



crab

# Exploring the X-ray Universe with ESASky

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<sup>1</sup> Quasar Science Resources for ESA, ESAC Science Data Centre (ESDC)

*On behalf of Bruno Merín<sup>2</sup>, Guido de Marchi<sup>2</sup>, Marcos Lopez-Caniego<sup>3</sup>, Henrik Norman<sup>4</sup>, Philip Matsson<sup>4</sup>, Elena Puga<sup>4</sup>, Javier Espinosa<sup>5</sup> in the ESDC*

<sup>2</sup> ESA, <sup>3</sup> AuroraTechnology for ESA <sup>4</sup> Winter Way for ESA, <sup>5</sup> RHEA for ESA

29/02/2024

- Introduction to ESASky
- High-energy data and useful functionalities in ESASky
- Demo
- Future Plans
- Summary

**Goal:** a scientific tool to facilitate data discovery and archival science

- Multi-wavelength, -mission, -messenger portal
- Access to ~100 mission metadata & data, 56,000+ catalogues, 1100+ HiPS images.
- Driven by scientific use cases and needs from the scientific community
- Exploration and Data Discovery
- Archival science and unplanned science!



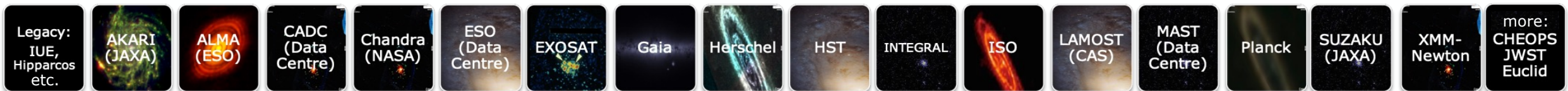
# Introduction: ESASky

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- Driven by scientific use cases and needs from the scientific community
- Exploration and Data Discovery
- Archival science and unplanned science!
- Interface 'on top of' all ESA astronomy archives + others



**ESASky** <https://sky.esa.int>

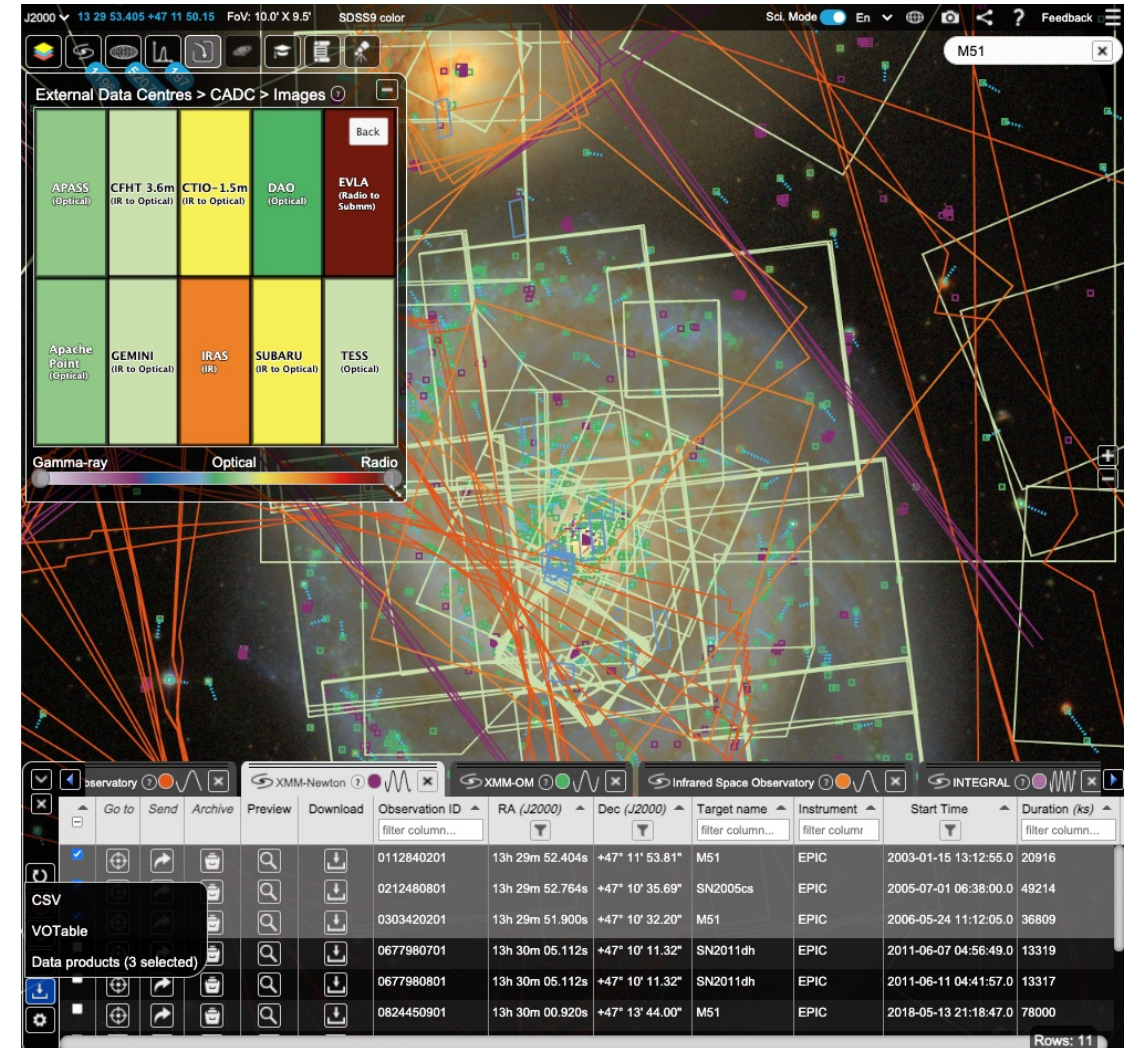


<https://youtu.be/iFFiNN1Iheg>

# How do users use ESASky for their science?

Main scientific functionalities:

- **Visual inspection** of skies (Hierarchical Progressive Surveys: HiPS), images, catalogues, footprints, probability regions, many in combination.
- **Data mining and downloading** (images, catalogues, spectra, cubes, time series, +), metadata and subsets of results tables.



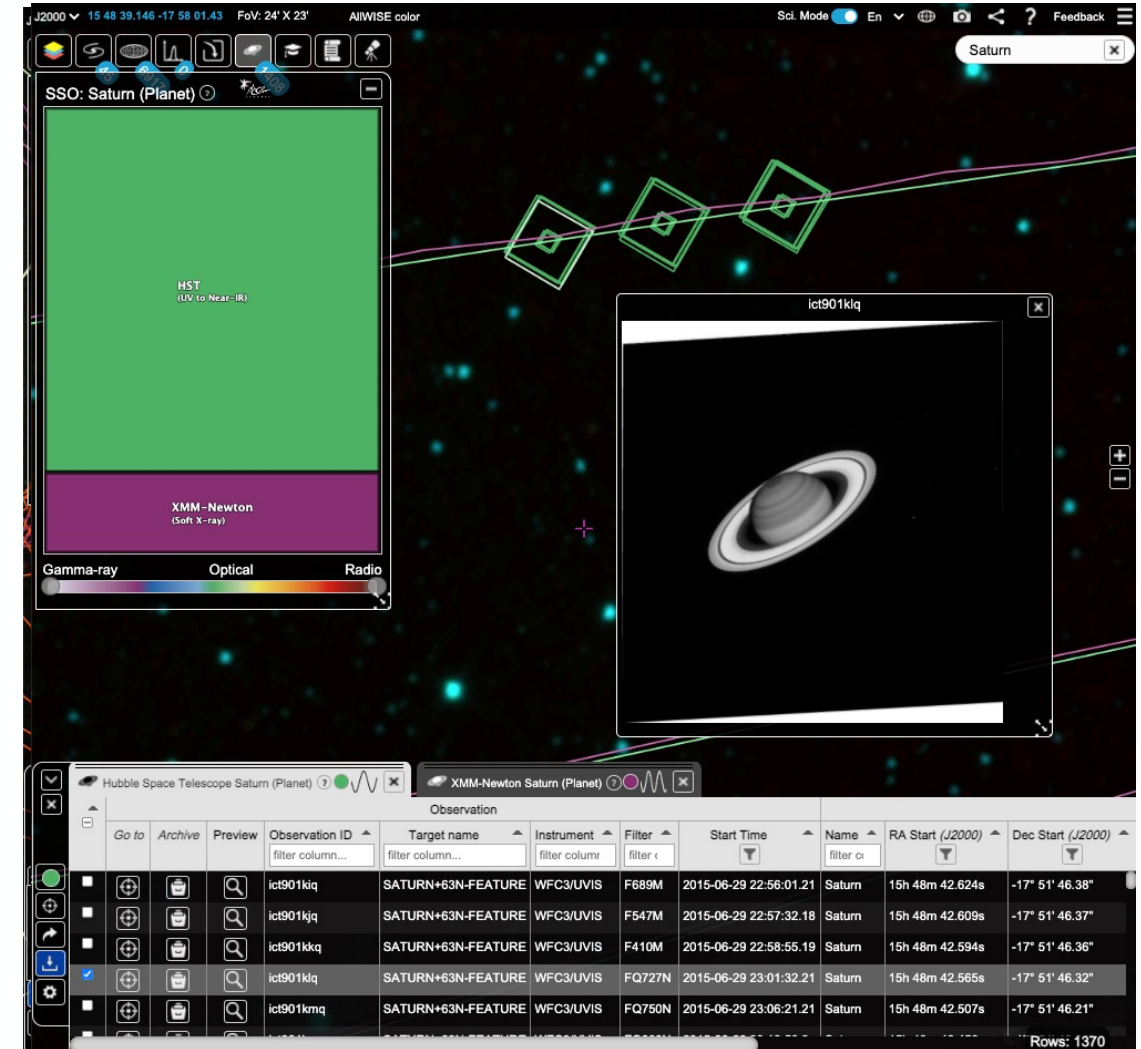
The screenshot displays the ESASky web interface. At the top, it shows coordinates (J2000: 13 29 53.405 +47 11 50.15) and a field of view (FoV: 10.0' X 9.5'). The main area is a star field with various colored lines and boxes representing survey footprints. A sidebar on the left lists external data centres and their instruments, categorized by wavelength: Gamma-ray, Optical, and Radio. The table at the bottom provides a list of observations with their respective metadata.

Observation ID	RA (J2000)	Dec (J2000)	Target name	Instrument	Start Time	Duration (ks)
0112840201	13h 29m 52.404s	+47° 11' 53.81"	M51	EPIC	2003-01-15 13:12:55.0	20916
0212480801	13h 29m 52.764s	+47° 10' 35.69"	SN2005cs	EPIC	2005-07-01 06:38:00.0	49214
0303420201	13h 29m 51.900s	+47° 10' 32.20"	M51	EPIC	2006-05-24 11:12:05.0	36809
0677980701	13h 30m 05.112s	+47° 10' 11.32"	SN2011dh	EPIC	2011-06-07 04:56:49.0	13319
0677980801	13h 30m 05.112s	+47° 10' 11.32"	SN2011dh	EPIC	2011-06-11 04:41:57.0	13317
0824450901	13h 30m 00.920s	+47° 13' 44.00"	M51	EPIC	2018-05-13 21:18:47.0	78000

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- **Search for observations of solar system objects** (targeted and serendipitous; Racero+ 2022 A&A 659 38)



The screenshot displays the ESASky interface. At the top, it shows the current sky location: J2000 15 48 39.146 -17 58 01.43, FoV: 24' X 23', and AINWIS color. The main view is a sky map of Saturn with several green observation footprints. A zoomed-in image of Saturn is shown in the bottom right, labeled 'ict901klq'. The interface includes a toolbar with various icons for navigation and analysis. Below the sky map, there is a table of observations.

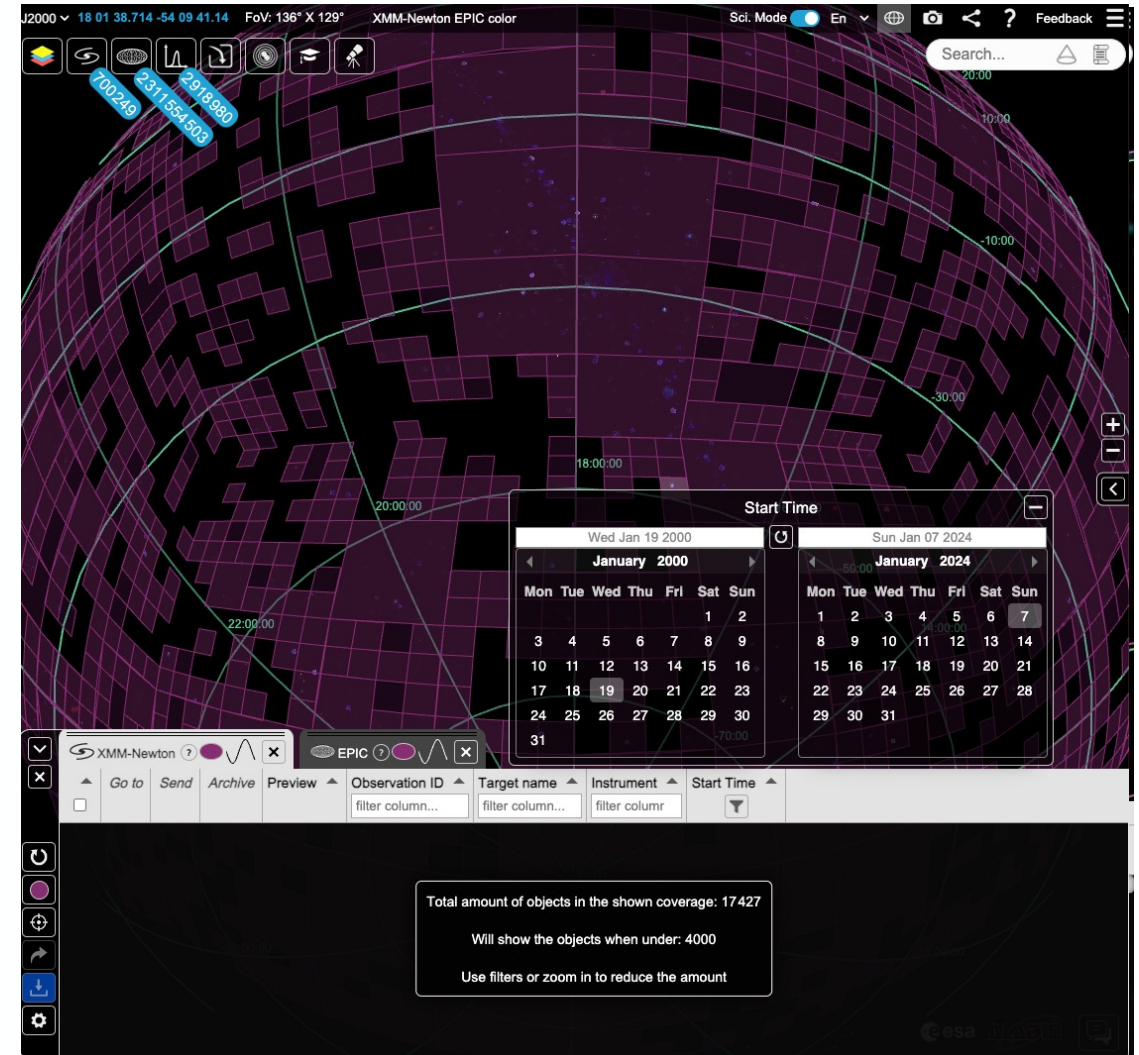
Go to	Archive	Preview	Observation ID	Target name	Instrument	Filter	Start Time	Name	RA Start (J2000)	Dec Start (J2000)
			ict901kiq	SATURN+63N-FEATURE	WFC3/UVIS	F689M	2015-06-29 22:56:01.21	Saturn	15h 48m 42.624s	-17° 51' 46.38"
			ict901kjq	SATURN+63N-FEATURE	WFC3/UVIS	F547M	2015-06-29 22:57:32.18	Saturn	15h 48m 42.609s	-17° 51' 46.37"
			ict901kkq	SATURN+63N-FEATURE	WFC3/UVIS	F410M	2015-06-29 22:58:55.19	Saturn	15h 48m 42.594s	-17° 51' 46.36"
			ict901klq	SATURN+63N-FEATURE	WFC3/UVIS	FQ727N	2015-06-29 23:01:32.21	Saturn	15h 48m 42.565s	-17° 51' 46.32"
			ict901kmq	SATURN+63N-FEATURE	WFC3/UVIS	FQ750N	2015-06-29 23:06:21.21	Saturn	15h 48m 42.507s	-17° 51' 46.21"

Rows: 1370

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- **Visualise and filter sky coverages** of observations and catalogues.

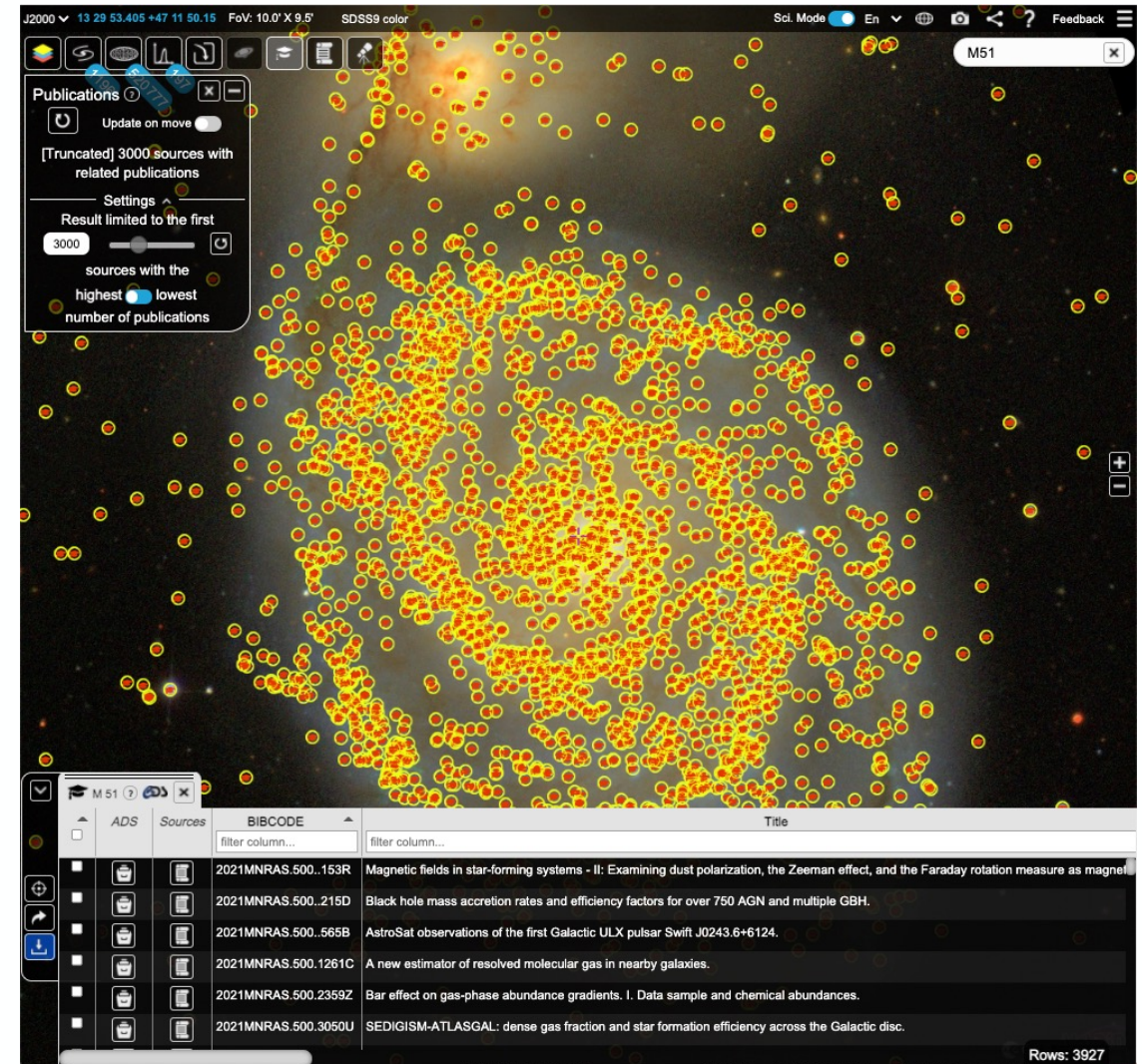




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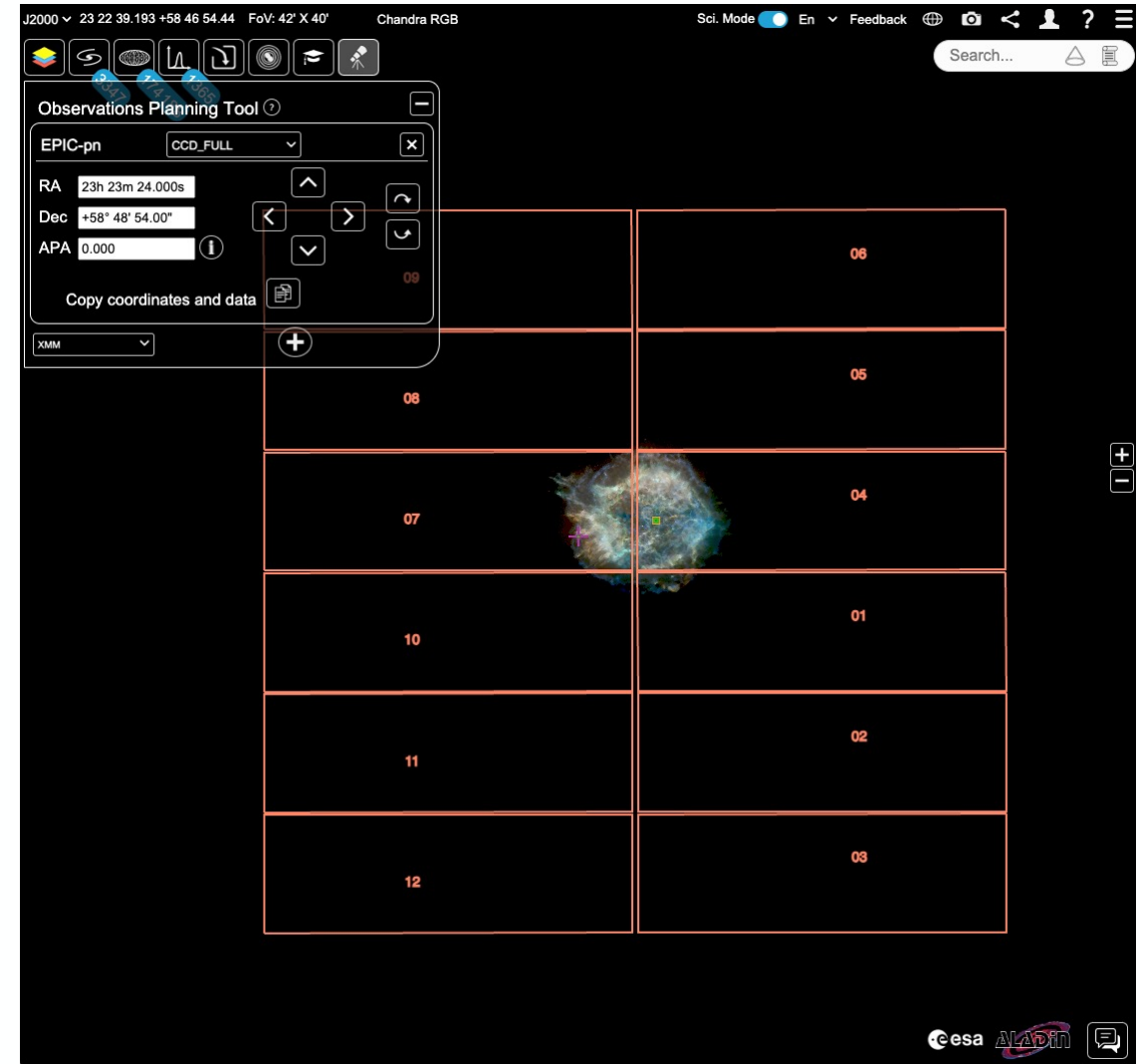
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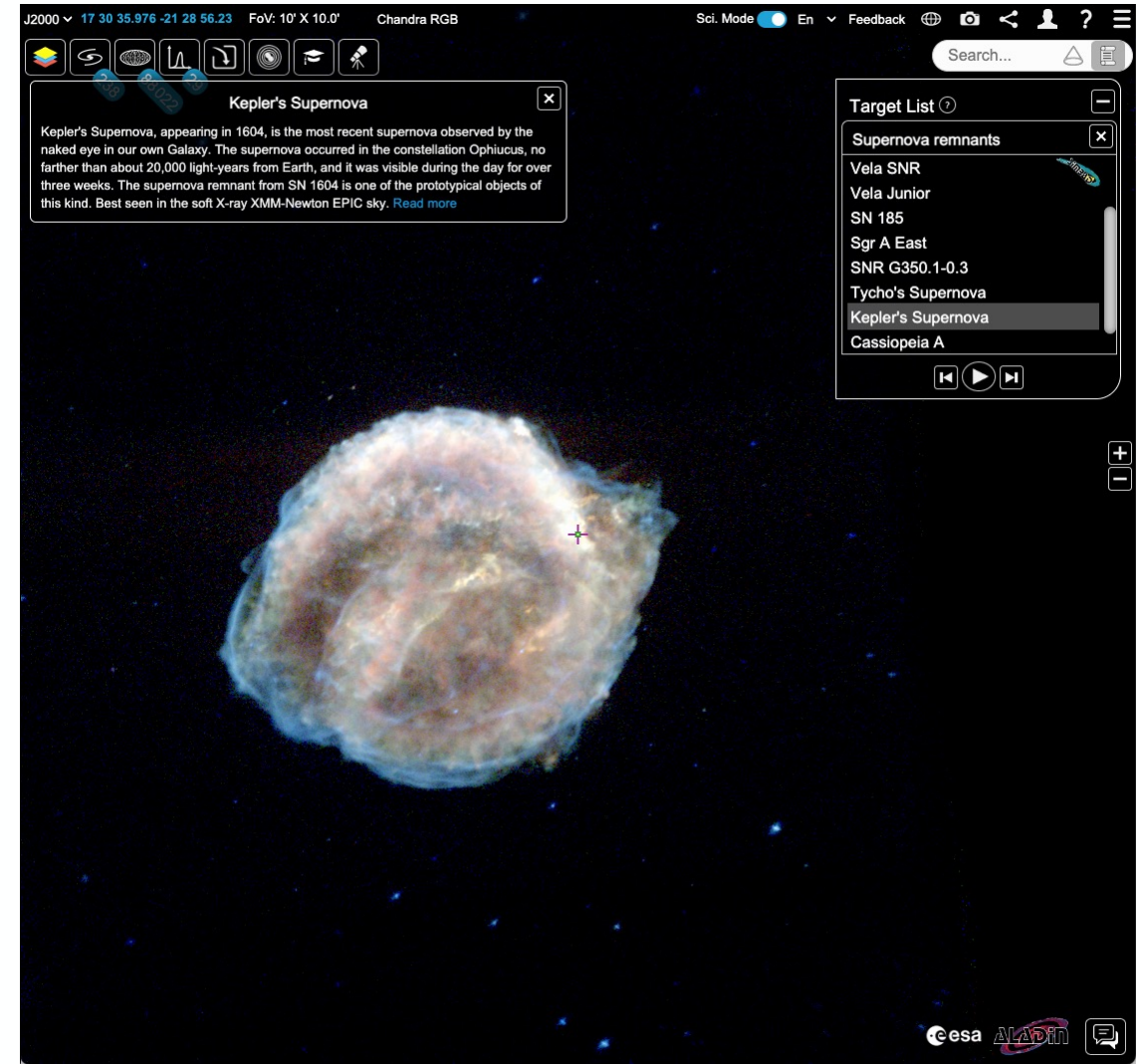
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- Upload and play through target lists.

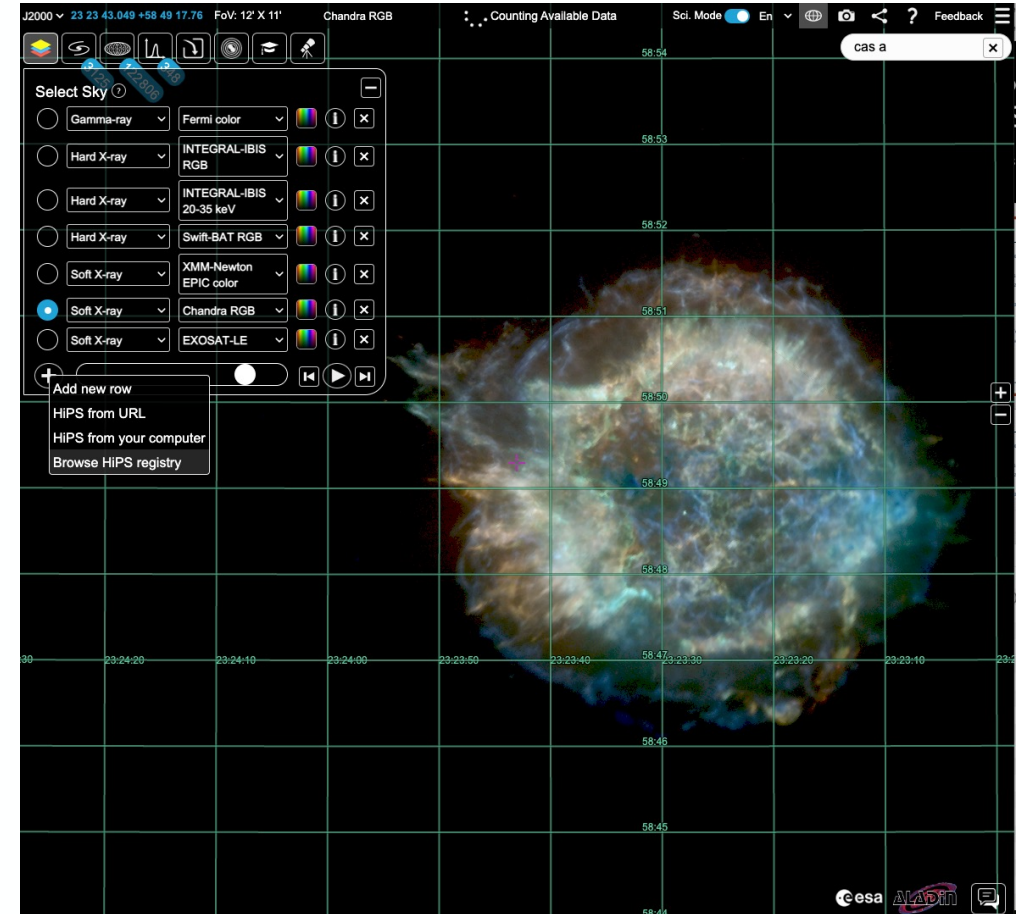


# High-energy data and functionalities

High-energy data and useful functionalities for high-energy astronomers:

## Data:

- **HiPS: Access to 12 high-energy HiPS and a further 60+ in the HiPS registry:** XMM-Newton EPIC; Chandra; SUZAKU; EXOSAT; eROSITA; INTEGRAL; Swift; Fermi plus ASCA; COMPTEL; EGRET; HGPS; Hitomi; MAXI; ROSAT.

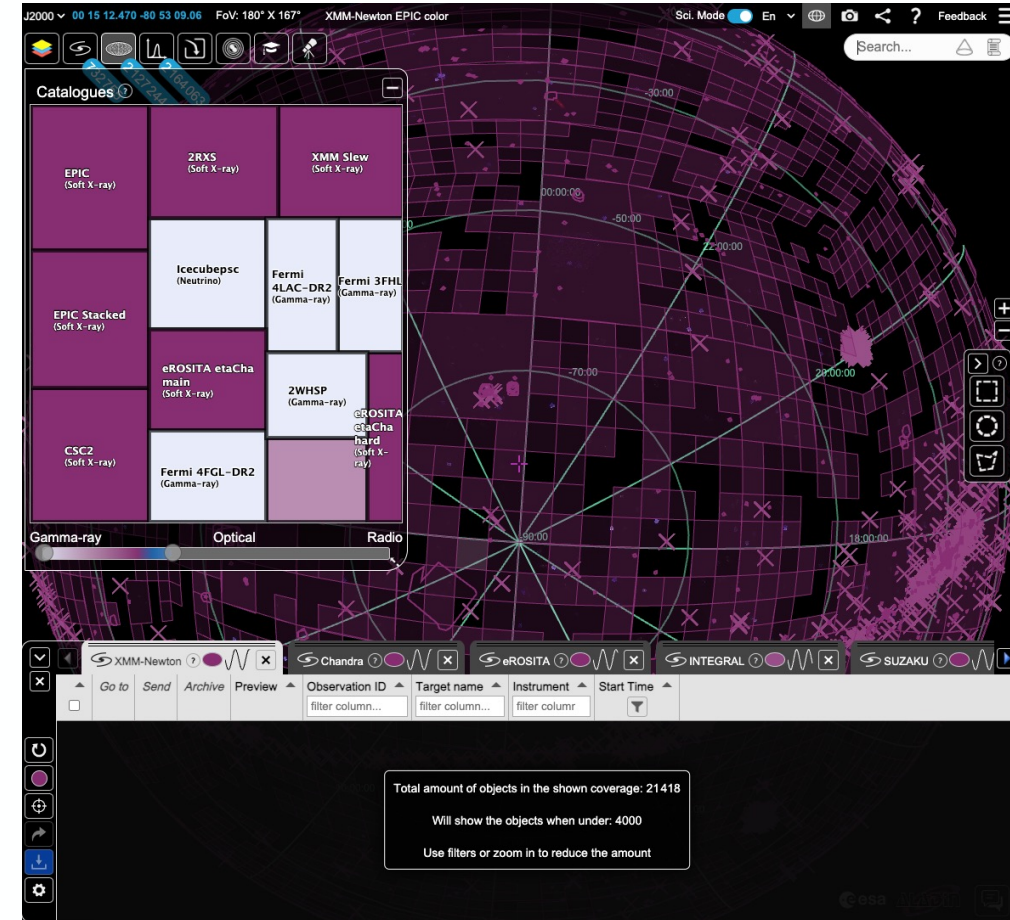


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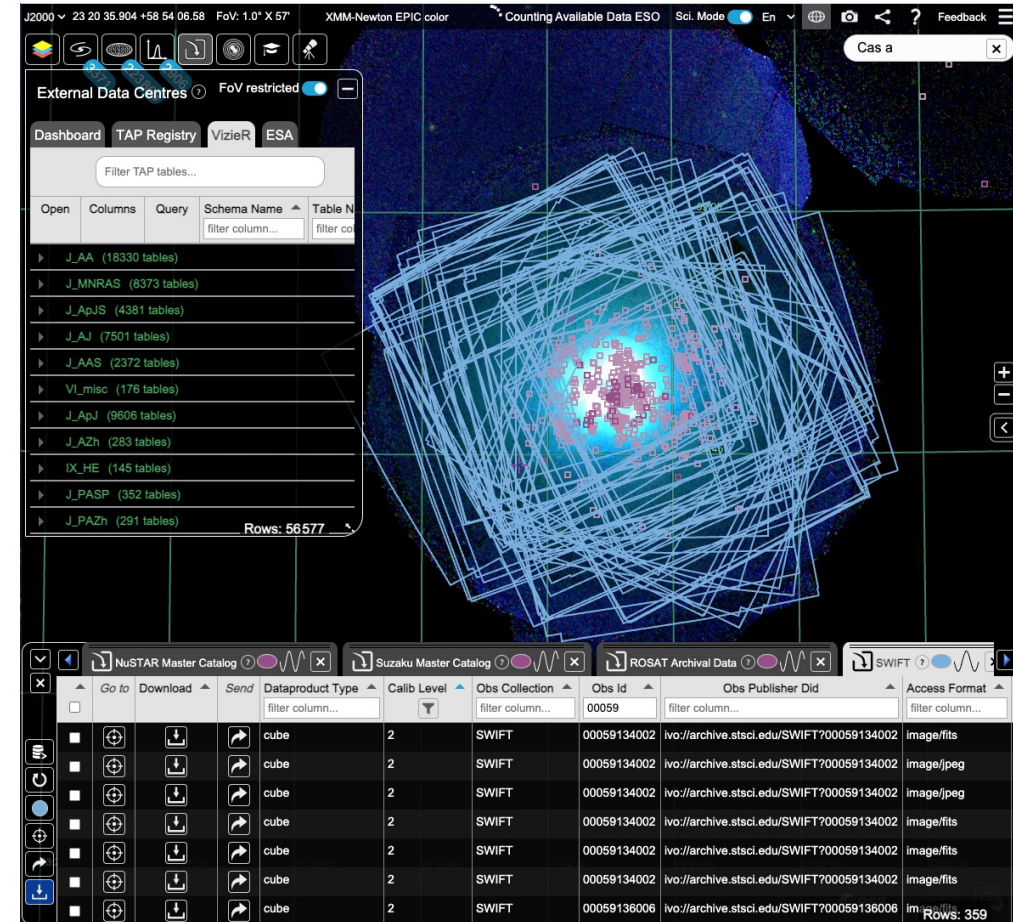


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- **High-energy catalogues:** XMM-Newton, Chandra, eROSITA, INTEGRAL, Fermi, ROSAT, IceCube and Blazars.
- **Access to high-energy data in the External Data Centres feature (TAPs):**
  - HEASARC, XMM-Newton, Chandra TAPs
  - ESASky legacy TAP (with EXOSAT, COS-B tables)
  - Access to all VizieR catalogues.

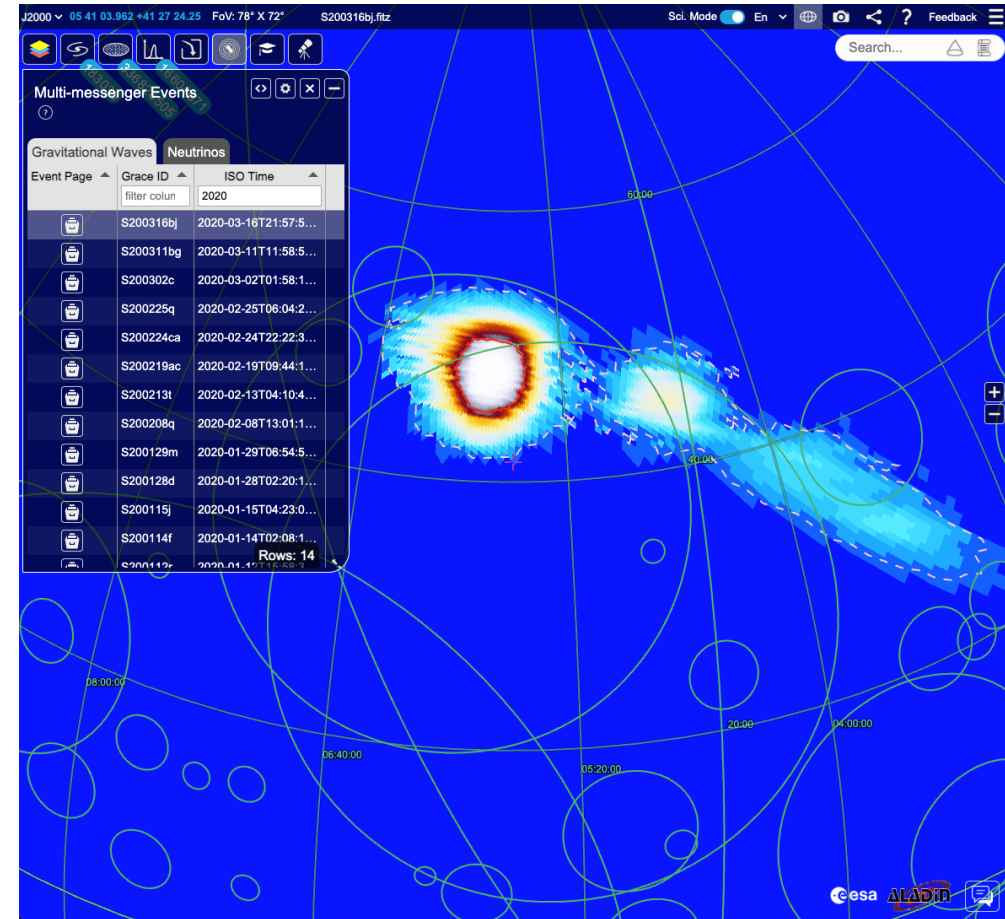


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## Multi-messenger Data:

- Access to Gravitational Wave events and probability maps: LIGO-Virgo-KAGRA collaboration
- Access to IceCube Neutrino events



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## Functionalities:

- Wavelength slider in treemaps (observations, catalogues and External Data Centres).
- XMM-Newton EPIC-pn footprint in planning tool.
- Publications feature.

The screenshot displays the XMM-Newton EPIC color interface. At the top, it shows the date J2000, coordinates 15 03 48.168 -42 03 04.92, and field of view (FoV) 1.0° X 56°. The main window features an 'Observations Planning Tool' with fields for RA (15h 02m 55.502s), Dec (-41° 55' 31.92"), and APA (18.000). Below these fields is a 'Copy coordinates and data' button. The background shows a color-coded astronomical image with a grid overlay and various colored circles. At the bottom, a table lists publications related to the field.

NAME Lupus SN	BIBCODE	Title
2023MNRAS.518.2574B		New ASKAP radio supernova remnants and candidates in the Large Magellanic Cloud.
2023ApJS...265...52W		The Long-term Monitoring Results of Insight-HXMT in the First 4 yr Galactic Plane Scanning Survey.
2023ApJ...946...44G		Rapid Expansion of the Young Type Ia Supernova Remnant 0519-69.0: More Evidence for a Circumstellar Shell.
2023ApJ...947...90R		A Possible Surviving Companion of the SN Ia in the Galactic SNR G272.2-3.2.
2023A&A...672A..57P		The X-ray synchrotron rims in Cassiopeia A narrow with energy.
2023A&A...672A..194R		Study of the effect of turbulent interstellar medium on the morphology of young supernova remnants.
2023A&A...672A..195D		Radio and infrared study of the supernova remnant candidate HESS J1912+101.

Rows: 1323



<https://youtu.be/ny2Zu2RUIpk>

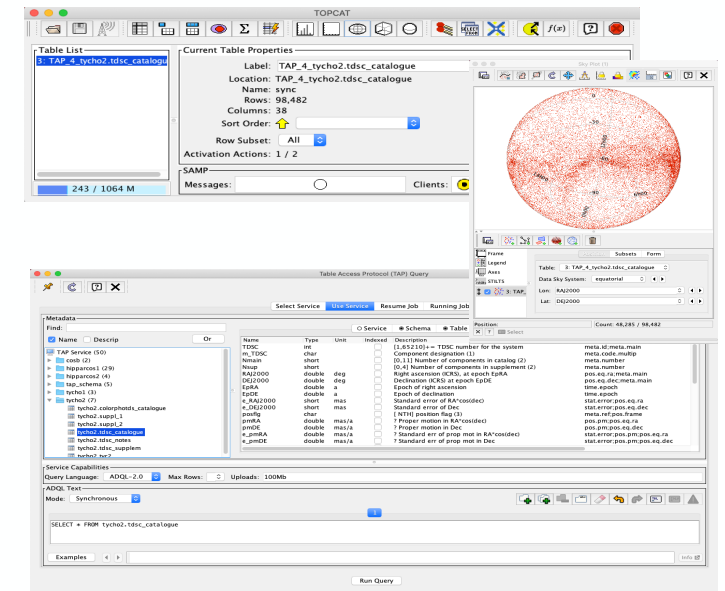
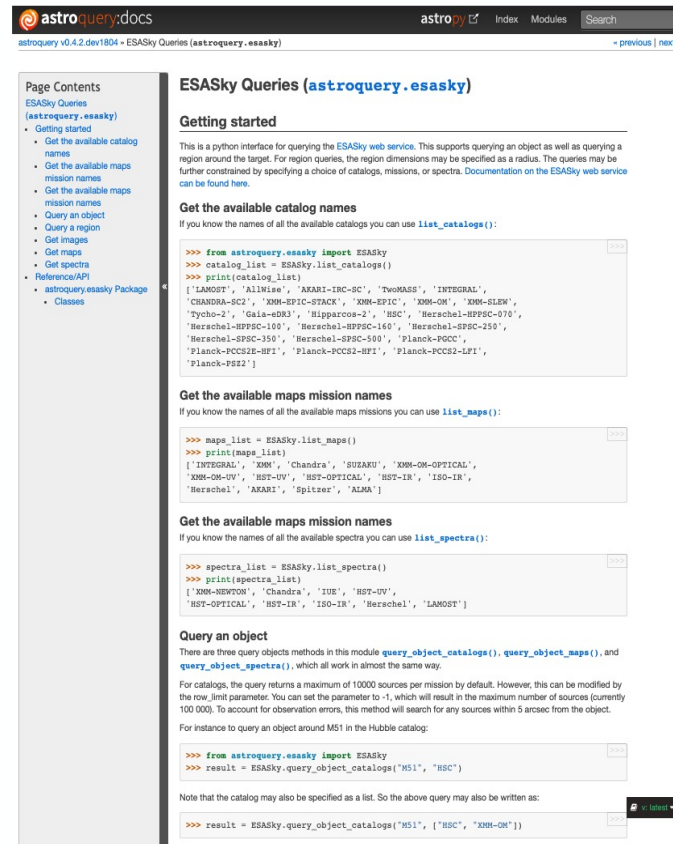
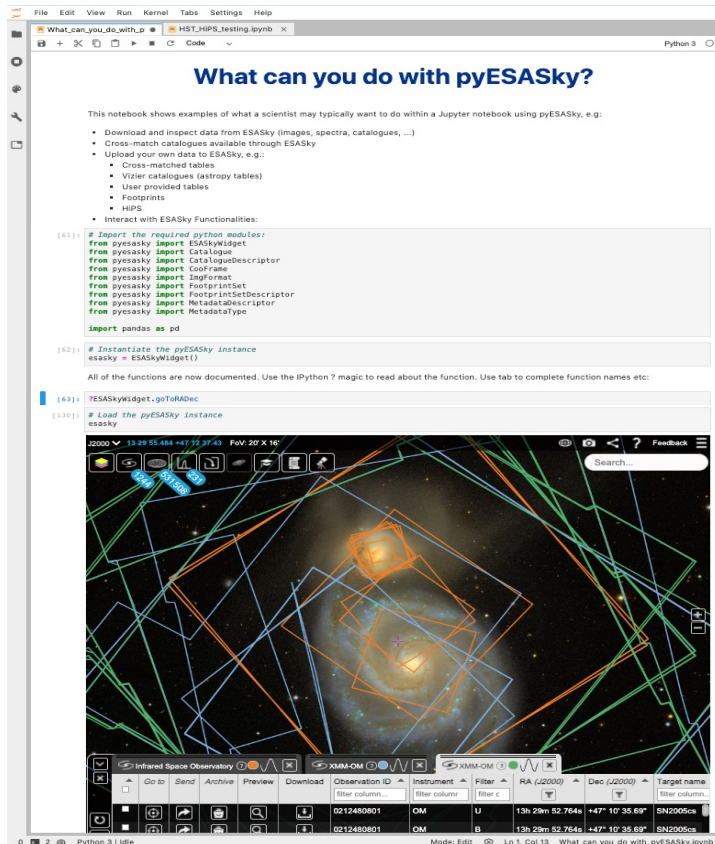
# Other ways to access data in ESASky



pyESASky  
Jupyter widget

Astroquery module:  
astroquery.esasky

Table Access Protocol  
(TAP) access

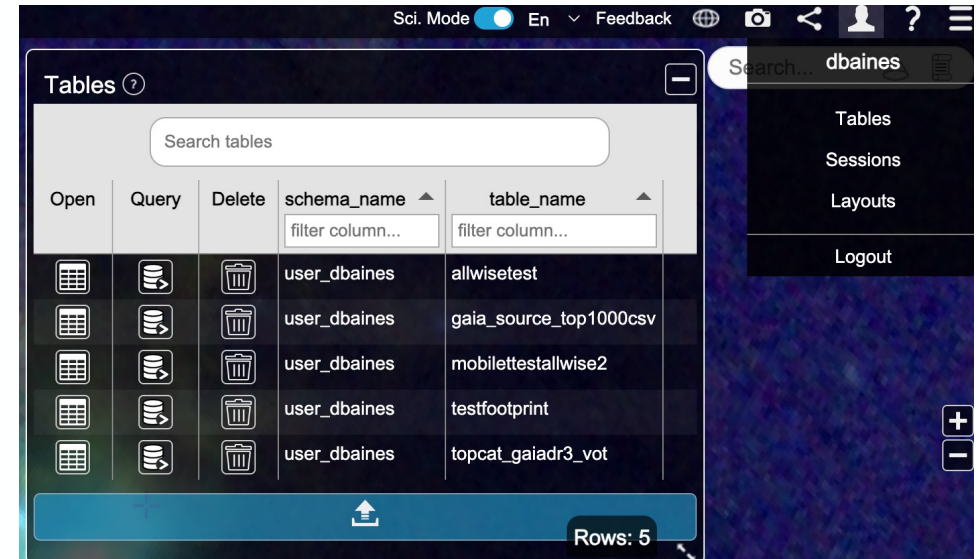


- <http://sky.esa.int/esasky-tap/tap>
- <http://esaskylegacy.esac.esa.int/esasky-legacy-sl-tap/tap>

Additional scientific use cases that you can't perform in the main interface.

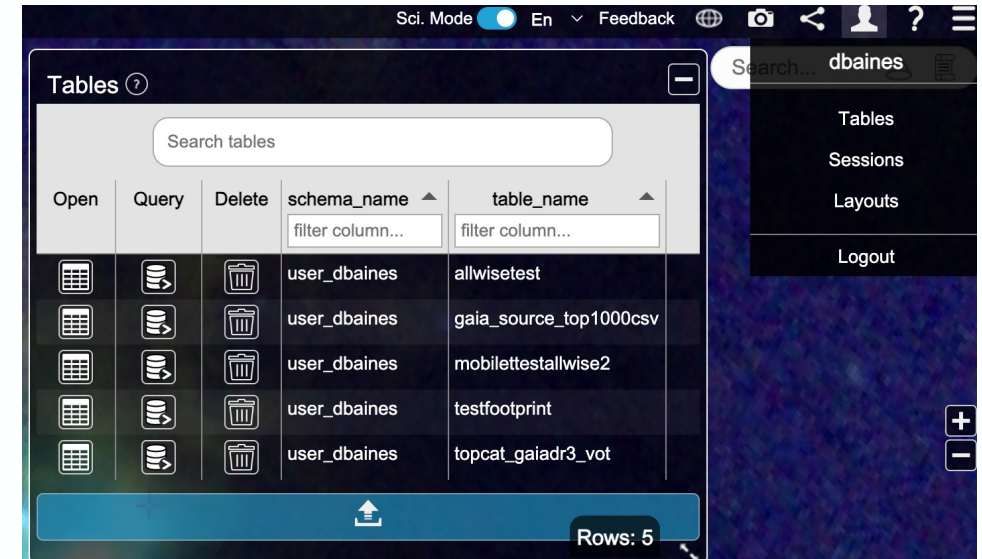
# ESASky (near)-future plans

- **User area** (released last week!): Upload your own tables, save your session, customise the ESASky layout, quotas per user currently 1 GB (more can be requested).
  - Future updates: upload your own images, sharing.



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  - Future updates: upload your own images, sharing.
- Access to **eROSITA DR1** data
- Extending the multi-messenger feature to include more types of events (e.g. **GRBs** etc.) reported in NASA GCN.
- Access to **Euclid Early Release Observations**.
- Updating to **AladinLite v3** -> fits image visualisation.
- **Time-series data visualization** functionality.
- And more! (catalogue updates, access to EPIC light curves, HILIGT, ...).



# Collaboration is key!



The screenshot shows the ALADIN web interface. At the top, it displays coordinates (J2000 15 03 44.312 -41 58 42.74) and instrument information (XMM-Newton EPIC color). A search bar contains 'SN 1006'. On the left, there's a 'External Data Centres' sidebar with a treemap showing connections to CADC, ESO, MAST, HEASARC, and ASTRON. Below this is a spectral energy distribution (SED) plot with 'Gamma-ray', 'Optical', and 'Radio' axes. The main view is a star field with overlaid observation tracks in various colors. At the bottom, there's a table of observation data:

Observation ID	RA (J2000)	Dec (J2000)	Target name	Instrument
w1dg5v01p	15h 03m 12.398s	-41° 59' 07.06"	HI-LAT	WFPC/WFC
w1dg5v02t	15h 03m 12.398s	-41° 59' 07.06"	HI-LAT	WFPC/WFC
w1dg5v03t	15h 03m 12.398s	-41° 59' 07.06"	HI-LAT	WFPC/WFC



# Collaboration is key!



International Virtual Observatory Alliance



Standards: HiPS

TAP

MOC

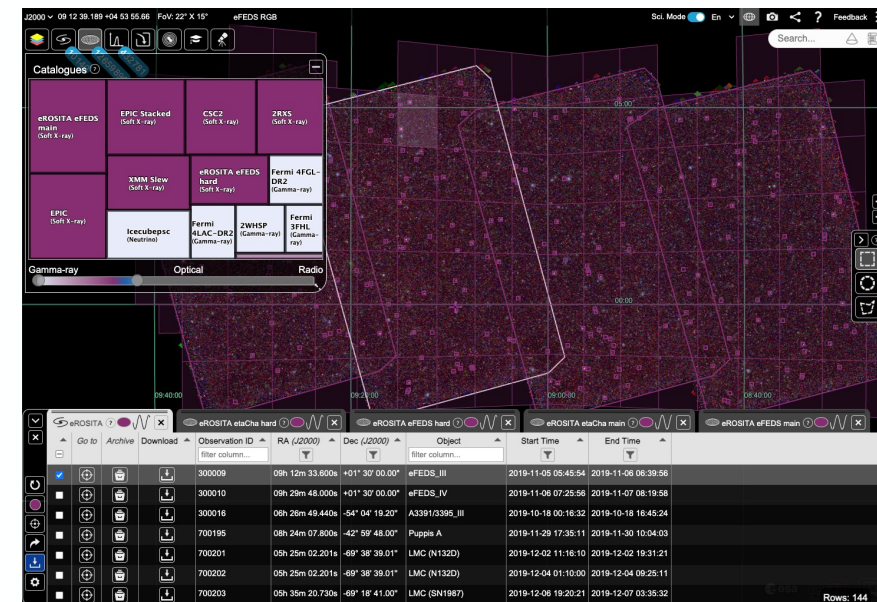
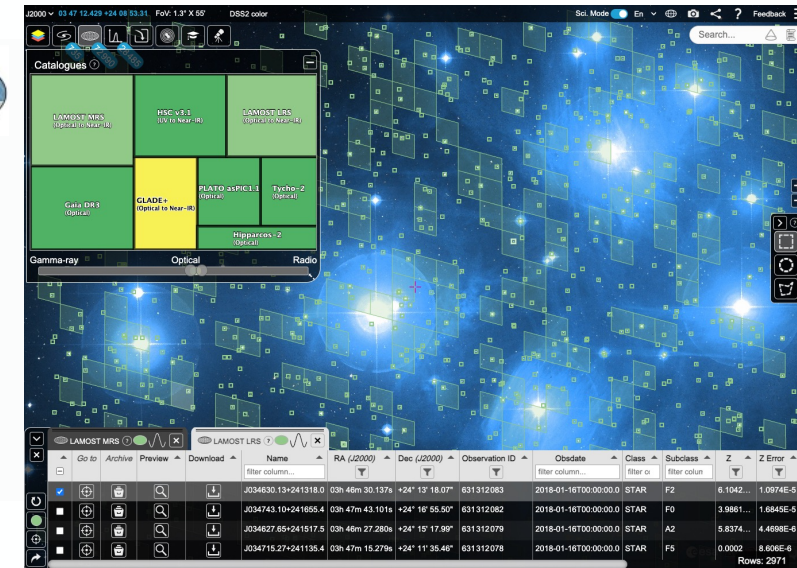
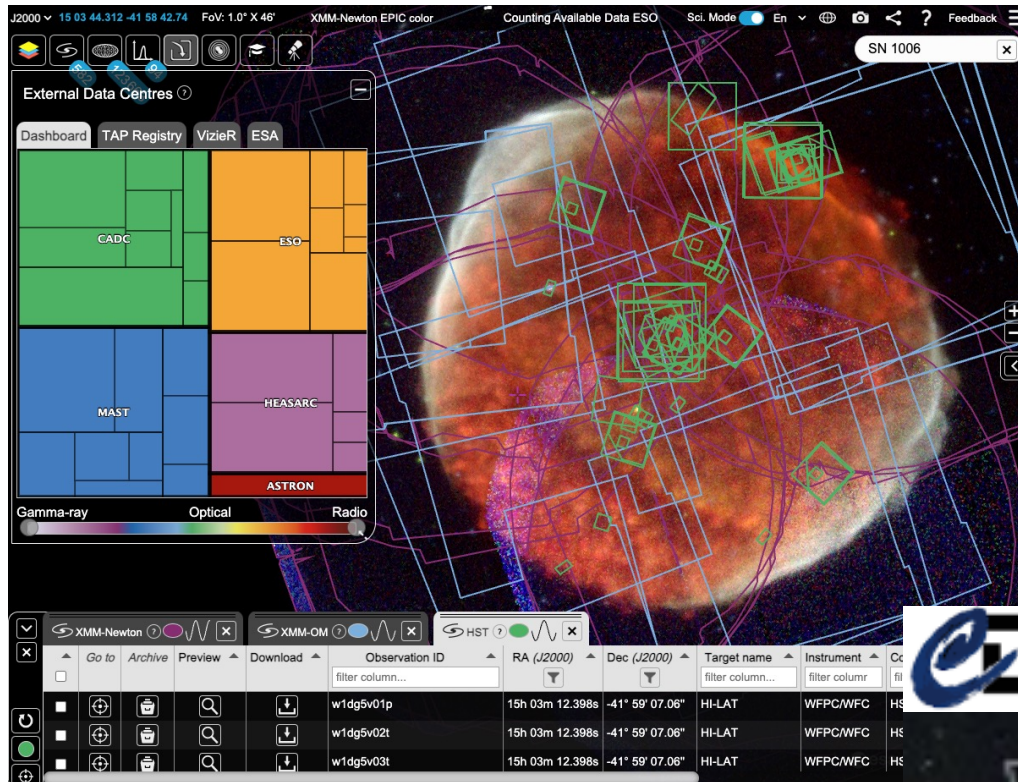
Datalink



ADQL

ObsCore

SAMP



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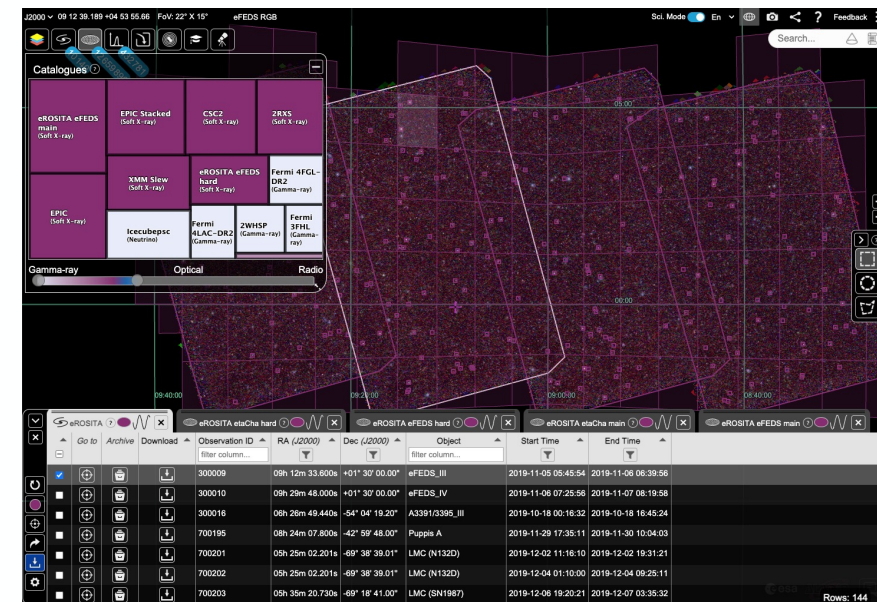
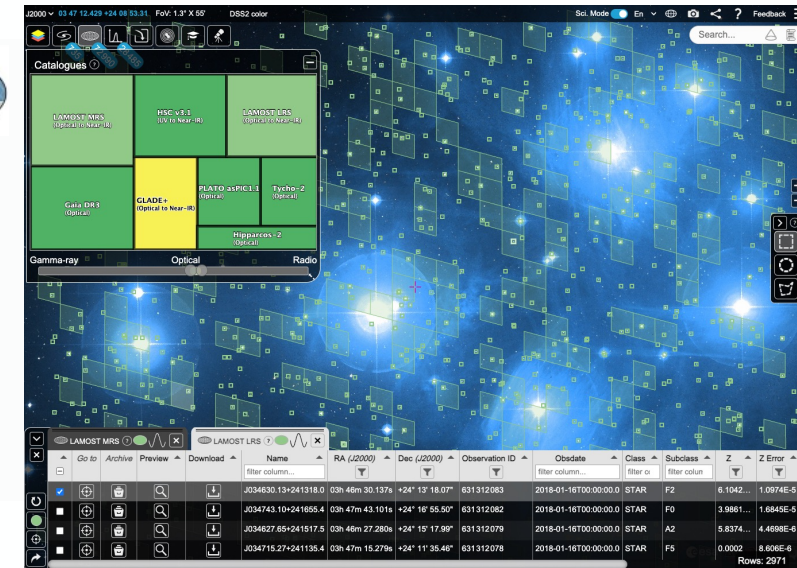
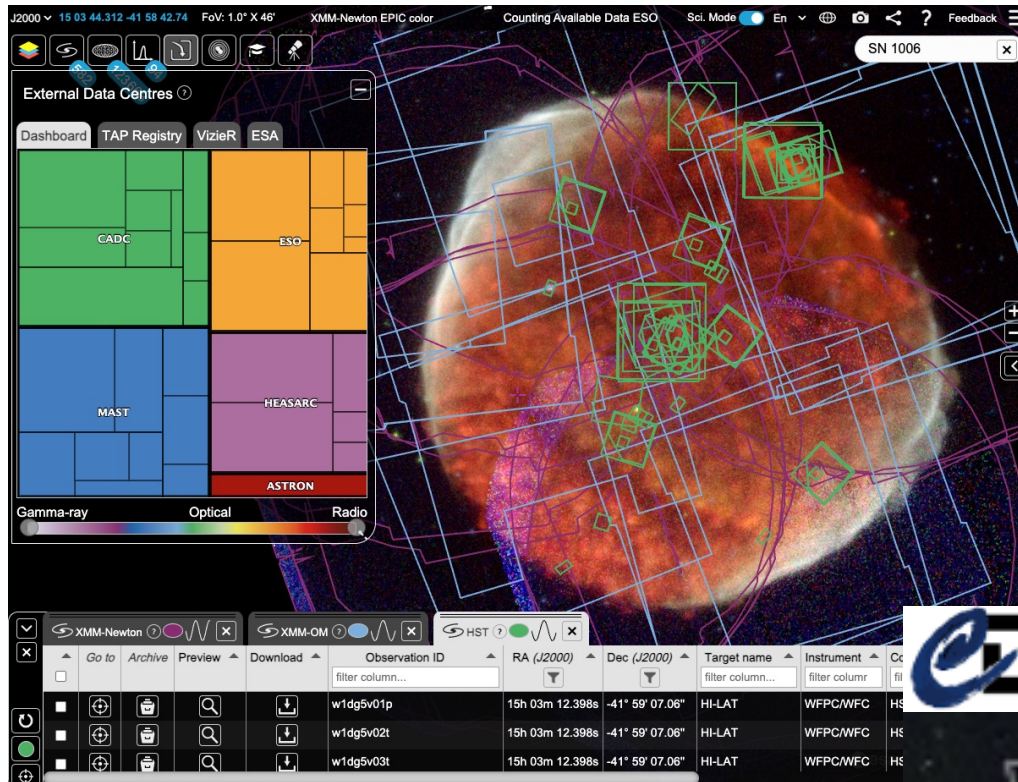
Datalink



ADQL

ObsCore

SAMP



Dedicated Python astroquery module to ESASky and pyESASky Jupyter widget

# Credits: a long and growing list of contributors!



- **Former ESASky team members:** Belén López Martí, Andy Pollock, Michael Rosa, Fabrizio Giordano, Elena Racero, Mattias Wångblad +more
- **CDS:** Pierre Fernique, Thomas Boch, Mark Allen, Anaïs Oberto, Matthieu Baumann, Caroline Bot.
- **XMM-Newton Science Operations Centre:** Pedro Rodríguez, Elena Jiménez-Bailón, Maria Santos-Lleo, Matthias Ehle and Norbert Schartel
- **INTEGRAL Science Operations Centre:** Guillaume Belanger, Erik Kuulkers, Peter Kretschmar, Jari Kajava.
- **Planck Science Office:** Marcos López-Caniego, Xavier Dupac and Jan Tauber.
- **Gaia Science Operations Centre:** Jos De Bruijne, Jorgo Bakker, Hector Canovas and Timo Prusti.
- **Herschel Science Centre:** Pedro García Lario, Eva Verdugo, Ivan Valtchanov, Miguel Sánchez-Portal, Pilar Esquej and Göran Pilbratt
- **ESAC Science and Operations IT Unit:** Alejandro Lorca, Roberto Prieto, Ruben Álvarez +team.
- **Centre for Astrobiology (CAB), ESAC:** Enrique Solano, Carlos Rodrigo. • **Euclid Science Centre:** Bruno Altieri, John Hoar and René Laureijs.
- **ASTRON:** Yan Grange, Mattia Mancini, Nico Vermaas • **HST:** Antonella Nota, Chris Evans, Paule Sonnentrucker and Jonas Haase (HST/ESO).
- **JWST:** Anthony Marston, Marco Sirianni, Sarah Kendrew, Tim Rawle and Macarena García-Marín.
- **Hubble/Webb outreach team:** Bethany Downer, Mahdi Zamani, Javier Enciso • **MAST/STScI:** Tom Donaldson • **HEASARC:** Tess Jaffe
- **Canadian Astronomy Data Centre (CADC):** Daniel Durand, Brian Major, JJ Kavelaars, Patrick Dowler, Séverin Gaudet
- **ESO:** Alberto Micol, Felix Stoehr • **Johns Hopkins University:** Tamás Budavári • **CHEOPS:** Kate Isaak
- **ISAS, JAXA:** Ken Ebisawa • **Jet Propulsion Laboratory, Caltech:** Krzysztof Górski • **LIGO Scientific Collaboration:** Chris North
- **Chandra, NASA:** Pepi Fabbiano, Janet Evans, Raffaele D'Abrusco, Yulie Zografou and Arnold Rots • **OCA, Nice:** Benoit Carry.
- **IMCCE, Paris:** Jérôme Berthier and Jonathan Normand (Solar system ephemeris and name resolver). • **Smithsonian/NASA ADS:** Alberto Accomazzi, Michael J. Kurtz, Sergi Blanco-Cuaresma • **China-VO/CAS:** Chenzhou Cui, Shanshan Li, Dongwei Fan, Hanxi Yang
- **eROSITA:** Andrea Merloni, Jonas Haase, Mara Salvato, Jeremy Sanders, Susanne Friedrich • **Spitzer, IRSA:** Steve Groom, Vandana Desai, Harry Teplitz. • **IceCube Neutrino Observatory:** Marcos Santander, Claudio Kopper, Michael Larson, Juan Antonio Aguilar

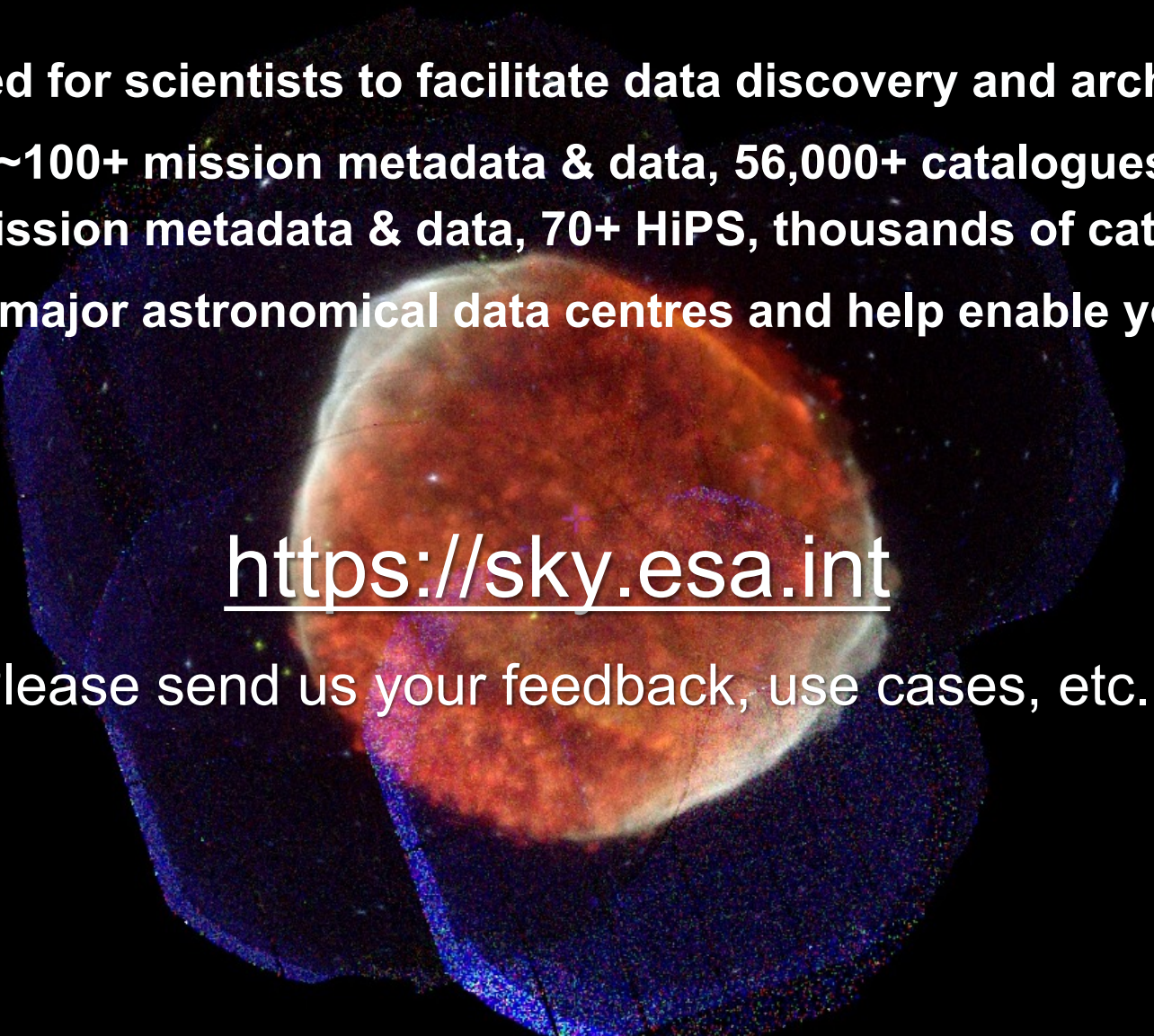


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- ESASky is developed for scientists to facilitate data discovery and archival science.
  - Provides access to ~100+ mission metadata & data, 56,000+ catalogues, 1100+ HiPS.  
High-energy: 30+ mission metadata & data, 70+ HiPS, thousands of catalogues.
  - Vision: to link to all major astronomical data centres and help enable your science!



# Many thanks!

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<https://sky.esa.int>

Please send us your feedback, use cases, etc.

Search View in WWT

- Hubble outreach images
- Webb outreach images
- Euclid outreach images
- Video Tutorials
- Release Notes
- Newsletter
- About Us
- Acknowledge ESASky
- ESA Virtual Assistant
- Save ESASky Session
- Restore ESASky Session





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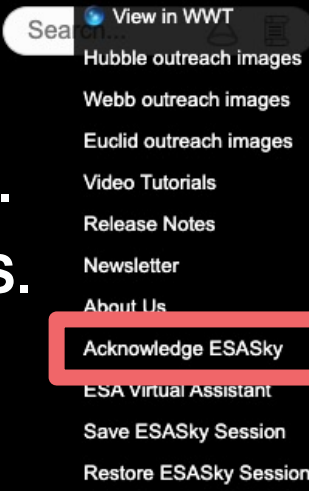
<https://sky.esa.int>

Please send us your feedback, use cases, etc.

Please acknowledge us if you use ESASky or pyESASky for your science!

deborah.baines@ext.esa.int

@parttimeastro



- ESASky: <https://sky.esa.int>
- How to use ESASky, videos and links to help pages: <https://www.cosmos.esa.int/web/esdc/esasky-how-to>
- pyESASky: <https://www.cosmos.esa.int/web/esdc/pyESASky>
- pyESASky notebooks: <https://github.com/esdc-esac-esa-int/pyesasky/tree/master/samples>
- astroquery.esasky: <https://www.cosmos.esa.int/web/esdc/esasky-astroquery-module>
- ESASky TAP: <https://sky.esa.int/esasky-tap/tap>
- ESASky Legacy archive TAP: <https://esaskylegacy.esac.esa.int/esasky-legacy-sl-tap/tap>
- ESASky Javascript API: <https://www.cosmos.esa.int/web/esdc/esasky-javascript-api>
- How to contribute data to ESASky: <https://www.cosmos.esa.int/web/esdc/esasky-contributing>
- Educational activities: <https://www.cosmos.esa.int/web/esdc/esasky-for-education>
- Contact and feedback: <https://esdc.userecho.com>