

# VO in the radio domain: the INAF experience

A Zanichelli - INAF IRA

*Contributors: V. Galluzzi, C. Gheller, M. Massardi, M. Messerotti,  
M. Molinaro, M. Pilia, F. Vitello*



# This talk

- Overview of INAF national / international projects and collaborations on radio data in the VO context
- Highlight of VO standards/services/tools
- VO data models in the radio domain: a recent history

# The INAF Radio Data Archive

Help Your files 0 Login

Simple search VLBI-IT search SD search Pulsar and transients search

File name

Name resolver:

RA (J2000)   Dec (J2000)  Radius (arcmin)

Toggle all

- Equinox
- Obs date From:   To:
- Project id
- Telescope
- Frontend
- Frequency [MHz] From:  To:
- Bandwidth [MHz] From:  To:
- Spectral resolution [MHz] From:  To:
- Frequency bins

Backend

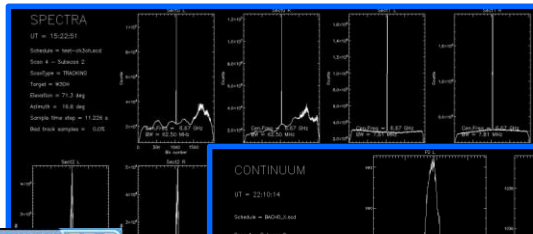
<http://radioarchive.inaf.it>

Raw data from the Medicina, Noto and SRT radio telescopes

Progressively being populated with Single Dish, pulsar and VLBI-IT data (VLBI-IT = software correlated in Bologna)



# Data formats



```

File Edit Tools Syntax Buffers Window Help
[Task version="1.0" encoding="UTF-8"]
<database>
<table>
<PROJID=13131</PROJID>
<FILEID=VLBI</FILEID>
<FILENAME=niccollo.610211</FILENAME>
<OBJECT=J2212+735</OBJECT>
<RA=22.38000000</RA>
<DEC=73.825728211</DEC>
<START=2014-03-28 14:28:43</START>
<ANTENNAS=NT_M5-MC</ANTENNAS>
<FREQ=496.49</FREQ>
<CORE_NODS=2</CORE_NODS>
<RATE=517.0</RATE>
</table>
    
```

Summary of 20140308-105092-Maintenance-Empty\_001\_002.fits in /home/alex/escs/archiv01

Index	Extension	Type	Dimension	View
0	Primary	Image	0	Header Image Table
1	SECTION TABLE	Binary	5 cols X 2 rows	Header Hist Plot All Select
2	RF INPUTS	Binary	9 cols X 2 rows	Header Hist Plot All Select
3	FEED TABLE	Binary	4 cols X 1 rows	Header Hist Plot All Select
4	DATA TABLE	Binary	12 cols X 364 rows	Header Hist Plot All Select
5	ANTENNA TEMP TABLE	Binary	2 cols X 364 rows	Header Hist Plot All Select
6	SERVO TABLE	Binary	8 cols X 364 rows	Header Hist Plot All Select

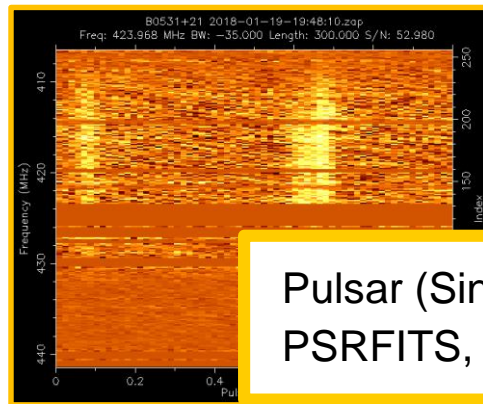
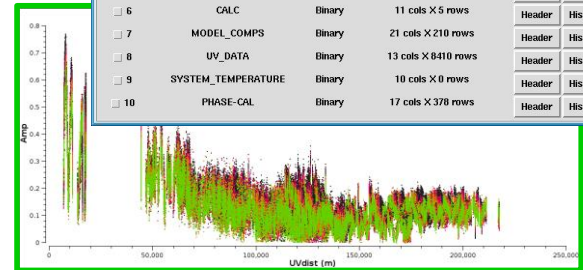
Single-dish FITS (and MBFITS)

```

SINGLE = 1 / file does conf
BITPIX = 0 / number of bits
NAXIS1 = 0 / number of data
EXTEND = 1 / FITS dataset a
COMMENT = FITS (Flexible Image Transport System)
COMMENT = and Astrophysics, volume 376, page 3
COMMENT = V 1.0 Created by S. Righini, M. Bartol
HISTORY V 0.0 First output standard for Italia
HISTORY V 0.80 The tsys column in data table is
HISTORY V 0.9 The section table has been split
HISTORY V 0.91 Added the flux column in section
HISTORY V 0.92 SubScanType added as primary key
HISTORY V 1.0 Added new table to store position
HISTORY receivers: SERVO TABLE
DATE = '2014-03-08T00:00:00.000' / file creation
HIERARCH Project_Name = 'G2700' / Name of the
(OBSERVE= / Name of the ob
ANTENNA = 'SNT
HIERARCH siteLongitude = 0.161358481
HIERARCH siteLatitude = 0.609295794
HIERARCH siteHeight = 650 / Me
HEADS = 2 / Num
SECTIONS = 2 / Tot
HIERARCH Sample Size = 'DCB' / Num
HIERARCH Receiver Code = 'DCB' / Sca
SOURCE = 'Empty' / Sca
HIERARCH RightAscension = 0.11789724509617 / Source right ascension at J2000 (c
HIERARCH Declination = 0.5512315421542 / Source declination at J2000 (radia
WLS = 0 / Longitude offset in horizontal fra
HIERARCH Azimuth Offset = 0 / Longitude offset in horizontal fra
HIERARCH Elevation Offset = 0 / Latitude offset in equatorial fra
HIERARCH RightAscension Offset = 0 / Longitude offset in equatorial fra
HIERARCH Declination Offset = 0 / Latitude offset in equatorial fra
HIERARCH Galacticonic Offset = 0 / Longitude offset in galactic fra
HIERARCH Galactolat Offset = 0 / Latitude offset in galactic fra
SCAND = 1 / Scan Identifier
HIERARCH SubScanID = 1 / Subsc Identifier
HIERARCH ScheduleName = 'G2700_20140308-105092'
HIERARCH LogP1Label = 'G2700_20140308-105092_Log'
HIERARCH SubScanType = 'RA' / describes the scan type based on telescope
    
```

## VLBI FITS-ID

Index	Extension	Type	Dimension	View
0	Primary	Image	0	Header Image Table
1	ARRAY_GEOMETRY	Binary	7 cols X 2 rows	Header Hist Plot All Select
2	SOURCE	Binary	26 cols X 4 rows	Header Hist Plot All Select
3	ANTENNA	Binary	13 cols X 10 rows	Header Hist Plot All Select
4	FREQUENCY	Binary	6 cols X 1 rows	Header Hist Plot All Select
5	INTERFEROMETER_MODEL	Binary	20 cols X 210 rows	Header Hist Plot All Select
6	CALC	Binary	11 cols X 5 rows	Header Hist Plot All Select
7	MODEL_COMPS	Binary	21 cols X 210 rows	Header Hist Plot All Select
8	UV_DATA	Binary	13 cols X 8410 rows	Header Hist Plot All Select
9	SYSTEM_TEMPERATURE	Binary	10 cols X 0 rows	Header Hist Plot All Select
10	PHASE-CAL	Binary	17 cols X 370 rows	Header Hist Plot All Select

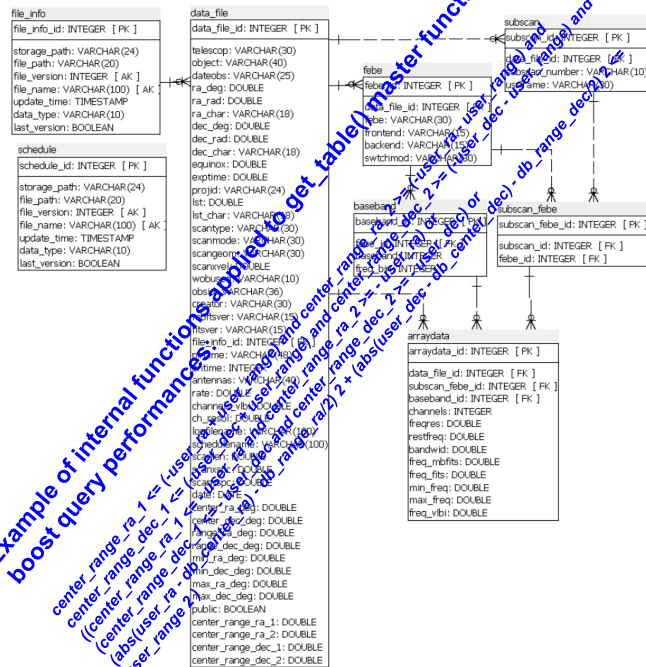


Pulsar (Single Dish / VLBI)  
PSRFITS, Filterbank, PSRCHIVE

# Discoverability

## TAP and DataLink

- TAP service:
  - IA2 implementation
- DataLink
  - Access to complex datasets:  
content list, ancillary resources  
(related datasets)
  - additional metadata (provenance,  
data quality, etc.)

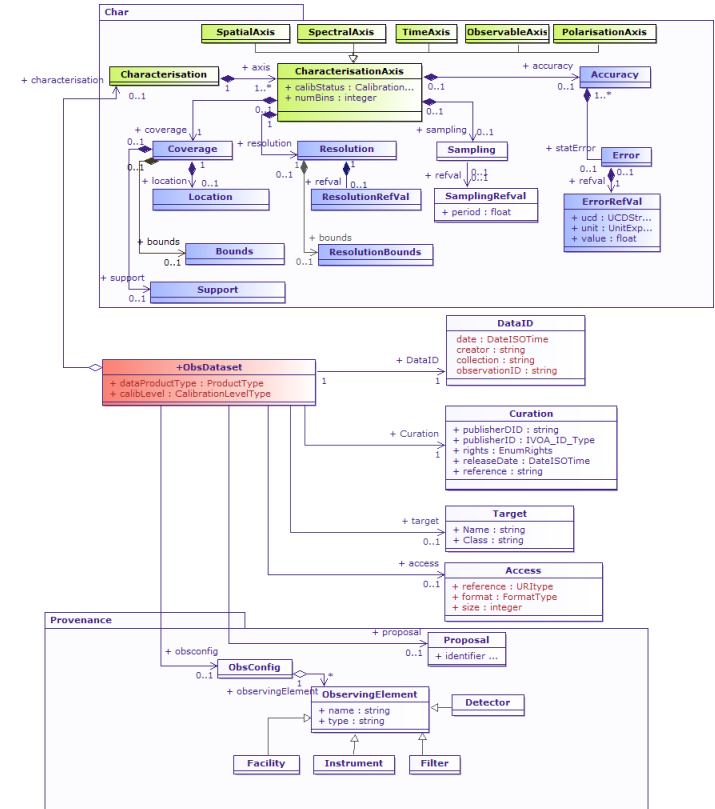


# IVOA ObsCoreDM

Global data discovery and access requires to expose a uniform, standard data model.

Analysis of the ObsCore **mandatory** components.

For data discovery purposes, all the required metadata core components are present in the radio data model.



# ObsCore mapping

OBSCore keyword	OBSCore Unit/Type	Mapping expression to populate ObsCore from mysql db radio_archive_database	Definition (eventually in terms of FITS keywords)	Required actions (preceded by the relevant actor)	Comments
<a href="#">obs_collection</a>	Unitless string (from an INAF list)	Proposed: <code>obs_collection = 'INAF-&lt;data_file.telescop&gt;.single dish'</code>  Example: INAF-Medicina, single dish	- TELESCOP	Discuss the proposed value with <a href="#">AG</a>	
<a href="#">obs_id</a>	Unitless string (regular expression)	Syntax: <code>obs_id = '&lt;data_file.telescop&gt;-&lt;data_file.dateobs&gt;-&lt;data_file.projid&gt;-&lt;febe.backend&gt;-&lt;data_file.object&gt;'</code>	TELESCOP-yyyy-mm-ddThh:mm:ss-PROJID-BACKENDNAME-SRC_NAME	To be discussed: use "-" instead of "_"	The ISO formatted UTC date and time, i.e. yyyy-mm-ddThh:mm:ss, is extracted from DATE_OBS (it typically differs by few seconds with respect to the date of

OBSCore keyword	OBSCore Unit (Type)	Value (expressions are based on fields of the table pulsar; db: metadata_pulsar)	Required actions (preceded by the relevant actor)	Comments
<a href="#">em_min</a>	m (float)	<code>c/[(&lt;pulsar.OBSFREQ&gt; - &lt;pulsar.OBSBW&gt;/2.0)*10e+6]</code> ,  where c is the speed of light in m/s		
<a href="#">em_max</a>	m (float)	<code>c/[(&lt;pulsar.OBSFREQ&gt; + &lt;pulsar.OBSBW&gt;/2.0)*10.0e+6]</code>		
<a href="#">em_res_power</a>		NULL		It is not applicable for the radio data type. Also, in a discovery phase it is of limited (if any) help for the user.  Use em_resolution from IVOA ObsCore radio extension?
<a href="#">em_xel</a>	Unitless (integer)	<code>&lt;pulsar.OBSNCHAN&gt;</code>		

An ObsCore Extension for Radio Data is being discussed within the IVOA RadioIG

Enhance data discoverability

Fruitful collaboration among facilities dedicated to radio data

ObsTAP service implementation for the INAF Radio Data Archive foreseen by 2023 Q4

# The Additional Representative Images for Legacy (ARI-L)

- **ARI-L is an ALMA Development Project** (PI: Massardi) that run in Jun 2019-Dec 2022
- It aimed at **restoring ALMA calibration and performing imaging with the ALMA Pipeline to complement datasets from cycles 2-4 in the ASA that missed a pipeline image** with representative images comparable to those of later cycles.
- The project **reprocessed 88.5% of the MOUS** processable with the pipeline (main goal was at least 70%)
- For each pipeline processable MOUS in Cy2-4 (no TP, VLBI, Solar, Full Stokes) for each source and calibrator encloses
  - overall spw continuum
  - mfs continuum for each spw
  - cube for each spw
- **Images are included in Archive previews and visualization can be queried as collection "ari\_l" and can be downloaded as "External products"**



**3.5** years



**91**  
delivery rate of  
processable MOUS



**3102**  
MOUS delivered



**150 127**  
images delivered



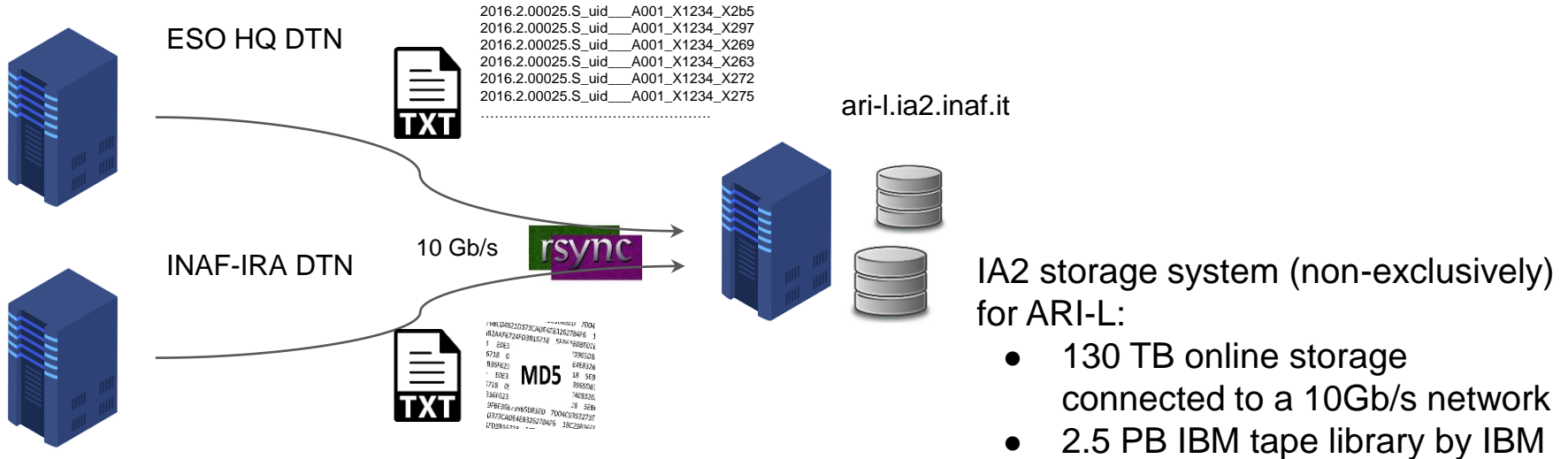
**445 328**  
files ingested in ASA

[https://almascience.eso.org/alma-data/ari\\_l](https://almascience.eso.org/alma-data/ari_l)



# Data transfer and preservation

Peer to peer communication from the IT-ARC cluster at INAF-IRA and from the ESO cluster towards the IA2 Data Centre front-end machine, to increase transfer speed and security



Data is intended to be preserved

# ARI-L Data access via IA2 VOSpace GUI

Please, report bugs at [vospace.ia2@inaf.it](mailto:vospace.ia2@inaf.it)

ROOT / ari-l

- New folder
- Upload files
- Create links
- Actions ▾

<input checked="" type="checkbox"/>	<input type="checkbox"/>	Name	Size	Group read	Group write
<input checked="" type="checkbox"/>	<input type="checkbox"/>	2013.1.00001.S_uid__A001_X	0 B		:
<input checked="" type="checkbox"/>	<input type="checkbox"/>	2013.1.00001.S_uid__A001_X	0 B		:
<input type="checkbox"/>	<input type="checkbox"/>	2013.1.00001.S_uid__A001_X100_X100	0 B		:

- Async recall
- Delete
- Move
- Copy
- Create zip archive
- Create tar archive

Please, report bugs at [vospace.ia2@inaf.it](mailto:vospace.ia2@inaf.it)

ROOT / ari-l / 2013.1.00020.S\_uid\_\_A001\_X122\_X52e / measurementsets

- New folder
- Upload files
- Create links

<input checked="" type="checkbox"/>	<input type="checkbox"/>	Name	Size	Group read	Group write
<input type="checkbox"/>	<input type="checkbox"/>	uid__A002_X836a4d_Xc23.ms.tgz	15.8 GB		:
<input type="checkbox"/>	<input type="checkbox"/>	uid__A002_X88063e_X84c.ms.tgz	11.8 GB		:



VOSpace data retrieve notification: Job QUEUED

noreply-vospace@inaf.it  
a vospace.ia2, me ▾

🌐 inglese ▾ > italiano ▾ [Traduci messaggio](#)

Dear user,  
your job has been QUEUED.

Job ID: 1348e610af4c44c19619538596b9134f  
Job type: pullToVoSpace  
Owner ID: 2163

VOSpace data retrieve notification: COMPLETED

noreply-vospace@inaf.it  
a vospace.ia2, me ▾

🌐 inglese ▾ > italiano ▾ [Traduci messaggio](#)

##### VOSpace data retrieval procedure summary #####

Dear user,  
your job has been COMPLETED.

Job ID: 1700487fe74240cb8792751f92518db7  
Job type: pullToVoSpace  
Owner ID: 2163

Your files are available and can be downloaded.  
A file containing the list of URLs is attached here below.



url\_list-1700487f...

# Solar Radio Data Management for Space Weather Science and Applications: TSRS

Part of the INAF Solar Radio Weather asset, the Trieste Solar Radio System 2.0 is the project for a new, state-of-the-art solar radio polarimeter primarily devoted to the solar radio surveillance.

Instrument/ Project	POC	Location	Operation Mode	SWx Application
TSRS 2.0	Mauro Messerotti	Trieste, Friuli- Venezia Giulia	Solar Radio Monitoring	Nowcasting/ Alerting
RSRS	Vincenzo Carbone	Rende, Calabria	Solar Radio Monitoring	Nowcasting/ Alerting
SUNDISH	Alberto Pellizzoni	SRT, Medicina, Noto	Solar Radio Monitoring on demand	Alerting
SOLARIS*	Alberto Pellizzoni	Antarctica	Solar Radio Monitoring	Alerting

\* With other Partners

# Trieste Solar Radio System – Archive and interfaces

TSRS 1.0 Archive Data:  
 ~1.2 TB (compressed)  
 6+6 (LHCP, RHCP) bands  
 Flux & CP time series  
 Full solar radio disk

Frequency [MHz]	Mean [SFU]	Max [SFU]	Mean [dBm/Hz]	Max [dBm/Hz]	SRN	Predicted [SFU]	Predicted [dBm/Hz]	Predicted SRN
237	2	2	-218	-218	Q	*****	****	Q
327	0	0	0	0	Q	*****	****	Q
408	9	316	-216	-201	Q	71	-208	M
610	2	2	-227	-227	Q	*****	****	Q
1420	46	113	-220	-216	L	87	-218	L
2695	63	90	-225	-223	L	91	-223	L

Last update: 29 Jul 2010 16:38 UTC

SRN: Solar Radio Noise  
 Q=Quiet sun  
 L=Low  
 M=Moderate  
 H=High

SFU: Solar Flux Unit

Select	Catalogue Description	Type	Status	Source	From	To	Info
<input type="checkbox"/>	Trieste Solar Radio System (TSRS) Solar Radio Event List	event	closed	URL	2000-07-12	2006-12-05	Info

# Data Management & Exploitation

- Real-Time data Acquisition
- Real Time Data Ingestion & Indexing
  - Metadata management
  - Modeling & annotation
    - > SSIG- & TDIG-driven standards
- Real Time Data Publication (TAP)
  - Dynamic time series
  - Space Weather events
    - > Catalogue
    - > Broadcast (VOEvent)

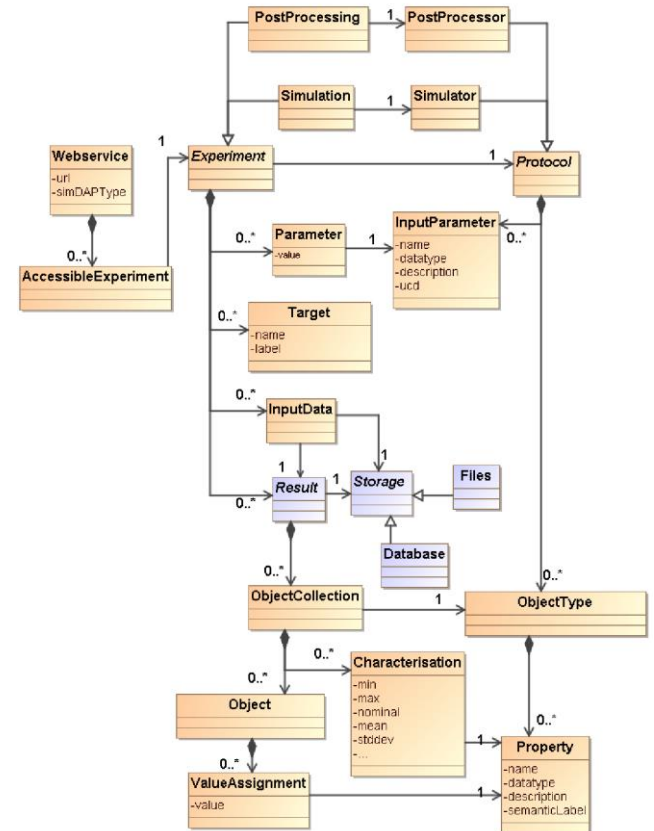
IMPACT



- Interoperability
- Data fusion
- Model Integration
- Knowledge Discovery in DBs
- Unified data Access, Search and Analysis

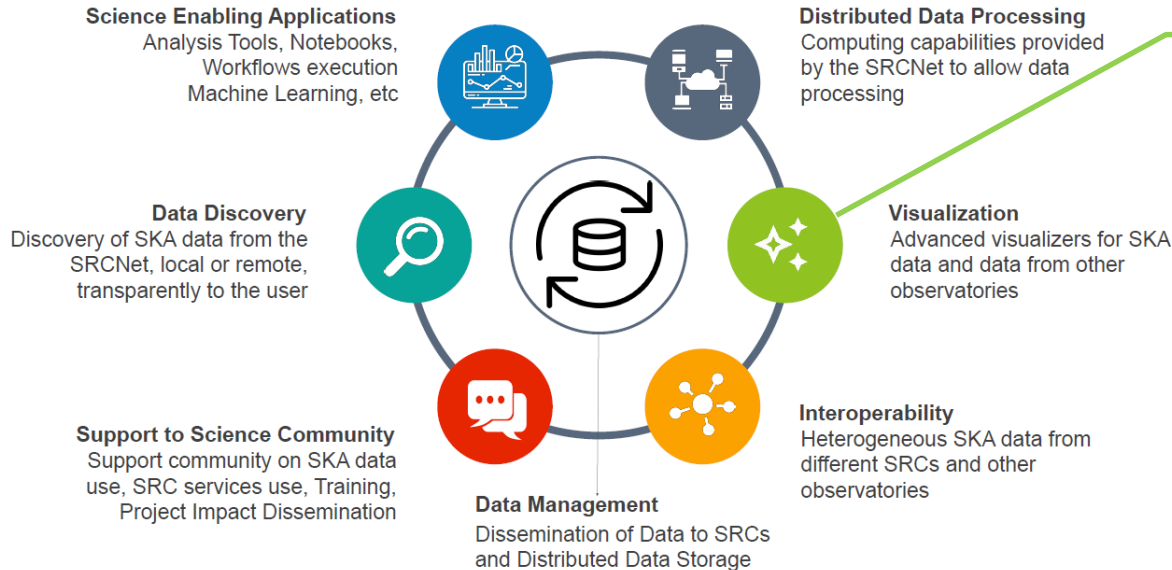
# Simulation Data Model

- Italian National Center for HPC and Big Data
  - Development of a data model for describing the results of astrophysical numerical simulations and observational data and make them FAIR
  - Dedicated tasks for simulations and data processing/analysis for LOFAR and SKA
- Reference Model:
  - Simulation Data Model (SimDM) Version 1.00, Lemson et al., 2012, arXiv:1402.4744
  - IVOA Recommendation 2012 May 3rd
  - The primary goal of the SimDM standard is to support discovery of simulations by describing those aspects of them that scientists might wish to query on, i.e. it is a model for meta-data describing simulations.
  - Extension to a general description of data products is expected.



# SKA REGIONAL CENTRE Network - visualisation of data

## SRC Node Capabilities



INAF leads the SRCSC Team dedicated to the realization of a prototype for the visualisation of SKA data with high volume of users and high amount of data.

# SRCNet visualisation tool prototype

Solution for the visualisation of big datacubes at the SRCNet data lake minimizing the latency.

The proposed approach:

- Visualisation tool servers will be deployed in all the SRCs that host big data files to be visualised (e.g. big data cubes)
- A REST (or similar) service will be used to discover the server that is close to a particular data entity
- The visualisation tool will connect to the selected remote server to start the visualisation



# IVOA tools/standards in SRCNet visualisation



The service output could be integrated into an ObsCore response and could be inspired by the IVOA Data Link standard.

Proposed input format: SIA2, ObsTAP

Proposed output format: VOTable

Alternative: directly query the ObsTAP discovery service with SAMP in client mode. This could be an option to get information from the SKA discovery service through communication with another (VO-compliant) tool such as Aladin or TopCat or, later, the SRC web portal. VO tools, after querying the discovery service displaying the ObsCore result and discovering the DataLink URI send “table.load.votable” messages to each tool providing them with this URI of the DataLink response.

# IVOA tools/standards in SRCNet visualisation



In order to properly distribute the analysis servers for visualisation (or other remote operations) into the SRC Net nodes, containerised versions of SODA service is being deployed.

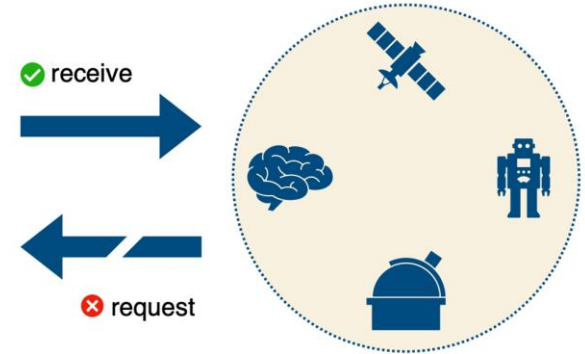
Also, a prototype SODA service on top of hips2fits to deliver fits images extracted from HiPS data is being investigated.

# Fast Radio Burst VOEvents

The Canadian radio telescope CHIME, with over 600 FRBs discovered in one year, is currently the flagship instrument to detect new FRBs. They started issuing discovery alerts through a VOEvent system.



Photo credit: CHIME Collaboration



Follow up of repeating FRBs is done with the Sardinia Radio Telescope and the Northern Cross interferometer in Italy.

Subscription to the CHIME VOEvent alert system has been experimented in view of the follow up + multi-wavelength campaigns.

Extra manpower is required to validate the very high number of alerts, currently preventing the use of the CHIME VOEvent system as an automatic trigger for observations with the INAF radio telescopes.

*Thank you*