.gz	event-list	events	2	HESS-DR	26077	ivo://padc.obspm/hess#..	application/fits	239040	Sco X-1	244.9916687011..
https://hess-dr.obspm.fr/	event-list	events	2	HESS-DR	25511	ivo://padc.obspm/hess#..	application/fits	233280	3C 273	187.77819824218
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https://hess-dr.obspm.fr/	event-list	events	2	HESS-DR	23736	ivo://padc.obspm/hess#..	application/fits	259200	SN 1987A	83.86775207519..

A = Accessible

- ObsCore `access_url`
 - Direct download link to the FITS file
- IVOA **DataLink** (to be implemented):
 - Access to different storage services
 - Access to analysis services, previews
- **Access rights**
 - Public data: no restrictions
 - Anticipating need for **permissions**:
 - PI proprietary period
 - Federation authentication
 - e.g. IAM ESCAPE service

DL3 event list directly opened in Aladin
(each black dot is an event)



I = Interoperable



A community initiative to define **common data formats for gamma-ray astronomy** based on FITS

<https://vodf.readthedocs.io>

<https://gamma-astro-data-formats.readthedocs.io>

- Includes formats for: event lists, effective area, energy resolution, point spread function, instrumental background...
- More and more used by current instruments: Fermi-LAT, HESS, VERITAS, MAGIC, FACT, ...

Open-source Python package (Astropy affiliated package)

- Core library for the Science Tools of CTA
- Used in the analysis of existing gamma-ray instruments, such as H.E.S.S., MAGIC, VERITAS, HAWC...

FAIR4RS: FAIR Principles for Research Software

→ <https://doi.org/10.15497/RDA00065>

[A&A 625, A10, 2019] [A&A 632, A72, 2019] [A&A 632, A102, 2019]

From F-A-I to FAIR

F-A-I

- Use the **Virtual Observatory standards**, protocols and services
- Define **community standards** where required
- To be discussed soon in projects, but **technical solutions exist**

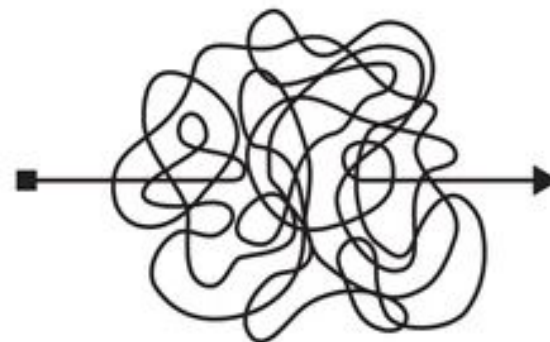
Reusability?

- Based on the **quality / reliability / trustworthiness** of the products
- What calibration was applied? What tools were used and how?
What assumptions were made during the data preparation?
- **Sustainability**: with time, key information may disappear...

Provenance information as an answer to reusability

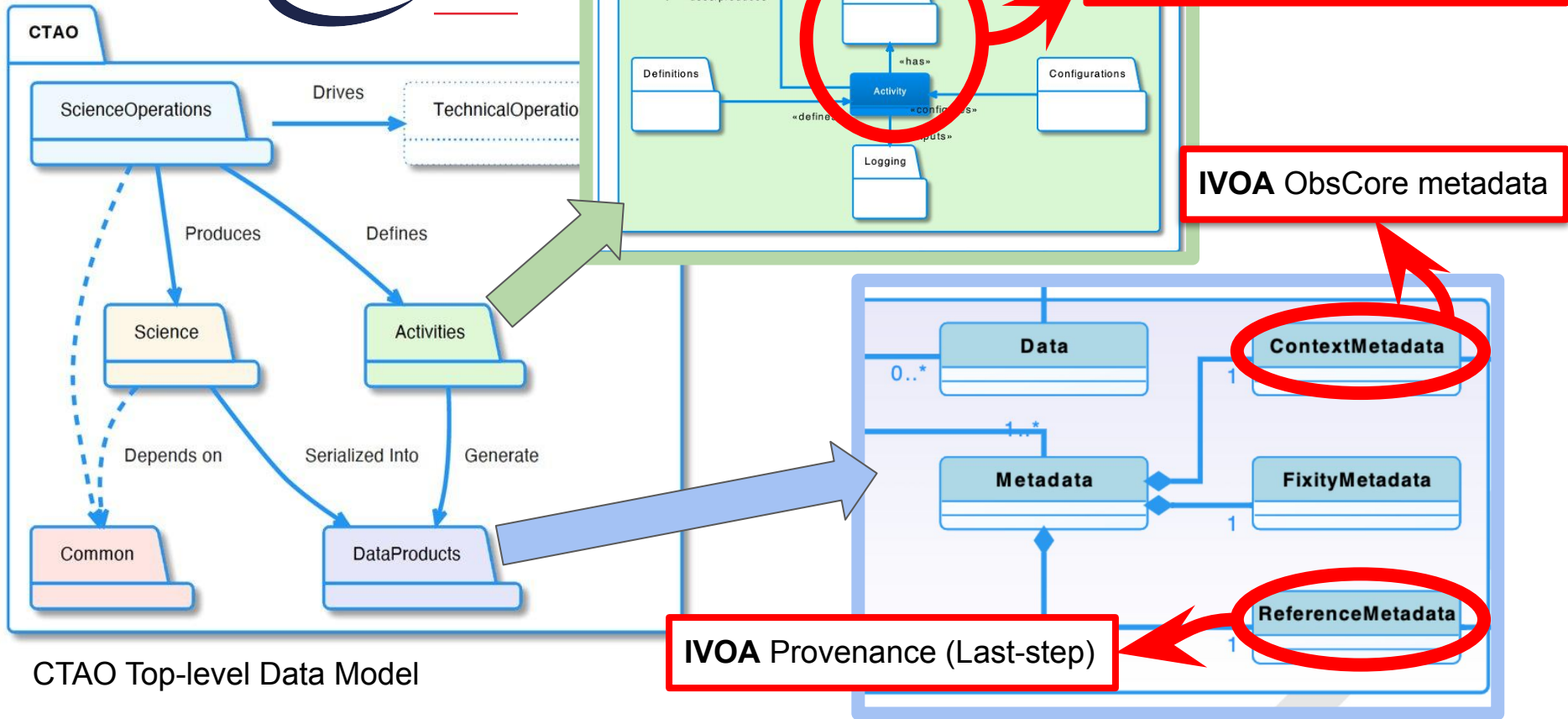
- Need for the **origin, trace**, and detailed manipulations
- Need to **structure** this information
- Need to **keep** it and **link** it to the data

→ **IVOA Provenance standard data model!**





cherenkov
telescope
array



A long way...

- Interactions between observatories and the IVOA
 - Astronomers and engineers need to be part of IVOA
 - They then need to convince their organisation!
 - And maintain the momentum!
- Early engagement of observatories/facilities
 - Construction and operations = different priorities
 - Seeds in the CTA requirements and data models
 - CTAO involved in ESCAPE open collab., OSTrails...
 - Role of European Projects
 - Role of OV-France



ObsCore fields

- **dataprodct_subtype** = DL3, maybe specific data format (VODF)
- **calib_level** = between 1 and 2
- **obs_collection** could contain many details : **obs_type** (calib, science, simulation), **obs_mode** (subarray configuration), **pointing_mode**, **tracking_type**, **event_type**, **event_cuts**, **analysis_type**...
- **s_ra**, **s_dec** = maybe telescope pointing coordinates
- **target_name** : several targets may be in the field of view
- **s_fov**, **s_region**, **s_resolution**, **em_resolution**... all those values are energy dependent, one should specify that the value is at a given energy, or within a range of values.
- **em_min**, **em_max** : add fields expressed in energy (e.g. eV, keV or TeV)
- **t_exptime** : ontime, livetime, stable time intervals... maybe a T-MOC would help
- **facility_name**, **instrument_name** : minimalist, would be e.g. CTAO and a subarray

ObsCore possible additions

- **ev_number** : number of rows in the event-list (not possible with `_xel`)
- **access_format** : Adding MIME-type to table
 - application/x-fits-ogip ...
 - application/x-gadf ...
 - application/x-vodf
- **energy_min, energy_max** : connected to `em_min`, `em_max`, but in eV
- **t_gti** : the searching criteria in terms of time coverage require the list of stable/good time intervals to pick appropriate datasets
- **IRF Table?**
- **DataLinks?**

