



ESCAPE

European Science Cluster of Astronomy &
Particle physics ESFRI research Infrastructures

The Virtual Observatory in ESCAPE and EOOSC

Mark ALLEN

CDS, Observatoire Astronomique de Strasbourg (CNRS-ObAS)

For the CEVO Team



One view of the VO from an application/portal :

Enables a *Virtual Research Environment* of interoperable tools and services based on IVOA standards:

Built from VO Registry

1000s All-Sky data sets

Data from many observatories and missions

Complex ADQL queries

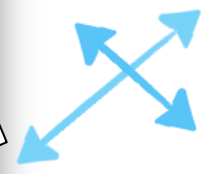
Largest catalogues: ESO surveys, Gaia etc.

```
In [ ]: 1 from ipyaladin import Aladin
2 a = Aladin(target='18 55 24.508 +04 29 46.72', survey='P/Mellinger/color', fov=180)
3 a

In [ ]: 1 ...

In [ ]: 1 a.survey = 'P/GALEXRG6/AIS/color'; a.target = 'M101'; a.fov = 0.3

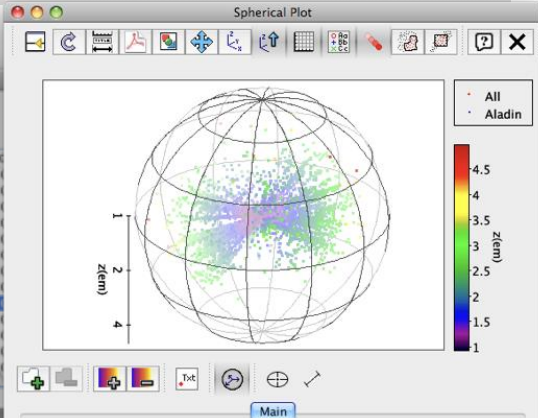
In [ ]: 1 nloadTableOutputFormat=vot&filename=vizier_M101_II_328_allwise_20190322, {'color': 'red', 'onClick': 'showTable'}
3
```



TOPCAT(1): Table Browser

Table Browser for 1: III.157

Seq	QSO	Name	z	Vmag	Type	Ns	Calip
31	1133+704	Mrk 180	0.046	14.49	BLZ	1	Calip
32	1146-037	PKS	0.341	16.9	QSO	1	Calip
33	1148+549	PG	0.969	15.82	QSO	1	Calip
34	1156+295	4C 29.45	0.729	14.41	BLZ	1	Calip
35	1202+281	PG	0.165	15.51	QSO	1	Calip
36	1211+141	PG	0.085	14.63	QSO	2	Calip
37	1219+755	Mrk 205	0.07	14.5	SY1	2	Calip
38	1225+317	B2	2.219	15.87	QSO	1	Calip
39	1276+074	3C 273	0.158	12.86	QSO	2	Calip
40	1229+204	TON 1542	0.064	15.3	SY1	2	Calip
41	1241+176	PG	1.273	15.38	QSO	1	Calip
42	1253-055	3C 279	0.538	17.75	BLZ	2	Calip
43	1302-102	PKS	0.286	14.92	QSO	2	Calip



Main

Data Table: 2: VII.158

Longitude Axis: _RAJ2000 degrees

Latitude Axis: _DEJ2000 degrees

Radial Axis: z(em)

Row Subsets: All, Aladin

Making data FAIR with the Virtual Observatory.

The **Virtual Observatory** is:

- **An operational framework** for interoperable access to world-wide astronomical data and services.
- **A pioneer of FAIR data sharing** - an existing global framework – populated by major data providers (space and ground based) that is heavily used by the community.
- **Built on International Virtual Observatory Alliance (IVOA) standards**
 - *Recognised in the ESFRI roadmap (2021).*
 - *'... a global implementation of a FAIR disciplinary framework and openly available data, the so-called astronomical Virtual Observatory.'*
 - *Quoted as an example in EOSC SRIA document (Feb 2021).*
- **Supported in Europe** by **Euro-VO** (VO Partners + EC projects since ~2001).
 - *Recognised in ASTRONET roadmap (2008, 2014, 2022).*



In ESCAPE, the Virtual Observatory is supported by WP4 “**CEVO**”

Connecting **ESFRI** projects to EOSC through the **VO** framework

- **EOSC** – European **O**pen **S**cience **C**loud
- **VO** – *Virtual astronomical* **O**bservatory



WP4 / CEVO in the ESCAPE 'thematic cell'

ESCAPE OSSR
Catalogue & Repository of resources

- Datasets
- Software & services
- Tutorials
- Training
- Publications

ESCAPE VO Virtual Observatory

- Astronomy Data centres
- VO Registry
- VO Registry
- Analysis Tools
- VO Services

TSP's

RI-Specific Science Platforms

ESCAPE ESAP Science Platforms

Workflows, notebooks, deployment platforms, packaging

ESCAPE CS Citizen Science

ESCAPE DIOS Data Lake

FAIR data management
Content discovery and delivery

HPC

PRACE

EuroHPC Joint Undertaking

HTC

Grid clusters, etc

Private/public clouds

Commercial clouds

GÉANT



Successful formula: Bringing together ESFRI/RIs and VO expert partners

Astronomy ESFRIs, Research Infrastructures and associated partners

ESO

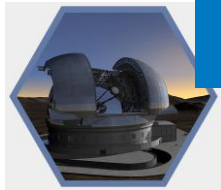
SKAO

JIVE

CTAO

KIS
ORB

EGO



NWO-I-ASTRON



CNRS-OBAS
CNRS-CPPM



INAF



UEDIN



UHEI



INTA

Heidelberg Institute for Theoretical Studies



HITS (WP3)

Partners bringing experience from European Virtual Observatory



The approach:

Integration of astronomy VO data and services into the EOSC

- Interaction with **EOSC** projects based on experience of onboarding via EUDAT

Implementation of FAIR principles for ESFRI data through the Virtual Observatory

- ESCAPE ESFRI and RI priorities represented at the IVOA
- Community training events for *scientists* and *data producers/providers*

Adding value to trusted content in astronomy archives

- Deep learning applied to archive data sets (joint with WP3)

ESCAPE Cross-WP interaction/integration

- VO services in ESAP, VO software in OSSR, explore VO data in Data Lake, VO data/services/tools for citizen science and Test Science Projects



Connecting to EOSC - a work in-progress!

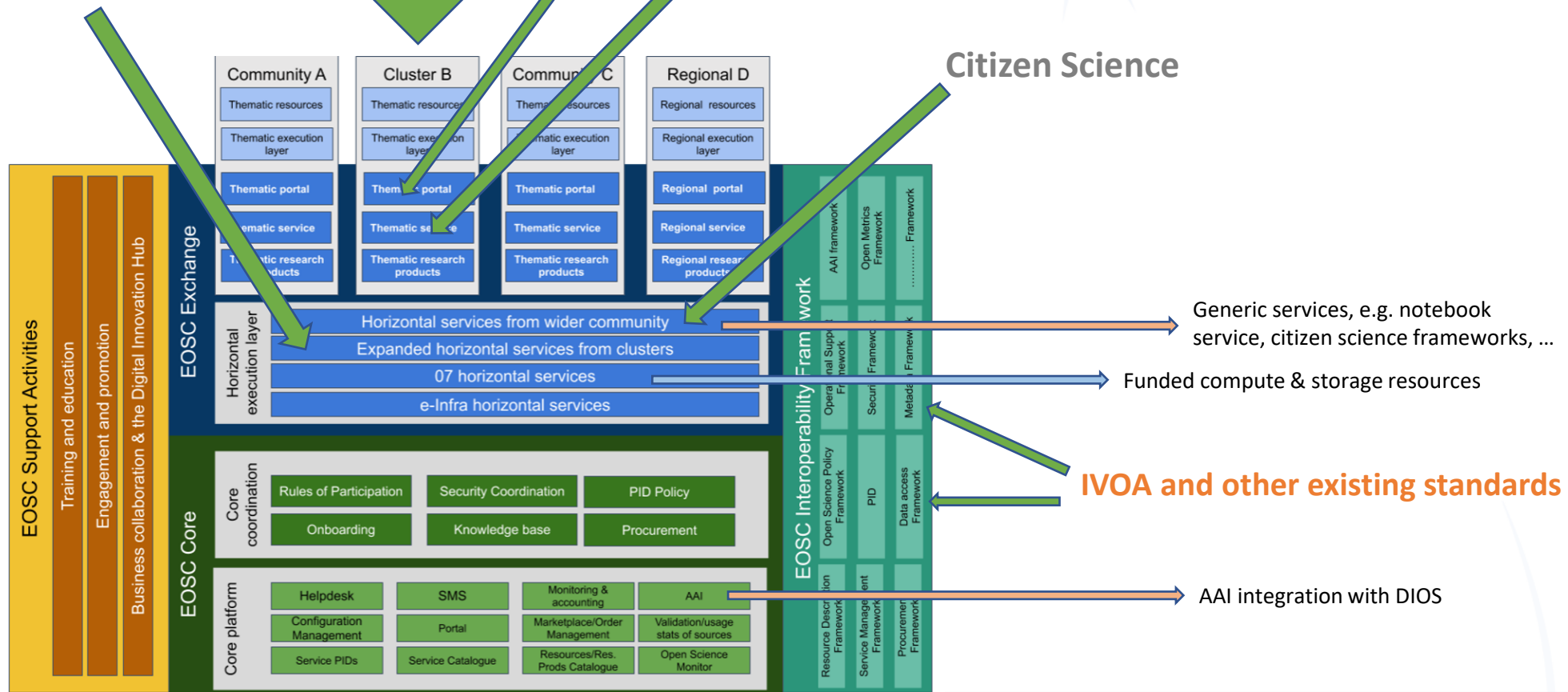
Data Lake
Software Repository

ESCAPE

Science Analysis Platform

Virtual Observatory services

Citizen Science





ESCAPE

European Science Cluster of Astronomy &
Particle physics ESFRI research Infrastructures

CEVO achievements and outlook

Mark ALLEN

CDS, Observatoire Astronomique de Strasbourg (CNRS-ObAS)

For the CEVO Team



The results:

Integration of astronomy VO data and services into the EOSC

- Interaction with EOSC projects based on experience of onboarding via EUDAT
 - *Analysis reports on VO data and service integration into EOSC (D4.4, D4.7)*

Implementation of FAIR principles for ESFRI data through the Virtual Observatory

- ESCAPE priorities at IVOA level : *(MS20, MS21, MS22, MS23, MS25, MS26)*
- Community training events for scientists and data producers/providers:
 - *2 Science with interoperable data schools (D4.3, D4.6)*
 - *European data providers Forum - Hands-on workshop for data providers (MS24)*

Adding value to trusted content in astronomy archives

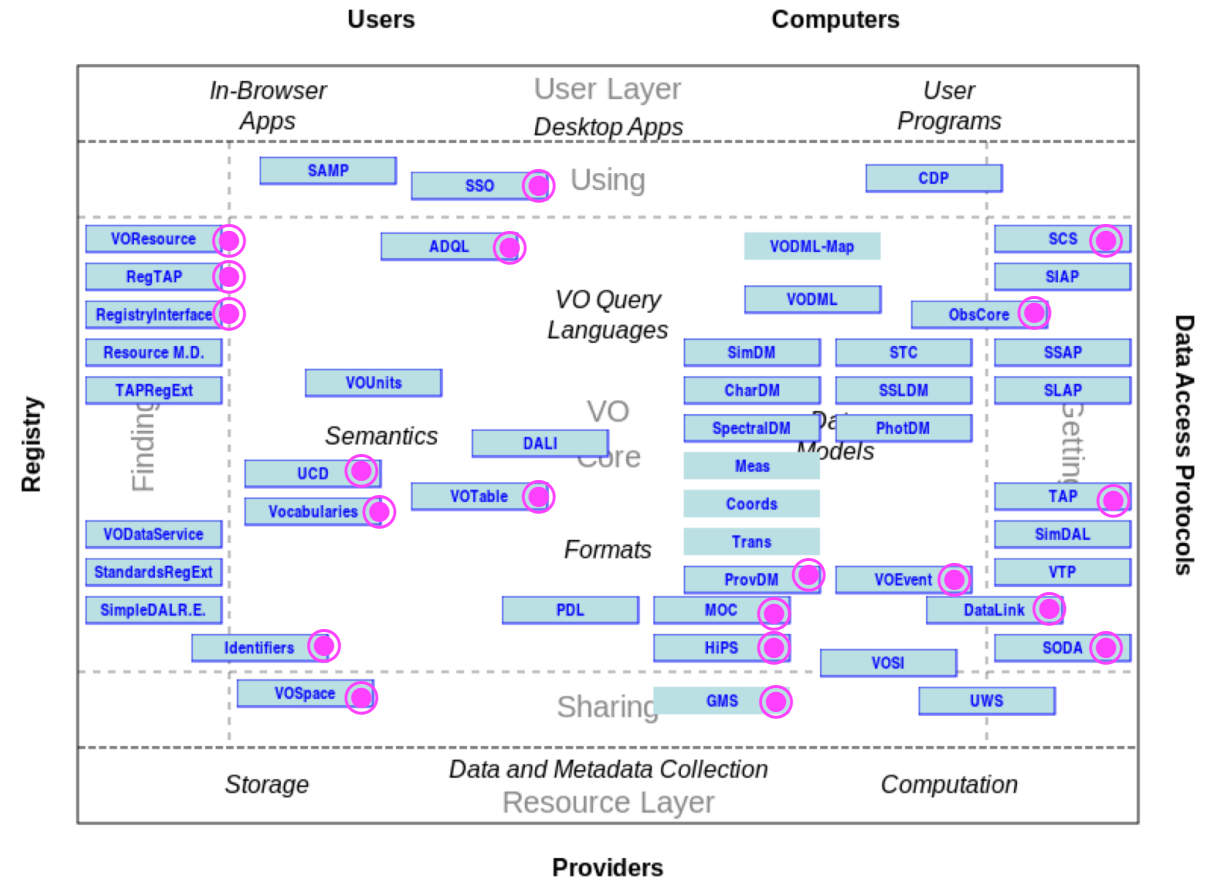
- Results of deep learning applied to archive data sets (joint with WP3)
 - *Prototype demonstrator for value-added archive services (D4.5)*



Highlight Task 4.2: Implementations of IVOA standards



- **Gravitational Waves (EGO-Virgo)** – Space time indexing and use in applications for GW follow-up
- **Solar physics (EST)** – Analysis of IVOA semantic UCD metadata for solar physics.
- **Radio Astronomy** – interoperability and data volume aspects, new Radio Astronomy services registered in VO registry, standardized metadata for radio astronomy (JIVE, ASTRON, SKAO, ALMA)
- **ESO science archive** services
- Relevant standards used/assessed in ESCAPE @ IVOA ○



- Working Draft
- IVOA Recommendation

Funded by the European Union's Horizon 2020 - Grant N° 824064








ESO, CNRS-ObAS,
INTA, INAF, UHEI
UEDIN, HITS

EGO (INFN),
CNRS-ObAS,

JIVE, ASTRON,
SKAO, ESO/ALMA,
UHEI, CNRS-ObAS

CTAO, Obs-Paris,
CNRS (ObAS+CPPM)
UHEI

ORB, KIS, CNRS-
ObAS, INTA, UHEI

ESFRI / RIs	Results for ESCAPE work toward FAIR standards and tools
<p>ESO-ELT</p> 	<ul style="list-style-type: none"> - Data access and visualisation standards and tools - Support of VO standards in ESO archive services – used as exemplary case to help others - Relevant IVOA standards updated
<p>EGO/VIRGO</p> 	<ul style="list-style-type: none"> - Development of MOC2.0 (approved IVOA standard) and mocpy - Tools / libraries integrated into GW community software - Paper published in Astronomy & Computing
<p>SKA, JIVE, ALMA (LOFAR)</p> 	<ul style="list-style-type: none"> - Creation and support of the IVOA Radio Astronomy Interest Group - New TAP services, accessible in VO tools and in the ESCAPE platform
<p>CTA & KM3NeT</p> 	<ul style="list-style-type: none"> - Data Provenance standards approved by IVOA - Many activities for adoption and implementation (Workshop held) - Reference paper published on a: Management System for Provenance Information
<p>EST</p> 	<ul style="list-style-type: none"> - VO metadata developed for Solar Physics - Prototype TAP services for solar data



Example – 2 of the standards led/contributed to by ESCAPE partners



IVOA Provenance Data Model Version 1.0

IVOA Recommendation 2020-04-11

Working group
DM

This version
<http://www.ivoa.net/documents/ProvenanceDM/20200411>

Latest version
<http://www.ivoa.net/documents/ProvenanceDM>

Previous versions
PR-ProvenanceDM-1.0-20190719.pdf
PR-ProvenanceDM-1.0-20181015.pdf
WD-ProvenanceDM-1.0-20180530.pdf
WD-ProvenanceDM-1.0-20170921.pdf
WD-ProvenanceDM-1.0-20161121.pdf
ProvDM-0.2-20160428.pdf
ProvDM-0.1-20141008.pdf

Author(s)
Mathieu Servillat, Kristin Riebe, Catherine Boisson, François Bonnarel, Anastasia Galkin, Mireille Louys, Markus Nullmeier, Nicolas Renault-Tinacci, Michèle Sanguillon, Ole Streicher

Editor(s)
Mathieu Servillat

Provenance Data Model

Finalised and approved April 2020.

Brought to community via
ESCAPE Provenance workshop
September 2020.

- **Published** - Servillat et al. – SPIE



MOC: Multi-Order Coverage map Version 2.0

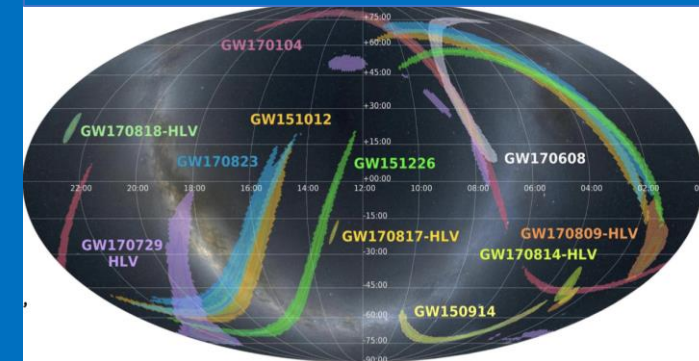
Multi-Order Coverage 2.0

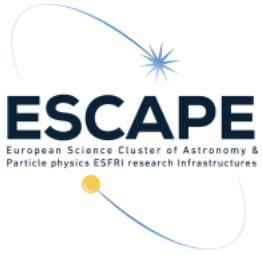
**Space coverage extended with
TIME coverage.**

Approved in April 2022.

Driven by ESFRI/RI needs (EGO,
ESO, Radio astronomy,+++).

e.g. IVOA metadata for Sky
Coverage maps of Gravitational
Wave detections



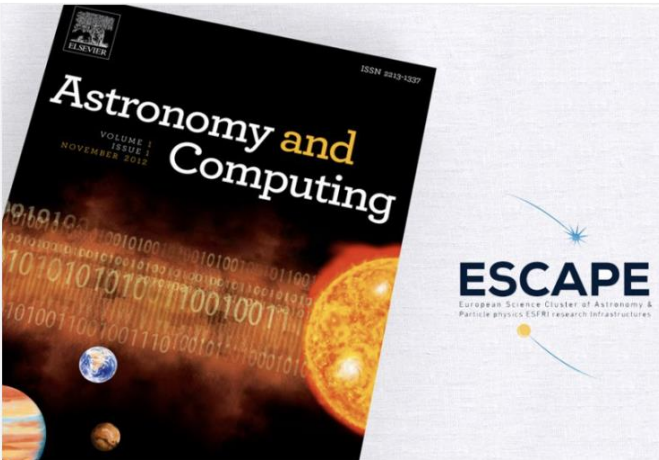


🕒 16 February 2022

ESCAPE Improves Data Discoverability in ESFRI Science Archives with New Machine Learning Prototype

ESCAPE has successfully tested new machine learning prototypes that have improved search capabilities in some European Strategic...

[READ MORE](#)



🕒 24 January 2022

ESCAPE paper on Multi-Messenger observations published in the Astronomy and Computing journal

This January 2022, ESCAPE CEVO team published the "Multi Order Coverage data structure to plan multi-messenger observations" article, focused on supporting multi-messenger astrophysics with...

[READ MORE](#)



Task 4.1 highlight : VO in B2FIND - Demonstrates 1st level of metadata compatibility

- Links to the actual service
- enables feedback to EOSC



IVOA

22,234 datasets found for "IVOA"

ESO TAP_OBS: a TAP service to browse and access raw and red

TAP_OBS is the ESO Science Archive TAP endpoint for observations (raw ambient measurements (atmospheric seeing, turbulence, water vapour, ...))

UCL DaCHS server TAP service

The UCL DaCHS server's TAP end point. The Table Access Protocol (TAP) against our database tables, inspect various metadata, and upload your

Dataset Communities

The VO @ ASTRON TAP service

The The VO @ ASTRON's TAP end point. The Table Access Protocol (TAP) lets you execute queries against our database tables, inspect various metadata, and upload your own data. It is thus the VO's premier way to access public data holdings.

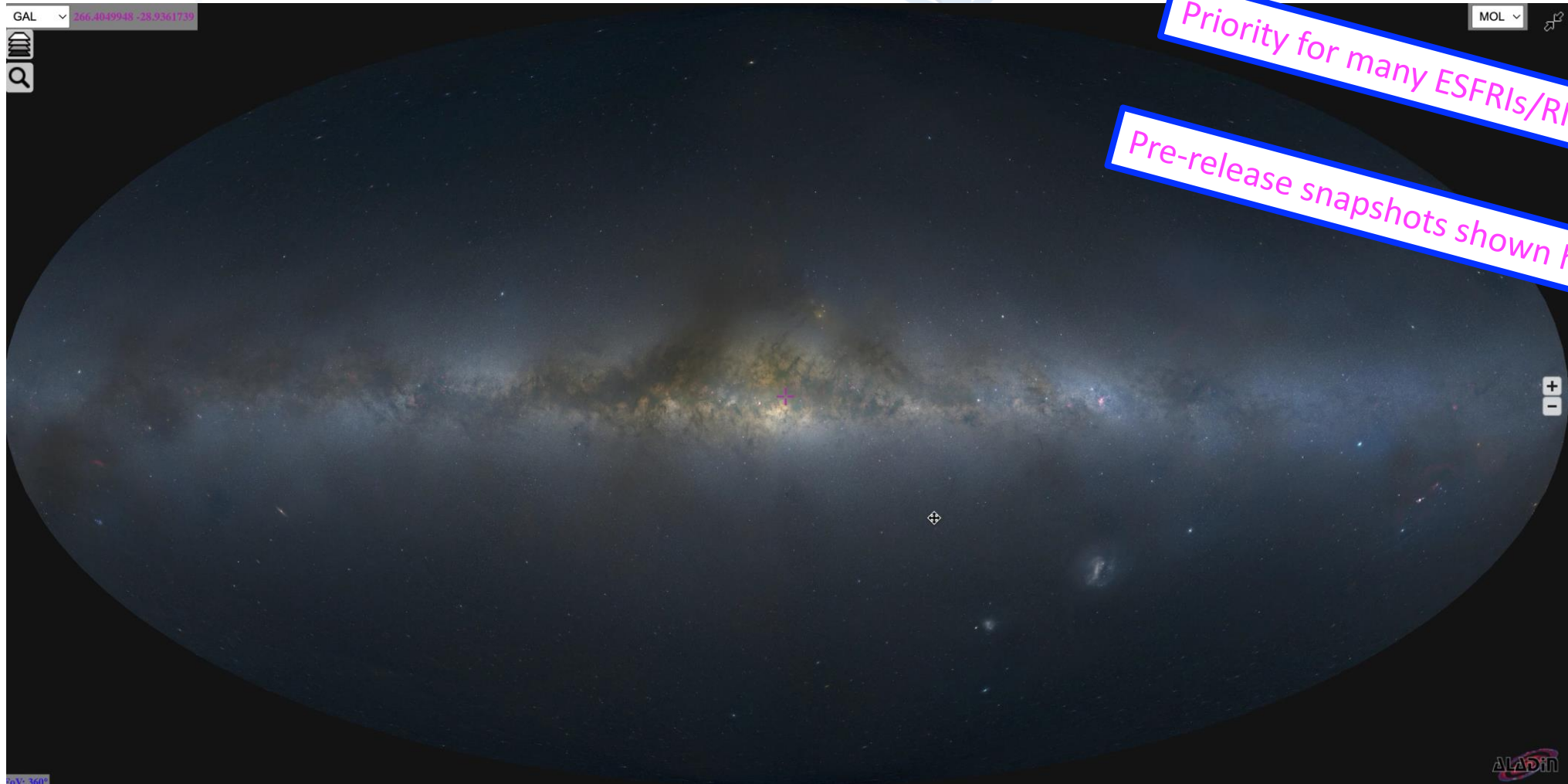
Tables exposed through this endpoint include: main from the lbcsc schema, main, mom0 from the sauron schema, img_main, main from the lofartier1 schema, img_main, main from the tgssadr schema, main, msssvf_img_main from the mvf schema, columns, groups, key_columns, keys, schemas, tables from the tap_schema schema, hetdex_images, img_main from the hetdex schema, img_main from the msss schema, obscure from the ivoa schema.

- ADQL
- Catalogs
- Virtual observatory

Identifier	
Source	
Metadata Access	https://vo.astron.nl/_system_/tap/run/info
Provenance	http://dc.g-vo.org/rr/q/pmb/...?verb=GetP...



Major update of Big Data visualisation for HiPS surveys

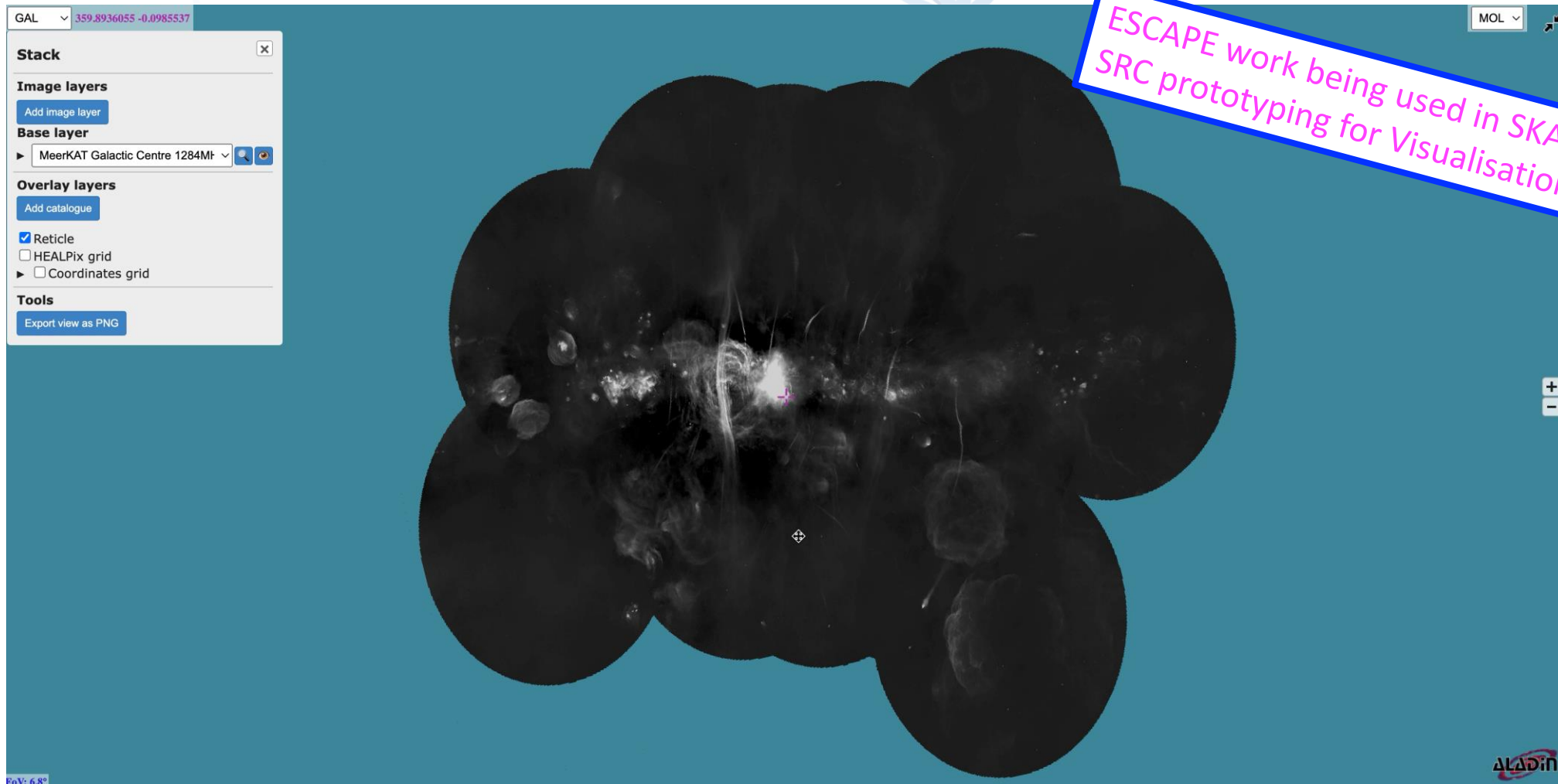


Priority for many ESFRIs/RI

Pre-release snapshots shown here



Example of MeerKAT SKA pathfinder data



Future outlook of VO in ESCAPE and EOSC

Integration of astronomy VO data and services into the EOSC

- Next big step is to use evaluate/use the new *'enhanced EOSC Resource Catalogue'* for on-boarding of 'data sources'

FAIR principles for ESFRI data through the Virtual Observatory

- ESCAPE has built capacity within ESFRI/RIs to become actors in defining the standards. *Future : Implementation / Coordination / Innovation / Scaling up*
- Continue networked approach – Standards, Data, tools/services, Training

Integration in platforms, virtual research environments

- Within ESCAPE, but also beyond: space agencies and major observatories.

