

Radio Interferometers' Data Archives

how to find, retrieve, and
image radio data:
a lay-person's primer

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By the end of this talk, you should know:

- The standard radio imaging surveys that provide FITS images
- How to find your source in the VLA/VLBA archives
- How to choose which data to download from those archives
- That there is an easy method to convert those data into preliminary images

Sources of radio data: Surveys

- Will soon cover entire sky at ≤ 1.5 GHz
- Resolutions typically 45 arcsec
- RMS noise of 0.5 mJy (NVSS/1.4 GHz, > -40) to 2 mJy (SUMSS/0.84 GHz, < -30)
- Postage stamp servers \rightarrow JPG/FITS images
- NVSS:



Sources of radio data: Surveys

- Several other sky surveys: WENSS, 4MASS/VLSS, FIRST, ...
- Many nifty targeted, special-interest surveys
 - Canadian Galactic Plane Survey (CGPS)
 - WHISP, BIMA-SONG
 - VLBI: MOJAVE, Radio Reference Frame Image Database, DRAGN, VLBA Calibrator Survey, ...
 - SIRTf/Spitzer First Look Survey

Sources of radio data: Archives

- NRAO
 - Very Large Array (VLA): the workhorse, ~ 3 TB of data!
 - Very Long Baseline Array (VLBA)
 - Green Bank Telescope (GBT)
 - Returns raw data via ftp
- Australia Telescope Compact Array (ATCA)
 - E-mail to get raw data
- MERLIN (England)
 - Working on processing all data for public use!
- Others
 - do not exist (WSRT, OVRO, PdBI, GMRT)
 - painful to search (BIMA, EVN/JIVE)

Finding radio data: choosing the telescope

- North or south?
 - Dec $> -40 \rightarrow$ VLA/VLBA
 - Dec $> 0 \rightarrow$ MERLIN
 - Dec $< -30 \rightarrow$ ATCA
- Desired resolution & source size?
 - VLA/ATCA: arcsecond to arcmin resolution over few to 10s of arcminutes
 - MERLIN: 10s of milliarcseconds res'n over arcmin
 - VLBA: milliarcsecond res'n over arcseconds

Finding radio data: checking the (VLA) archive

NRAO Data Archive System

Return a tabular listing based on query parameters.

You are here: [Archive Data](#) - Advanced Query Search by highlighted yellow area only
You may restrict your search further by setting the frequency of observed dates and/or observing stations. The organization of the parameters on this page is structured as it was, which we have preserved. Click on the links at the bottom to learn more about the VLA archive or how to download your results. It always pays to be prepared!

Select Query	Check Query	Create Form
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[Enter into an already created query data...](#)

Catalog Control Parameters

Query Criteria:	CCW: Summary Table	Son Column(s): SR Minima
Active Date Type:	All	Son Column(s): All
Output Format:	HTML	Son Column(s): SR Minima
Max Column Size:	NOOD	Son Column(s): All

General Search Parameters

Station ID:	Radio Sequence
Observer Name:	Archive File ID
Date Start:	To

Query Search Field

Criteria Name (CASC)	Search type (SIMBAD Filterword)
Desired Search Field	
Lat: [select]	Grid: U-D
Long: [select]	RA: J2000
Altitude: [select]	Ecliptic: Galactic

- Search by
 - source name (SIMBAD)
 - or position + radius
 - VLA configuration
 - obs. frequency
- Check Obs. Summary Table

Actively evolving – feedback is very welcome!!!

- Check Obs. Summary Table
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Finding radio data: checking the (VLA) archive

NAOJ Archive DB Query Results - OBSUMMARY Table Listing

Data Selection Parameters:

Obser Name = J0433
 J2014+62.1 Long. Center = J2014064.756
 J2014+62.1 Lat. Center = +2504117.8
 Epoch = 54500
 Epoch Rate = 1.2
 Max RMS = 1000
 Scan Range = 1000

Table Sort Order:

Sort By = Observation
 Sort Order = Asc

Display rows: 12

Obs	Source	Project	Frequency MHz	Integration sec	Integration s/chan	1/2 sec	1/2 sec chan	Resolution arcsec	SAB array	FWHM array	FWHM chan	SBF MHz	Stokes	Start Time UTC	End Time UTC	IO Code
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:24:24	2014-07-12 01:25:02	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:25:02	2014-07-12 01:25:40	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:25:40	2014-07-12 01:26:18	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:26:18	2014-07-12 01:26:56	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:26:56	2014-07-12 01:27:34	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:27:34	2014-07-12 01:28:12	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:28:12	2014-07-12 01:28:50	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:28:50	2014-07-12 01:29:28	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:29:28	2014-07-12 01:30:06	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:30:06	2014-07-12 01:30:44	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:30:44	2014-07-12 01:31:22	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:31:22	2014-07-12 01:32:00	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:32:00	2014-07-12 01:32:38	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:32:38	2014-07-12 01:33:16	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:33:16	2014-07-12 01:33:54	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:33:54	2014-07-12 01:34:32	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.500	1.500	1.7	50.0	5.0	5.0	100.000	1	2014-07-12 01:34:32	2014-07-12 01:35:10	1
J2014	J0433	J0433-0000	8.000	3.000	3.000	1.5										

- returns:

- **Observing frequency**
- **Configuration**
- Field of view
- Resolution
- Largest angular scale
- Time on source
- Theoretical rms noise
- Number of channels
- Bandwidth
- Stokes

Choosing your data: resolution

$\Theta \propto \lambda/B$

"So it's easy: you always use A configuration!"
Well...no...:

- Surface brightness sensitivity: you want to match the resolution to the source size, for maximum sensitivity
- Chromatic aberration
- Interferometers act as spatial filters...and you're quite likely to high-pass filter your source away


$\Theta_{\infty} \lambda/B$

Choosing your data: missing structure

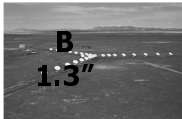
- Interferometers have the resolution of a telescope the size of the antenna separation (e.g. kilometers)
- Unfortunately that size scale's the only one they measure!
 - hence the need for $\gg 2$ antennas ☺
- If you have lots of telescopes widely separated from one another, you learn lots about the fine-scale source structure...and nothing at all about the source as a whole.
- Archive reports **LAS**= largest angular scale

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A real-life example




A
0.3"



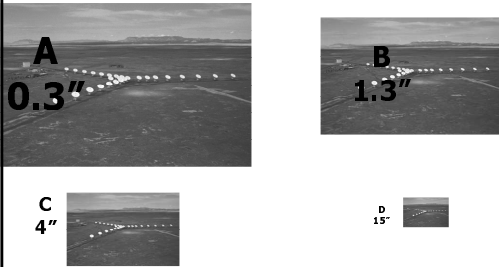
B
1.3"



C
4"

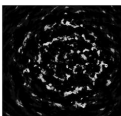


D
15"



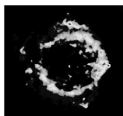
Cas A: four VLA configurations

A
0.3"



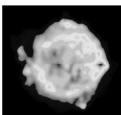
RFPS 10m F10 CAS A

B
1.3"



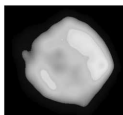
RFPS 10m F10 CAS A-B-C-D

C
4"



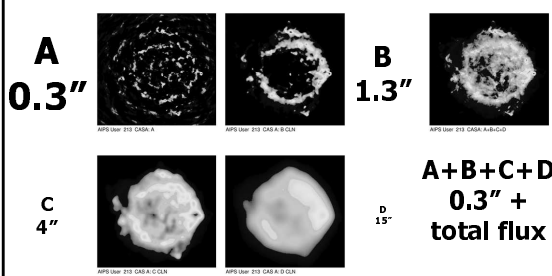
RFPS 10m F10 CAS A-C-D-E

D
15"



RFPS 10m F10 CAS A-B-C-D-E

A+B+C+D
0.3" +
total flux



[illegible]

- ✓ Date
- ✓ Observing frequency
- ✓ Configuration
- ✓ **Field of view**
- ✓ **Resolution**
- ✓ **Largest angular scale**
 - Time on source
 - Theoretical rms noise
 - Number of channels
 - Bandwidth
 - Stokes

- Archive reports BW, time on source, and **theoretical rms noise** (what you could get in a perfect world)
- Longer observations are better
 - even more true for interferometers
- More bandwidth is good
 - apart from spectroscopy, chromatic aberration, etc.
- Some frequency bands are more sensitive than others
 - depends on the instrument
 - 5 or 8 GHz probably a good bet

[illegible]

- ✓ Date
- ✓ Observing frequency
- ✓ Configuration
- ✓ Field of view
- ✓ Resolution
- ✓ Largest angular scale
- ✓ **Time on source**
- ✓ **Theoretical rms noise**
- Number of channels
- ✓ **Bandwidth**
- Stokes

- Spectral line
 - total bandwidth must cover the entire line
 - spectral resolution is BW/N_{chan}
- Polarization
 - **Stokes** field reports available correlations (eventually will move to RCP, linear, circular, full)
 - need a long run for standard pol'n calibration

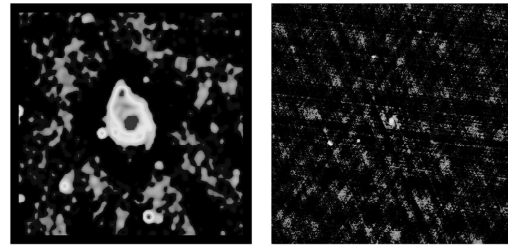
Age	Sex	Height	Weight	Body fat	1000 sec	muscular mass	last action	Time	Time	Last Time	Last Time
yr		m	kg	%	sec	kg		min	sec	min	sec
20	M	1.80	70.0	12.0	101.0	21.0	1000 sec	10:00	00:00	10:00	00:00
20	F	1.60	55.0	15.0	102.0	18.0	1000 sec	10:00	00:00	10:00	00:00
20	M	1.85	80.0	10.0	103.0	25.0	1000 sec	10:00	00:00	10:00	00:00
21	M	1.90	90.0	11.0	104.0	30.0	1000 sec	10:00	00:00	10:00	00:00
21	F	1.70	65.0	14.0	105.0	20.0	1000 sec	10:00	00:00	10:00	00:00
22	M	1.95	100.0	12.0	106.0	35.0	1000 sec	10:00	00:00	10:00	00:00
22	F	1.75	75.0	16.0	107.0	22.0	1000 sec	10:00	00:00	10:00	00:00
23	M	2.00	110.0	13.0	108.0	40.0	1000 sec	10:00	00:00	10:00	00:00
23	F	1.80	85.0	17.0	109.0	25.0	1000 sec	10:00	00:00	10:00	00:00
24	M	2.05	120.0	14.0	110.0	45.0	1000 sec	10:00	00:00	10:00	00:00
24	F	1.85	95.0	18.0	111.0	28.0	1000 sec	10:00	00:00	10:00	00:00
25	M	2.10	130.0	15.0	112.0	50.0	1000 sec	10:00	00:00	10:00	00:00
25	F	1.90	105.0	19.0	113.0	30.0	1000 sec	10:00	00:00	10:00	00:00
26	M	2.15	140.0	16.0	114.0	55.0	1000 sec	10:00	00:00	10:00	00:00
26	F	1.95	115.0	20.0	115.0	32.0	1000 sec	10:00	00:00	10:00	00:00
27	M	2.20	150.0	17.0	116.0	60.0	1000 sec	10:00	00:00	10:00	00:00
27	F	2.00	125.0	21.0	117.0	35.0	1000 sec	10:00	00:00	10:00	00:00
28	M	2.25	160.0	18.0	118.0	65.0	1000 sec	10:00	00:00	10:00	00:00
28	F	2.05	135.0	22.0	119.0	38.0	1000 sec	10:00	00:00	10:00	00:00
29	M	2.30	170.0	19.0	120.0	70.0	1000 sec	10:00	00:00	10:00	00:00
29	F	2.10	145.0	23.0	121.0	40.0	1000 sec	10:00	00:00	10:00	00:00
30	M	2.35	180.0	20.0	122.0	75.0	1000 sec	10:00	00:00	10:00	00:00
30	F	2.15	155.0	24.0	123.0	42.0	1000 sec	10:00	00:00	10:00	00:00
31	M	2.40	190.0	21.0	124.0	80.0	1000 sec	10:00	00:00	10:00	00:00
31	F	2.20	165.0	25.0	125.0	45.0	1000 sec	10:00	00:00	10:00	00:00
32	M	2.45	200.0	22.0	126.0	85.0	1000 sec	10:00	00:00	10:00	00:00
32	F	2.25	175.0	26.0	127.0	48.0	1000 sec	10:00	00:00	10:00	00:00
33	M	2.50	210.0	23.0	128.0	90.0	1000 sec	10:00	00:00	10:00	00:00
33	F	2.30	185.0	27.0	129.0	50.0	1000 sec	10:00	00:00	10:00	00:00
34	M	2.55	220.0	24.0	130.0	95.0	1000 sec	10:00	00:00	10:00	00:00
34	F	2.35	195.0	28.0	131.0	52.0	1000 sec	10:00	00:00	10:00	00:00
35	M	2.60	230.0	25.0	132.0	100.0	1000 sec	10:00	00:00	10:00	00:00
35	F	2.40	205.0	29.0	133.0	55.0	1000 sec	10:00	00:00	10:00	00:00
36	M	2.65	240.0	26.0	134.0	105.0	1000 sec	10:00	00:00	10:00	00:00
36	F	2									

- ✓ **Date**
- ✓ Observing frequency
- ✓ Configuration
- ✓ Field of view
- ✓ Resolution
- ✓ Largest angular scale
- ✓ Time on source
- ✓ Theoretical rms noise
- ✓ **Number of channels**
- ✓ **Bandwidth**
- ✓ **Stokes**

Dealing with data: a first look

- The archives send raw uv-data, not images
- Quick & dirty processing: VLARUN, VLBARUN (kudos to Loránt Sjouwerman ☺)
 - can get reasonable quick-look images in a few minutes, with no special punditry required
- Steps:
 - AIPS
 - Load in data (FILLM)
 - Set array configuration; image size; depth of deconvolution
 - VLARUN → calibrated data & images
 - Write them out (FITP)
- N.B.: why not just give people images?!?

M51: Surveys...



NVSS: 45"

NVSS: 45" res'n

FIRST: 5.4"

FIRST: 5.4" res'n

Finding radio data: checking the (VLA) archive

NRAO Archive DB Query Results - OBSUMMARY Table Listing

Obs. Name	Obs. Date	Obs. Time	Obs. Duration	Obs. Frequency	Obs. Resolution	Obs. Bandwidth	Obs. Flux Density	Obs. Signal-to-Noise	Obs. Dynamic Range	Obs. Continuum	Obs. Polarization	Obs. Calibration	Obs. Flagging	Obs. Cleaning	Obs. Imaging	Obs. Archiving	Obs. Release
1307+47	199008	1514.000	1.178	VLAC	1410	0.048	12.0	900.0	30.0	1	100.0K	1	100.0K	1	100.0K	1	100.0K
1307+47	199008	1514.000	1.178	VLAC	1410	0.048	12.0	900.0	30.0	1	100.0K	1	100.0K	1	100.0K	1	100.0K
1307+47	199008	1514.000	1.178	VLAC	1410	0.048	12.0	900.0	30.0	1	100.0K	1	100.0K	1	100.0K	1	100.0K
1307+47	199008	1514.000	1.178	VLAC	1410	0.048	12.0	900.0	30.0	1	100.0K	1	100.0K	1	100.0K	1	100.0K
1307+47	199008	1514.000	1.178	VLAC	1410	0.048	12.0	900.0	30.0	1	100.0K	1	100.0K	1	100.0K	1	100.0K
1307+47	199008	1514.000	1.178	VLAC	1410	0.048	12.0	900.0	30.0	1	100.0K	1	100.0K	1	100.0K	1	100.0K
1307+47	199008	1514.000	1.178	VLAC	1410	0.048	12.0	900.0	30.0	1	100.0K	1	100.0K	1	100.0K	1	100.0K
1307+47	199008	1514.000	1.178	VLAC	1410	0.048	12.0	900.0	30.0	1	100.0K	1	100.0K	1	100.0K	1	100.0K
1307+47	199008	1514.000	1.178	VLAC	1410	0.048	12.0	900.0	30.0	1	100.0K	1	100.0K	1	100.0K	1	100.0K
1307+47	199008	1514.000	1.178	VLAC	1410	0.048	12.0	900.0	30.0	1	100.0K	1	100.0K	1	100.0K	1	100.0K

Obs. Frequency

- 1.4 GHz for size

Configuration

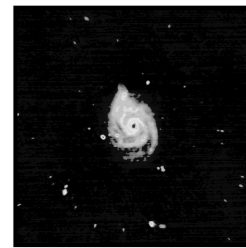
- C for res'n (15") + large structure

Exposure time

- Longest available

Continuum

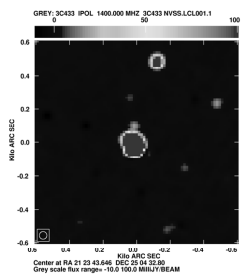
...and the archive



VLA/C: 15"

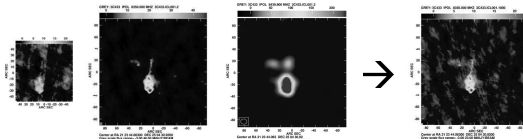
VLA/C @ 20cm:
15" res'n

3C433: NVSS...



D @ 20cm:
45" res'n

...and the archive:



B

C

D

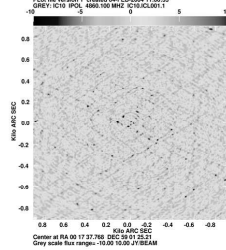
B+C+D

VLA/B+C+D @ 4cm → 1.5" res'n

Elapsed time: ~1 hour

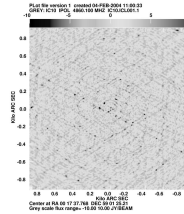
Dealing with data: a first look

- Failures tend to be obvious:
 - it is easier to destroy than to create!
 - the wackier the image, the easier it is to fix

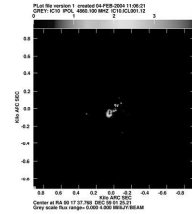


IC10

IC10



Flag two 10-second records...



...et voilà!

The future

- Actively working on improving the archive
 - already producing lots of good stuff
- e2e is required for ALMA and the EVLA
- Lots of new radio telescopes coming this decade: SMA, EVLA, ALMA, eMERLIN, ...
 - a good time to learn!