



Astronomical **Open Research Data** Analysis Services

Volodymyr Savchenko

Digital Innovators [Webinar](#)

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Overview

- Multi-Messenger and Time-domain **Astronomy**: challenges and successes
- **Ecosystems for supporting science lifecycle**: data, process/workflow/service, and knowledge **stewardship**
- **Development environment for crowd-sourcing scientific workflows**
- **Knowledge Graphs**, Linked Data, Ontologies: **why** do we need them and **how** to use them
- Integration with **Publications**
- **Synergies** with other related developments within astronomy and other domains
- **Future** plans, hopes, open questions

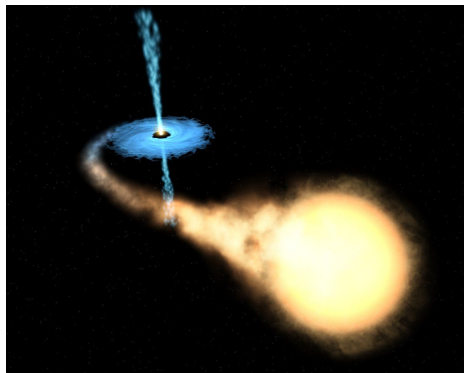
Multi-Messenger Time Domain Astronomy

Exploding field!

Last decade key **new observables** were discovered, and conventional telescopes dramatically upgraded to match.

Number of alerts and **volume of data** we deal with **increased by couple orders of magnitude in the last years**, and several nearly-ready telescopes promise another comparable increase

Star and black hole



"Just" a star



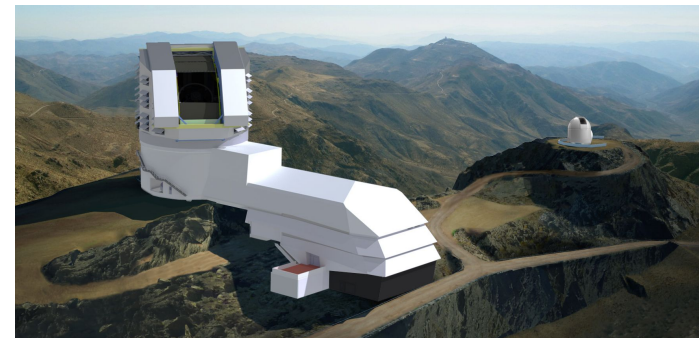
Two neutron stars



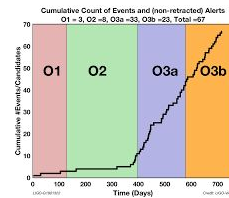
Radio



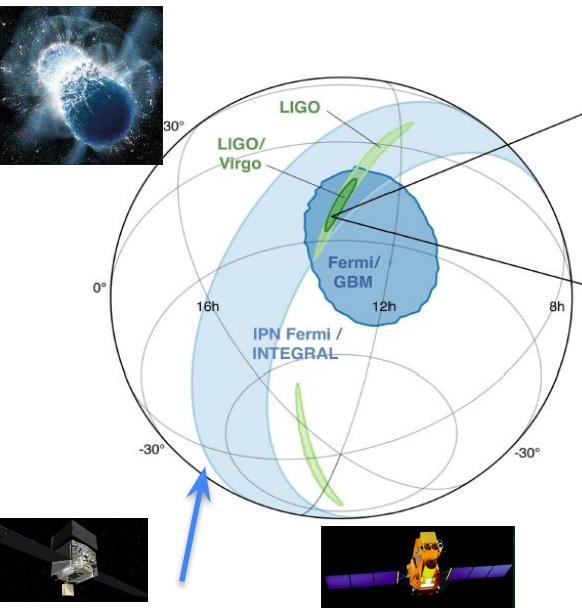
Visible



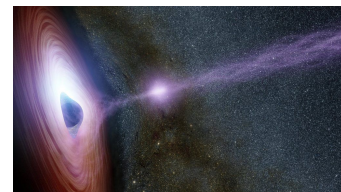
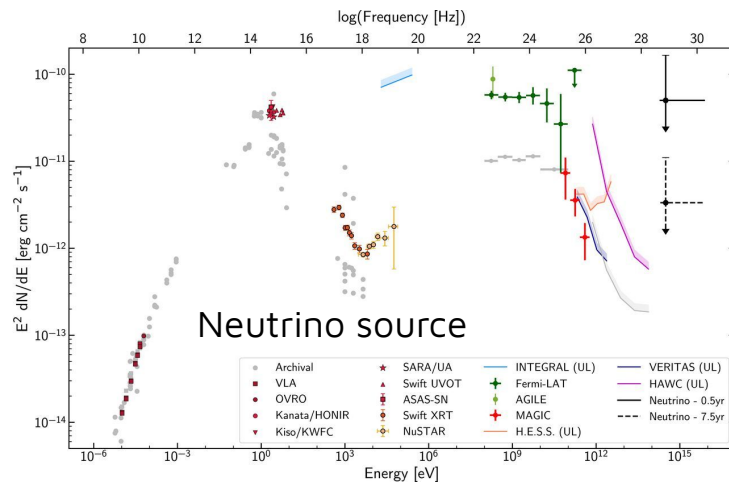
Gravity



Multi-messenger astronomy is collaborative and fast



Fermi + INTEGRAL
“Triangulation”
unique multi-mission approach



Our focus on **broad synergies** allowed us to take a leading role or contribute in some of the key recent discoveries in our domain:

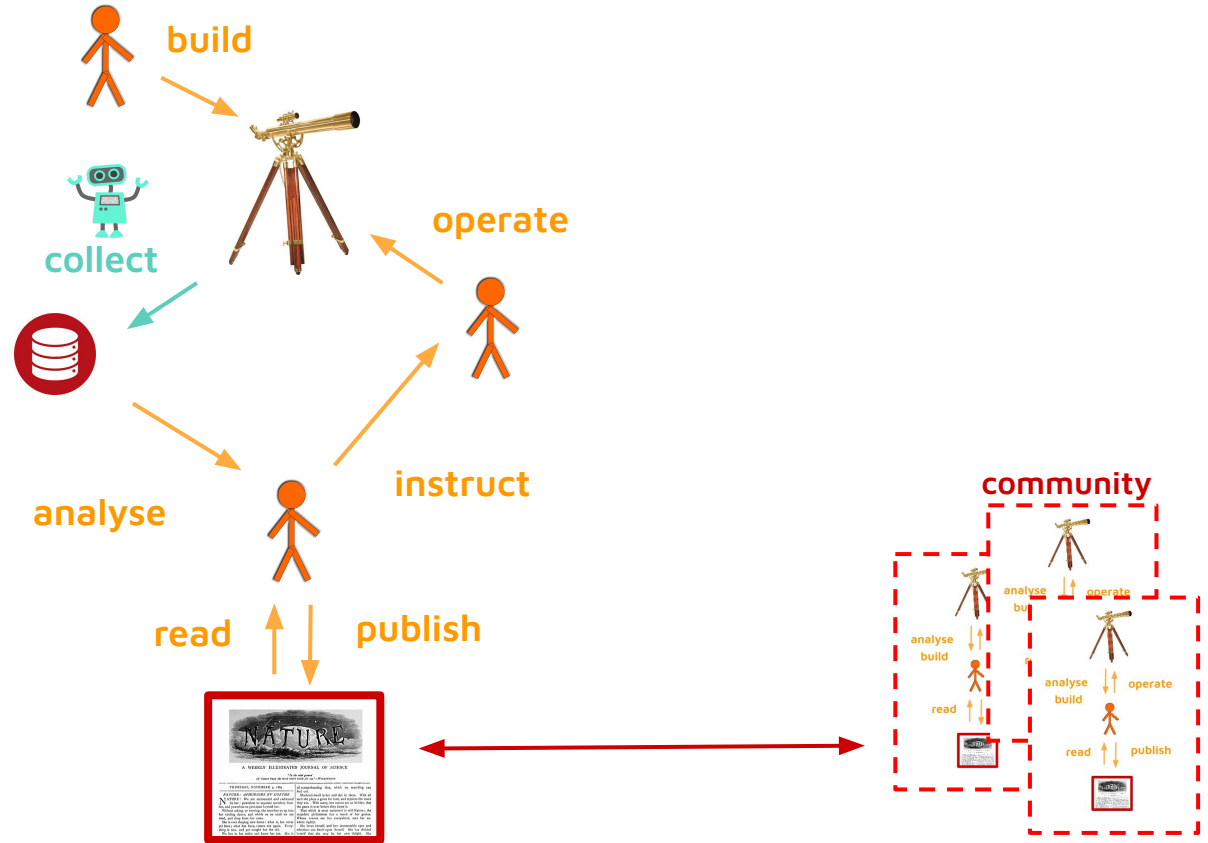
- Detection of the **first Gravitational Wave - Light Burst** coincidence (2017)
- First detection of light emission from **high-energy neutrino source** (2018)
- Discovery of the origin of a **Fast Radio Burst** (2020)

And it's getting worse: much more data, more diverse.

It's getting really hard to keep up with volume and veracity

Mostly-human Astronomy

- Reaction to sky: **slow**
- Reaction to papers: **slow**
- Trials (p-hacking): **uncontrolled**
- Publishing: **slow**
- Scalability: **bad**
- Creativity: **high**
- Communication: **nuanced but imprecise and slow**

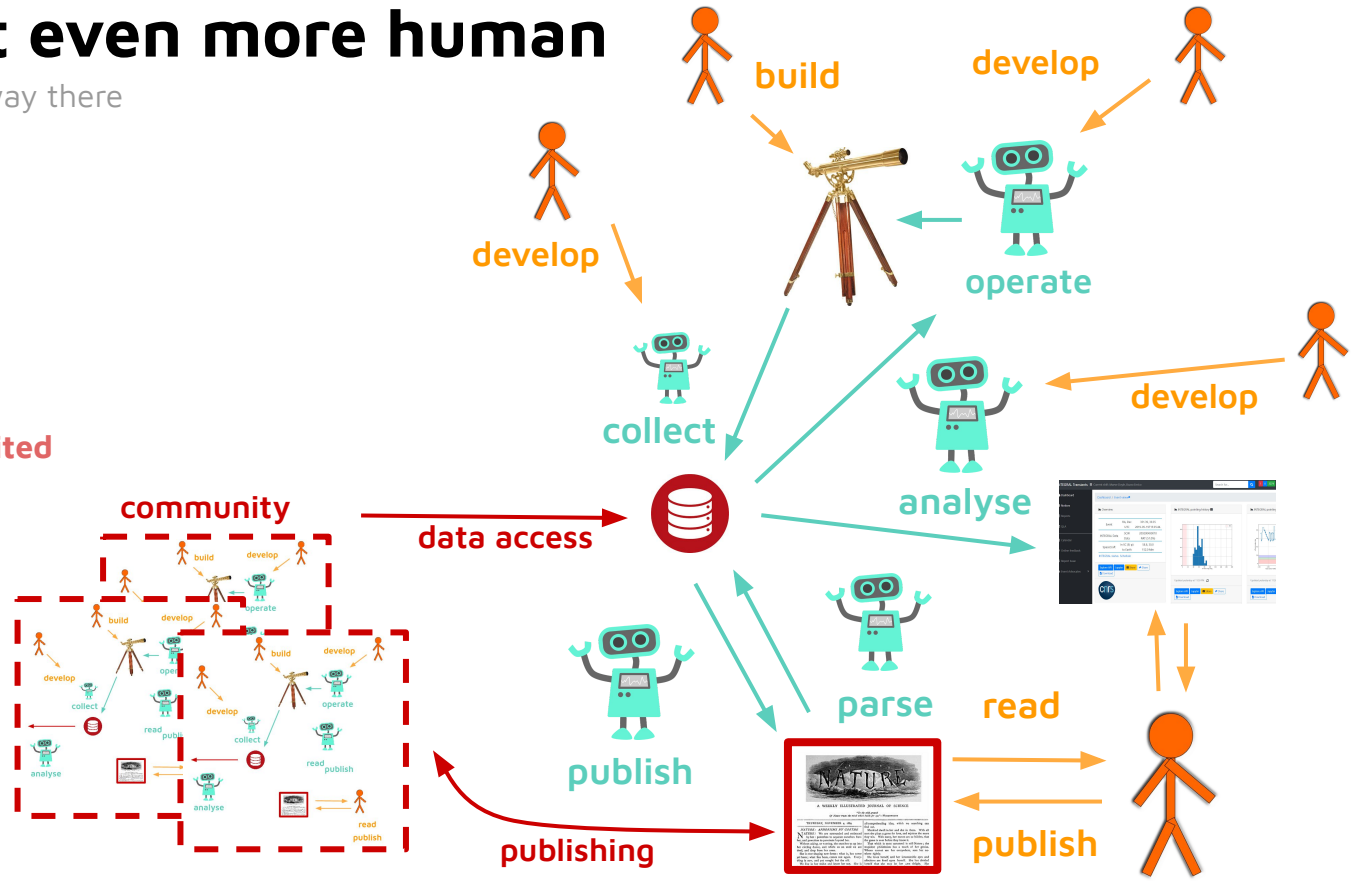


Human reaction and processing **is slow**, even if it's within even one person. But people are **smart**

More robot, but even more human

"Ideal" picture: most reality halfway there

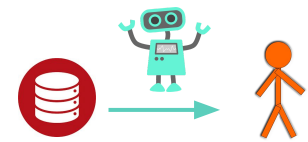
- Reaction to sky: **fast**
- Reaction to papers: **fast**
- Trials (p-hacking): **controlled**
- Publishing: **fast**
- Scaling: **good**
- Creativity: **low**
- Communication: **precise, limited**



- **Making smart robots is hard**: always lacking **developers who are also research scientists**.
- If all is automated, **scientists have hard time seeing what's going on**, since **they do not speak robot**
- Robots are **fast**, but **lack creative reaction** in **new situations**.



Tools for exploring, transforming research data



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

MMODA

Multi-Messenger Online Data Analysis

Deploy your own copy! <https://github.com/oda-hub>

The screenshot displays six panels from the MMODA interface:

- INTEGRAL all-sky view:** A map of the sky showing the INTEGRAL satellite's field of view and localization regions. Updated yesterday at 11:59 PM.
- IBIS/Veto light curve:** A plot of counts per second versus seconds since 2020-03-16T21:57:56.167221 (INTEGRAL). Updated yesterday at 11:59 PM.
- SPI-ACS light curve:** A plot of counts per second versus seconds since 2020-03-16T21:57:56.167221 (INTEGRAL). Updated yesterday at 11:59 PM.
- LIGO/Virgo localization:** A map of the sky showing localization regions for LIGO and Virgo. Updated yesterday at 11:59 PM.
- PICsIT Spectral-Timing light curve (multi-band):** A plot of counts per second versus seconds since 2020-03-16T21:57:56.167221 (INTEGRAL). Updated yesterday at 11:59 PM.
- INTEGRAL pointing history:** A histogram showing the distribution of off-axis angles. Updated yesterday at 11:59 PM.

The screenshot shows the MMODA search and analysis interface for the source GRB120711A:

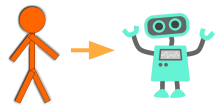
- Search Parameters:** Object name (4U 1700-377), RA (257.815417), Dec (-41.593417), Start time (2003-03-15T23:27:), End time (2003-03-16T00:03:), Time unit (ISC).
- Instrument Query Parameters:** INTEGRAL ISGRI, INTEGRAL JEM-X, INTEGRAL SPI-ACS, Polar, Magic, Antares.
- OSA Version:** OSA10.2.
- Energy Min:** 20.0.
- Query Type:** Real.
- Product Type:** Image.
- Time bin:** 30.
- Source:** GRB120711A - Image catalog.
- Table:** A table listing sources with columns for src names, significance, ra, dec, NEW SOURCE, and ISGRI FLAG.
- Visualizations:** A heatmap showing the localization region with labels for LMC X-4 and NEW_1, and a light curve plot showing counts per second versus exposure time.
- Data Plot:** A bar chart showing the distribution of data points.

Very hard to build these tools, need expert astronomers with state-of-the-art tool-building skills self.

<https://marketplace.eosc-portal.eu/services/astronomical-online-data-analysis-astroda>



Development space: help scientists make robots



There are much **more scientists who can make a jupyter notebook than write organized code.**

JupyterHub(s), Google-collab, ESA DataLabs, Renku

- **Continuous integration and testing**
- Supports in **publishing of data and code** (e.g. in zenodo)
- Support in **annotation** for scientists and robots reuse with ontology terms

Develops and integrates metadata in a **Knowledge Graph** (see later)

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

The screenshot shows a Jupyter Notebook environment for a project named 'integral-visibility'. The interface includes a file browser on the left, a top navigation bar with 'Overview', 'Collaboration', 'Files', 'Datasets', 'Sessions', and 'Settings', and a main workspace. The workspace contains a map titled 'INTEGRAL visibility at 2019-08-16T21:22:14' and a code cell with the following output:

```
[17]: visibility_summary['esac']
```

```
[17]: {'on_peak': 1.0,
      'on_peak_frac': 1.0,
      'on_probability': 0.5933975973212301,
      'visible': 0.5933975973212301,
      'peak_of_target': [51.026785714285715, 48.141267794360284],
      'peak_of_visible': [51.026785714285715, 48.141267794360284],
      'points': [{'descr': 'total visible', 'prob': 0.5933975973212301},
                 {'descr': 'peak', 'ra': 51.026785714285715, 'dec': 48.141267794360284},
                 {'descr': 'visible peak',
                  'ra': 51.026785714285715,
                  'dec': 48.141267794360284},
                 {'alt_descr': 'peak at 5 deg scale',
                  'descr': 'best for staring',
                  'ra': 52.734375,
                  'dec': 31.738384244764443,
                  'prob': 0.06091258655451286,
                  'distance_to_true_peak_deg': 16.45387006118873,
                  'distance_to_now': 45.0471614666983}],
      'distance_to_true_peak_deg': 16.45387006118873,
      'distance_to_now': 45.0471614666983},
```


Making the developed workflow available as a web tool

ipython may be easy, but sometimes we want just put parameters and click one button **in web interface**.

And even more so, we want to **leverage workflow as a service, possibly calling from another workflow**

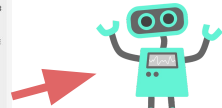
We are publishing the live tool, not just it's output



```
[2]: # name input = "PKS 1156+295"
# name input = "Mrk 421"
# name input = "Crab"
# name input = "NGC 2155-304"
# name input = "050 B0229+200"
# name input = "NGC 1068"
name_input = ""
ra_s = 166.113000 # ra in degree
dec_s = 38.208833 # dec in degree
image_size = 3 # in arcmin (integrate flux of all sources within this radius)
radius_photometry = 1. # in arcsec
dr9 # data release
image_bands="g" #
pixsize=1. # arcsec per pixel

[4]: from astropy.io import ascii
import numpy as np
from numpy import pi, cos,sin
import os

# astroquery API that will be traced by Renuk plugin
from astroquery.ned import Ned
from astroquery.simbad import Simbad
Simbad.add_votable_fields('sttype')
```



Object name *
ngc1033

RA * 40.067160416667 Dec * -8.7769544444444

The right ascension. The declination.

Start time * 2019-04-25T08:18:00.000 End time * 2019-04-25T08:18:15.000 Time unit ISO/IR

INTEGRAL ISGR1 INTEGRAL JEM-X INTEGRAL SPI-ACS Polar Antares GW LegacySurvey

Instrument query parameters: [2022.02.22]

Data Release: DR9

Product Type: Image Photometry

Select product type

Image size: 3 arcmin Pixel size: 1 arcsec per pixel

Image Band: g r z

Select image band

Submit

J59 Download Catalog Query parameters Log Share API code Publish

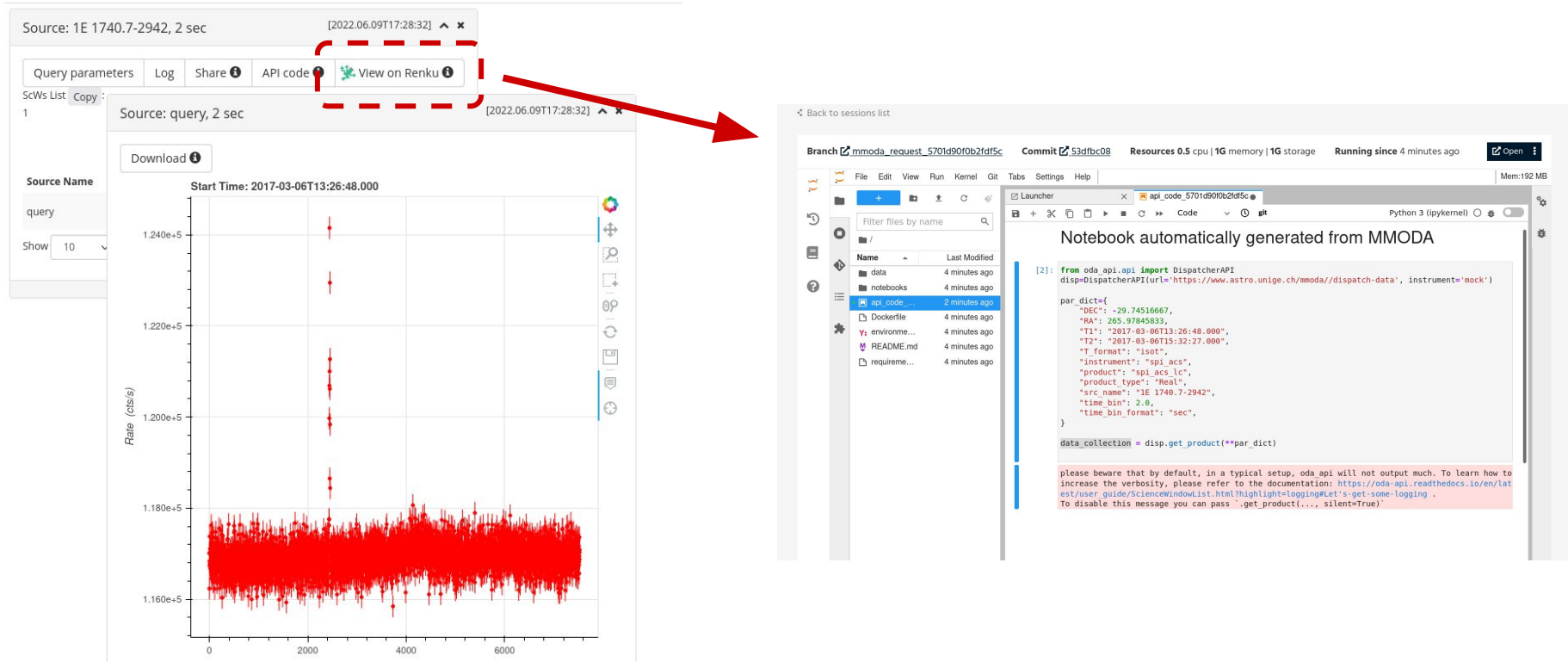
Sig. Range: 0.01 - 10.96

Toggle Log Norm



Helping to request MMODA services from Jupyter/Renku

Building new workflows by using results of the existing ones



The image shows a workflow in a Jupyter environment. On the left, a notebook titled 'Source: 1E 1740.7-2942, 2 sec' contains a plot of 'Rate (cts/s)' vs. time. The plot shows a noisy baseline around 1.17e+5 cts/s with several sharp peaks reaching up to 1.24e+5 cts/s. A red dashed box highlights the 'View on Renku' button in the top right of the notebook's header. A red arrow points from this button to a second notebook on the right. This second notebook, titled 'Notebook automatically generated from MMODA', contains Python code that uses the 'oda.api' to request data and generate a product. The code includes a dictionary of parameters and a call to 'disp.get_product'. Below the code, a warning message is displayed.

Source: 1E 1740.7-2942, 2 sec [2022.06.09T17:28:32]

Query parameters Log Share API code View on Renku

Source Name: query

Start Time: 2017-03-06T13:26:48.000

Rate (cts/s)

Branch: mmoda_request_5701d90f0b2fd5fc Commit: 53dfb08 Resources: 0.5 cpu | 1G memory | 1G storage Running since 4 minutes ago

Notebook automatically generated from MMODA

```
[2]: from oda.api import DispatcherAPI
disp=DispatcherAPI(url='https://www.astro.unige.ch/mmoda/dispatch-data', instrument='mock')

par_dict={
  "DEC": -29.74516667,
  "RA": 265.57845933,
  "T1": "2017-03-06T13:26:48.000",
  "T2": "2017-03-06T13:32:27.000",
  "T_format": "isot",
  "instrument": "spi_acs",
  "product": "spi_acs_lc",
  "product_type": "Real",
  "src name": "1E 1740.7-2942",
  "time bin": 2.0,
  "time_bin_format": "sec",
}

data_collection = disp.get_product(**par_dict)
```

please beware that by default, in a typical setup, oda api will not output much. To learn how to increase the verbosity, please refer to the documentation: https://oda-api.readthedocs.io/en/latest/user_guide/ScienceWindowList.html#highlight=logging!let's-get-some-logging. To disable this message you can pass '.get_product(..., silent=True)'

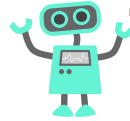
Ontology-based service schema

Feedback loop for crowd-sourcing workflow catalog



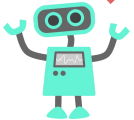
Scientist develops data reduction with deep scientific expertise

Publishing renku workflow as discoverable and executable asset

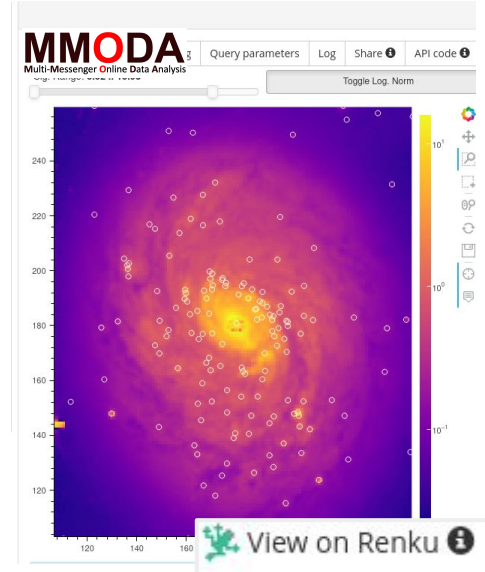


The screenshot shows a Renku workflow interface. At the top, it displays 'renku' branding and navigation tabs: Overview, Collaboration, Files, Datasets, Sessions, Settings. Below this, it shows session details: Branch 'master', Commit '055fcd66', Resources '0.25 cpu | 1G memory | 1G storage', and 'Running since 21 minutes ago'. A file browser on the left lists files like 'decab.ip...', 'DESCR...', 'Dockerfile', 'envion...', 'final.an...', 'image.fits', 'Legacy...', 'LegacyS...', 'New_ast...', 'out.elynb', 'output.p...', 'README...', 'requirem...', 'requirem...', and 'sample 1'. The main area shows a code editor with Python code for data reduction, including comments and imports from 'astropy.io' and 'numpy'. A 'Workflow catalog' window is overlaid on the bottom left, showing a network diagram of workflows.

Workflow catalog



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



new workflow



Scientist creates new workflow leveraging the existing one

Add "creativity": Linked Open Data Knowledge Graphs

People know a lot, and form free associations. Robots have much information too.

E.g. much insight is reported in GCN Circulars but only accessible to people.

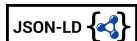
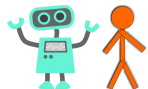
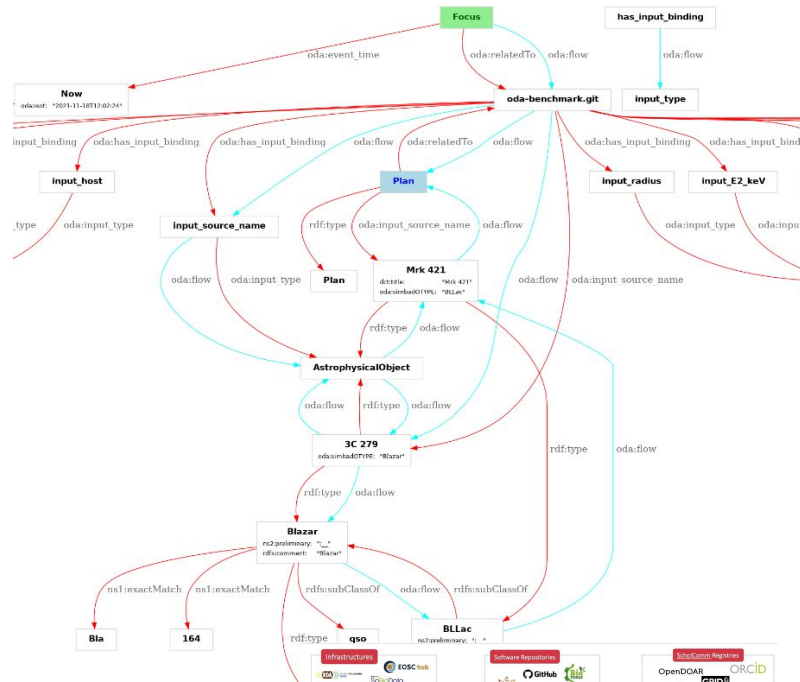
- **Global linked identifiers - URI** (ivo://, http://, ..): building common vocabularies. URIs point to documents, workflows, data, astro objects
- Explain possible **relations** in **ontologies**
- Embedding and following references, to express connections between different URIs



Need link more in the common KG language:

- we try to **consume graciously**
- for **annotating** and **publishing** integrate **code/workflows** with **data**: making sure we **produce cautiously**
- Using **graph relations** to rank and **optimize publication production**

Suitable balance between rigidity and flexibility of schemas. Linked Data ideas: make it connected into larger world with it's language



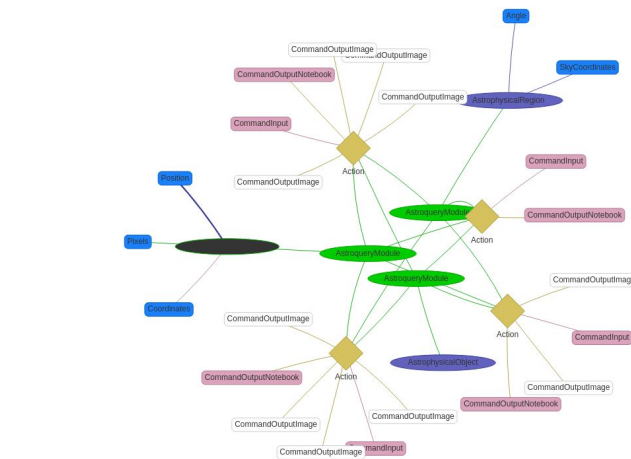
```
paper:gcn31435 paper:NUMBER "31435" ;
paper:SUBJECT "GRB 220111A: BALROG localization ...";
paper:balrog_dec 6.380345e-01;
paper:balrog_ra 1.498846e+02;
paper:gbm_trigger_id 663621714 ;
paper:grb_isot "2022-01-11T19:21:49.430000" ;
paper:location <https://gcn.gsfc.nasa.gov/gcn3/31435.gcn3> ;
paper:mentions_named_event <http://odahub.io/ontology/astroobject#GRB220111A>;
paper:source "GCN" ;
paper:url_json <https://grb.mpe.mpg.de/grb/GRB220111807/json> .
```



Harvesting metadata for KG

To find these workflows in automation, we need suitable metadata.

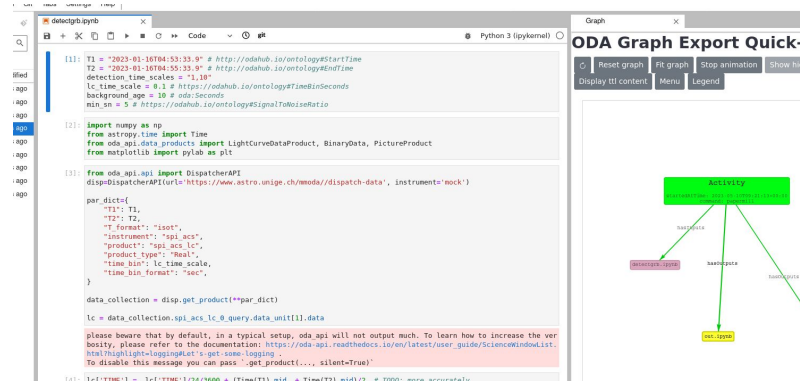
SDSC/Renku uses RDF KG for storing workflow metadata. We developed tools to **harvest astro-specific metadata from code runtime**, in particular by intercepting calls to other services/workflows, and the parameters used.



Interactive Knowledge Graph Explorer

To make the **KG more accessible to the user and the developer**, we made a jupyter plugin to show **provenance and ontology graphs** along within jupyterlab.

It helps to understand what was done and make choices for new annotations.



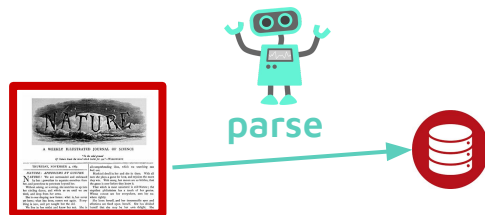
<https://github.com/oda-hub/renku-aqs/>

Time-domain astronomy domain has **micro-publications**: short, rapid, high-impact, indexable/citable, with data embedded

Everything shared can be equally considered a publication:

- new data segment
- automated alert
- nature paper

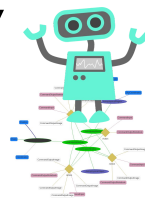
Robots can automatically harvest and parse them (e.g. to RDF)



Need to build tools to explore and process these streams

URI	Title	Facts	Workflows
paper:gcn32182 2022-06-08T23:46:40	GRB 220609A: Fermi GBM Final Real-time Localization	DATE NUMBER SUBJECT gbm_dec gbm_ra gbm_rad gcn_authors gcn_from_email gcn_from_name grb_isot instrument mentions_grb mentions_named_event mentions_named_event_type mentions_named_grb source	Explore
paper:gcn32178 2022-06-08T03:13:20	GRB 220608A: Fermi GBM Final Real-time Localization	DATE NUMBER SUBJECT gbm_dec gbm_ra gbm_rad gcn_authors gcn_from_email gcn_from_name grb_isot instrument mentions_grb mentions_named_event mentions_named_event_type mentions_named_grb source	Explore
paper:gcn32174 2022-06-07T14:26:40	GRB 220606B: Fermi GBM Observation	DATE NUMBER SUBJECT cites cites_gcn_id gcn_authors gcn_from_email gcn_from_name grb_isot instrument mentions_grb mentions_named_event mentions_named_event_type mentions_named_grb source	Explore
paper:gcn32181 2022-06-08T12:40:00	GRB 220606A: Fermi GBM observation	DATE NUMBER SUBJECT cites cites_gcn_id gcn_authors gcn_from_email gcn_from_name grb_isot instrument mentions_grb mentions_named_event mentions_named_event_type mentions_named_grb source	Explore
paper:gcn32173 2022-06-07T11:40:00	GRB 220606B: Swift follow-up observations	DATE NUMBER SUBJECT cites cites_gcn_id gcn_authors gcn_from_email gcn_from_name mentions_grb mentions_named_event mentions_named_event_type mentions_named_grb reports_characteristic source <ol style="list-style-type: none"> 1. paper:DATE: [22/06/07 13:36:38 GMT] 2. paper:NUMBER: [32173] 3. paper:SUBJECT: [GRB 220606B: Swift follow-up observations] 4. paper:cites: {paper:gcn32170: {@id: 'http://odahub.io/ontology/paper#gcn32170'}} 5. paper:cites_gcn_id: [32170] 6. paper:gcn_authors: [J.P. Osborne (U. Leicester), K.L. Page (U. Leicester), M.G. Bernardini (INAF-OAB), E. Ambrosi (INAF-IASFFA) , M. Capalbi (INAF-IASFFA), D.N. Burrows (PSU), J. D. Gropp (PSU), J.A. Kennea (PSU), P.A. Evans (U. Leicester), A. Breeveld (UCL-MSSL) report on behalf of the Swift team:] 7. paper:gcn_from_email: [pae9@leicester.ac.uk] 8. paper:gcn_from_name: [Phil Evans at U of Leicester] 9. paper:mentions_grb: [body] 10. paper:mentions_grb_time: [22] 	Explore

KG-informed automation: **computational “Experiments”**



Since KG contains records of workflows, with I/O types, and data, it is easy to run “**experiments**”: combine workflows with data and see what it gives.

Processes that do compositions, and objective measures are also registered workflows.

- “**Act on new paper or observation report**”
- “**Act on new software or data**”: re-do analysis of a “test case assumptions about instruments
- “**Act on new observation**”: testing assumptions about physical reality
- “**Act on new platform or time moment**”: make sure platform runs smoothly and is sane

View ▾ Act ▾ Paper ▾ Objectives ▾ Objects ▾ 0 more goals This service implements standards discussed here [here](#) and [here](#). Source of the [deployment](#) and the [application](#)

3 from 0 to 3 days ago [todays](#) [last week](#) [future](#) [past](#) [GCNs](#) [arXiv](#) [ATel](#) Search for...

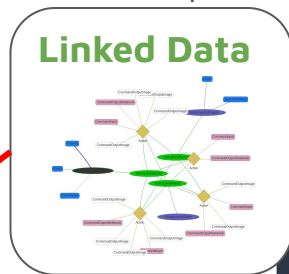
URI	Title	Facts	Workflows f
paper:gcn29707 2021-03-24T11:24:43	GRB 210324A: Fermi GBM Final Real-time Localization	DATE NUMBER SUBJECT gcn_authors gcn_from_email gcn_from_name grb_isot instrument mentions_grb mentions_named_grb source	Explore paper origin fetch-workflow-paper:gcn29707 Run INTEGRAL follow-up Run my affinity oda:me oda:cares_for paper:gcn29707 Care Uncare
paper:gcn29715 2021-03-24T19:35:15	GRB 210324B: Fermi GBM Final Real-time Localization	DATE NUMBER SUBJECT gcn_authors gcn_from_email gcn_from_name grb_isot instrument mentions_grb mentions_named_grb source	Explore
paper:gcn29718 2021-03-24T20:10:22	GRB 210324C: Fermi GBM Final Real-time Localization	DATE NUMBER SUBJECT gcn_authors gcn_from_email gcn_from_name grb_isot instrument mentions_grb mentions_named_grb source	Explore
paper:gcn29709	GRB 210324A: Fermi GBM detection	DATE NUMBER SUBJECT gcn_authors gcn_from_email gcn_from_name grb_isot instrument mentions_grb mentions_named_grb source	Explore

“Live” publications from data

To complete the science loop, we must rethink **production of publications** as well.

“**Dead**” publications kill the data by embedding mutilated irreproducible untraceable representations and references to it.

“**Live**” publications are themselves workflow outputs, compiled from data.



Appendix~{\ref{sec:association}}).

```
\begin{figure}
\centering
\includegraphics[width=1\linewidth]{acs_lc}
\caption{SPI-ACS light curve of GRB~170817A (100~ms time
resolution),
detected 2 seconds after GW170817. The red line highlights the
100~ms pulse \ch{which has an S/N of
\VAR{search.grb.snr|round(1)}} in
SPI-ACS. The blue shaded region corresponds to a range of one
standard deviation of the background.}
\label{fig:acslc}
\end{figure}
```

<https://github.com/oda-hub/linked-data-latex/>

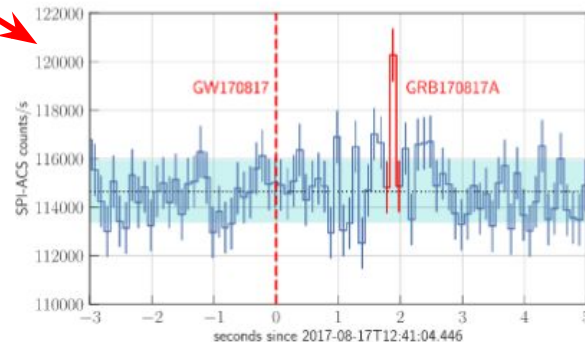


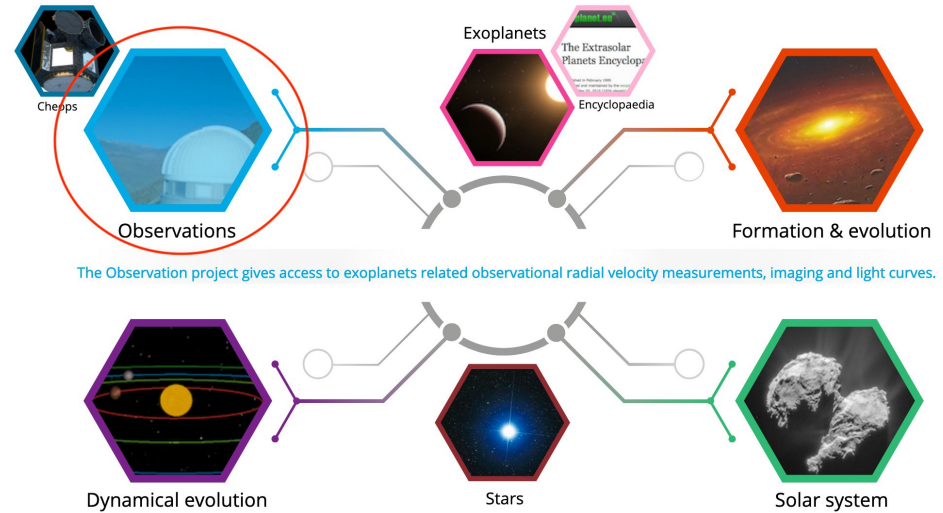
FIG. 2.— SPI-ACS light curve of GRB 170817A (100 ms time resolution), detected 2 seconds after GW170817. The red line highlights the 100 ms pulse, which has an S/N of 4.6 in SPI-ACS. The blue shaded region corresponds to a range of one standard deviation of the background.

Synergies: DACE

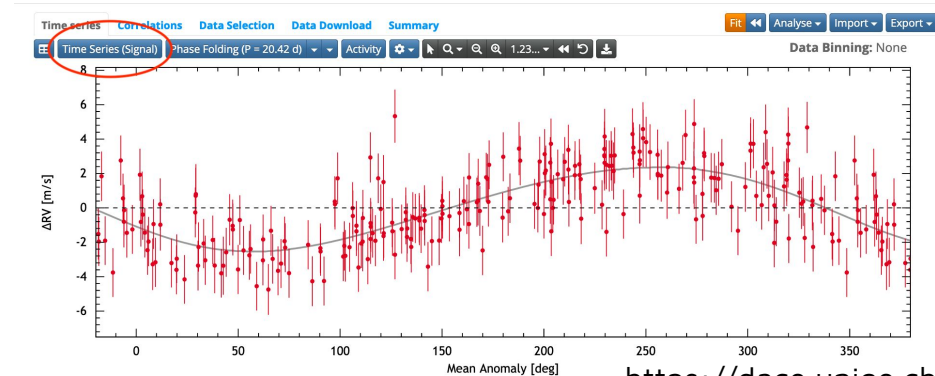
Exoplanet community is facing similar challenges to that in the multi-messenger astronomy, and recently we discovered potential for synergy with **DACE project**, as **our goals and means started to overlap**

We are now actively developing horizontal integration and re-use of tools and technologies

Other communities finding that analysis services are beneficial, e.g. we are working with similar development in [Posydon](#) project.



The Observation project gives access to exoplanets related observational radial velocity measurements, imaging and light curves.



Synergies: Particle physics, ESAP/ESCAPE; ESA/DataLabs

EU/EOSC ESCAPE project developed ESAP platform joining particle physics and astronomy.

ESA developed [DataLabs](#) platform providing collection of diverse interactive environments for space science and technology. UNIGE/DepAstro was substantially involved in use case definition and design of its components and is now involved in platform integration.

The screenshot shows the ESAP IVOA Query interface. At the top, there are navigation links: Archives, Multi Query, Interactive Analysis, and IVOA-SAMP. Below this, the 'ESAP IVOA Query' section includes a 'Catalog' dropdown set to 'IVOA', a 'Keyword' input field containing 'h.e.s.s.', a 'Service Type' dropdown set to 'TAP: Tables', and a 'Waveband' dropdown set to 'All'. A 'Query Registry' button is visible. Below the search filters is a 'List of VO Resources' section with a search bar for workflows. A red arrow points to the search bar. Below this is a 'List of Facilities' section with a search bar and a 'Deploy' button. A red arrow points to the search bar. Below the facilities list, there are two entries: 'CSGS CTA BinderHub' and 'JIVE BinderHub', each with a description and a link. A red arrow points to the 'Deploy' button next to the 'JIVE BinderHub' entry. At the bottom, a terminal window shows a list of data points and a plot of data points with error bars.

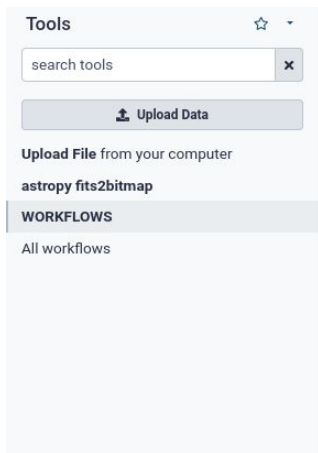
The screenshot shows the ESA DataLabs interface. At the top, there is a 'Create Datalabs' section with a grid of tools including 'ESOC Desktop Analysis', 'GNSS Desktop Analysis', 'GNSS Crowdsourcing', 'Jive analysis', 'Integral Spectral Analysis', and 'Gaia DR2 Analysis'. Below this is a 'Datalabs' section with a grid of tools including 'ESOC Analysis Labs', 'GNSS Desktop Analysis', 'GNSS Crowdsourcing', 'Jive analysis', 'Integral Spectral Analysis', and 'Gaia DR2 Analysis'. A circular diagram with four green boxes labeled 'Find', 'Launch', 'Use', and 'Switch' is overlaid on the interface. Below the interface, there is a row of European Union member state flags and the text 'THE EUROPEAN SPACE AGENCY'.

Synergies: EuroScienceGateway

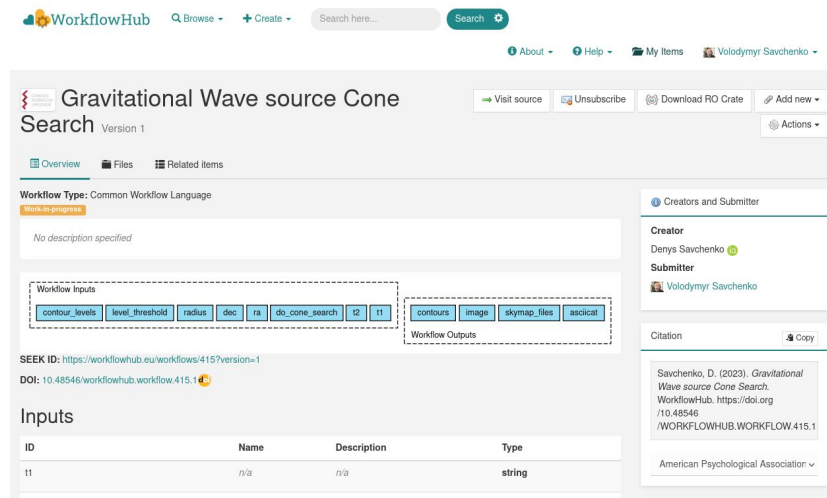
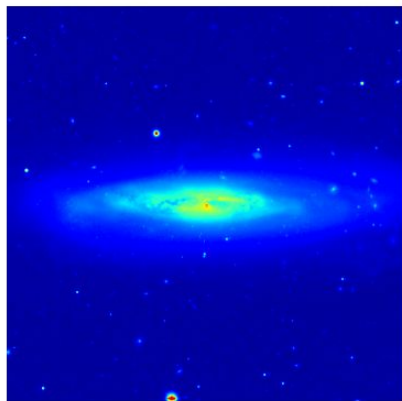
Bioinformatics community has somewhat widely adapted **Galaxy platform** enabling open data analysis services with distributed compute.

We joined (along with particle physics, material science, climate science) an EOSC project to **bring our tools and workflows into Galaxy platform**.

The project also focuses on **integration with publications** and publishing workflows in WorkflowHub



The screenshot shows the Galaxy Tools panel. At the top, there is a search bar with the text "search tools" and a star icon. Below the search bar is an "Upload Data" button. Underneath, there is a section for "Upload File from your computer" with the tool "astropy fits2bitmap" listed. A "WORKFLOWS" section is also visible, showing "All workflows".



The screenshot shows a WorkflowHub page for a workflow titled "Gravitational Wave source Cone Search" (Version 1). The page includes a search bar, navigation links (About, Help, My Items), and a user profile (Volodymyr Savchenko). The workflow is described as "Common Workflow Language" and "Work in progress". It has no description specified. The workflow inputs are listed as "contour_levels", "level_threshold", "radius", "dsc", "ra", "do_cone_search", "l2", and "l1". The workflow outputs are listed as "contours", "image", "skymap_files", and "asciiat". The workflow has a SEEK ID of <https://workflowhub.eu/workflows/415?version=1> and a DOI of [10.48546/workflowhub.workflow.415.1](https://doi.org/10.48546/workflowhub.workflow.415.1). The inputs table is as follows:

ID	Name	Description	Type
l1	n/a	n/a	string

The page also includes a "Citation" section with the following text: "Savchenko, D. (2023). Gravitational Wave source Cone Search. WorkflowHub. <https://doi.org/10.48546/workflowhub.workflow.415.1>. American Psychological Association".

Summary

- **Why** ● **Rapidly growing astronomy** needs new **intelligent automation, both fast and creative** especially for:
 - **Multi-messenger and cross-domain** research
 - Ensuring science results **reuse and reproducibility**
 - Avoiding repetition and **saving energy**
 - **Teaching**
- **What** ● Alongside with **Astronomical Data Centers** and often within, reusable practices for managing data analysis processes develop, leveraging **FAIR analysis “functions” (methods, workflows, tools) to Open Research Data**. Current project aims to **consolidate and establish** the **ecosystem of tools and technologies developed by us, leveraging synergies with other projects**
 - Focus on **workflow development environment** allows to **crowd-source tool creation** with our **MMODA** web-analysis platform
 - Workflow metadata in **KG** following **Linked Open Data** paradigm makes assets **discoverable** and **re-usable** fits well in **federalistic nature our community**
- **How** ● **Sustainability** of this sort of activity is sometimes challenging, but the need to ensure it is recognized.
 - Continue **working closely with Data Centers** for their needs
 - **Added-value scientific services** beyond basic Data Centers (e.g. **multi-messenger**)
 - **Building up from infrastructure service provider level** (e.g. extra services along with a computing cluster)
 - Building **synergies (including technology integration)** with **other related projects** is one of the ways to make sure the developments continue being used and re-used. **In part for this, all our work is [open](#)**

