# High Energy Astrophysics in the Virtual Observatory





*IVOA Bologna meeting*
*2023-05-11*

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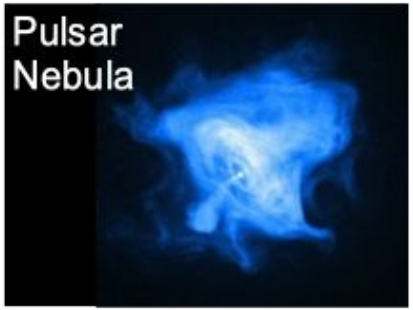


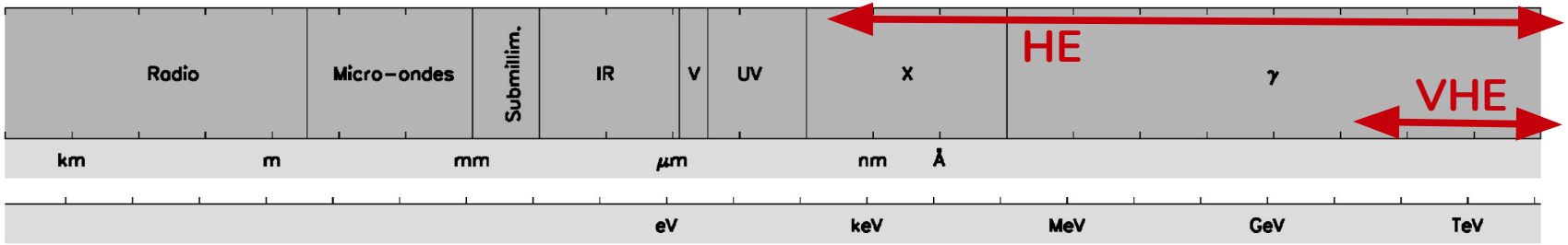




- Violent, transient, non-thermal phenomena
- Matter under extreme conditions
- Particle Acceleration
- Fundamental Physics
- Role of Black Holes in the structuration of the Universe

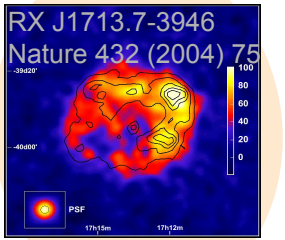


# High Energy Astrophysics

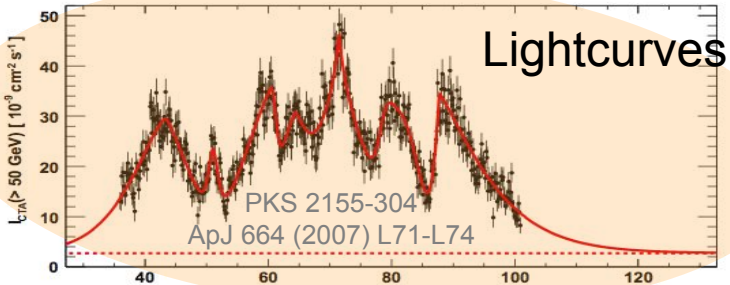


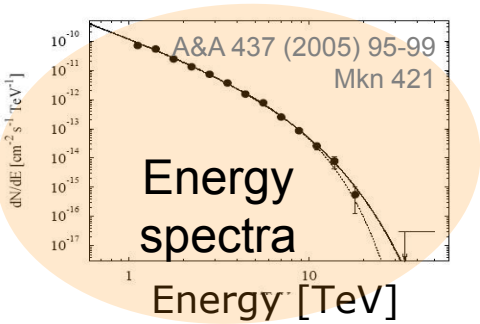

Several orders of magnitude - Photon **counting** - Low count **statistics** - High background

→ **Event lists** (coordinates, time, energy)




Images




+ **multi-messenger data** (photons, cosmic rays, neutrinos, gravitationnal waves...)

# A HE “event” in the VO

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.


a HE event is **not** a VOEvent

# ASOV dedicated workshop

- October 2022 in Strasbourg - https://indico.obspm.fr/event/1489
- *The aim was to bring together representatives of high energy observatories (GW, neutrino, VHE, HE) in order to share practices for the distribution and analysis of their data and to improve interoperability. In particular, we want to assess the need to define a common model of a high energy event (detection probably associated with a photon or a high energy phenomenon) and its dependencies (instrumental response, ...).*
- Presentations of HE observatory operations and data:
  - CTA (Mathieu Servillat)
  - Ligo Virgo Kagra (Pierre Chanial)
  - Neutrino (Damien Dornic)
  - XMM & SVOM (Laurent Michel)
  - GADF/VODF (Bruno Khelifi)

**Next meeting in Paris - 28-29 June 2023**

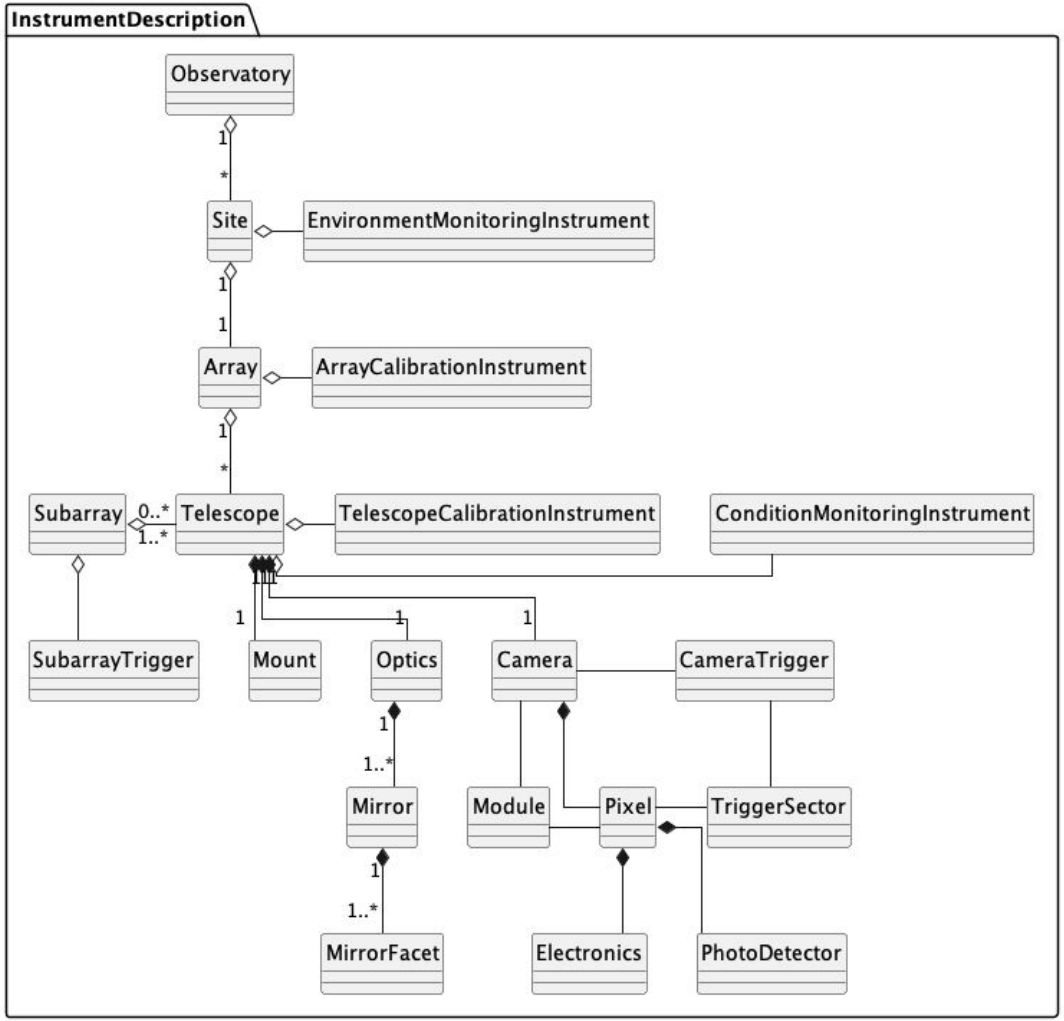
# Main topics of interest

- Event list properties
  - **Lower level** dataset, used to generate images, lightcurves, spectra
  - generally **reprocessed** from event lists for a dedicated analysis
  - Calibrated data, but instrument signature not totally removed (see ObsCore calib_level… between 2 and 3)
  - **Instrument Response Functions** (IRF) are needed
- Data Discovery
  - Is there missing information in an **ObsCore** record for a HE event list?
  - Possible extension for HE (see e.g. extension for radio astronomy)
- An Event List data model
  - Would describe the context of an event dataset
  - **Relations** to IRF and Instrument Configuration

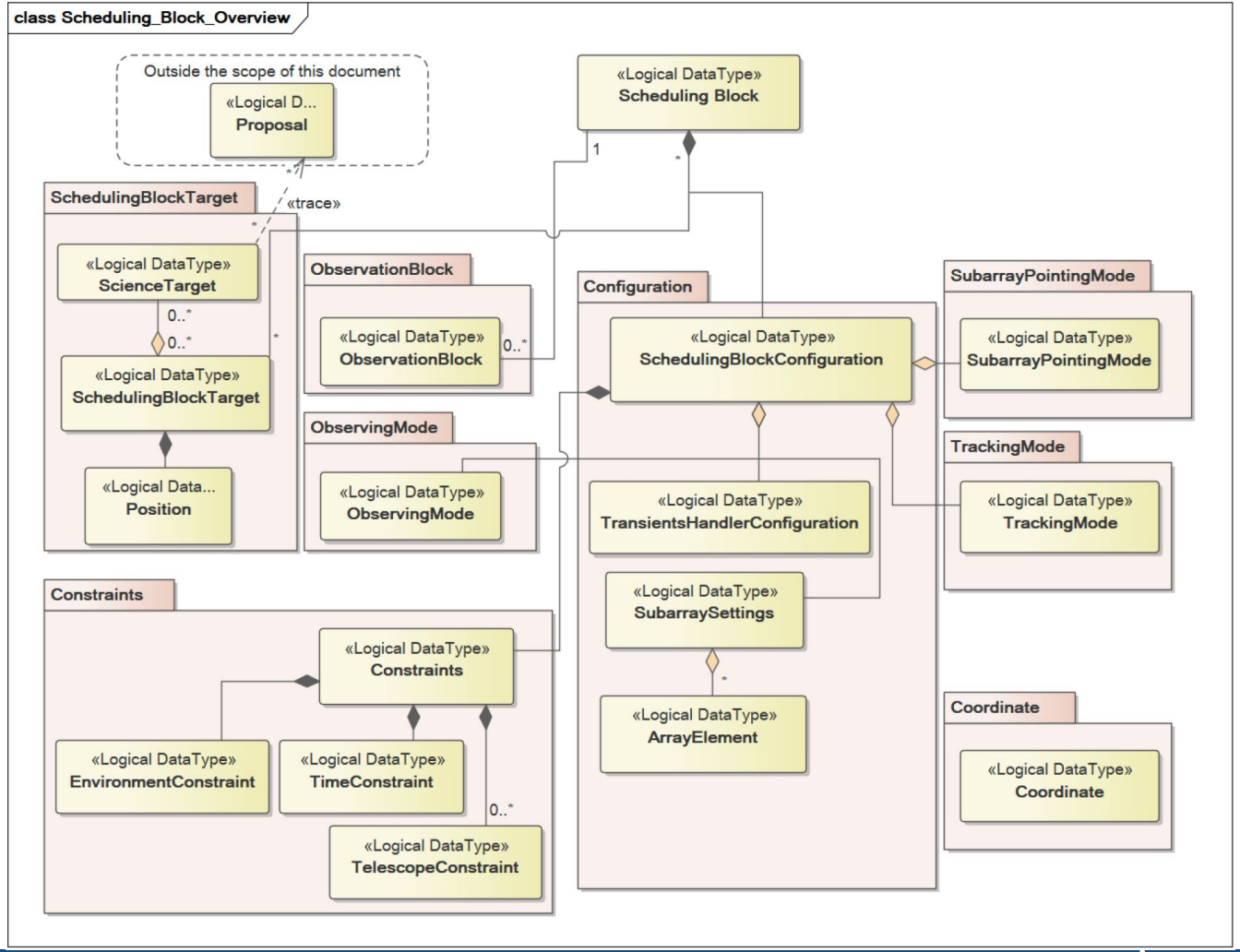
# ObsCore for Cherenkov event datasets

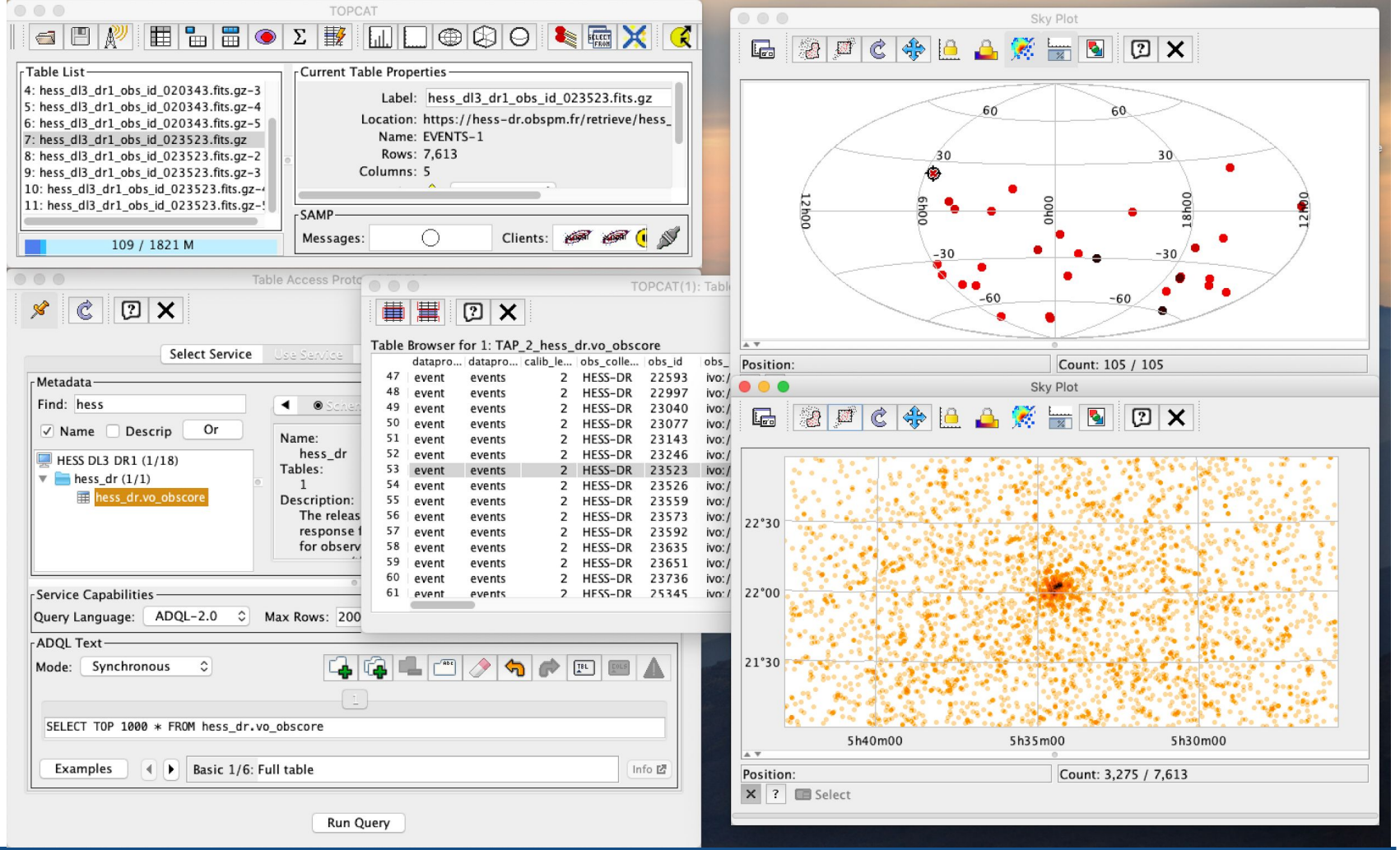
- Example of H.E.S.S. DL3 public data release
  - http://voparis-tap-astro.obspm.fr/__system__/dc_tables/show/tableinfo/hess_dr.vo_obscore
- Filling the ObsCore fields…
  - **dataproduct_subtype** = DL3, maybe specific data format (VODF)
  - **calib_level** = between 2 and 3…
  - **obs_collection** could contain many details : obs_type (calib, science), obs_mode (subarray configuration), pointing_mode, tracking_mode, event_type, event_cuts, analysis_type…
  - **s_ra**, **s_dec** = 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
    - value at a given energy?
    - range of values
  - **em_min**, **em_max** : add fields expressed in 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
  - many fields are empty or null

# CTA Instrument Description



# CTA Scheduling Block DM




TOPCAT
Table List
4: hess_dl3_dr1_obs_id_020343.fits.gz-3
5: hess_dl3_dr1_obs_id_020343.fits.gz-4
6: hess_dl3_dr1_obs_id_020343.fits.gz-5
7: hess_dl3_dr1_obs_id_023523.fits.gz
8: hess_dl3_dr1_obs_id_023523.fits.gz-2
9: hess_dl3_dr1_obs_id_023523.fits.gz-3
10: hess_dl3_dr1_obs_id_023523.fits.gz-4
11: hess_dl3_dr1_obs_id_023523.fits.gz-5
109 / 1821 M
Current Table Properties
Label: hess_dl3_dr1_obs_id_023523.fits.gz
Location: https://hess-dr.obspm.fr/retrieve/hess_
Name: EVENTS-1
Rows: 7,613
Columns: 5
SAMP
Messages:
Clients:
Sky Plot
Position:
Count: 105 / 105
Sky Plot
Position:
Count: 3,275 / 7,613
Select
Table Access Proto
Select Service
Use Service
Metadata
Find: hess
Name
Descrip
Or
HESS DL3 DR1 (1/18)
hess_dr (1/1)
hess_dr.vo_obscore
Name:
hess_dr
Tables:
1
Description:
The releas
response
for observ
Service Capabilities
Query Language: ADQL-2.0
Max Rows: 200
ADQL Text
Mode: Synchronous
SELECT TOP 1000 * FROM hess_dr.vo_obscore
Examples
Basic 1/6: Full table
Info
Run Query
TOPCAT(1): Table
Table Browser for 1: TAP_2_hess_dr.vo_obscore
47 event events 2 HESS-DR 22593
48 event events 2 HESS-DR 22997
49 event events 2 HESS-DR 23040
50 event events 2 HESS-DR 23077
51 event events 2 HESS-DR 23143
52 event events 2 HESS-DR 23246
53 event events 2 HESS-DR 23523
54 event events 2 HESS-DR 23526
55 event events 2 HESS-DR 23559
56 event events 2 HESS-DR 23573
57 event events 2 HESS-DR 23592
58 event events 2 HESS-DR 23635
59 event events 2 HESS-DR 23651
60 event events 2 HESS-DR 23736
61 event events 2 HESS-DR 25345
60
30
-30
-60
12h00
6h00
0h00
18h00
22°30
22°00
21°30
5h40m00
5h35m00
5h30m00

# EventList Data Model

- Issue
  - what is really in the event dataset?
  - does it include IRFs? only an event list?
  - where can one find the corresponding IRFs?
- Related ObsCore fields
  - dataproduct_subtype?
  - obs_collection?
- Need a way to link an EventList to its IRFs

→ Having a data model with relations between those elements would help

→ possible ObsCore extension fields would appear in this data model