Radio Interferometers' Data Archives

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

Michael P Rupen
(NRAO)

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 → 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

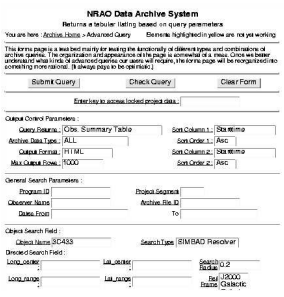
Sources of radio data: Archives

- 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 → VLA/VLBA
    - Dec> 0 → MERLIN
  - Dec <-30 → 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

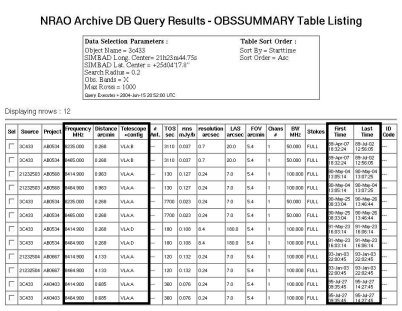
Finding radio data: checking the (VLA) archive



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

Actively evolving – feedback is very welcome!!!

Finding radio data: checking the (VLA) archive



Returns:

- **Date**
- **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!"

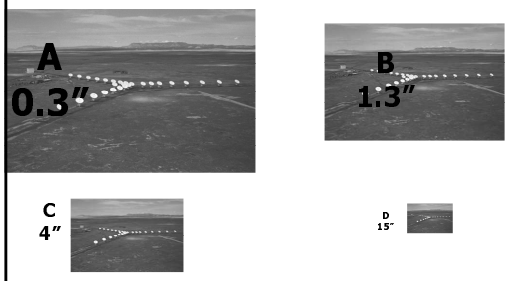
Well…no…:

- 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

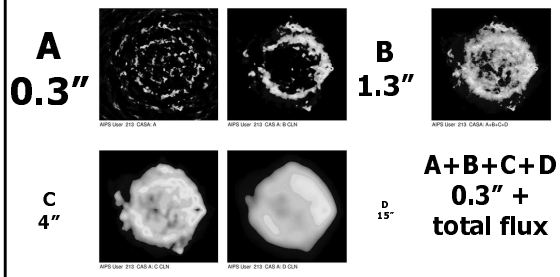
Choosing your data: missing structure

- 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 >> 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

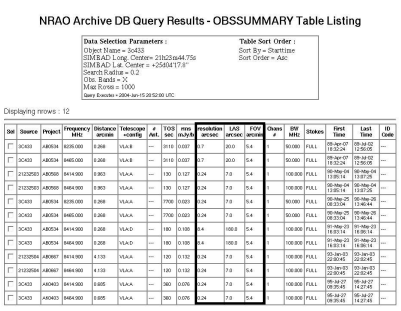
A real-life example



Cas A: four VLA configurations



Finding radio data: checking the (VLA) archive


NRAO Archive DB Query Results - OBSSUMMARY Table Listing

Data Selection Parameters :
Object Name = 3c433
SIMBAD Long. Center= 21h23m44.75s
SIMBAD Lat. Center = +25d04'17.6"
Search Radius = 0.2
Obs. Band= X
Max Rows = 1000
Query Executed = 2004-Jan-15 20:52:00 UTC

Table Sort Order :
Sort By = Starttime
Sort Order = Asc

Displaying nrows : 12

Sel	Source	Project	Frequency MHz	Distance arcmin	Telescope +config	# Ant.	TOS sec	rms mJy/b	resolution arcsec	LAS arcsec	FOV arcmin	Chans #	BW MHz	Stokes	First Time	Last Time	ID Code
☐	3C433	AB0534	8235.000	0.268	VLA:B	---	3110	0.037	0.7	20.0	5.4	1	50.000	FULL	03-Apr-07 18:32:24	03-Apr-02 12:50:05	---
☐	3C433	AB0534	8485.000	0.268	VLA:B	---	3110	0.037	0.7	20.0	5.4	1	50.000	FULL	03-Apr-07 18:32:24	03-Apr-02 12:50:05	---
☐	21232583	AB0565	8414.900	0.963	VLA:A	---	130	0.127	0.24	7.0	5.4	1	100.000	FULL	04-May-04 13:05:14	04-May-04 13:07:25	---
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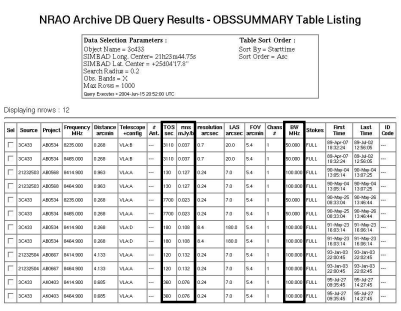
Returns:
- ✓Date
- ✓Observing frequency
- ✓Configuration
- ✓**Field of view**
- ✓**Resolution**
- ✓**Largest angular scale**
- Time on source
- Theoretical rms noise
- Number of channels
- Bandwidth
- Stokes

Choosing your data: sensitivity

$$\sigma \propto 1/(\tau\,\Delta\nu)^{1/2}$$

- 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

Finding radio data: checking the (VLA) archive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- Stokes

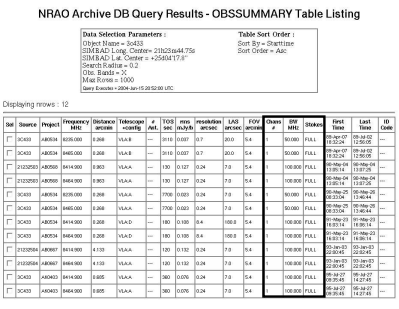
Choosing your data: special purposes

- 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

Choosing your data: ease of reduction

- Continuum is easier than spectral line
  - single-channel data are simplest
- "Center" frequencies are easier than edges
  - 1-15 GHz is easier than <1 GHz or >15 GHz
- VLBI is trickier than VLA/ATCA
- New data are better than old

Finding radio data: checking the (VLA) archive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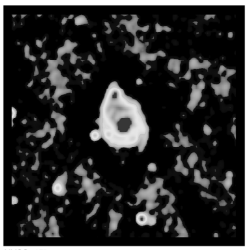
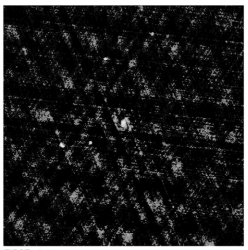
- ✓**Number of channels**
- ✓**Bandwidth**
- ✓**Stokes**

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 (FITTP)
- N.B.: why not just give people images?!?

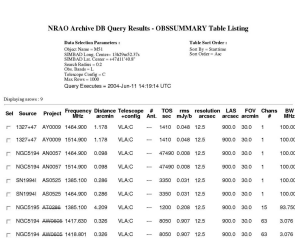
M51: Surveys…





NVSS: 45″ res'n FIRST: 5.4″ res'n

Finding radio data: checking the (VLA) archive



NRAO Archive DB Query Results - OBSSUMMARY Table Listing

Data Selection Parameters :
Object Name = M51
SIMBAD Long. Center = 13h29m52.37s
SIMBAD Lat. Center = +47d11'43.0"
Search Radius = 0.2
Max Rows = 1000
Query Executes = 2004-Jun-11 14:19:14 UTC

Table Sort Order :
Sort By = Start time
Sort Order = Asc

Displaying scans : 9

Sel	Source	Project	Frequency MHz	Distance arcmin	Telescope -config	# Ant.	TOS sec	rms mJy/b	resolution arcsec	LAS arcsec	FOV arcmin	Chans #	BW MHz
☐	1327+47	AY0009	1464.900	1.178	VLA:C	---	1410	0.048	12.5	900.0	30.0	1	100.0(
☐	1327+47	AY0009	1514.900	1.178	VLA:C	---	1410	0.048	12.5	900.0	30.0	1	100.0(
☐	NGC5194	AN0057	1464.900	0.098	VLA:C	---	47490	0.008	12.5	900.0	30.0	1	100.0(
☐	NGC5194	AN0057	1514.900	0.098	VLA:C	---	47490	0.008	12.5	900.0	30.0	1	100.0(
☐	SN1994I	AS0525	1365.100	0.286	VLA:C	---	3350	0.031	12.5	900.0	30.0	1	100.0(
☐	SN1994I	AS0525	1464.900	0.286	VLA:C	---	3350	0.031	12.5	900.0	30.0	1	100.0(
☐	NGC5195	~~AT0286~~	1365.100	4.209	VLA:C	---	1200	0.208	12.5	900.0	30.0	15	93.75(
☐	NGC5194	~~AW0606~~	1417.630	0.326	VLA:C	---	8050	0.907	12.5	900.0	30.0	63	3.076
☐	NGC5194	~~AW0606~~	1418.801	0.326	VLA:C	---	8050	0.907	12.5	900.0	30.0	63	3.076

Obs. Frequency
- 1.4 GHz for size

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

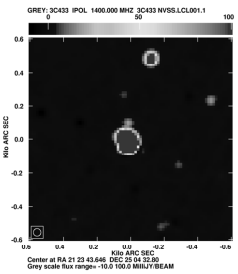
Exposure time
- Longest available

Continuum

…and the archive

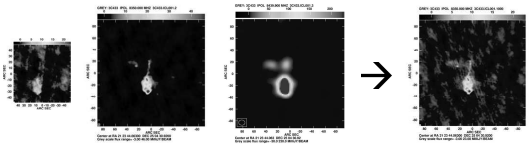
VLA/C @ 20cm: 15″ res'n

3C433: NVSS…



D @ 20cm: 45″ res'n

…and the archive:



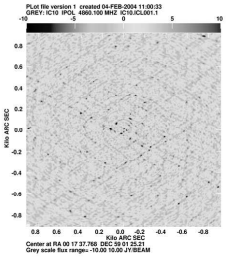
B **C** **D** **B+C+D**

VLA/B+C+D @ 4cm → 1.5″ res'n

Elapsed time: ~1 hour

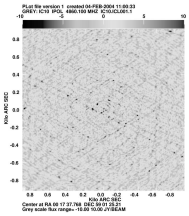
Dealing with data: a first look

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

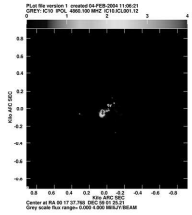


IC10

IC10



Flag two 10-second records…



…et voilá!

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!