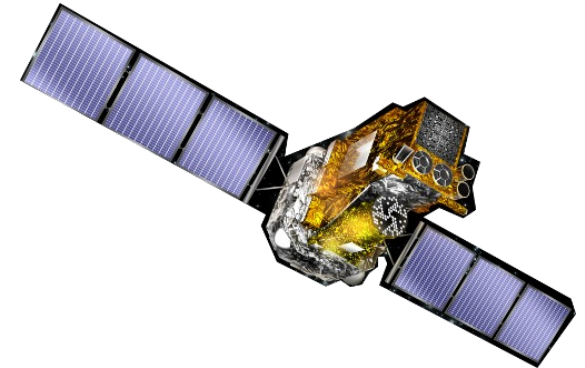


MultiMessenger Online Data Analysis



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<https://www.astro.unige.ch/mmoda>

<https://www.astro.unige.ch/mmoda/gallery>

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The need of reliable high-level products

- The success of a mission as INTEGRAL relies (among other assets) on the availability of easily accessible products for both Near Real Time and archive data.
- In the mission maturity, it is becoming rarer to be able to perform dedicated INTEGRAL analysis.
- The emerging paradigm for data centers is bringing the analysis to the data (NASA Hera, Science Case, ESA DataLabs, etc.)
- We have developed MMODA for this purpose exploiting various funding lines (including Open research Data)

<https://www.astro.unige.ch/mmoda>



Data analysis of telescopes and astronomical messenger detectors can now be done on remotely via dedicated services accessible via

- **Interactive: From a browser web interface**
- **Coded: Python API (e.g. Jupyter notebooks)**

The screenshot shows the MMODA web interface. At the top, there are logos for MMODA, UNIVERSITÉ DE GENÈVE, ISDC, EPFL, and KAU. A navigation bar includes 'Sign in with GitHub', 'Sign In', and 'Sign up'. Below this, there are input fields for 'Object name *' (1E 1740.7-2942), 'RA *' (265.97845833), 'Dec *' (-29.74516667), 'Start time *' (2017-03-06T13:26:48.0), and 'End time *' (2017-03-06T15:32:27.0). A 'Resolve' button is next to the object name field. Below the search fields, there are tabs for different instruments: 'Hard X-rays INTEGRAL ISGRI', 'X-rays INTEGRAL JEM-X', 'Gamma-rays INTEGRAL SPI-ACS', 'Gamma-rays Polar', 'Neutrino Antares', 'Gravitational waves Ligo/VIRGO', and 'IR/Visible DESI LegacySurvey'. Under 'Instrument query parameters', there are dropdowns for 'OSA Version' (OSA11.2) and 'Radius' (15 deg). There are also radio buttons for 'Use INTEGRAL pointing Science Windows (ScWs)' with options 'Select for time range' (selected) and 'Custom list', and a 'Maximum number of ScWs' field set to 50.

The screenshot shows a Jupyter notebook titled 'Generic Revolution Mosaics'. The code in the notebook is as follows:

```

In [ ]: parameters
1 rev_num = 0
2 #if <= 0 it will take the current revolution (zero) or previous ones, select NRT as data_version
3 E1_keV = "28.0"
4 E2_keV = "40.0"
5 J_E1_keV = "3.0"
6 J_E2_keV = "20.0"
7 osa_version = 'OSA11.2'
8 detection_threshold = 7
9 host_type = 'staging'
10 to_exclude_from_title = '' # 'Cen A'
11 #if this string is in the title of the observation, this is excluded from the analysis. Leave '' to not use it.
12 use_isgri = True
13 use_jemx1 = True
14 use_jemx2 = True
15 include_new_sources = False
16 data_version = 'CONS' #It can be CONS or NRT
17 token='' #to run it as web service, we pass a token

In [ ]:
1 import astropy.io.fits as fits
2 import numpy as np
3 from astroquery.simbad import Simbad
4 from astropy import units as u
5 from astropy.coordinates import SkyCoord
6 import copy
7 import re
8 import pandas as pd
9 import os, sys
10 from importlib import reload
11 import json
    
```

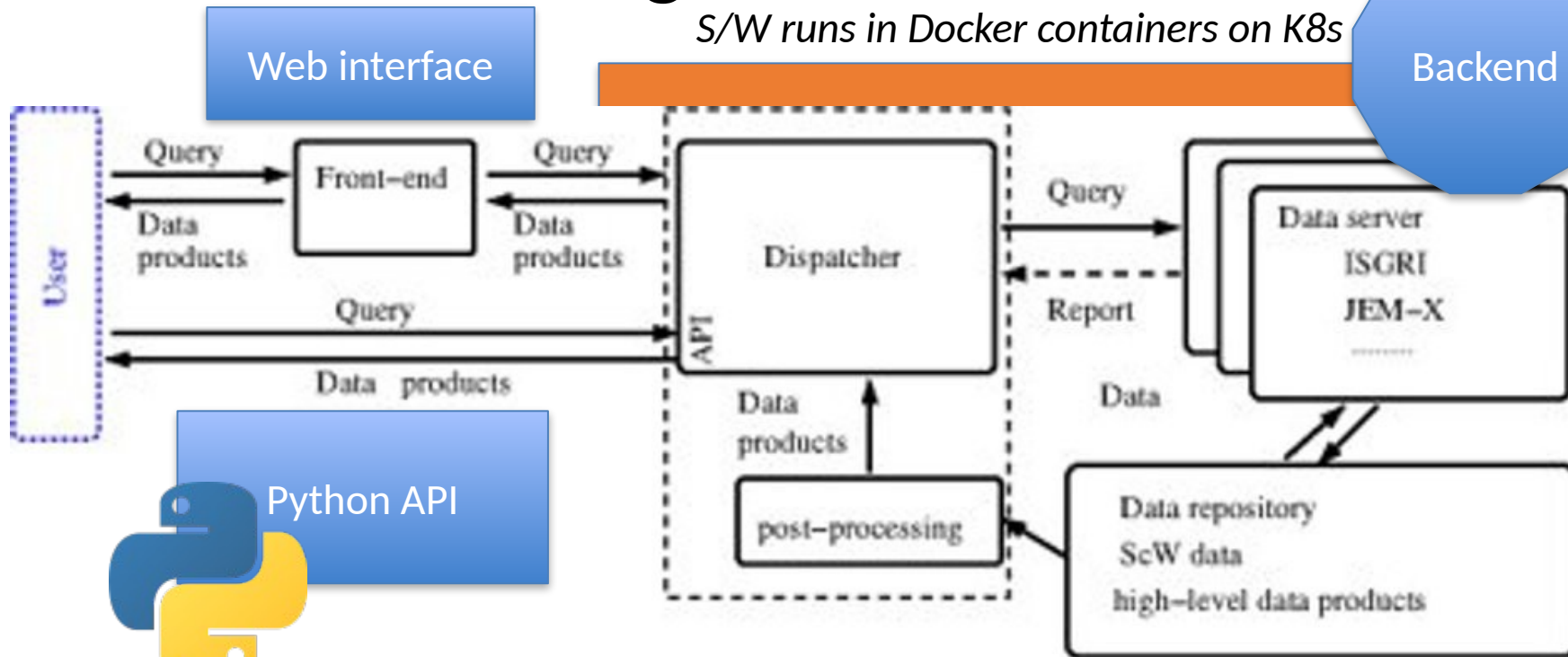
Accessing online services

- The web interface for MMODA is meant to be intuitive and easy to use, with emails notifications functionalities for submission and completion
- The python api can be used to build and perform more complex calls analysis
- A Third possibility is to make custom workflows based on an accessible development guide:
<https://odahub.io/docs/guide-development/>
-

The general architecture

S/W runs in Docker containers on K8s

Backend



- Coded in python
- Plugins for instruments
- Plugins for data products
- Asynchronous requests
- A daemon listens to requests from the dispatcher
- Deployed also on HPC cluster.

Kubernetes cluster

Open source and portable

- All the infratructure is publicly available
- It can be run on any Kubernetes cluster (something that is common use nowadays)
- Public on github -> **oda-hub**
<https://github.com/oda-hub>
- Available from ESA Datalabs !

The screenshot shows a list of GitHub repositories for ODA charts. Each entry includes the repository name, a 'Public' badge, a description, a language icon, star count, license, forks, issues, and update date.

Repository Name	Language	Stars	License	Forks	Issues	Updated
dqueue-chart	Mustache	0	GPL-2.0	0	0	Updated 2 days ago
dispatcher-chart	Shell	0		1	0	Updated on Aug 9
helm-charts		0		0	0	Updated on Aug 1
frontend-chart	Shell	0		8	1	Updated on May 25
oda-resolver-chart	Smarty	0		0	0	Updated on Apr 4
antares-chart	Mustache	0		0	0	Updated on Mar 22
integral-timesystem-chart	Smarty	0		0	0	Updated on Mar 22
dda-chart						

Flexible and extensible implementation of workflows

- Public Workflows are available for:
 - INTEGRAL IBIS/ISGRI (images, spectra, lightcurves)
 - INTEGRAL SPI-ACS (lightcurves)
 - INTEGRAL JEM-X (images, spectra, lightcurves)
 - Polar (light curves)
 - LIGO-Virgo (spectrograms, localizations)
 - Desi Legacy Survey (images, photometry)
 - GRB analysis
- We provide workflows in python for many other analysis (e.g. Euclid, Gaia, SKA prototype, CTA are in development)

The MMODA product gallery



On these pages, we expose a collection of high-level products from the **INTEGRAL IBIS/ISGRI**, and **JEM-X** instruments.

These are obtained through the [MMODA online platform](#) through [dedicated workflows](#) developed by the [INTEGRAL Science Data Centre](#) experts. Our products are *images* for observations, *light curves*, and *spectra* for individual sources. They can be conveniently searched per source name, per satellite revolution, per instrument, time span, and other criteria. [Recent Near Real Time](#) data are conveniently displayed per satellite revolutions.

We welcome your feedback and wishes for products that are not yet available, [contact us](#) through our [MMODA platform](#).

Notes:

- the the "source type" field is the classification provided by [Simbad](#)
- To reproduce the results using the [python API](#) to the MMODA service, please see [these instructions](#).

- An explorable collection of high-level products from the IBIS/ISGRI, and JEM-X instruments (for now)
- Hosted on a Drupal-powered website with full REST-API access for content creation, editing, and exploration.

Exploring the Gallery from MMODA

The screenshot shows the MMODA web interface. At the top, there are logos for MMODA, UNIVERSITÉ DE GENÈVE, ISDC, EPFL, and KAU. Below the logos, there is a search bar for 'Object name *' containing '1E 1740.7-2942'. To the right of the search bar are two buttons: 'Resolve' and 'Explore'. A large green arrow points from the 'Explore' button towards the right. Below the search bar, there are input fields for 'RA' (265.97845833) and 'Dec' (-29.74516667). Further down, there are input fields for 'Start time *' (2017-03-06T13:26:48.0) and 'End time *' (2017-03-06T15:32:27.0), along with a 'Time unit' dropdown set to 'ISO/SC'. Below this is a green header bar that reads 'MMODA Gallery - Object : 1E 1740.7-2942'. Underneath is a navigation bar with 'Manage', 'Shortcuts', 'gferrigno', and 'Admin Toolbar quick search'. Below the navigation bar is a toolbar with icons for 'Content', 'Structure', 'Appearance', 'Extend', 'Configuration', 'People', 'Reports', and 'Help'. Below the toolbar is a section titled 'Long baseline products' which contains two product cards. The first card is for 'IGR J16194-2810' and the second is for 'GX 1+4'. Each card shows a sky map, the instrument used ('isgri'), the data time span, and the revolution span.

By Clicking on “Explore” button, it is possible to have a snapshot of what is available in the gallery for a specific source.

Legacy products as a gallery

- Based on a study for legacy products triggered by ESA, we produce:
 - Standard products per each observation in each satellite revolution for Consolidated data: images for IBIS/ISGRI and JEM-X with source fluxes, spectra and light curves for each detected source.
 - Long-term light curve of each significantly bright source
 - Special products for sources: e.g. outburst light curve, spectra over longer campaigns will be provided (*we need your inputs !*)
 - Other ...

Near Real Time Data

- We expose the standard operations we do for quick look:
 - We process **daily** data to produce images and detect possible sources with their flux
 - We extract light curves and spectra for each detected source
 - This is done per observation within the satellite revolution
 - Conveniently highlighted in green

Data Products per INTEGRAL revolution

Revolution number

Instrument

Product type

Apply

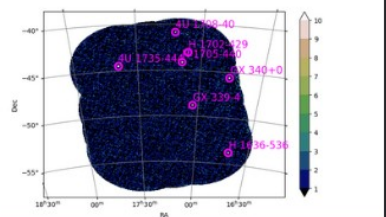
Reset

2836

Galactic Center Rev. 2836 (NRT)

Sources: [4U 1708-40](#), [4U 1735-444](#), [GX 3...](#)

Instrument: jemx1



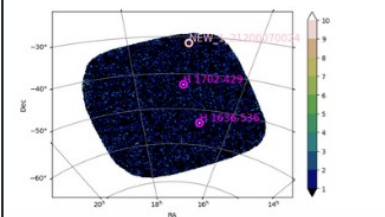
Data time span: 2024-10-19T04:36:15 - 2024-10-19T12:51:54

Proposal IDs: [2120007](#)

Galactic Center Rev. 2836 (NRT)

Source: [Galactic Center](#)

Instrument: isgri



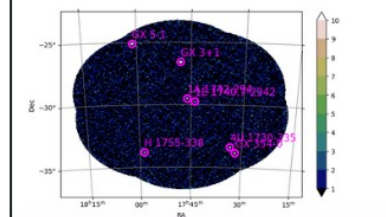
Data time span: 2024-10-19T04:36:15 - 2024-10-19T12:51:54

Proposal IDs: [2120007](#)

Gal. Bulge region Rev. 2836 (NRT)

Sources: [GX 3+1](#), [GX 5-1](#), [GX 354-0](#), [4U 17...](#)

Instrument: jemx1



Data time span: 2024-10-19T00:25:44 - 2024-10-19T03:38:44

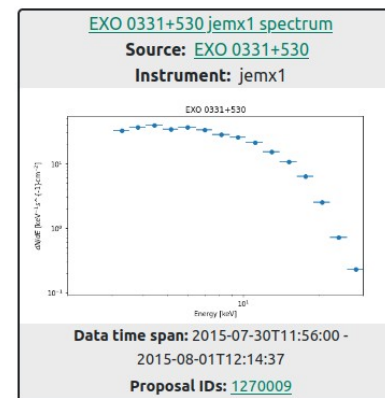
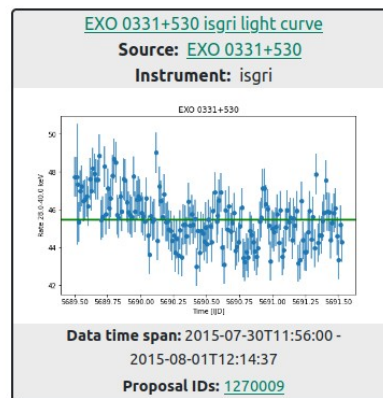
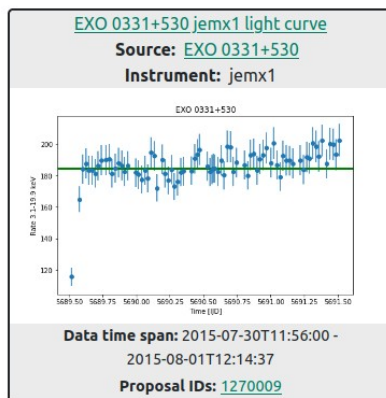
Proposal IDs: [2120001](#)

Products per revolution

- After data consolidation, we replace NRT with CONS products
- Products are easily searchable per satellite revolutions

Data Products per INTEGRAL revolution

1570



INTEGRAL Sources

- Every source that is detected by ISGRI or JEM-X during at least in single observations appears in the Gallery.
- Search can be done also on source class: e.g. all blazars
- We (will) produce long-term light curves for most of them for reference and spectra on certain targeted intervals using a single catalog to optimize resources.

MMODA Multi-Messenger Online Data Analysis | UNIVERSITÉ DE GENÈVE FACULTÉ DES SCIENCES | ISDC | EPFL

All sources | Products per revolution | All products | Contact

MMODA PRODUCT GALLERY

List of all sources

View Edit Grants Delete Revisions Clone Devel

Source name Source type

Search within the list of available sources also with alternative names

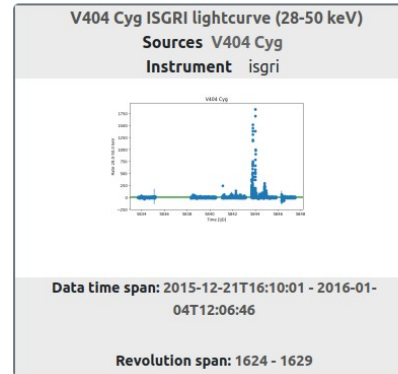
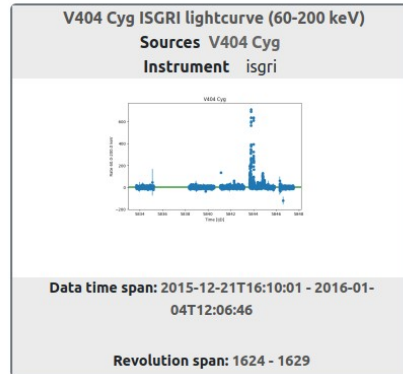
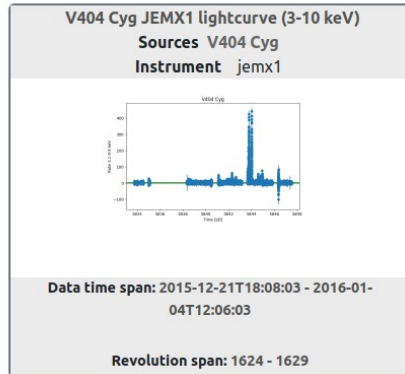
Source ^	RA	DEC	Source type	Online catalog
1A 0535+262	84.727400	26.315800	HighMassXBin	🔗
1A 1742-294	266.522000	-29.514800	LowMassXBin	🔗
1A 1743-288	266.761000	-28.883000	LowMassXBin	🔗
1E 1145.1-6141	176.869000	-61.953700	HighMassXBin	🔗

Distribution of relevant products

- V404 Cyg data products were distributed and led to tens of publications
- They are straightforwardly produced and shared (about 1 hour per product)

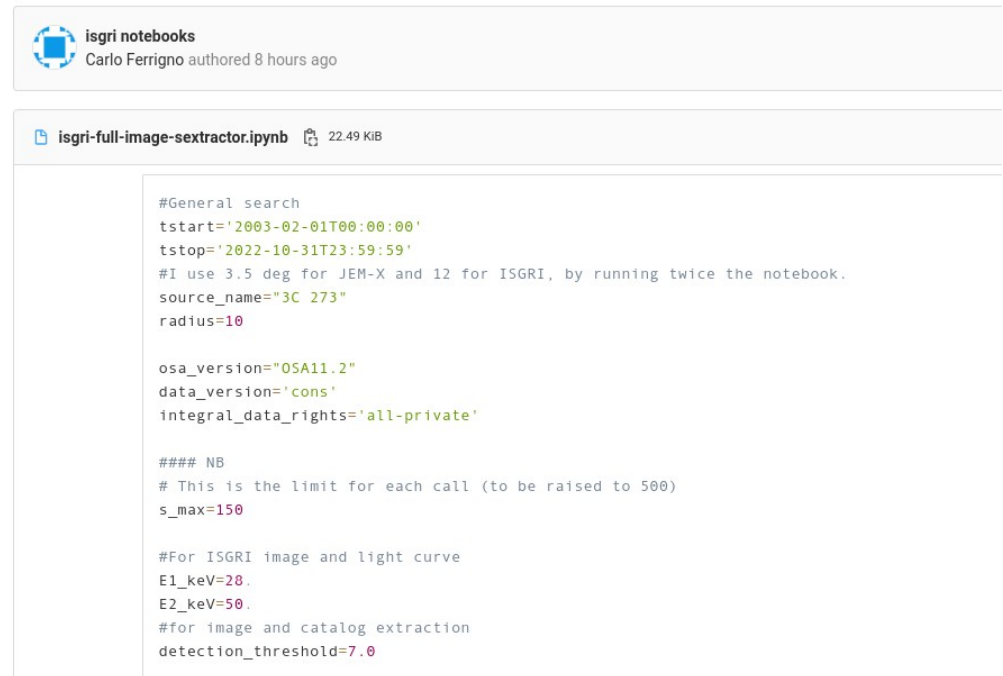
V404 Cyg

Highlights



Provenance

- The python notebooks used to create these products have been developed by us and are linked at the page of the product together with the input parameters.
- The analysis is fully reproducible -> FAIR and open data !



isgri notebooks
Carlo Ferrigno authored 8 hours ago

isgri-full-image-sextractor.ipynb 22.49 KiB

```
#General search
tstart='2003-02-01T00:00:00'
tstop='2022-10-31T23:59:59'
#I use 3.5 deg for JEM-X and 12 for ISGRI, by running twice the notebook.
source_name="3C 273"
radius=10

osa_version="OSA11.2"
data_version='cons'
integral_data_rights='all-private'

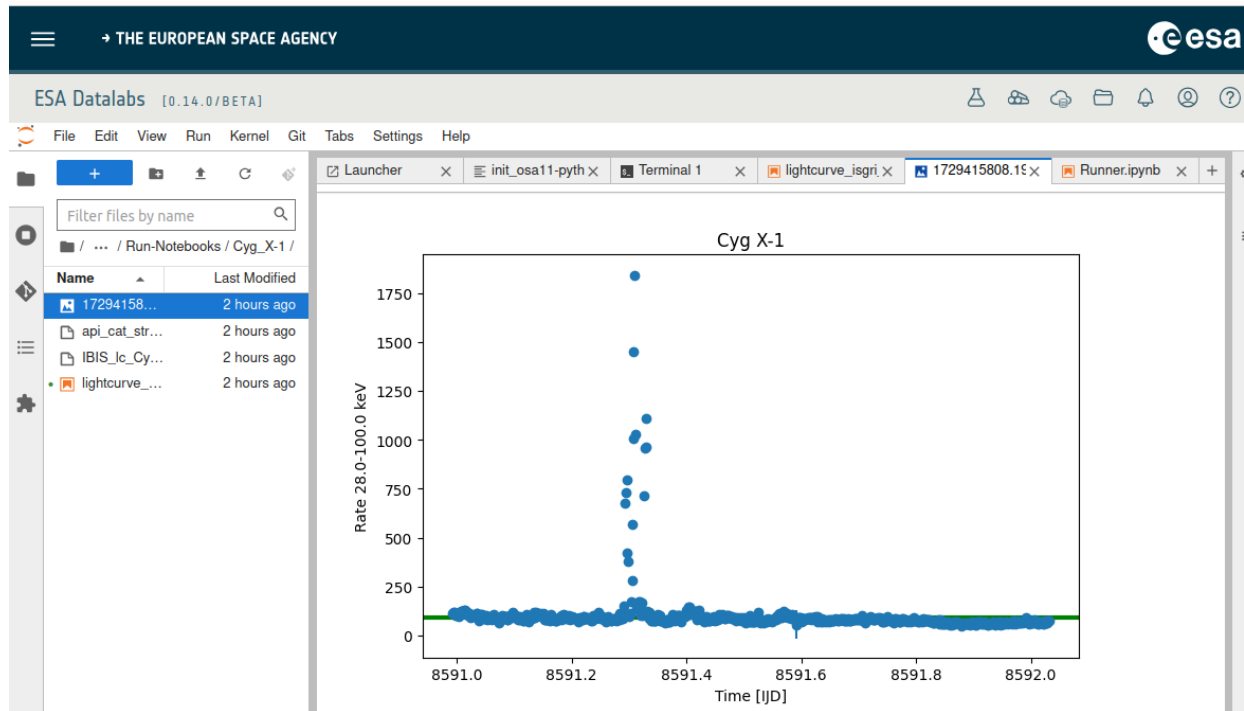
#### NB
# This is the limit for each call (to be raised to 500)
s_max=150

#For ISGRI image and light curve
E1_keV=28.
E2_keV=50.
#for image and catalog extraction
detection_threshold=7.0
```

- Needed an account with specific privileges in MMODA to upload the analysis in the gallery

Portable and extensible

- It is now possible to run product extraction also from ESA Datalabs for everybody (instructions to be shared)



Status and Future perspectives

- We have extracted images, spectra and light curve for each observation in each satellite revolution (waiting for ISGRI calibration after 2020)
- We will collect a catalog of noticeable sources to extract mission-long light curves, using available products and specific runs
- For some sources, we plan to extract "highlights"
- We provide workflows to easily process any custom data set both at UNIGE and at ESA

Conclusions

- We have both a the multi-messenger online analysis framework to reproduce data and a gallery to present easily and quickly accessible INTEGRAL products.
- Gallery products are used for Legacy Archive at ESA
- The backend (including dispatcher) is available on the ESA cluster internally from Datalabs
- Extending functionalities can be done with relative ease e.g. for GRBs