



The ALMA Science Archive

Marcella Massardi (INAF-IRA / Italian ARC node)

**with contributes from the tutors of the
“EU ARC ALMA Archive School 2022”**

The ALMA Science Archive

almascience.eso.org/aq

The ALMA Science archive is the one-stop-shop to access ALMA data

It collects all the data observed with ALMA for science purposes.

PI proposal is accepted

Project is split in science goals

Science goals are observed

Data are Quality Assessed

Data are stored to the archive

For 1yr they are available only to PI

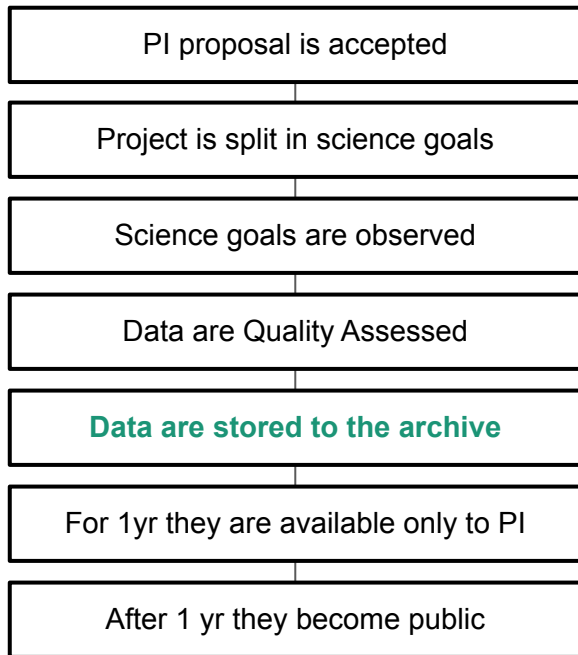
After 1 yr they become public

The ALMA Science Archive

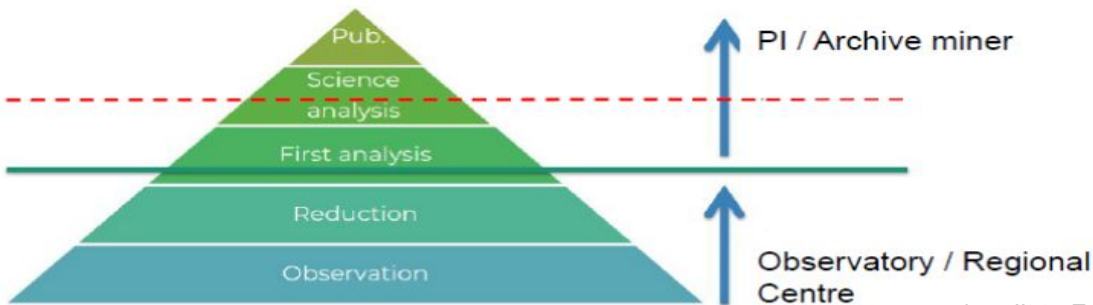
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The ALMA Science archive is the one-stop-shop to access ALMA data

It collects all the data observed with ALMA for science purposes.



- 10 years of observations collected
- Science categories from the solar system to cosmology
- 1.4 PB of data
- 50 000 observations are already publicly accessible
- >10 000 of those have not yet been published at all!!!
- Recently under major upgrade to improve the user experience



(credit to F. Stoehr)

The EU ARC ALMA Science Archive School

<https://www.eso.org/sci/facilities/alma/arc/alma-archive-school2022.html>
Italian ARC headquarters, INAF-IRA, Bologna 5-7 October 2022

The EU ARC nodes staff

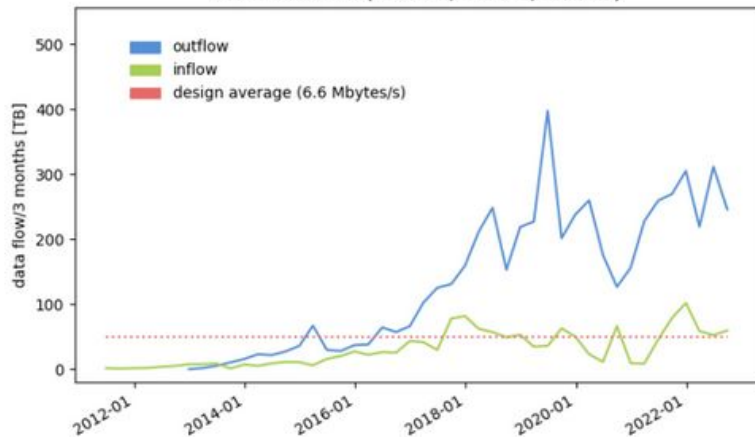
- presented the current status of the ALMA Science archive and its development
- taught on basic queries
- presented tools for programmatic query
- described the basics of calibration and imaging of interferometric data
- tutored on the CARTA visualization tool
- gave advanced tricks and tips on ALMA archival data management

This talk give you a summary of the school main take-home messages

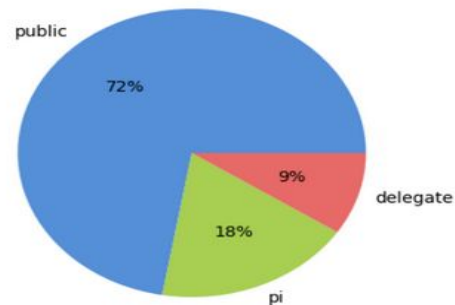
The ALMA Science Archive: overview

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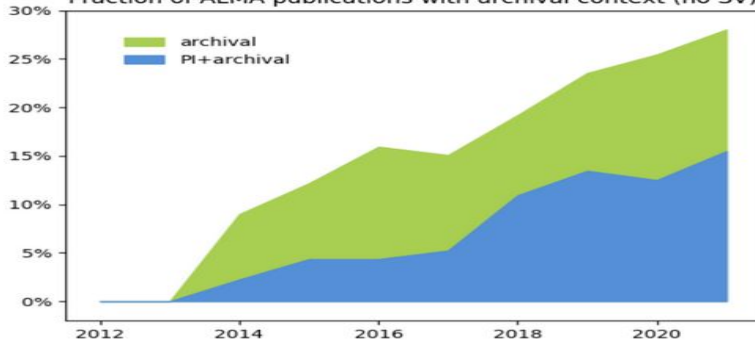
ALMA data flow (total out/in: 5500/1422 TB)



Downloaded ALMA data (total: 18262 users)



Fraction of ALMA publications with archival context (no SV)

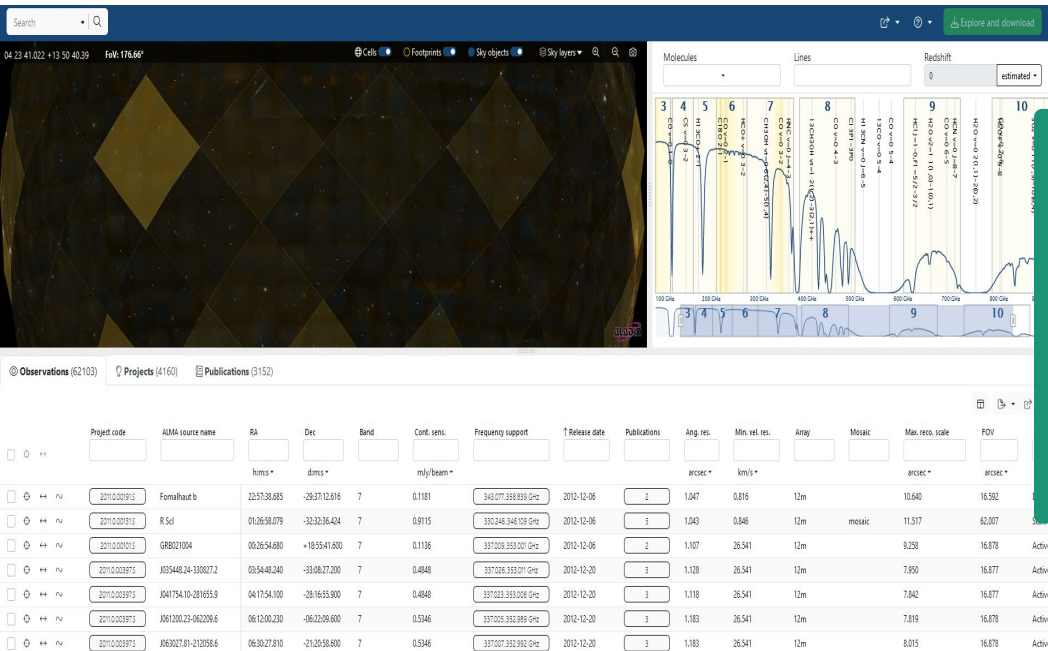


- Steady increase in usage across the years
- Not only for PIs
- About 30% of the 3180 refereed publications with ALMA use archival data

(credit to F. Stoehr)

The ALMA Science Archive: overview

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Main ingredients:

- Physical quantities
- Unscoped search
- Observations, Proposals, Publications
- Target-list upload
- Previews
- Modern user-experience
- Programmatic access (VO)
- Metadata are public
- Science-grade products + PL
- Anonymous downloads
- Self-describing FITS files
- Parallel downloads
- Authors must cite data-use
- Frequent Reprocessing
- **NEW:** Science platforms

LIVE DEMO

The ALMA Science Archive: overview

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Direct query

Query on physical quantities

Query on text similarity

The screenshot displays the ALMA Science Archive search interface. It features several filter panels on the left: 'Position' (Source name, ALMA source name, RA Dec, Galactic, Target List), 'Energy' (Frequency, Band, Spectral resolution, Continuum sensitivity, Line sensitivity), 'Project' (Project code, Project Title, Project abstract, PI Full Name, Proposal authors, Science keyword), 'Publication' (BibCode, Publication Title, Abstract, First Author, Authors), and 'Observation' (Observation Date, Polarisation Type, Member ous id, Object type, Public data only, Calibration observations). A 'Search' button is at the top left, and 'Explore and download' is at the top right. On the right side, there is a 'Molecules' dropdown, 'Lines' dropdown, and 'Redshift' input (0.00182627781759947). Below these is a spectral plot showing intensity versus frequency (100-700 GHz) with labeled lines and calibrators. The plot includes labels for molecules like CO, CS, NH₂, H₂CO, HCO, and CH₃OH, and their quantum states. The plot is divided into sections 3 through 10.

Query including calibrators

Query for target lists

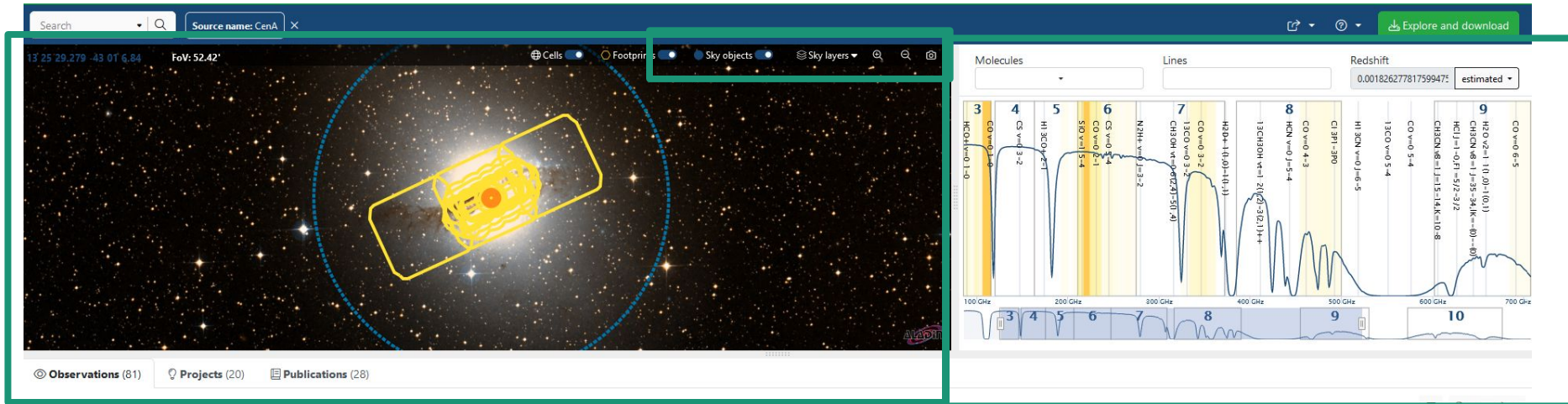
	hms	dms	mJy/beam	Publications	Ang. res.	Min. vel. res.	Array	Mosaic	Max. reco. scale	FOV					
					arcsec	km/s			arcsec	arcsec					
<input type="checkbox"/>	2011.0.00010.5	CenA	13:25:27.615 -43:01:08.803	6	0.0617	217.592.220.459 GHz	2015-02-12	1	1.495	0.664	12m	13.305	26.586	A	
<input type="checkbox"/>	2011.0.00010.5	CenA	13:25:27.615 -43:01:08.803	3	0.0932	90.383.93.123 GHz	2015-02-12	1	1.356	0.393	12m	10.422	63.463	A	
<input type="checkbox"/>	2011.0.00010.5	CenA	13:25:27.615 -43:01:08.803	3	0.0917	87.054.89.145 GHz	2015-02-12	1	1.496	0.411	12m	12.221	66.095	A	
<input type="checkbox"/>	2011.0.00010.5	CenA	13:25:27.615 -43:01:08.803	3	0.0892	85.958.99.353 GHz	2015-02-12	1	1.410	0.368	12m	10.507	62.845	A	
<input type="checkbox"/>	2011.0.00010.5	CenA	13:25:27.615 -43:01:08.803	3	0.1179	109.475.113.36 GHz	2015-02-12	1	1.150	0.323	12m	8.280	52.263	A	
<input type="checkbox"/>	2012.1.00019.5	Centaurus_A	13:25:27.615 -43:01:08.801	6	1.4175	218.108.220.99 GHz	2015-05-07	0	4.642	0.166	7m	mosaic	32.267	206.087	C

The ALMA Science Archive: overview

Positional overview, VO tool overlap,
Multi-wavelength detections

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Spectral overview with link to
Splatalogue



	Project code	ALMA source name	RA	Dec	Band	Cont. sens.	Frequency support	Release date	Publications	Ang. res.	Min. vel. res.	Array	Mosaic	Max. reco. scale	FOV	Scient
			hms	dms		mJy/beam				arcsec	km/s			arcsec	arcsec	
<input checked="" type="checkbox"/>	2011.0.00010.5	CenA	13:25:27.615	-43:01:08.803	6	0.0617	217.592-220.459 GHz	2015-02-12	1	1.495	0.664	12m		13.305	26.586	Active
<input type="checkbox"/>	2011.0.00010.5	CenA	13:25:27.615	-43:01:08.803	3	0.0932	90.383-93.123 GHz	2015-02-12	1	1.356	0.393	12m		10.422	63.463	Active
<input type="checkbox"/>	2011.0.00010.5	CenA	13:25:27.615	-43:01:08.803	3	0.0917	87.054-89.145 GHz	2015-02-12	1	1.496	0.411	12m		12.221	66.095	Active
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<input checked="" type="checkbox"/>	2011.0.00010.5	CenA	13:25:27.615	-43:01:08.803	3	0.1179	109.475-113.36 GHz	2015-02-12	1	1.150	0.323	12m		8.280	52.263	Active
<input type="checkbox"/>	2012.1.00019.5	Centaurus_A	13:25:27.615	-43:01:08.803	6	1.4175	218.108-220.99 GHz	2015-05-07	0	4.642	0.166	7m	mosaic	32.267	206.087	Galaxy
<input type="checkbox"/>	2012.1.00019.5	Centaurus_A	13:25:26.557	-43:01:28.898	6	0.2201	218.18-222.594 GHz	2015-05-23	0	0.864	0.166	12m	mosaic	7.356	178.675	Galaxy

Possibility to filter and select, sort
lines and columns

The ALMA Science Archive: overview

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The screenshot displays the ALMA Science Archive interface. At the top, a search bar contains 'Source name: CenA'. Below the search bar, a navigation menu includes 'Cells', 'Footprints', 'Sky objects', and 'Sky layers'. A green button labeled 'Explore and download' is visible in the top right corner.

The main content area is divided into two sections. On the left, a preview for 'Centaurus_A' is shown, featuring two circular beam pattern plots and a spectral plot. The preview includes the following details:

- SPW 0:** 99.824..101.808GHz, 31,250 kHz, XX YY
- SPW 1:** 101.82..103.804GHz, 31,250 kHz, XX YY

Each preview includes a 'member.uid' link, a download icon, and a file size of 5 MB. The details for each preview are:

- Band:** 3
- Frequency type:** continuum
- Frequency range:** 99.824..101.808 (SPW 0) / 101.82..103.804 (SPW 1)
- Frequency resolution:** 31,250 kHz
- Continuum sensitivity:** 0.213
- Line sensitivity 10km/s (estimate):** 8.384 mJy/beam@10km/s (SPW 0) / 8.042 mJy/beam@10km/s (SPW 1)
- Line sensitivity native (estimate):** 0.344 uJy/beam@native (SPW 0) / 0.333 uJy/beam@native (SPW 1)
- Polarizations:** XX YY
- Array:** 7m

On the right, a spectral plot shows the frequency range from 100 GHz to 700 GHz. The plot displays several absorption lines, with labels for molecules and transitions. A green box highlights the 'Explore and download' button in the top right corner of the preview area.

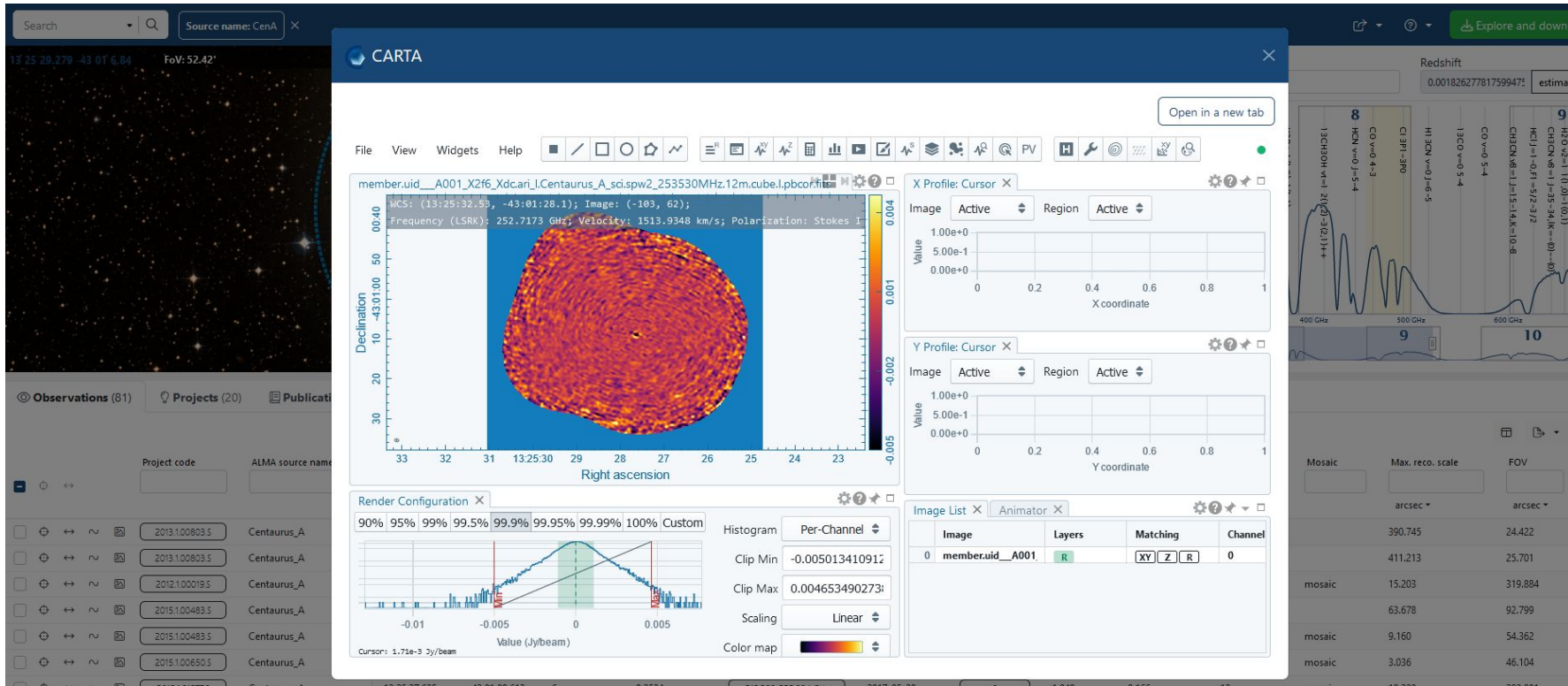
At the bottom, a table lists search results for Centaurus A. The table has columns for 'Observations', 'Ang. res.', 'Min. vel. res.', 'Array', 'Mosaic', 'Max. reco. scale', 'FOV', and 'Scienc'. The table contains several rows of data, including observation IDs, frequencies, and dates.

Just click to visualize previews and single file download

The ALMA Science Archive: overview

Interactive CARTA previews

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The ALMA Science Archive: overview

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ALMA Request Handler

Log

Anonymous User: Request #2164613889491 ✓

Request Title: [click to edit](#)

Download Selected

Single or multiple file download along the whole data tree

readme product auxiliary raw raw (semipass) external

Project / OUSet / Executionblock	Updated	File	Size	Accessible	Actions
Request 2164613889491			123 MB		
Project 2015.1.00483.S					
Science Goal OUS uid://A001/X2f6/Xc6					
Group OUS uid://A001/X2f6/Xc7					
Member OUS uid://A001/X2f6/Xc8	2020-07-08				
SB Centauru_a_03_TE					
<input checked="" type="checkbox"/> readme		memberuid_A001_X2f6_Xc8_README.txt	12 kB	✓	
<input checked="" type="checkbox"/> auxiliary		2015.1.00483.S_uid_A001_X2f6_Xc8_auxiliary.tar	12 kB	✓	
<input type="checkbox"/> raw (semipass)		2015.1.00483.S_uid_A002_Xb2f730_X9b1.asdm.sdm.tar	12 GB	✓	
Member OUS uid://A001/X2f6/Xca	2020-04-03				
SB Centauru_a_03_TC					
<input checked="" type="checkbox"/> readme		memberuid_A001_X2f6_Xca_README.txt	10 kB	✓	
<input checked="" type="checkbox"/> product		2015.1.00483.S_uid_A001_X2f6_Xca_001_of_001.tar	26 MB	✓	
<input type="checkbox"/> product		memberuid_A001_X2f6_Xca.Centaurus_A.CO10.flux.fits.gz	7 MB	✓	
<input type="checkbox"/> product		memberuid_A001_X2f6_Xca.Centaurus_A.CO10.image.pbcor.fits	19 MB	✓	⌂
<input type="checkbox"/> product		memberuid_A001_X2f6_Xca.Centaurus_A.continuum.flux.fits.gz	68 kB	✓	
<input type="checkbox"/> product		memberuid_A001_X2f6_Xca.Centaurus_A.continuum.image.pbcor.fits	274 kB	✓	⌂
<input checked="" type="checkbox"/> auxiliary		2015.1.00483.S_uid_A001_X2f6_Xca_auxiliary.tar	35 MB	✓	
<input type="checkbox"/> raw		2015.1.00483.S_uid_A002_Xae4720_X1354.asdm.sdm.tar	7 GB	✓	
<input type="checkbox"/> external		2015.1.00483.S_uid_A001_X2f6_Xca_external_ari_1_001_of_001.tar	4 GB	✓	
<input type="checkbox"/> external		memberuid_A001_X2f6_Xca.ari_1.Centaurus_A.sci.spw0_113082MHz-12m.cube.l.mask.fits.gz	30 kB	✓	
<input type="checkbox"/> external		memberuid_A001_X2f6_Xca.ari_1.Centaurus_A.sci.spw0_113082MHz-12m.cube.l.pb.fits.gz	6 MB	✓	
<input type="checkbox"/> external		memberuid_A001_X2f6_Xca.ari_1.Centaurus_A.sci.spw0_113082MHz-12m.cube.l.pbcor.fits	25 MB	✓	⌂
<input type="checkbox"/> external		memberuid_A001_X2f6_Xca.ari_1.Centaurus_A.sci.spw0_113082MHz-12m.mfs.l.mask.fits.gz	2 kB	✓	
<input type="checkbox"/> external		memberuid_A001_X2f6_Xca.ari_1.Centaurus_A.sci.spw0_113082MHz-12m.mfs.l.pb.fits.gz	60 kB	✓	
<input type="checkbox"/> external		memberuid_A001_X2f6_Xca.ari_1.Centaurus_A.sci.spw0_113082MHz-12m.mfs.l.pbcor.fits	242 kB	✓	⌂
<input type="checkbox"/> external		memberuid_A001_X2f6_Xca.ari_1.Centaurus_A.sci.spw0_1_2_3_107641MHz-12m.cont.l.alpha.error.fits	242 kB	✓	⌂

What is in the archive

- For each project **the main deliverables are Raw Data, Calibration Scripts and Tables**
- Users need to run CASA to generate the Calibrated Data. The resulting calibrated data is considered science-ready.
- **Imaging Products are delivered too, as result of QA2 processing.** Typically pipeline-generated products include:
 - continuum-subtracted image cubes at the native resolution
 - a continuum image for all line-free channels for each spw
 - continuum image combining all spw
- **CAVEAT:** Early cycle products can have different formats, require old CASA version, images can be incomplete (unless there are ARI-L data!)

Additional tools and docs

- Previews
- CARTA interactive previews
- VO Suite (TAP, SIAv2, DataLink, SODA)
- Links to Aladdin and Topcat
- ALMA Data Mining Tool-Kit (ADMiT) previews for line identification
- Google calendars for data publication
- ALMINER tool for query

ALMA Science Archive

Jupyter Notebooks

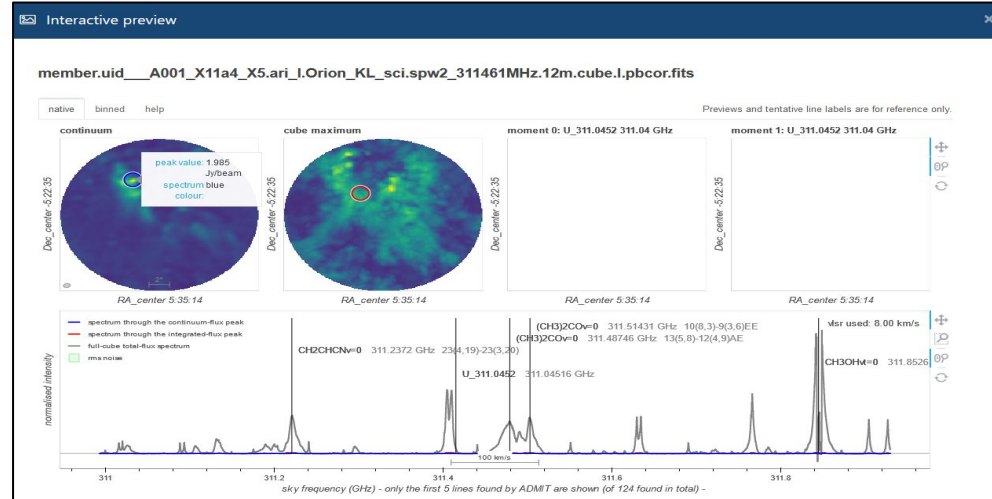
This page contains Jupyter Notebooks to programmatically access the ALMA Science Archive. The notebooks interact through Virtual Observatory standards with ALMA's ObsCore Table Access Protocol (TAP) service.

Queries in TAP are written in the SQL-like Astronomical Data Query Language (ADQL). ADQL queries include spatial queries as well as operations on other properties/columns of the database. This also allows the user detailed control over the returned columns.

In these Jupyter notebook we will exemplify some of the most common queries. For this we will be using the astropy affiliated PyVO client, which is interoperable with other valid TAP services from other observatories.

Table of Contents

0. Installation
1. Query one source
2. Query a catalogue of sources
3. Query by proposal and IDs
4. Query by science keyword
5. Query by spatial resolution
6. Query by covered frequency range
7. Query by Sensitivity
8. Query using Astroquery.ALMA
9. Download data after query



- Archive Manual
<https://almascience.eso.org/alma-data/documents-and-tools/latest/science-archive-manual>
- Video tutorials
<https://almascience.eso.org/alma-data/archive/archive-video-tutorials>
- ALMA Archival data – a Primer
<https://almascience.eso.org/documents-and-tools/cycle9/archive-primer>
- Jupyter notebooks
<https://almascience.eso.org/alma-data/archive/archive-notebooks>

(credit to F. Stoehr)

The Additional Representative Images for Legacy

<https://almascience.eso.org/alma-data/aril>

- **ARI-L is an ALMA Development Project** (PI: Massardi) that run in June 2019- December 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



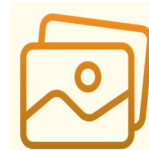
88.5

delivery rate of processable MOUS



2954

MOUS delivered



150 127

images delivered

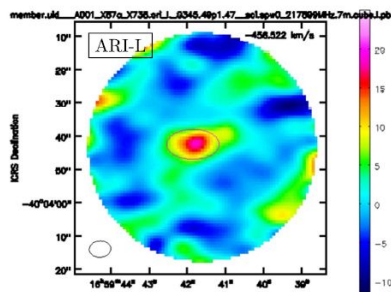
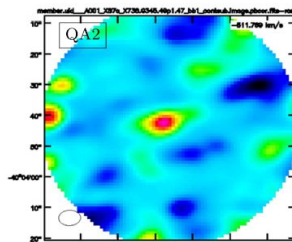
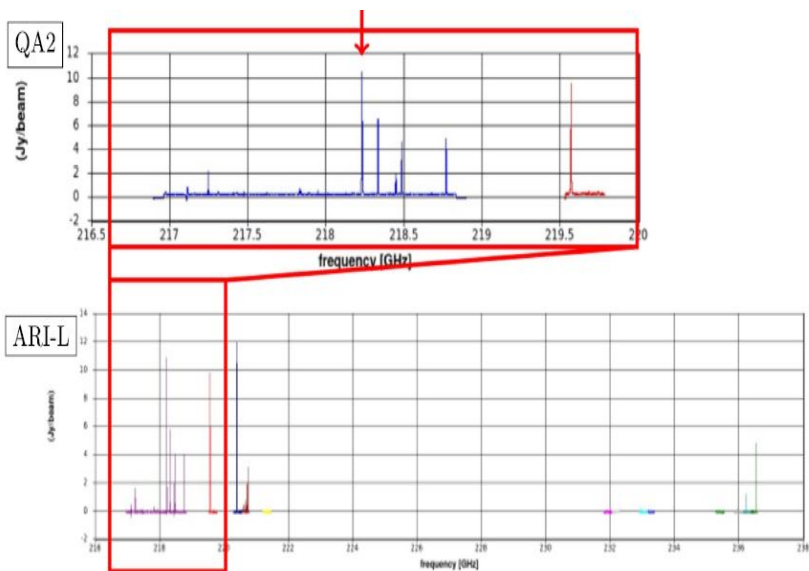


445 328

files ingested in ASA

The Additional Representative Images for Legacy

<https://almascience.eso.org/alma-data/aril>



3.5 years



88.5
delivery rate of
processable MOUS



2954
MOUS delivered



150 127
images delivered

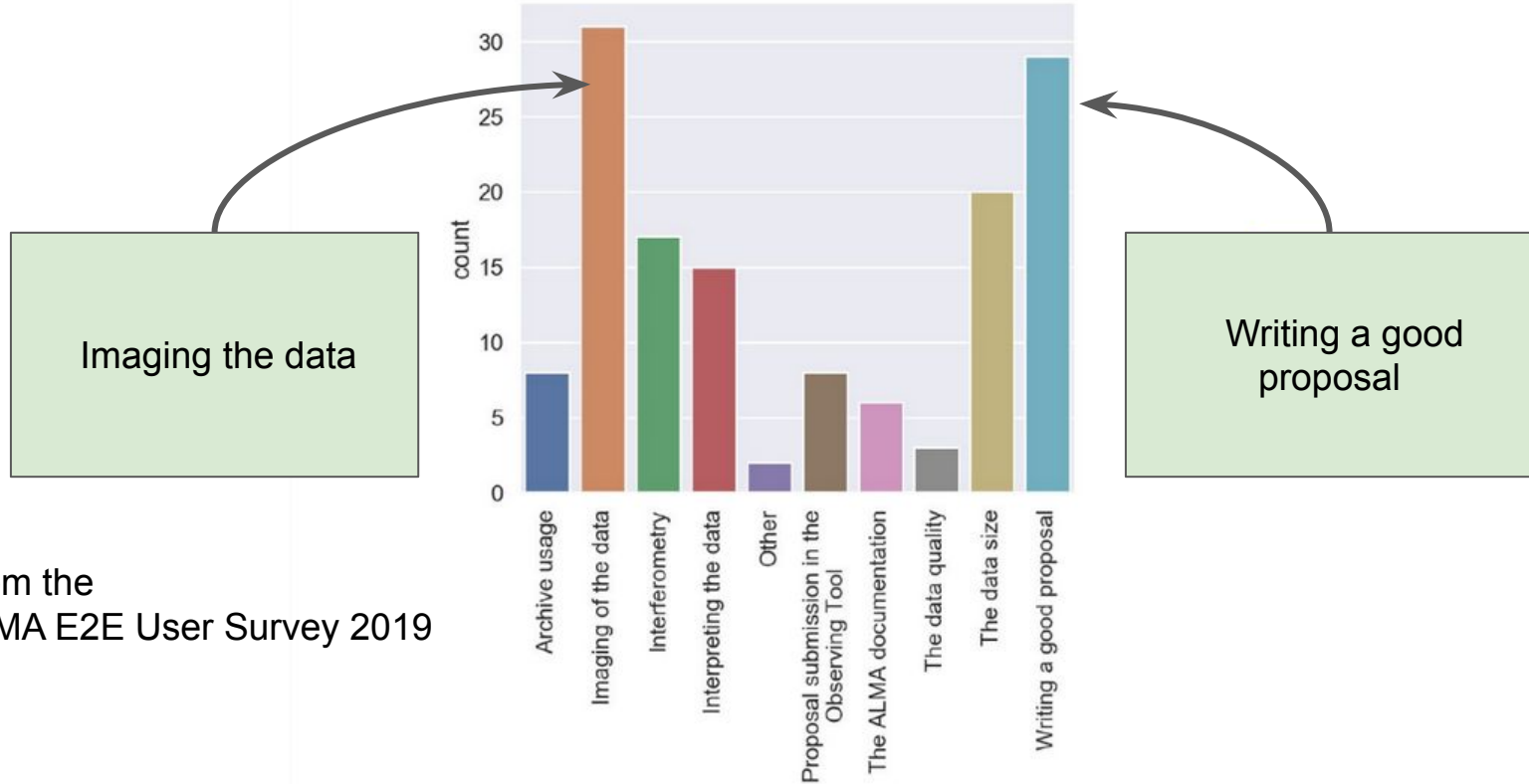


445 328
files ingested in ASA

ACKNOWLEDGE ARI-L in your papers by citing Massardi et al. (2022)

Why should I use the archive???

What are the most challenging aspects of using ALMA according to your experience?



From the
ALMA E2E User Survey 2019

Why should I use the archive???

- **Check if data are already available** for a target
- Check the **feasibility of a project** looking for similar targets
- Retrieving information on a **large sample of objects** (e.g. statistics of populations, stacking, ...)
- Retrieving **information on a single object** but with different configuration (e.g. multifrequency studies) or in different epochs (e.g. variability studies)
- **Extracting unpublished information** from existing data (e.g. finding additional spectral lines, targets in the same region/time of other observations,)
- For ALMA in particular **avoid the stress of competition and oversubscription**

	PROPOSAL SUBMISSION	ARCHIVE MINING
Time to get data	✗	+
Amount of data	✗	+
Data homogeneity	+	✗
Adherence to idea	+	✗

A lot of public, but still unpublished data are waiting for you!!!

Acknowledge ALMA data in your paper

Acknowledgement Statement:

"This paper makes use of the following ALMA data: ADS/JAO.ALMA#2011.0.01234.S.

ALMA is a partnership of ESO (representing its member states), NSF (USA) and NINS (Japan), together with NRC (Canada), NSC and ASIAA (Taiwan), and KASI (Republic of Korea), in cooperation with the Republic of Chile. The Joint ALMA Observatory is operated by ESO, AUI/NRAO and NAOJ."

Add the statement to your paper so it will be included in ESO TELBIB and could be searched through the ALMA archive

European Southern Observatory

ESO Telescope Bibliography

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REFINE SEARCH

Year

- 2015 (329)
- 2014 (934)
- 2013 (884)
- 2012 (887)
- 2011 (802)

more...

Journal

- A&A (5945)
- ApJ (2327)
- MNRAS (11982)
- AJ (494)
- A&AS (242)

more...

Instrument

- UVES (1557)
- FORS2 (1191)
- FORS1 (967)
- ISAAC (929)
- SOFI (729)

more...

TELbib SEARCH

All fields or and

Author 1st auth. +

Title / Abstract / Keywords or and

Journal

Publication year From To

BibCode

ProgramID

Instrument +

Telescope +

Site/Archive

Only papers based on ESO time

The Telescope Bibliography (telbib) is maintained by the ESO library. It contains refereed publications that directly use ESO data.

News

telbib can now also be queried via API. For more information, see <http://telbib.eso.org/api-docu.php>.

Explore telbib metrics:

- Click the **VISUALIZE** button on the results page to view **animated charts** of your search results
- Access the **telbib Statistics** area to find **interactive graphs** of selected statistics
- Find publication and citation info in the **Basic ESO Statistics document**
- Use the **overview** of annual publication statistics to access all telbib papers that pertain to a given year

Further info:

Contact the ESO librarians at library@eso.org

i For information about search fields move the mouse over the labels.

Send comments to [ESO library](#)

Can we do even better???



ALMA is going to face further upgrades with increased data size and capabilities (see Maria Diaz Trigo presentation)

The Archive will constitute a reference point for users and its development will critically define the possibilities for users. For this reason has a role in the ALMA 2030 Roadmap

**What would you like it to be?
How would you improve it even more?**

Let's discuss it in the discussion session or contact us at any time with comments/questions/ideas

<https://help.almascience.org/>

**For any ALMA related issue remember
that you can always contact us**



EUROPEAN ARC
ALMA Regional Centre

<https://help.almascience.org>

ALMA Science Archive: almascience.eso.org/aq

**EU ARC ALMA Science Archive School 2022:
<https://www.eso.org/sci/facilities/alma/arc/alma-archive-school2022.html>**