MMODA

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Funded by the European Union

MMODA is part of a project that has received funding from the European Union's Horizon Europe Research and innovation programme under Grant Agreement No 101131928.

The team

Former

Andrea Tramacere (UniGe)

Mohamed Meharga (UniGe)

Andrei Variu (EPFL)

François Morier-Genoud (EPFL)

Oleg Kalashev (EPFL)

...

Present

Andrii Neronov (UPCité & EPFL)

Volodymyr Savchenko (EPFL)

Carlo Ferrigno (UniGe)

Gabriele Barni (UniGe)

Denys Savchenko (UPCité)

Bohdan Hnatyk (KNU)

Lidiia Zadorozhna (KNU)

Oleksandr Gugnin (KNU)

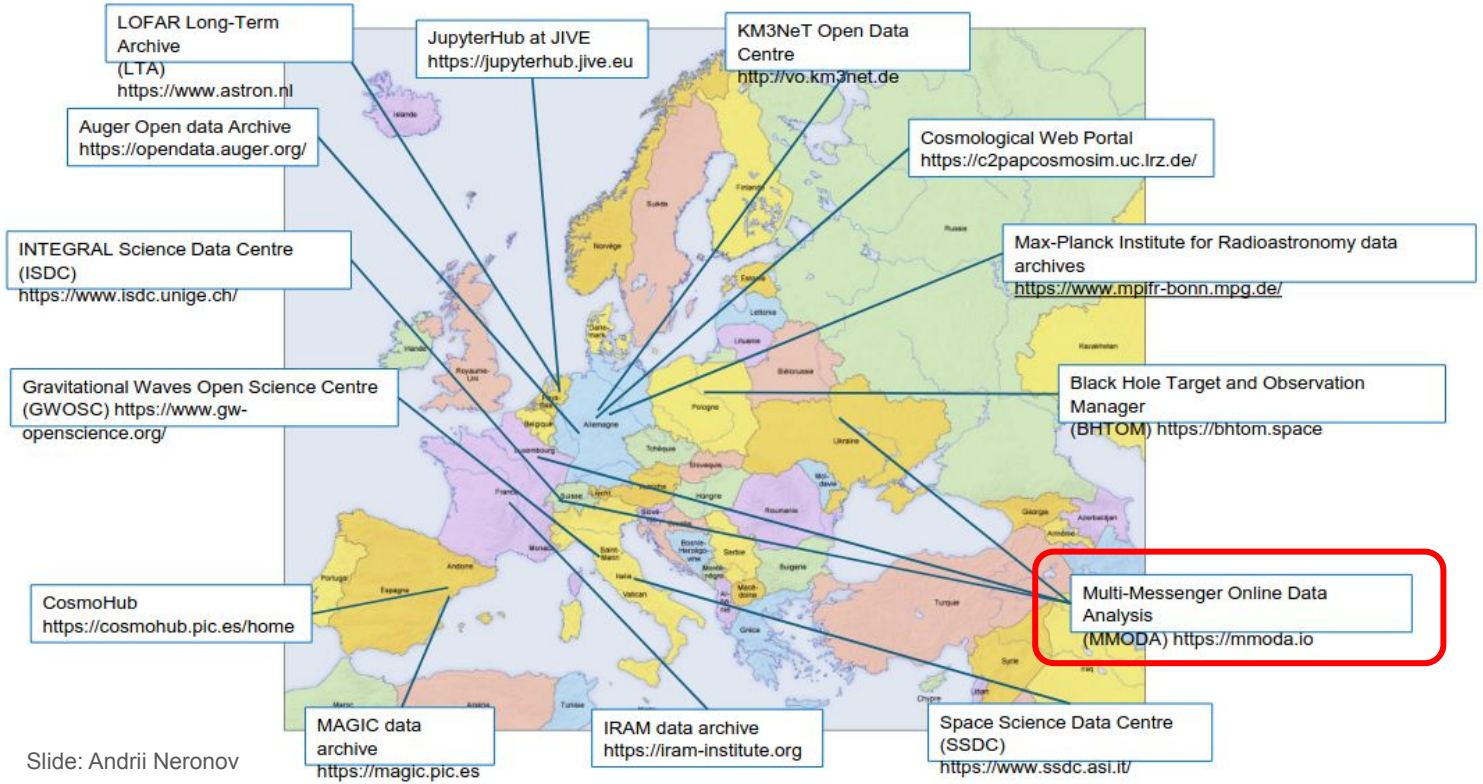
...

WP4 – Provision of improved access to near-real time and archival multimessenger data

Funded by the European Union

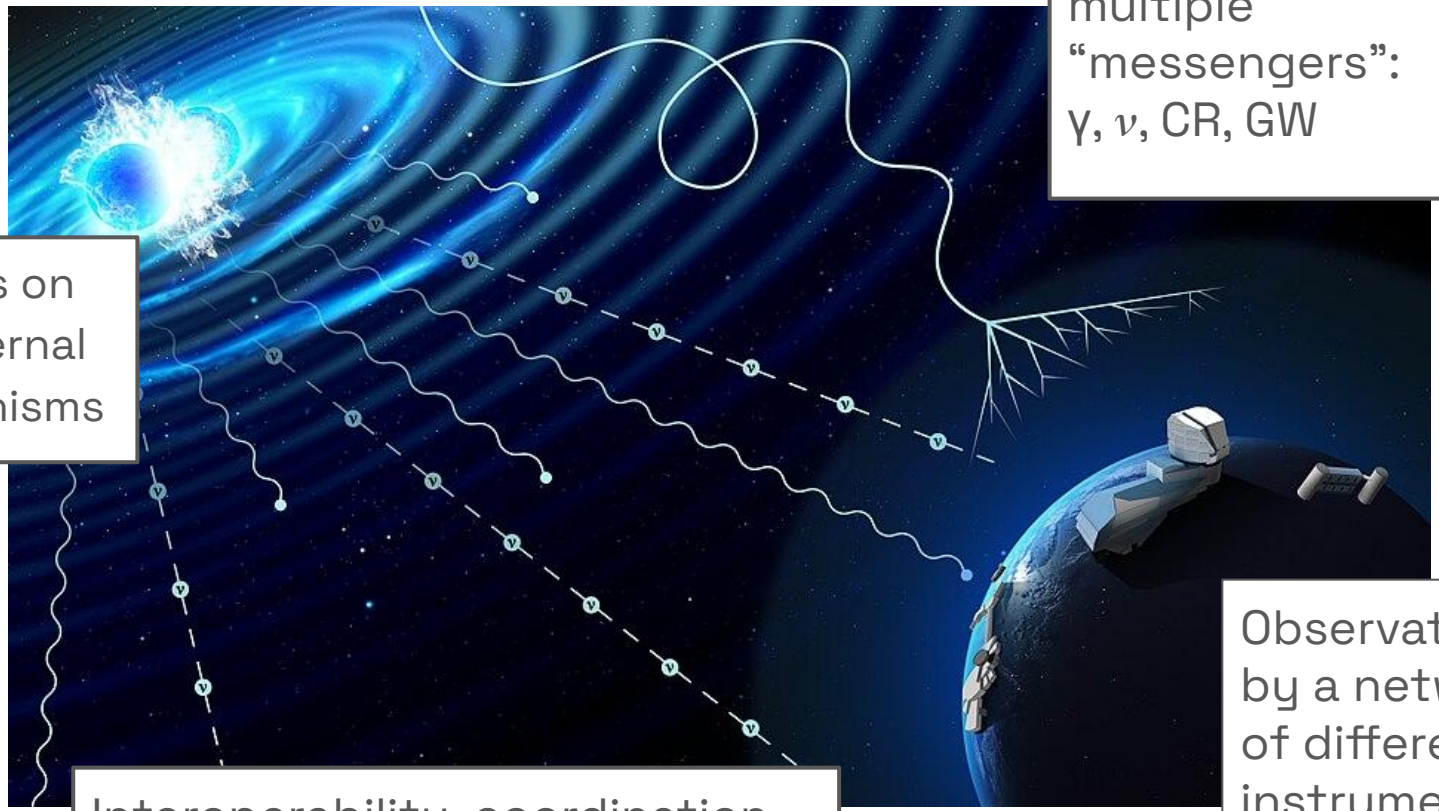
WP Leaders:
Łukasz Wyrzykowski
Andrii Neronov

Infrastructures involved



Slide: Andrii Neronov

Multi-Messenger Astronomy



multiple “messengers”: γ, ν, CR, GW

Insights on the internal mechanisms

Observation by a network of different instruments

Interoperability, coordination, and harmonized access

Image credit: Rubin Observatory/NOIRLab/NSF/AURA/P. Marenfeld

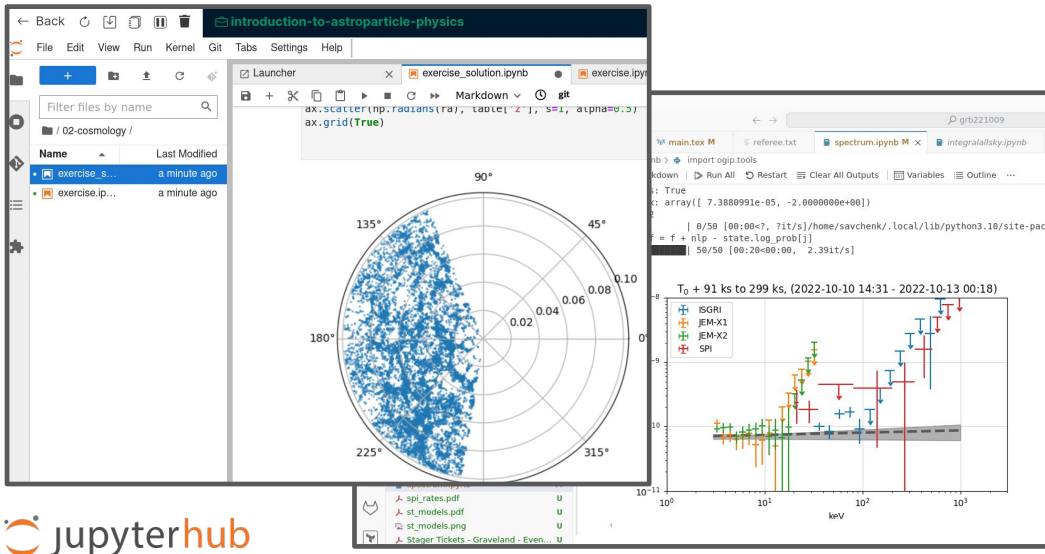
Interactive data exploration & development environments

Jupyter notebooks usage is a de-facto standard in the astronomical data analysis. Scientists can easily produce notebook, incorporating scientific logic, but not always a structured code.

JupyterHub(s), Google-collab, ESA DataLabs, Renkulab (Rok's talk)

- Interactive sessions
- Environment preinstalled
- Continuous integration and testing
- Support in publishing of data and code (e.g. in zenodo)

Annotated notebook can be viewed as a **function**, producing deterministic result given input parameters.



jupyterhub

VRE at CERN

renku

colab

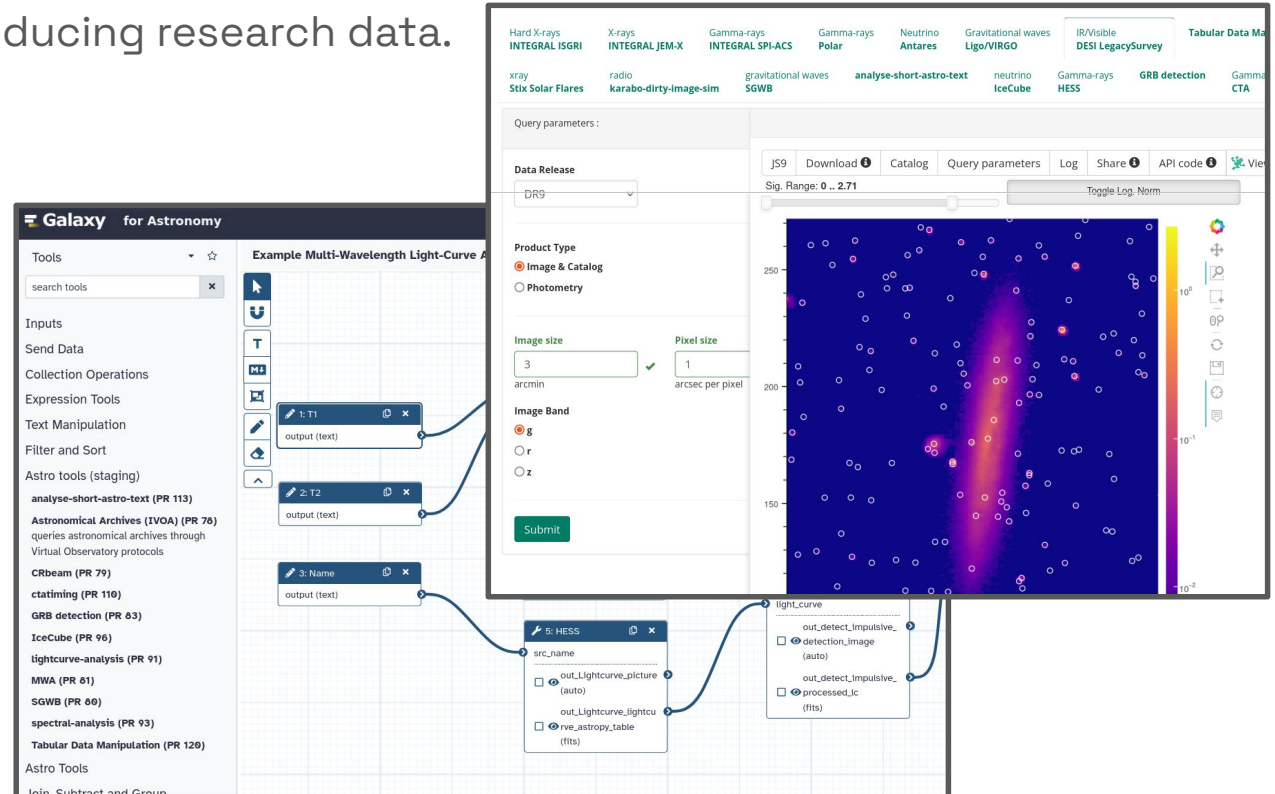
OPEN OnDemand

This process creates a collection of notebooks and other workflows, but they are only really accessible interactively one-by-one

Data analysis services: tools and workflows

Development environment allows writing code, e.g. in python.
But this is never enough, need existing assets: **data and data transformation tools** in a form of "**service**" producing research data.

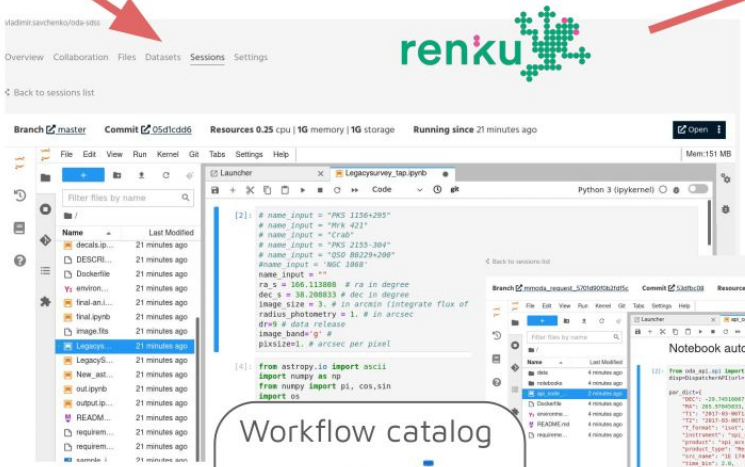
Typically, are containers annotated as **functions** with **input** and **output**. They be realised live a **web service endpoint** (e.g. swagger), a **tool in a workflow language** (e.g. CWL) or a **function** general purpose language, and can be converted between these forms.

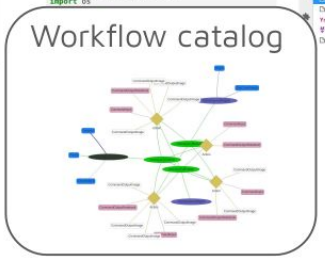


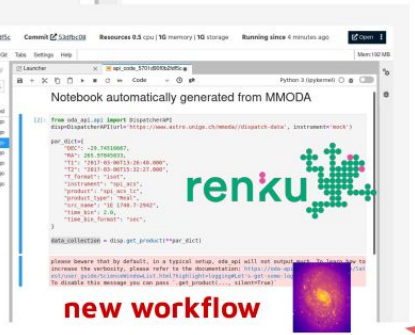
Feedback loop to crowdsource a tool catalogue

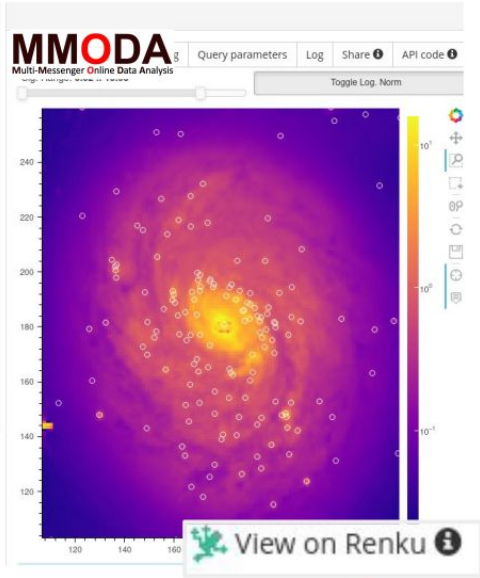
Scientist develops data reduction with deep scientific expertise

Publishing renku workflow as discoverable and executable asset





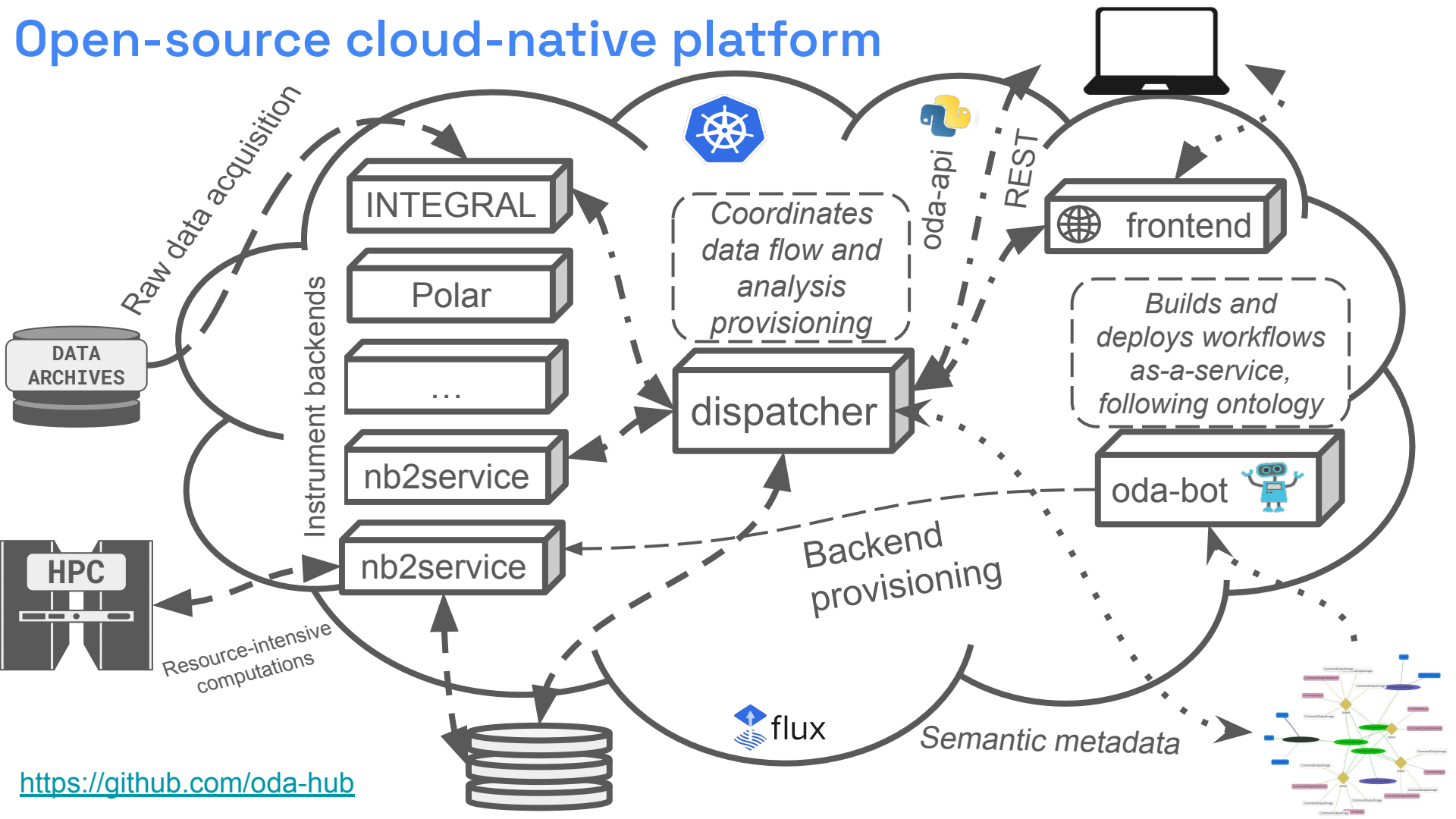




Automated workflow testing, benchmarking, reaction to space events, etc

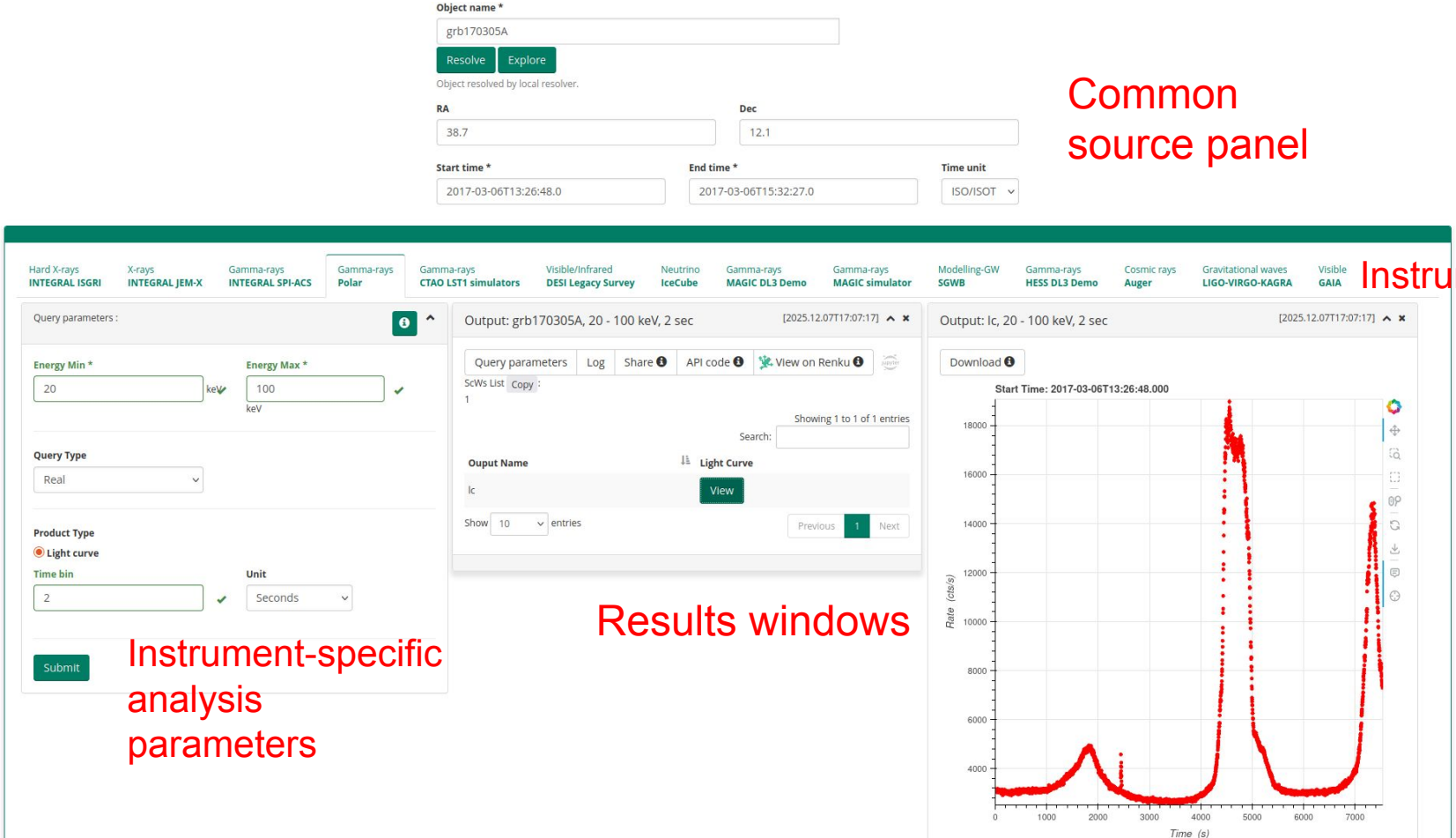
Scientist creates new workflow leveraging the existing one

Open-source cloud-native platform



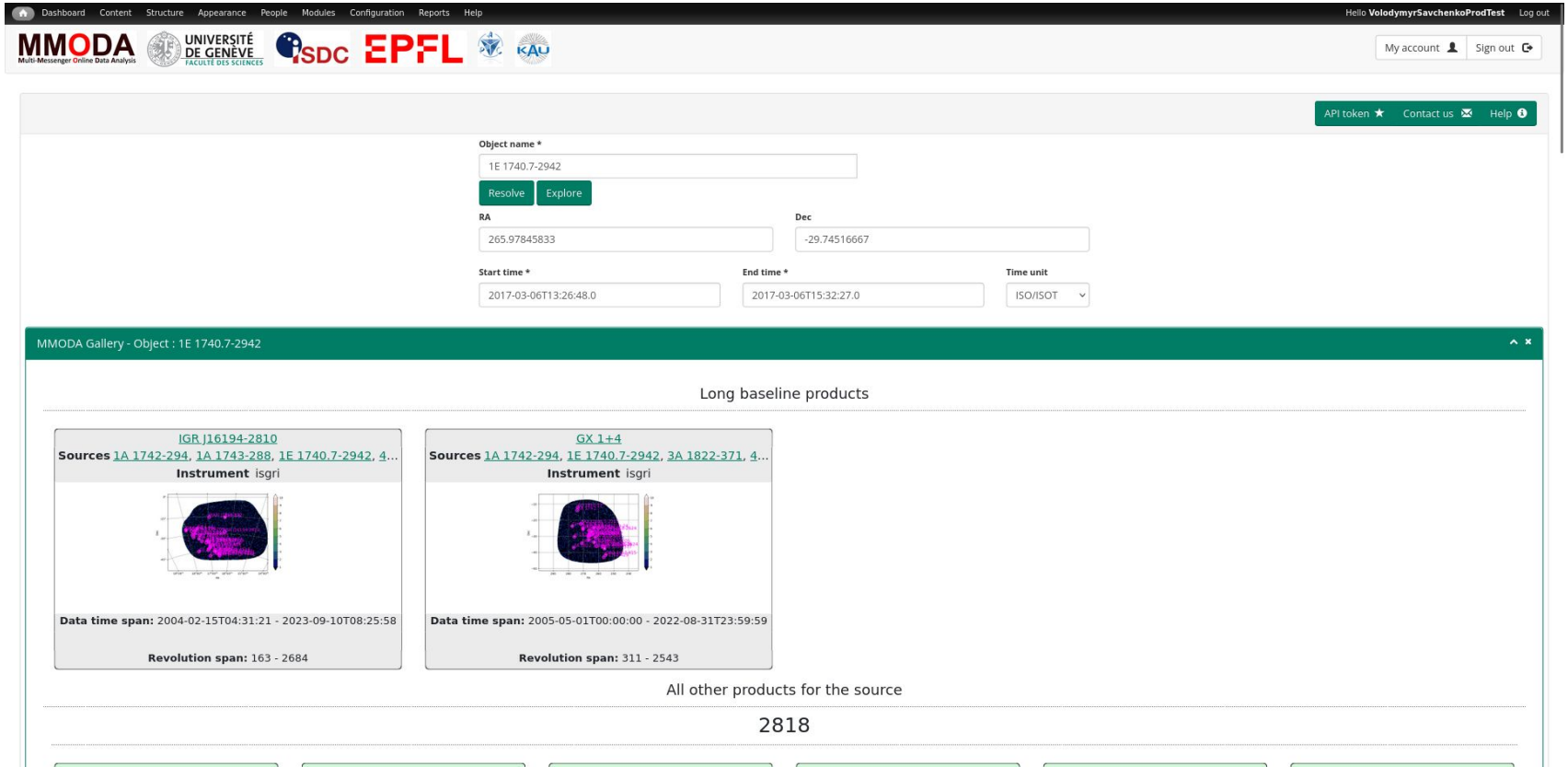
https://github.com/oda-hub

Web UI


Object name *
grb170305A
Resolve
Explore
Object resolved by local resolver.
RA
38.7
Dec
12.1
Start time *
2017-03-06T13:26:48.0
End time *
2017-03-06T15:32:27.0
Time unit
ISO/ISOT
Common source panel
Hard X-rays INTEGRAL ISGRI
X-rays INTEGRAL JEM-X
Gamma-rays INTEGRAL SPI-ACS
Gamma-rays Polar
Gamma-rays CTAO LST1 simulators
Visible/Infrared DESI Legacy Survey
Neutrino IceCube
Gamma-rays MAGIC DL3 Demo
Gamma-rays MAGIC simulator
Modelling-GW SGWB
Gamma-rays HESS DL3 Demo
Cosmic rays Auger
Gravitational waves LIGO-VIRGO-KAGRA
Visible GAIA
Instrument tabs
Query parameters :
Energy Min *
20
keV
Energy Max *
100
keV
Query Type
Real
Product Type
Light curve
Time bin
2
Unit
Seconds
Submit
Instrument-specific analysis parameters
Output: grb170305A, 20 - 100 keV, 2 sec
[2025.12.07T17:07:17]
Query parameters
Log
Share
API code
View on Renku
ScWs List
Copy
1
Showing 1 to 1 of 1 entries
Search:
Ouput Name
Light Curve
lc
View
Show 10 entries
Previous 1 Next
Results windows
Output: lc, 20 - 100 keV, 2 sec
[2025.12.07T17:07:17]
Download
Start Time: 2017-03-06T13:26:48.000
Rate (cts/s)
Time (s)

Gallery: reproducible data products

MMODA Gallery keeps track of user-selected computations done by MMODA services. These data products can be referenced as-is or recomputed with some changes, reproducing the results in new conditions.

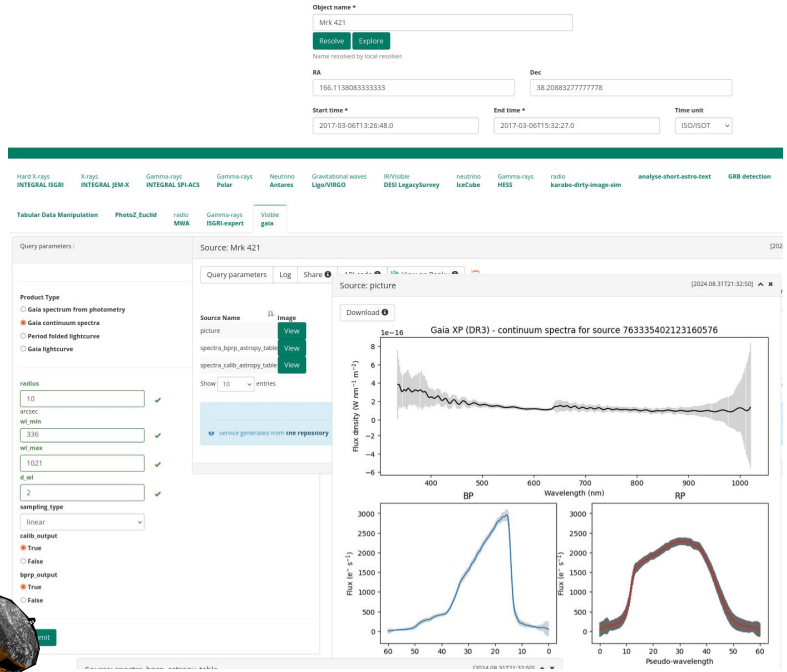


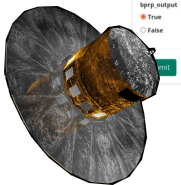
Wavelengths and messengers in MMODA

Optical/Infrared

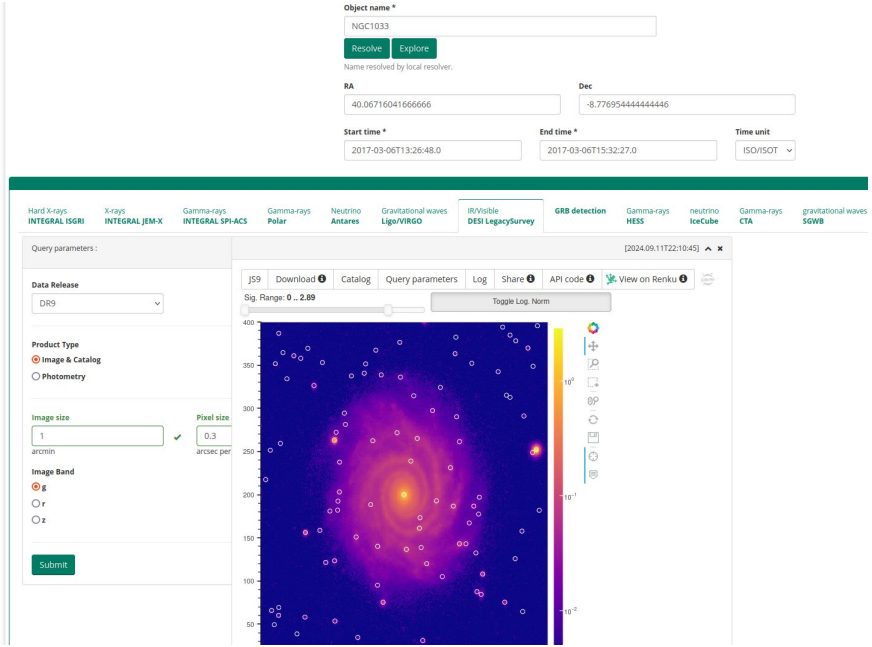
Gaia

Milestone astrometric mission, we include tools for accessing its data





DESI Legacy Survey



Gravitational waves: LIGO-Virgo-Kagra

Daniel's demo on Thursday

Query parameters :

Output: skymap [2025.10.22T23:38:07]

Download

Product Type

- Parameters estimation
- Skymap search
- Catalogs event selection

RA std (deg)
1
deg

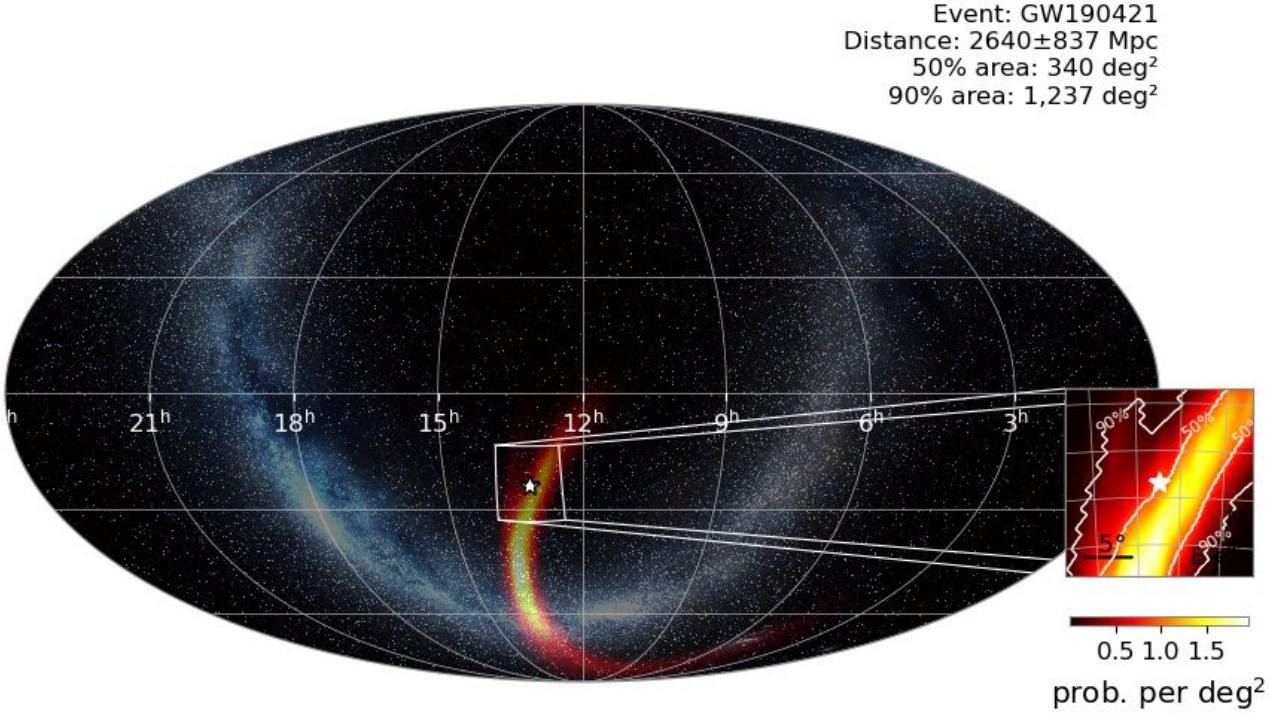
DEC std (deg)
1
deg

Probability envelop [0-1]
0.8

Waveform approximant
Mixed

use_glade

use_grb



Neutrino: IceCube open data

Visible **gaia** | **GRB detection** | Gamma-rays **HESS** | Gamma-rays **IACT simulators** | neutrino **IceCube** | Infrared **WISE**

Query parameters :

Product Type

- ○ Image
- ○ Lightcurve
- ◉ Spectrum

- ☐ IC40
- ☐ IC59
- ☐ IC79
- ☑ IC86_I
- ☑ IC86_II_VII

Slope

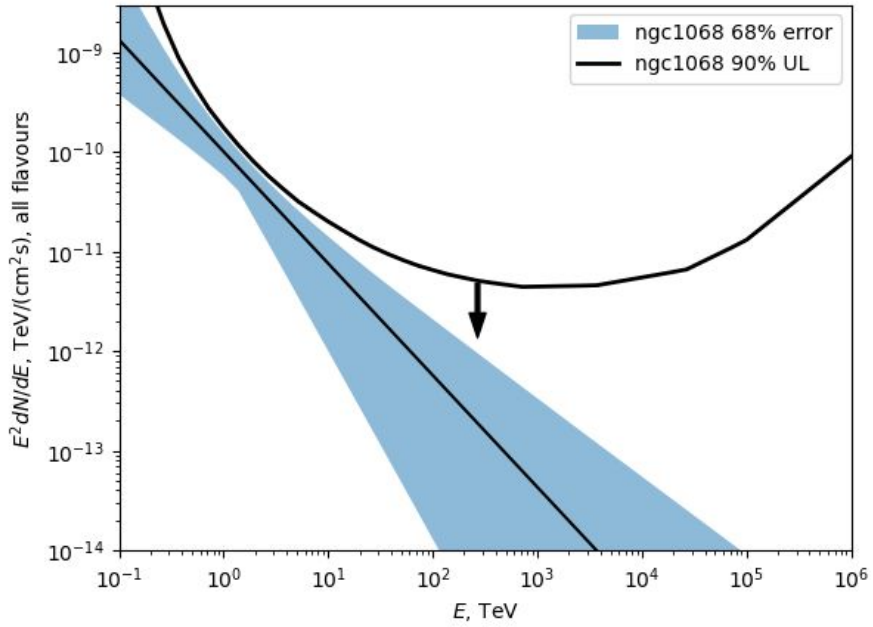
3

Spectrum_type

Free_slope

Output: png [2025.10.22T23:53:41]

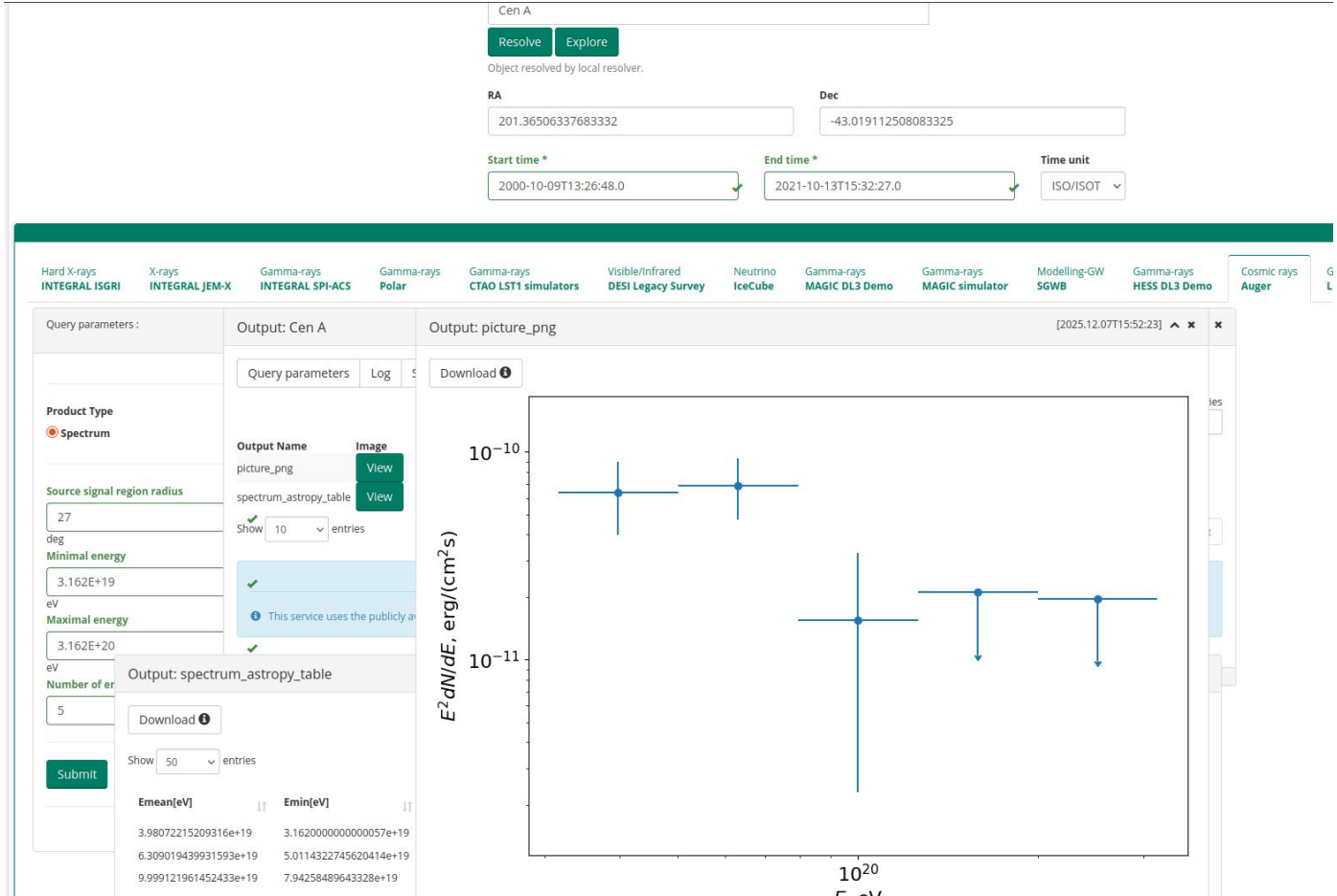
Download



10 years open data release
(13 years to come)

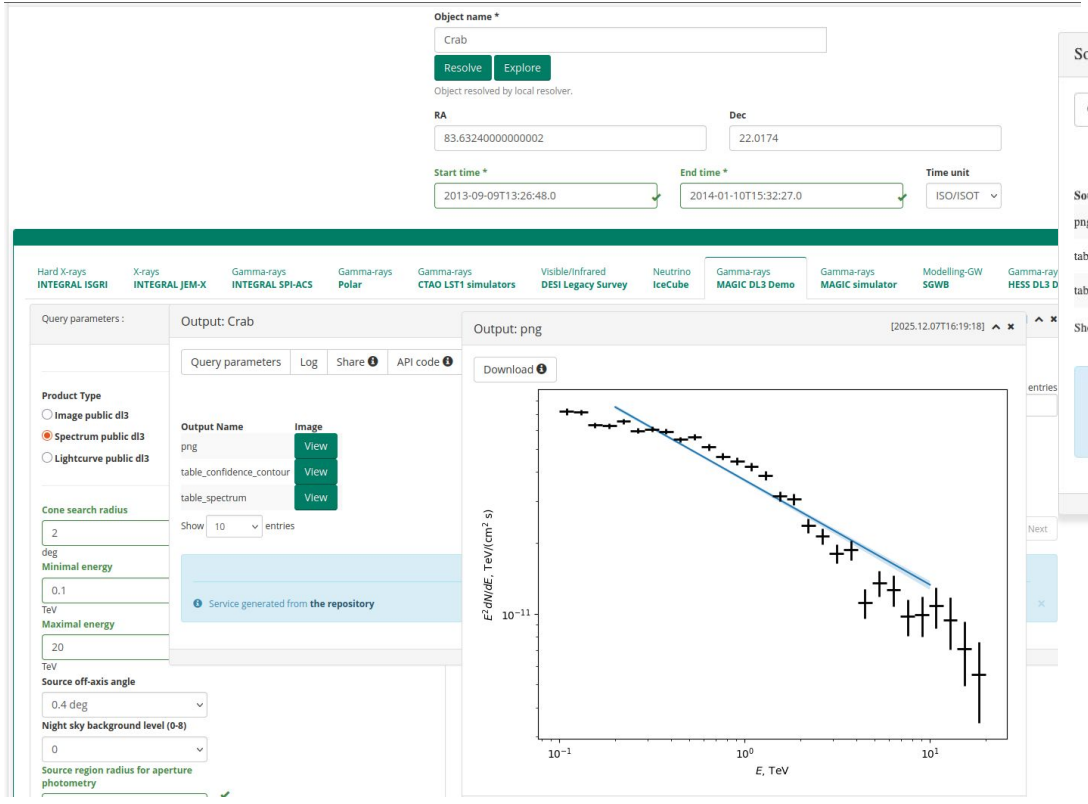
Based on SkyLLH

Cosmic rays: Auger

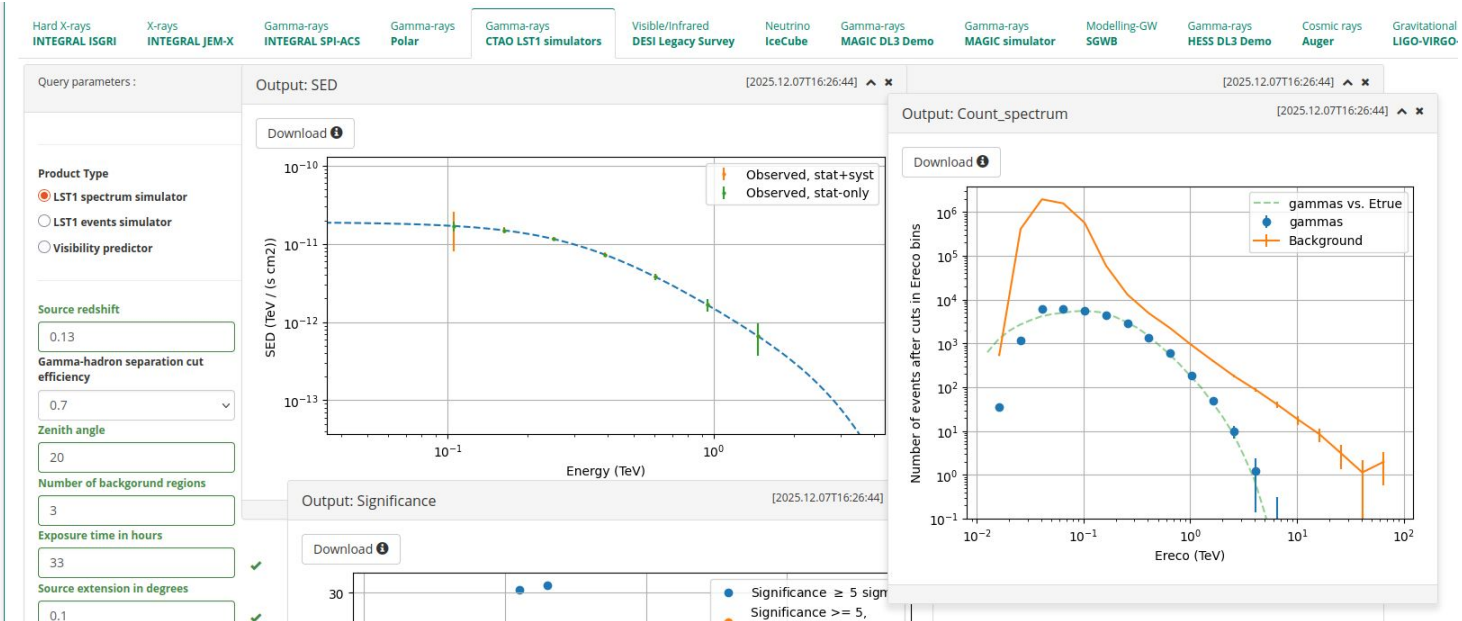


IACTs: MAGIC, H.E.S.S.

Demo services based on DL3 data releases



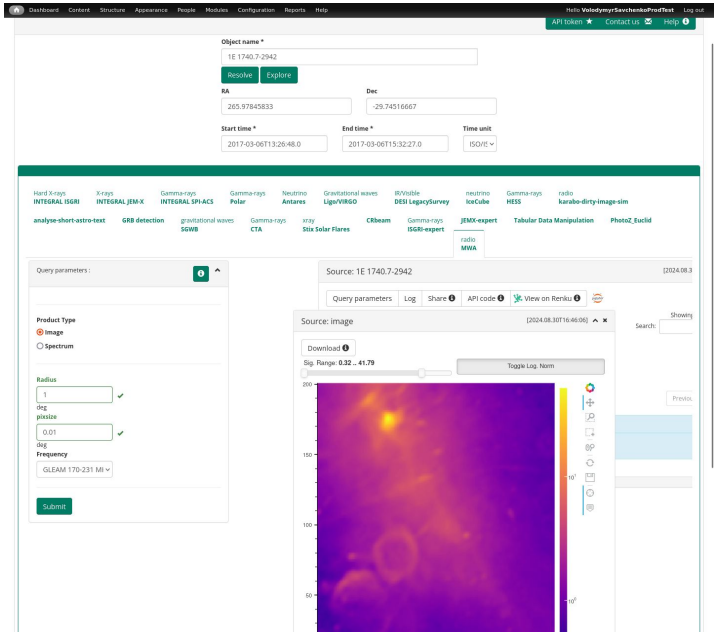
IACTs observation simulators: MAGIC, LST1



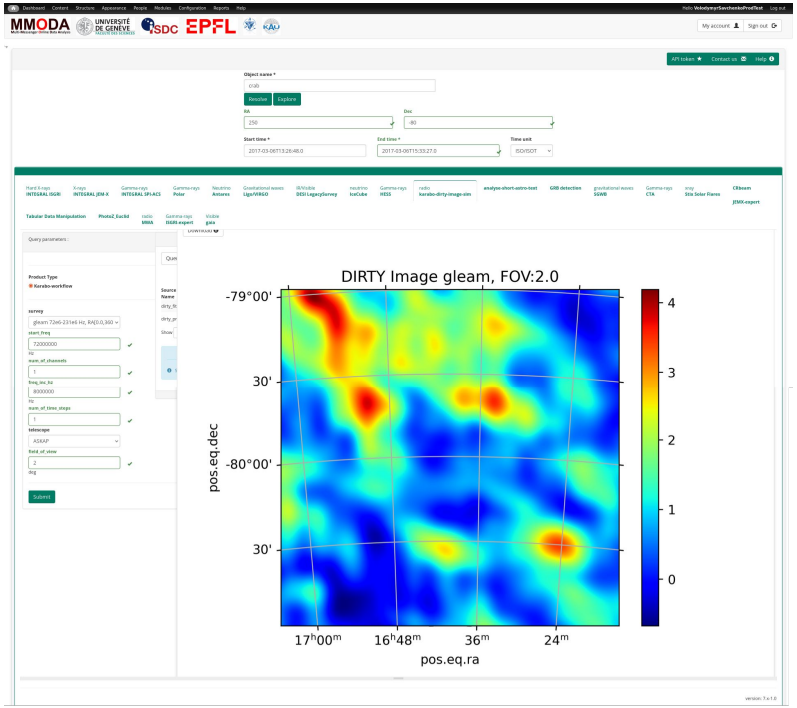
We provide services to simulate IACT observations of MAGIC and CTAO LST1 to facilitate proposal preparation

AstroORDAS Radio

MWA GLEAM: an interface to **SkyView** incorporating it in **AstroORDAS/MMODA** and **Galaxy**



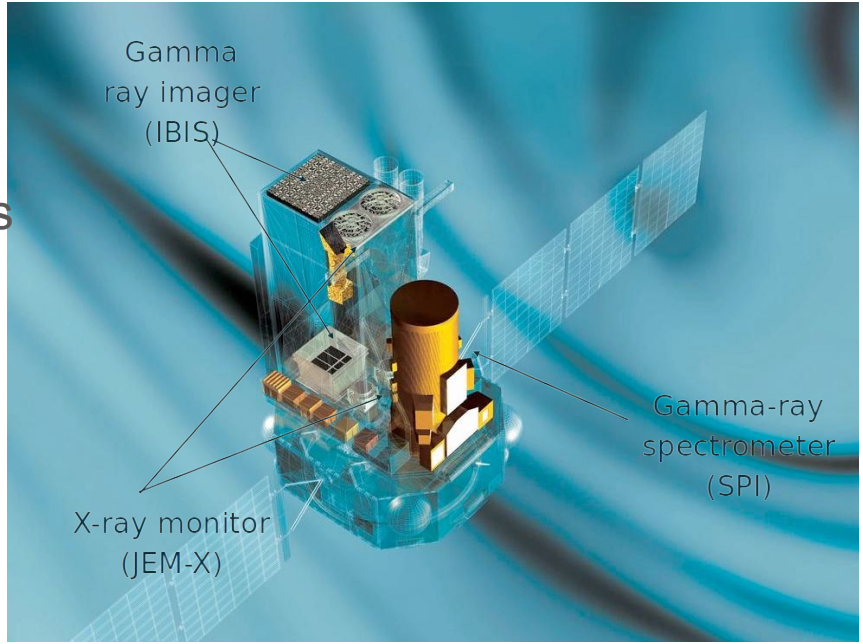
Karabo Simulation, dirty image.



INTEGRAL

INTErnational Gamma-Ray Astrophysics Laboratory: INTEGRAL

5 meters high
More than 4 tons in weight.
Launched on October 17, 2002
Optimal orbit for long observations
Operations ended in Feb 2025



Unique coverage from 3 keV to 30 MeV

INTEGRAL Science Data Centre for MMODA

At University of Geneva, we host the INTEGRAL Science Data Centre (ISDC), which:

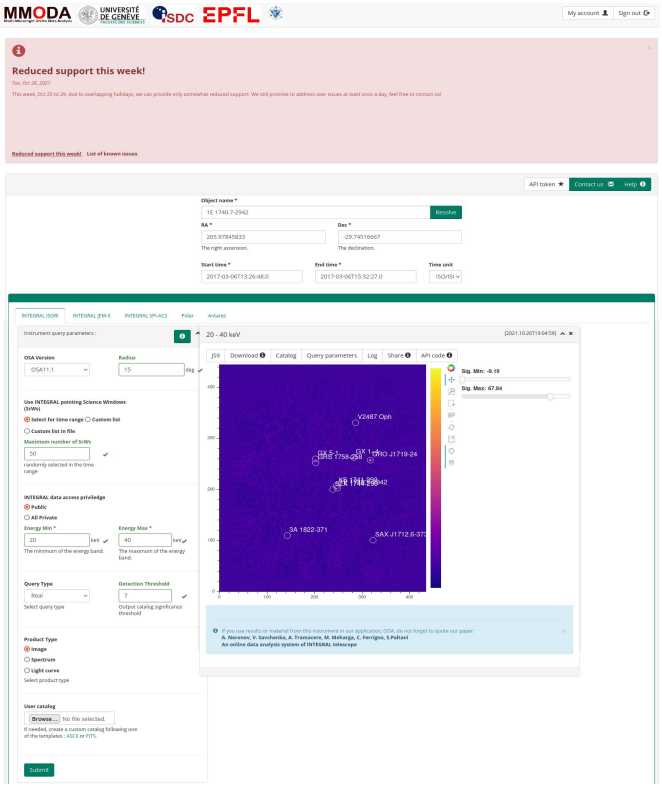
- maintains the operations mission archive (25 Tb)
- integrates and provides the mission software to the community (OSA)
- provides online services in collaboration with the ACME, Astro-ORDAS, CDCI open-research-data projects
- Makes a gallery of ready to-use products for immediate availability
- Provides these products for the ESA legacy INTEGRAL archive

We published a paper on A&A: Online data analysis system of the INTEGRAL telescope by A. Neronov et al. :
https://www.aanda.org/articles/aa/abs/2021/07/aa37850-20/aa37850-20.html

We exploit in-kind contribution of the Department of astronomy to elaborate data in the local HPC cluster.

We deployed the back-end at ESA premises as a prototype.

INTEGRAL in MMODA



get the product

now we skip the dry_run to actually get the products

```
In [30]: data=disp.get_product(instrument='isgri',
                               product='isgri_image',
                               T1='2003-03-15T23:27:40.0',
                               T2='2003-03-16T00:03:15.0',
                               E1_keV=20.0,
                               E2_keV=40.0,
                               osa_version='OSA10.2',
                               RA=255.986542,
                               DEC=-37.844167,
                               detection_threshold=5.0,
                               radius=15.,
                               product_type='Real')

waiting for remote response, please wait run_analysis http://cdcicn01.isdc.unige.ch:32003/dispatch-data


query done succesfully!
```

We can extract data making a full analysis either from the web interface or a python interface.

It provides high-level science products for:

IBIS/ISGRI +JEM-X + SPI-ACS (Gamma-ray burst)

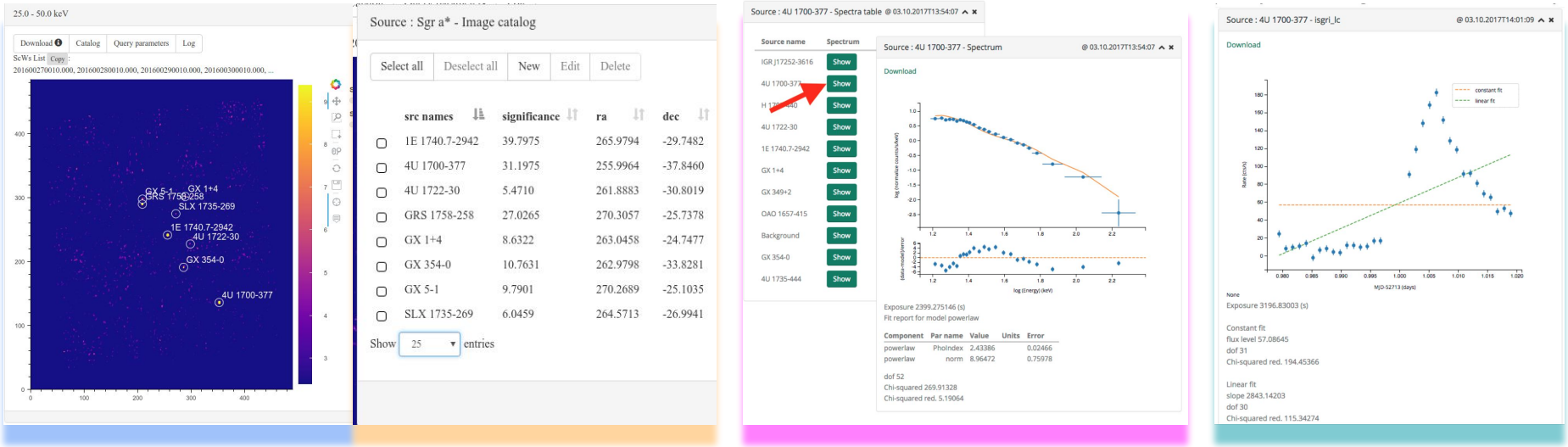
Workflows for specialized analysis are also provided using the AstroORDAS extension as web services.

INTEGRAL products with asynchronous calls

We compute images to make a catalog of sources in a given time frame for a given sky direction

For sources in the catalog, we compute spectra and/or light curves

For registered users, we alert with emails and may provide additional resources



Sustainability and optimization

The system is built with internal cache to save intermediate products.

The second time you make the same query, results are almost instantaneous.

It optimizes resources for frequent calls with different cache levels.

Backend can be deployed near the archive, because it is based on a scalable virtual cluster, which runs the many individual data portion in parallel.

We have a public github project open to contributions

https://github.com/oda-hub/

Demo time

https://github.com/oda-hub/tutorials/