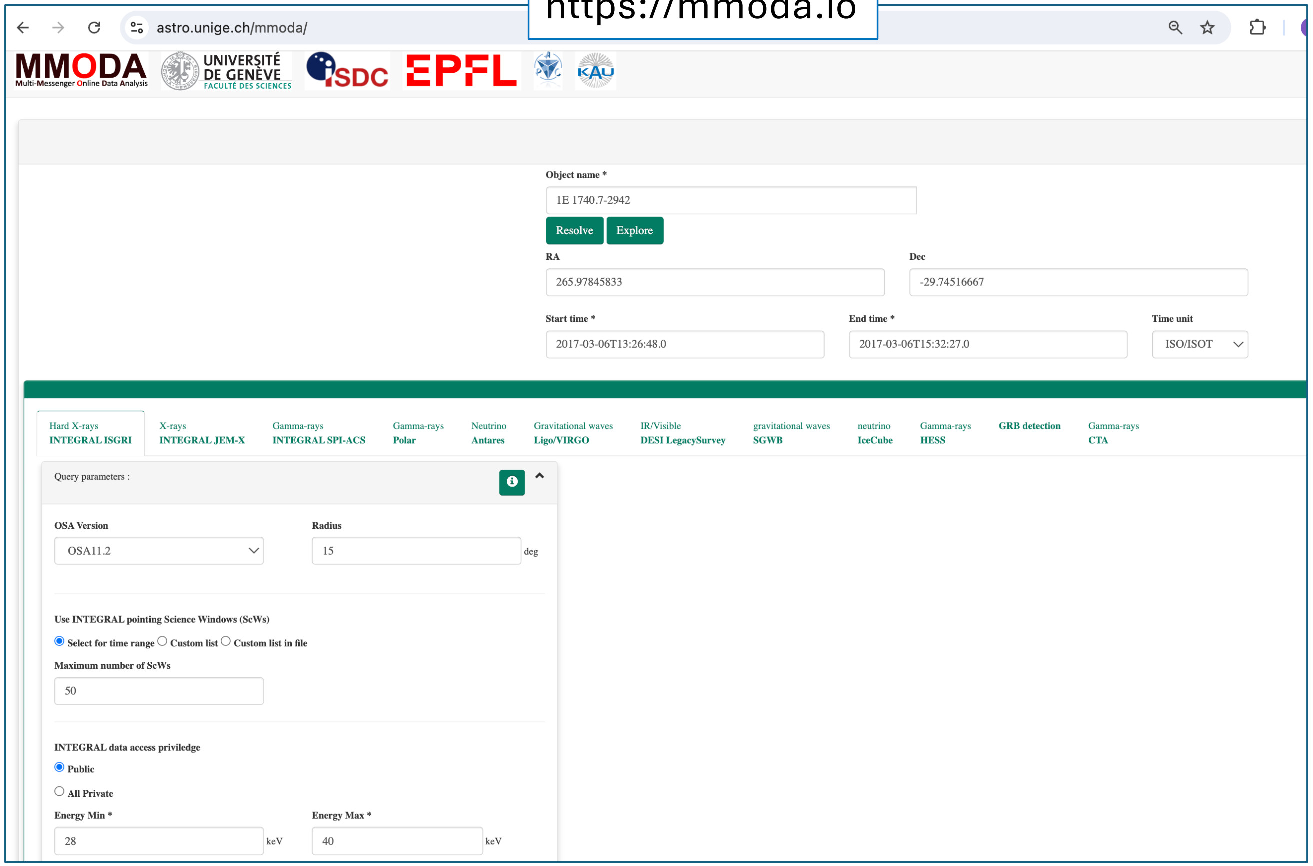
Multi-Messenger Online Data Analysis

Andrii Neronov
APC Paris, EPFL Lausanne

https://mmoda.io



V.Savchenko, C.Ferrigno, G.Barni, M.Meharga, S.Paltani, O.Kalashev, A.Variu, F.Morier-Genoud, E.Tolley, J.-P. Kneib, A.Wassmer, L.Gering, A.Csillaghy

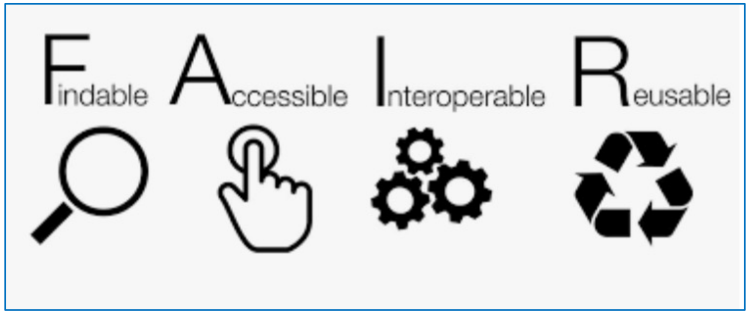
MMODA motivation: open data

It becomes a common practice to make datasets publicly available, to implement "**FAIR** principle" of data management….. "**F**"-Ok, "**A**"-Ok….

How about "**I**"=Interoperable and "**R**"=Reusable? This requires :

- Data analysis workflow (that needs to be FAIR as well)
- Expertise in manipulating that data analysis workflow

This is not always available "by default", compromising the "IR" part of the FAIR principle.



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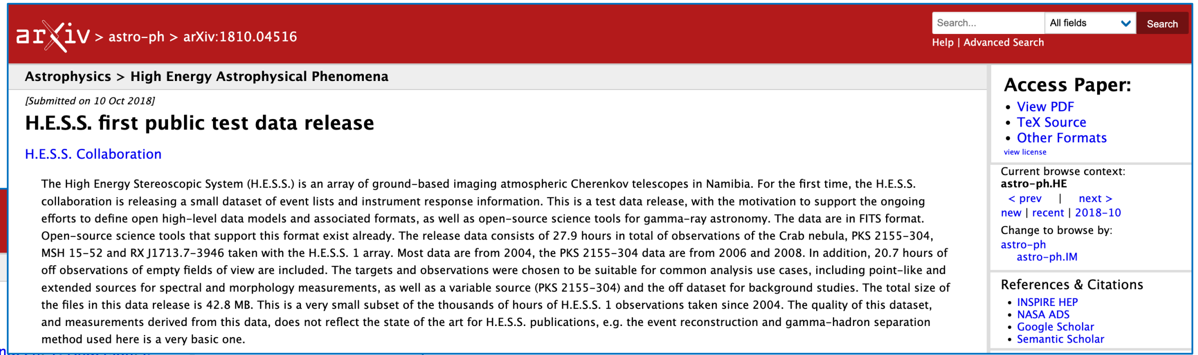
arXiv > astro-ph > arXiv:1810.04516

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Astrophysics > High Energy Astrophysical Phenomena

[Submitted on 10 Oct 2018]

H.E.S.S. first public test data release

H.E.S.S. Collaboration

The High Energy Stereoscopic System (H.E.S.S.) is an array of ground-based imaging atmospheric Cherenkov telescopes in Namibia. For the first time, the H.E.S.S. collaboration is releasing a small dataset of event lists and instrument response information. This is a test data release, with the motivation to support the ongoing efforts to define open high-level data models and associated formats, as well as open-source science tools for gamma-ray astronomy. The data are in FITS format. Open-source science tools that support this format exist already. The release data consists of 27.9 hours in total of observations of the Crab nebula, PKS 2155-304, MSH 15-52 and RX J1713.7-3946 taken with the H.E.S.S. 1 array. Most data are from 2004, the PKS 2155-304 data are from 2006 and 2008. In addition, 20.7 hours of off observations of empty fields of view are included. The targets and observations were chosen to be suitable for common analysis use cases, including point-like and extended sources for spectral and morphology measurements, as well as a variable source (PKS 2155-304) and the off dataset for background studies. The total size of the files in this data release is 42.8 MB. This is a very small subset of the thousands of hours of H.E.S.S. 1 observations taken since 2004. The quality of this dataset, and measurements derived from this data, does not reflect the state of the art for H.E.S.S. publications, e.g. the event reconstruction and gamma-hadron separation method used here is a very basic one.

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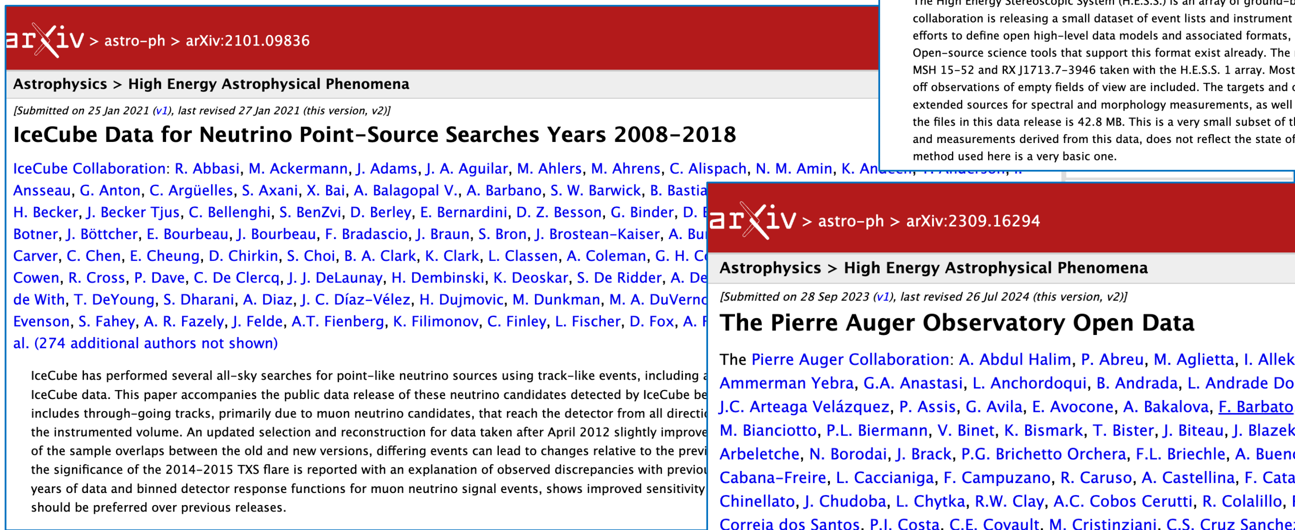
arXiv > astro-ph > arXiv:2101.09836

Astrophysics > High Energy Astrophysical Phenomena

[Submitted on 25 Jan 2021 (v1), last revised 27 Jan 2021 (this version, v2)]

IceCube Data for Neutrino Point-Source Searches Years 2008-2018

IceCube Collaboration: R. Abbasi, M. Ackermann, J. Adams, J. A. Aguilar, M. Ahlers, M. Ahrens, C. Alispach, N. M. Amin, K. An…
Anseau, G. Anton, C. Argüelles, S. Axani, X. Bai, A. Balagopal V., A. Barbano, S. W. Barwick, B. Bastia…
H. Becker, J. Becker Tjus, C. Bellenghi, S. BenZvi, D. Berley, E. Bernardini, D. Z. Besson, G. Binder, D. …
Botner, J. Böttcher, E. Bourbeau, J. Bourbeau, F. Bradascio, J. Braun, S. Bron, J. Brostean-Kaiser, A. Bu…
Carver, C. Chen, E. Cheung, D. Chirkin, S. Choi, B. A. Clark, K. Clark, L. Classen, A. Coleman, G. H. C…
Cowen, R. Cross, P. Dave, C. De Clercq, J. J. DeLaunay, H. Dembinski, K. Deoskar, S. De Ridder, A. De…
de With, T. DeYoung, S. Dharani, A. Diaz, J. C. Díaz-Vélez, H. Dujmovic, M. Dunkman, M. A. DuVern…
Evenson, S. Fahey, A. R. Fazely, J. Felde, A.T. Fienberg, K. Filimonov, C. Finley, L. Fischer, D. Fox, A. F…
al. (274 additional authors not shown)

IceCube has performed several all-sky searches for point-like neutrino sources using track-like events, including … IceCube data. This paper accompanies the public data release of these neutrino candidates detected by IceCube be… includes through-going tracks, primarily due to muon neutrino candidates, that reach the detector from all directi… the instrumented volume. An updated selection and reconstruction for data taken after April 2012 slightly improve… of the sample overlaps between the old and new versions, differing events can lead to changes relative to the previ… the significance of the 2014-2015 TXS flare is reported with an explanation of observed discrepancies with previo… years of data and binned detector response functions for muon neutrino signal events, shows improved sensitivity… should be preferred over previous releases.


arXiv > astro-ph > arXiv:2309.16294

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[Submitted on 28 Sep 2023 (v1), last revised 26 Jul 2024 (this version, v2)]

The Pierre Auger Observatory Open Data

The Pierre Auger Collaboration: A. Abdul Halim, P. Abreu, M. Aglietta, I. Allekotte, K. Almeida Cheminant, A. Almela, R. Aloisio, J. Alvarez-Muñiz, J. Ammerman Yebra, G.A. Anastasi, L. Anchordoqui, B. Andrada, L. Andrade Dourado, S. Andringa, L. Apollonio, C. Aramo, P.R. Araújo Ferreira, E. Arnone, J.C. Arteaga Velázquez, P. Assis, G. Avila, E. Avocone, A. Bakalova, F. Barbato, A. Bartz Mocellin, J.A. Bellido, C. Berat, M.E. Bertaina, X. Bertou, G. Bhatta, M. Bianciotto, P.L. Biermann, V. Binet, K. Bismark, T. Bister, J. Biteau, J. Blazek, C. Bleve, J. Blümer, M. Boháčová, D. Boncioli, C. Bonifazi, L. Bonneau Arbeletche, N. Borodai, J. Brack, P.G. Brichetto Orchera, F.L. Briechle, A. Bueno, S. Buitink, M. Buscemi, M. Büsken, A. Bwembya, K.S. Caballero-Mora, S. Cabana-Freire, L. Caccianiga, F. Campuzano, R. Caruso, A. Castellina, F. Catalani, G. Cataldi, L. Cazon, M. Cerda, B. Čermáková, A. Cermenati, J.A. Chinellato, J. Chudoba, L. Chytka, R.W. Clay, A.C. Cobos Cerutti, R. Colalillo, R. Conceição, A. Condorelli, G. Consolati, M. Conte, F. Convenga, D. Correia dos Santos, P.J. Costa, C.E. Covault, M. Cristinziani, C.S. Cruz Sanchez, S. Dasso, K. Daumiller, B.R. Dawson, R.M. de Almeida, B. de Errico, J. de Jesús, S.J. de Jong, J.R.T. de Mello Neto, I. De Mitri, J. de Oliveira, D. de Oliveira Franco, F. de Palma, V. de Souza, E. De Vito, A. Del Popolo, O. Deligny, N. Denner, L. Deval, A. di Matteo et al. (261 additional authors not shown)

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MMODA motivation: open data analysis software

Analysis frameworks that constitute the basis of of data analysis workflows are often publicly available:

- Data analysis workflows can be extracted from open software repositories

These workflows can be made “live” explicitly fostering the **I**nteroperability and **R**euse of data.

arXiv > astro-ph > arXiv:1904.11747

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Astrophysics > Instrumentation and Methods for Astrophysics

[Submitted on 26 Apr 2019]

CASA on the fringe: VLBI data processing in the CASA software package

Ilse van Bemmel, Des Small, Mark Kettenis, Arpad Szomoru, George Moellenbrock, Michael Janssen

In recent years new functionality for VLBI data processing has been added to the CASA package. This paper presents the new CASA tasks 'fringefit' and 'accor', which are closely matched to their AIPS counterparts FRING and ACCOR. Several CASA tasks received upgrades to handle VLBI specific metadata. With the current CASA release VLBI data processing is possible, and functionality will be expanded in the upcoming release. Longer term developments include fringe fitting of broad, non-continuous frequency bands and dispersive delays, which will ensure that the number of use cases for VLBI calibration will increase in future CASA releases.

Comments: 5 pages, 2 figures, EVN 2018 symposium proceedings
Subjects: **Instrumentation and Methods for Astrophysics (astro-ph.IM)**
Cite as: arXiv:1904.11747 **[astro-ph.IM]**
(or arXiv:1904.11747v1 **[astro-ph.IM]** for this version)
https://doi.org/10.48550/arXiv.1904.11747

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arXiv > astro-ph > arXiv:2107.08934

Astrophysics > Instrumentation and Methods for Astrophysics

[Submitted on 19 Jul 2021]

The SkyLLH framework for IceCube point-source search

Tomas Kontrimas, Martin Wolf (for the IceCube Collaboration)

Hypothesis tests based on unbinned log-likelihood (LLH) functions are a common technique used in multi-messenger as... source searches. We present the general Python-based tool "SkyLLH", which provides a modular framework for implemen... perform data analyses with multi-messenger astronomy data. Specific SkyLLH framework features for a new and improve... analysis are highlighted, including the support for kernel density estimation (KDE) based probability density functions. In addition, the support for a variety of point-source analysis types, such as stacked and time-variable searches, will be presented.

Comments: Presented at the 37th International Cosmic Ray Conference (ICRC 2021). See arXiv:2107.06966 for all IceCube contributions
Subjects: **Instrumentation and Methods for Astrophysics (astro-ph.IM)**; High Energy Astrophysical Phenomena (astro-ph.HE)
Report number: PoS-ICRC2021-1073
Cite as: arXiv:2107.08934 [astro
(or arXiv:2107.08934v1
https://doi.org/10.4855

Submission history
From: Tomas Kontrimas [view email]
[v1] Mon, 19 Jul 2021 14:49:16 UTC (

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arXiv > astro-ph > arXiv:2308.13584

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Astrophysics > Instrumentation and Methods for Astrophysics

[Submitted on 25 Aug 2023]

Gammapy: A Python package for gamma-ray astronomy

Axel Donath, Régis Terrier, Quentin Remy, Atreyee Sinha, Cosimo Nigro, Fabio Pintore, Bruno Khélifi, Laura Olivera-Nieto, Jose Enrique Ruiz, Kai Brügge, Maximilian Linhoff, Jose Luis Contreras, Fabio Acero, Arnau Aguasca-Cabot, David Berge, Pooja Bhattacharjee, Johannes Buchner, Catherine Boisson, David Carreto Fidalgo, Andrew Chen, Mathieu de Bony de Lavergne, José Vinícius de Miranda Cardoso, Christoph Deil, Matthias Füßling, Stefan Funk, Luca Giunti, Jim Hinton, Léa Jouvin, Johannes King, Julien Lefaucheur, Marianne Lemoine-Goumard, Jean-Philippe Lenain, Rubén López-Coto, Lars Mohrmann, Daniel Morcuende, Sebastian Panny, Maxime Regeard, Lab Saha, Hubert Siejkowski, Aneta Siemiginowska, Brigitta M. Sipőcz, Tim Unbehaun, Christopher van Eldik, Thomas Vuillaume, Roberta Zanin

In this article, we present Gammapy, an open-source Python package for the analysis of astronomical γ-ray data, and illustrate the functionalities of its first long-term-support release, version 1.0. Built on the modern Python scientific ecosystem, Gammapy provides a uniform platform for reducing and modeling data from different γ-ray instruments for many analysis scenarios. Gammapy complies with several well-established data conventions in high-energy astrophysics, providing serialized data products that are interoperable with other software packages. Starting from event lists and instrument response functions, Gammapy provides functionalities to reduce

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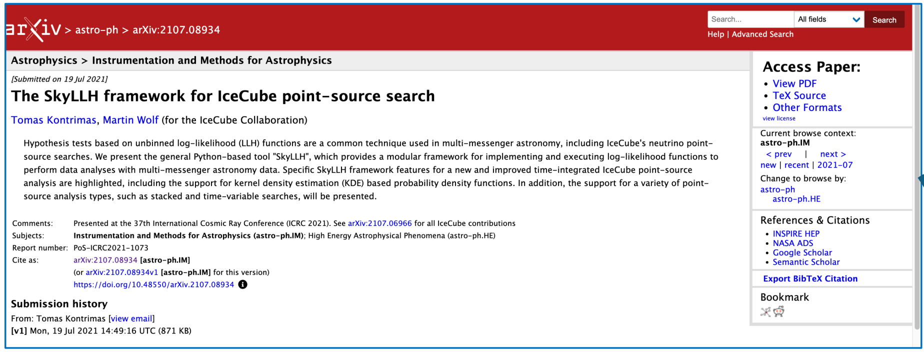
MMODA motivation: open data, open software → web services



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[Submitted on 19 Jul 2021]

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Tomas Kontrimas, Martin Wolf (for the IceCube Collaboration)

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Comments: Presented at the 37th International Cosmic Ray Conference (ICRC 2021). See arXiv:2107.06966 for all IceCube contributions
Subjects: Instrumentation and Methods for Astrophysics (astro-ph.IM); High Energy Astrophysical Phenomena (astro-ph.HE)
Report number: PoS-ICRC2021-1073
Cite as: arXiv:2107.08934 [astro-ph.IM]
(or arXiv:2107.08934v1 [astro-ph.IM] for this version)
https://doi.org/10.48550/arXiv.2107.08934

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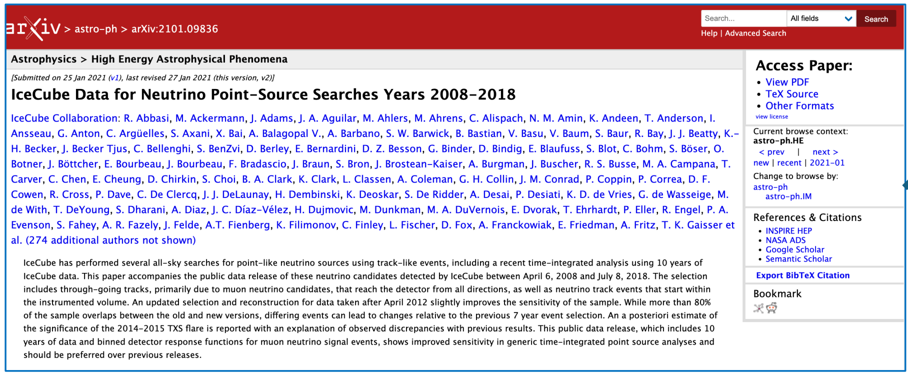

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[Submitted on 25 Jan 2021 (v1), last revised 27 Jan 2021 (this version, v2)]

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IceCube has performed several all-sky searches for point-like neutrino sources using track-like events, including a recent time-integrated analysis using 10 years of IceCube data. This paper accompanies the public data release of these neutrino candidates detected by IceCube between April 6, 2008 and July 8, 2018. The selection includes through-going tracks, primarily due to muon neutrino candidates, that reach the detector from all directions, as well as neutrino track events that start within the instrumented volume. An updated selection and reconstruction for data taken after April 2012 slightly improves the sensitivity of the sample. While more than 80% of the sample overlaps between the old and new versions, differing events can lead to changes relative to the previous 7 year event selection. An a posteriori estimate of the significance of the 2014-2015 TXS flare is reported with an explanation of observed discrepancies with previous results. This public data release, which includes 10 years of data and binned detector response functions for muon neutrino signal events, shows improved sensitivity in generic time-integrated point source analyses and should be preferred over previous releases.

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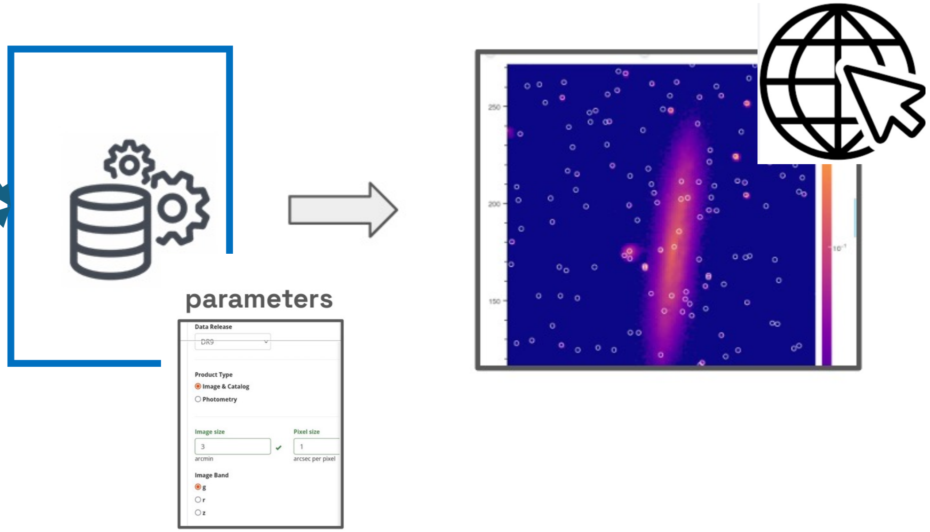
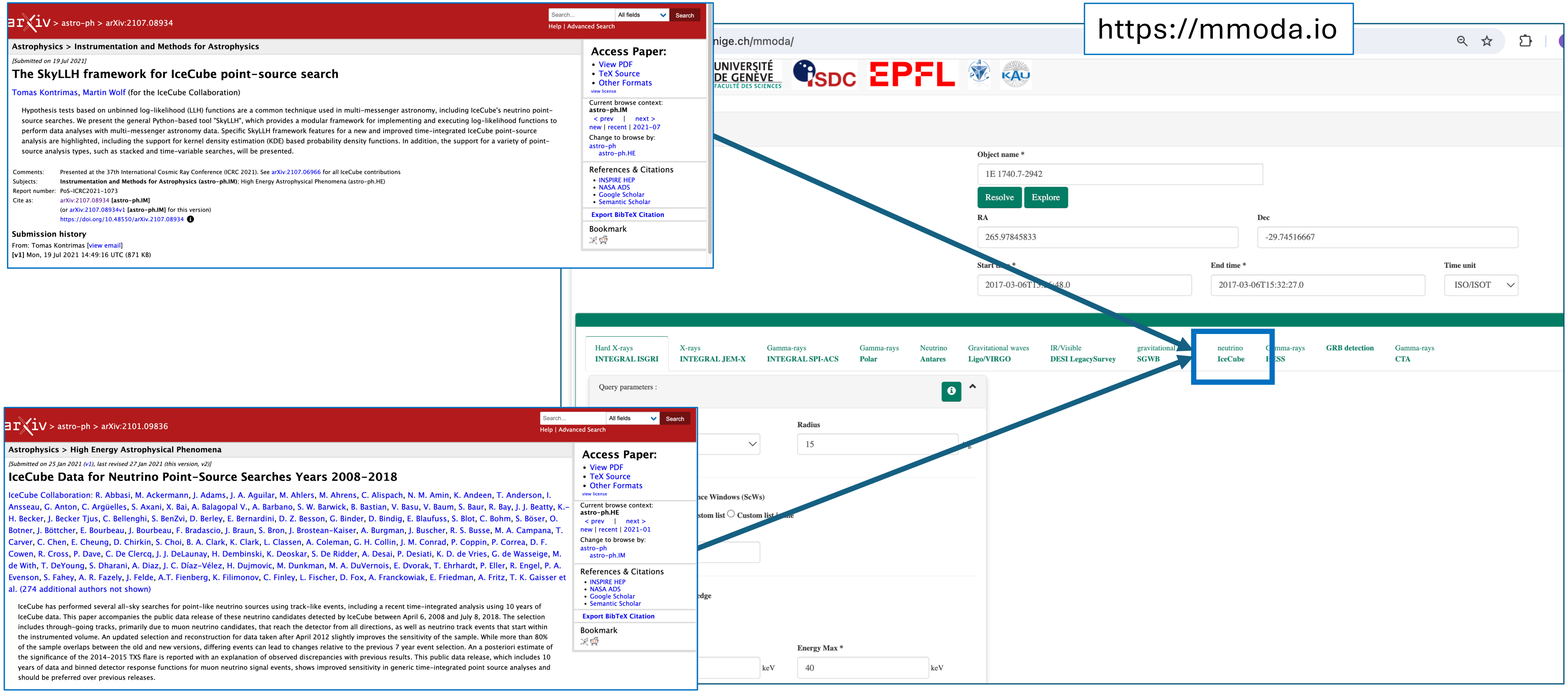


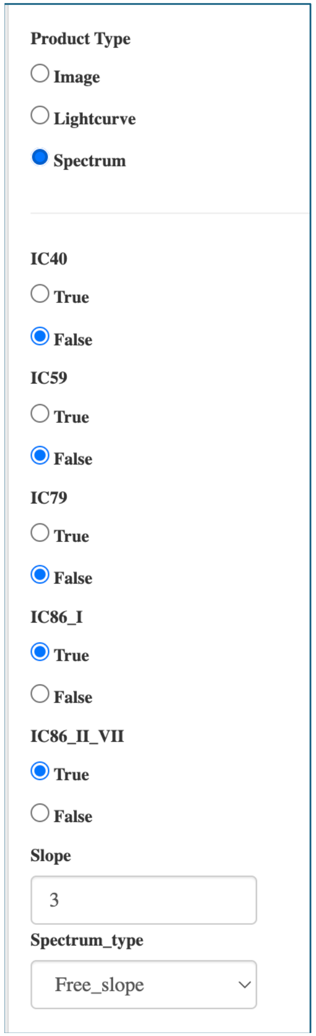
Example: IceCube analysis

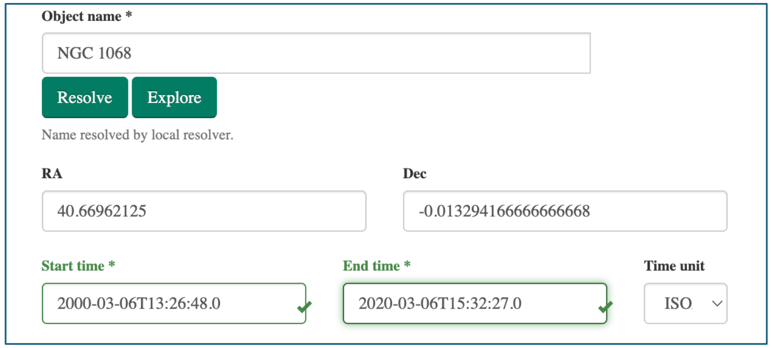


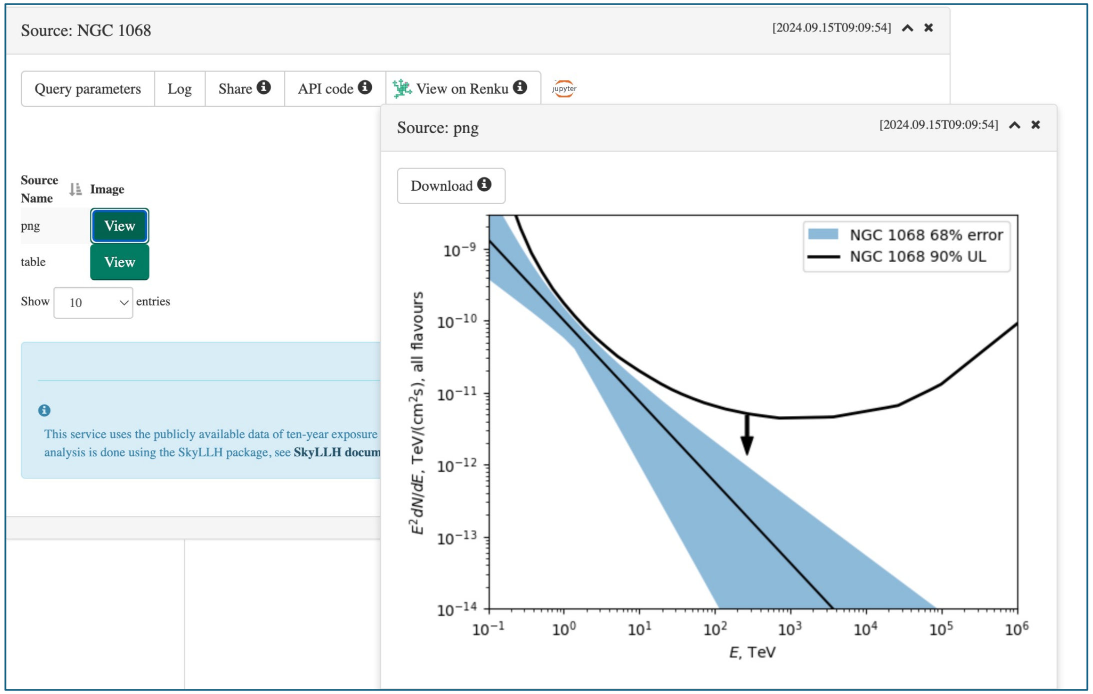
Example: IceCube analysis

Added value to the data: the original IceCube 10-year analysis publication only reported upper limits on (or measurements of) neutrino flux for a fixed set of sources from a pre-defined catalogue, for two different spectral models (E^{-3} or E^{-2} powerlaws).

Reuse cases: e.g. get an upper limit on neutrino flux for an an arbitrary *sky position*, arbitrary assumed *source spectrum*, for a given *time interval*, etc.







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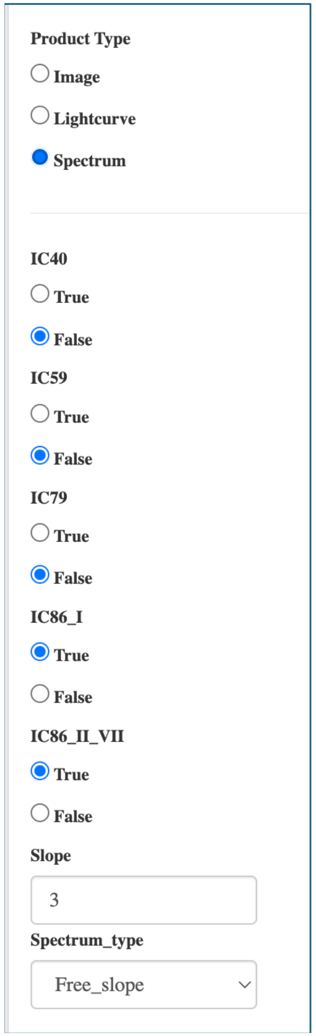
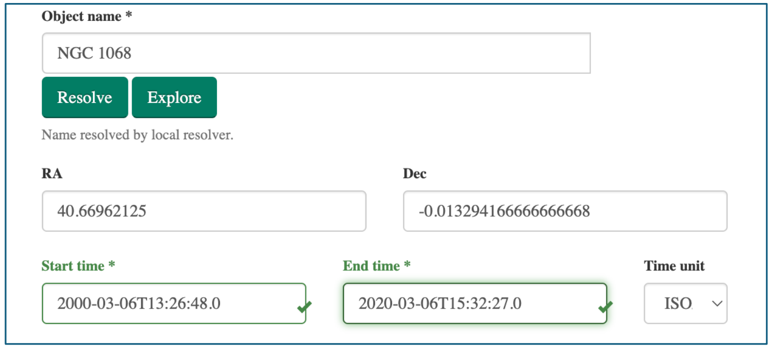


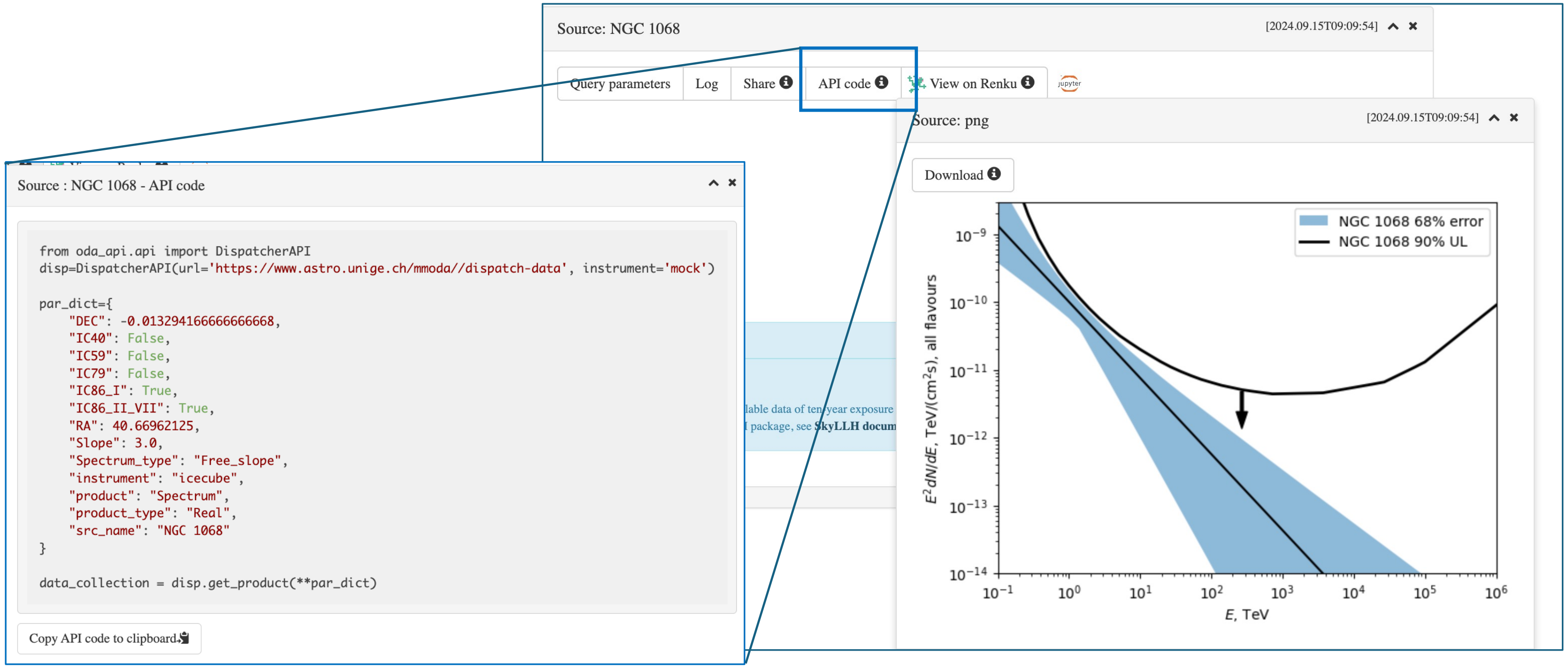


There are two ways to get the data product:

- through MMODA web front-end
- through Python API

`pip install --upgrade oda_api`

e.g. from a Python notebook locally on user laptop



open data, open software → web services (how to)

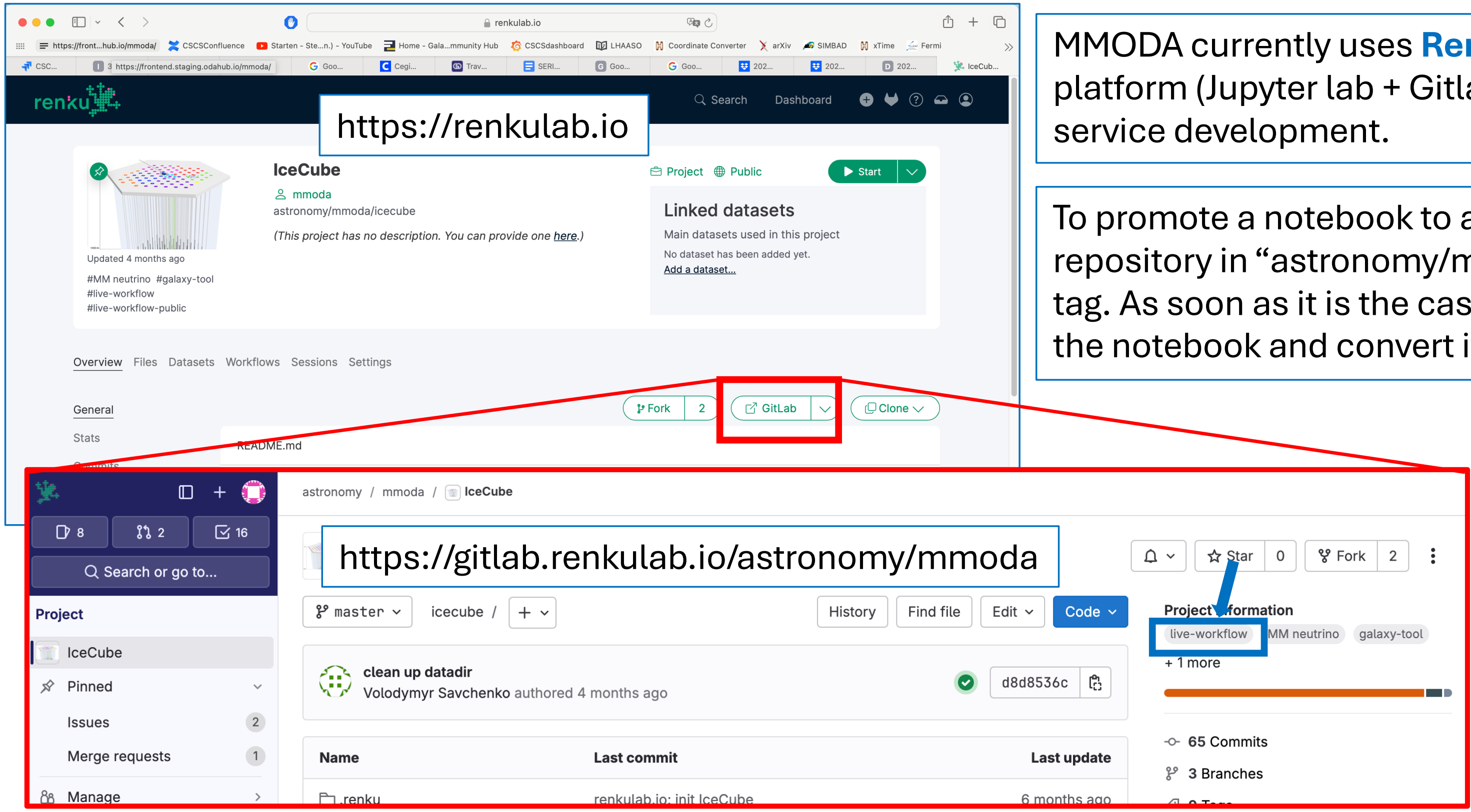
MMODA services can be created starting from e.g. a Python notebook, deposited to a dedicated Gitlab domain:

https://gitlab.renkulab.io/astronomy/mmoda

by users known to the MMODA team (you are welcome to give it a try!)

MMODA currently uses **Renkulab** collaborative data science platform (Jupyter lab + Gitlab) as a convenient environment for new service development.

To promote a notebook to a service, it is enough to tag the Gitlab repository in “astronomy/mmoda” domain with a “**live workflow**” tag. As soon as it is the case a “bot” scanning the domain will pick up the notebook and convert it to a service of MMODA.



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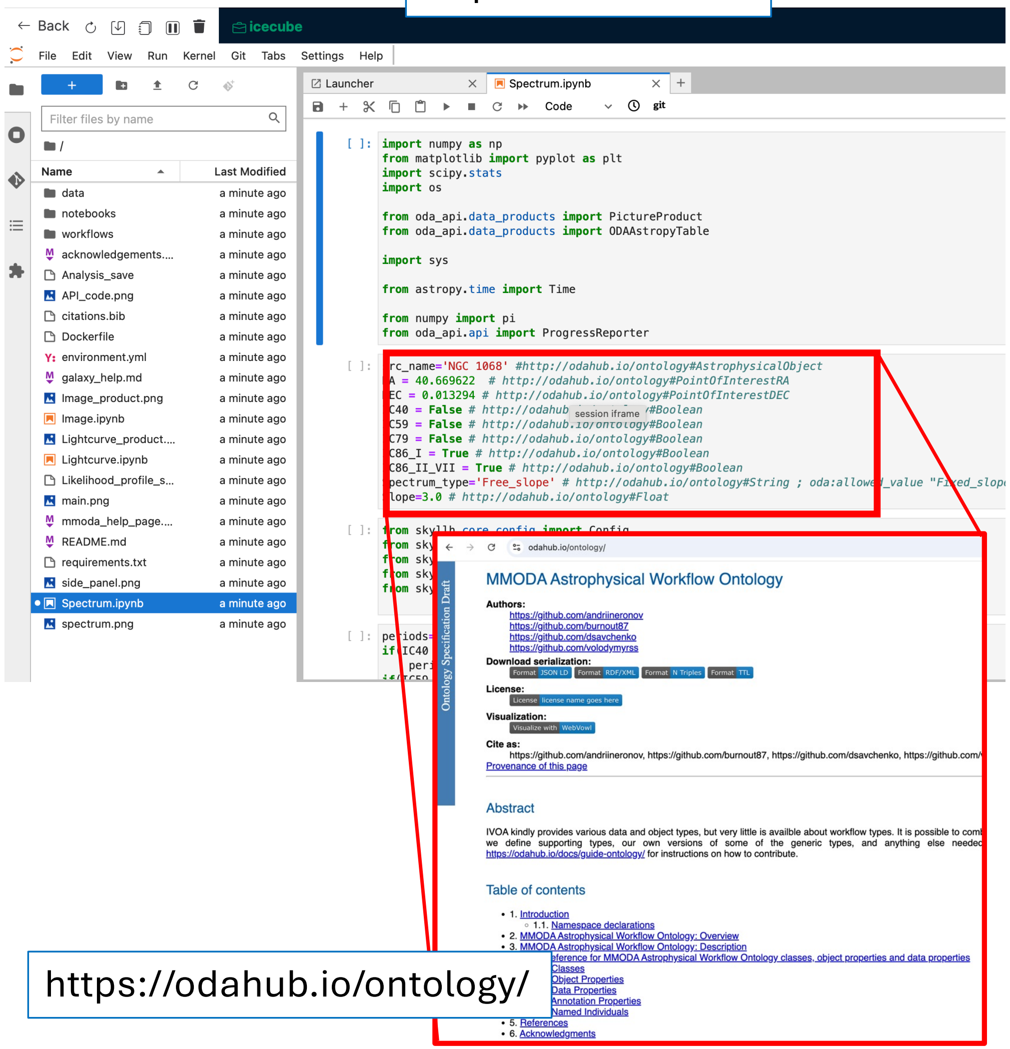

https://odahub.io/ontology/

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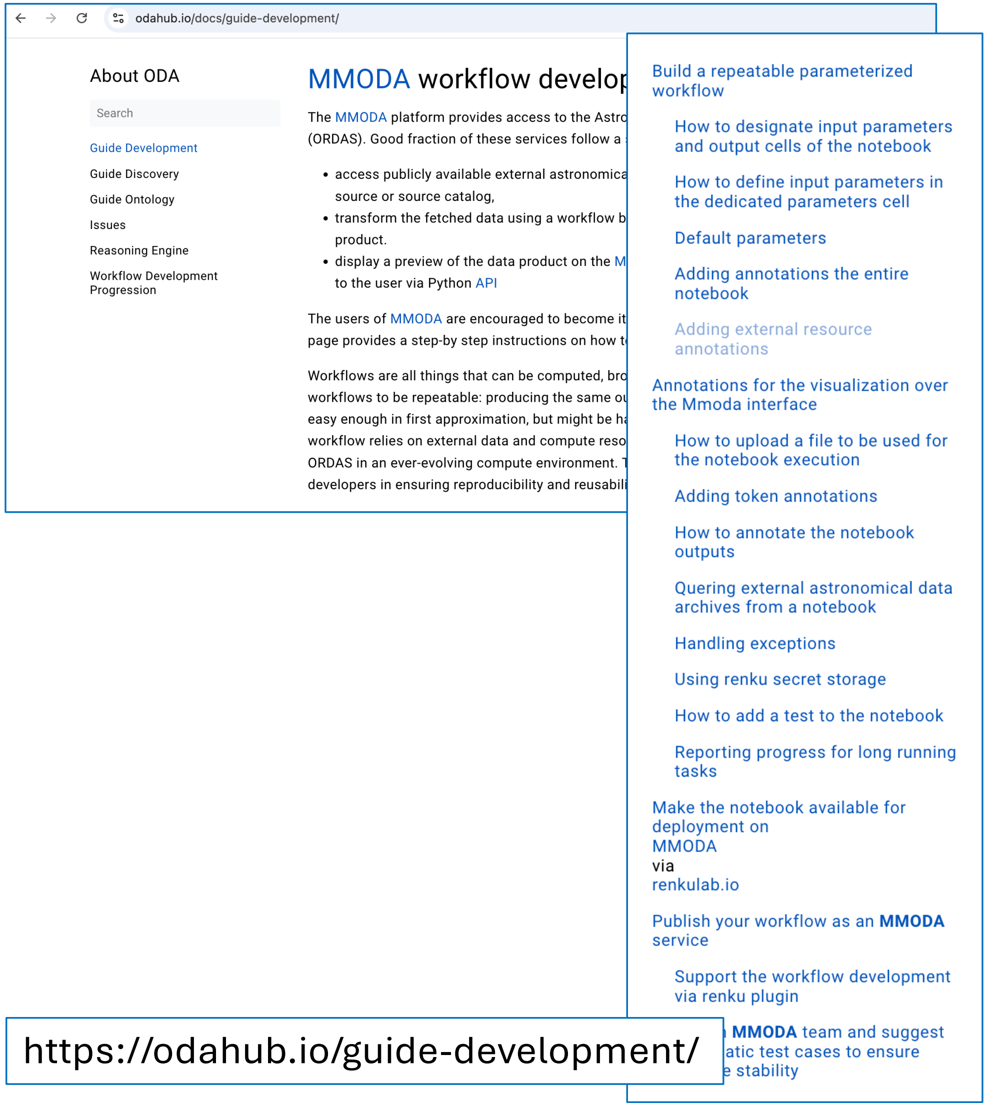
The ***bot*** identifies specific cells of the notebook that provide **input parameters** and **output data products** of the workflow. It also can interpret the parameters and outputs if they are annotated following certain “**astrophysical workflow ontology**”.

open data, open software → web services (how to)



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… MMODA team supports a “step-by-step” guide for adding new workflows. Give it a try adding a service for a telescope in which you have expertise in data analysis!

web service “flavours”

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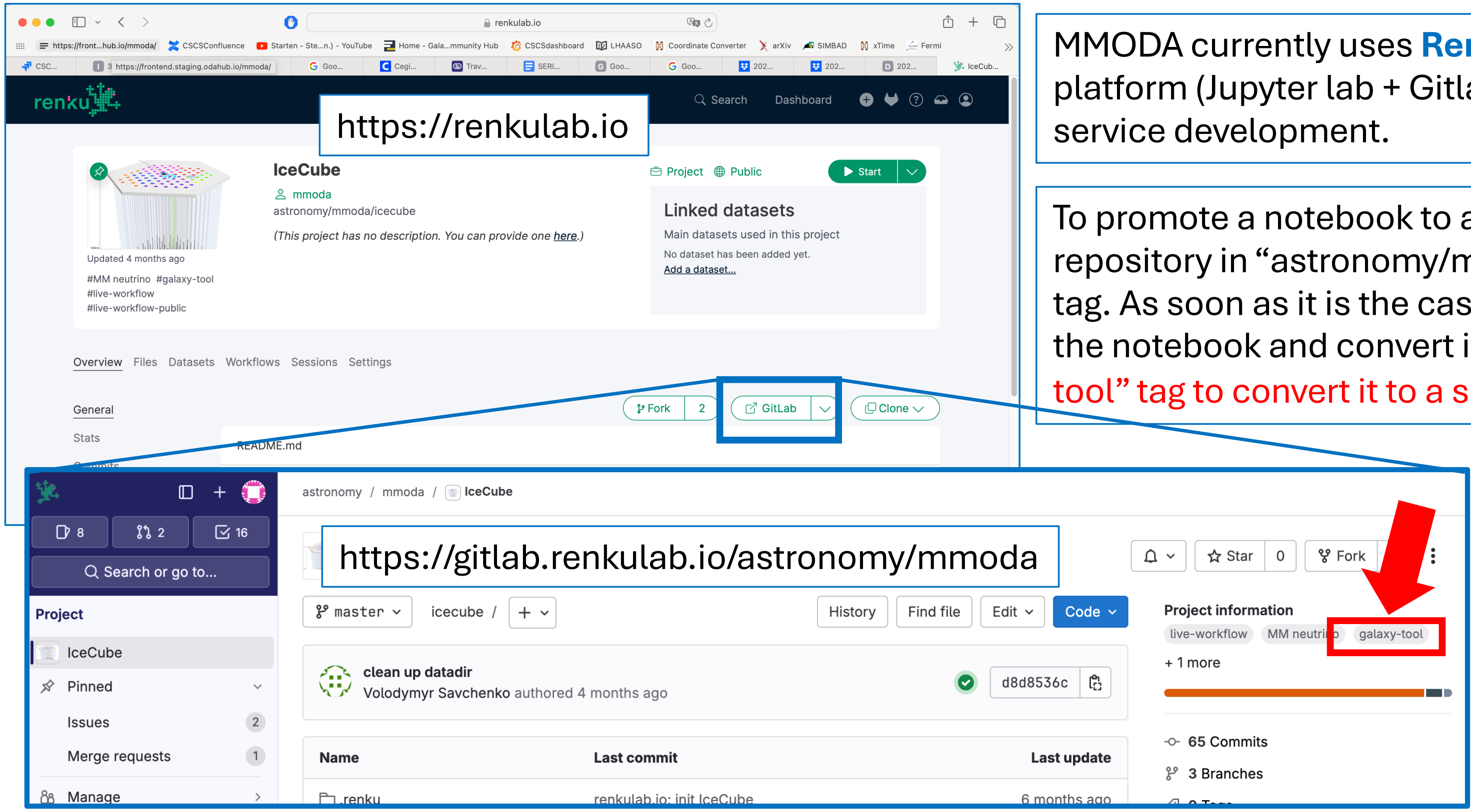
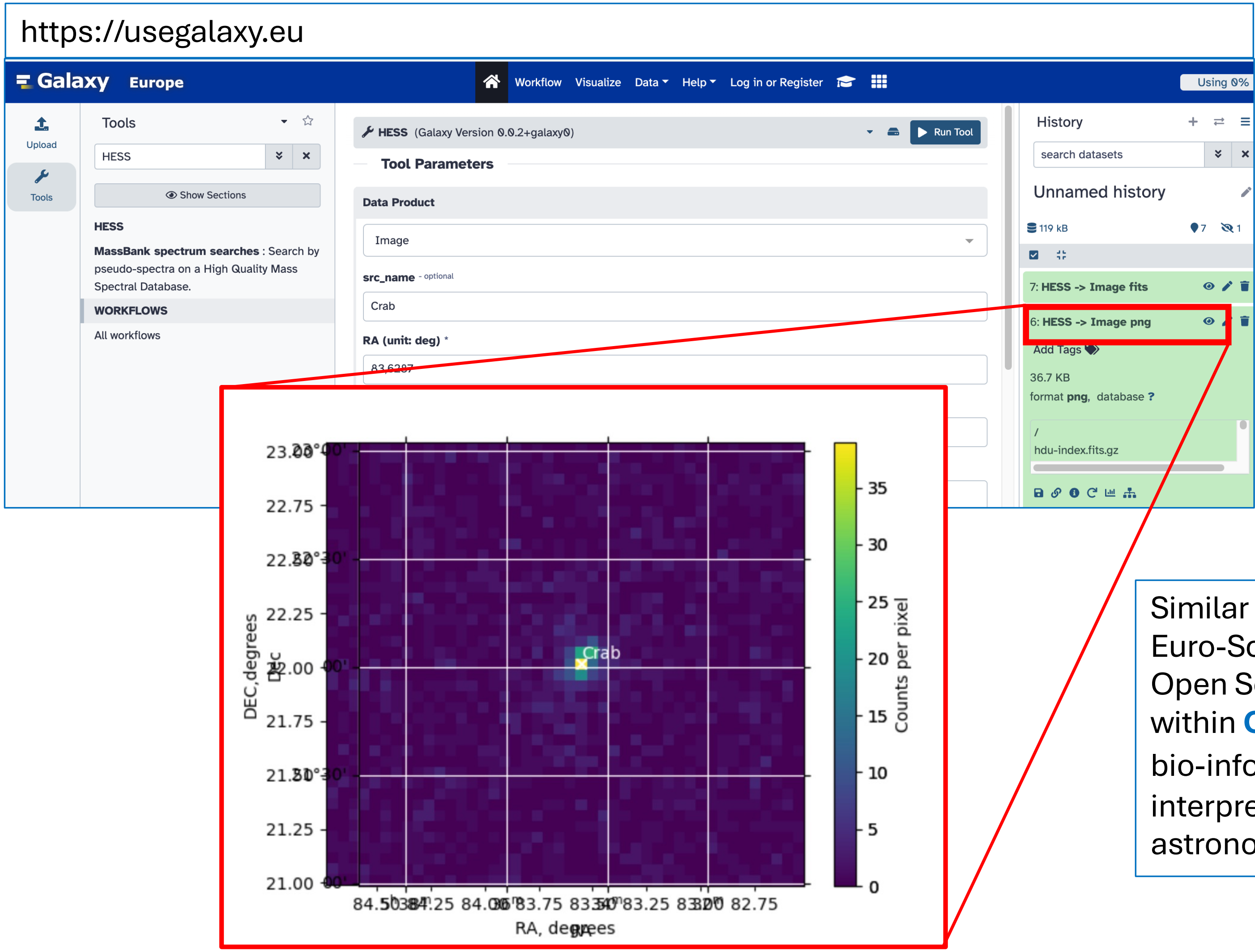
by users known to the MMODA team (you are welcome to give it a try!)

MMODA currently uses **Renkulab** collaborative data science platform (Jupyter lab + Gitlab) as a convenient environment for new service development.

To promote a notebook to a service, it is enough to tag the Gitlab repository in “astronomy/mmoda” domain with a “**live workflow**” tag. As soon as it is the case a “bot” scanning the domain will pick up the notebook and convert it to a service of MMODA… or a “galaxy-tool” tag to convert it to a service **Galaxy** platform!



web service “flavours”

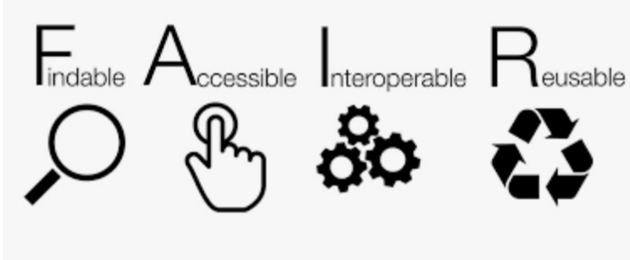


eosc
EuroScienceGateway

Similar “live-workflow” approach is developed by Euro-Science-Gateway project of the European Open Science Cloud (EOSC). It is implemented within **Galaxy** platform (originally developed by the bio-informatics community). MMODA ***bot*** can also interpret the workflows in the dedicated astronomy/mmoda Gitlab domain.

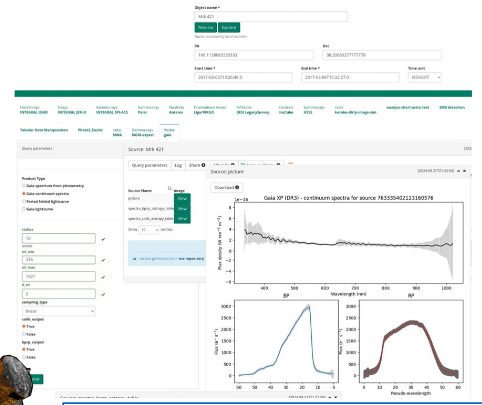
Summary

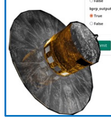
MMODA / Galaxy provide promising approach for making telescope data analysis workflow "live", a way to boost the **I**nteroperability / **R**eusability of data



Gaia

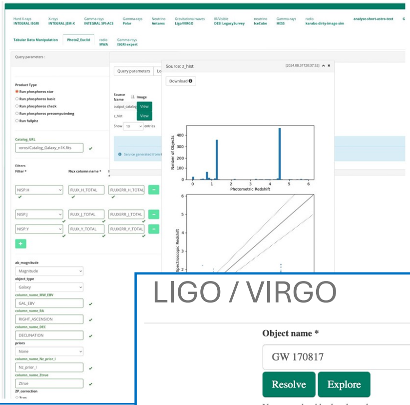
Milestone astrometric mission, we include tools for accessing is



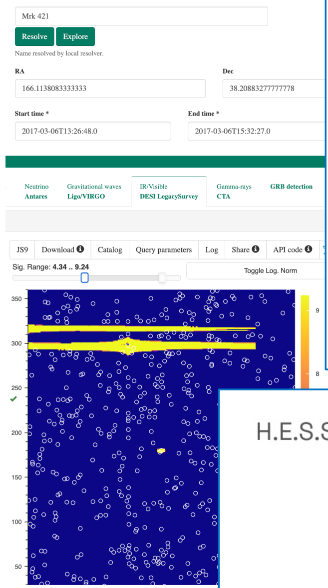


Euclid

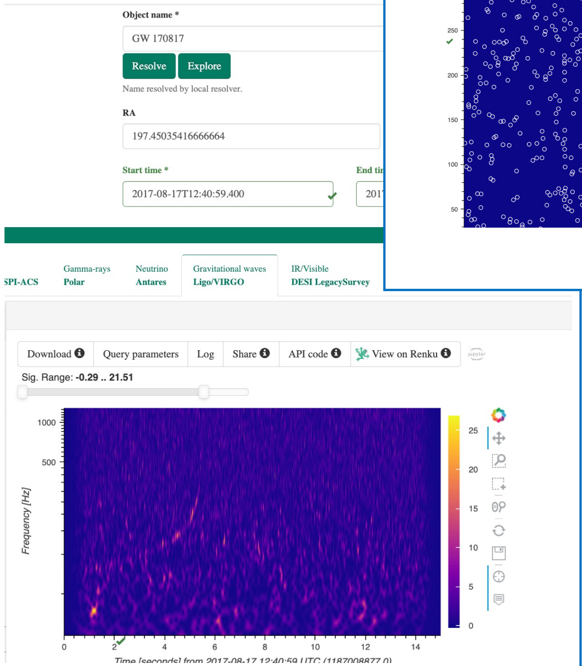
Recently launched cosmology mission, we include tool computing Photometric Redshift.



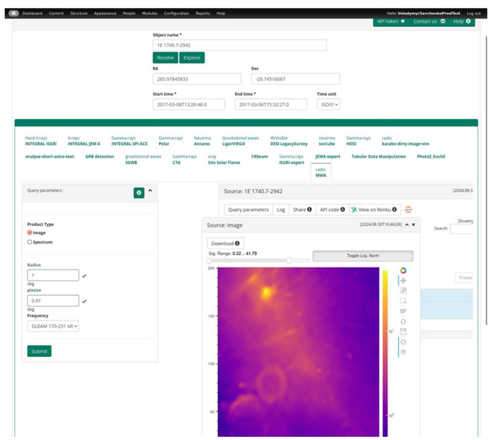
DESI Legacy Survey



LIGO / VIRGO



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



H.E.S.S.: older telescope, public data.