Modernizing ESA Science Archives:

Reusable Components and Automated HiPS Generation in a VO-Aligned ecosystem

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ESA science archives modernization

ESAC Science Data Centre (**ESDC**)

Designs, develops, and operates **science archives** for the **ESA space science missions**

Astronomy Science Archives

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

The Planetary Science Archive

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

Heliophysics Science Archives

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

Future Archives

- ariel
- plato
- smile
- proba-3

Human and Robotic Exploration Science Archives*

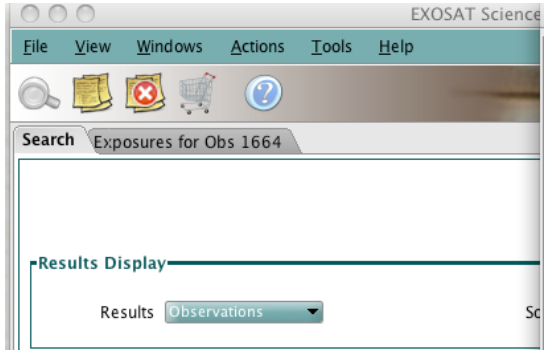
- HRE data archive
- ISS- SolACES*

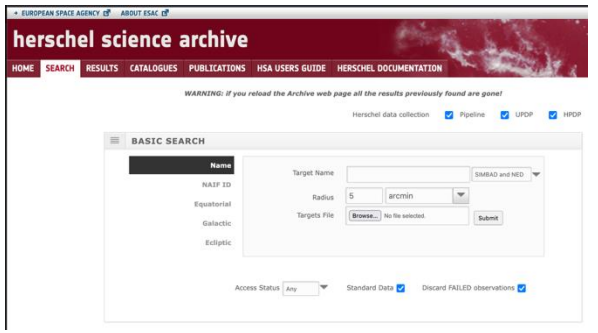
* in coordination with the Human Spaceflight and Robotic Exploration directorate

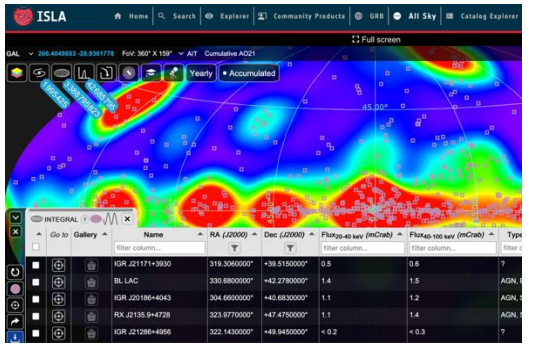
ESA science archives modernization

Over the decades, the software architecture of these archives has experienced **significant changes** passing through several generations of technology:

Client Layer:	Java applets	Java Web Start	Google Web Toolkit GWT	**Angular**
Server Layer:	In-house Java servers		Open source Java servers	Open source Java servers (**IVOA** protocols)







ESA science archives modernization

Each mission archive was historically developed **independently**, with its own bespoke **backend** logic (proprietary endpoints and data delivery mechanisms) and its own custom **frontend** (hardcoded search forms, hard-to-reuse components, ..)

Problems:
- Engineers: obsolete software, specific knowledge per archive, hard to maintain
- Scientists: completely different experience when moving from one archive to another.

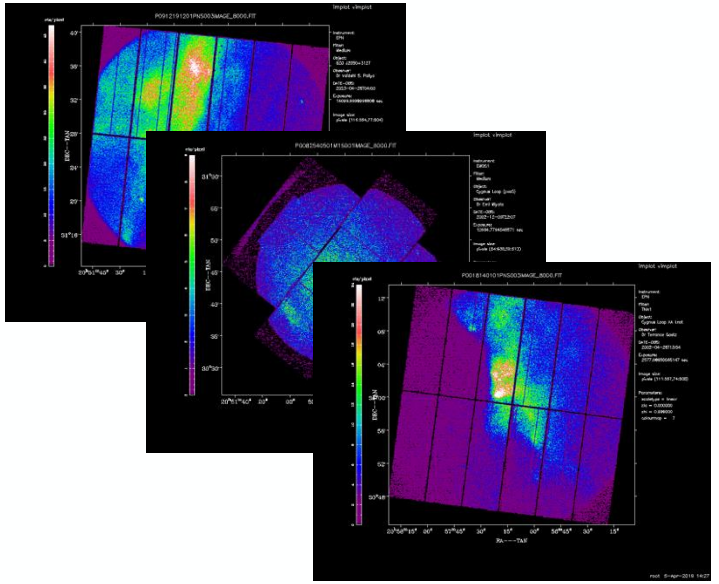
Solution (gradually):
The backend of the archives started to be migrated to **IVOA standards** (i.e. **TAP, ObsCore**, ..), and the frontend to Angular web technology with a shared **component framework** (widgets).

Goals: interoperability, **reusability**, **maintainability**

HiPS generation* pipeline

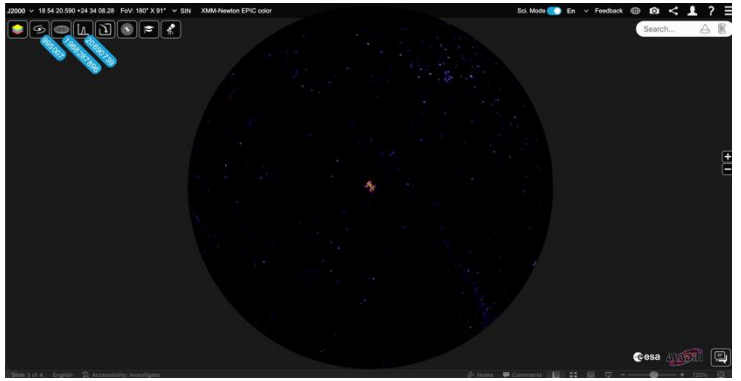
XMM-Newton Science Archive (XSA) use case

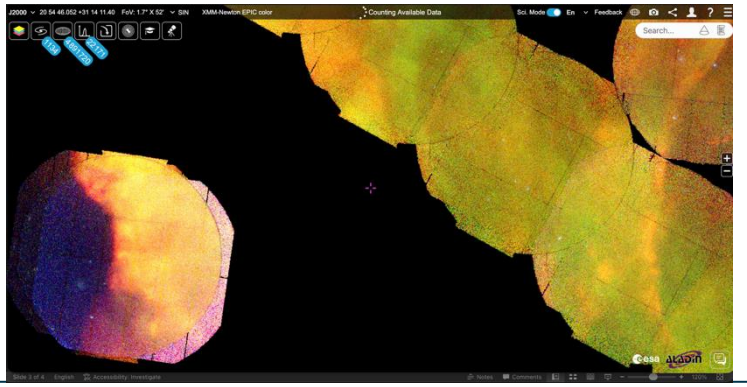
From pointed observations…



…

…to ESASky





zoom in

*Generated with ‘CDS Aladin/Hipsgen’

HiPS generation* pipeline

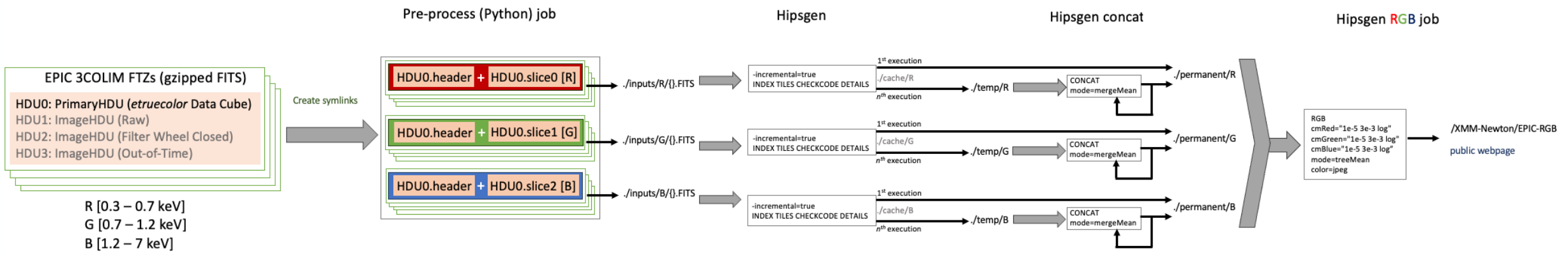
XMM-Newton Science Archive (XSA) use case

Traditionally, for each ESA archive:

- **HiPS generation was performed by manually and occasionally executing archive-custom Linux shell scripts. (even years passed between executions)**
- **Cumbersome if many instruments/filters; easy to lose track of status.**

New approach:

- **Common Java Spring application to orchestrate the generation. Still custom settings per archive, but all same flow: Input files gathering → Python preprocessing → Hipsgen (new/concat) steps → Webserver publish**
- **Keeps track of the progress in a database. Easy to integrate new observations.**
- **Scheduled or triggered execution.**

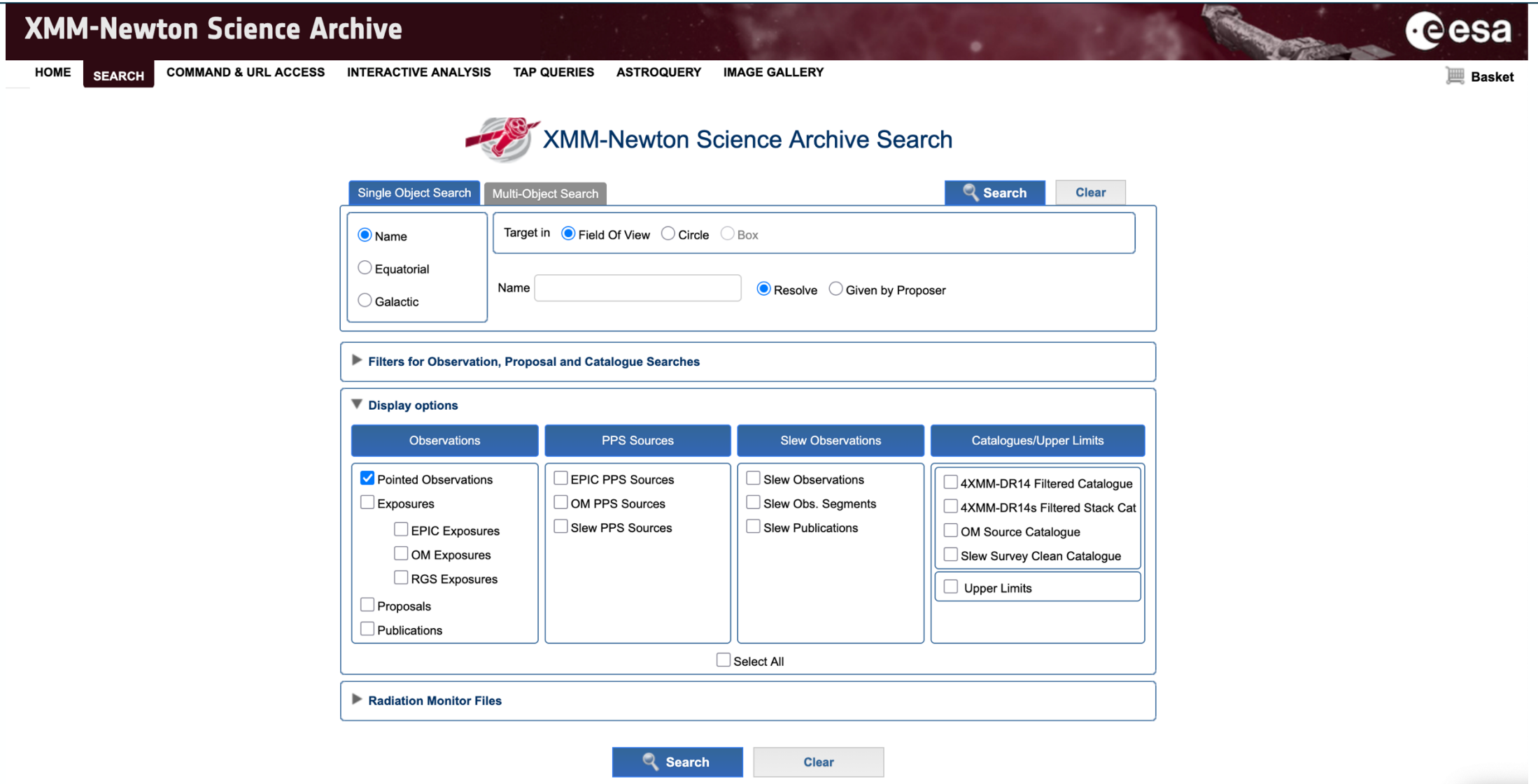


Pre-process and Hipsgen parameters defined by the Scientists

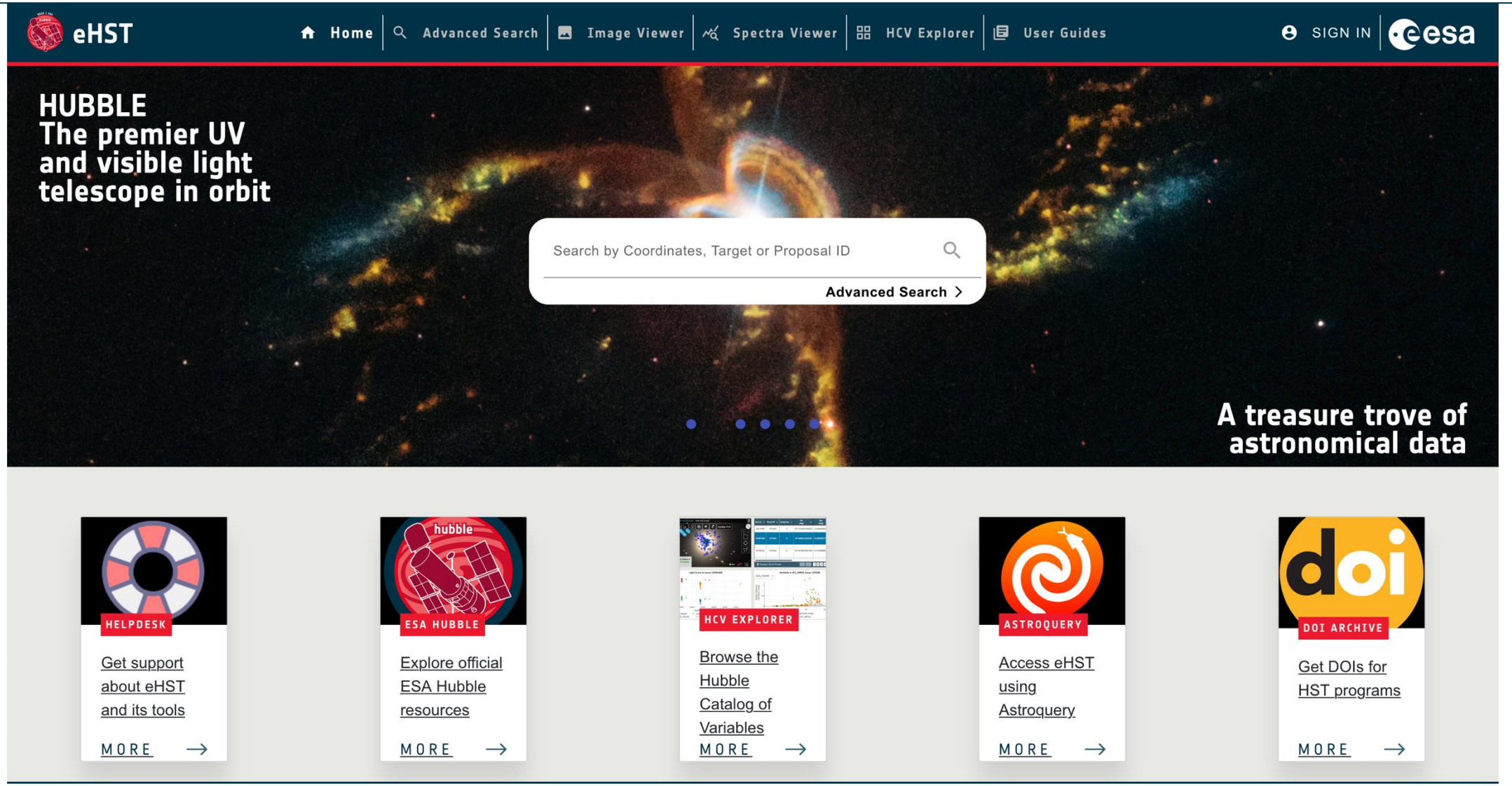
‘M’ is for ‘Maintainability’ (FAIRM?)

- Every mission archive was building and maintaining the components independently
- ESDC’s answer: a shared, common widget library across all services
- Built on open standards: TAP-aligned, VO-compatible, and **mission-agnostic**

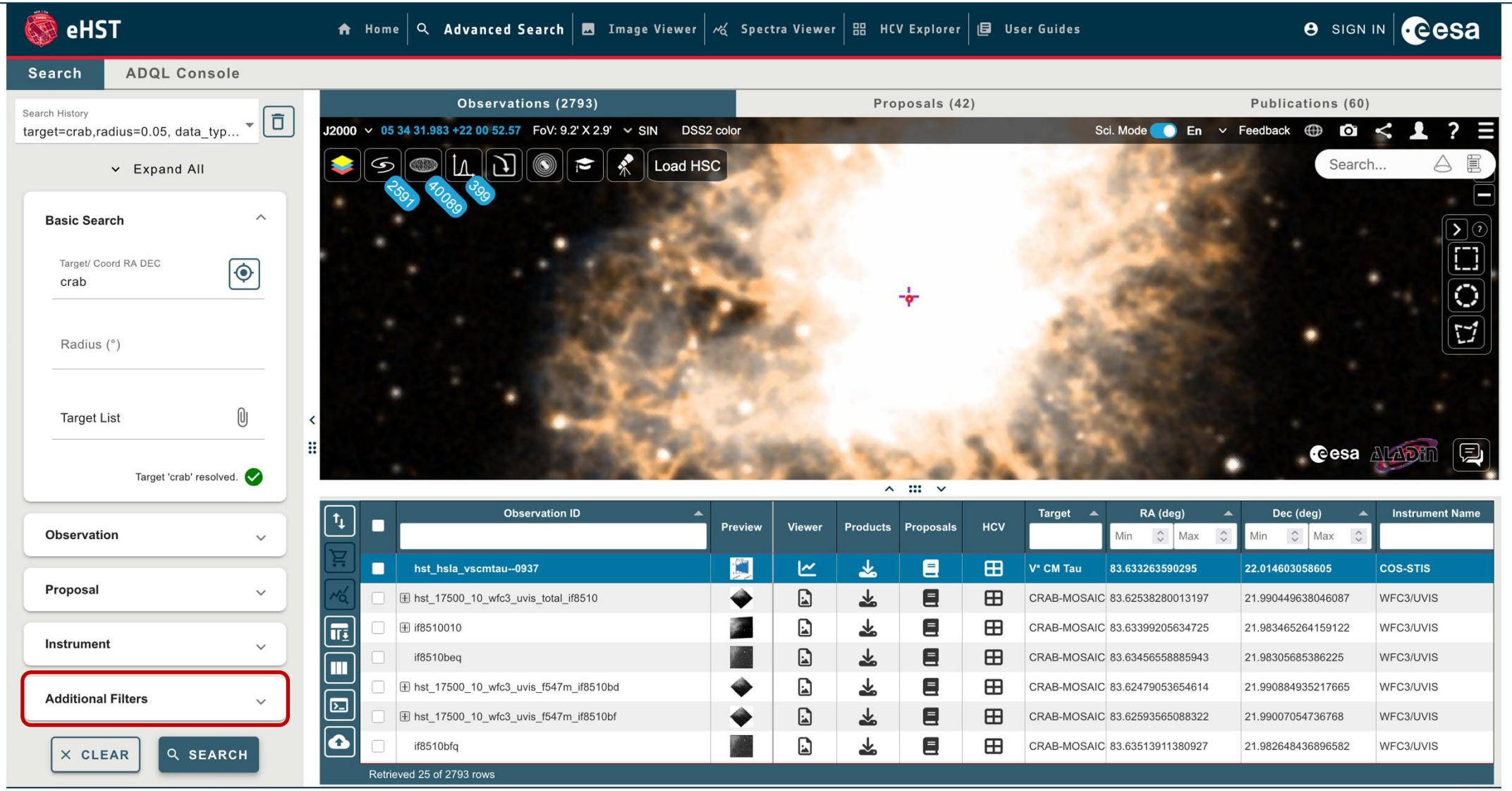
Modernizing the Archives: from bespoke platforms…



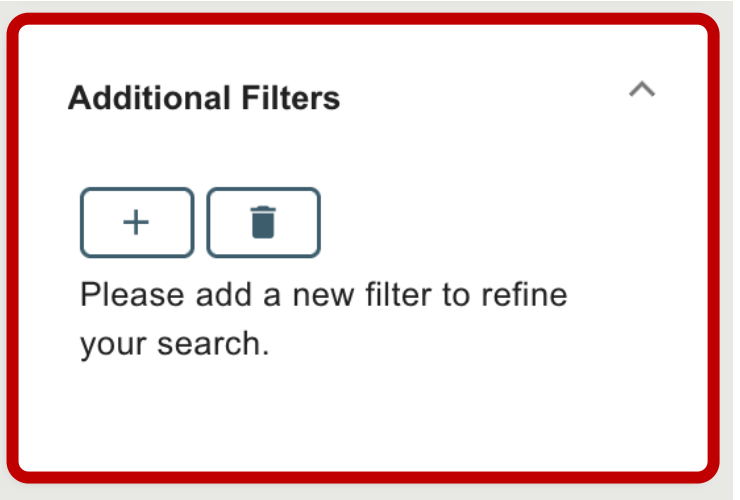
Modernizing the Archives: …to a common approach



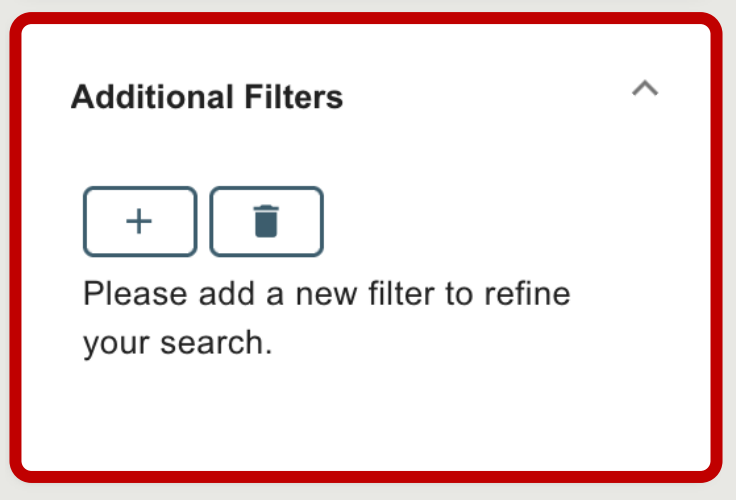
Data Discovery: a simple search



ESDC Search Panel: flexible data discovery



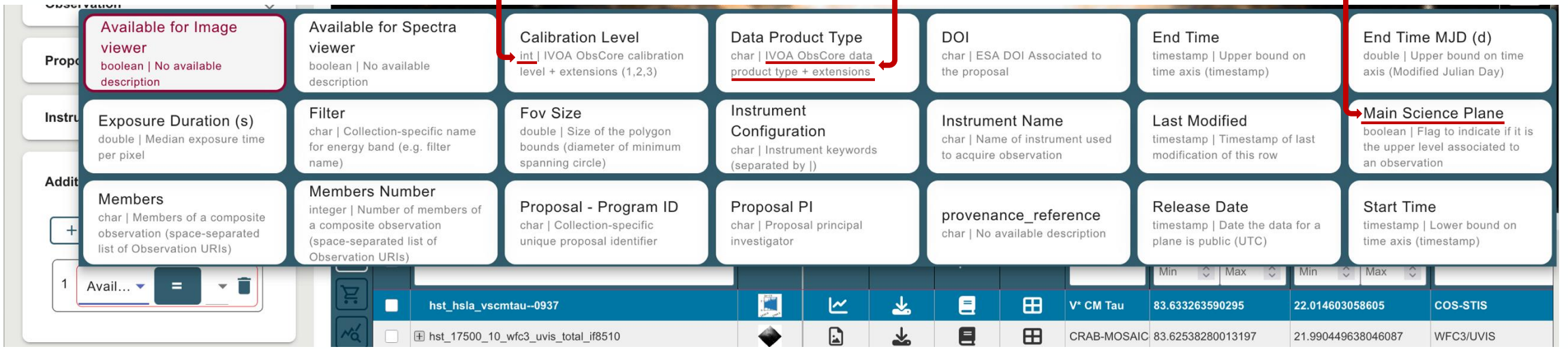
ESDC Search Panel: flexible data discovery



datatype

detailed description

search criteria filter



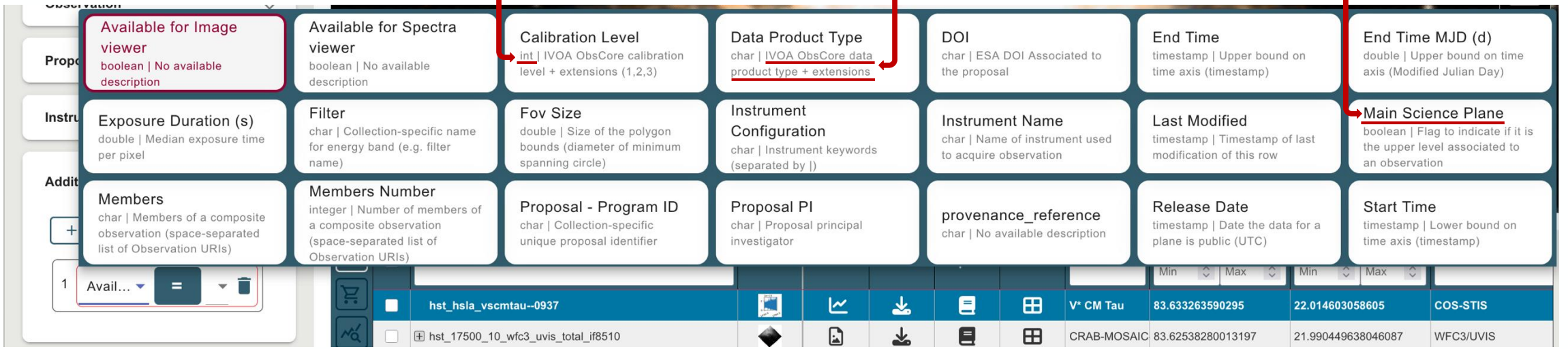
ESDC Search Panel: flexible data discovery

(exposed by the TAP)

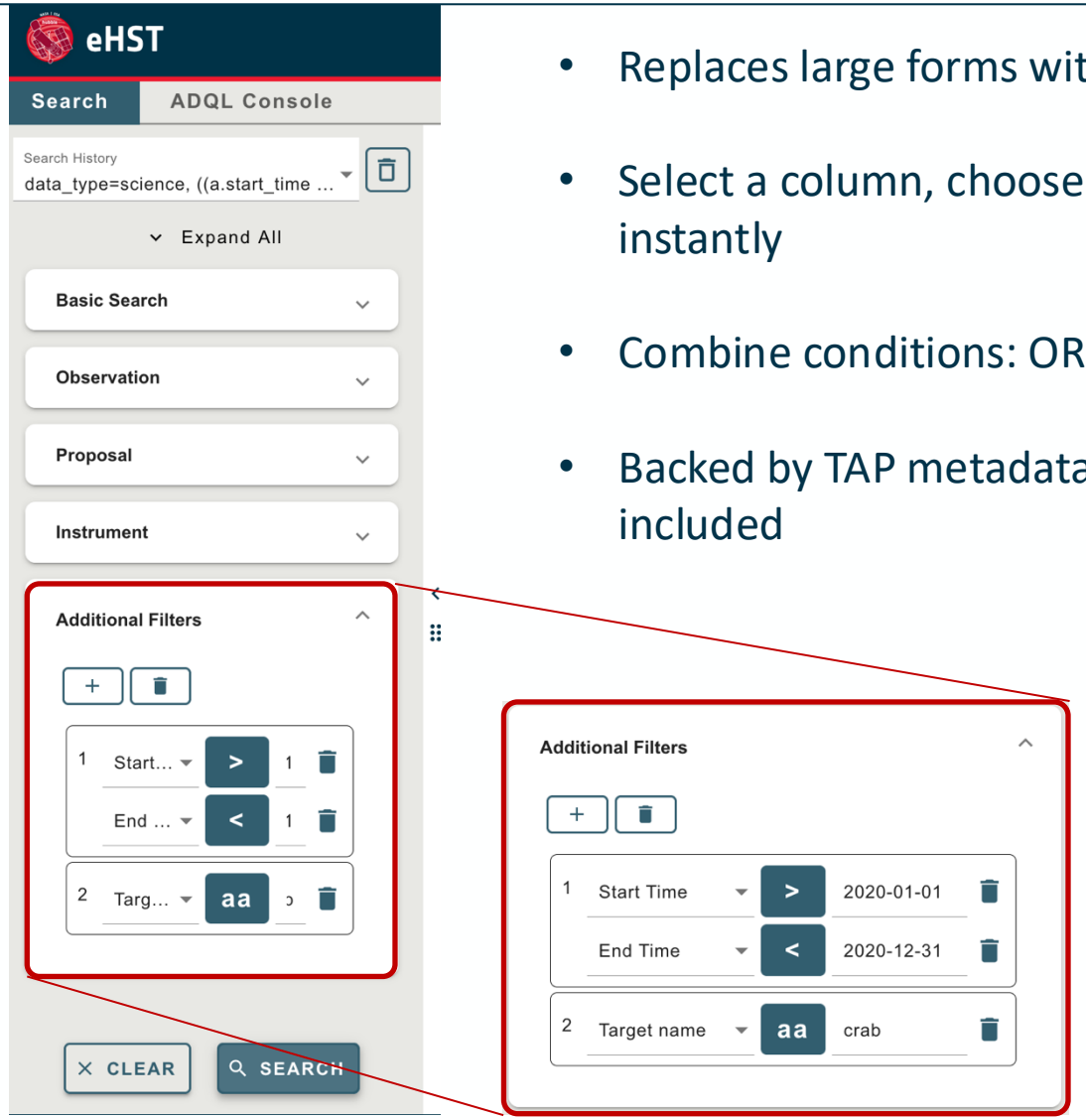
```
<column std="false" esatapplus:flags="0" esatapplus:ref="">
  <name>calibration_level</name>
  <description>IVOA ObsCore calibration level + extensions (1,2,3)</description>
  <ucd>caom:Plane.calibrationLevel</ucd>
  <dataType xsi:type="vod:VOTableType">int</dataType>
</column>
```

```
<column std="false" esatapplus:flags="0" esatapplus:ref="">
  <name>dataproducttype</name>
  <description>IVOA ObsCore data product type + extensions</description>
  <utype>caom:Plane.dataProductType</utype>
  <dataType xsi:type="vod:VOTableType">char</dataType>
</column>
```

```
<column std="false" esatapplus:flags="0" esatapplus:ref="">
  <name>main_science_plane</name>
  <description>Flag to indicate if it is the upper level associated to an observation</description>
  <dataType xsi:type="vod:VOTableType">boolean</dataType>
</column>
```

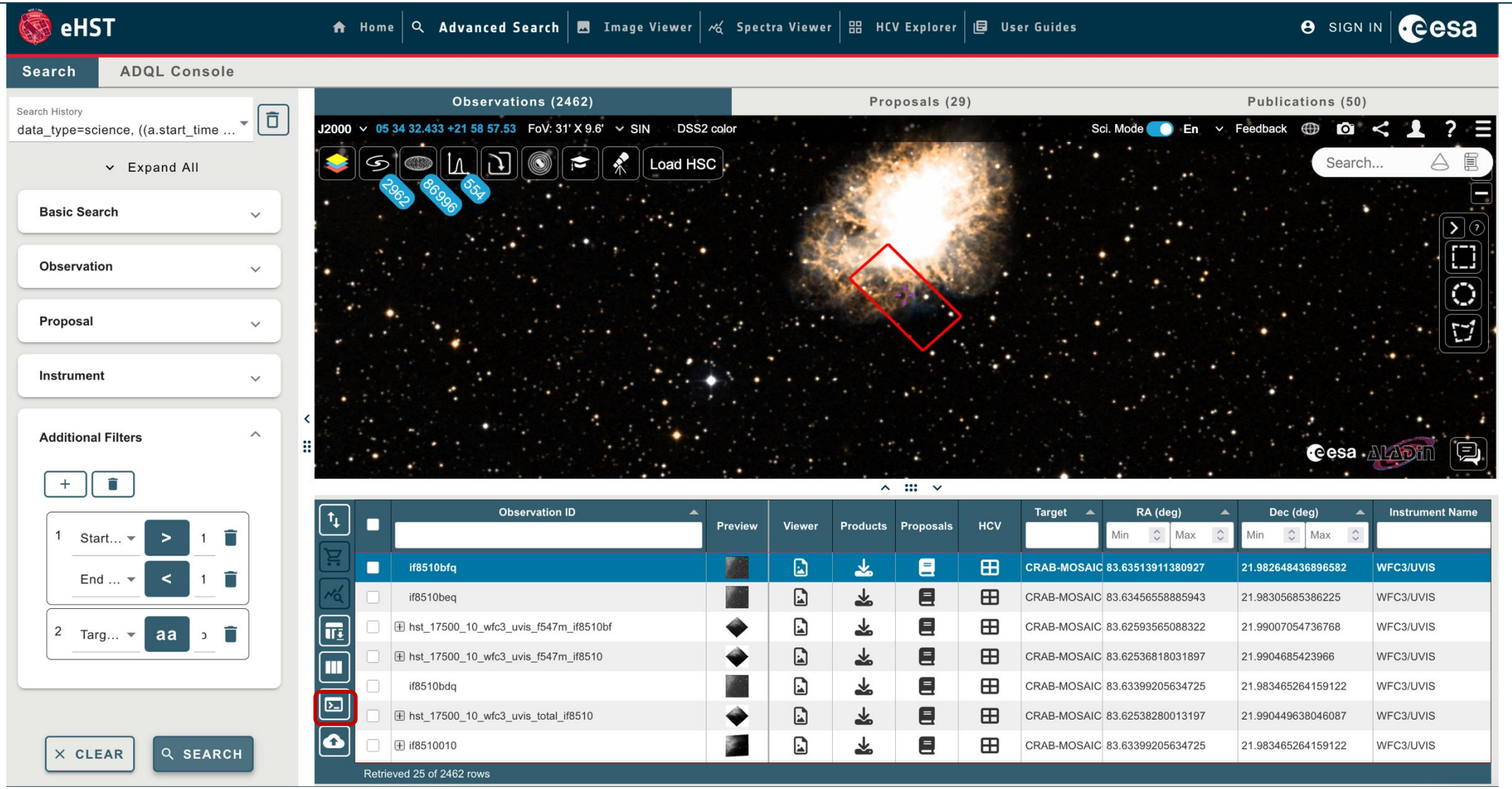


ESDC Search Panel: flexible data discovery



- Replaces large forms with a dynamic, column-based filter builder
- Select a column, choose a comparator, define a value: create any filter instantly
- Combine conditions: OR within a group, AND across groups
- Backed by TAP metadata: column names, types, descriptions and UCDs included

ESDC Search Panel: flexible data discovery (bonus)



Multiple methods for programmatic accessibility

Programmatic Access

Query

```
select * from ehst.archive a where (a.intent = 'science') and ((a.start_time > '2019-12-31') OR (a.end_time < '2020-12-30')) AND ((a.target_name ilike '%crab%')) order by a.release_date desc
```

CURL

```
curl -o file.vot "https:// hst.esac.esa.int / tap-server/tap/sync?LANG=ADQL&REQUEST=doQuery&FORMAT=VOTABLE&TAPCLIENT=ehst-6.0.0-rc2&QUERY=select * from ehst.archive a where (a.intent = %27science%27) and ((a.start_time > %272019-12-31%27) OR (a.end_time < %272020-12-30%27)) AND ((a.target_name ilike %27%25crab%25%27)) order by a.release_date desc"
```

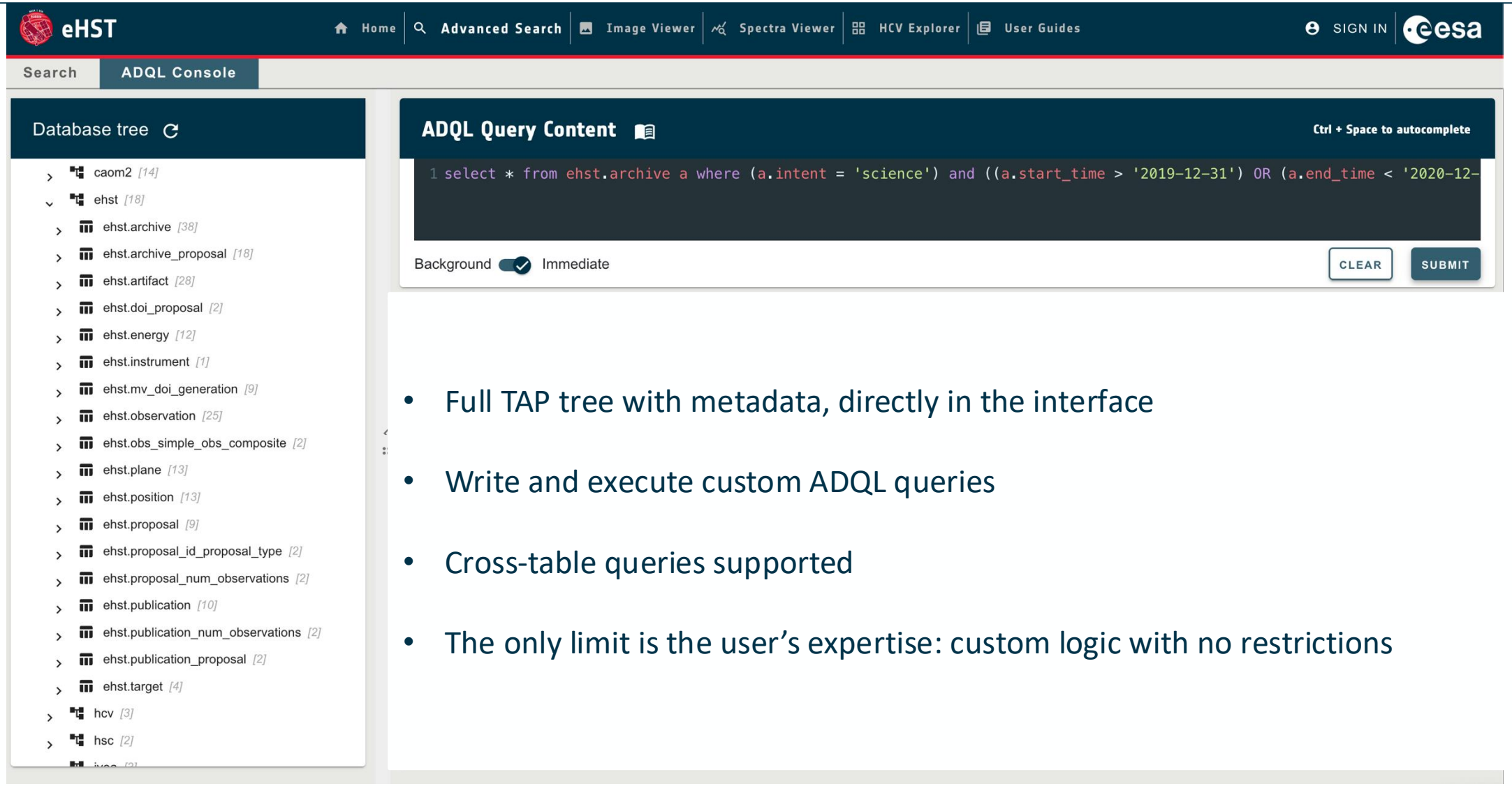
WGET

```
wget -O file.vot "https:// hst.esac.esa.int / tap-server/tap/sync?LANG=ADQL&REQUEST=doQuery&FORMAT=VOTABLE&TAPCLIENT=ehst-6.0.0-rc2&QUERY=select * from ehst.archive a where (a.intent = %27science%27) and ((a.start_time > %272019-12-31%27) OR (a.end_time < %272020-12-30%27)) AND ((a.target_name ilike %27%25crab%25%27)) order by a.release_date desc"
```

Astroquery

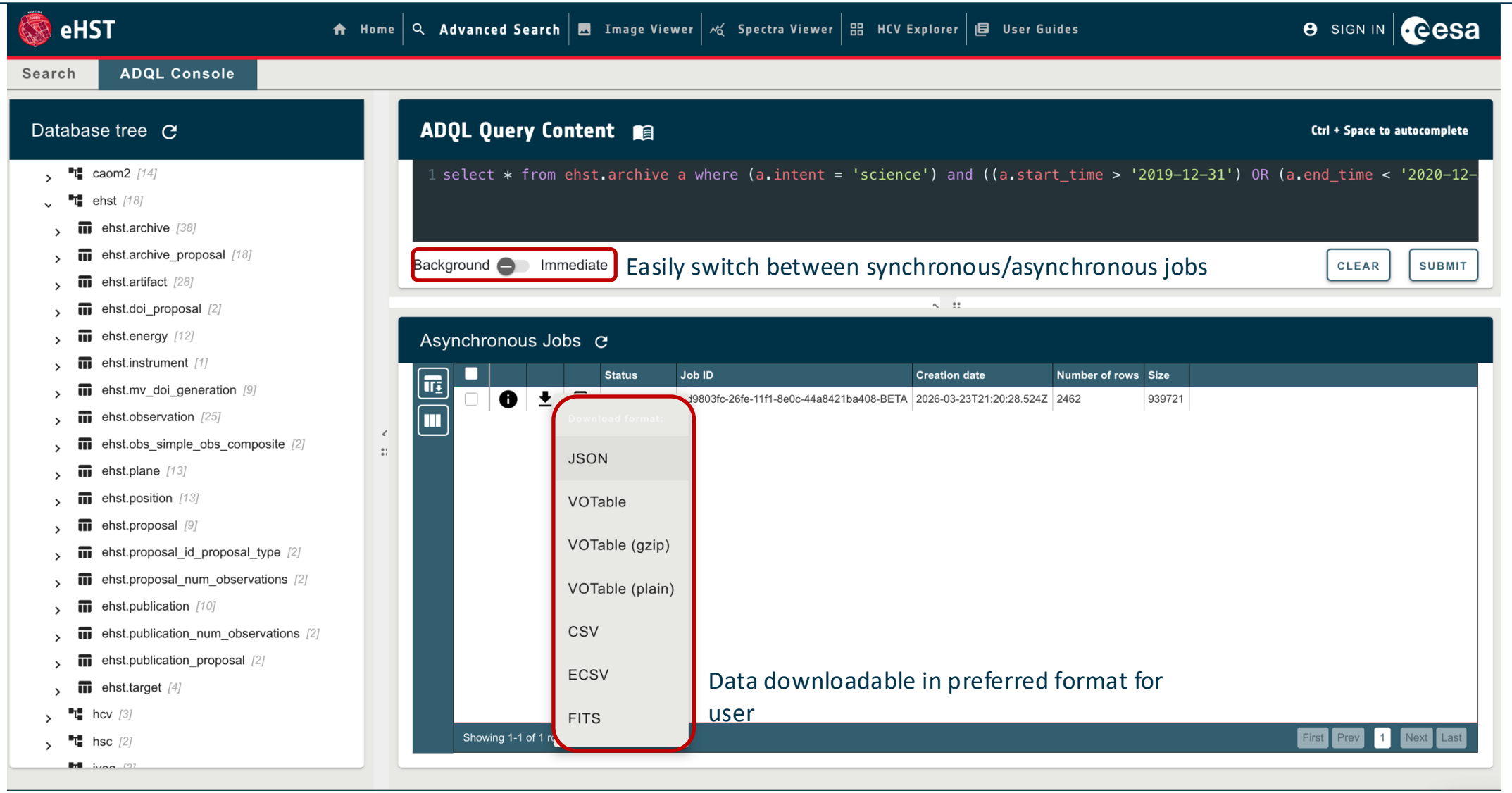
```
from astroquery.esa.hubble import ESAHubble
esahubble = ESAHubble()
query = "select * from ehst.archive a where (a.intent = 'science') and ((a.start_time > '2019-12-31') OR (a.end_time < '2020-12-30')) AND ((a.target_name ilike '%crab%')) order by a.release_date desc"
result = esahubble.query_tap(query)
```

ESDC ADQL Console: query without limits



- Full TAP tree with metadata, directly in the interface
- Write and execute custom ADQL queries
- Cross-table queries supported
- The only limit is the user's expertise: custom logic with no restrictions

ESDC ADQL Console: multiple formats available



A Step Forward for ESA Science Data

- ESDC's commitment to interoperability and the Virtual Observatory community
- **HiPS Pipeline:** continuous, automated sky maps that are always current, and fully VO-compatible
- **Reusable ESDC widgets:** flexible discovery tools, consistent across every archive
- Together: data more accessible and exploitable

Thank you

ESAC Science Data Centre

https://www.cosmos.esa.int/web/esdc

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