

# Radio Astronomy in the Virtual Observatory :

"Bringing radio data to researchers in the  
spirit of Open Science"



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# Radio astronomy data : tremendous increase era (1)

- Increase in volume and variety of radio data in astronomy : images, spectra, cubes, dynamic spectra, single dish and interferometers, raw data as well as reduced data
- Legacy, or long term projects
  - Arecibo
  - Westerbork → Apertif
  - NRAO / VLA
  - MERLIN
  - ATCA, Parkes
  - IRAM → NOEMA
  - Nançay → Nenufar,
  - Italian radio astronomy archive
  - ....



# Radio astronomy data : tremendous increase era (2)

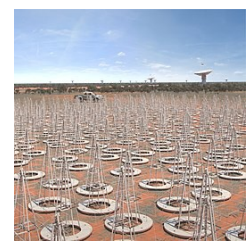
- Recent projects (SKA pathfinders or and others)

- ALMA
- LOFAR
- ASKAP
- MWA
- MeerKat



- Future : SKA, ngVLA

- SKAO : future observations and processing , simulations
- SKA regional centers : data processing and data facilities



# Astronomical Radio Data in the international Virtual Observatory (VO)

- Keyword is « **I**nteroperability »
  - Required for Multi-wavelength / multi-messenger science
  - Requires standardization of data , metadata and API
- Other **FAIR** principles
  - **F**indable : *registration of services and data collections, discovery services*
  - **A**ccessible : *access services*
  - **R**eusable : *Desktop applications, WEB services, science platforms*



# Progress on VO protocols for radio astronomy data

## Multidimensional discovery and access protocols

- ObsCore 1.1 / ObsTAP : standardized SQL-like interface to dataset descriptions
- SIA2 : parameter based interface for Image Discovery and Access
- SODA : standardized data access interface / dataset cut-outs
- DataLink : interface for linking data sets to additional resources

## HiPS : hierarchical progressive access to 2D and 3D image data

- Based on multi-order HEALPix tessellation of the sky

## MOC : spatial (and more recently time) coverage description

- Also based on multi-order HEALPix tessellation of the sky

## Provenance data model: tracing the history of data

## Service implementations : libraries and tools (e.g. DaCHS, VOLLT, OpenCADC)

## Applications: TOPCAT, Aladin, CASSIS, AladinLite, SPLAT, astropy with pyvo ...

e.g. Recently added ObsTAP or SIA services : CADC, ALMA, CSIRO/CASDA ASKAP, MWA, JIVE, ASTRON ( Apertif and LOFAR) . Also HiPS for ASTRON



# Aladin – one way to access VO

Aladin v10.1 \*\*\* PROTOTYPE VERSION (based on v10.130) \*\*\*

Available data → 251 / 24139  
● in view ● out view

- GaiaSource DR2 data (gaia2)
- Solar System object observati
- Mean radial velocities on abs
- Distances to 1.33 billion stars in
- Gaia DR1 (Gaia Collaboration, 201
- GaiaSource data (gaia)
- TGAS: Subset of GaiaSource c
- TGAS supplement with BT anc
- Auxiliary Quasar Solution for
- RRLyrae stars identified in tal
- Cepheid stars identified in tal
- IGSL3 – The Initial Gaia Source Li
- GPS1 – Gaia-PS1-SDSS (GPS1) pr

**Data Discovery Tree: search and access available data**

Command: [Dropdown]

Frame: ICRS | Projection: Aitoff

**Main view: visualize, compare**

Stack of loaded datasets

- Select src
- CDS / P / ROSAT WFC / F2
- Fold~3
- Filter1
- CDS / P / 345\_gaia2
- CDS / P / GALEXGR6
- Fold~2
- CDS / Simbad
- Fold~1
- Contours~1
- Contours
- CDS / P / PanSTARRS

Search: [Input field]

ra_error	dec	dec_error	parallax	parallax...	pmra	pmra_error	pmdec
0.4082	22.02970...	0.3969	0.4156	0.5305	1.709	0.675	-0.461
0.3276	22.02970...	0.3150	0.1446	0.3945	2.546	0.497	-6.121
0.0921	22.03555...	0.0835	3.6372	0.1086	-15.229	0.162	-32.575
0.0519	22.03044...	0.0481	0.2184	0.0622	1.059	0.083	-0.5

**keyword search**

select Gaia

coll. sort view scan filter

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4 sel / 18030 src 719Mb

# ASKAP SIA service query within Aladin : cube discovery

Aladin v11.0

Fichier Edition Image Catalogue Graphique Couverture Outil Vue Interop Aide

Données disponibles → 9 / 26498

Commande

DSS2 color

DSS  PanSTARRS  SDSS  ZMASS  GALEX  Gaia  Simbad  NED +

Collections → 9 / 26498  
 Catalog → 5 / 24744  
 nasa.heasarc → 1 / 953  
 Radio → 1 / 184  
 BETA Pilot Multi-Epoch Continuum Survey of Spitzer SPT  
 VizieR → 4 / 23269  
 Journal table → 4 / 21599  
 A+A → 1 / 6169  
 Abell 3391-Abell 3395 ASKAP/EMU image (Brueggem...  
 MNRAS → 3 / 3553  
 ASKAP EMU ESP, Radio Continuum Survey of the SMC ( ...  
 Point source catalogue derived from our ASKAP 96  
 Point source catalogue derived from our ASKAP 13  
 Combined catalogue of point sources (table4)  
 Others → 4 / 1119  
 SIA2 (image|cube) → 1 / 13  
 au.csiro → 1  
 CSIRO ASKAP Science Data Archive Image Access Service  
 SSA (spectrum) → 1 / 129  
 au.csiro → 1  
 CSIRO ASKAP Science Data Archive Spectrum Access Sen...  
 CS (table) → 1 / 226  
 au.csiro → 1 / 2  
 CSIRO ASKAP Science Data Archive Cone Search Service  
 TAP (table) → 1 / 179  
 au.csiro → 1 / 3  
 CSIRO ASKAP Science Data Archive TAP Service

360° x 180°

Chercher

obs  publisher  acces  acces  targ...  
 cube-28165 applit: 760... 268.09164627... -37.65035425... 93.84... 13.5 13... 13... 0.0 1 0.3377977442... 0.3377977442...  
 cube-1073 applit: 550... q35 261.95845493... -34.839867080... 31.77... 144.0 0.0 1 0.21084980877... 0.21116712065...  
 cube-1270 applit: 12... q34 260.21198810... -36.907582028... 30.18... 99.99 0.0 1  
 cube-1271 applit: 12... q34 260.21199506... -36.907574017... 30.18... 99.99 0.0 1  
 cube-1272 applit: 12... q34 260.21199506... -36.907574017... 30.18... 99.99 0.0 1  
 cube-685 applit: 54... 258.54022305... -34.03332679... 120.8... 930... 0.0 1 0.21015484917... 0.22002611666...  
 cube-686 applit: 54... 267.04022305... -34.03332679... 120.8... 930... 0.0 1 0.21015484917... 0.22002611666...  
 cube-687 applit: 54... 275.29022305... -34.03332679... 120.8... 930... 0.0 1 0.21015484918... 0.22002611666...

sélect. askap  
 dans -- toutes les collections --

red  tri  vue  scan  filtre

Sélecteur de serveurs

Autres

Generic SIAV2 query ?

L23 59 59.04000+00 00 14.4000

2°

au.csiro/casda/sia2

99999

?

SkyView  
 Aladin  
 Hips2fits  
 Sloan  
 DSS...  
 Archives...

SIMBAD  
 TAP  
 Gaia  
 SkyBot  
 NED  
 HyperLEDA  
 VO

# ASKAP SIA service query within Aladin : SODA cutout result

Aladin v11.0

Fichier Edition Image Catalogue Graphique Couverture Outil Vue Interop Aide

Données disponibles → 9 / 26498  
in view out view

Commande  Référentiel ICRS Projection Altoff

Service casda.csiro.au

● Cutout prototype for SODA server ?  
Renseignez tous les champs puis appuyez sur le bouton ...

Position (ICRS, na...

Rayon

Band

Pol

ID

▼

Reset Clear Submit Fermer

Contrôleur de tâches

Asynchronous jobs of current session:

- COMPLETED, Start time: 2021-06-23T22:06:17.140+0800 (server: [SODA]casda.csiro.au)
- COMPLETED, Start time: 2021-06-23T22:37:45.341+0800 (server: [SODA]casda.csiro.au)
- COMPLETED, Start time: 2021-06-23T23:01:21.808+0800 (server: [SODA]casda.csiro.au)

Or choose an already submitted job:

Job URL  GO

Charger les résultat ABORT DELETE  Delete on closing Aladin

Job details:

Load on Aladin:

LOAD

...	res	t	xel	em	min	em	max	e
0	1	0.3377977442...	0.3377977446...					
0	1	0.21084980877...	0.21116712065...					
0	1							
0	1							
0	1	0.21015484917...	0.22002611666...					
0	1	0.21015484917...	0.22002611666...					
0	1	0.21015484918...	0.22002611666...					



# ESCAPE - supporting radio astronomy in VO



**ESCAPE is a H2020 project** to support the ESFRI activities in the European Open Science cloud (EOSC).

WP4 '**CEVO**' is Connecting VO to EOSC

- VO experts and ESFRI working together for inclusion data archives in the VO
- ESFRI or *alike* : **SKAO, JIVE, ASTRON, ALMA**
- + other partners : Nançay-ObsParis and Italian Radioastronomy Archive

**ESCAPE provides:**

- Help for service implementation : GAVO for DaCHS
- Help for service implementation : CDS for HiPS, MOC



# CEVO Example results: Visibility data discovery prototype - proof of concept



```
select obs_id, obs_publisher_did, facility_name, target_name,
s_ra, s_dec, s_fov, s_region, f_min, f_max, em_min, em_max, em_res_power, em_xel,
t_min, t_max, pol_xel, pol_states
from ivoa.obscore where f_max < 300000
```

TapHandle 2.2

saada.u-strasbg.fr/taphandle/#

http://130.79.129.126:8080/tap

Tap Nodes

- 130791291268080tap SJA
- TAP\_SCHEMA
- ivoa
- obscore
- provenance
- Goodies (not used yet)

130791291268080tap

Show 5

Hide query

SUBMIT

Result Limit: 1000

Link Browser

(click on titles to expand links)

Link #this

the primary (as opposed to related) data of the identified resource

ListObs for Measurement set obs\_source\_calib\_1410MHz\_1384MHzzt

em_max	em_res_power	o ucd	pol_xel	pol_states	access_url	access_format
0.22574733	173.00000	13	2	XX-YY		application/x-votable+x ...
0.21322602	90240.000	513	2	XX YY		application/x-votable+x ...
0.22574733	173.00000	13	2	XX YY		application/x-votable+x ...
0.21322602	90240.000	513	2	XX YY		application/x-votable+x ...
0.22574733	173.00000	13	2	XX YY		application/x-votable+x ...

Link #this

the primary (as opposed to related) data of the identified resource

Full retrieval Measurement set obs\_source\_calib\_1410MHz\_1384MHzzt

Link #auxiliary

auxiliary resources

uv coverage map Measurement set obs\_source\_calib\_1410MHz\_1384MHzzt

Link #auxiliary

auxiliary resources

Antennae plot Measurement set obs\_source\_calib\_1410MHz\_1384MHzzt

Link #auxiliary

auxiliary resources

amplitude versus time plot Measurement set obs\_source\_calib\_1410MHz\_1384MHzzt

Link #auxiliary

auxiliary resources

phase versus time plot Measurement set obs\_source\_calib\_1410MHz\_1384MHzzt

Widgets do not reflect the query anymore after you modified it directly

Preview of https://atadin.u-strasbg.fr/dl/uv\_coverage\_obs\_source\_calib\_1410MHz\_1384MHz.png

1) ObsTap data selection and discovery

2) DataLinks retrieval

3) Uv coverage Display



# IVOA radio astronomy Interest Group



- Created April 2020 : → 100 % virtual since then!
- Organizing sessions to share experience on radio astronomy data VO publishing.
- First pre-draft of a radio astronomy data VO implementation note (May 2021)  
<https://ivoa.net/documents/Notes/RadioVOImp/index.html>
- Development of an extension to the Obscore standard for radio/visibility data



# Conclusion

- Radio Astronomy projects and archives :
  - Don't hesitate to distribute your data for further scientific valorisation
  - IVOA activities are completely open – please join!

***Thank you for your attention !!!***



# Apertif DR1 HiPS : two orders

Aladin v11.0

Fichier Edition Image Catalogue Graphique Couverture Outil Vue Interop Aide

Données disponibles → 9 / 26498

● in view ● out view

Commande

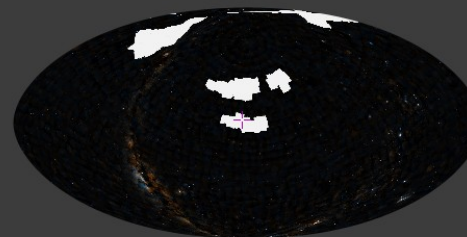
Référentiel ICRS

Projection Aitoff

ALADIN



DSS2 color



**Arbre de découverte**

Ce bandeau permet l'affichage, la consultation, le filtrage et la sélection des collections de données que vous souhaitez charger, afficher et manipuler dans Aladin. Il s'agit de la quasi totalité des données astronomiques publiques disponibles, ce qui représente plusieurs milliers de collections d'images astronomiques, de catalogues, de tables de spectres issues du Centre de Données de Strasbourg ainsi que des autres fournisseurs de données mondiaux supportant les standards et protocoles de "l'Observatoire Virtuel". Pour chacune de ces collections, vous pourrez choisir parmi plusieurs moyens d'accès suivant la nature des données, par exemple en mode d'affichage progressif (HiPS), ou recouvrant uniquement une région spécifique, etc... Vous pourrez également charger d'éventuels produits dérivés tels que...

- ASTRON/P/apertif
- ASTRON/P/apertif
- CDS/P/DSS2/color



sélect. APERTIF  
dans -- toutes les collections --

red. tri vue scan filtre

grille exam. clique. bord. hdr. multivoies. unit.

[Vue A1] - ASTRON/P/apertif\_dr1