

Cherenkov data access and HE ObsCore implementation

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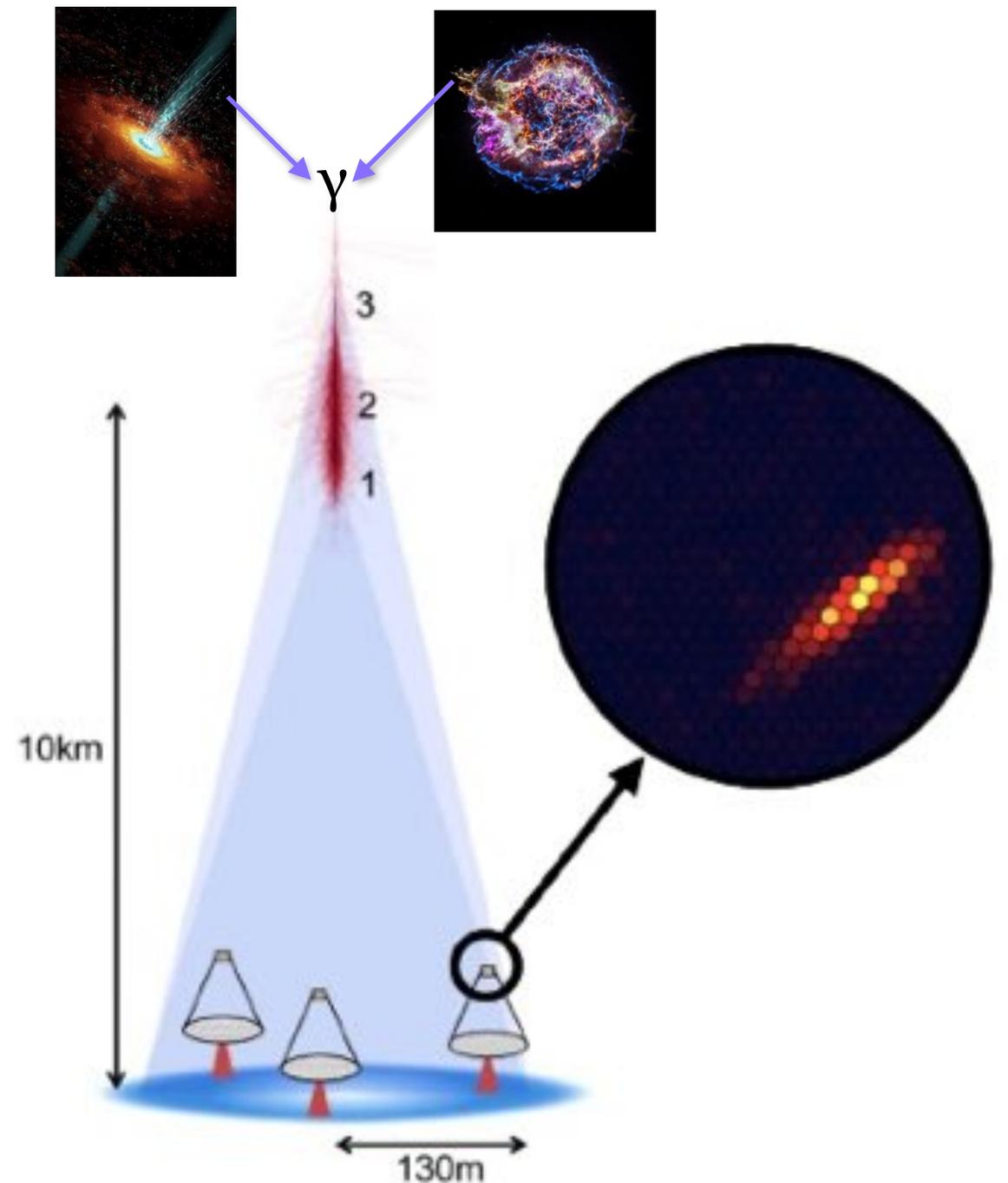
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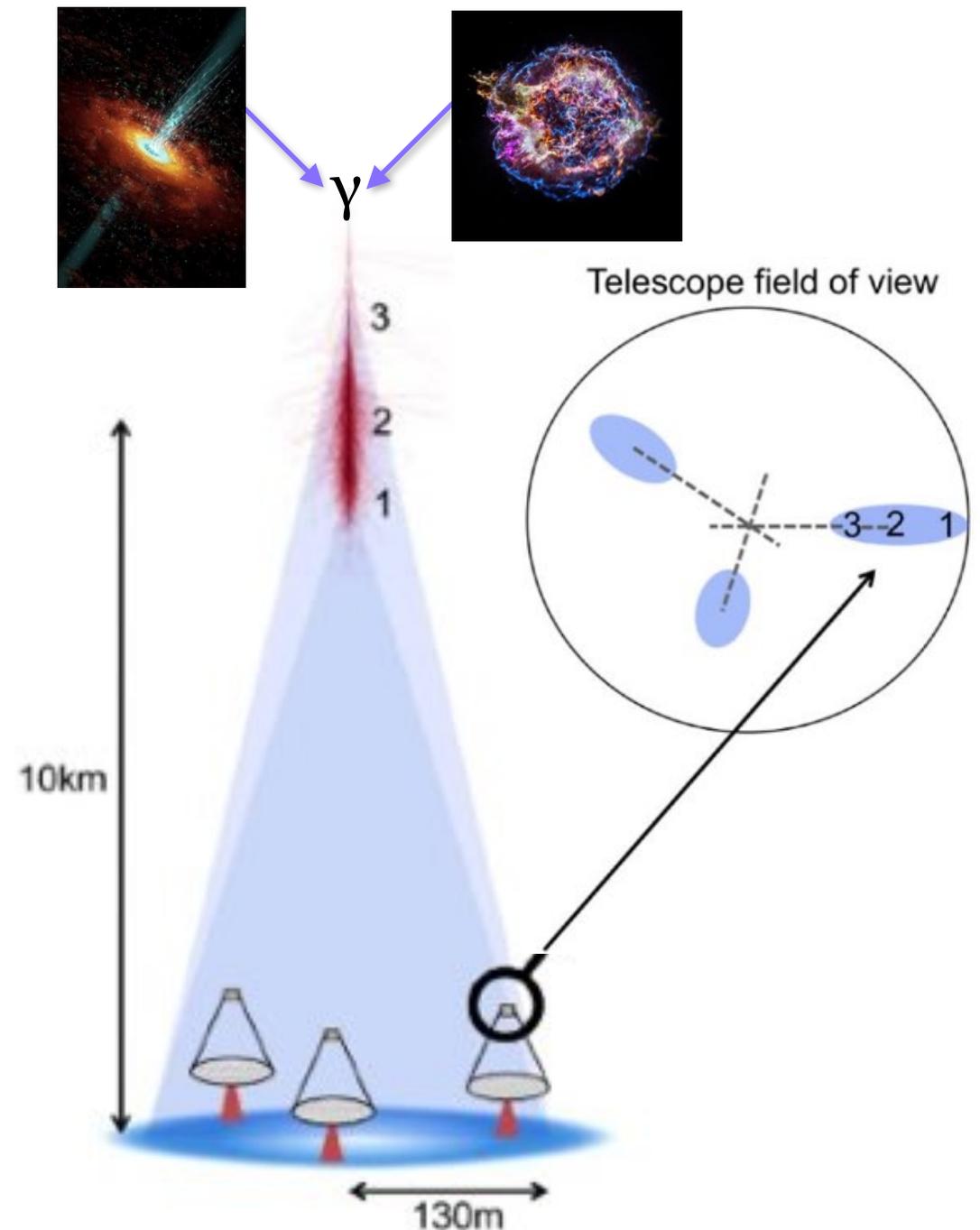
Cherenkov Astronomy

- Detection of **γ -rays** covering several orders of magnitude in energy (~ 0.1 to 100 **TeV**)
- **Indirect** observation via Cherenkov light (particle shower)



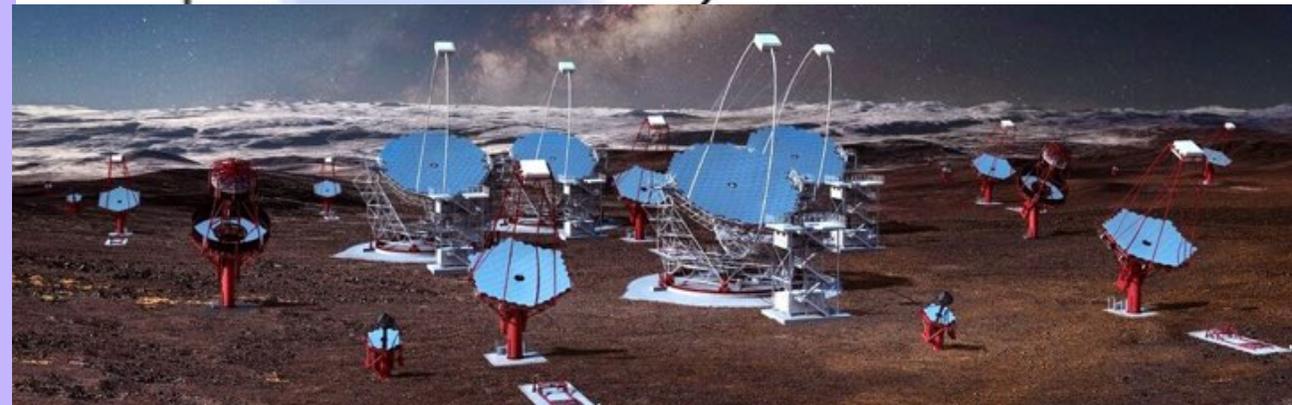
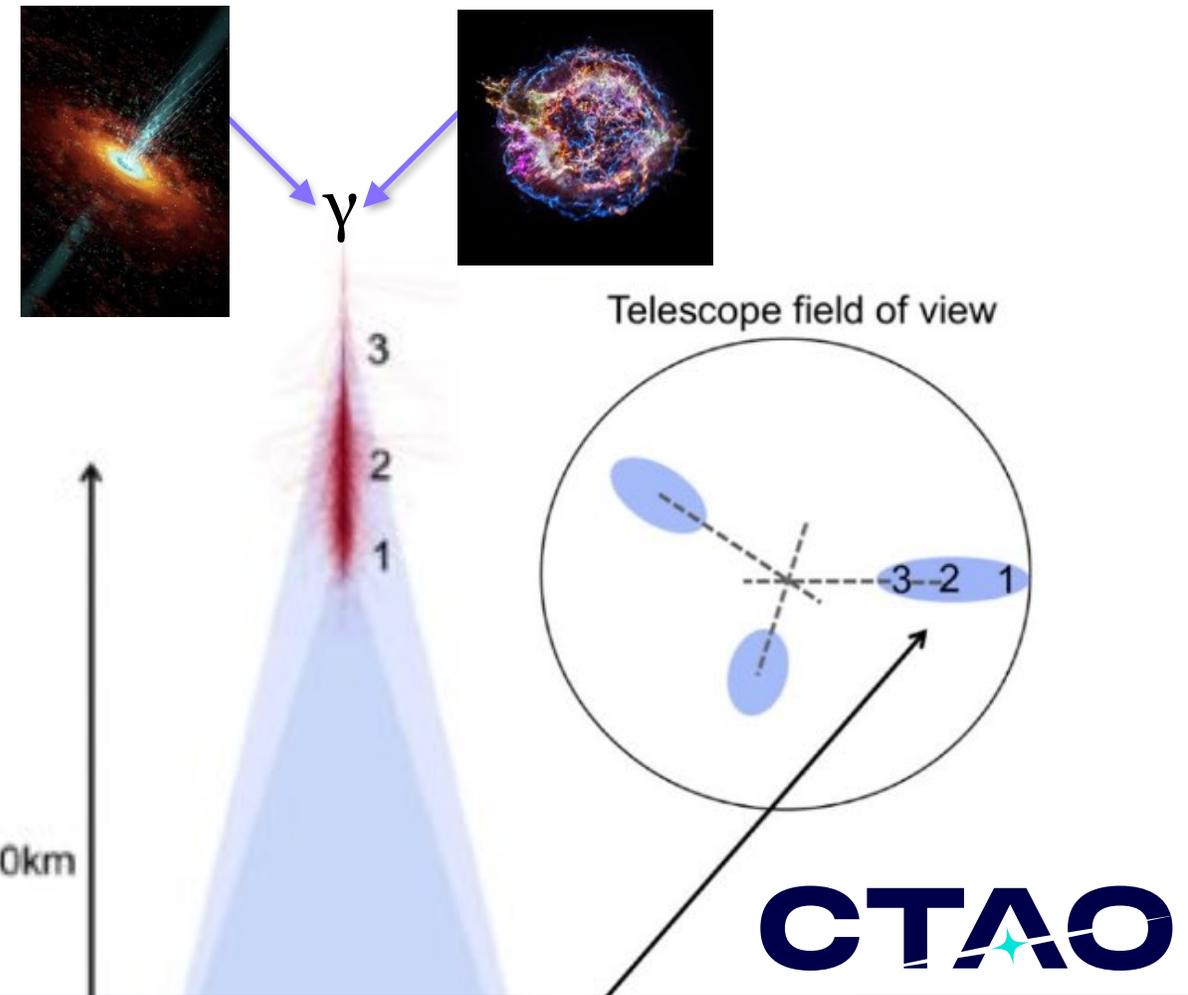
Cherenkov Astronomy

- Detection of **γ -rays** covering several orders of magnitude in energy (~ 0.1 to 100 **TeV**)
- **Indirect** observation via Cherenkov light (particle shower)
- **Event** counting
- Low count **statistics**
- High **background**



Cherenkov Astronomy

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- **CTAO**: Cherenkov Telescope Array
- **Big data era** (PB of data per year)



Open Science

- « Make scientific research accessible to everyone for the benefits of scientists and society as a whole » [\[UNESCO\]](#)
- **FAIR** principles for data access [\[Wilkinson et al. 2016\]](#)
- International Virtual Observatory Alliance (**IVOA**)

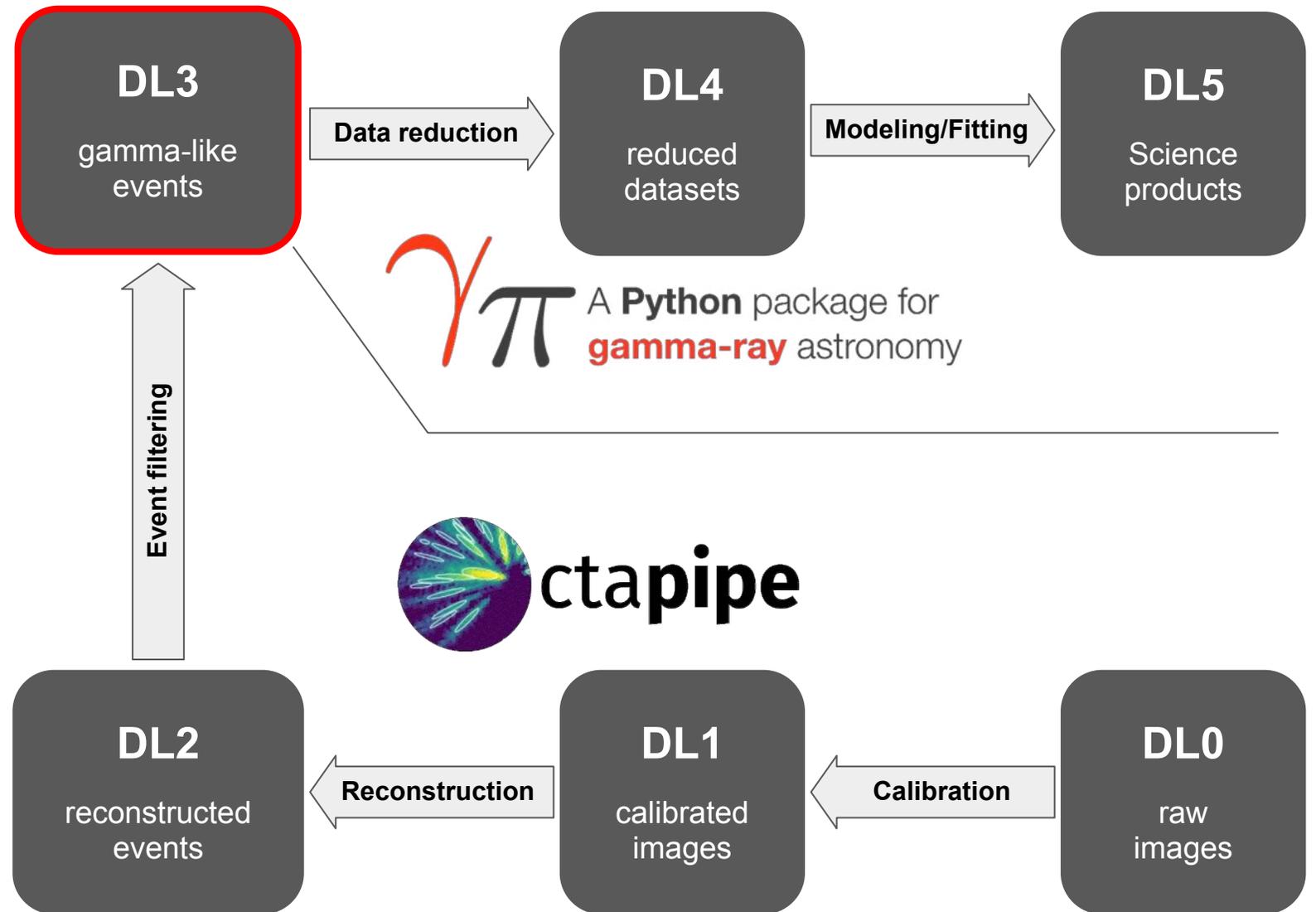
See e.g. [\[Servillat et al. 2022\]](#)

"FAIR high level data for Cherenkov astronomy"
ADASS XXXI, ASP Conference Series



Cherenkov data preparation

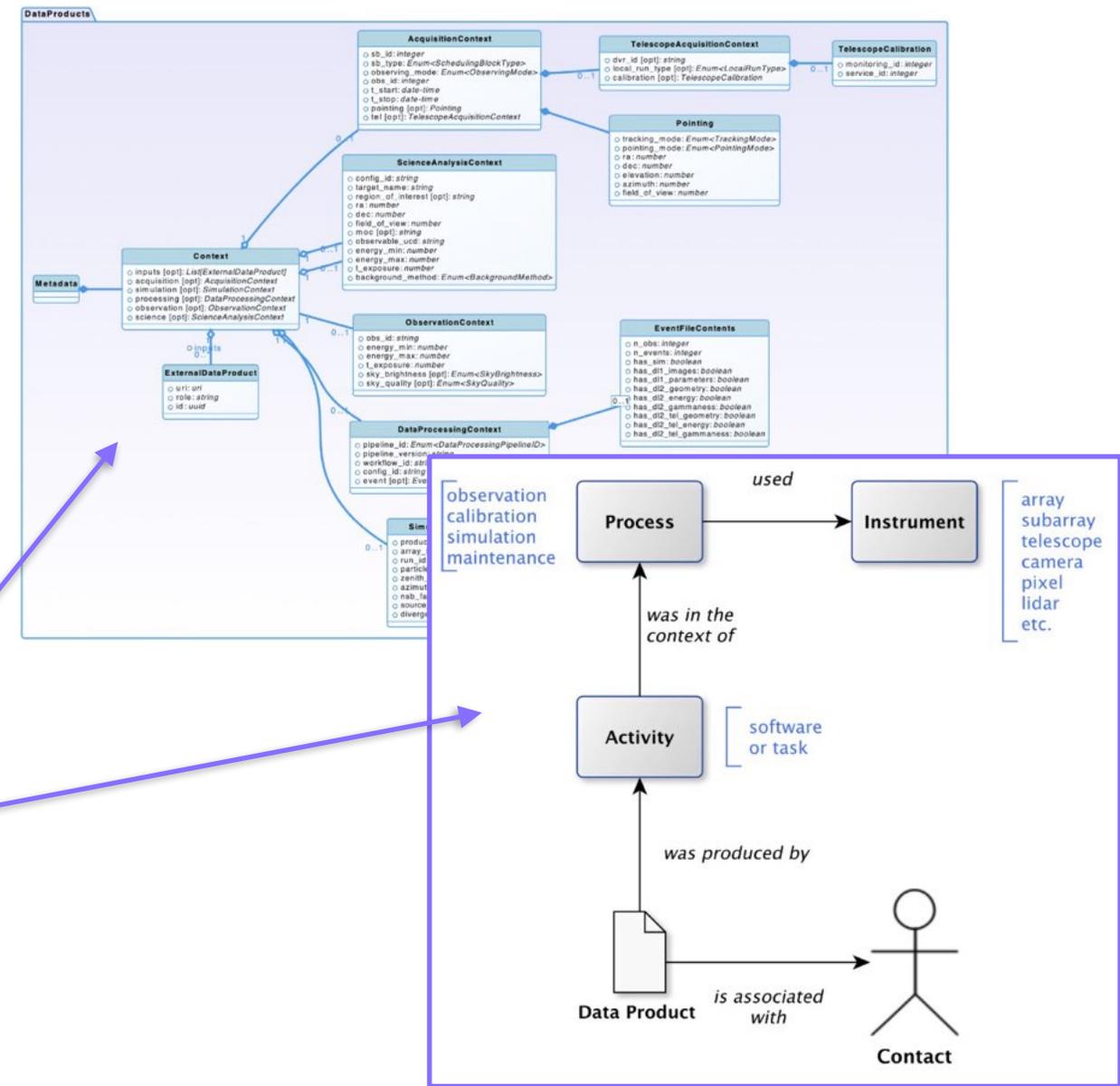
- Data Levels (DL)
From camera to science data products
- **Event lists** (DL3)
(coordinates, time, energy)
- Requires:
 - **Calibration**
 - **Reconstruction**
 - **Filtering**
- Instrument Response Function (IRFs) needed for DL3



Associated metadata

Description of data, assumptions and context of observations

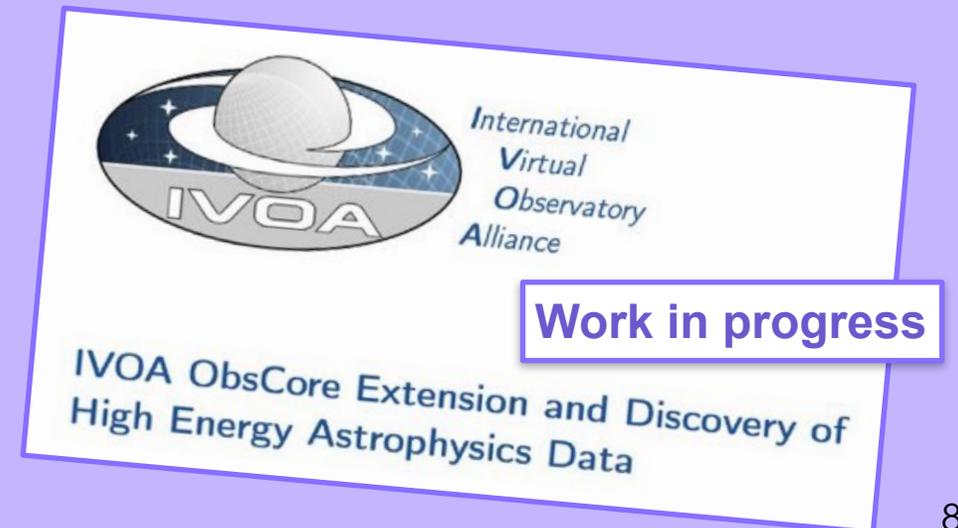
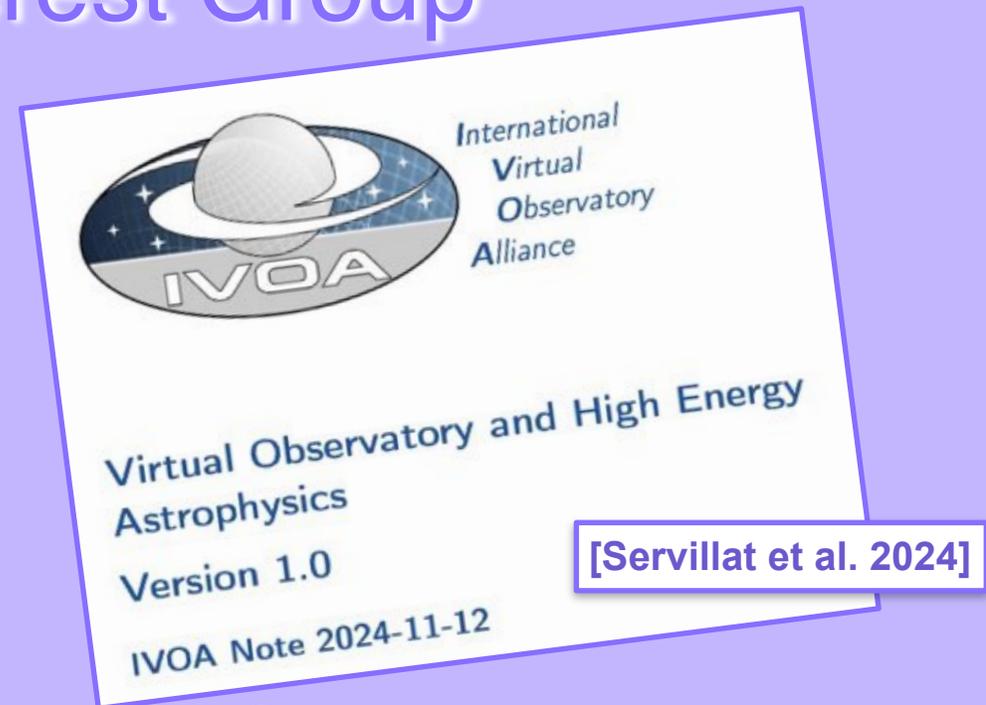
- **IVOA ObsCore**
spatial coordinates, time, energy...
[IVOA Recommendation, Louys et al. 2017]
- **High Energy specific** [IVOA HEIG]
counts, instrument modes, IRFs
- **Cherenkov specific**
atmosphere, statistics, filtering, analysis
- **IVOA Provenance**
due to complex data preparation
[IVOA Recommendation, Servillat et al. 2020]



Context and Reference metadata (provenance) that will be included in each CTAO data product
(credits: Karl Kosack and CTAO Data Model group)

IVOA High Energy (HE) Interest Group

- **Formed in 2024 (IVOA Malta)**
after several dedicated meetings
(PADC, OV-France, IVOA)
- Different **HE observatories**
represented
X-ray, γ -ray, Cherenkov, neutrinos...
- **Commonalities** for data
dissemination and analysis
- Current work on **ObsCore
extension** for HE astrophysics



HE ObsCore extension

- (Re)define data product types:
 - event-list (instead of event)
 - event-bundle
 - response-function
 - ...
- Discuss ObsCore attributes
- Propose new attributes
- Evolution of UCD list
- DataLink with content_qualifier
- Use cases

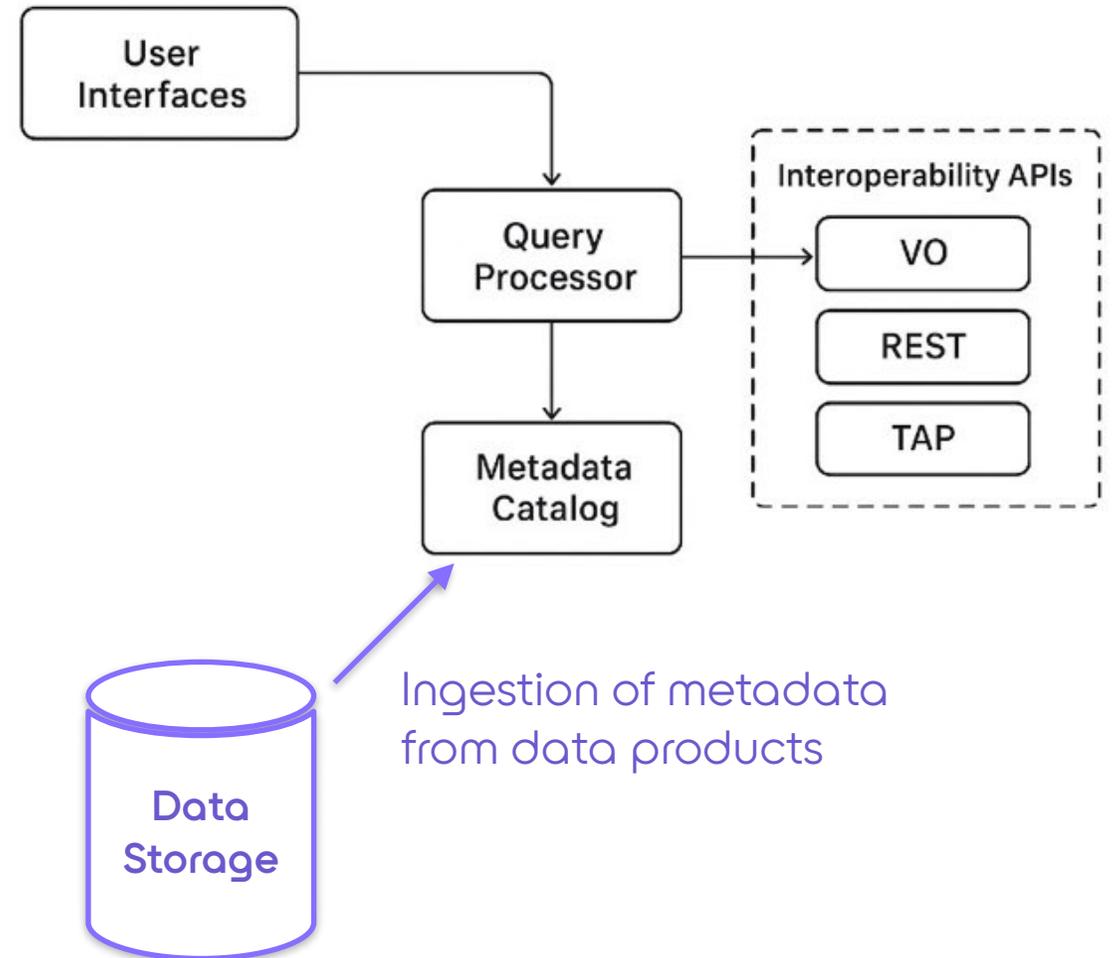
Column Name	UType	Unit	Type	Description	MAN
<i>ev_xel</i>	TBD	unitless	integer	Number of events in an event list	NO
<i>s_ref_energy</i>	TBD	eV	double	Energy at which the ObsCore spatial characterization attributes <i>s_fov</i> , <i>s_region</i> , <i>s_resolution</i> are defined	NO
<i>em_ref_energy</i>	TBD	eV	double	Energy at which the ObsCore spectral characterization attributes <i>em_res_power</i> , <i>em_resolution</i> are defined	NO
<i>s_ref_oaa</i>	TBD	deg	double	Off-axis angle (<i>i.e.</i> , the angular separation of the target or source from the telescope optical axis) at which the ObsCore spatial characterization attributes <i>s_fov</i> , <i>s_region</i> , <i>s_resolution</i> are defined	NO
<i>em_ref_oaa</i>	TBD	deg	double	Off-axis angle (<i>i.e.</i> , the angular separation of the target or source from the telescope optical axis) at which the ObsCore spectral characterization attributes <i>em_res_power</i> , <i>em_resolution</i> are defined	NO
<i>t_intervals</i>	TBD	unitless	string	List of observation intervals or stable/good time intervals describing the exact observation time coverage as a TMOC	NO
<i>energy_min</i>	TBD	eV	double	Energy associated to the ObsCore attribute <i>em_max</i> , describing the minimum energy of the dataset	NO
<i>energy_max</i>	TBD	eV	double	Energy associated to the ObsCore attribute <i>em_min</i> , describing the maximum energy of the dataset	NO
<i>obs_mode</i>	TBD	unitless	string	Observation mode of an observation	NO
<i>tracking_type</i>	TBD	unitless	string	Tracking type of an observation	NO
<i>scan_mode</i>	TBD	unitless	string	Scan mode of an observation	NO
<i>pointing_mode</i>	TBD	unitless	string	Pointing mode of an observation	NO
<i>analysis_mode</i>	TBD	unitless	string	Data reduction/analysis mode	NO
<i>event_type</i>	TBD	unitless	string	Event subset indicator (<i>e.g.</i> , data quality flag for the events)	NO

```
SELECT * FROM ivoa.obscore
NATURAL JOIN ivoa.obscore_healpix
WHERE
(target_name = 'BL Lac' OR
CONTAINS(POINT(s_ra, s_dec), CIRCLE, 330.680338, +42.27777, 0.083333) = 1)
AND (datapoint_type = 'event-list')
AND (calib_level >= 2)
AND (em_calib_status = 'calibrated')
AND (ev_xel >= 10000)
```

VO Services for Cherenkov data

- Provide web **access endpoints** for **metadata**
- Following **IVOA standards**
- **Query Processor**
 - DaCHS software [Demleitner et al.]
 - Resource descriptor
 - Described metadata (UCDs, units...)
- Ensures **Interoperability**

Web Portals
VO compatible tools
Scripts (PyVO, ...)



H.E.S.S. DL3 Public data

- Published in the VO <https://hess-dr.obspm.fr/>
- Simple Cone Search service
- ObsCore table
 - Including HE extension fields
 - FITS GADF header
- DataLink service
 - #this → event-list
 - #calibration → IRFs
 - #package → event-bundle

PADC TAP Server on voparis-tap-he.obspm.fr ADQL Query

Parameters

- ADQL query: select dataproduct_type,dataproduct_subtype,obs_collection,obs_id,target_name,s_ra,s_dec,t_min,t_max,access_url from hess_dr.obscore

Result

Matched: 105

Send via SAMP Quick Plot

Product type	Subtype	Collection	Obs. Id	Target Name	RA [deg]	Dec [deg]	Min. t	Max. t	Access URL
event-list	GADF DL3	HESS-DL3-DR1	20136	MSH15-52	228.6125	-58.771667	2004-03-26T02:57:46Z	2004-03-26T03:25:48Z	hess_dl3_dr1_obs_id_020136.fits.gz
event-list	GADF DL3	HESS-DL3-DR1	20137	MSH15-52	228.6125	-59.771667	2004-03-26T03:28:25Z	2004-03-26T03:43:27Z	hess_dl3_dr1_obs_id_020137.fits.gz
event-list	GADF DL3	HESS-DL3-DR1	20151	custom	228.6125	-58.771667	2004-03-27T02:28:16Z	2004-03-27T02:56:19Z	hess_dl3_dr1_obs_id_020151.fits.gz
event-list	GADF DL3	HESS-DL3-DR1	20275	3C 273	187.27792	2.552389	2004-04-14T19:51:40Z	2004-04-14T20:19:43Z	hess_dl3_dr1_obs_id_020275.fits.gz
event-list	GADF DL3	HESS-DL3-DR1	20282	MSH 15-5-02	228.6125	-58.771667	2004-04-14T23:32:13Z	2004-04-15T00:00:20Z	hess_dl3_dr1_obs_id_020282.fits.gz
event-list	GADF DL3	HESS-DL3-DR1	20283	MSH 15-5-02	228.6125	-59.771667	2004-04-15T00:02:31Z	2004-04-15T00:30:34Z	hess_dl3_dr1_obs_id_020283.fits.gz
event-list	GADF DL3	HESS-DL3-DR1	20301	MSH 15-5-02	228.6125	-58.771667	2004-04-15T23:35:42Z	2004-04-16T00:03:45Z	hess_dl3_dr1_obs_id_020301.fits.gz
event-list	GADF DL3	HESS-DL3-DR1	20302	MSH 15-5-02	228.6125	-58.771667	2004-04-15T23:35:42Z	2004-04-16T00:03:45Z	hess_dl3_dr1_obs_id_020302.fits.gz

Links for 20275

▼ the data itself

the primary (as opposed to related) data of the identified resource

[The event-list dataset](#)

▼ Applicable Calibration

Data products that can be used to remove instrumental signatures from #this. Note that the calibration steps such data products feed have not been applied to #this yet.

[IRFs](#)

▼ Single Download Package

All file-like items related to #this and #this itself packaged together in a single downloadable archive.

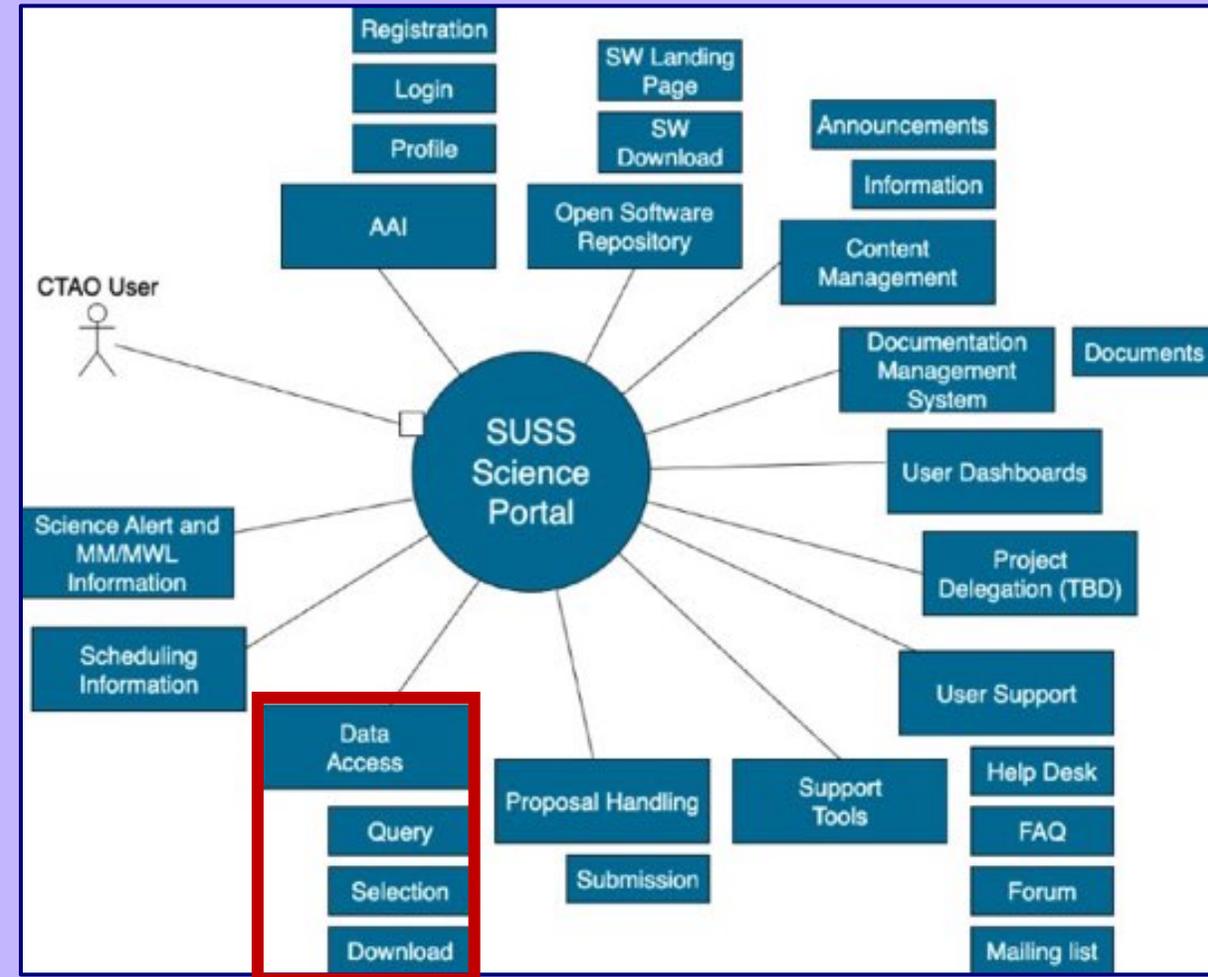
[Event bundle including IRFs](#)

CTAO Science Portal

SUSS (Science User Support System)

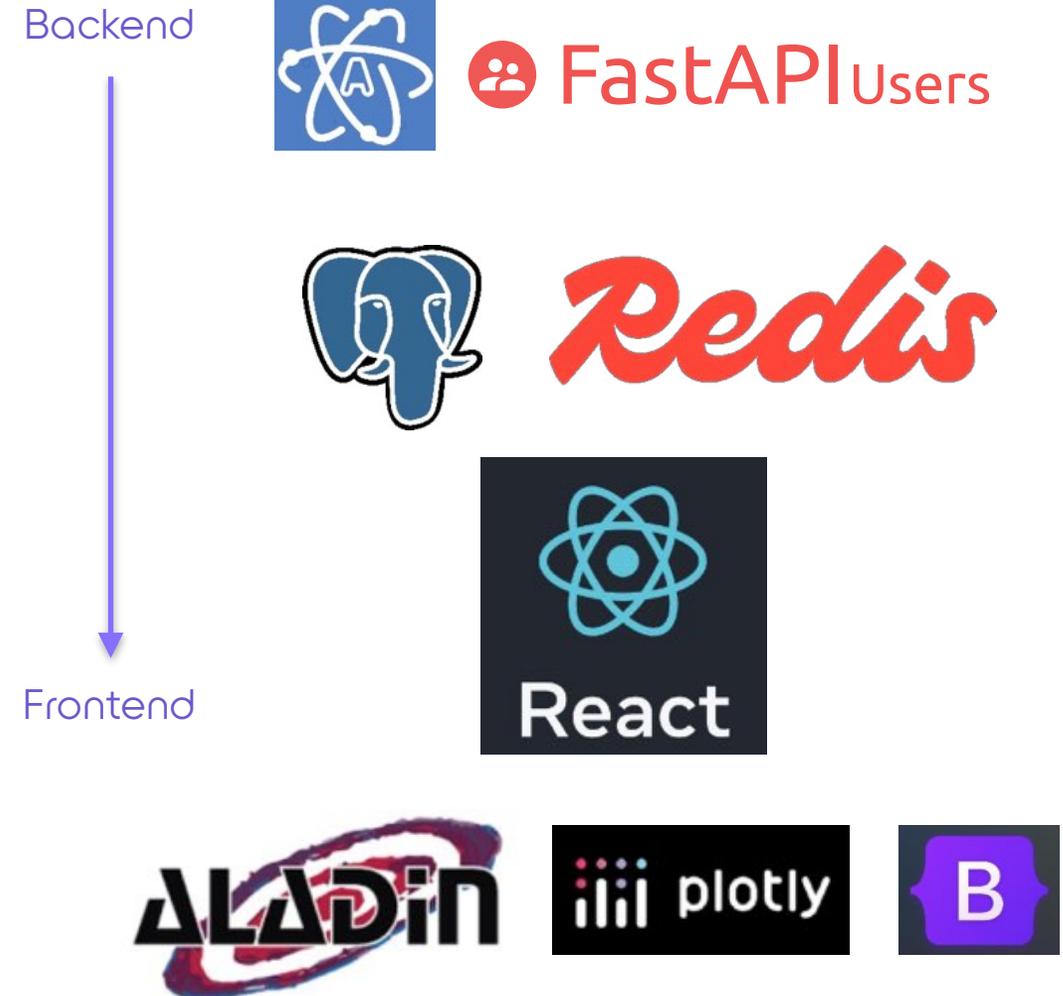
Portal objectives and use cases:

- Get documentation and links (UC1)
- Authentication and Authorization (UC2)
- Find data (UC3)
- Download data (UC4)
- Process data (optional)
 - Interactive analysis (UC5)
 - Batch mode analysis (UC6)



Web development tools

- **FastAPI:** speed, flexibility, and modern features like async functions
- **Postgres** with **SQLAlchemy:** Non private user info and history
- **Redis:** Cache app and user data, session id
- **Authlib** with **FastAPI Users:** OpenID Connect
- **React.js:** Interactive, responsive user interface.
- **Aladin Lite:** A sky atlas to show targets
- **Plotly:** Visualisation library
- **Bootstrap:** Navigation and style of frontend
- **PyTest:** Testing the backend
- **Prometheus & Grafana:** Monitoring production & staging with metrics



Searching data

- **Cone Search**

- RA/Dec or galactic coordinates
 - Resolve object via SIMBAD/NED

- **Time Search**

- Different time fields (Gregorian, MJD, MET)
 - Auto conversion

- **Energy Search (TeV)**

- **Observation and Context**

- Proposal ID
 - Tracking type/mode: Sidereal
 - Pointing mode: Parallel
 - Observation mode: Wobble, On/Off...
 - Scan mode (similar to Radio extension)
 - Analysis mode
 - Moon level / Sky brightness: None, Dark, Moderate

- **More criteria to come**

- Dataproduct type (images, spectra...)
 - Data Level (DL3, DL4...)
 - Science Target ID
 - Object type
 - Average azimuth, elevation
 - Livetime
 - Quality

The screenshot displays a search interface with two main sections: 'Cone Search' and 'Time Search'. Both sections have a 'Use' toggle switch in the top right corner.

Cone Search Section:

- Source Name:** A text input field containing 'crab'.
- Resolve:** A button with a dropdown menu showing 'SIMBAD' (selected) and 'NED'.
- Coordinate system:** Three buttons: 'Equatorial (deg)' (selected), 'Equatorial (hms/dms)', and 'Galactic (l/b deg)'. Each button has a 'J2000' label.
- RA (deg):** A text input field containing '83.632400'. Below it, the text 'e.g., 83.6324' is shown.
- Dec (deg):** A text input field containing '22.017400'. Below it, the text 'e.g., 22.0174' is shown.
- Radius (deg):** A text input field containing '5'.

Time Search Section:

- Time System:** Two buttons: 'TT' (selected) and 'UTC'.
- Epoch for MET seconds:** A text input field containing '2001-01-01 00:00:00 TT'.
- Observation Start:** A row of three input fields: '2004-01-01 00:00:00' (with a clock icon), 'MJD 53005.0000000', and 'MET 946079'.
- Observation End:** A row of three input fields: '2005-01-01 00:00:00' (with a clock icon), 'MJD 53371.0000000', and 'MET 126230'.

Bottom Section:

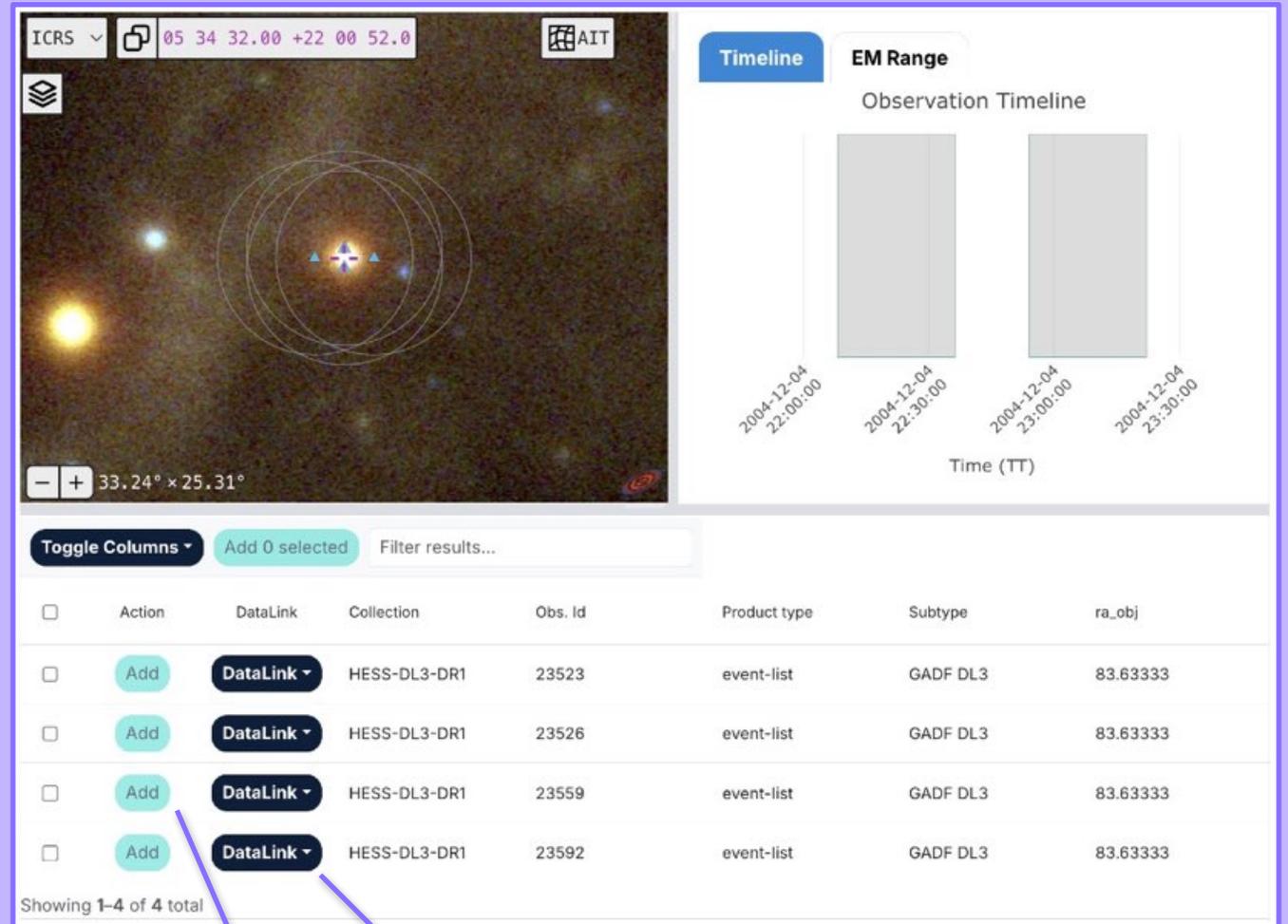
- Energy Search:** A dropdown menu with a downward arrow.
- Observation Configuration:** A dropdown menu with a green 'Active' button and a downward arrow.
- Observation Program:** A dropdown menu with a downward arrow.

Viewing the results

- **Visualisation:**
 - Sky map with markers
 - Timeline
 - Electromagnetic range
- **Results Table:**
 - Metadata (ObsCore extended)
 - Buttons to add to Basket
 - Download / DataLink services

Visualise field of view
on a Sky Map

Visualise
Timeline



Download / DataLinks
Add to a selection basket

For logged-in users

- **Authentication**

OpenID Connect standard
CTAO IAM for Identity Management

- **Query Store**

History of queries & results
Traceability

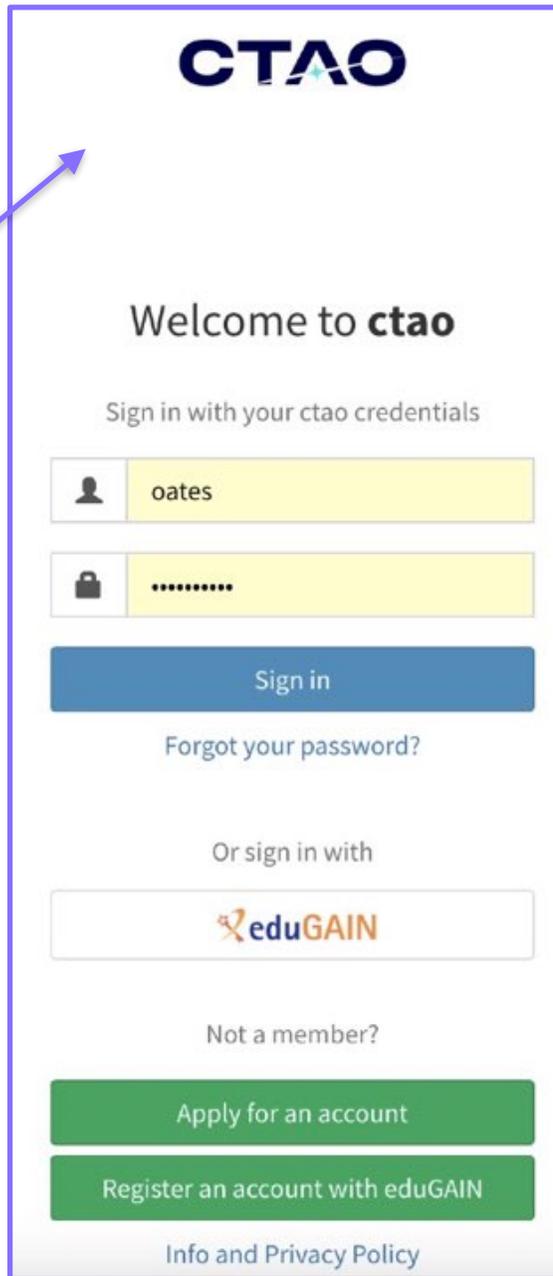
- **Baskets**

Selected Datasets

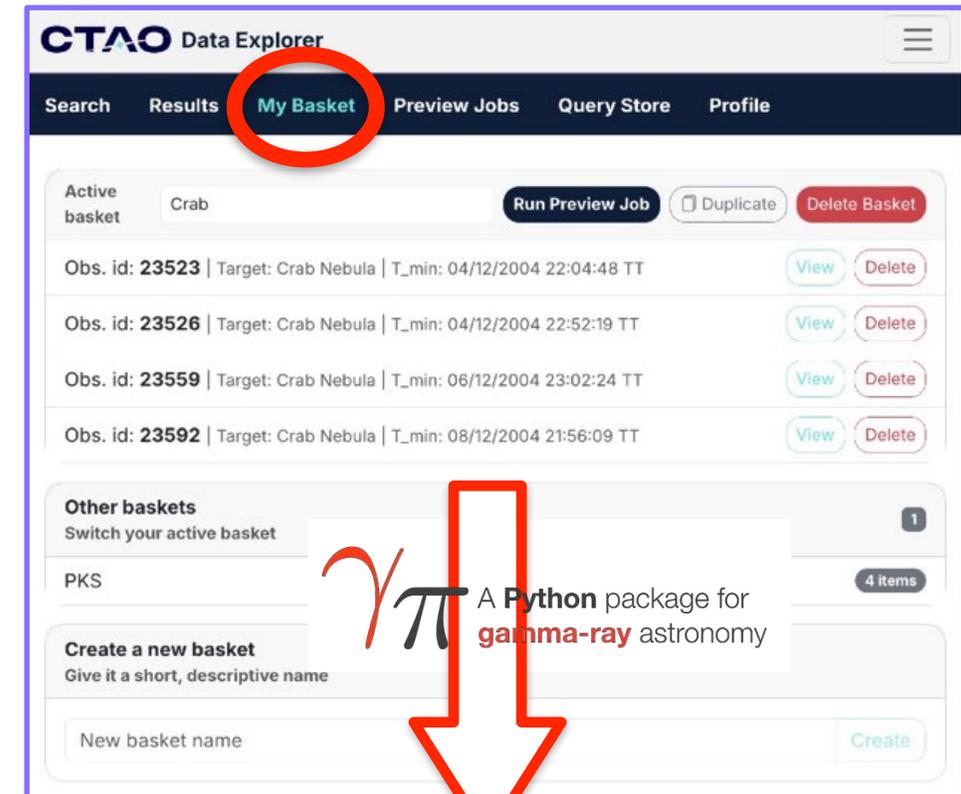
- **Basket Preview**

- via asynchronous job
- using IVOA UWS standard
- traceability of jobs (provenance)

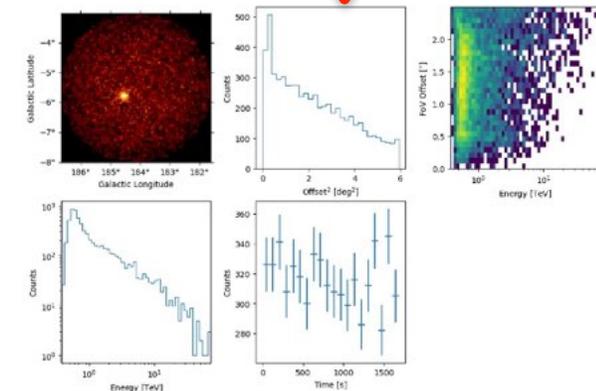
[OPUS software]



The image shows the CTAO login page. At the top is the CTAO logo. Below it, the text reads "Welcome to ctao". There is a section for signing in with CTAO credentials, featuring a username field with "oates" and a password field with masked characters. A "Sign in" button is present, along with a link for "Forgot your password?". Below this, there is an option to sign in with eduGAIN. At the bottom, there are two green buttons: "Apply for an account" and "Register an account with eduGAIN". A link for "Info and Privacy Policy" is at the very bottom. A blue arrow points from the "Authentication" section of the text to the login form.



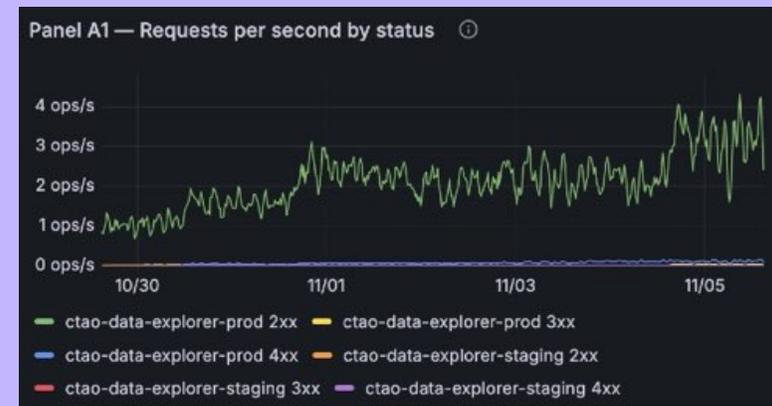
The image shows the CTAO Data Explorer interface. The top navigation bar includes "Search", "Results", "My Basket" (highlighted with a red circle), "Preview Jobs", "Query Store", and "Profile". Below the navigation bar, there is a section for the "Active basket" named "Crab", with buttons for "Run Preview Job", "Duplicate", and "Delete Basket". A table lists four observations with their IDs, targets, and start times, each with "View" and "Delete" buttons. Below the table, there is a section for "Other baskets" with a "Switch your active basket" dropdown showing "PKS" (4 items). A "Create a new basket" section is also visible, with a "New basket name" input field and a "Create" button. A large red arrow points from the "My Basket" section down to the analysis plots.



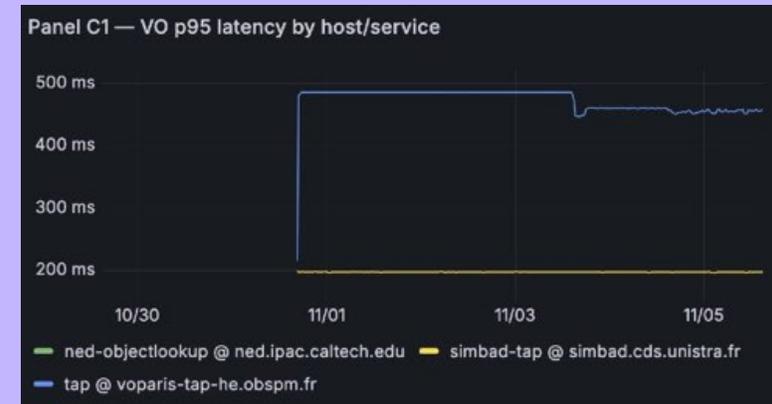
→ Assess the relevance of the basket

Monitoring & Testing

- We expose app metrics to **Prometheus** and visualize them in **Grafana** for live health, latency, and errors
- Using **Pytest**, we validated auth/session lifecycle, query-history writes, basket flows, and UWS job utilities end-to-end, catching regressions with minimal fixes



Traffic & health: requests and their status



Latency for TAP/SIMBAD/OPUS requests



Redis cache footprint over time

Cherenkov Data Access

- Based on standards for Open Science and IVOA standards
- Next steps:
 - Extend form with additional query criteria
 - Improve job previews for users
 - Integration to the CTAO Portal and Archive
- Open Source: MIT License
- GitHub:
<https://github.com/aopy/ctao-data-explorer>
- Documentation:
<https://aopy.github.io/ctao-data-explorer>

