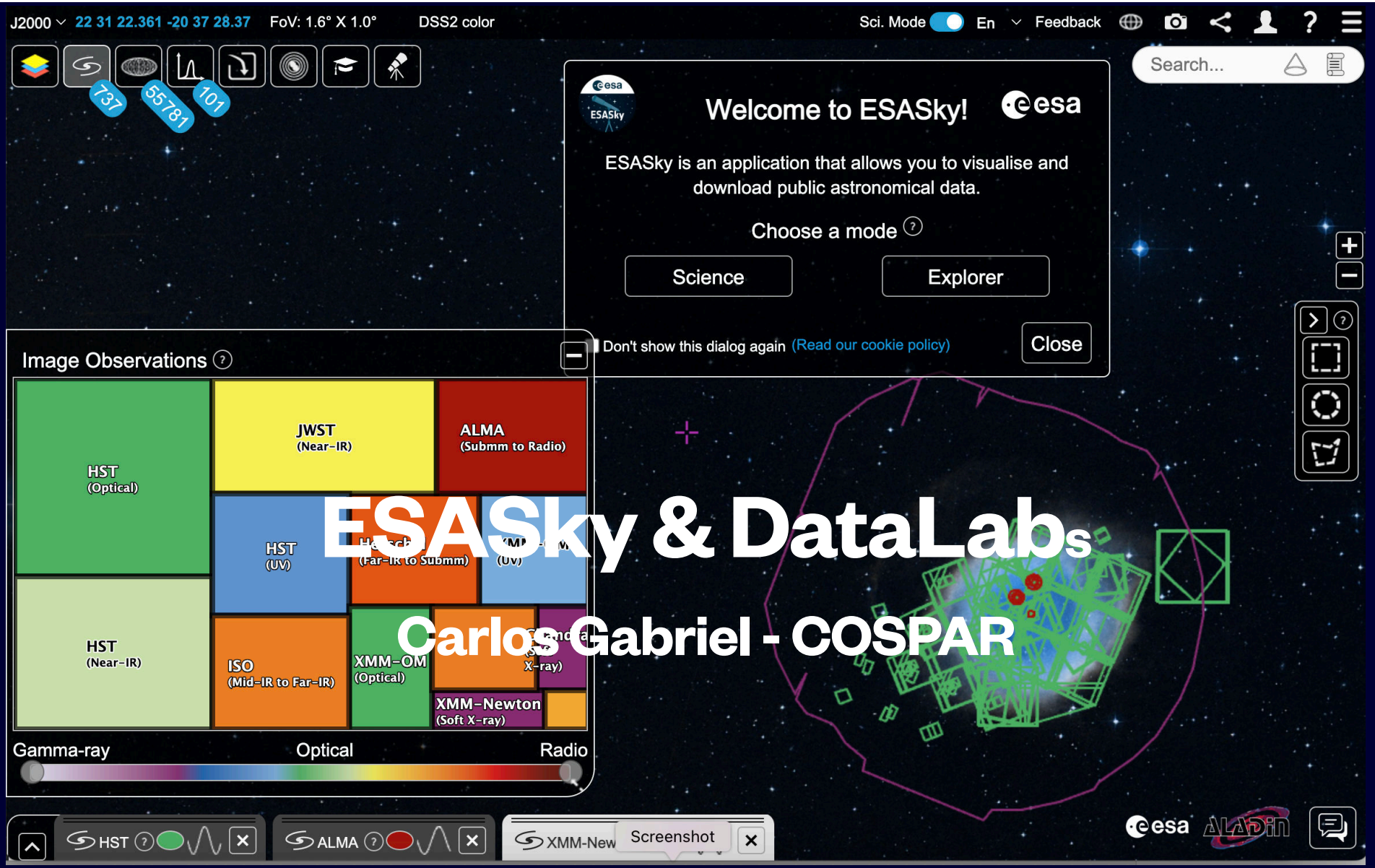


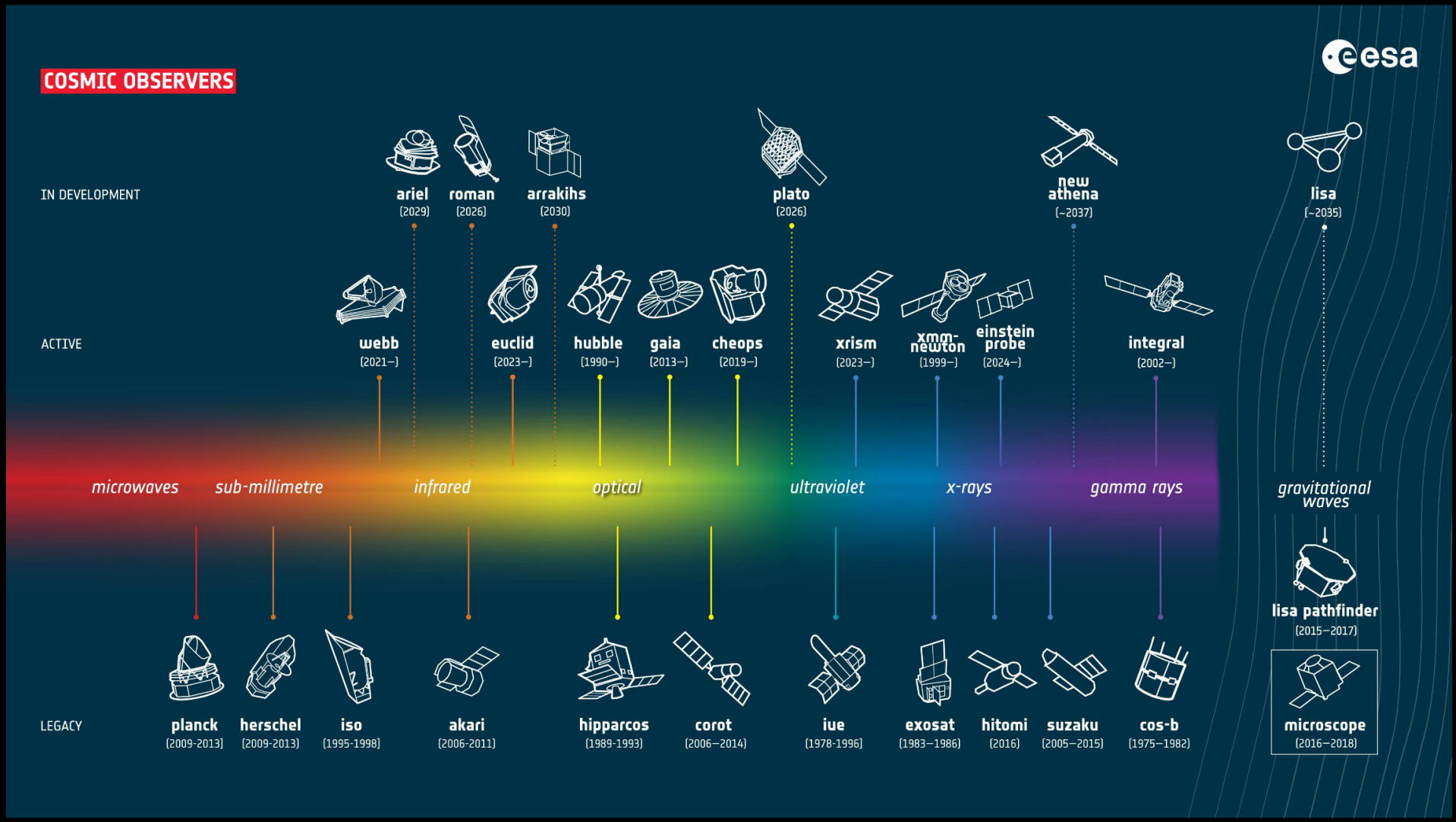
ESASky & DataLabs

Carlos Gabriel - COSPAR

Outline

- A world of data
- Many archives
- Archives + tools + services + protocols : the VO
- A special tool: ESASky
- ESASky interface
- Interacting with ESASky
- If time allows: demos

ESA's sky



ESASky and DataLabs | Carlos Gabriel - Bangalore, India - Oct 2025

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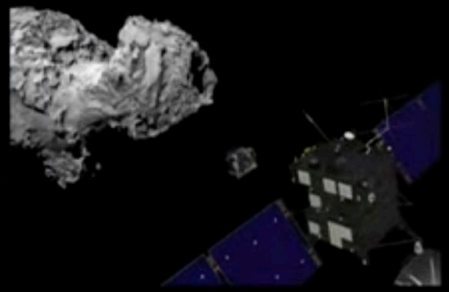
ESAC: ESA's astronomy centre

European Space Astronomy Centre



European Space Astronomy Centre:

- Science Operations Centres
- Science Archives for Astronomy and Solar System missions

ESAC archives

ESAC SCIENCE DATA CENTRE

ESDC Statistics

Monthly Users (*)	Monthly Downloaded (*)	Archive Total Size
32 092	80.0 TB	941.5 TB

* Monthly averages in 2023

Astronomy Science Archives

- cheops
- esasky
- exosat
- gaia
- herschel
- hubble space telescope
- iso
- jwst
- lisa pathfinder
- planck
- xmm-newton
- euclid

Heliophysics Science Archives

- cluster
- double star
- proba-2
- soho
- solar orbiter
- ulysses

The Planetary Science Archive

- bepicolombo
- cassini huygens
- chandrayaan -1
- exomars
- giotto
- juice
- mars express
- rosetta
- smart-1
- venus express

Future Archives

- ariel
- plato

Human and Robotic Exploration Science Archives*

- HRE data archive
- ISS- SolACES*

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Virtual Observatory VO

International Virtual Observatory Alliance (IVOA)

Before: VO idea born & discussed for many years in main Astro-IT yearly conference

ADASS conference series

- Argentine Virtual Observatory
- Armenian Virtual Observatory
- AstroGrid, United Kingdom
- Australian All-Sky Virtual Observatory
- Brazilian Virtual Observatory
- Chinese Virtual Observatory
- Canadian Virtual Observatory
- Chilean Virtual Observatory
- European Space Agency
- European Virtual Observatory
- German Astrophysical Virtual Observatory
- Japanese Virtual Observatory
- Kazakhstan Virtual Observatory
- Netherlands Virtual Observatory
- Observatoire Virtuel France
- Russian Virtual Observatory
- Square Kilometer Array Observatory
- South African Astroinformatics Alliance
- Spanish Virtual Observatory
- Italian Virtual Observatory
- Ukrainian Virtual Observatory
- US Virtual Observatory Alliance
- Virtual Observatory India

Virtual Observatory VO

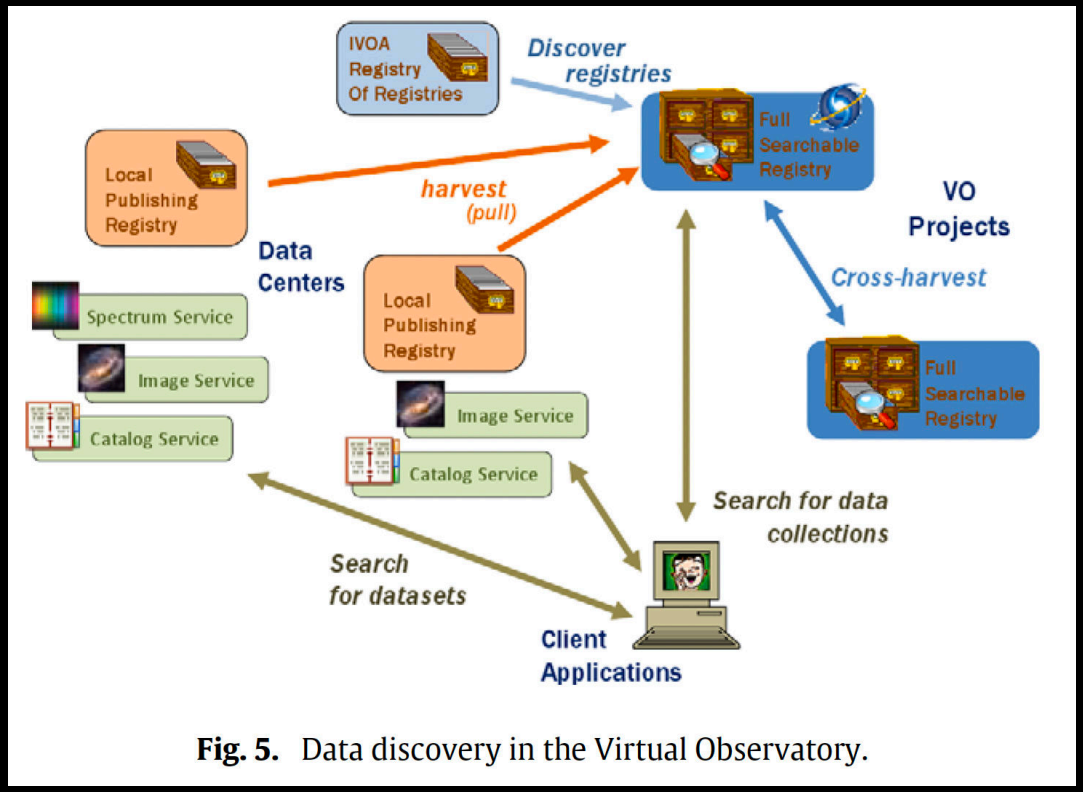
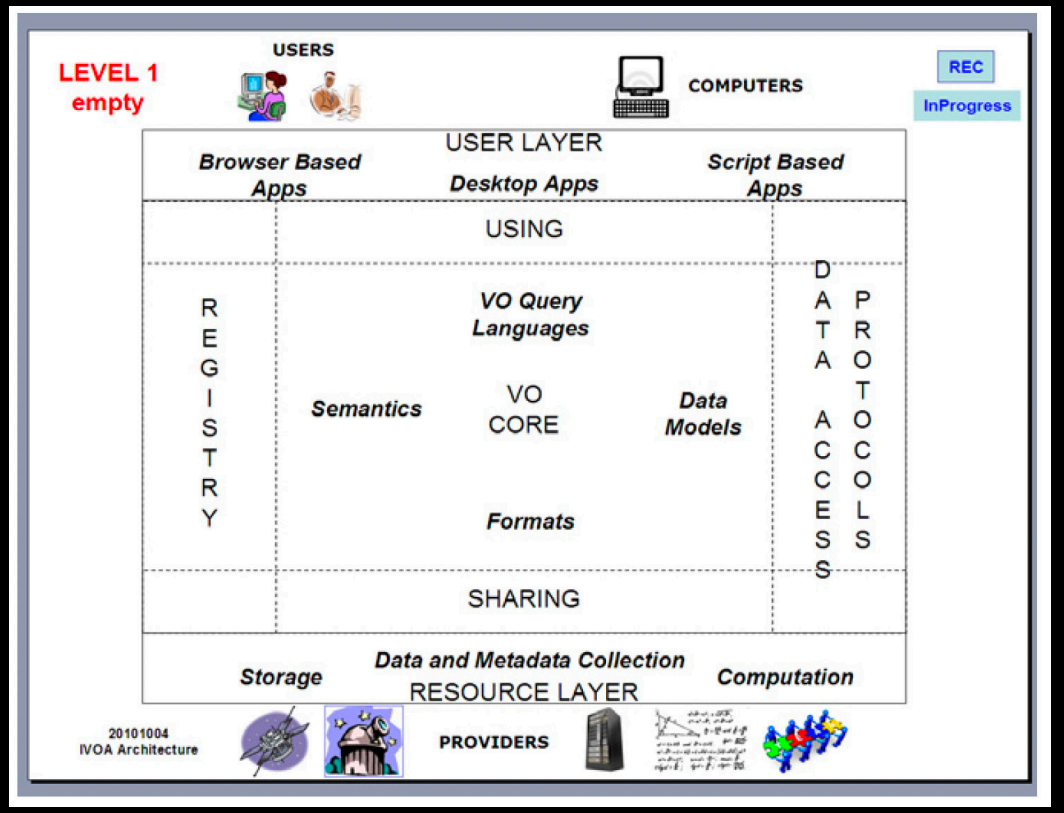
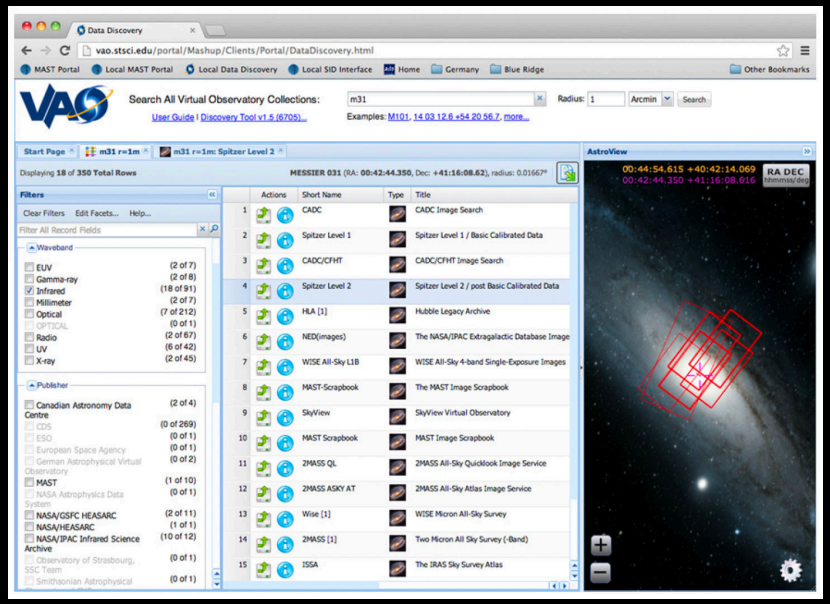


Fig. 5. Data discovery in the Virtual Observatory.

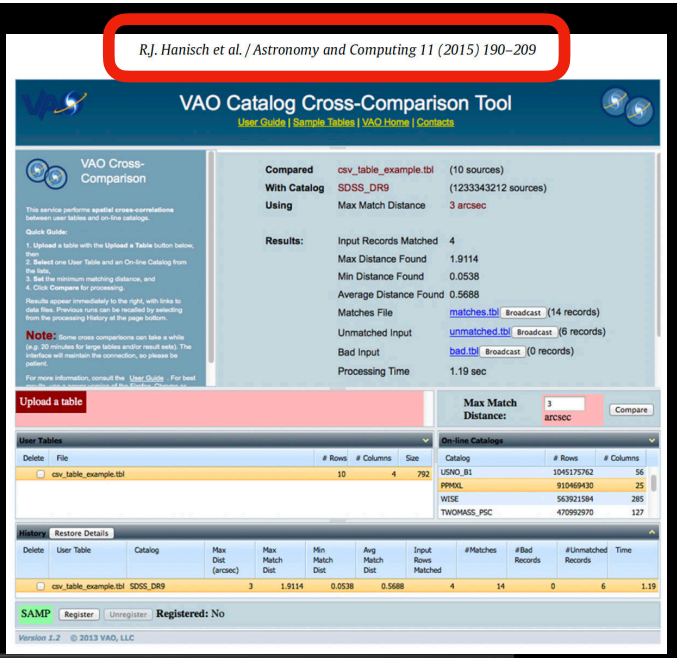


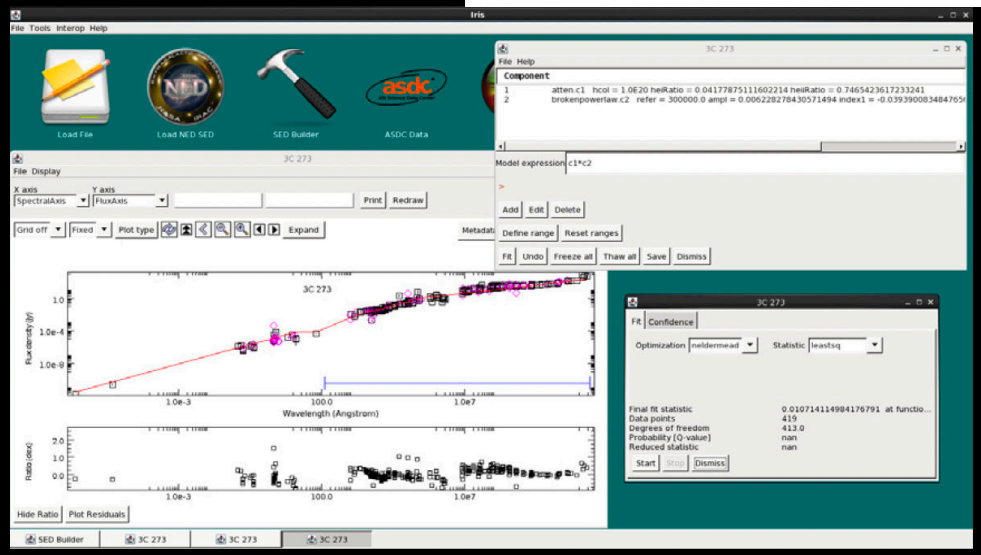
Virtual Observatory VO tools



Data Discovery Tool (DDT) (after a search for M31)

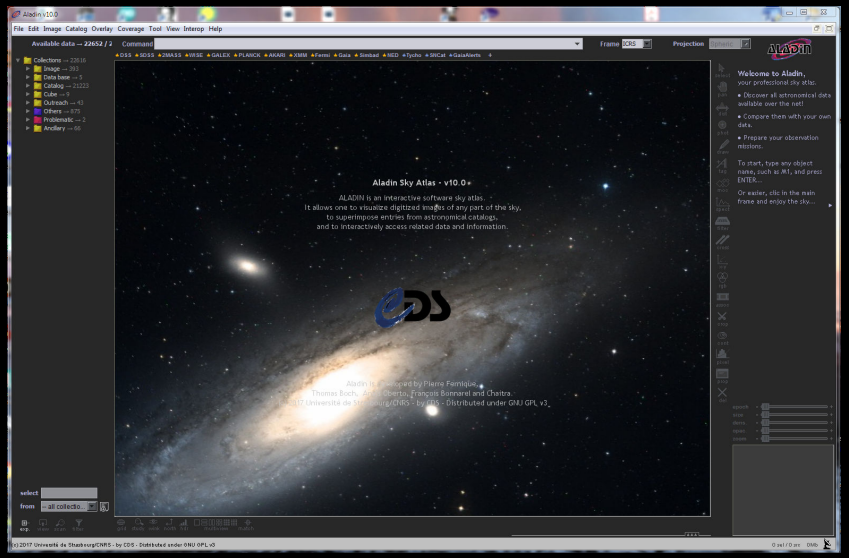
Scalable Cross Comparison Service (User uploaded table cross-matched with SDDS catalogue)



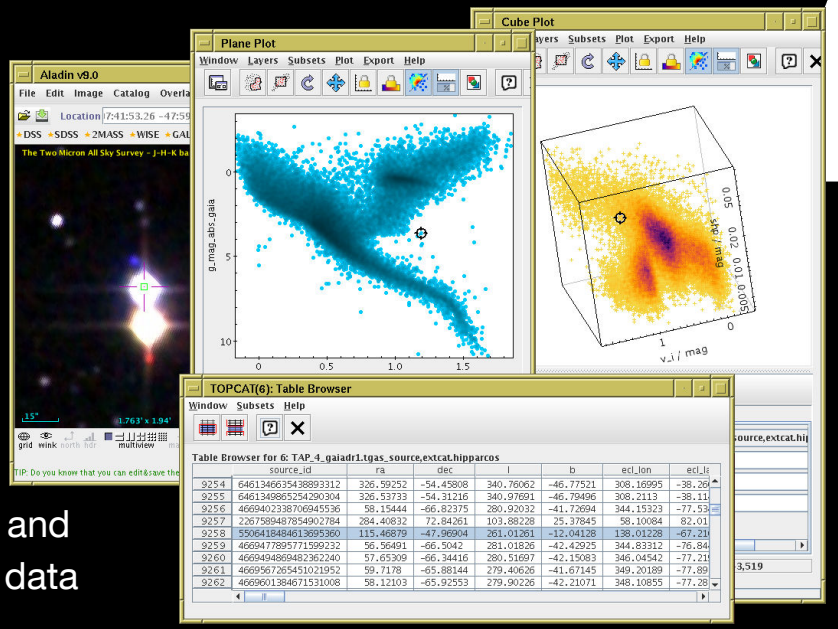


SED access and analysis tool Iris (model fit of 3C273 with i/a control of parameters)

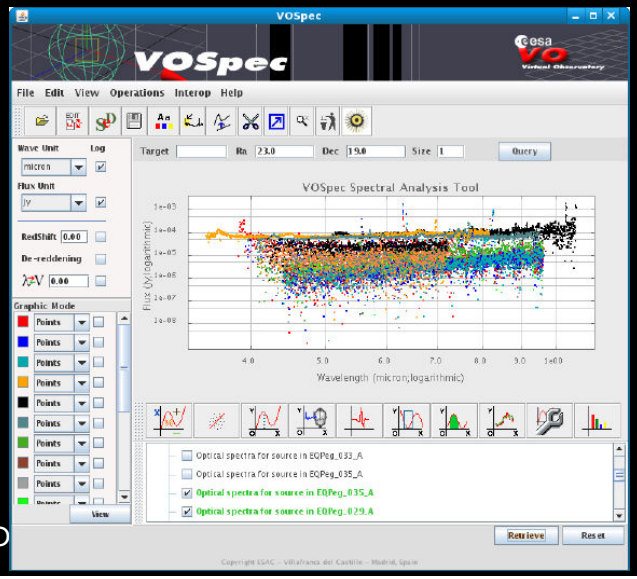
Virtual Observatory VO tools



Aladin - CDS - Universal I/A Sky Atlas



TOPCAT (UK) graphical viewer and editor for tabular data



VOSpec - ESA - multi-wavelength spectral analysis tool with access to spectra, theoretical models and atomic and molecular line databases

… and many, many more…

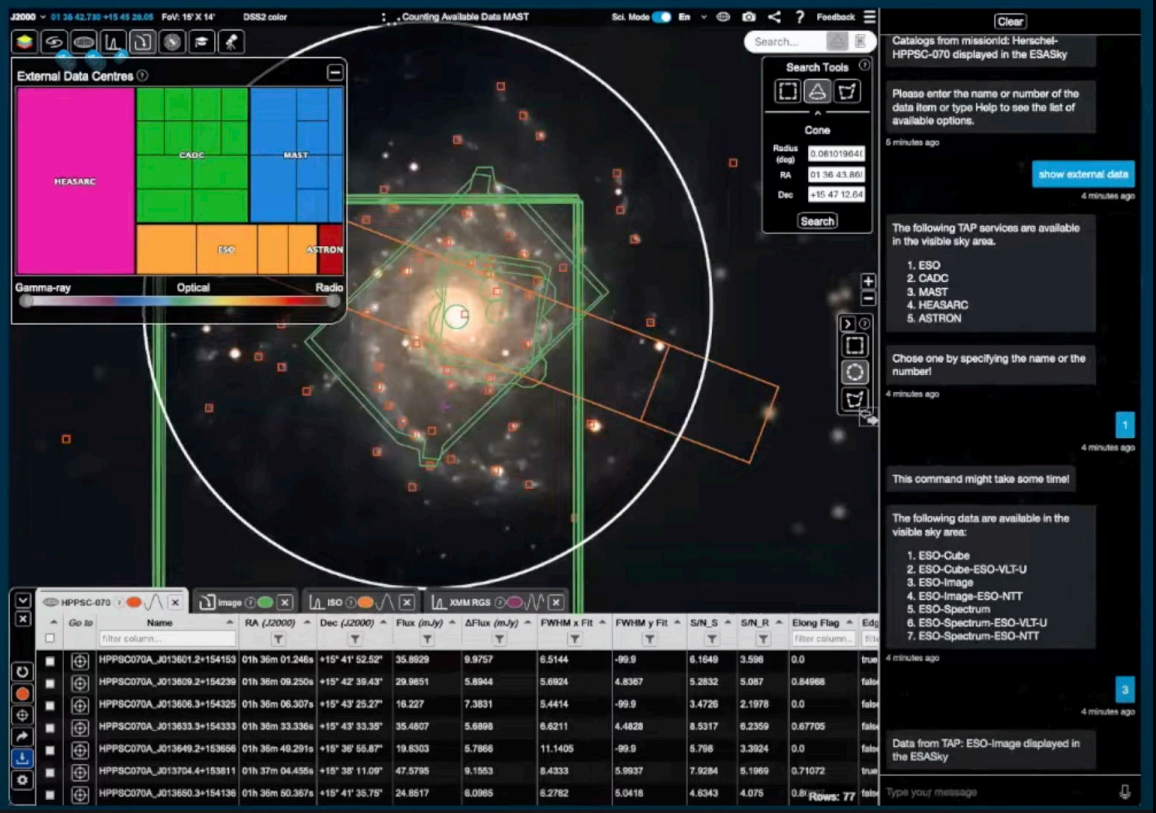
The cherry on the cake: ESASky

ESASKY – sky.esa.int

ESASky is a multi-mission, multi-frequency science driven discovery portal developed by the Data Science and Archives Division at ESAC.

ESASky users can access data from a wide variety of missions ESA, NASA, CSA, JAXA, and others, and also give the possibility to explore the data contents from other partner data centres using IVOA protocols to interoperate.

Very recently it also became multi-messenger with the addition of GW and neutrino alerts.



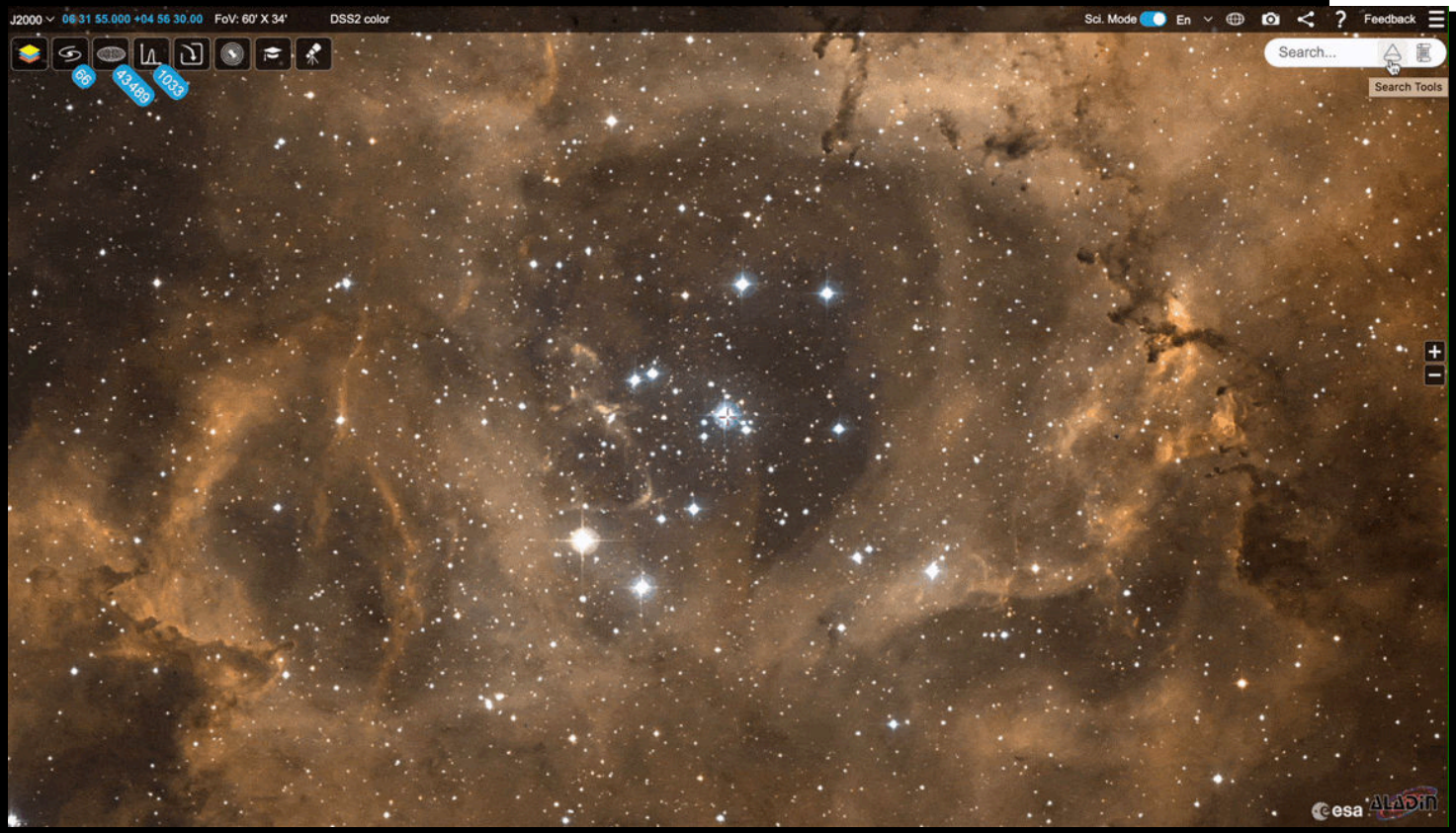
A science driven discovery portal

Full access to the entire sky

Data from space, ground base + multi-messenger astronomy (ESA, NASA, JAXA, ESO, CADC, MAST…)

Science-mode or Explorer mode

Planning tool for JWST & XMM-Newton

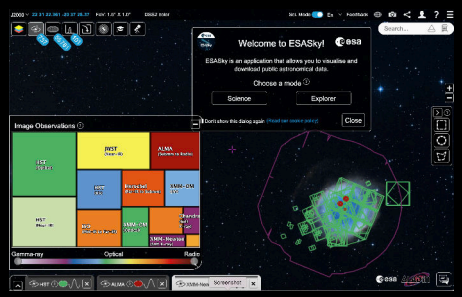


What is ESASky?

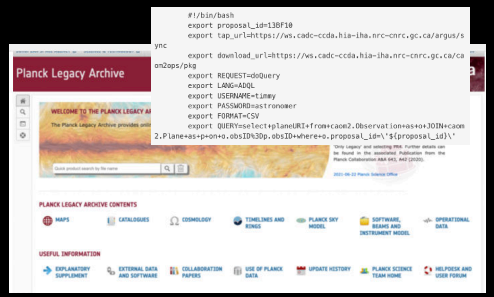
ESASky is:

- A platform and suite of tools for scientists, driven by scientific use cases, responding to needs from the scientific community

ESASky interface
sky.esa.int

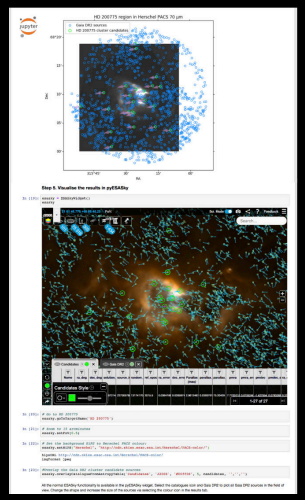


ESA Legacy Archive
(Table Access
Protocol, TAP)

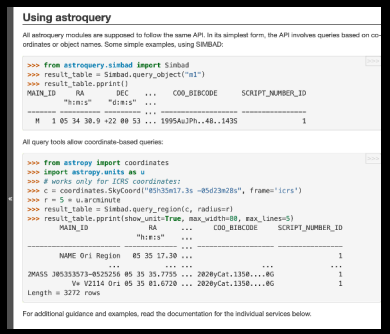


Programmatic access (scripts, notebooks, etc)

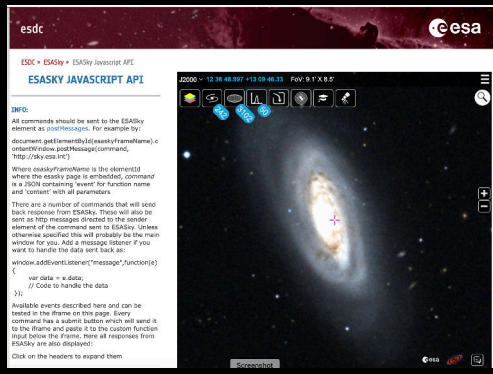
pyESASky
Jupyter widget



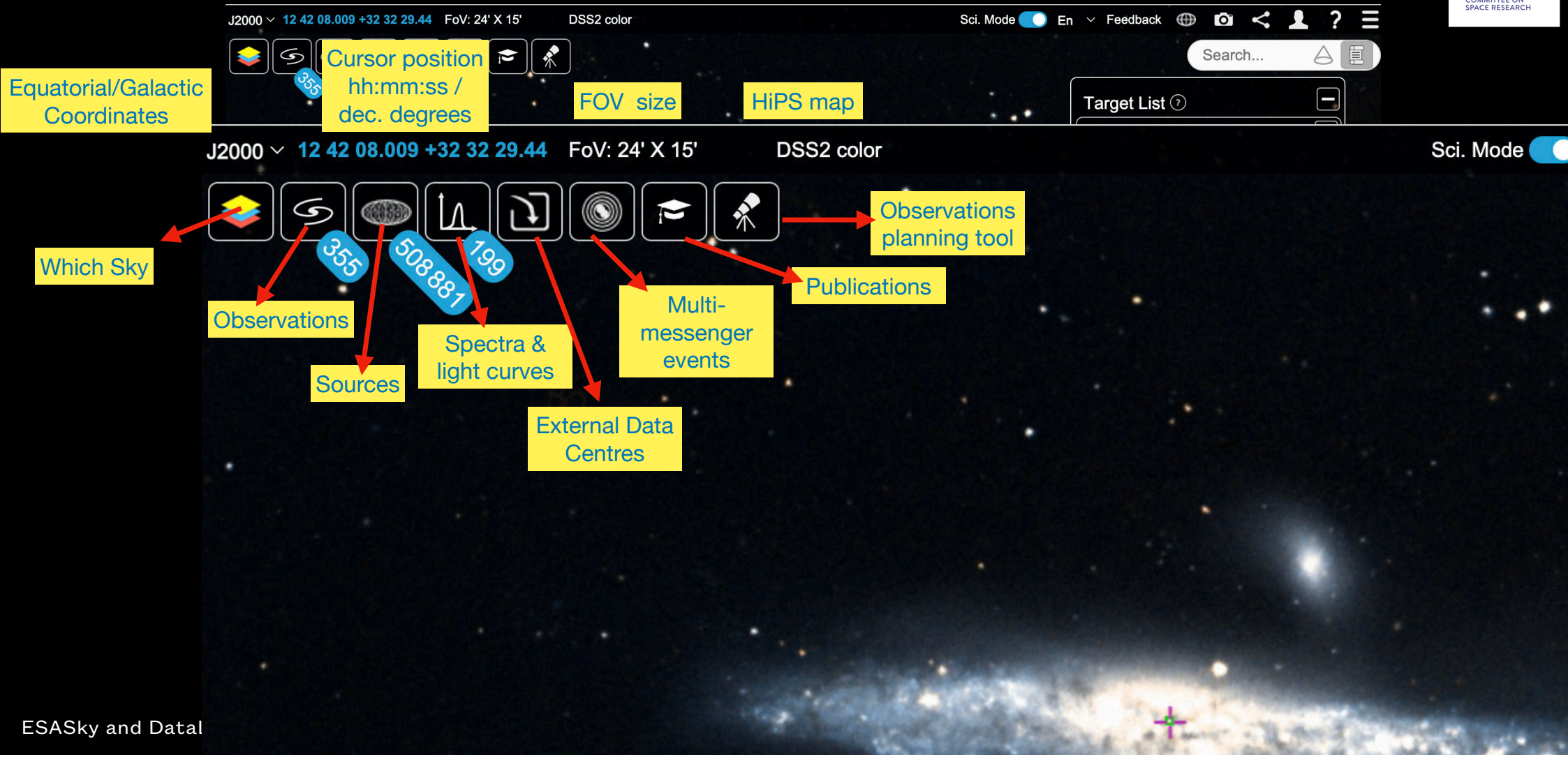
Astroquery & TAP



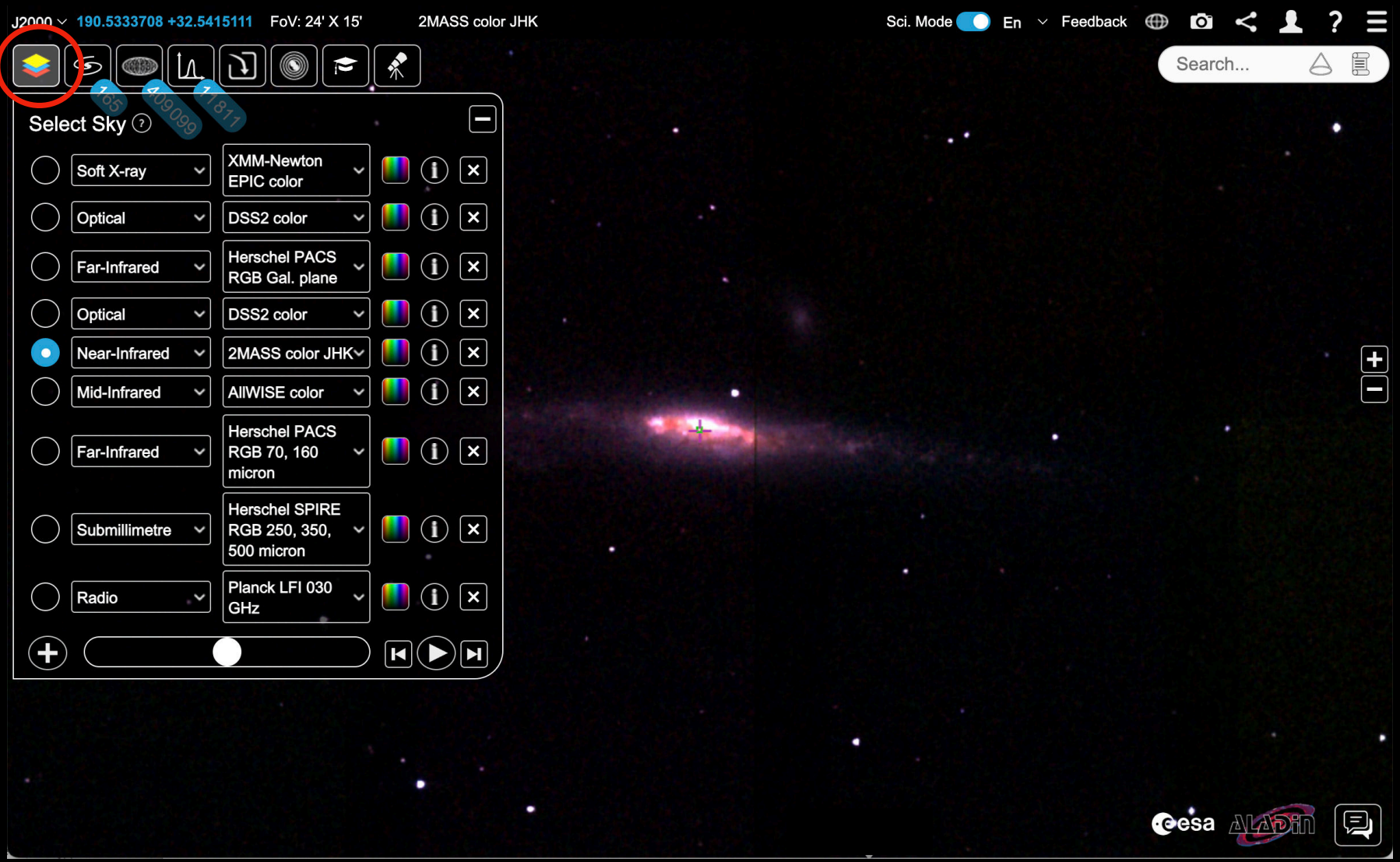
Javascript API



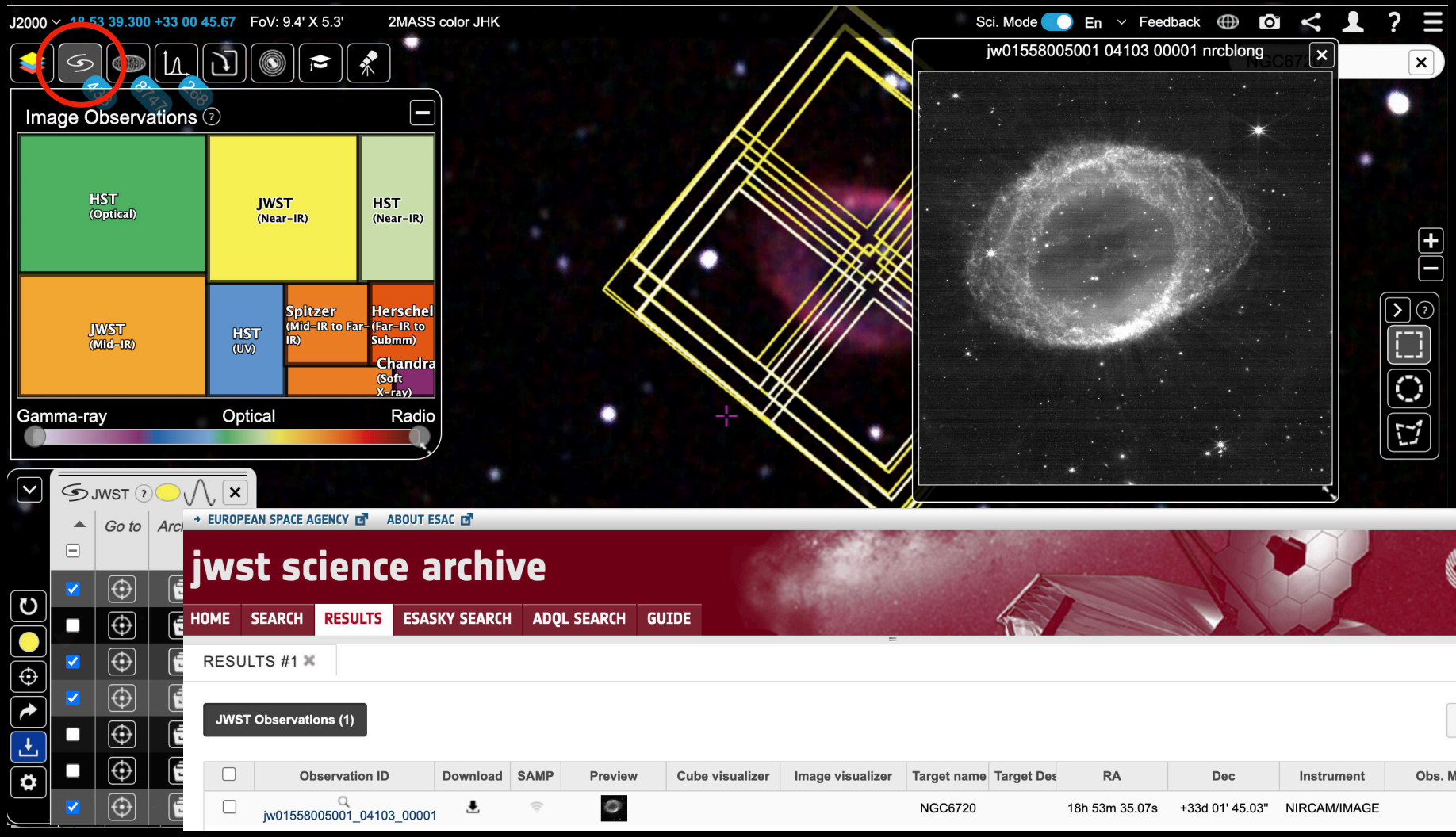
ESASky - the interface



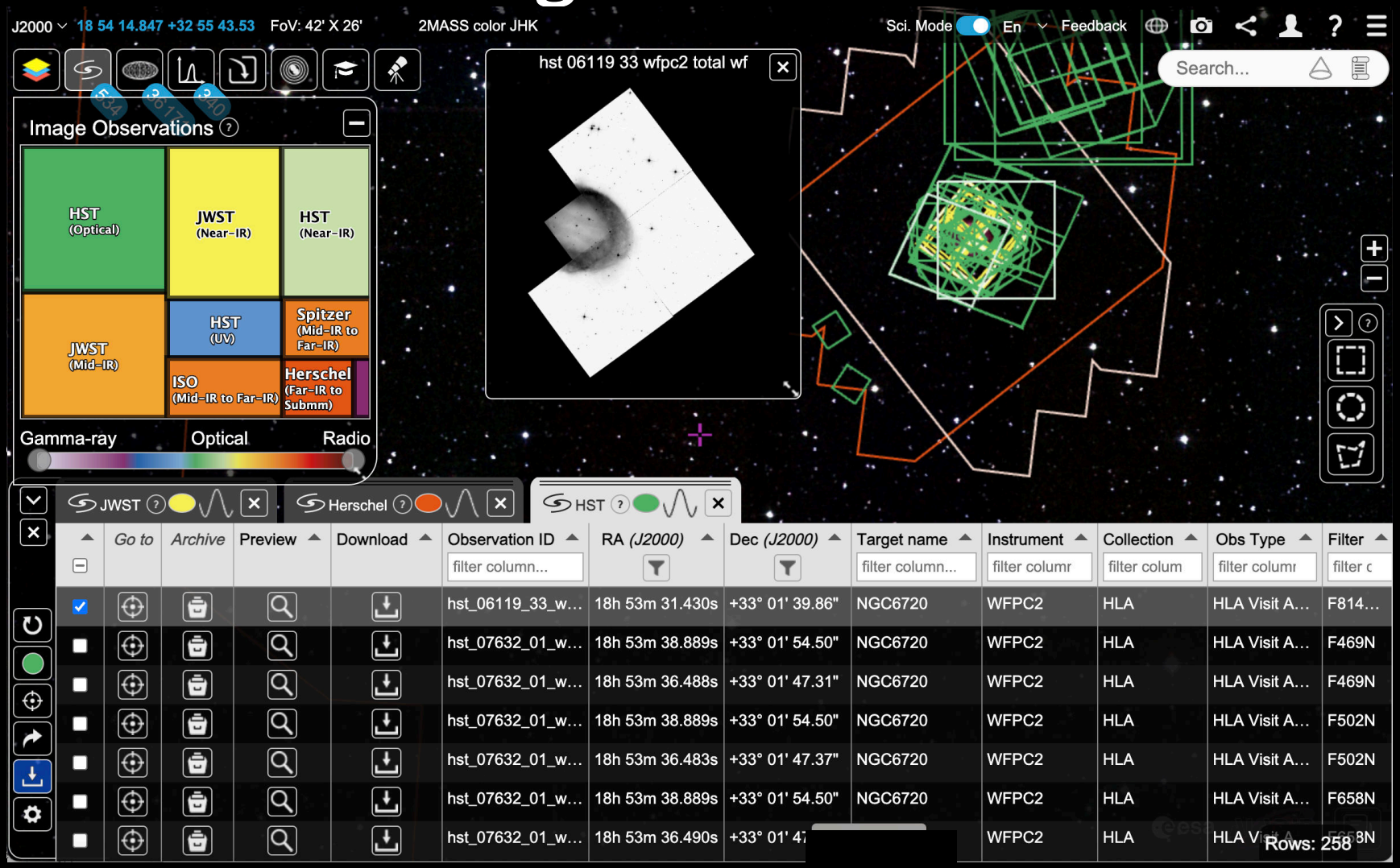
Different skies



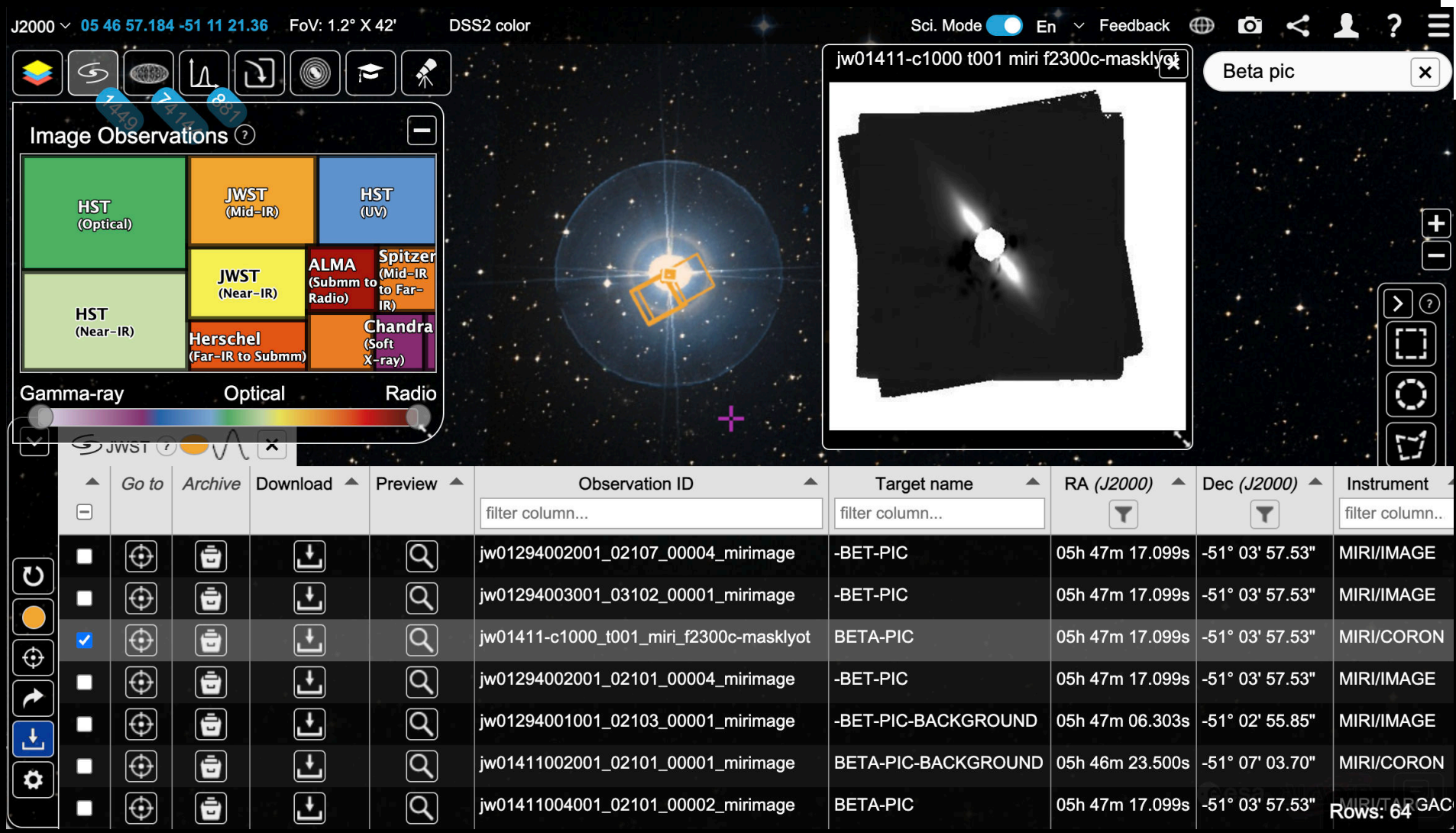
Direct access of all ESA archives, poststamps, metadata



Images...archives...images



One of Isa's favourites



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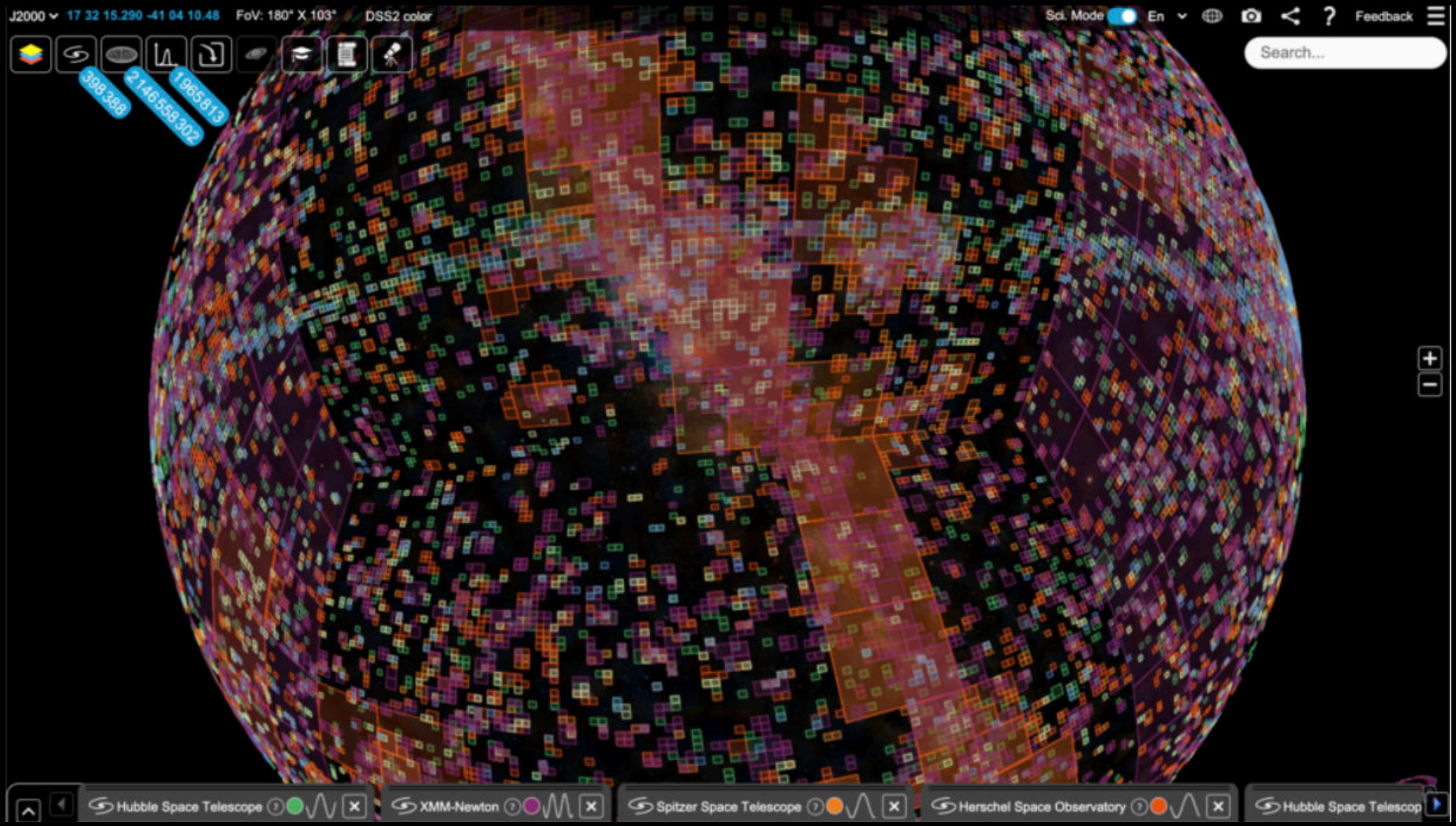
Images, images, images



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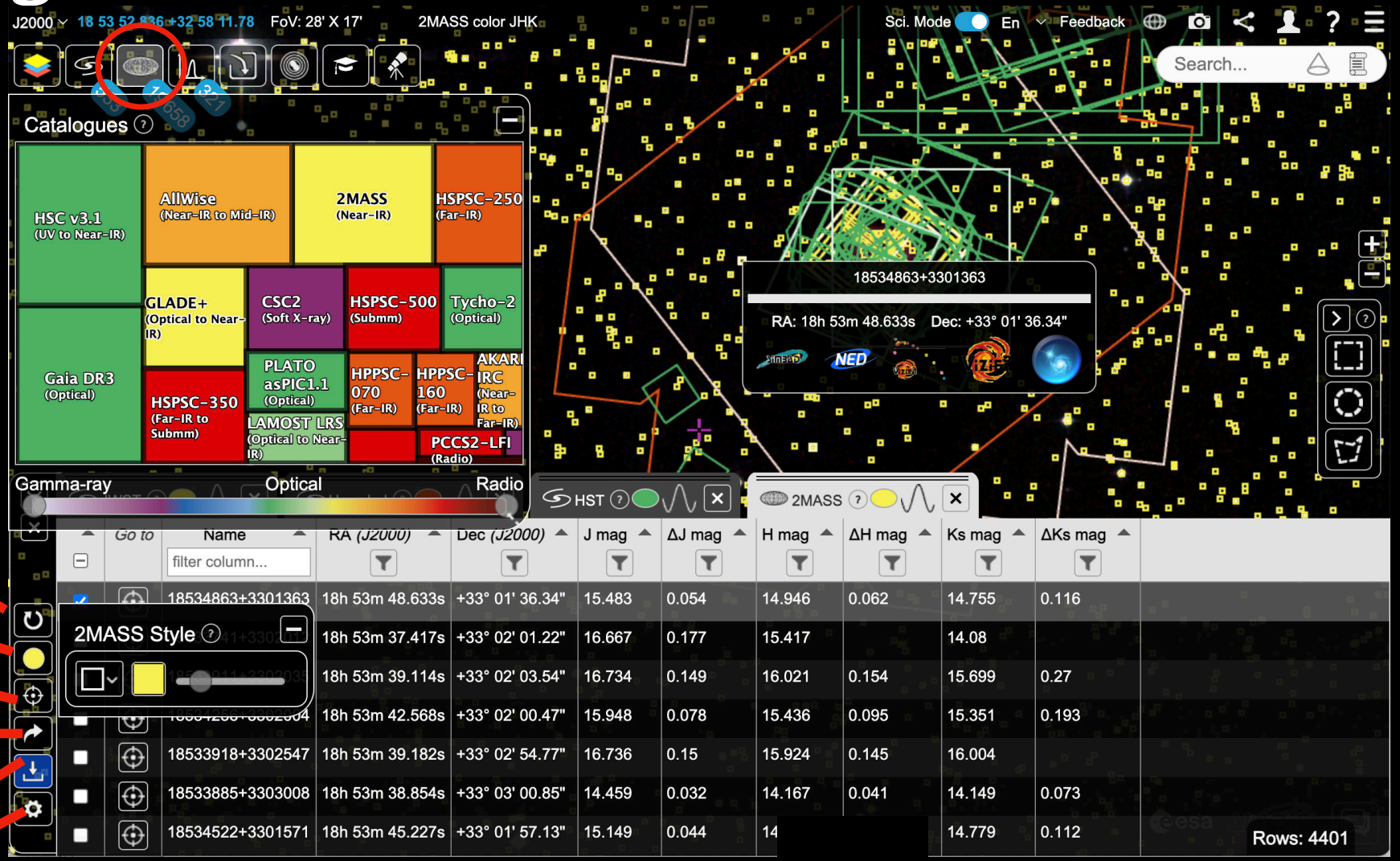
Catalogues



Refresh

Color

Recentre

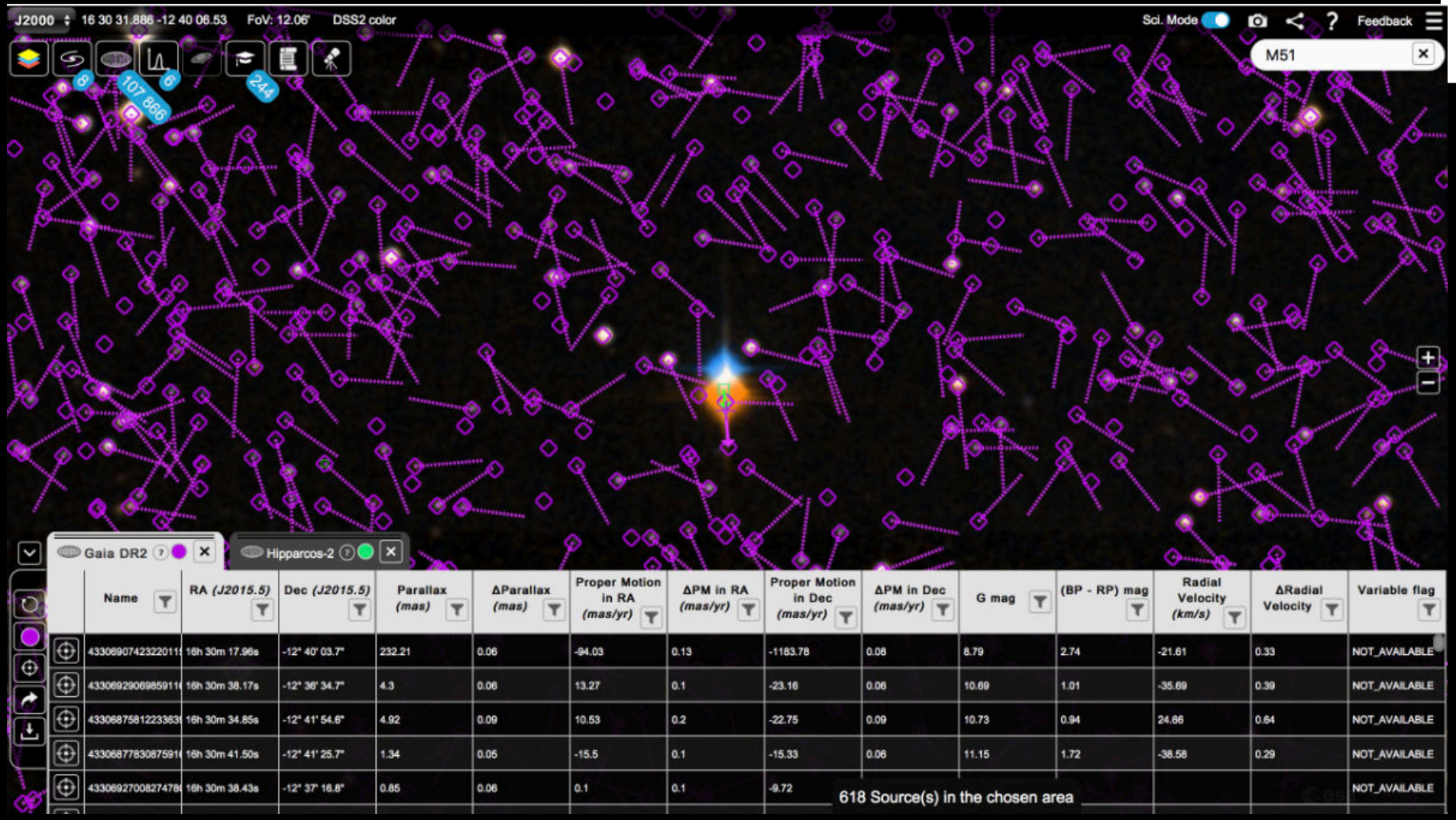
Send table to VO

Download

Configure table

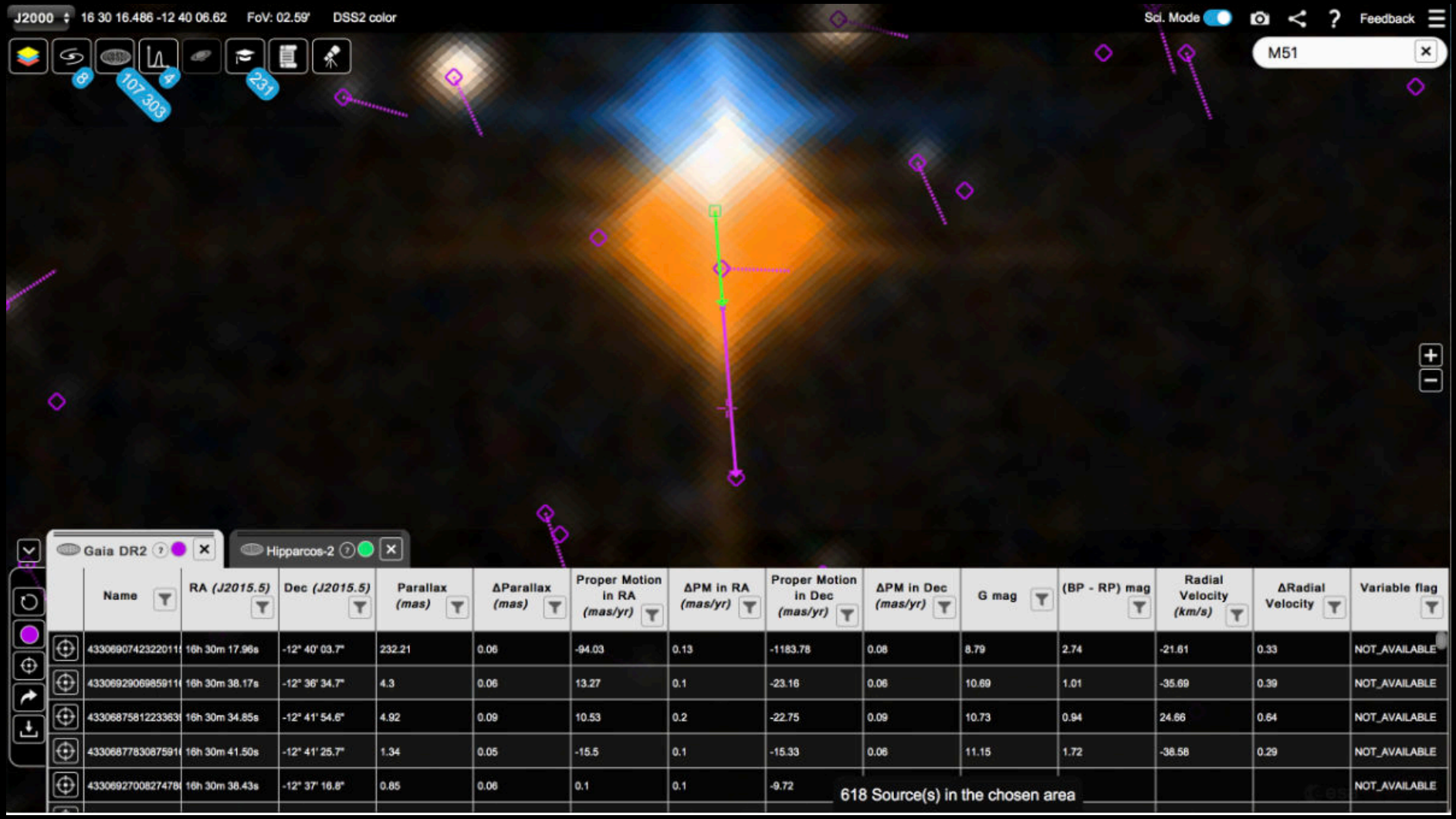
PCB

Accesing catalogues... and proper motions



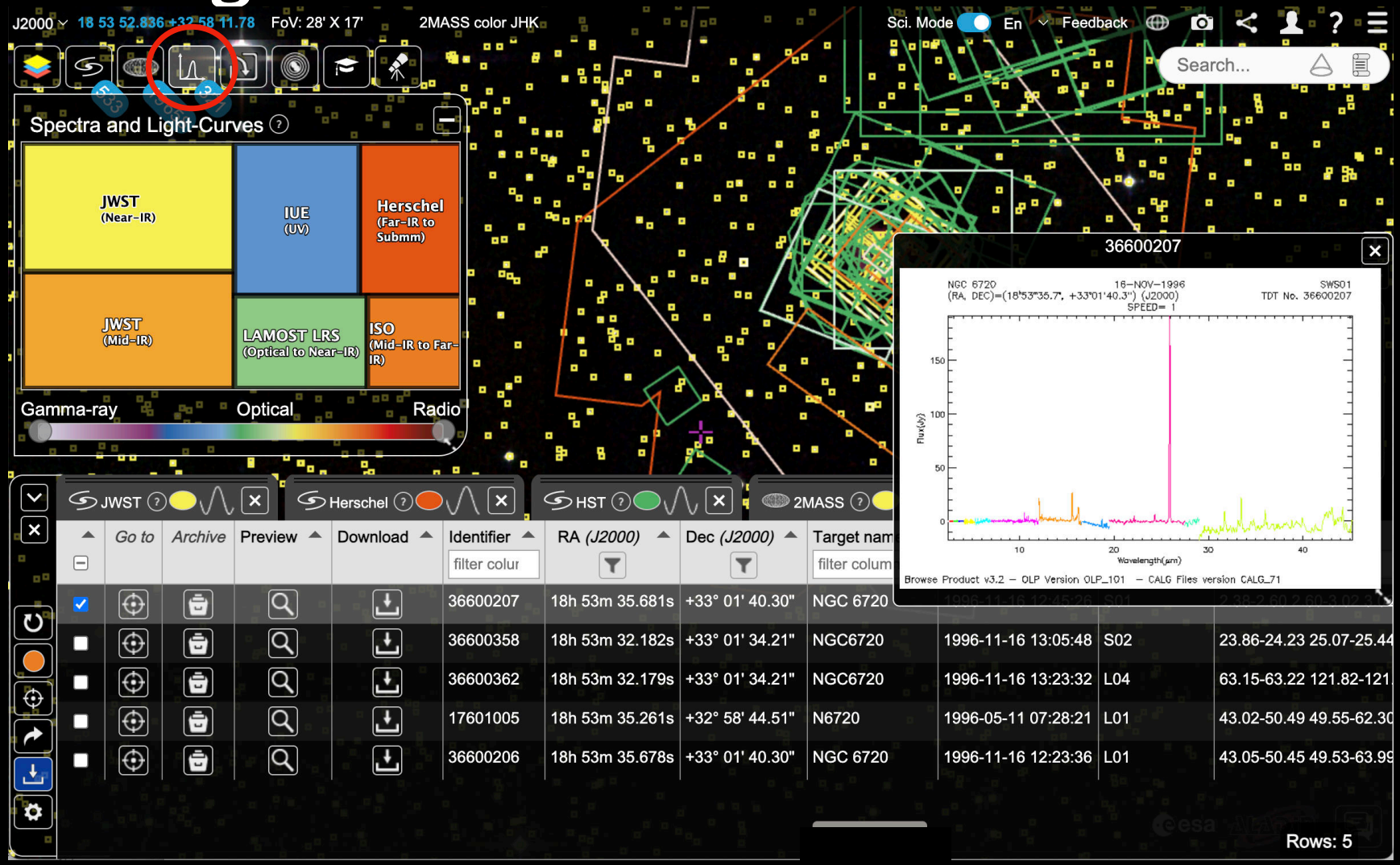
Name	RA (J2015.5)	Dec (J2015.5)	Parallax (mas)	ΔParallax (mas)	Proper Motion in RA (mas/yr)	ΔPM in RA (mas/yr)	Proper Motion in Dec (mas/yr)	ΔPM in Dec (mas/yr)	G mag	(BP - RP) mag	Radial Velocity (km/s)	ΔRadial Velocity	Variable flag
4330690742322011	16h 30m 17.96s	-12° 40' 03.7"	232.21	0.06	-94.03	0.13	-1183.78	0.08	8.79	2.74	-21.61	0.33	NOT_AVAILABLE
4330692906985911	16h 30m 38.17s	-12° 36' 34.7"	4.3	0.06	13.27	0.1	-23.16	0.06	10.69	1.01	-35.69	0.39	NOT_AVAILABLE
4330687581223363	16h 30m 34.85s	-12° 41' 54.6"	4.92	0.09	10.53	0.2	-22.75	0.09	10.73	0.94	24.66	0.64	NOT_AVAILABLE
4330687783087591	16h 30m 41.50s	-12° 41' 25.7"	1.34	0.05	-15.5	0.1	-15.33	0.06	11.15	1.72	-38.58	0.29	NOT_AVAILABLE
4330692700827478	16h 30m 38.43s	-12° 37' 16.8"	0.85	0.06	0.1	0.1	-9.72						NOT_AVAILABLE

Eppur si muove

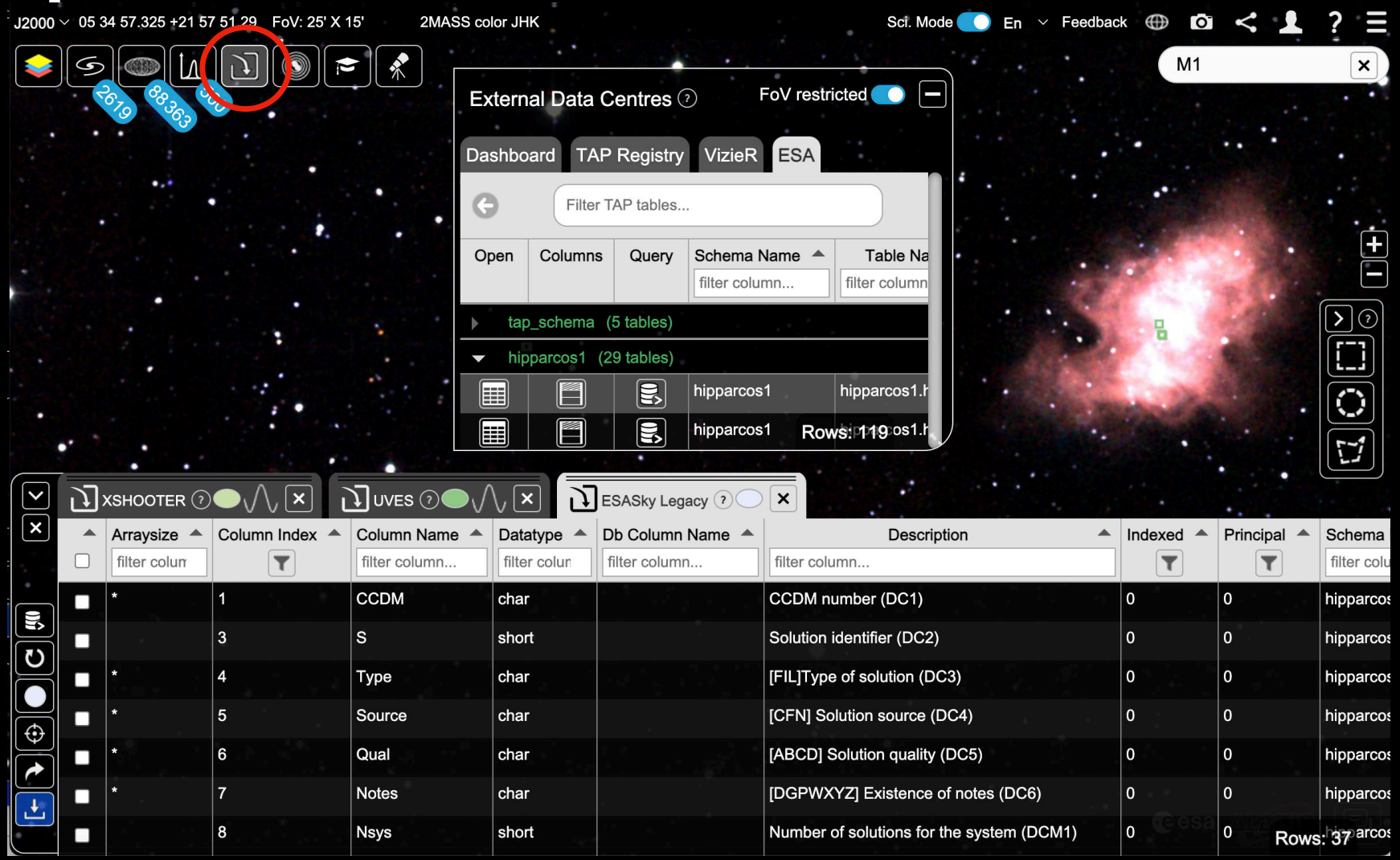


Name	RA (J2015.5)	Dec (J2015.5)	Parallax (mas)	ΔParallax (mas)	Proper Motion in RA (mas/yr)	ΔPM in RA (mas/yr)	Proper Motion in Dec (mas/yr)	ΔPM in Dec (mas/yr)	G mag	(BP - RP) mag	Radial Velocity (km/s)	ΔRadial Velocity	Variable flag
4330690742322011	16h 30m 17.96s	-12° 40' 03.7"	232.21	0.06	-94.03	0.13	-1183.78	0.08	8.79	2.74	-21.61	0.33	NOT_AVAILABLE
4330692906985911	16h 30m 38.17s	-12° 36' 34.7"	4.3	0.06	13.27	0.1	-23.16	0.06	10.69	1.01	-35.69	0.39	NOT_AVAILABLE
4330687581223363	16h 30m 34.85s	-12° 41' 54.6"	4.92	0.09	10.53	0.2	-22.75	0.09	10.73	0.94	24.66	0.64	NOT_AVAILABLE
4330687783087591	16h 30m 41.50s	-12° 41' 25.7"	1.34	0.05	-15.5	0.1	-15.33	0.06	11.15	1.72	-38.58	0.29	NOT_AVAILABLE
4330692700827478	16h 30m 38.43s	-12° 37' 16.8"	0.85	0.06	0.1	0.1	-9.72						NOT_AVAILABLE

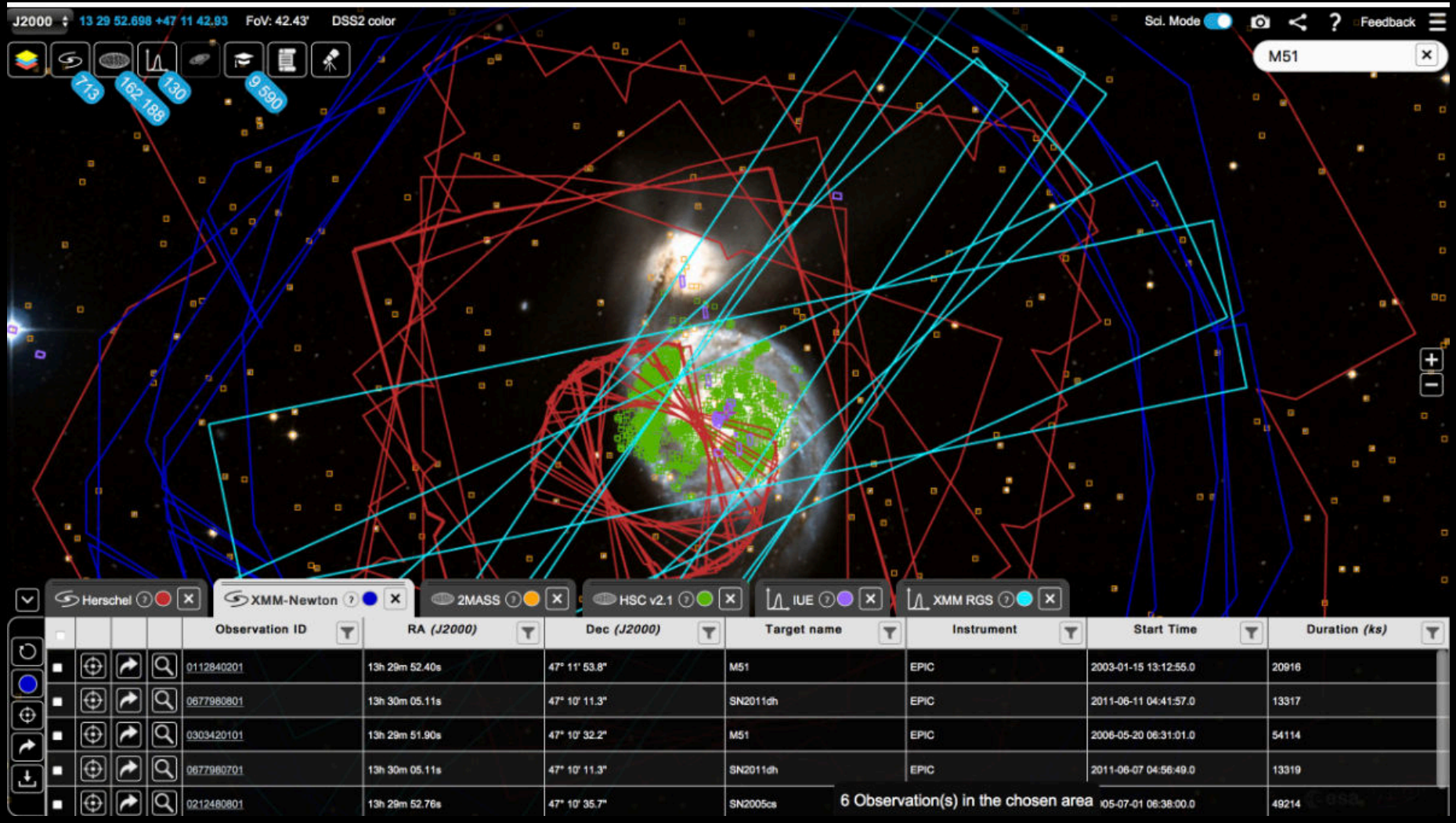
Spectra + Light curves



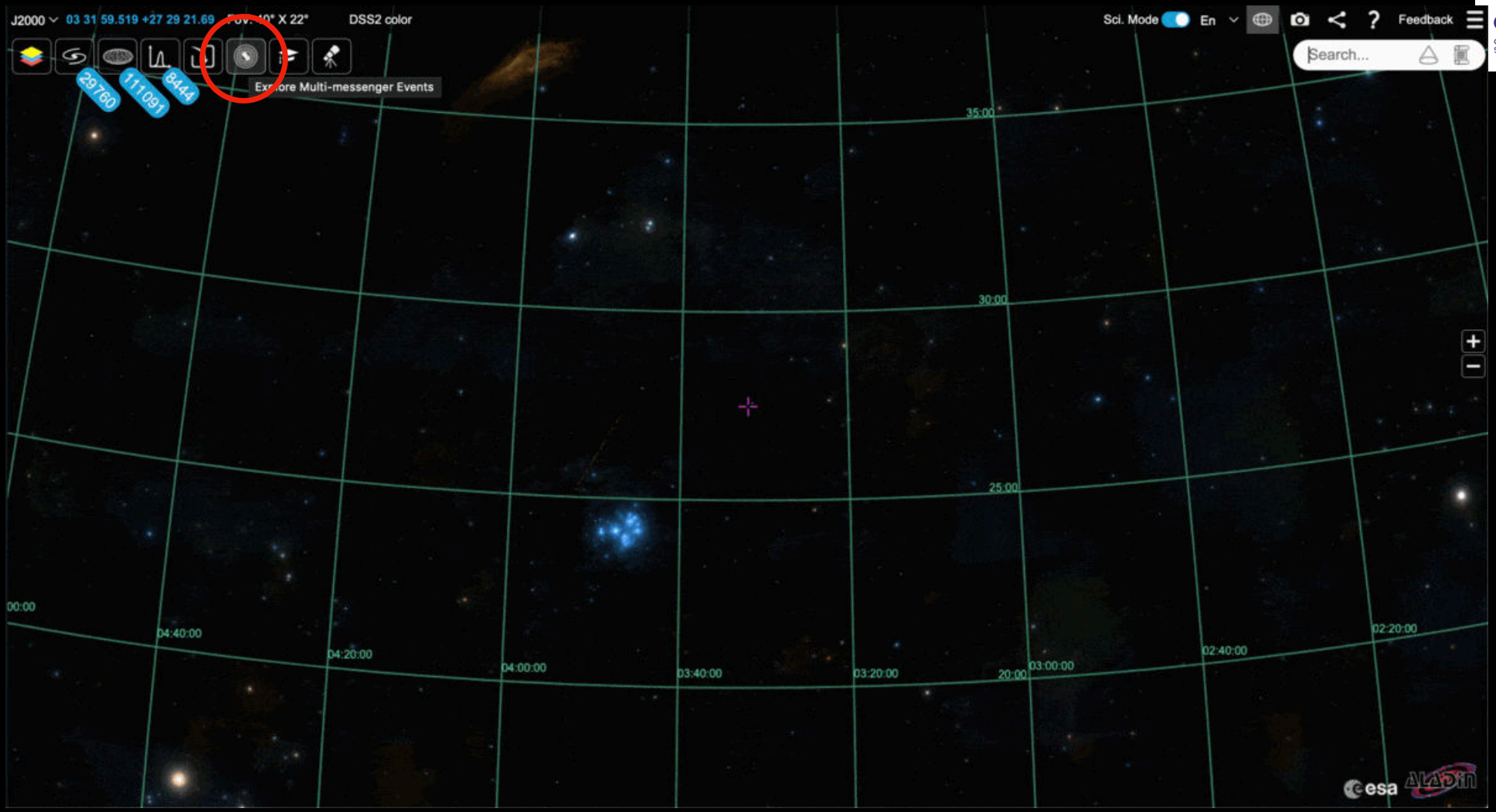
Other providers



Exploring images, catalogues, spectra, light curves...



The message can be of different nature



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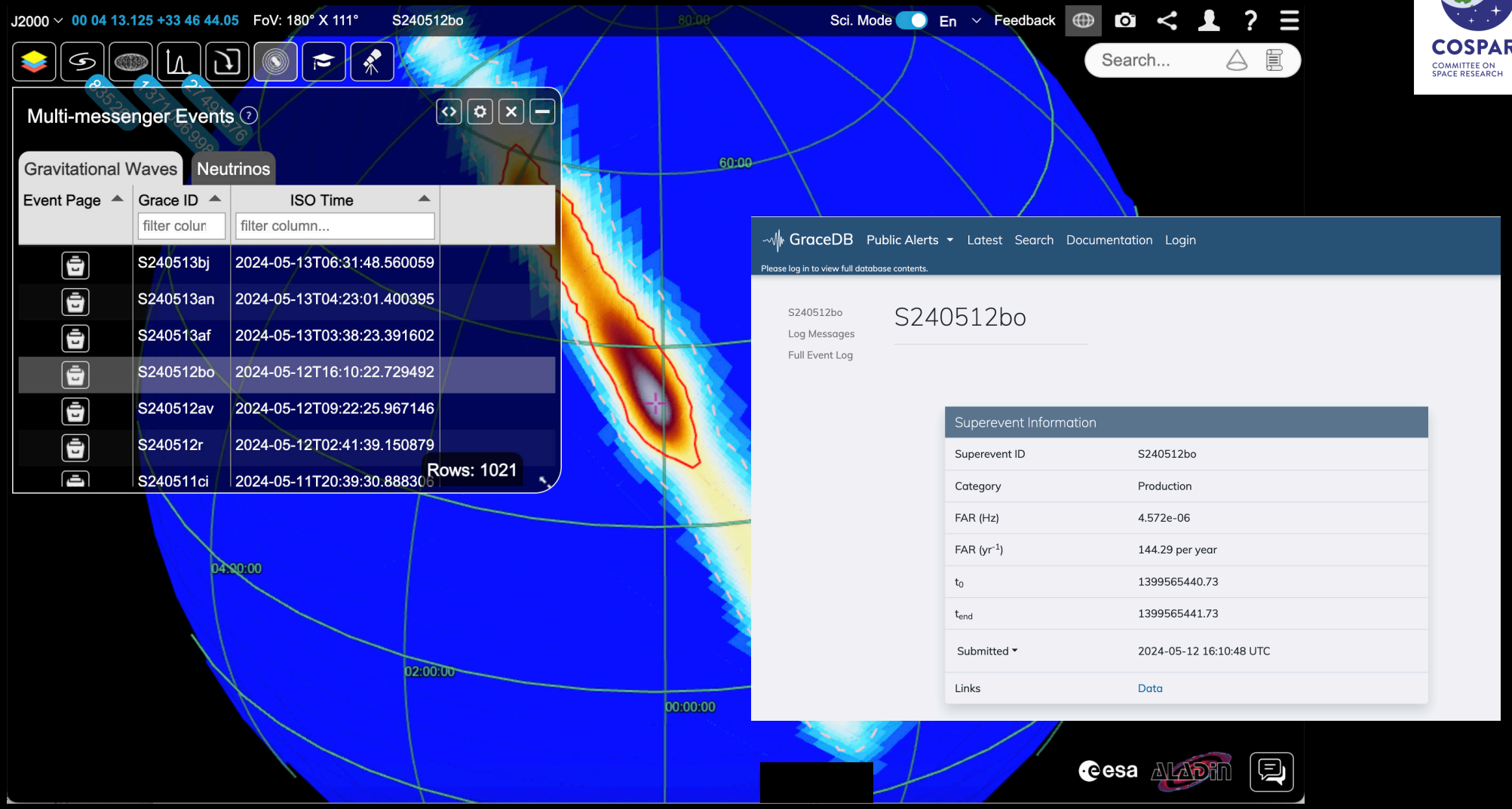
Gravitational waves



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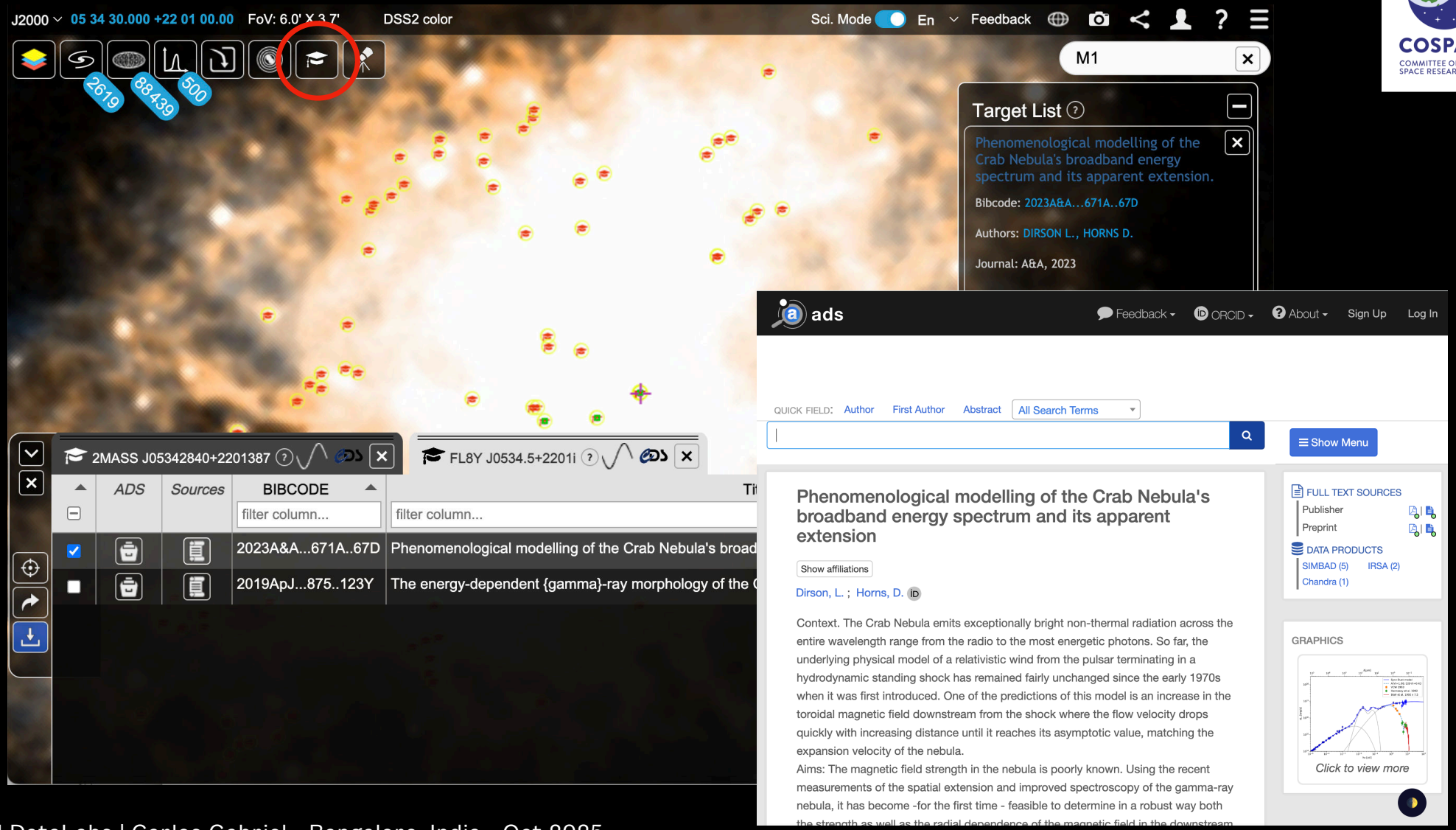
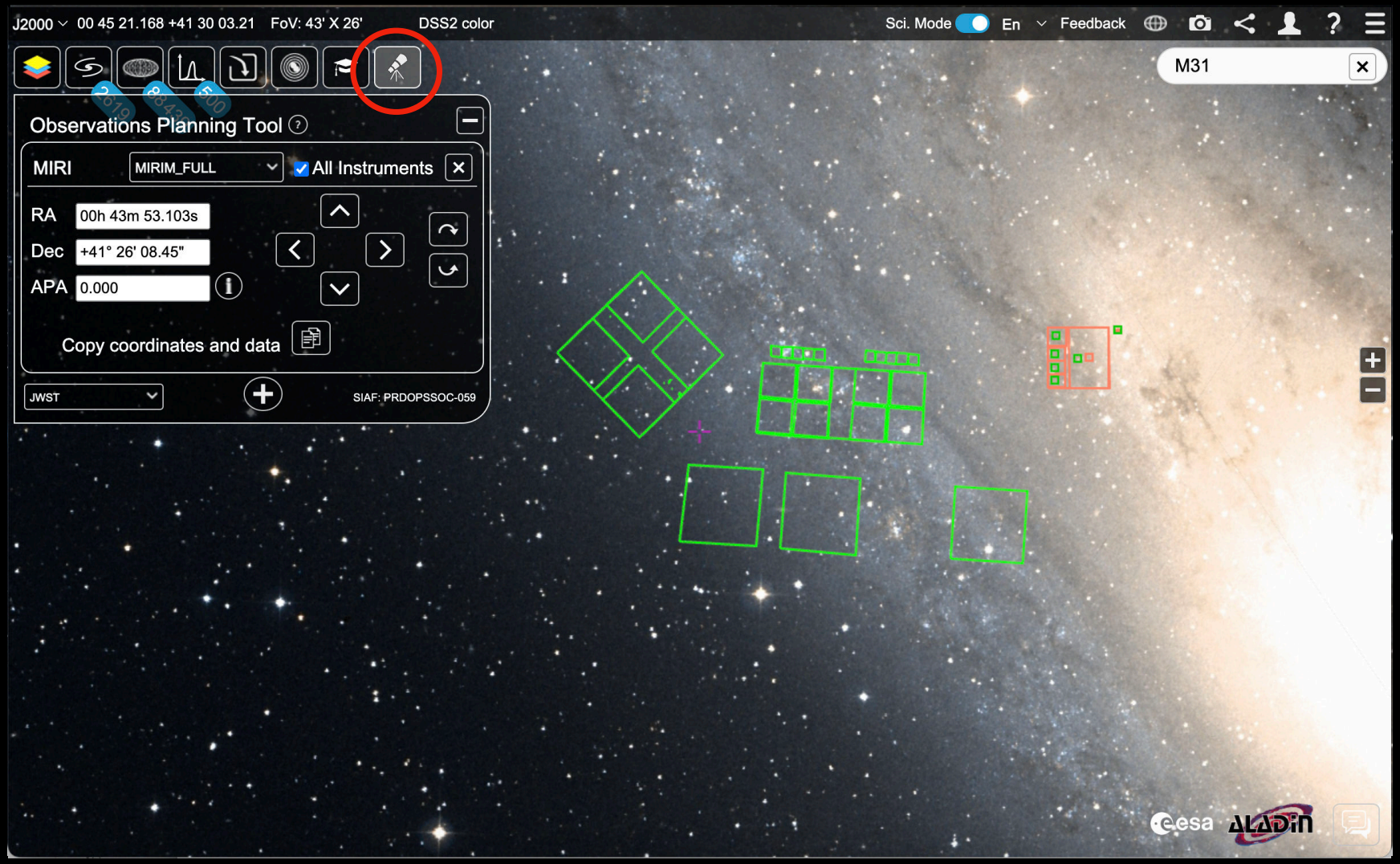
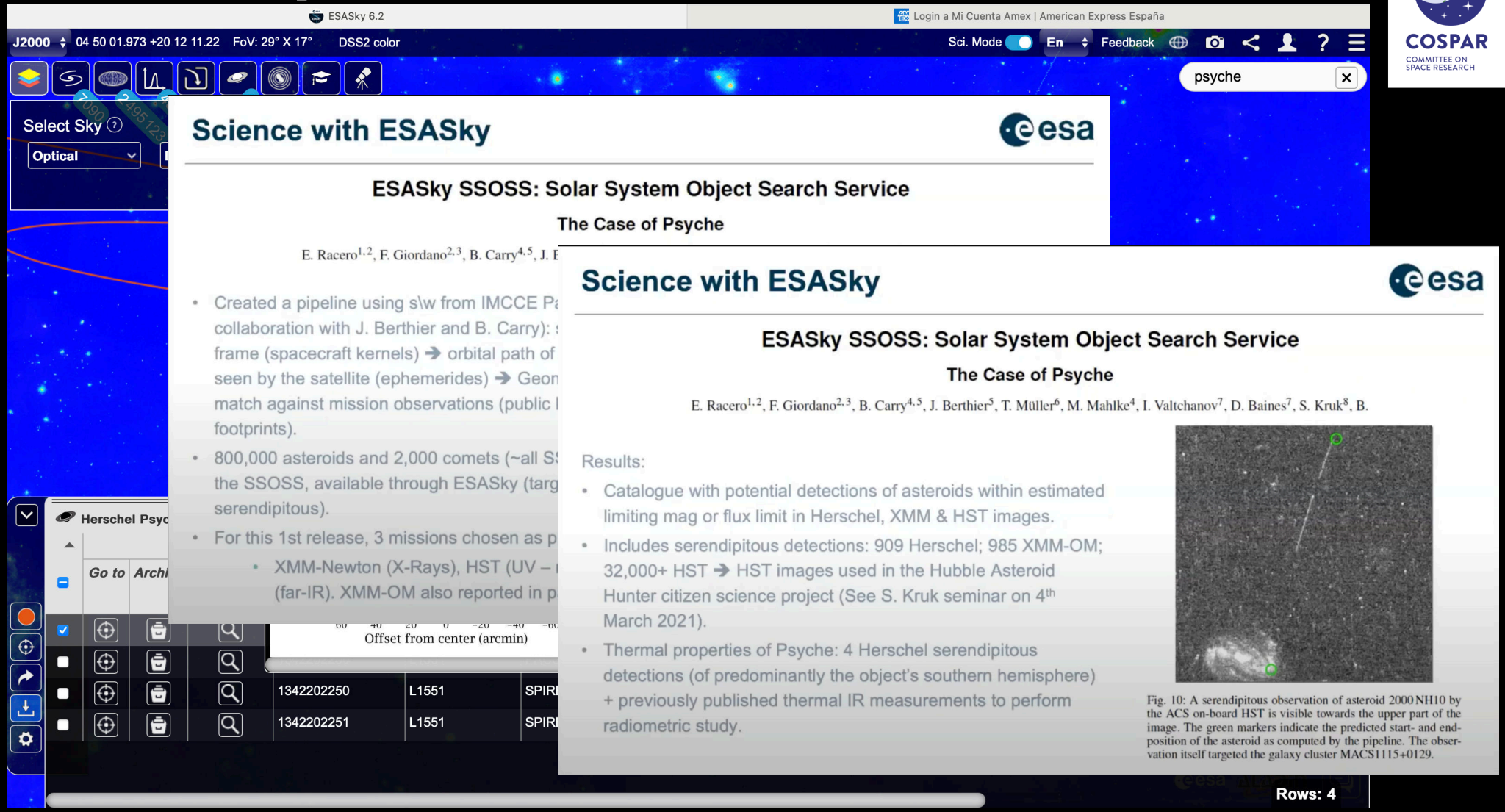
Publications



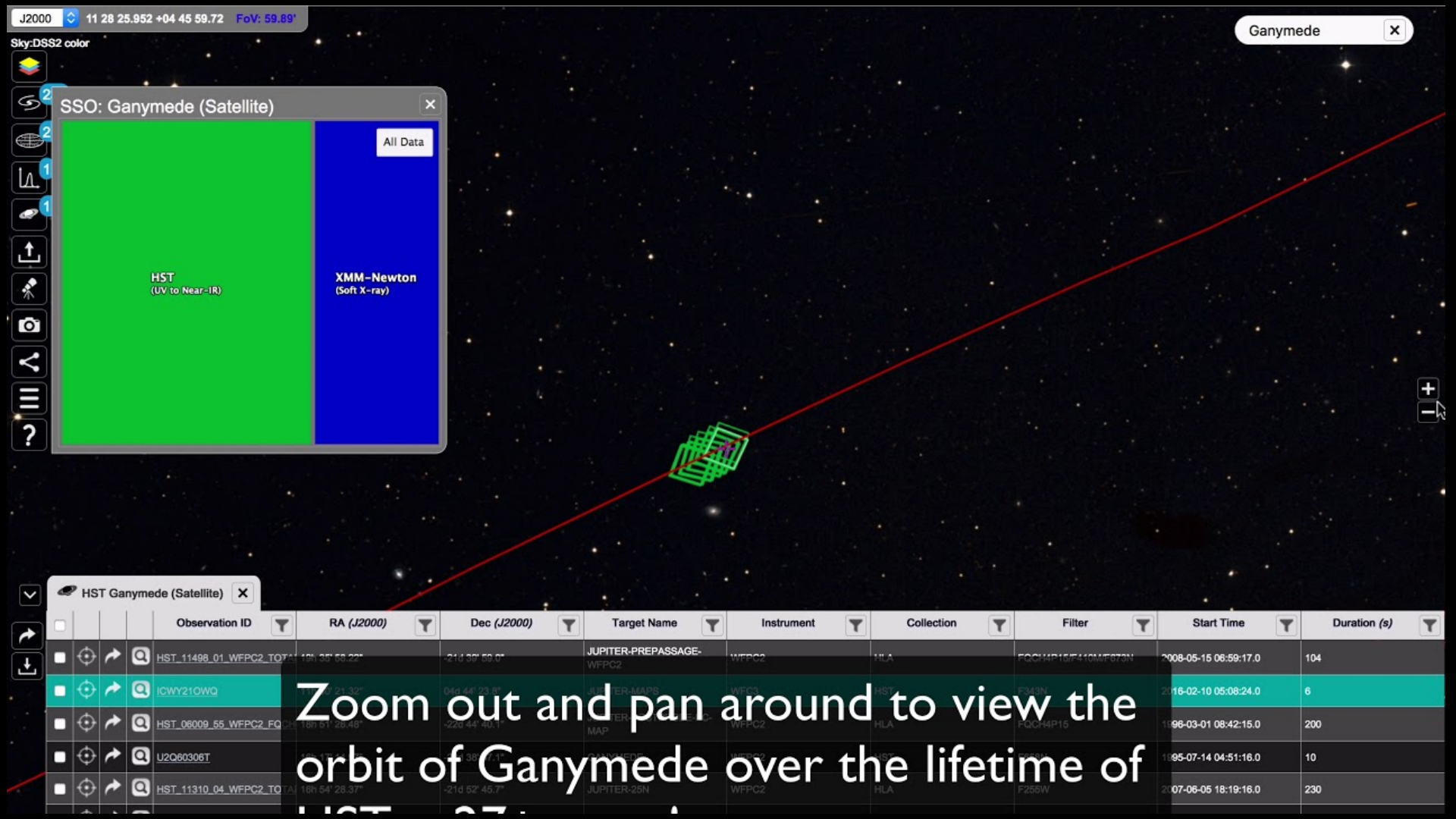
Let's plan an observation... (and ignore the oversubscription)



SSOs in ESASky



SSOs in ESASky



AI is also present in ESASky: EVA

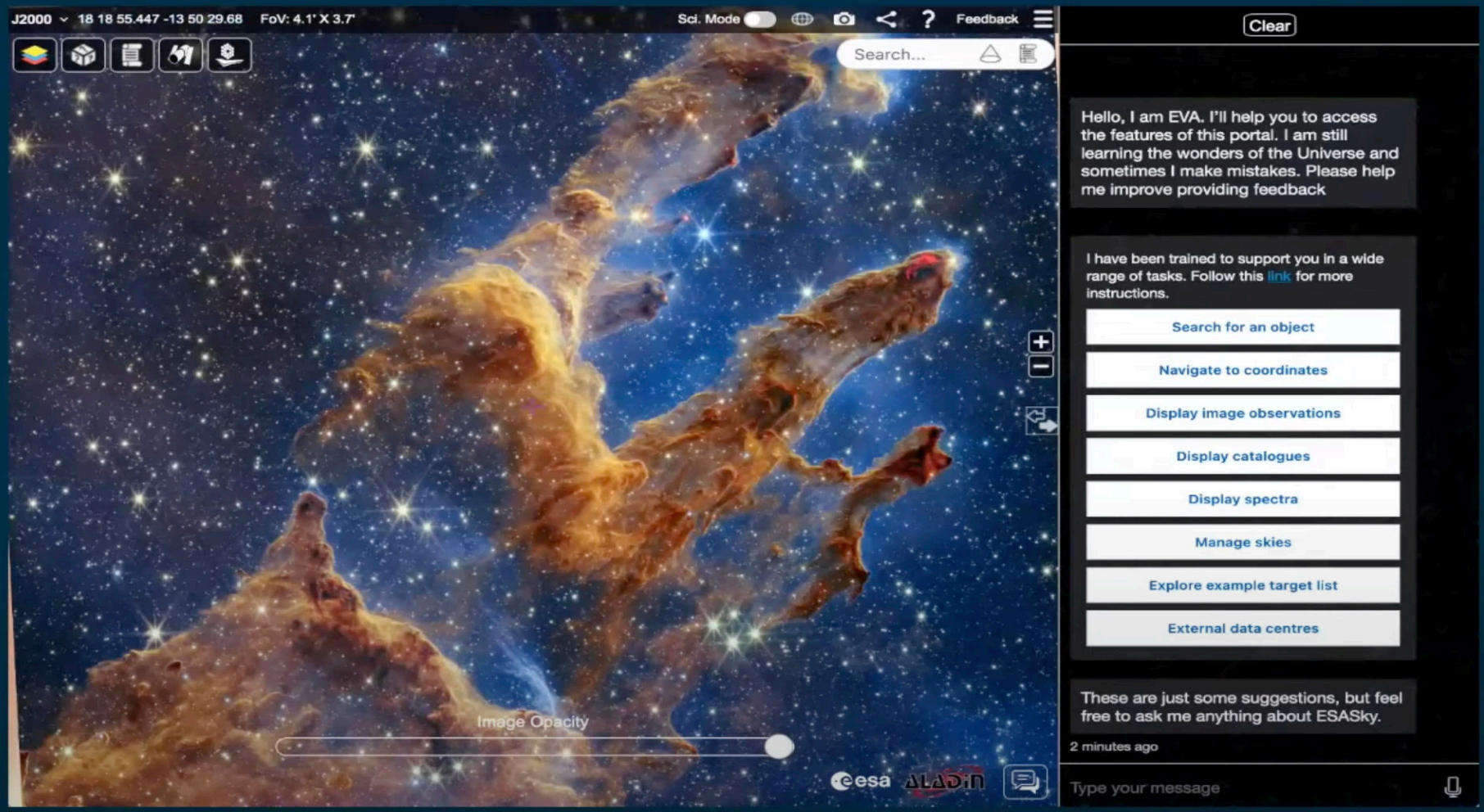
"A Virtual Assistant or Chatbot is a computer program that uses AI, namely Natural Language Processing, to have a conversation with humans. Users can ask questions, make requests and respond to chatbot questions and statements using natural language. A chatbot could support text input, audio input, or both."

— IBM —

Benefits

- Responds immediately
- Provides assistance 24x7
- Keep it conversational
- Advanced information searching
- Improve loyalty and accessibility

EVA can help, especially newcomers



Astroquery accessing ESASky

Access ESASky products with astroquery.esasky

Authors: Ivan Valtchanov, Belén López Martí, H. Norman, Nuria Álvarez Crespo

Last update: Jul 07, 2021

This notebook illustrates some example usages of the ESASky implementation in astroquery.

First you need to install astroquery and esasky.

Astroquery can be installed with `pip install --pre astroquery`, the latest version should come with esasky. Alternatively, you can grab the latest astroquery with esasky from here.

The documentation for astroquery.esasky is available here.

Use Case 1: Retrieve imaging data for a single object

In this use case, imaging data are retrieved for a single object, indicated by its name (resolved by Simbad) or coordinates.

We start by importing the ESASky astroquery module and other necessary packages:

In [1]:
```
%matplotlib inline
import matplotlib.pyplot as plt
from matplotlib.colors import LogNorm
import os
from astroquery.esasky import ESASky
```

```
Created TAP+ (v20200428.1) - Connection:
        Host: sky.esa.int
        Use HTTPS: True
        Port: 443
        SSL Port: 443
```

First, let's check the available maps:

In [2]:
```
ESASky.list_maps()
```

Out[2]:
```
['INTEGRAL',
 'XMM',
 'Chandra',
 'SUZAKU',
```

query ESASky using a dedicated module within the python Astroquery package.

In [4]:
```
maps = ESASky.query_object_maps(position='13h29m52.7s +47d11m43s')
print (maps)
```

```
WARNING: InputWarning: Coordinate string is being interpreted as an ICRS coordinate. [astroquery.utils.commons]

TableList with 12 tables:
        '0:INTEGRAL' with 18 column(s) and 1 row(s)
        '1:XMM' with 15 column(s) and 11 row(s)
        '2:CHANDRA' with 53 column(s) and 17 row(s)
        '3:XMM-OM-OPTICAL' with 17 column(s) and 12 row(s)
        '4:XMM-OM-UV' with 17 column(s) and 19 row(s)
        '5:HST-UV' with 15 column(s) and 19 row(s)
        '6:HST-OPTICAL' with 15 column(s) and 260 row(s)
        '7:HST-IR' with 15 column(s) and 41 row(s)
        '8:ISO-IR' with 18 column(s) and 7 row(s)
        '9:HERSCHEL' with 15 column(s) and 9 row(s)
        '10:AKARI' with 11 column(s) and 3 row(s)
        '11:SPITZER' with 14 column(s) and 4 row(s)
```

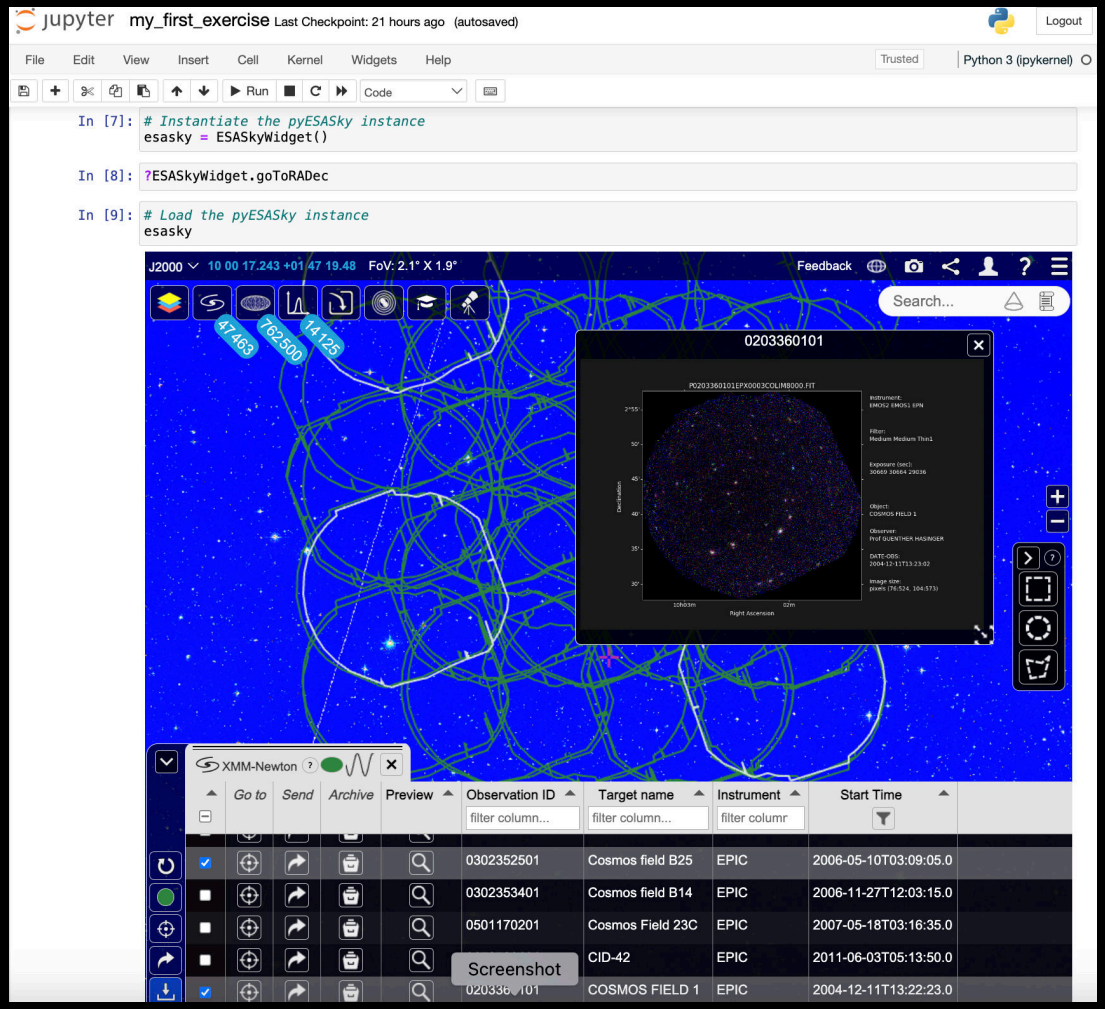
The method has a tolerance of 5 arcsec to allow for positional errors.

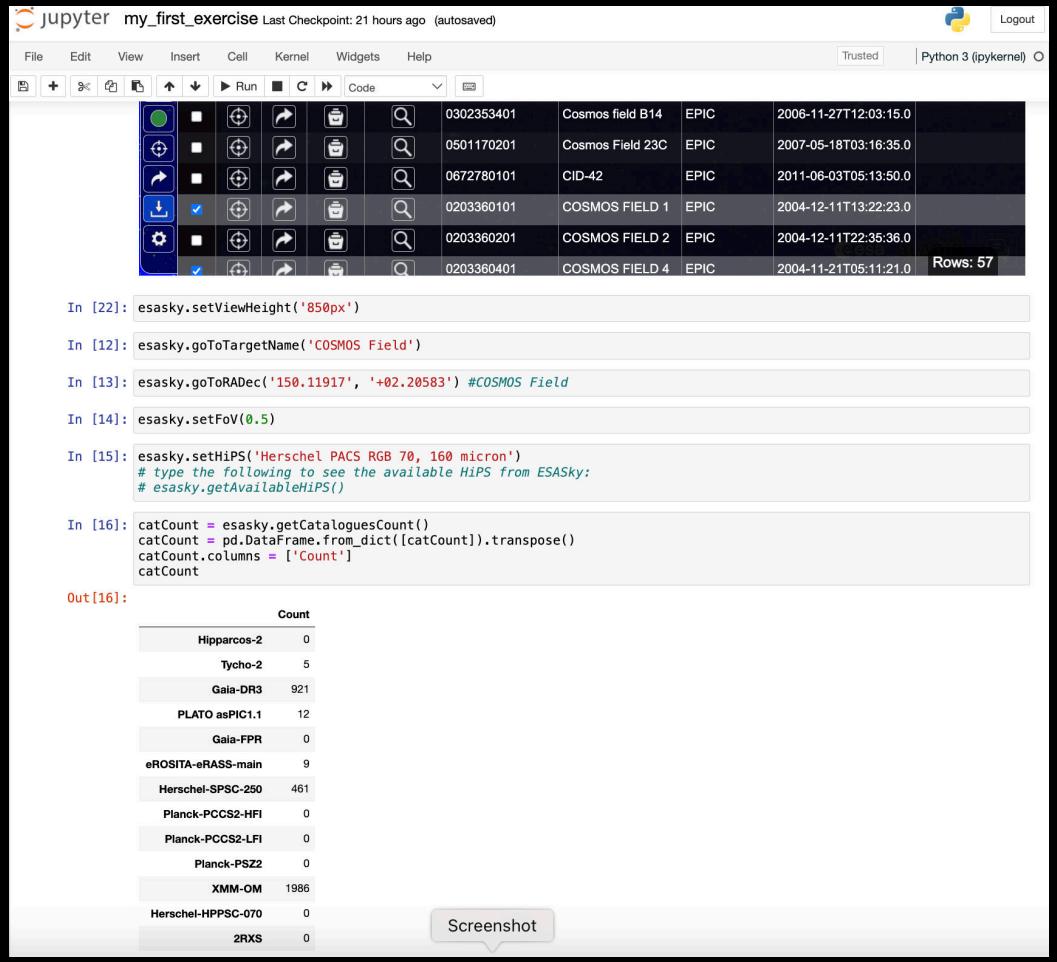
Let's check the content of the 'XMM-OM-OPTICAL' table:

In [5]:
```
maps['XMM-OM-UV'].info
```

Out[5]:
```
<Table length=19>
        name          dtype  unit                description
------------------- ------- ---- ------------------------------------------
             dec_deg float64
            duration   int64    s       Total exposure time of observation
             end_utc  object
              filter  object                                          Filter
                 fov  object
          instrument  object                                      Instrument
      observation_id  object     The XMM-Newton observation identification
     observation_oid   int32              Observation internal identifier
      position_angle float64
        postcard_url  object      The URL to download the postcard preview
         product_url  object              The URL to download the product
proprietary_end_date  object
              ra_deg float64
           start_utc  object
               stc_s  object
              target  object
       xmm_om_uv_oid   int64
```

Jupyter Notebook: pyESASky





pyESASky - Jupyter notebooks

Example notebooks illustrating the capabilities of pyESASky can be found in Github:

https://github.com/esdc-esac-esa-int/pyesasky/blob/master/samples/

DEMO

```
[ ]: # Import the required python modules:
from pyesasky import ESASkyWidget
from pyesasky import Catalogue
from pyesasky import CatalogueDescriptor
from pyesasky import CooFrame
from pyesasky import ImgFormat
from pyesasky import FootprintSet
from pyesasky import FootprintSetDescriptor
from pyesasky import MetadataDescriptor
from pyesasky import MetadataType

import pandas as pd
```

```
[ ]: # Instantiate the pyESASky instance
esasky = ESASkyWidget('En')
#Es and Zh are available for Spanish or Mandarin
```

All of the functions are now documented. Use the IPython ? magic to read about the function. Use tab to complete function names etc:

```
[ ]: # Load the pyESASky instance
esasky
```

Go to a target name resolved against SIMBAD

```
[ ]: esasky.goToTargetName('M81')
```

Set the Field of View in degrees

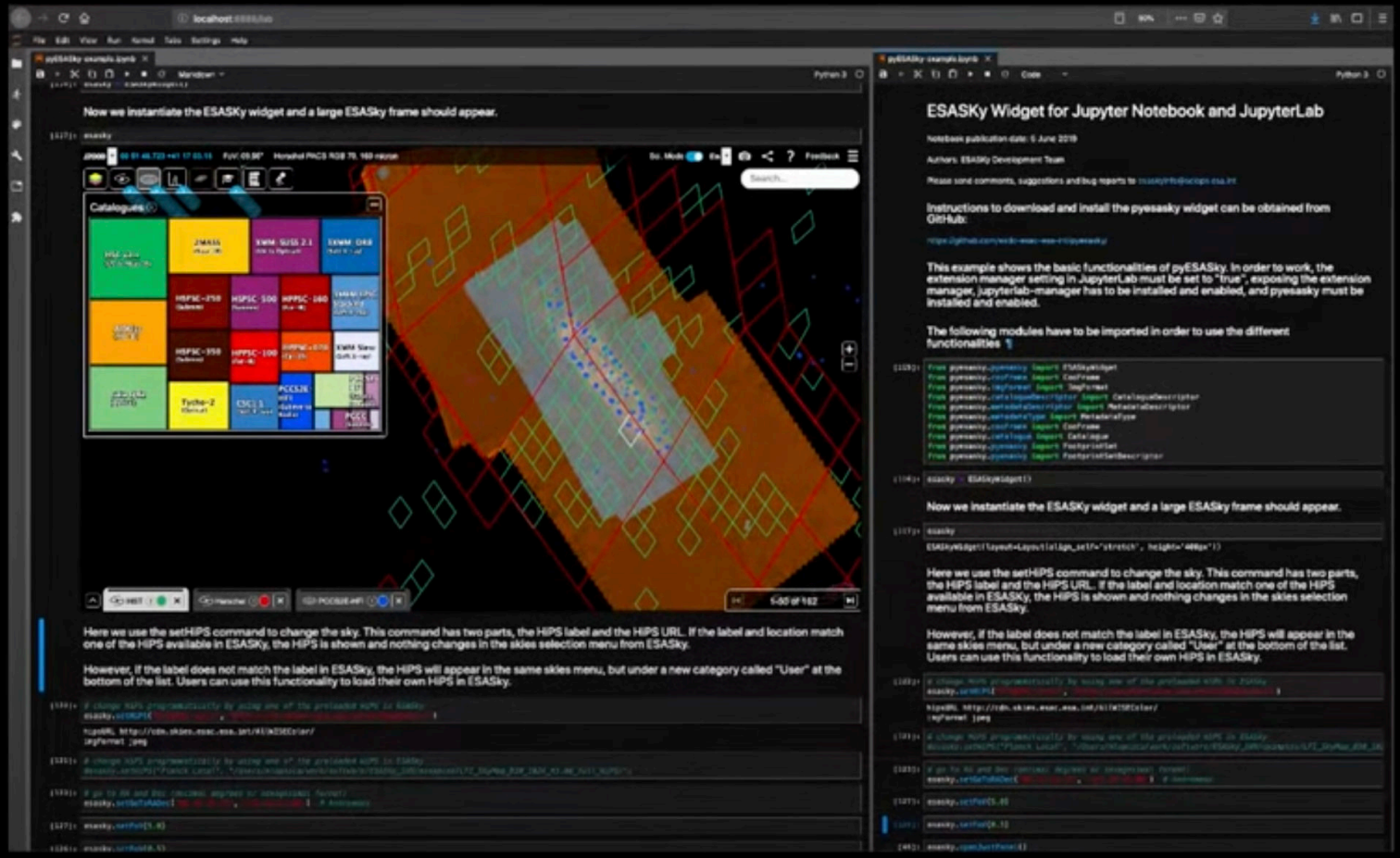
```
[ ]: esasky.setFoV(0.75)
```

Example Notebooks:
https://github.com/esdc-esac-esa-int/pyesasky

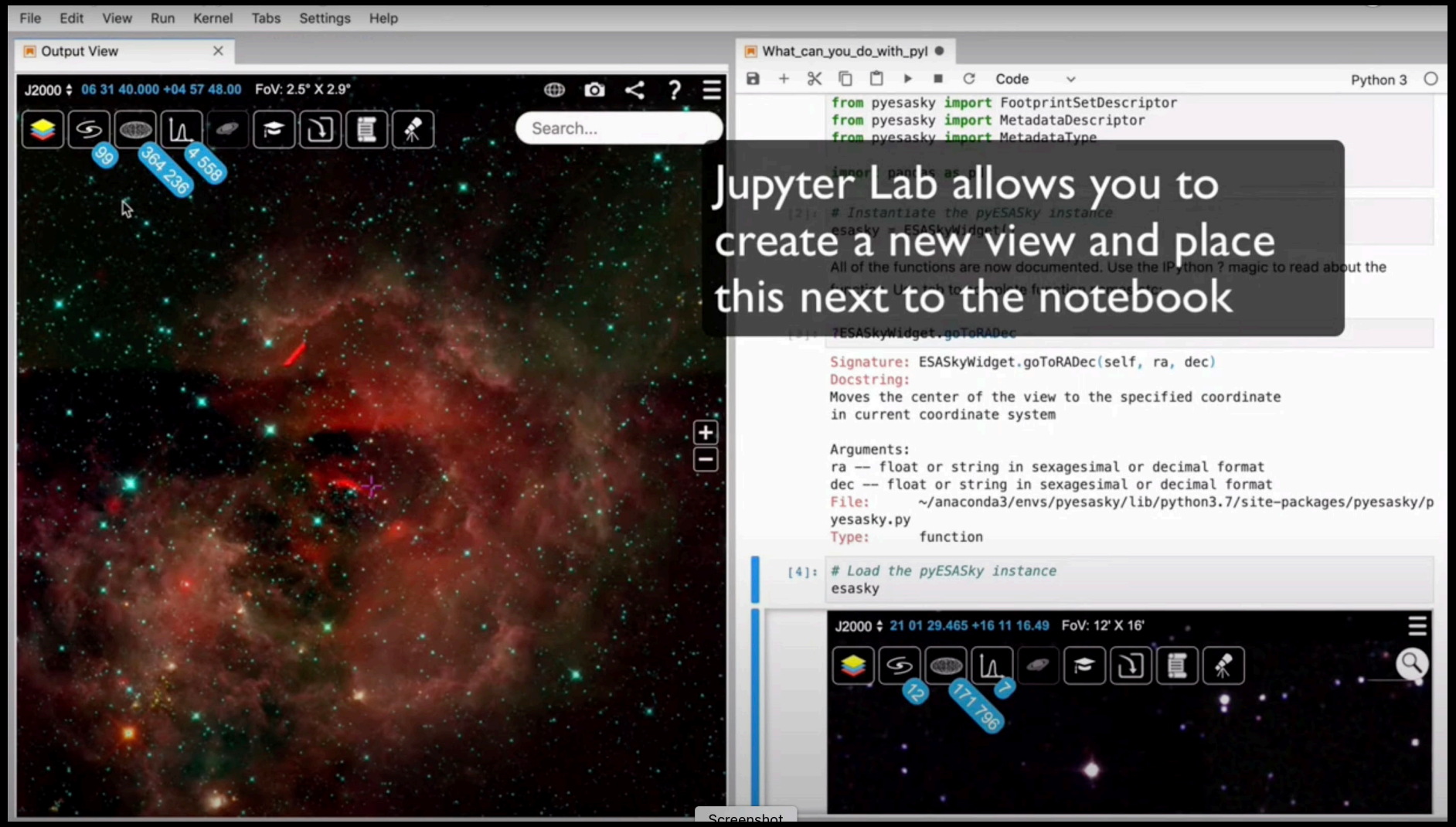
pyESASky and JupyterLab

JupyterLab Widget for ESASky

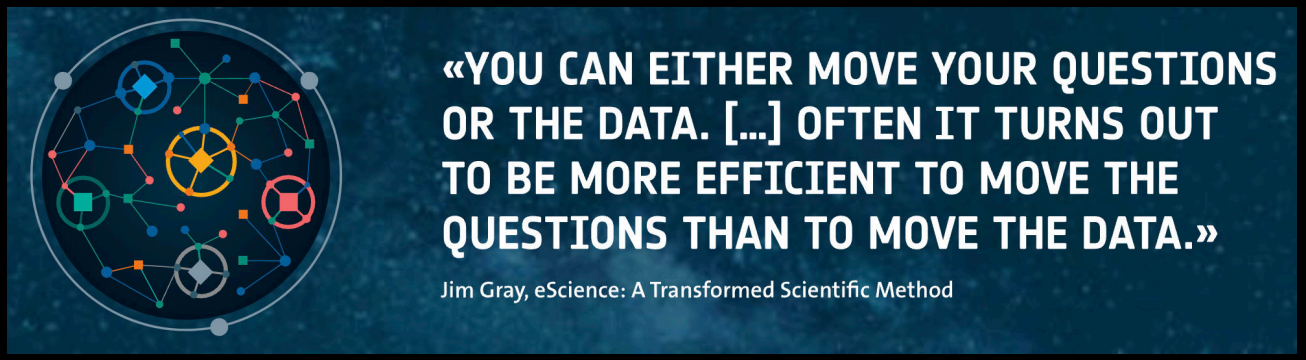
https://github.com/esdc-esac-esa-int/pyesasky/



Jupyter Lab

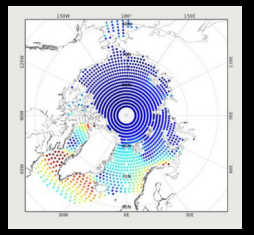

File Edit View Run Kernel Tabs Settings Help
Output View
J2000 06 31 40.000 +04 57 48.00 FoV: 2.5° X 2.9°
Search...
99
364 236
4 558
What_can_you_do_with_pyl
Code
Python 3
from pyesasky import FootprintSetDescriptor
from pyesasky import MetadataDescriptor
from pyesasky import MetadataType
Jupyter Lab allows you to create a new view and place this next to the notebook
# Instantiate the pyESASky instance
esasky = ESASkyWidget()
All of the functions are now documented. Use the IPython ? magic to read about the
?ESASkyWidget.goToRADec
Signature: ESASkyWidget.goToRADec(self, ra, dec)
Docstring:
Moves the center of the view to the specified coordinate
in current coordinate system
Arguments:
ra -- float or string in sexagesimal or decimal format
dec -- float or string in sexagesimal or decimal format
File: ~/anaconda3/envs/pyesasky/lib/python3.7/site-packages/pyesasky/pyesasky.py
Type: function
[4]:
Load the pyESASky instance
esasky
J2000 21 01 29.465 +16 11 16.49 FoV: 12' X 16'
12
171 796
7
Screenshot

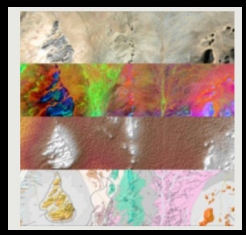
ESA DataLabs

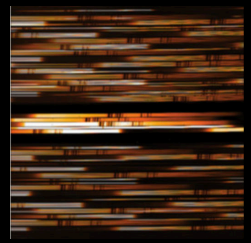


COSPAR
COMMITTEE ON SPACE RESEARCH

- Bring your questions to the data
- Use new tools and your favourite old ones
- Discover all of ESA's domains
- Keep your data and code safe (and also share it)



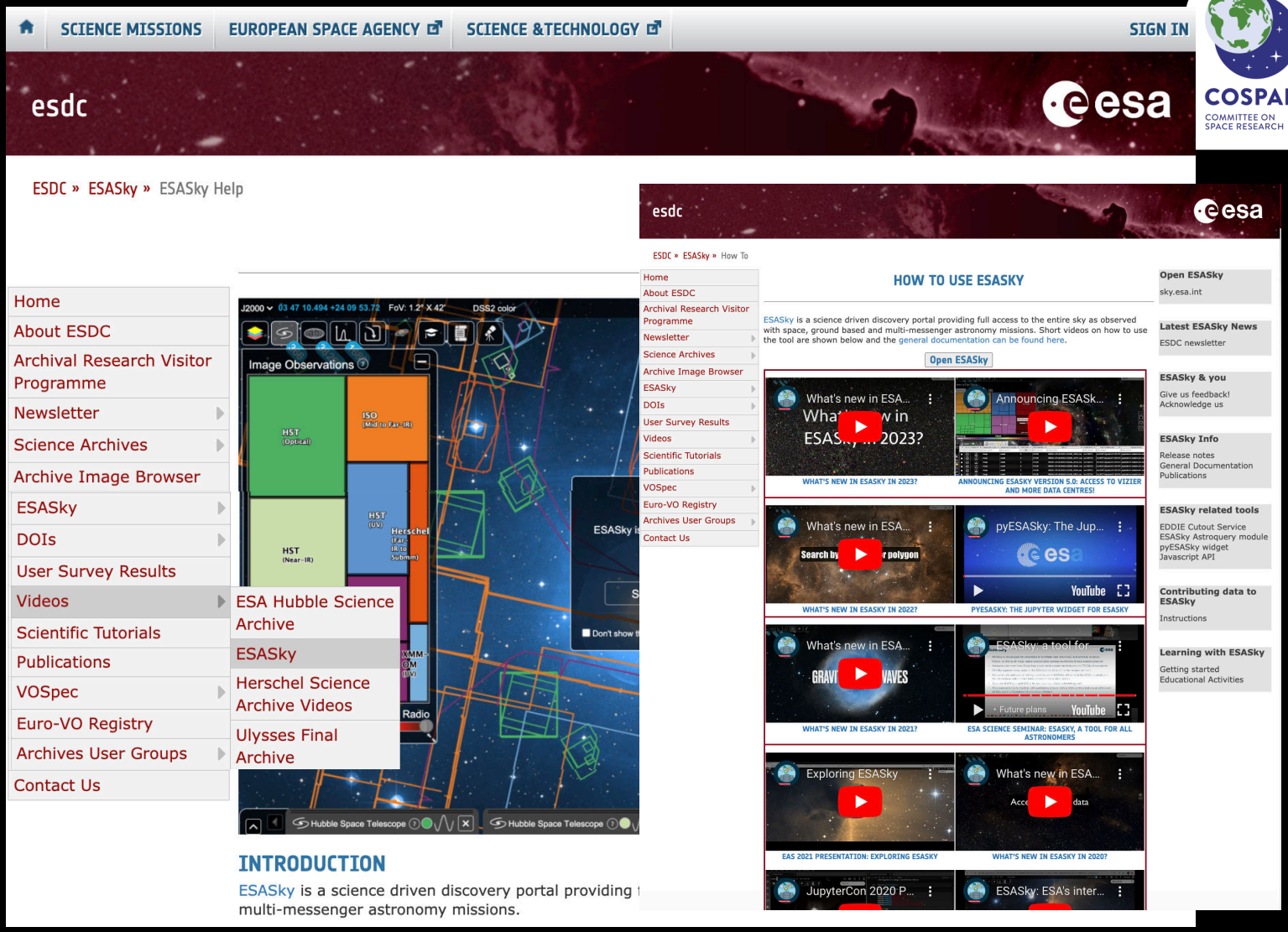




Help!!

https://www.cosmos.esa.int/web/esdc/esasky-help

- User Manual
- Examples
- Science use cases
- Videos
- … and much more



Summary

- ESASky: developed for scientists to facilitate data discovery and archival science
- Vision: to link all major astronomical data centres worldwide & help enable science
- One of the major accomplishments within the IVOA
- It shows how powerful scientific collaboration and openness of data providers can be
- Importance of protocols and international collaboration between astronomical centres
- ESA DataLabs as an alternative for integrated data analysis