

Radio (and millimetric) Data in the VO : State of the art



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acknowledges extensive collaborative work with DAL WG, DM WG, TDIG,
DADI collaborators, Strabourg CDS and SVOM teams



Summary

- I) multi-dimensional data in the VO
 - Examples of projects
 - Problems for interoperability
 - DataModels overview
 - Discovery solutions : ObsCore, SIAV2
 - Access Solutions : DataLink and SODA
- II) Client-side Interfaces
 - Aladin
 - TOPCAT
- III) ALMA Science Archive implementation
 - Available data in the archive
 - Archive ObsTAP Interface
- IV) ASKAP data : CASDA implementation



Multi-dimensional data

- Radio datacubes
- Xray cubes
- Time dimensions
- Polarisation
- Visibility data



Radio data Cubes

- ALMA
 - LOFAR, ASKAP
 - Towards SKA
- data discovery by selecting criteria on description attributes (metadata)
- data access : extracting useful data from the datasets



DataAccess

Radio Cubes are « huge »

→ full retrieval cumbersome

→ Cutouts

→ eventually regridding, reprocessing ?

→ need for detailed data (metadata)
representation further than ObsCore (Cube
DM, may come later)....



VO modelling

1) Obscore : metadata for discovery

obs_collection	unitless	String	Name of the data collection
obs_id	unitless	String	Observation ID
obs_publisher_did	unitless	String	Dataset identifier given by the publisher
access_url	unitless	String	URL used to access (download) dataset
access_format	unitless	String	File content format (see in App. BB.5.2)
access_estsize	kbyte	integer	Estimated size of dataset in kilo bytes
target_name	unitless	String	Astronomical object observed, if any
s_ra	deg	double	Central right ascension, ICRS
s_dec	deg	double	Central declination, ICRS
s_fov	deg	double	Diameter (bounds) of the covered region
s_region	unitless	String	Sky region covered by the data product (expressed in ICRS frame)
s_xel1	unitless	integer	Number of elements along the first spatial axis
s_xel2	unitless	integer	Number of elements along the second spatial axis
s_resolution	arcsec	double	Spatial resolution of data as FWHM
t_min	d	double	Start time in MJD
t_max	d	double	Stop time in MJD
t_exptime	s	double	Total exposure time
t_resolution	s	double	Temporal resolution FWHM
t_xel	unitless	integer	Number of elements along the time axis
em_min	m	double	Start in spectral coordinates
em_max	m	double	Stop in spectral coordinates
em_res_power	unitless	double	Spectral resolving power
em_xel	unitless	integer	Number of elements along the spectral axis

VO modelling

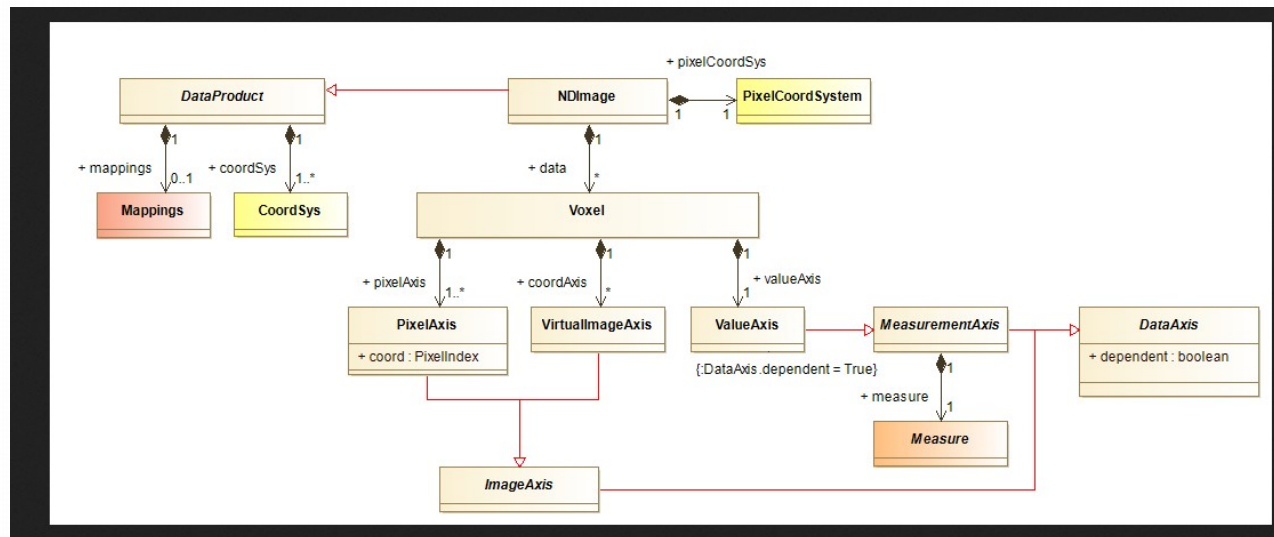
2) Other existing useful data models

- STC 1.0 : useful concepts, currently under strong revision (Coords, Measurements and Transformations)
- PhotDM : mostly for Optical astronomy
- Characterisation 1.0 : reused by other datamodels (such as ObsCore, Cube) under revision
- Spectral Line Data Model : From observation to Physics
- Simulation DataModels. Comparison with Simulations



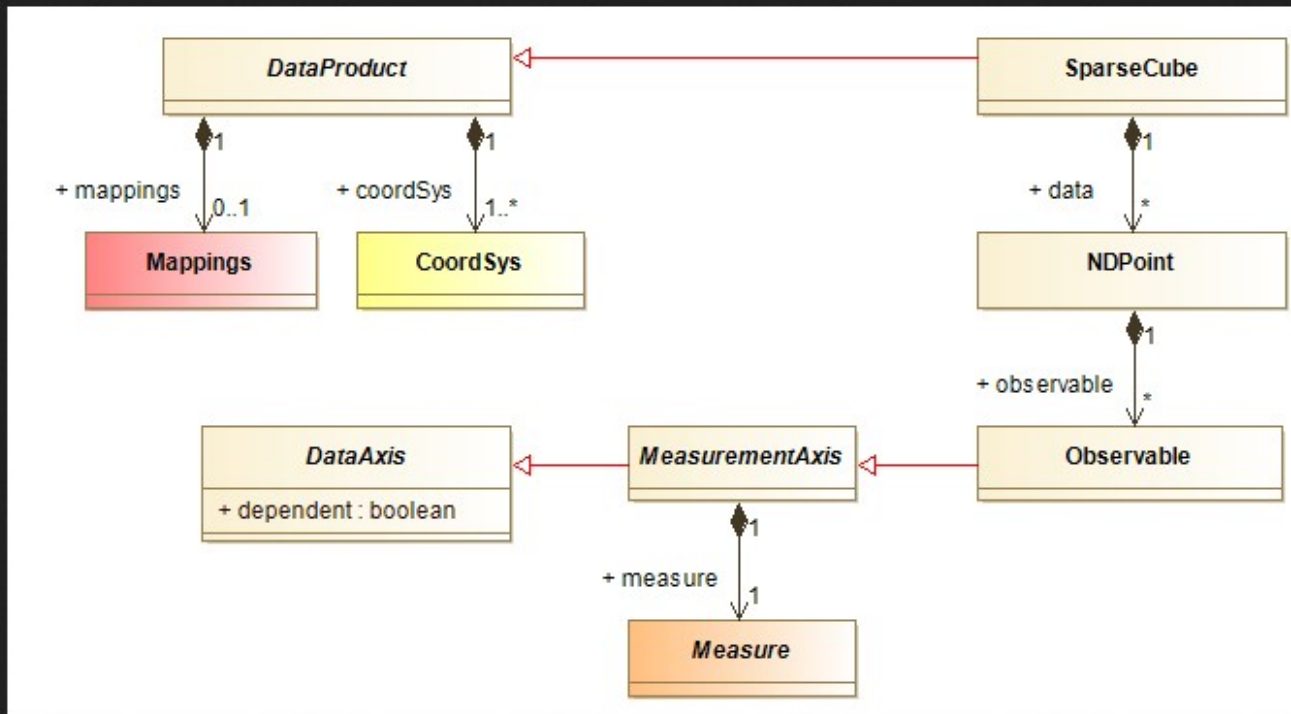
VO modelling

3) Cube datamodel (in progress) : ND Image



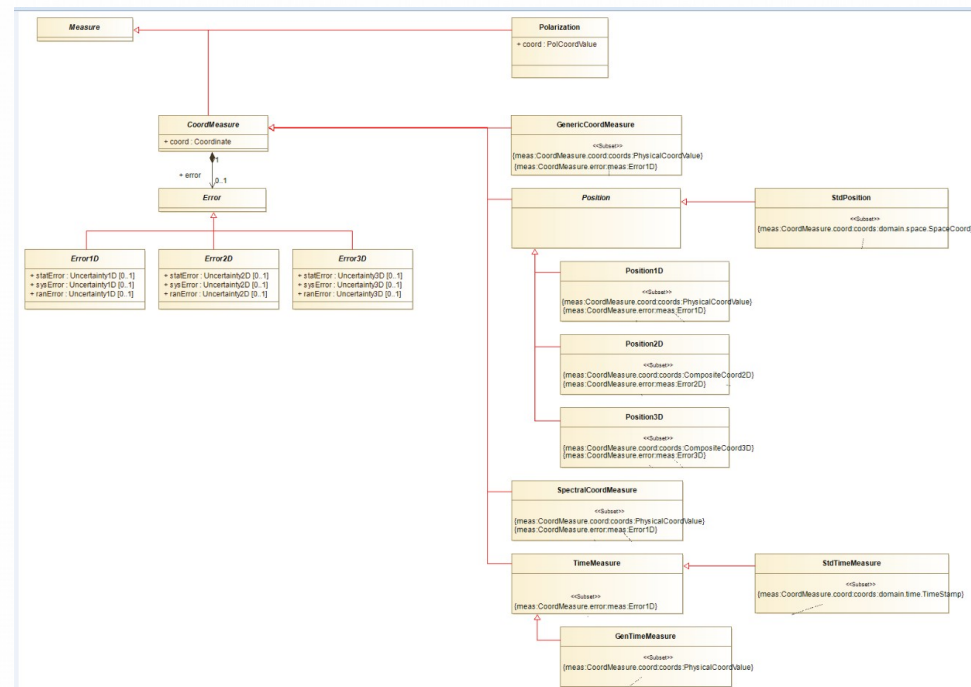
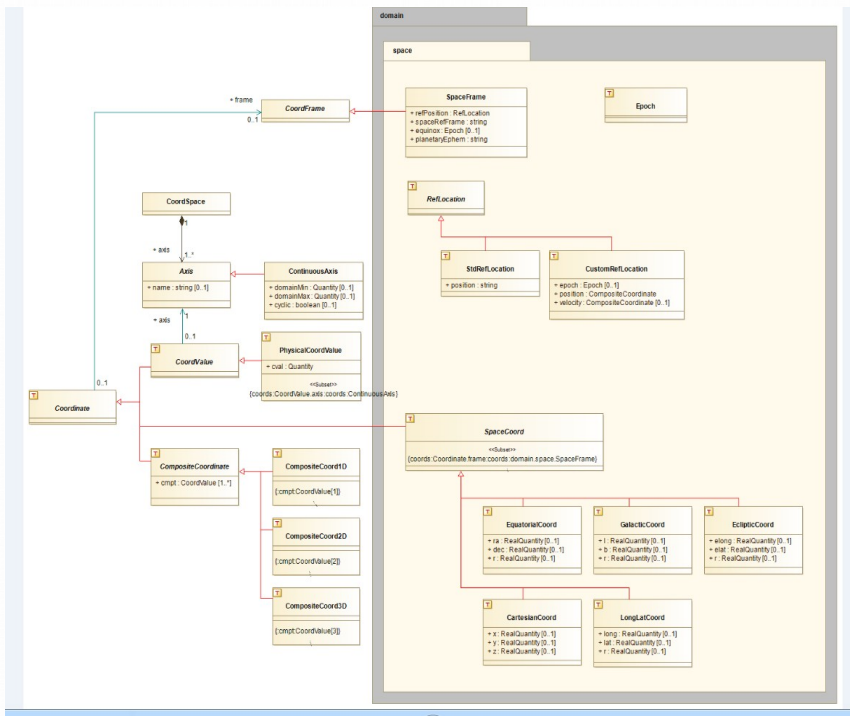
VO modelling

3 bis) Cube datamodel : sparse cube

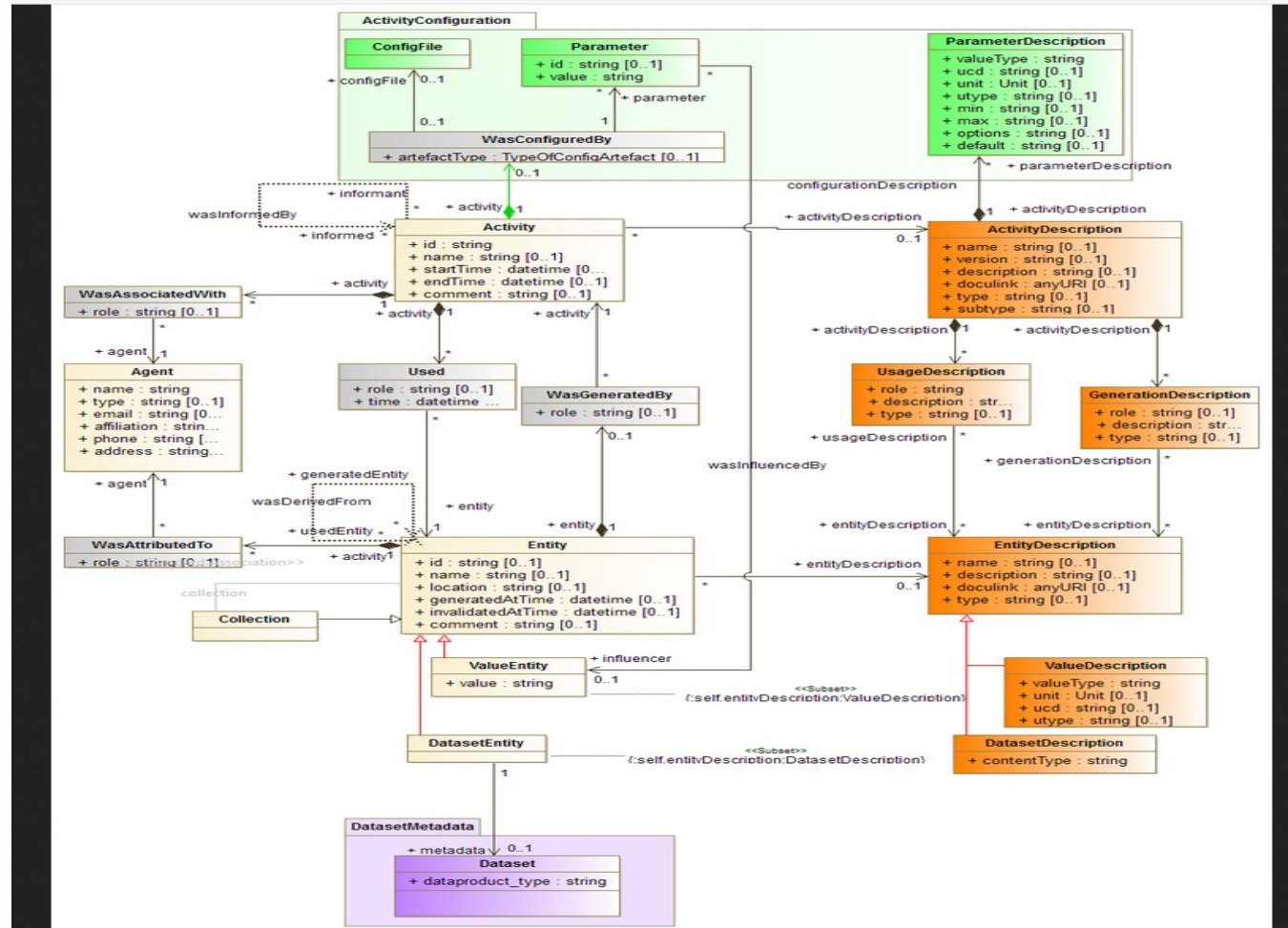


VO datamodelling

4) STC : Coords and Measurements (in progress)



vityAndConfigurationDescriptionForPR2_1502.png



VO access layer Solutions

- ObsTAP (serving ObsCORE table) : allows to select datasets on criteria such as `dataprodut_type= cube` and characterisation of axes
- SIAV2 : allows queries for images and cubes with PARAMETERS
 - such as `DPTYPE = cube, POS = BAND = 0.0005 0.0006 TIME = 52618 53700` etc.
- Full Data Retrieval via `access_reference` field (if manageable)
 - Or access to DataLink and SODA (direct access to SODA also possible)
- Alternative : Discovery , Representation and View via HiPS for cubes



SIAS2 parameters

POS (spatial constraints)

BAND (spectral constraints)

TIME (time constraints)

POL (polarisation constraints)

SPATRES (spatial resolution constraints)

SPECRES (spectral resolution constraints)

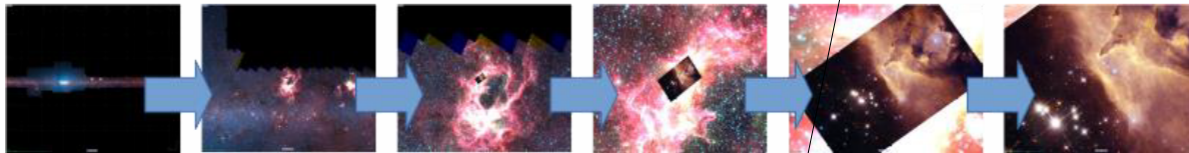
COLLECTION (restrict to a data collection)

FACILITY (restrict to a facility)



□ HiPS ? What is it ?

- **H**ierarchical **P**rogressive **S**urvey
"The more you zoom in on a particular area, the more details show up"
- Multi-resolution **HEALPix** data structure
- for **I**mages, **C**atalogues, 3-dimensional data **c**ubes, ...
- **C**onserves **s**cientific data properties alongside visualisation considerations
- No databases or dedicated servers are required, just http



3

And MOC for
discovery

View, Access, Discovery of DataCube



DataLink

- Link a list of RESOURCES to a DataSet via a small votable giving url, media type, semantics, description, size of the linked resource
- Useful for linking :
 - Additional metadata (provenance, fine characterisation)
 - Auxiliary or associated files
 - Other formats
 - Previews
 - Services applied to the dataset
- DataLink service descriptor

A resource to describe a service (included in main DAL service or {links} resource response)



SODA parameters

Similar to SIAMV2, but with a different meaning

ID : ivo ID of the dataset to process

POS : spatial area to be matched

BAND : spectral range to match

TIME : time range to match

POL : selection of polarisation states



Interface : Aladin

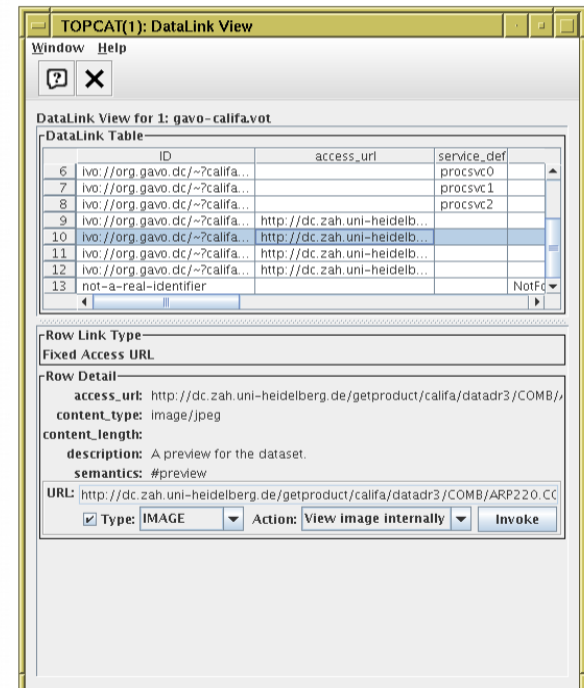
- ASTERICS developments : discovery tree, SIA interface, DataLink interface and SODA interface (see above)
- ASTERICS development :
 - TAP interface
 - ADQL control and assistance
 - Synchronous, asynchronous
 - JOIN
 - UPLOAD

The screenshot displays the Aladin web interface. On the left, the 'Server selector' panel shows 'CDS/Simbad' as the selected server. Below it, a query editor contains an ADQL query: `SELECT TOP 9999 main_id, ra, dec, pmra, pmdec, SQRT(POWER(pmra,2)+POWER(pmdec,2)) as pm FROM basic WHERE SQRT(POWER(pmra,2)+POWER(pmdec,2)) > 20`. The 'Check..' button is set to 'SYNC'. On the right, a star field visualization is shown with a 'Welcome to Aladin' message and a list of tools like 'All VizieR', 'Simbad', 'NED', 'TAP', 'Gala', 'SkyBot', 'VO', and 'Others..'. At the bottom, a table of results is displayed with columns: main_id, ra, dec, pmra, pmdec, and pm. The table lists various astronomical objects and their coordinates and proper motion values.

main_id	ra	dec	pmra	pmdec	pm
UCAC2 33429...	269.990821	4.598942	-14.7	-14.1	20.369094
TYC 994-1499...	266.809109	8.844841	-1.799	-39.197	39.238262
TYC 994-2401...	266.814408	8.847592	-5.633	-43.158	43.524658
2MASS J1812556...	272.231000	11.602548	-29.3	24.1	34.941378
2MASS J1846107...	281.544764	10.551941	-16.4	-27.4	31.933055
2MASS J1846209...	281.587148	10.503709	-19.4	-33.1	38.366261
2MASS J1846460...	281.681769	11.09897	-21.2	-16.8	27.049584
UGCS J174207.6...	265.531882	5.172271	9.85	-38.68	39.91447
UGCS J174348.2...	265.951045	5.703928	-19.43	-8.57	21.23605
UGCS J174348.1...	265.954572	4.976473	-2.0	-22.0	22.090722
UGCS J174355.1...	265.979948	4.743094	-12.24	-26.21	28.927175
UGCS J174433.3...	266.13878	6.001072	-20.22	-51.9	55.699716
UGCS J174519.0...	266.329346	5.335037	-11.53	-26.56	28.954697

Interface : TOPCAT

- TOPCAT is an interface to ObsTAP
 - Discovery, SAMP to other Tools
- TOPCAT takes into account DataLink
 - Feedback
 - Improvement proposals

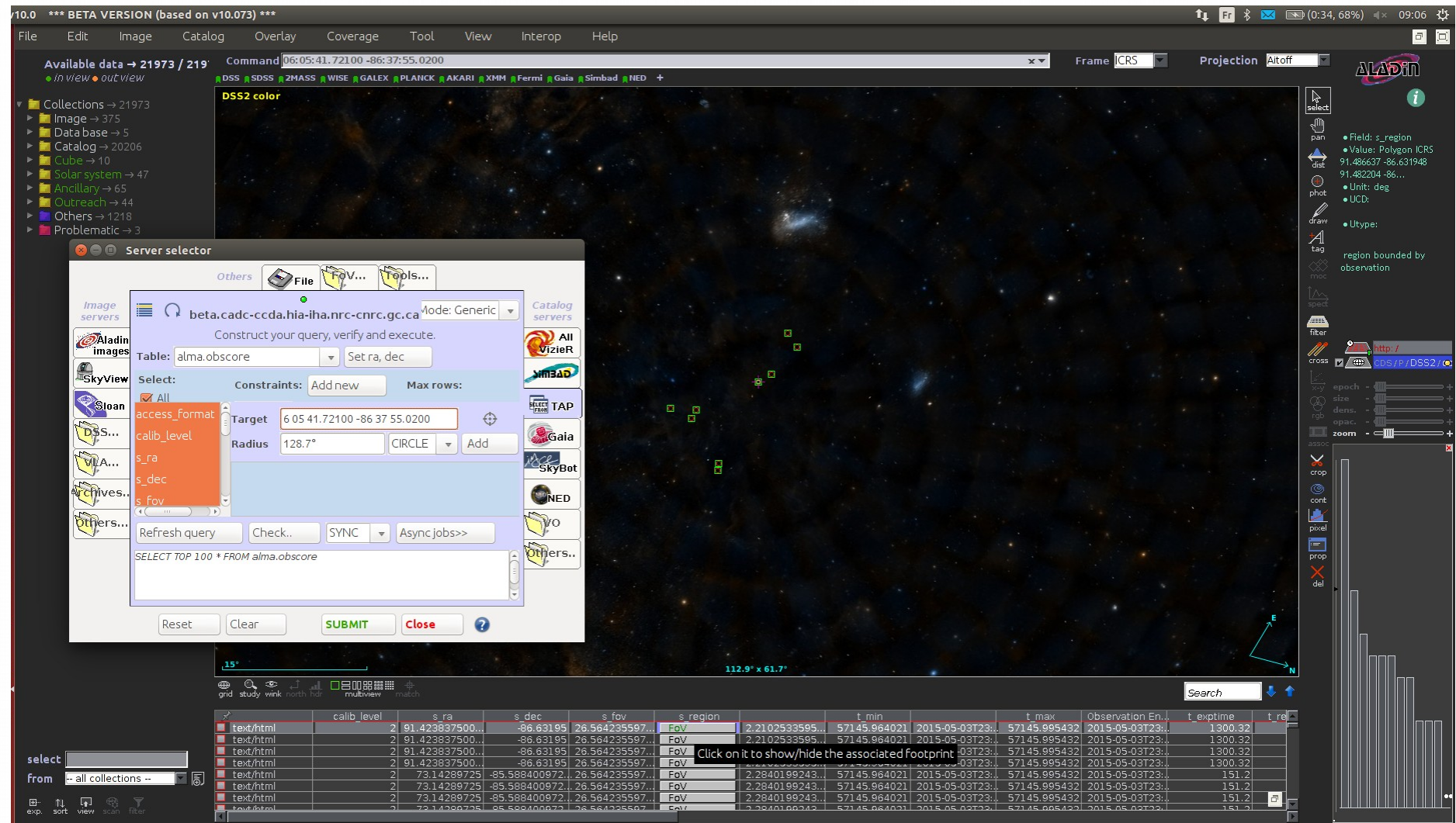


ALMA science archive

- ALMA provides interferometric data in the millimetric domain
- Science archive has a specific interface
- Imaging data are not available everywhere
- Alma science archive slowly releasing VO interface blocks :
 - An ObsTAP service is available (see next slides)
 - MOC is available
 - Integrated in ESA Sky
 - Plans to integrate : DataLink, SIAPV2, SAMP in terface
 - Service for reprocessing installed as UWS (maybe SODA extension)



ALMA science archive Tap service within Aladin



ALMA science archive

url in ObscOre response links to a page displayed in the browser
(no data download available yet)

The screenshot displays the ALMA Science Archive web interface in Mozilla Firefox. The browser's address bar shows the URL: `almascience.eso.org/aq/?member_ous_id=uid://A001/X145/X199`. The interface includes a sidebar with navigation options like 'Available data', 'Collections', and 'Image'. The main content area features a large astronomical image of a galaxy cluster with a yellow circle highlighting a specific region. Below the image is a table of search results.

Project code	Source name	RA	Dec	Band	Integration	Release date	Velocity resolution	Frequency support
2013.1.00623.S	ESO005-G004	06:05:41.72	-86:37:55.0	6	1300.320	2016-12-12	38006.03	227.81_246.51GHz

ASKAP data : CASDA services

- CASDA implemented
 - MOC
 - ObsTAP, SIA services available
 - DataLink with Cutouts
 - SODA interface
 - Scripts



CASDA (= ASKAP data) (allsky datacubes distribution)

10.0 *** BETA VERSION (based on v10.073) ***

File Edit Image Catalog Overlay Coverage Tool View Interop Help

Available data → 4 / 21976

Command

Frame ICRS Projection Aitoff

DSS2 color

CSIRO ASKAP Science Data Archive Image Access Service ...

no preview Coverage: 433.2^{sq}

Access mode & derived prod. ☐ in view ☐ custom ☒ space cov.

Load

au.csiro/casda/sia2

select casda

from all collections

coll sort view scan filter

360° x 180°

55:57.72658 -60:28:06.65 360° x 180°

ALADIN

Welcome to Aladin,
your professional sky
atlas.

- Discover all astronomical data available over the net!
- Compare them with your own data.
- Prepare your observation missions.

To start, type any object name, such as M1, and press ENTER...

Or easier, clic in the main frame and enjoy the sky...

select
pan
dist
phot
draw
tag
moc
spect
filter
cross
x-y
rgb
assoc
crop
cont
epoch
size
dens.
opac.
zoom
prop
del

au.csiro/...
CDS/P/DSS2

epoch
size
dens.
opac.
zoom
prop
del

grid study wink north hdr multiview match

ASKAP data : CASDA services

SIAP 2.0

ASKAP data : CASDA services response FOV

Aladin v10.0

File Edit Image Catalog Overlay Coverage Tool View Interop Help

Command: 16:25:08.90 -26:02:00.0

Frame: ICRS Projection: Aitoff

Available data → 4
in view out view

CSIRO ASKAP Science I

SA (spectrum) → 1 / 115
au.csiro → 1

CSIRO ASKAP Science I

S (table) → 1 / 565
au.csiro → 1 / 2

CSIRO ASKAP Science I

AP (table) → 1 / 224
au.csiro → 1 / 3

* CSIRO ASKAP Science I

DSS2 color

select pan dist phot draw tag moc spect filter cross x-y rgb assoc crop cont pixel prop del

results

- Field: access_url
- Value:
- UCD: meta.ref.url
- Utype:
- URL used to access (download) dataset

CSIRO/casda

CDS JP / DSS2

epoch -
size -
dens. -
opac. -
zoom -

Rho Oph

15:41:00.69 -25:47:21.1
83.29° x 47.17°

15° 83.29° x 47.17°

results

access_url	calib_level	obs_id	cube-729	54467	target name	s_ra	s_dec
https://data.csiro.au/casda/vot/proxy/catalin/vot/cube	3	P248	cube-729	54467		246.28709726...	-26.03332860...
	3	P248	cube-778	54456	application/x-vot	247.28505537...	-18.03333018...

Click on it to load the corresponding archive data in the stack

ASKAP data : CASDA services

DataLink

Aladin v10.0 *** BETA VERSION (based on v10.073) ***

Aladin v10.0 *** PROTOTYPE VERSION (based on v10.098) ***

File Edit Image Catalog Overlay Coverage Tool View Interop Help

Command: 18:19:23.82 -29:05:24.8

Frame: ICRS Projection: Altoff

Available data → 4
in view out view

- Collections → 4 / 22
 - Others → 4 / 1258
 - SIA2 (image) cut
 - au.csiro → 1
 - CSIRO ASKA
 - SSA (spectrum)
 - au.csiro → 1
 - CSIRO ASKA
 - CS (table) → 1 /
 - au.csiro → 1 /
 - CSIRO ASKA
 - TAP (table) → 1
 - au.csiro → 1 /
 - CSIRO ASKA

639675.618

15° 94.06' x 50.27'

Search

epoch - size - dens. - opac. - zoom -

Download data product via web (size 55774208 byte)

Download data at Pawsey Centre. Note: Only users from within PSC network can access the data through this link. Only use if you currently have access to Pawsey facilities. (size 55774208 byte)

Scripted file access via Web (size 55774208 byte)

Scripted file access via Pawsey Centre. Note: Only users from within PSC network can access the data through this link. Only use if you currently have access to Pawsey facilities. (size 55774208 byte)

Scripted cut-out service

Scripted spectrum generation service

2 sel / 2 src 527Mb

ASKAP data : CASDA services SODA interface

Aladin v10.0 *** BETA VERSION (based on v10.073) ***

File Edit Image Catalog Overlay Coverage Tool View Interop Help

Available data → 4 Command 16:25:08.90334 -26:01:59.9830 Frame ICRS Projection Aitoff

in view out view DSS SDSS 2MASS WISE GALEX PLANCK AKARI XMM Fermi Gaia Simbad NED +

DSS2 color

Service casda.csiro.au

○ Cutout prototype for SODA server ?

Fill in all these fields and press the SUBMIT button

Target (ICRS, name)

Radius

Time

Band 0.21015484916529545 0.220026116655881

Pol

ID |AwjdlcT1HIEq7251deoebNLMEEsqZ3bmz

ASUNC

Reset Clear Submit Close

23.42° x 13.87°

Search

access url dataproduct t... calib level obs collection obs id obs publisher... access format access estsize target name s ra s dec

Download data product via web (size 55774208 byte)

Download data at Pawsey Centre. Note: Only users from within PSC network can access the data through this link. Only use if you currently have access to Pawsey facilities. (size 55774208 byte)

Scripted file access via Web (size 55774208 byte)

Scripted file access via Pawsey Centre. Note: Only users from within PSC network can access the data through this link. Only use if you currently have access to Pawsey facilities. (size 55774208 byte)

Scripted cut-out service

Scripted spectrum generation service

2 sel / 3 src 449Mb

ASKAP data : CASDA services

Ready for SODA query

Aladin v10.0 *** BETA VERSION (based on v10.073) ***

Aladin v10.0 *** PROTOTYPE VERSION (based on v10.098) ***

File Edit Image Catalog Overlay Coverage Tool View Interop Help

Available data → 4
in view out view

Command: J3:58:08.23 -60:42:26.6

Frame: ICRS Projection: Aitoff

DSS2 color

Service: casda.csiro.au

● Cutout prototype for SODA server ?

Fill in all these fields and press the SUBMIT button

Target (ICRS, name): 16 34 13.5 -25 43 46.0

Radius: 0.73°

Time:

Band: 0.21015484917063945 0.2200261166617463

Pol:

ID: T21AwjdlcT1HIEpZLk-AQYke0t5LMtVlqiUX

ASync

Reset Clear Submit Close

15°

122.2° x 69.91°

Search

access url	data product t...	calib level	obs collection	obs id	obs publisher	access format	access estsize	target name	s.ra	s.dec
https://data.c...	cube		P248	P248	cube-729	application/x-vot	54467		246.28709726...	-26.03332860...
https://data.c...	cube		P248	P248	cube-778	application/x-vot	54456		247.28505537...	-18.03333018...

select: casda

from: all co...

coll. sort view scan

Job controller

epoch: size: dens.: opac.: zoom:

17:01:25.83163 -35:56:35.1887

122.2° x 69.91°

ASKAP data : CASDA services

Asynchronous SODA task completed

Aladin v10.0 *** BETA VERSION (based on v10.073) ***

Aladin v10.0 *** PROTOTYPE VERSION (based on v10.098) ***

File Edit Image Catalog Overlay Coverage Tool View Interop Help

Available data → 4 Command 16:29:08.41329 -18:01:59.9887

in View out View DSS SDSS 2MASS WISE GALEX PLANCK AKARI XMM Fermi Gaia Simbad NED +

Service casda.csiro.au

● Cutout prototype for SODA server ?

Fill in all these fields and press the SUBMIT button

Target (ICRS, name) 16 34 13.5 -25 43 46.0

Radius 0.73°

Time

Band 0.21015484917063945 0.2200261166617463

Pol

ID T21AwjdlcT1HIEpZLk-AQYke0tSLMtVlqiUX

Job controller

Asynchronous jobs of current session:

COMPLETED, Start time: 2019-01-10T02:00:39.680+0800 (server: [SODA]casda.csiro.au)

Or choose an already submitted job:

☐ Job URL GO

Load from /results/result ABORT DELETE ☒ Delete on closing Aladin

Job details:

Load on Aladin: LOAD

Job ID: 2a0b425e-9fc8-43fb-b58e-e0474563cb0b

Run ID: null

URL: https://casda.csiro.au/casda_data_access/data/async/2a0b425e-9fc8-43fb-b58e-e0474563cb0b

File	Type	Size	Format	Download
cube-729	imagecube	54467	application/x-vot	246.28/09/26...-26.03332880... 120
cube-778	imagecube	54456	application/x-vot	247.28505537...-18.03333018... 120

select casda

from -- all co...

coll sort view scan

17:01:25.83163 -35:56:35.1887
122.2° x 69.91°

2 sel / 3 src 676Mb

ASKAP data : CASDA services cutout cube loaded

Aladin v10.0 *** BETA VERSION (based on v10.073) ***

Aladin v10.0 *** PROTOTYPE VERSION (based on v10.098) ***

File Edit Image Catalog Overlay Coverage Tool View Interop Help

Available data → 4
in view out view

Command:

DSS SDSS 2MASS WISE GALEX PLANCK AKARI XMM Fermi Gaia Simbad NED +

ctions → 4 / 22641
hers → 4 / 1258
IA2 (image|cube) → 1 / 8
au.csiro → 1
CSIRO ASKAP Science I
SA (spectrum) → 1 / 114
au.csiro → 1
CSIRO ASKAP Science I
S (table) → 1 / 566
au.csiro → 1 / 2
CSIRO ASKAP Science I
AP (table) → 1 / 219
au.csiro → 1 / 3
CSIRO ASKAP Science I

30°

2.622° x 0.494°

058 / 1024

Search

access url	dataprod	cube	calib level	obs collection	obs id	obs publisher	access format	access estsize	target name	s ra	s dec
https://data.csiro.au	cube		3	P248	P248	cube-729	application/x-vot	54467		246.28709726...	-26.03332860...
https://data.csiro.au	cube		3	P248	P248	cube-778	application/x-vot	54456		247.28505537...	-18.03333018...

select casda
from all co...

epoch size dens. opac. zoom

2 sel / 3 src 620Mb

ASKAP data : CASDA services spectrum cutout

Aladin v10.0 *** BETA VERSION (based on v10.073) ***

File Edit Image Catalog Overlay Coverage Tool View Interop Help

Available data → 4 Command 16:28:09.05 -25:58:01.6

in view out view DSS SDSS 2MASS WISE GALEX PLANCK AKARI XMM Fermi Gaia Simbad NED +

ctions → 4 / 22641
ers → 4 / 1258
IA2 (image/cube) → 1 / 8
au.csiro → 1
CSIRO ASKAP Science I
SA (spectrum) → 1 / 114
au.csiro → 1
CSIRO ASKAP Science I
S (table) → 1 / 566
au.csiro → 1 / 2
CSIRO ASKAP Science I
AP (table) → 1 / 219
au.csiro → 1 / 3
CSIRO ASKAP Science I

Service casda.csiro.au

○ Cutout prototype for SODA server ?
Fill in all these fields and press the SUBMIT button

Target (ICRS, name) 16 27 46.15903 -25 44 54.2702

Radius 25.26'

Time

Band 0.21015484916529545 0.220026116655881

Pol

ID IAwjdlcT1HIEq7251deoebNLMEEsqZ3bmz
ASUNC

Reset Clear Submit Close

23.42° x 13.87°

Search

select casda
from all co...

coll sort view scan

epoch +
size +
dens. +
opac. +
zoom -

16:25:35.11766 -23:26:49.9150
23.42° x 13.87°

0 sel / 9 src 345Mb

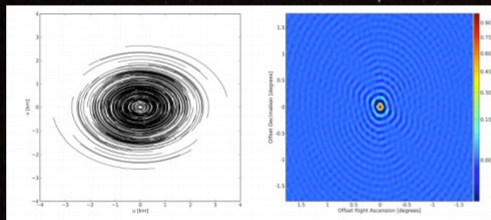
[illegible]

Visibility data ? (direct discovery or via

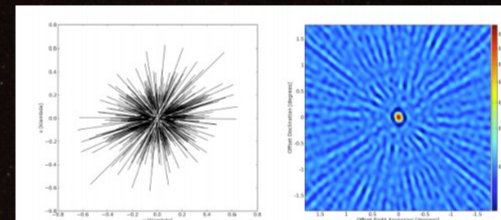
Data Types: Visibilities

ASTRON

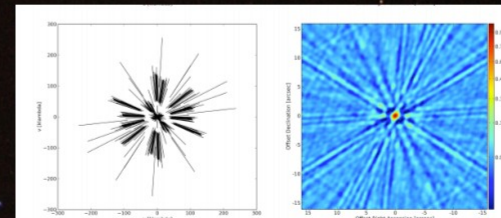
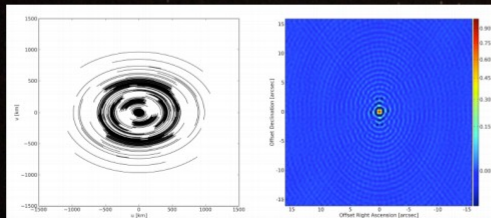
- Interferometer: Creating virtual aperture up to $\sim 2000\text{km}$ (λ/D)
- Incomplete coverage
- Typical use of Radio Telescopes: imaging depending on science
- LOFAR: Projection effects (No moving dish/mirror)



6 hours



1 second

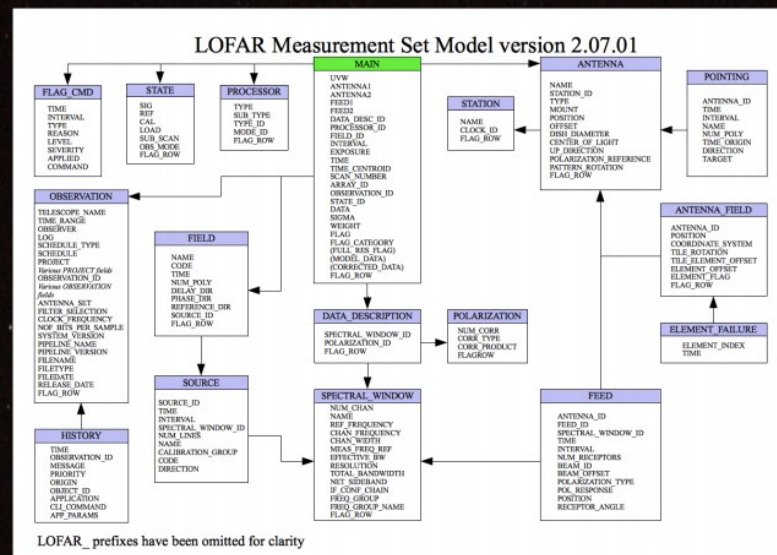


Visibility data ? (LOFAR measurement sets model :)

Data Types: Visibilities

ASTRON

- Stored as CASA Measurement Sets
 - 10 MB - 100 GB in size, per 192 kHz frequency band
 - Usually 400-488 per observation
 - Relational structure
 - Each cell can have multiple dimensions (pol x freq)



Visibility datamodel ?:

derived from cube datamodel
inspired by TimeSeries datamodel

