

# IVOA standards for High Energy Astrophysics

28-29 June 2023

Observatoire de Paris & ASOV

<https://indico.obspm.fr/event/1963>

## Participants:

- Mathieu Servillat, OP LUTH, CTA data
- Ada Nebot, CDS, XMM
- Jutta Schnabel, KM3Net, FAU
- Catherine Boisson, OP LUTH, CTA HESS
- Bruno Khelifi, APC, HESS-CTA, gammapy, VODF
- Karl Kosack, CTAO / CEA-AIM, CTA DPPS coord, IVOA, VODF
- Pierre Cristofari, OP LUTH, CTA
- François Bonnarel, CDS, IVOA
- Francis Fortin, APC
- Anish Kalsi, APC
- Mireille Louys, CDS, IVOA
- Fabian Schussler, CEA IRFU (ANTARES, H.E.S.S., CTA)
- Claudio Galelli, OP LUTH, CTA
- Paula Kornecki, OP LUTH, CTA
- Laurent Michel, Obs Strasbourg, XMM, SVOM

## Visio:

- Matthias Fuessling, CTAO
- Janet Evans, CfA, IVOA, Chandra
- Ian Evans, CfA, IVOA, Chandra
- Mark CresitelloDittmar, CfA, IVOA, Chandra

## PREVIOUS MEETINGS

Note: all the material listed here is available on the indico page (button "Previous meetings materials")

### I ) 25 juin 2021: HomeWork Luth/CDS/APC

ESCAPE/IVOA metadata and High Energy Astrophysics

Preliminary Working meeting

Face to face meeting in Meudon

Agenda : <https://cloud.projectescape.eu/index.php/s/Zl1bFMZs4bK9RnA>

Minutes by ML and MS : <https://cloud.projectescape.eu/index.php/s/hcaPw8GDLKrj6W7>

### II ) 1/09/2021: Visio to prepare Workshop ESCAPE/CEVO

IVOA metadata and High Energy Astrophysics

Preliminary Working meeting

Face to face meeting in Meudon

Agenda : <https://cloud.projectescape.eu/index.php/s/K2uPmoi9vgcv5P0>

Introduction : <https://cloud.projectescape.eu/index.php/s/n6uGCZWDCzNnJts>

June25thView : <https://cloud.projectescape.eu/index.php/s/verY6WXPnzWYTd4>  
DL3 datamodel proposal : <https://cloud.projectescape.eu/index.php/s/U5vwsbZ6PgHeUMd>  
minutes : <https://cloud.projectescape.eu/index.php/s/rcufK61Imq9wvhe>

### **III ) 8/12/2021: Workshop ESCAPE/CEVO**

Agenda + Intro : <https://cloud.projectescape.eu/index.php/s/oa5TLUuV7thBbZU>  
CTA DL3 draft datamodel : <https://cloud.projectescape.eu/index.php/s/1P5oTA1Zow8qn5e>  
KM3Net : <https://cloud.projectescape.eu/index.php/s/SJZj3iSTHE1chqf>  
GADF : <https://cloud.projectescape.eu/index.php/s/5duAqYBL7DQAsF9>  
Legacy work 1 : <https://cloud.projectescape.eu/index.php/s/R1O08S3NYVSOtad>  
Legacy work 2 : <https://share.obspm.fr/s/EcjmSdasZ8ob2pZ>  
IVOA DM/Specs for HEA : <https://cloud.projectescape.eu/index.php/s/qCqsszZpMnQXInT>  
minutes : <https://cloud.projectescape.eu/index.php/s/ML7DvANH2Y0GsqQ>

### **IV ) 15-16/03/2022: HackaThon Obscore for HEA at Tech Forum CEVO**

#### **CTA/KM3Net VO DataModels progress**

"Mapping CTA datamodels and more specifically gammapy index files to IVOA standard in the overall perspective of using/defining interoperability datamodels and standards for KM3Net and CTA."

Our objective is to properly describe CTA data products in the VO framework. To make this data findable, a first step is to associate the right metadata in the standardised fields of the VO ObsCore data model. We thus expect to find a mapping between the ObsCore data model and the general CTA data model. We can use as a base to the discussion the gammapy DataStore concept, where gammapy expects an index file or several (obs-index and hdu-index) that shortly describe each data product and its content. However, some information may not be found in the index files, and in that case it may be in the more general CTA data model, or one may need to extract the information from the data itself. The steps of the discussions would be as follow :

#### **Review of use cases and objectives**

- \* discussion on each ObsCore keyword to create a mapping table
- \* Identify important metadata not covered by ObsCore (may be the base for an ObsCore extension for VHE/HE) The discussion may be illustrated by ObsParis prototype ObsTAP service that exposes HESS public DL3 data :

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

Use/science cases are listed below material needed to be read before the meeting for more fluent discussion

**VO ObsCore mandatory and optional fields**, see ObsCore UML diagram in:

<https://cloud.projectescape.eu/index.php/s/verY6WXPnzWYTd4>

or full specification here:

<https://www.ivoa.net/documents/ObsCore/20170509/index.html>

**CTA data levels, data content, and general data models**, see:

<https://cloud.projectescape.eu/index.php/s/1P5oTA1Zow8qn5e>

**Gammapy DataStore structure** and the content of the index files :

<https://docs.gammapy.org/dev/api/gammapy.data.DataStore.html>  
[https://gamma-astro-data-formats.readthedocs.io/en/latest/data\\_storage/obs\\_index/index.html](https://gamma-astro-data-formats.readthedocs.io/en/latest/data_storage/obs_index/index.html)  
[https://gamma-astro-data-formats.readthedocs.io/en/latest/data\\_storage/hdu\\_index/index.html](https://gamma-astro-data-formats.readthedocs.io/en/latest/data_storage/hdu_index/index.html)

**Minutes:**

<https://indico.in2p3.fr/event/26364/contributions/107278/attachments/69361/97863/HackaThonCTAKM3Net.pdf>

**Summary:**

<https://indico.in2p3.fr/event/26364/contributions/107261/attachments/69344/97836/HackaThon-1-and4-Feedback.pdf>

**V ) 12/04/2022: ASOV 2022**

Program: <https://asov.obspm.fr/journees-asov-2023/journeesasov/>

**VI ) 21-22/06/2022: HomeWork Luth/CDS/APC in Meudon**

ObsCore CTA presented during the meeting: <https://share.obspm.fr/s/zE3qrL9HzKXHds9>

Minutes and miscellaneous notes from the meeting: [https://docs.google.com/document/d/1MKdNQcAi2KH50ZzjCFSb7ewQvDt\\_UH1DUHuryxS\\_cCw/edit#heading=h.eblcz7po7qim](https://docs.google.com/document/d/1MKdNQcAi2KH50ZzjCFSb7ewQvDt_UH1DUHuryxS_cCw/edit#heading=h.eblcz7po7qim)

Post meeting summary: [https://docs.google.com/document/d/14lGmDFoD7jy83pBzJybuwkGvIS44h\\_pHVph\\_ACgRCJg/edit#heading=h.8fk773c6hng8](https://docs.google.com/document/d/14lGmDFoD7jy83pBzJybuwkGvIS44h_pHVph_ACgRCJg/edit#heading=h.8fk773c6hng8)

**VII ) 10-11/10/2022 : ASOV workshop on VO for HE**

Minutes de la pré-réunion du 10/10 (obscore extension + provenance):

[https://docs.google.com/document/d/1udYf\\_M9rgA5DpvzcjdoY1KlgLJEga58F-IrwipIvoE4/edit](https://docs.google.com/document/d/1udYf_M9rgA5DpvzcjdoY1KlgLJEga58F-IrwipIvoE4/edit)

ASOV (11/10): <https://indico.obspm.fr/event/1489/>

**VIII ) ASOV 2023 semi-hackathon et Interop Bologne**

Presentations by Mathieu Servillat :

\* CTAO DM group:

[https://wiki.ivoa.net/internal/IVOA/IntropMay3023DM/2023-03-11\\_IVOA\\_meeting\\_-\\_CTAO\\_DM.pdf](https://wiki.ivoa.net/internal/IVOA/IntropMay3023DM/2023-03-11_IVOA_meeting_-_CTAO_DM.pdf)

\* VOHE:

[https://wiki.ivoa.net/internal/IVOA/IntropMay3023DM/2023-05-11\\_IVOA\\_meeting\\_-\\_VOHE.pdf](https://wiki.ivoa.net/internal/IVOA/IntropMay3023DM/2023-05-11_IVOA_meeting_-_VOHE.pdf)

(avec le diagramme du event list data model ébauché en Octobre à Strasbourg)

See also:

Chandra use-cases (p14) <https://github.com/ivoa-std/MANGO/releases>

## LIST OF TOPICS FOR DISCUSSION

### I) definition of an HE "event" in the VO

**event** is a **dataprodukt\_type** in ObsCore (<https://www.ivoa.net/documents/ObsCore>)

**event:** An event-counting (e.g. X-ray or other high energy) dataset of some sort. Typically this is instrumental data, i.e., "event data". An event dataset is often a complex object containing multiple files or other substructures. An event dataset may contain data with spatial, spectral, and time information for each measured event, although the spectral resolution (energy) is sometimes limited. Event data may be used to produce higher level data products such as images or spectra.

<https://www.ivoa.net/rdf/product-type/2023-06-26/product-type.html>

**event:** A collection of some sort of observed events, such as high-energy particles observed. A row in an event list is typically characterised by spatial, spectral, and time information.

Warning: a HE event is not a VOEvent (<https://www.ivoa.net/documents/VOEvent>)

--> data is not an event, but an "event list"

--> Find a definition for a "HE Event"

--> IVOA Semantics group working on a list of dataprodukt types

### II) ObsCore extension

How to fill the mandatory fields ?

- **dataprodukt\_subtype** = DL3, maybe specific data format (VODF)
  - particle type : e.g. expected particle in the event list (gamma, neutrino, protons, muons...)
    - a type of particle is assumed in the processing, in the filtering...
- **calib\_level** = between 2 and 3...
- **obs\_collection** could contain many details, but imply as free text :
  - **obs\_type** (calib, science),
  - **obs\_mode** (subarray configuration), --> obsconfig related, not obs\_collection
  - **pointing\_mode**, --> obsconfig related, not obs\_collection
  - **tracking\_mode**, --> obsconfig related, not obs\_collection
  - **analysis\_type**:
    - various workflows exist and could be differentiated ?
    - it helps to differentiate between the types of results
    - can be handled with a version nb ?
    - how is it carried with release names?
    - related to Provenance information ?
  - linking primary versions and later versions of datasets ...
  - François :

- accessing documentation on obs\_collection : can be included in ACCESS Format pointing on a datalink service, where there would be :
    - this : the dataset access url
    - doc\_url: Obs\_collection\_ documentation
- s\_ra, s\_dec** = telescope pointing coordinates
  - epoch?
    - ICRS, but used for data discovery only
  - not working for non-pointing telescopes, always point at Zenith
  - list of RA/Dec? as a function of time
  - mean RA/Dec + region, but also a reference time
- 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
  - value at a given energy?
  - range of values?
- em\_min, em\_max** : add fields expressed in TeV
  - see user defined functions,
- 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
- many fields are empty or null

To be discussed:

- > **release?**
  - related to **obs\_collection**
  - obs\_release\_date in ObsCore: indicates when the data becomes public (private before or if NULL)
  - > what is the common context of a release?
    - analysis\_type ?
    - software used and version
    - calibration used
    - release description, docurl, doi
  - what characteristics are relevant for data discovery?
- > **Obs Config**
  - obs/pointing/tracking modes? see scan mode for radio astronomy
  - New fields if relevant for data selection
- > Full Provenance?
  - DataLink to detailed provenance
  - could define a specific activity : data release publication, then the description would have a docurl

pb of pointing coordinates depending on time

Use case: generation of ObsCore fields inside Gammapy (Paula)

### III) EventList data model

see diagram in:

[https://wiki.ivoa.net/internal/IVOA/IntropMay3023DM/2023-05-11\\_IVOA\\_meeting\\_-\\_VOHE.pdf](https://wiki.ivoa.net/internal/IVOA/IntropMay3023DM/2023-05-11_IVOA_meeting_-_VOHE.pdf)

Related to GADF (and future VODF):

<https://gamma-astro-data-formats.readthedocs.io/en/v0.3/>

StableTimeInterval (STI) is now called by CTAO StableObservationInterval (SOI)

#### IV) IVOA Cube data model for HE

<https://www.ivoa.net/documents/CubeDM>  
Sparse Cube

Seems to compare well with CTAO model

page 11: overview

- in a SparseCube, all dimensions are NDPoints, not possible to have Voxels
  - SparseCube == a list of "events" ???
  - In TeV (for the DL3 IRFs or the DL4 and DL5), one needs N-dimensional maps, with voxels that can be sparse or not and that can be points or bins (ie [Xmin, Xmax]... with associated units

#### V) Access to catalogues of HE (sources, ObsCore)

Release metadata (in registry, in tables...)

#### VI) Datalink for HE

"Second step" information  
access\_url --> DataLink service  
but could be from a source in a catalogue

Vocabulary for links:

- #preview, plot of the spectrum
- #this, the data (spectrum here)
  - PS: with the spectrumDM? maybe ;-)
- #calibration, + description (human readable)
  - "IRFs" for the VHE ?
  - #InstrumentResponseFunctions ?

#progenitor?

- PS: this is a part of the provenance data... why not provenance directly?
- main science product? i.e. raw data
- also calibration that was applied

#documentation

could be an ObsCore record, describing #this

#### Remarks from the HE group

- Findability of HE service and data collection in the Registry is not standardized
  - example of CSC2, found in TopCAT with "Chandra", but not with "CSC"
  - version of the collection?
- Use of MOCs relevant to search HE data
- Units for em\_min, em\_max
  - TeV --> m (wavelength) gives numerical values that may be "outside" precision

## Presentation of user scenarii

### IVOA HE Note structure / topics for discussion

**Orateur:** Mathieu Servillat (LUTH, Observatoire de Paris - CNRS)

- see above

### Access and analysis of XMM-Newton data

**Orateur:** Ada Nebot

XMM-Newton Science Archive

TAP query to the XSA

Astroquery module

XCatDB: XMM-Newton Catalogue Interface

Catalogues as a single file (e.g. 4XMM-DR13 in FITS)

User story:

- download the slim catalogue
- Match with other catalogues
- Analyse in more details
  - visualize
    - lc, sp, im...
  - reanalyze with dedicated software (SAS)
    - download individual obs
    - download Calib files
      - effective area curve as a function of energy (ARF) + redistribution matrix file (RMF)
      - <https://www.cosmos.esa.int/web/xmm-newton/current-calibration-files>
  - extract lc, select GTI...

Also explore catalogues with Vizier, then link to data as a field in catalogue

SAS Startup thread in Python

Calibration portal

Another way to access the data

Find simultaneous observations between XMM and Fermi, using ST-MOC

have to generate the MOC, would help to have it provided by the observatory

### Access and analysis of Chandra data

**Orateurs:** Janet Evans , Mark CresitelloDittmar , Ian Evans

Data Levels (0, 0.5, 1, 1.5, 2

Data Processing (ex of ACIS Level 1 Processing, HRC L1)

Chandra Data Archive

Archive Search and Retrieval: ChaSeR (we app), CSCview (App)

CDA VO services: TAP, SIA...

CIAO

\* Analysing X-ray Photon Event Files --> lc, im-sp, grating-sp

\* Chandra data are 4-dim (2 spatial, 1 time, 1 energy)

\* follows standards: instructions and mission independent

\* Combine HST, Spitzer, XMM...

\* Sherpa fitting engine

\* DataModel filtering and binning syntax

Chandra Source Catalogue, 2.0 : 317K X-ray sources, O(100) properties, 2.1 being prepared

CSC User Interfaces

\* Simple web form, ra/dec

\* WWT visualizer

\* IVOA TAP, SCS, SIAP

\* JHub notebooks using PyVO

Reprocessing may not be necessary for sources in the catalogue

Multiwavelength users would use catalogue values of the catalogue directly

Data releases,

Calibration database identified in the header of the data product

Calibrations stabilized after a few months

## **Access and analysis of H.E.S.S. data**

**Orateurs:** Bruno KHELIFI (APC) , Catherine Boisson

VHE pointing gamma-ray instruments, large for, res of arcmin , stacked ops O(10)h

IACT: Imaging Atmospheric Cherenkov Technique, stereoscopy, reconstruction from Cherenkov light

Reconstruction pipelines, e.g. for H.E.S.S., large raw data, relatively small DL3 size

Data Levels: DL3=gamma-like events, DL4=binned data, DL5=im,sp, lc, DL6=catalogues

DL3 contains:

events,

effective area (3D: FOV offset, True, Area),

energy dispersion (3D: FOV offset, True, E reco/E true)

PSF (4D: FOV offset, True, pdf(theta))

Background (3D: FOV offset, RTrue, Rate)

Auxiliary info: time ref, some-rob, pointing, stable time intervals...

DL3 index files:

Observation index table

HDU index

DL4: binned data, collection of maps (exposure, bkg...), may have an energy dimension

DL5

H.E.S.S. legacy archive

VODF



## **H.E.S.S. Public Data Release in the VO**

**Orateur:** Mathieu Servillat (LUTH, Observatoire de Paris - CNRS)

[http://voparis-tap-he.obspm.fr/browse/hess\\_dr/q](http://voparis-tap-he.obspm.fr/browse/hess_dr/q)  
<https://voparis-cta-test.obspm.fr>

## **Access and analysis of Neutrino data**

**Orateur:** Jutta Schnabel

KM3Net Open Science System

example 1: CTA+KM3NeT common sources

events and IRFs in GADF format for gammapy

MC simu behind

VODF

EOSC Future VRE

example 2: ANTARES legacy data

2 decades of data

for now: web pages and plots, "send email"

VO Server: DaCHS TAP

## **Preparation of topics for next day**

18:00

Q to MCD: what doc from the VO to read and use ?

answer:

In general, the event list Data Product is a combination of a Cube instance (Data) + Dataset Metadata

DatasetDM: <https://www.ivoa.net/documents/DatasetDM/20170928/index.html>  
General metadata for a dataset

Cube DM: <https://www.ivoa.net/documents/CubeDM/20180516/index.html>

Provides framework for describing N-Dimensional data ( binned images to sparse cubes).

The properties represented in the various axes are instances of the Measurement model.

Examples:

<https://volute.g-vo.org/svn/trunk/projects/dm/Cube/examples/>

\* 00README.txt: describes content (source files and serializations mapping to the models

\* Source Files:

chandra\_events.fits = Chandra L1 Event list

chandra\_grat\_events.fits = Chandra L2 Gratings Event list

chandra\_2Dsky\_image.fits = event list binned in sky coordinates to 2D image

VLA\_4D\_image.fits = VLA 4D image cube [ 2-spatial, 1-spectral, 1-polarization ]

Formats provided:

<ext> Flavor

---

vot VOTable-1.3 standard syntax  
avot VOTable-1.3 annotated with VO-DML/Mapping syntax  
\* This will be migrated to MIVOT as the project gets picked back up.  
xml XML - validates to Cube model schema  
xxx An internal DOC format  
XML/DOM structure representing the instances generated when interpreting the template

Formats?:

could be Votable list of events , mapped as cube points of multiple dimensions

Fabien: Dimensions supported for MOC ?

2 dim are manageable : ST, FT,

but 3 dim are not yet supported

follow up to plan for Cube / Chandra examples . within 2 weeks if possible

## Summary of data access methods

- Cone Search
  - Local table (e.g. gammapy)
  - Web forms, not always based on an IVOA Cone Search service
  - Astroquery
  - PyVO (allows to query spectra using SSA, images using, TAP services,...)
- TAP and ObsCore
- Catalogue download
  - Creation of MOCs for coverages and filtering
- Notebook (using PyVO)
- VRE: Virtual Research Environment (data lake + notebooks + workflows)
- WWT visualizer (or ESASky?--> you mean AladinLite?)

Importance of cross-matching with other catalogues/MOC/data releases

other material:

User defined functions

<https://www.ivoa.net/documents/udf-catalogue/20210310/EN-udf-catalogue-1.0-20210310.pdf>

<https://www.ivoa.net/documents/Notes/RadioVOImp/20211119/RadioVOImplementation.pdf>

## Homework

The note should first acknowledge that HE data is already available in the VO. However, the discovery of event data is not completely covered. The note thus focuses on this aspect.

Write sections of the note:

- Collaborative work
- all : review notes and comment on note structure
- Etherpad --> IVOA Note on Overleaf
  - François: 4.5 (datalink), and participates to 4.2 (obscure)
  - Mireille: 4.4 (cube), participates to 4.2 (obscure)
  - Mathieu: 4.1 (def event), 4.2 (obscure), 4.3 (context), + overview of all points
  - Ada: XMM UC
  - Jutta: KM3Net UC