Virtual Observatory and High Energy Astrophysics
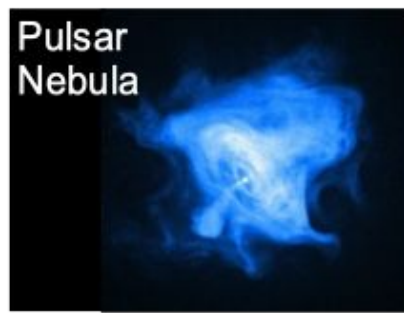
Mathieu Servillat (LUTH - Observatoire de Paris / CNRS)
with work from the IVOA HE Club
+ OV-France and several European projects

IVOA Sydney
2024-05-21

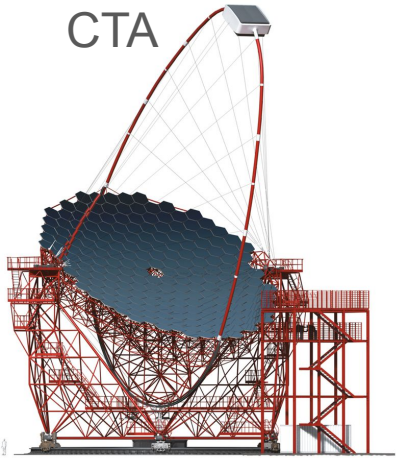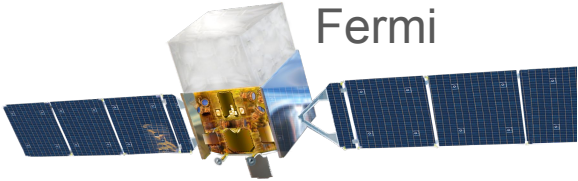Pulsar Nebula

Starburst

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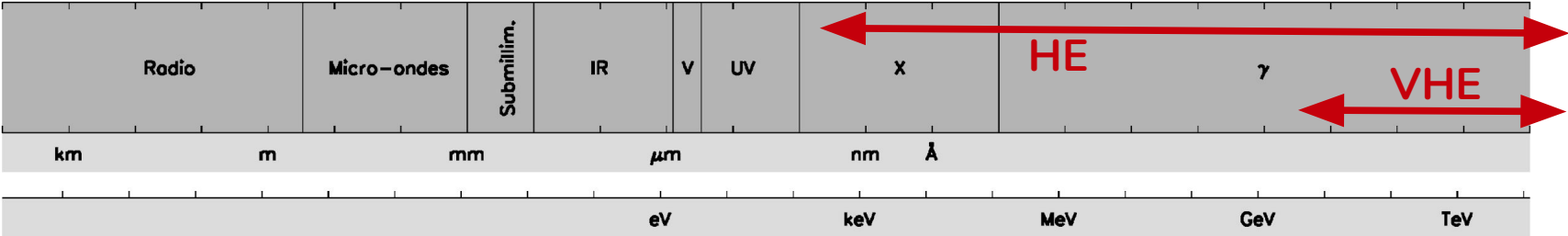
Active Galactic Nuclei
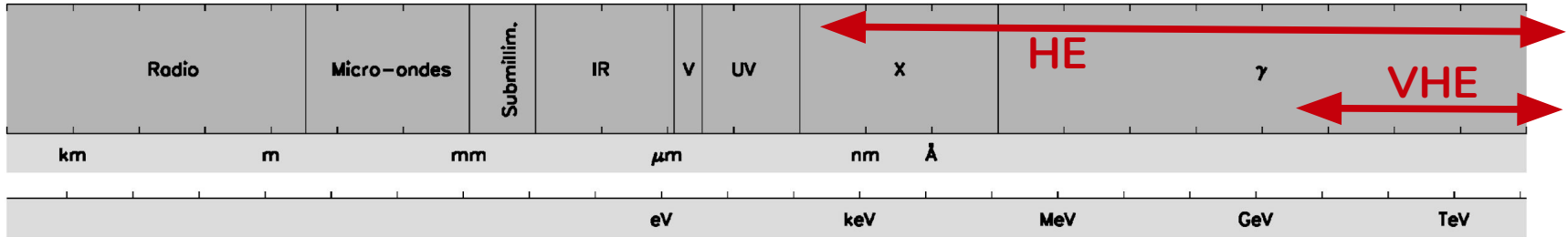
- Violent, transient, non-thermal phenomena
- Matter under extreme conditions
- Particle Acceleration
- Fundamental Physics
- Role of Black Holes in the structuration of the Universe

Supernova
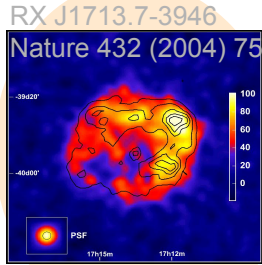
Nova

Compact Binaries

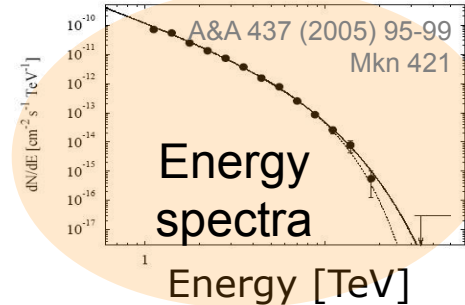Gamma-Ray Burst

High Energy Astrophysics

High Energy Astrophysics

Several orders of magnitude - Event **counting -** Low count **statistics** - High background
→ **Event lists** (coordinates, time, energy)

Images

Lightcurves

Energy spectra
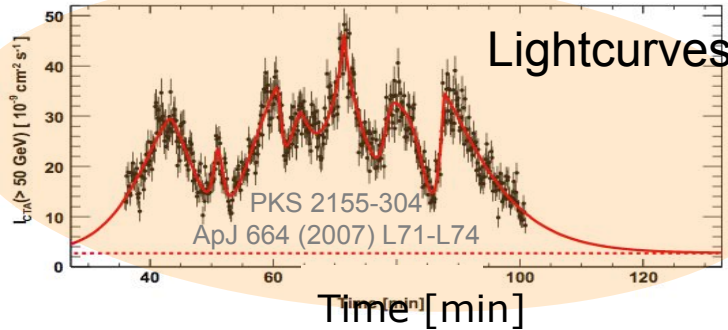
+ **multi-messenger data** (photons, cosmic rays, neutrinos, gravitational waves...)

Current High Energy data in the VO

- **Images**
  - Fermi Full Sky, eRosita, XMM-Newton, H.E.S.S. galactic plane

- **Catalogs**
  - Vizier dedicated section
  - NASA HEASARC (many legacy archives)
  - Generally catalogs of sources

- **SIA/TAP services**
  - High level data, catalogs, proposals, …

Aladin Search Tree

CHANDRA SOURCE CATALOG
Table Access Protocol

XMM-Newton Science Archive
TAP queries to the XSA database

NASA's HEASARC
High Energy Astrophysics Science Archive Research Center
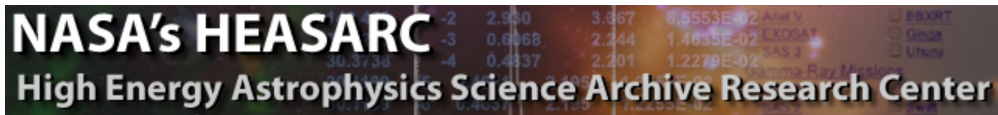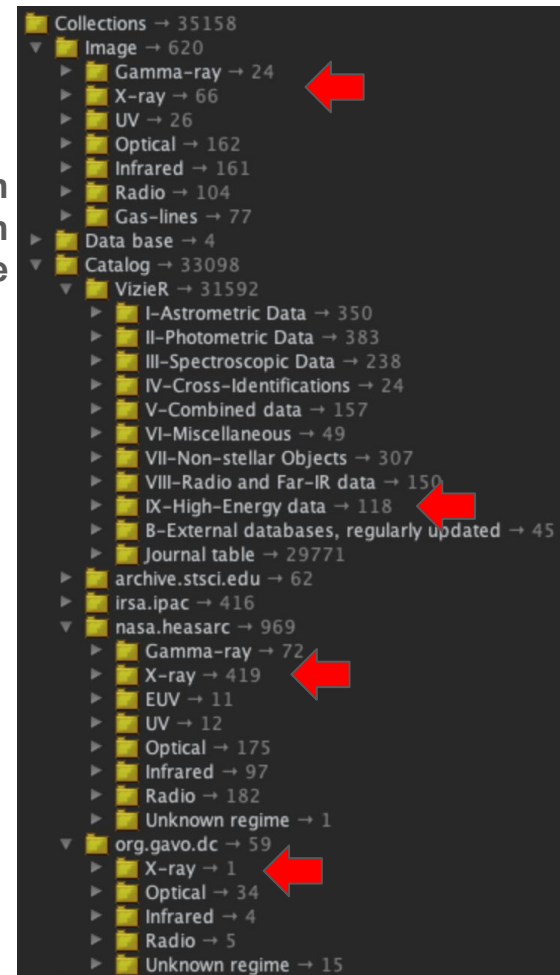
October 2022: VO HE dedicated workshop

- **OV-France workshop in Strasbourg**
  - https://indico.obspm.fr/event/1489

- Continue activities of the **ESCAPE European project** that embarked High Energy Facilities (**2019-2023** H2020 project).
- Bring together representatives of HE observatories (VHE, HE, GW, neutrino)
- Focus on HE observatory **operations** and **data**:
  - CTA (Mathieu Servillat)
  - Ligo Virgo Kagra (Pierre Chanial)
  - Neutrino (Damien Dornic)
  - XMM & SVOM (Laurent Michel)
  - GADF/VODF (Bruno Khelifi)

May 2023: HE meeting at IVOA Interop

- **Talk and Splinter at the IVOA Bologna**
  - Dedicated talk at the en of the DM session
    https://wiki.ivoa.net/twiki/bin/view/IVOA/IntropMay3023DM
  - Fruitful splinter IVOA meeting
    Larger community

- Creation of a **HE "Club"**
  - IVOA mailing list and wiki page
    - https://wiki.ivoa.net/twiki/bin/view/IVOA/HEGroup
  - Several online meetings
    - IVOA data models (cube, dataset)
    - Details of HE data, with a focus on Instrument Response Functions

June 2023: Second workshop enlarged to IVOA

- **OV-France workshop in Paris**
  - *IVOA standards for High Energy Astrophysics*
  - https://indico.obspm.fr/event/1963

- Review of previous documents since 2021
- Focus on **user scenarios** in HE
  - Access and Analysis of HE data
  - Used IVOA standards
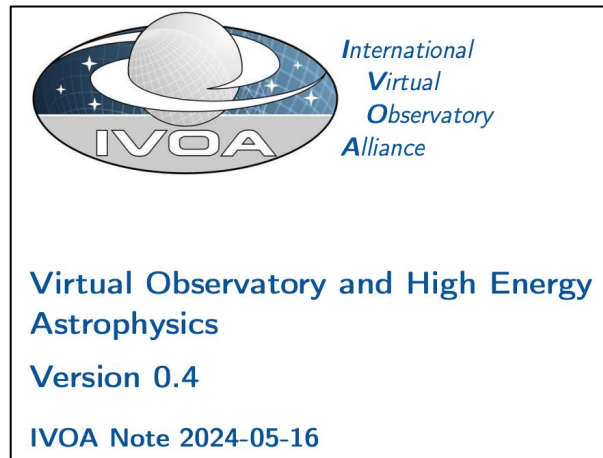 - What specific developments are needed

- Prepare an IVOA Note to justify a HE Interest Group
  - https://wiki.ivoa.net/internal/IVOA/HEGroup/2024-05-16_VOHE-Note-draft.pdf

Content of the Note

- High Energy observatories and experiments
- Common practices in the High Energy community
  - Event-counting, Data levels, Background signal, Time intervals, Instrument Response Functions, Granularity of data products,
  - Event selection, Assumptions and probabilistic approach,
  - Data formats, Tools…
- Use cases
  - UC1: re-analyse event-list data for a source in a catalog
  - UC2: observation preparation
  - UC3: transient or variable sources
  - UC4: Multi-wavelength and multi-messenger science
- IVOA standards of interest for HE
- Topics for discussions in an Interest Group

International Virtual Observatory Alliance

Virtual Observatory and High Energy Astrophysics

Version 0.4

IVOA Note 2024–05–16

Content of the Note

- Common practices and concept of event-list
  - **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
  - **Instrument Response Functions** (**IRFs**) are tightly connected
  - As well as Housekeeping or service data
- Data Discovery
  - **ObsCore** for a HE event list? Possible extension for HE
  - **Datalink** to interconnect event-list, IRFs and all relevant data for interpretation
- An event-list context data model
  - **Relations** to IRF, Instrument Configuration, other…
- Modelling the content of an event-list
  - Cube and Dataset Data Model

HE "event" in the VO

⚠️ a HE event is **not** a VOEvent

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.

**http://www.ivoa.net/rdf/product-type** (Preliminary)

event-list: A collection of observed events, such as incoming high-energy particles. A row in an event list is typically characterised by a spatial position, a time and an energy.

Event-list Context Data Model

- Issue
  - What is really in the event-list dataset?
  - Does it include IRFs? only an event-list?
  - Where can one find the corresponding IRFs?
- Need a way to link an event-list to its IRFs
  - proposition of an "event-bundle"

→ A proper **data model** with relations between those elements would help

→ Possible **ObsCore extension** fields would appear in this data model
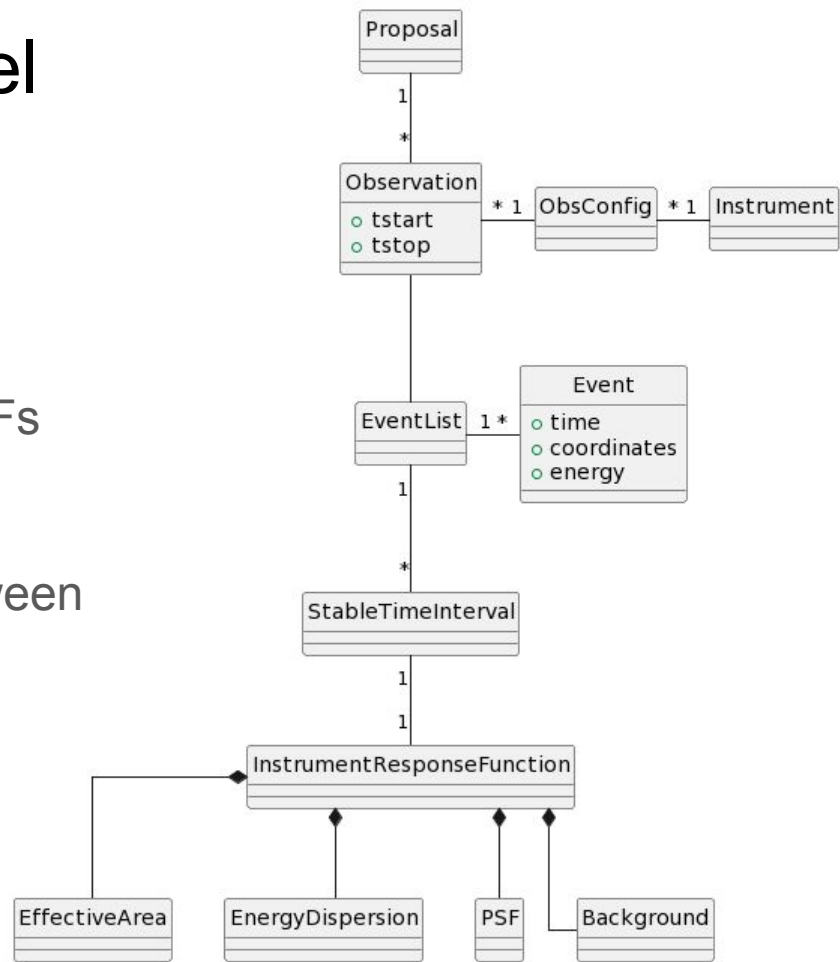
Summary and conclusions

- **HE data available** through the VO

- HE domain have **specificities**
    - In particular the concept of **event-list**
    - and **Instrument Response Functions** (IRFs)

- Very limited number of VO services giving access to event-lists

- On the path to build an **HE Interest Group** at IVOA