

From an idea to an image: how to use a radio interferometer

Example source: 3C35

- Take one source as an example of the process of making radio maps.
- 3C35 is not a very well-known source
 - Overlooked because it's known to be a double of some kind and there are lots of double radio sources
 - But not many have good X-ray data.
- X-ray image shows a hint of something interesting
- Need a better radio map than what is available in the literature

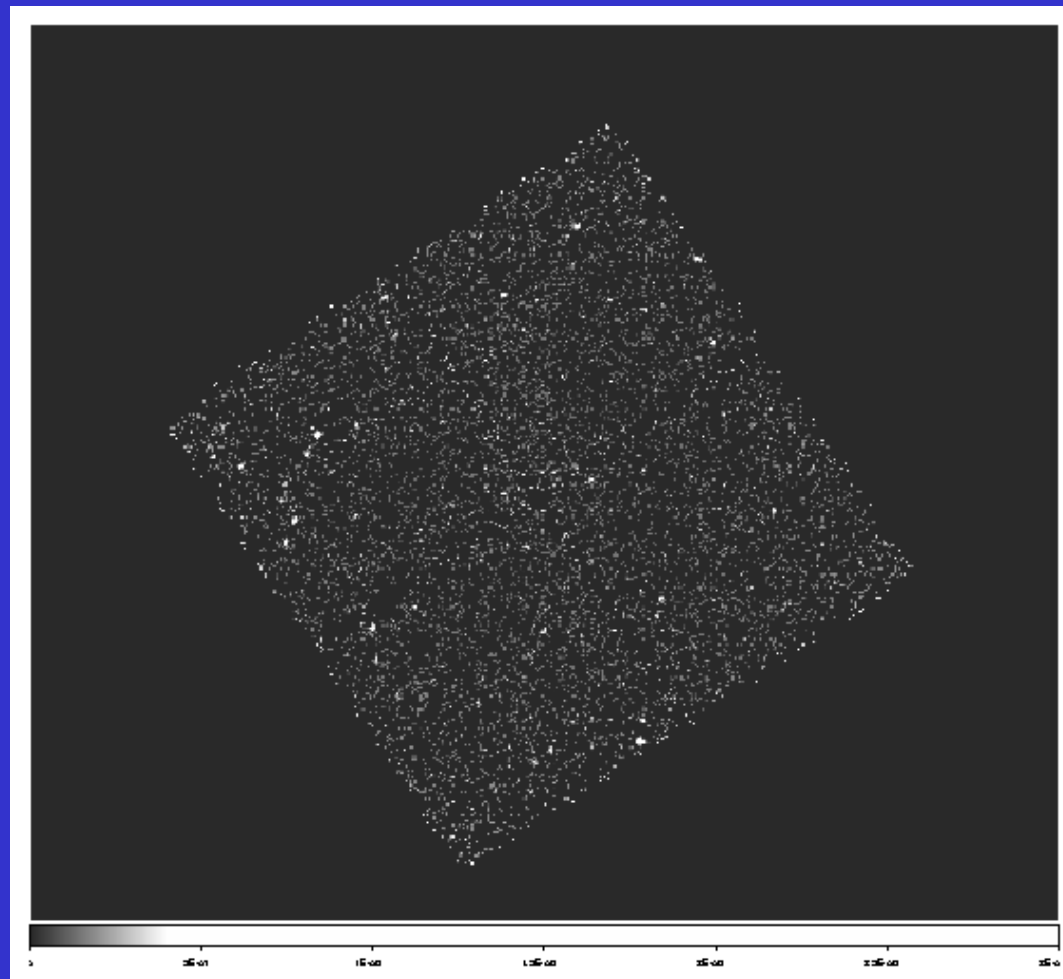
Example source: 3C35

The 3C35 image from the Chandra ACIS-I instrument.

0.5-2.5 keV

Not very inspiring: and shows nothing much until we know where to look.

Need the radio map.



The VLA archive

- To avoid a 1-year delay in getting a radio map, what is already available?
- Data from many interferometers is available on-line.
- Check the VLA archive, since the VLA is the largest functioning interferometer.

The VLA archive

VLA

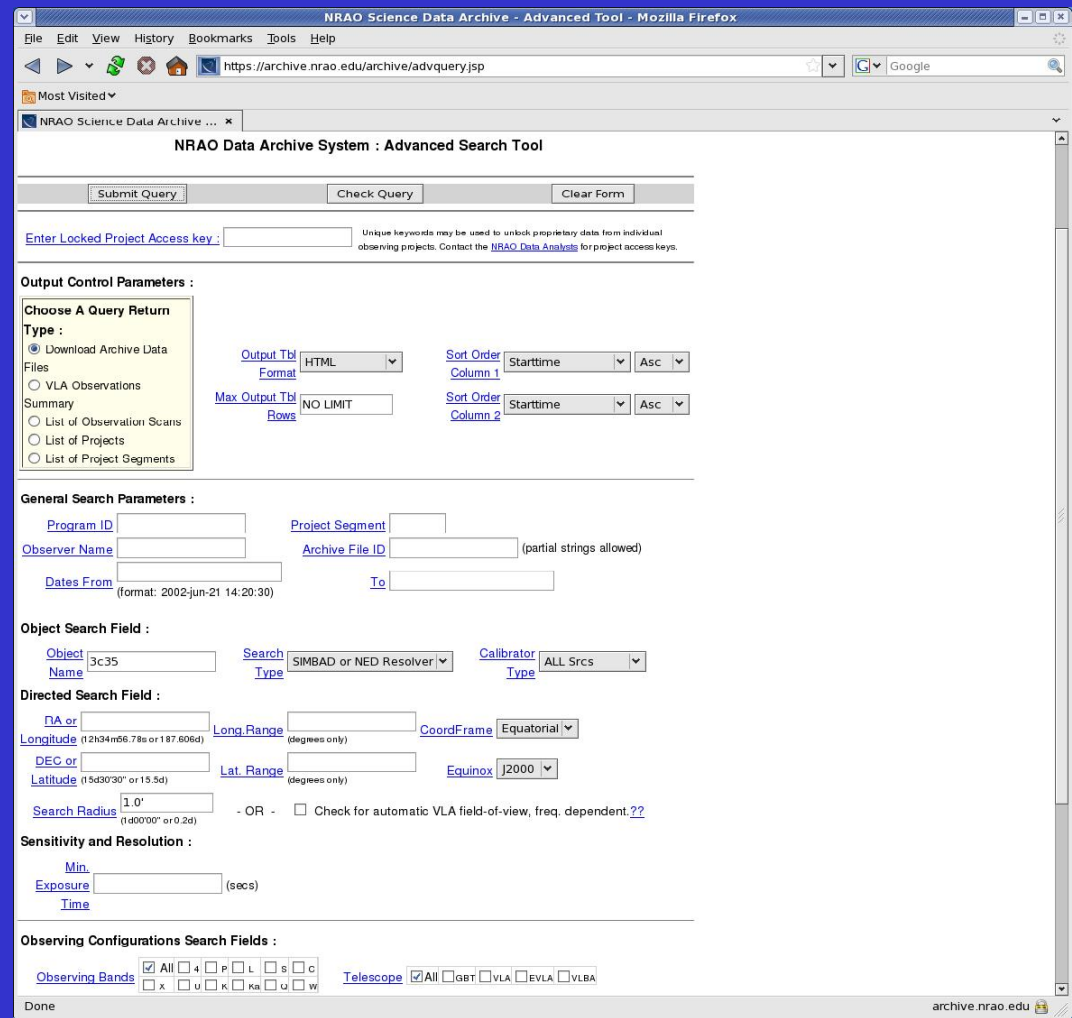
Compact
configuration
(easier to
photograph).

Looking south,
down the
northern arm.



The VLA archive

Search for data taken near 3C35 using the “Advanced Query Tool”



NRAO Science Data Archive - Advanced Tool - Mozilla Firefox

File Edit View History Bookmarks Tools Help

https://archive.nrao.edu/archive/advquery.jsp

Most Visited

NRAO Science Data Archive ...

NRAO Data Archive System : Advanced Search Tool

Submit Query Check Query Clear Form

Enter Locked Project Access key : Unique keywords may be used to unlock proprietary data from individual observing projects. Contact the [NRAO Data Analysis](#) for project access keys.

Output Control Parameters :

Choose A Query Return Type :

☒ Download Archive Data Files

☐ VLA Observations

☐ Summary

☐ List of Observation Scans

☐ List of Projects

☐ List of Project Segments

Output Tabl Format HTML

Sort Order Starttime Column 1 Asc

Max Output Tabl Rows NO LIMIT

Sort Order Starttime Column 2 Asc

General Search Parameters :

Program ID Project Segment

Observer Name Archive File ID (partial strings allowed)

Dates From (format: 2002-jun-21 14:20:30) To

Object Search Field :

Object Name 3c35

Search Type SIMBAD or NED Resolver

Calibrator Type ALL Srcs

Directed Search Field :

RA or Longitude (12h34m56.78s or 187.606d)

Long Range (degrees only)

CoordFrame Equatorial

DEC or Latitude (15d30'30" or 15.5d)

Lat Range (degrees only)

Equinox J2000

Search Radius 1.0' (140000" or 0.2d) - OR - ☐ Check for automatic VLA field-of-view, freq. dependent.??

Sensitivity and Resolution :

Min. Exposure Time (secs)

Observing Configurations Search Fields :

Observing Bands ☒ All ☐ 4 ☐ P ☐ L ☐ S ☐ C

☐ X ☐ U ☐ K ☐ Ka ☐ Q ☐ W

Telescope ☒ All ☐ GBT ☐ VLA ☐ EVLA ☐ VLBA

Done

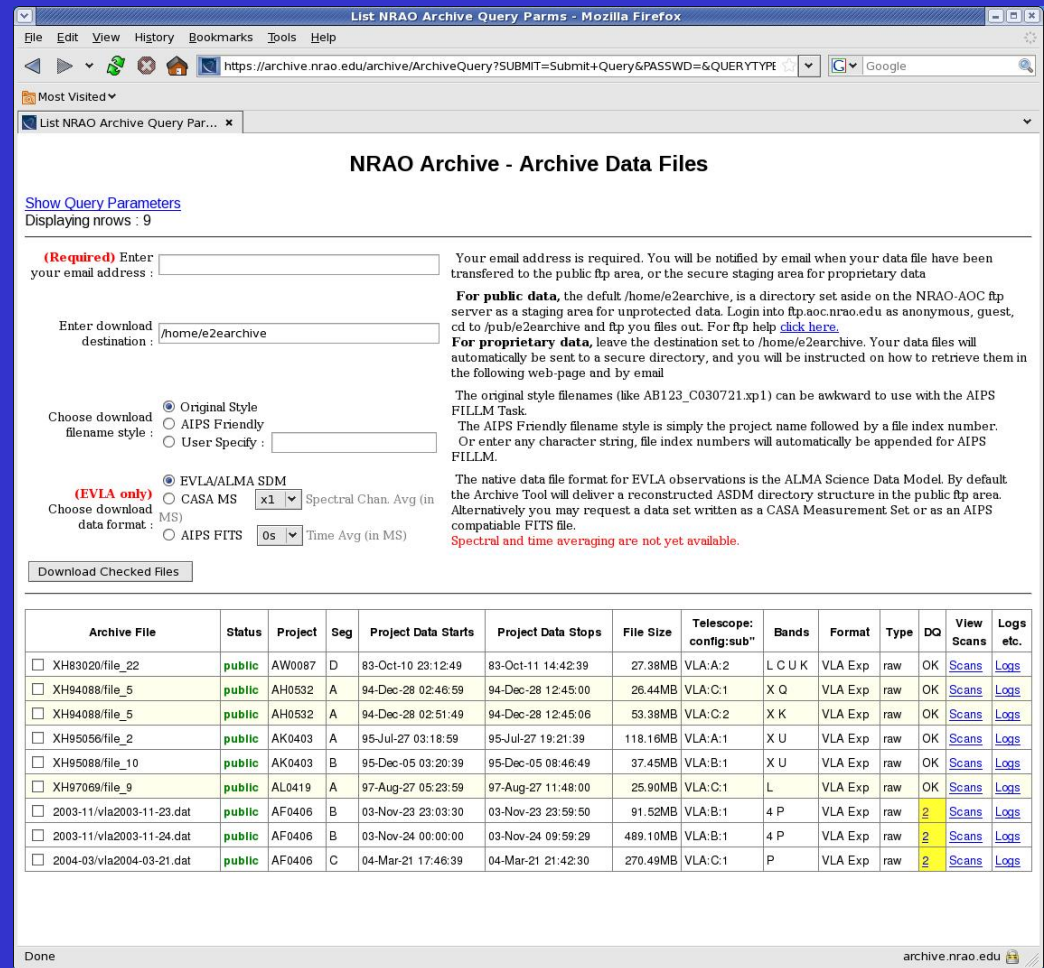
archive.nrao.edu

The VLA archive

Search result: there are data that can be used.

But are any of them useful?

What do I need?



NRAO Archive - Archive Data Files

[Show Query Parameters](#)
Displaying rows : 9

(Required) Enter your email address :

Enter download destination :

Choose download filename style : ☒ Original Style ☐ AIPS Friendly ☐ User Specify :

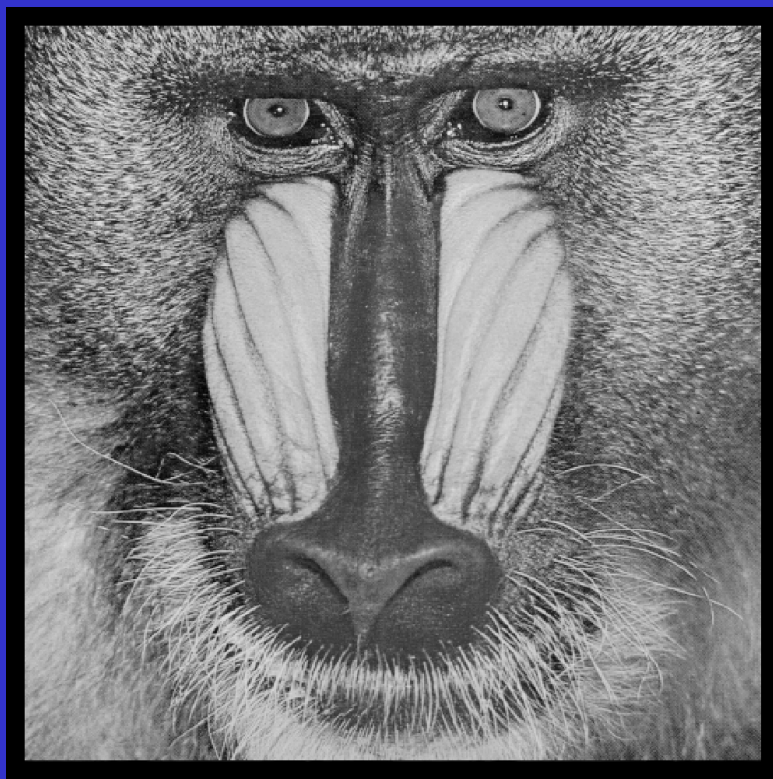
(EVLA only) Choose download data format : ☒ EVLA/ALMA SDM ☐ CASA MS Spectral Chan. Avg (in MS) ☐ AIPS FITS Time Avg (in MS)

Archive File	Status	Project	Seg	Project Data Starts	Project Data Stops	File Size	Telescope: config:sub"	Bands	Format	Type	DQ	View Scans	Logs etc.
☐ XH83020/file_22	public	AW0087	D	83-Oct-10 23:12:49	83-Oct-11 14:42:39	27.38MB	VLA:A:2	L C U K	VLA Exp	raw	OK	Scans	Logs
☐ XH94088/file_5	public	AH0532	A	94-Dec-28 02:46:59	94-Dec-28 12:45:00	26.44MB	VLA:C:1	X Q	VLA Exp	raw	OK	Scans	Logs
☐ XH94088/file_5	public	AH0532	A	94-Dec-28 02:51:49	94-Dec-28 12:45:06	53.38MB	VLA:C:2	X K	VLA Exp	raw	OK	Scans	Logs
☐ XH95056/file_2	public	AK0403	A	95-Jul-27 03:18:59	95-Jul-27 19:21:39	118.16MB	VLA:A:1	X U	VLA Exp	raw	OK	Scans	Logs
☐ XH95088/file_10	public	AK0403	B	95-Dec-05 03:20:39	95-Dec-05 08:46:49	37.45MB	VLA:B:1	X U	VLA Exp	raw	OK	Scans	Logs
☐ XH97069/file_9	public	AL0419	A	97-Aug-27 05:23:59	97-Aug-27 11:48:00	25.90MB	VLA:C:1	L	VLA Exp	raw	OK	Scans	Logs
☐ 2003-11/via2003-11-23.dat	public	AF0406	B	03-Nov-23 23:03:30	03-Nov-23 23:59:50	91.52MB	VLA:B:1	4 P	VLA Exp	raw	2	Scans	Logs
☐ 2003-11/via2003-11-24.dat	public	AF0406	B	03-Nov-24 00:00:00	03-Nov-24 09:59:29	489.10MB	VLA:B:1	4 P	VLA Exp	raw	2	Scans	Logs
☐ 2004-03/via2004-03-21.dat	public	AF0406	C	04-Mar-21 17:46:39	04-Mar-21 21:42:30	270.49MB	VLA:C:1	P	VLA Exp	raw	2	Scans	Logs

Done archive.nrao.edu

Editing and calibration

- Data downloaded
- Now take a look at them in AIPS



AIPS = Astronomical Image
Processing System

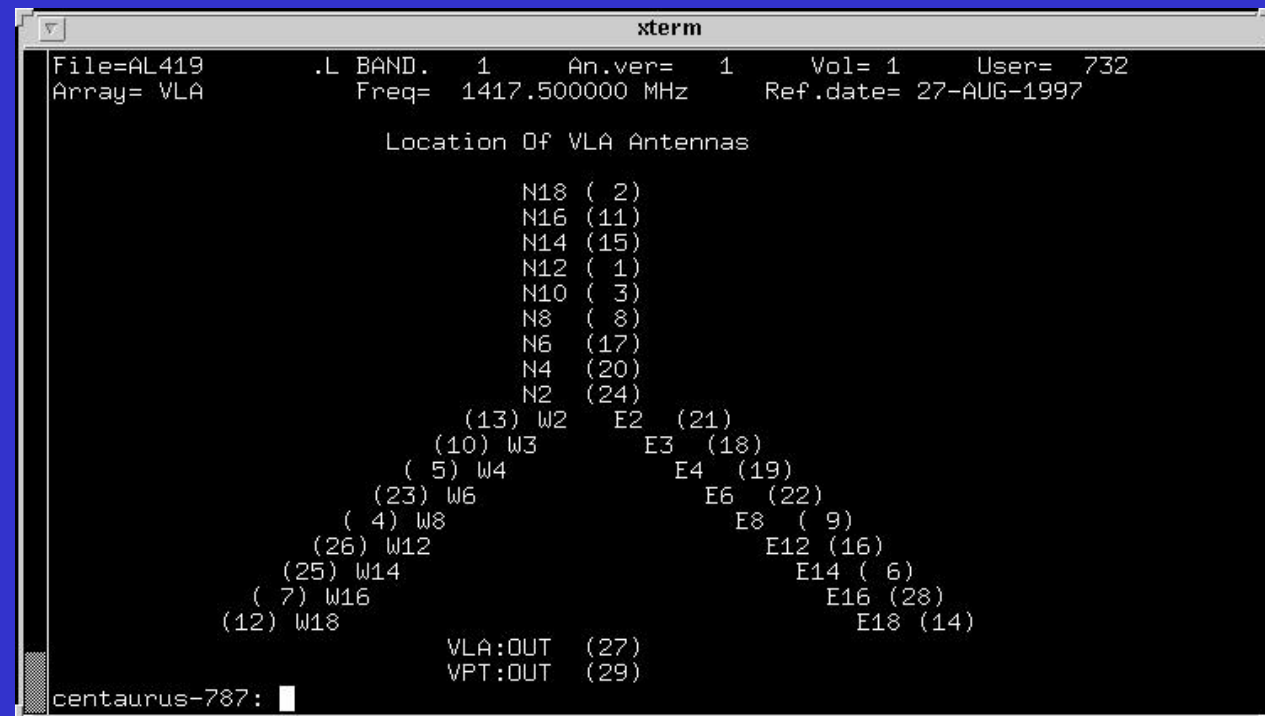
Now replaced by something
better (?) CASA

Editing and calibrations

Need to know
antenna layout.

Diagram is
included with
the data.

Shows which
stations the
antennas
occupied in
August 1997.



Editing and calibration

Diagram arranged
to look like the
antenna layout on
the ground.

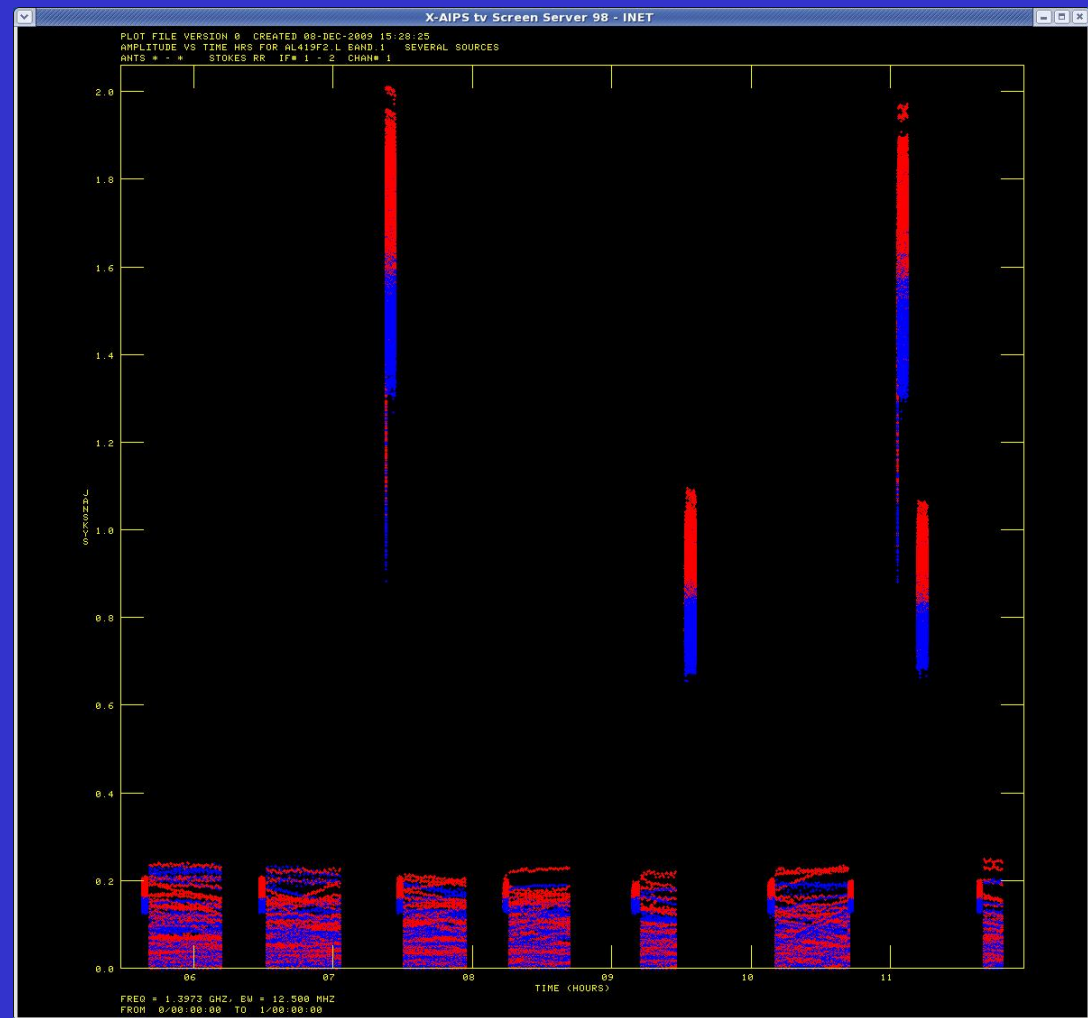


Editing and calibrations

Plot data voltages
against time

Calibrators and target

See bad things: must
edit data to remove
intermittent
telescope problems



Editing and calibrations

After edit and calibration,
plot the visibility
function

Amount of signal as a
function of distance
between pair of
antennas measuring
signal.

Shape looks good: not too
much missing flux
density.

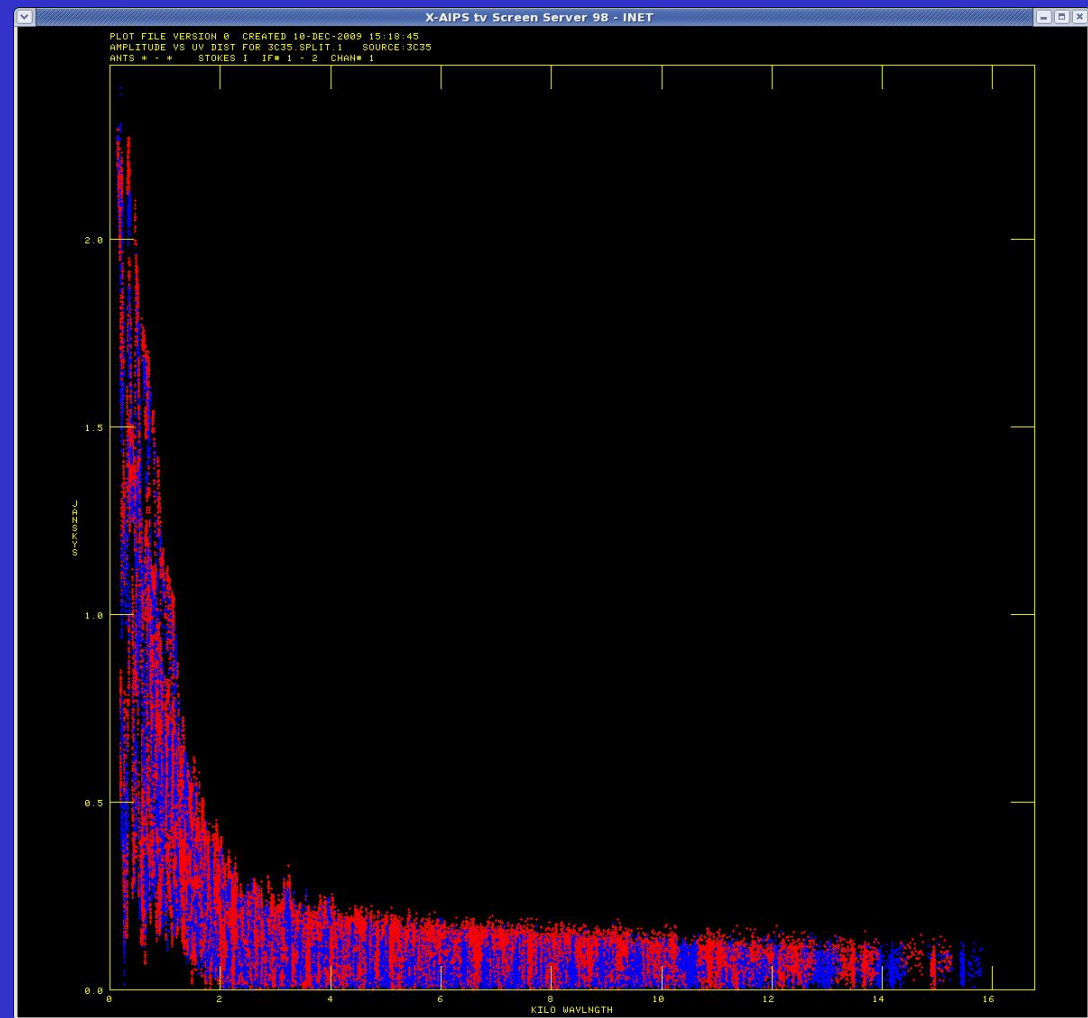


Image making

- Now have data with no obvious problems
- Time to see if it shows anything useful by making a picture
- Fourier transform to get an image of the sky
- Quality of result depends on coverage

Image making

“uv plane coverage”

Shows distribution of distances between antenna pairs in units of observing wavelength.

Red and blue: two frequencies separated by about 5%.

Coverage good, fewer gaps than sometimes.

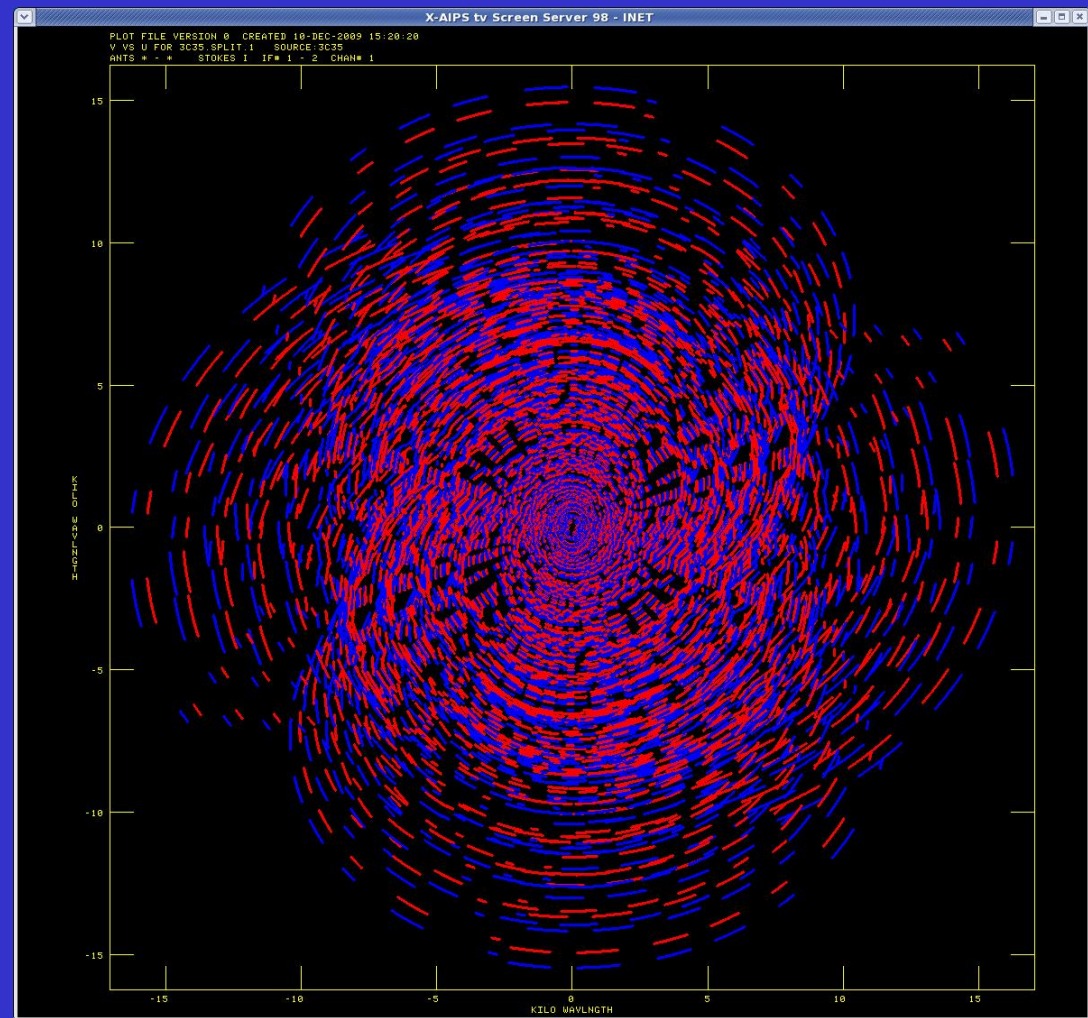


Image making

First map: basic
Fourier transform

Grey-scale range -10
to +10 mJy

See major features:
double structure,
bright core

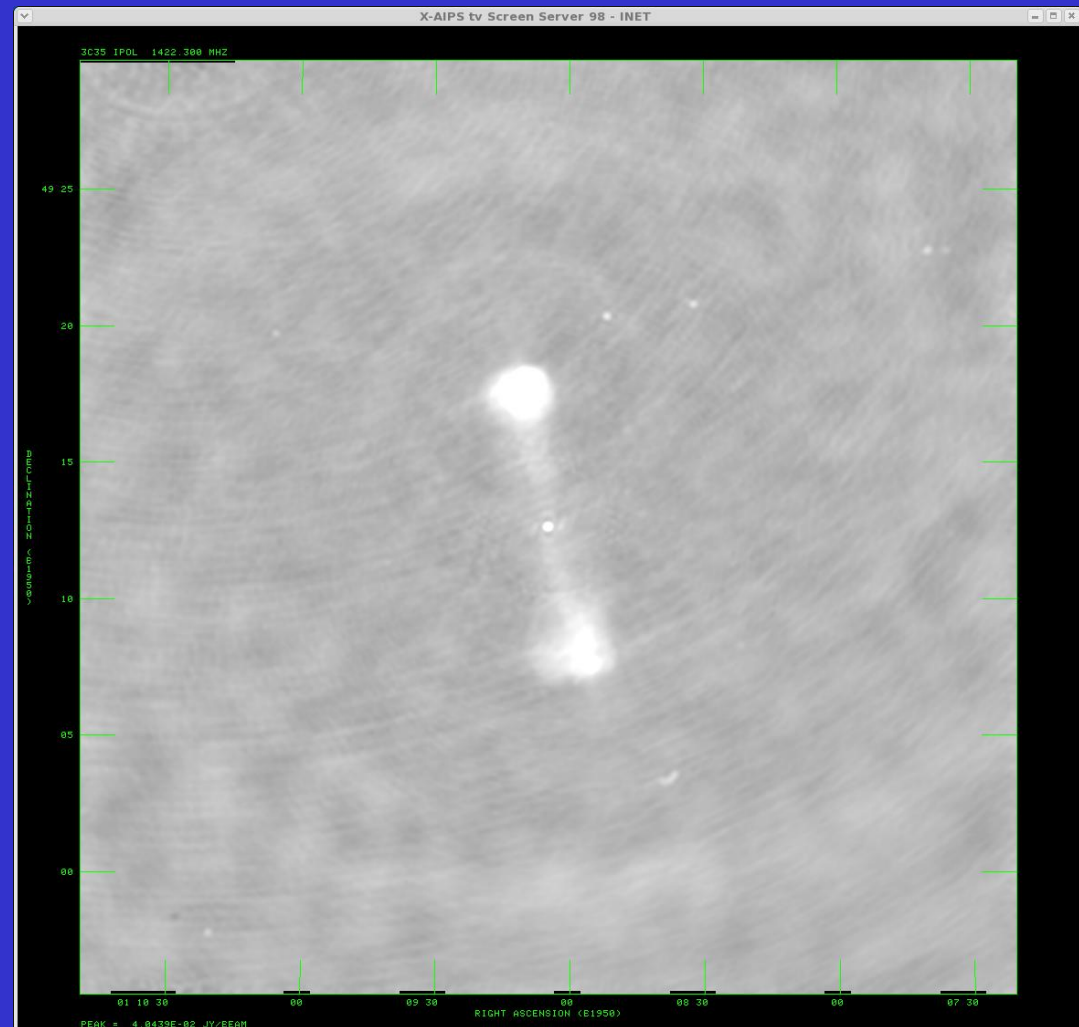


Image making

First map: basic
Fourier transform

Grey-scale range -10
to +10 mJy

Larger region: see
spiral-like pattern,
bright source to NE

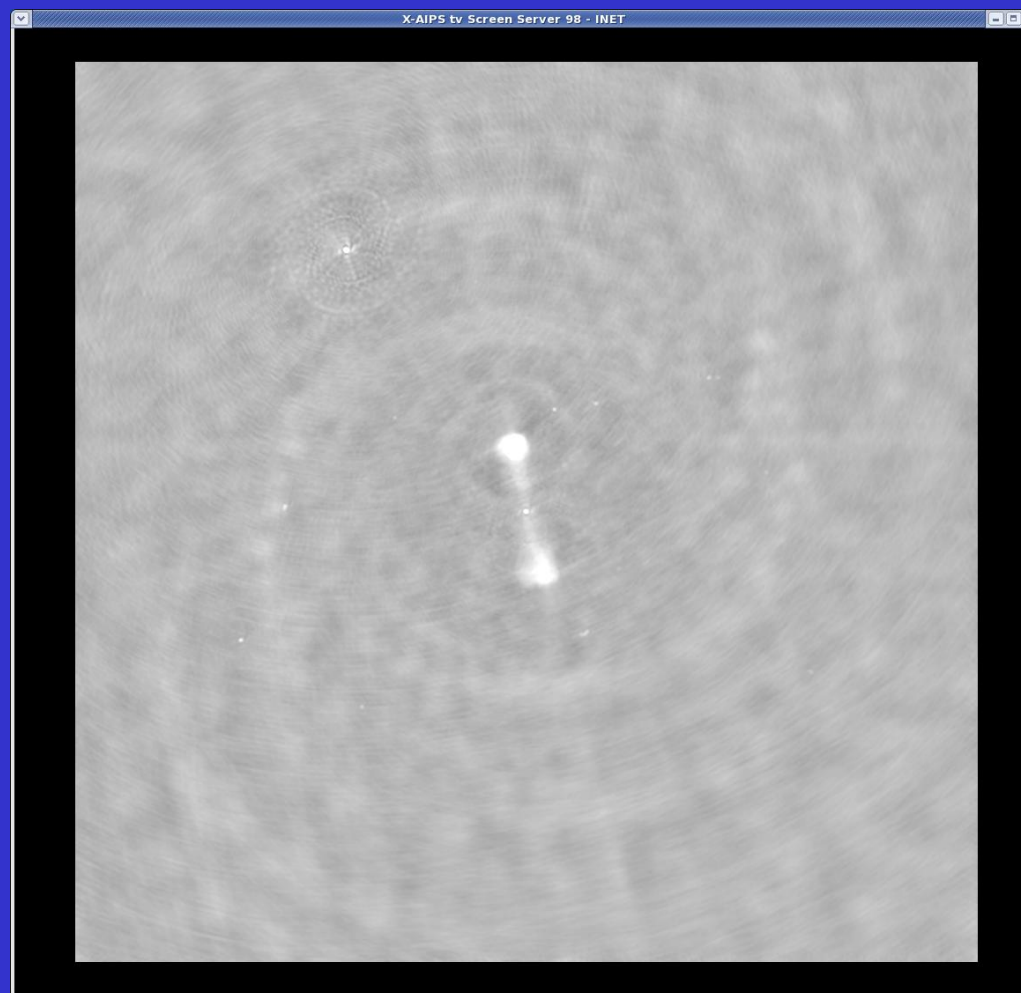


Image making

Next map: simple
cleaning

Grey-scale range -10
to +10 mJy

See other sources
better, most of
background pattern
has gone

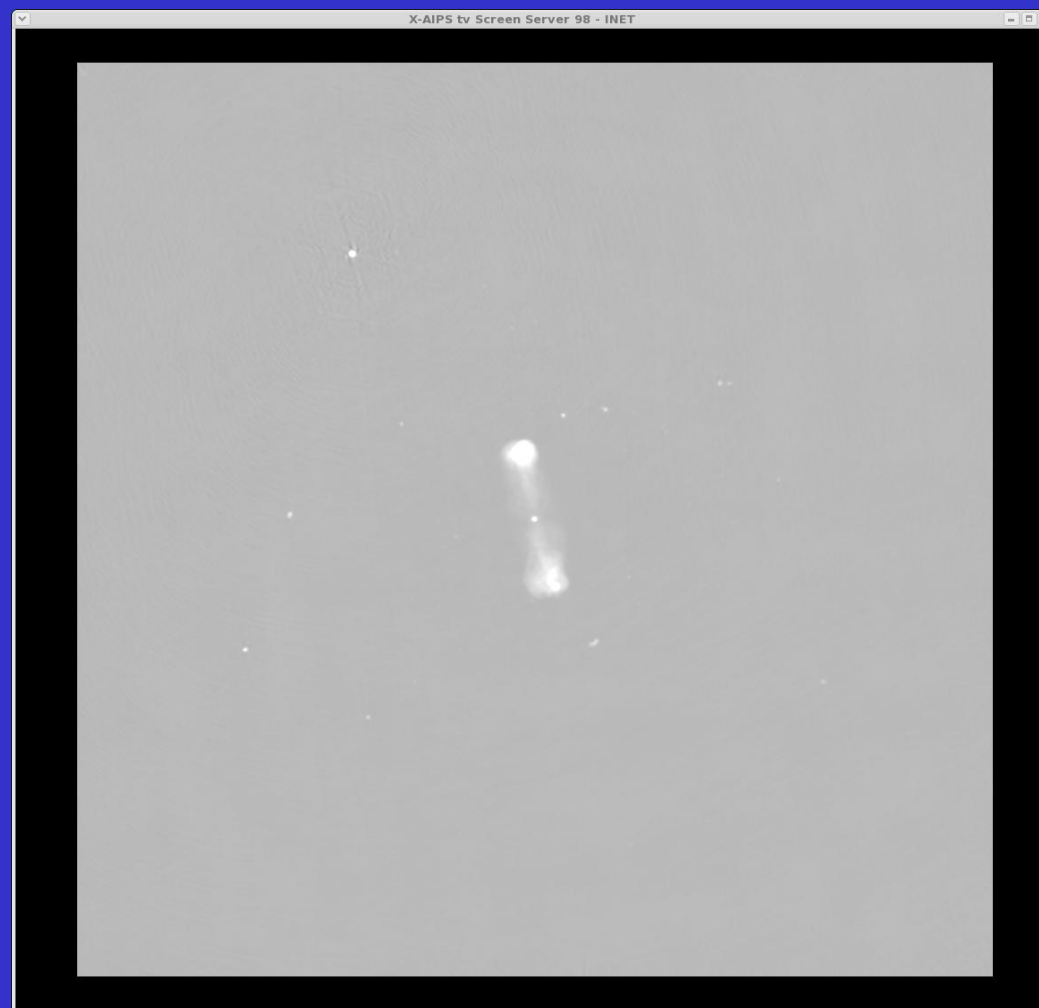


Image making

Next map: simple
cleaning

Grey-scale range -1.0
to +1.0 mJy

Sources nearby more
obvious, but still
some background
pattern



Image making

Self-calibrate: work
out what errors in
the calibration
remain in the data

See mostly small
errors, but some
large problems in
phase on one
antenna

Edit, apply corrections

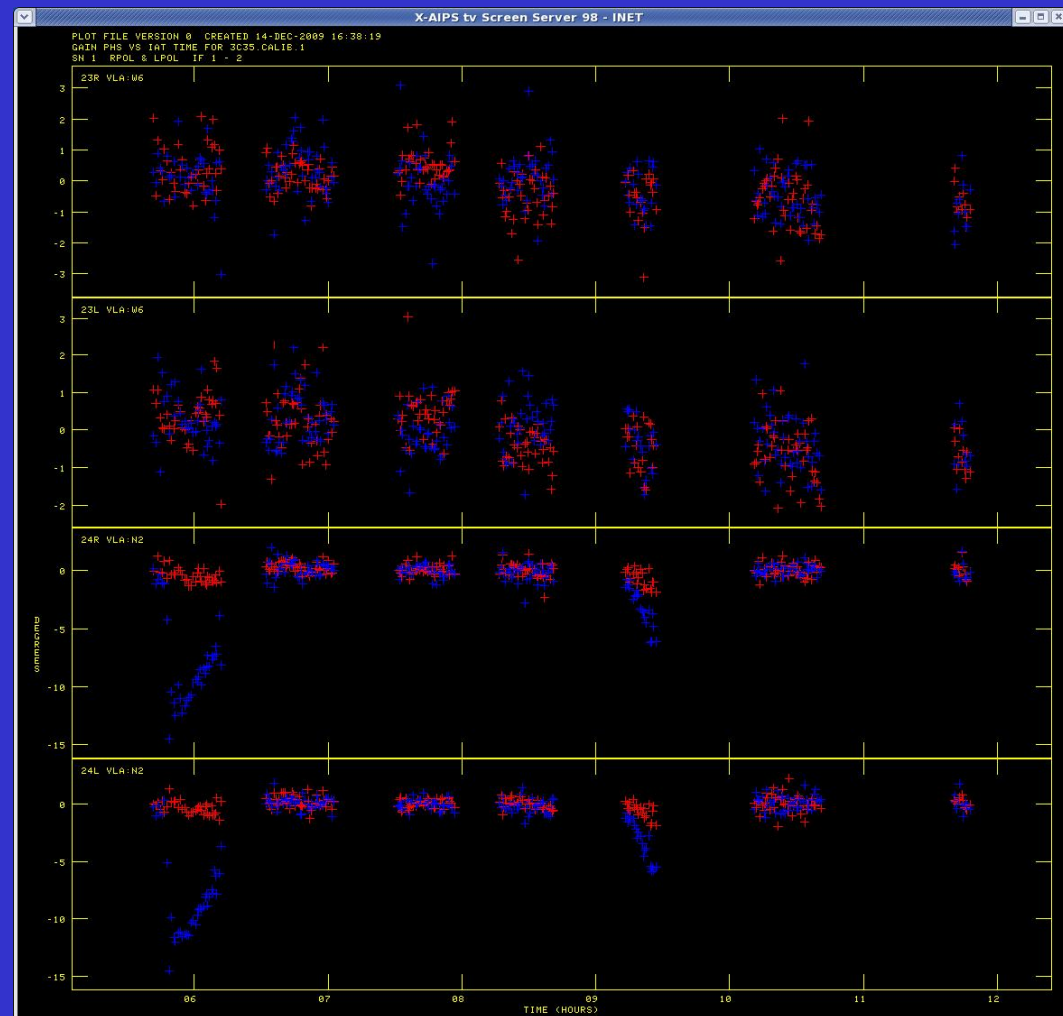


Image making

Repeat 10 times ... or more.

Correct for the
primary beam of the
VLA antennas

Final result (central
noise $40 \mu\text{Jy}$)

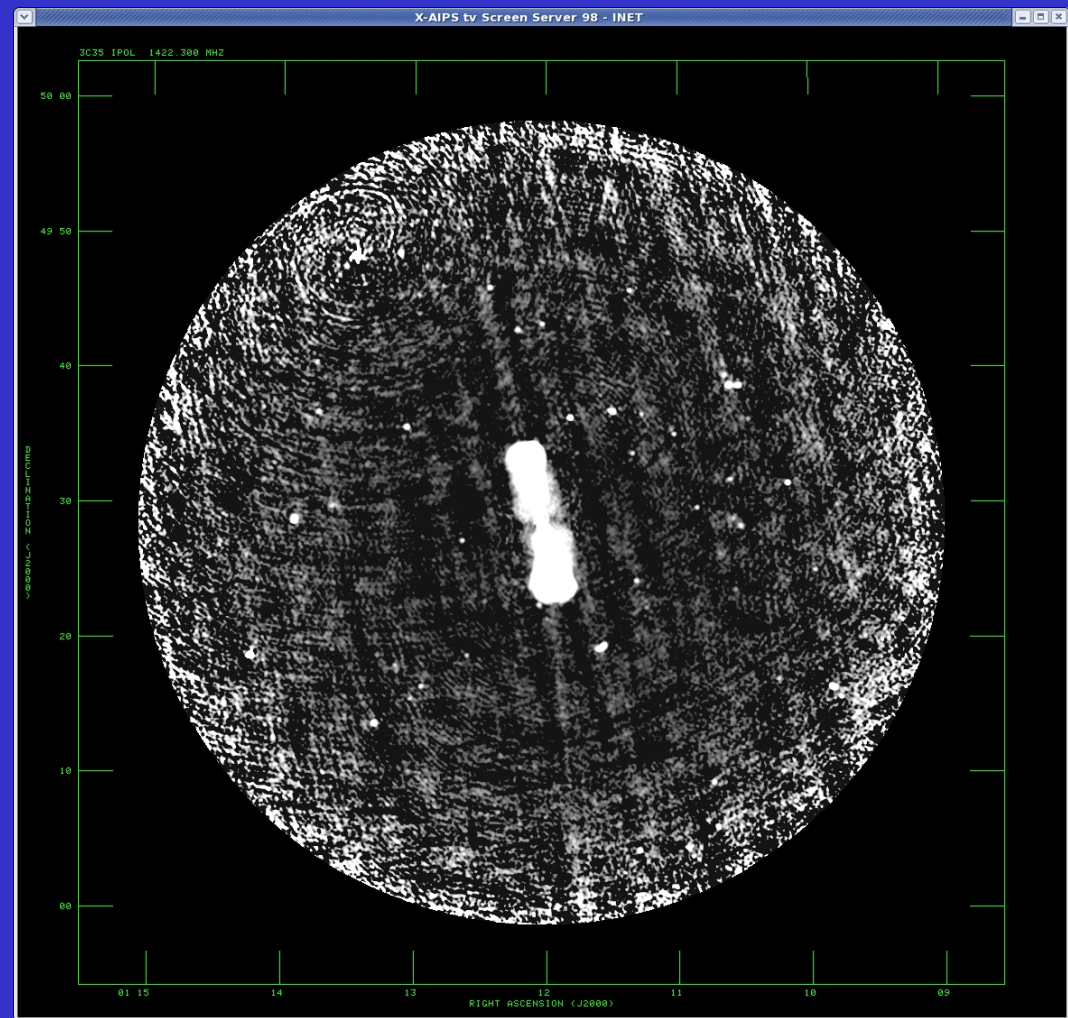


Image making

Normally you don't see the full horror of the outer parts of the field: typical final image is of the target alone.

Here with logarithmic contours, showing full (believable) dynamic range.

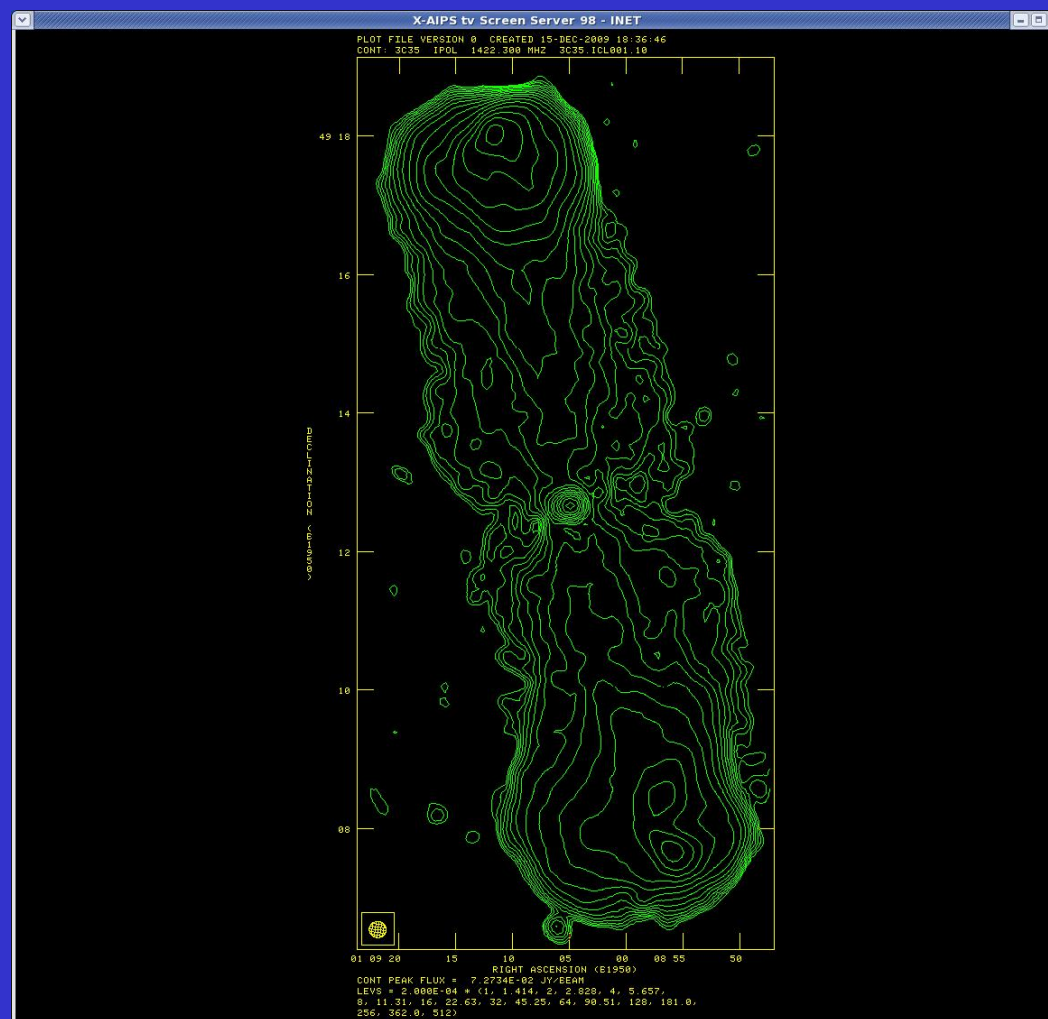
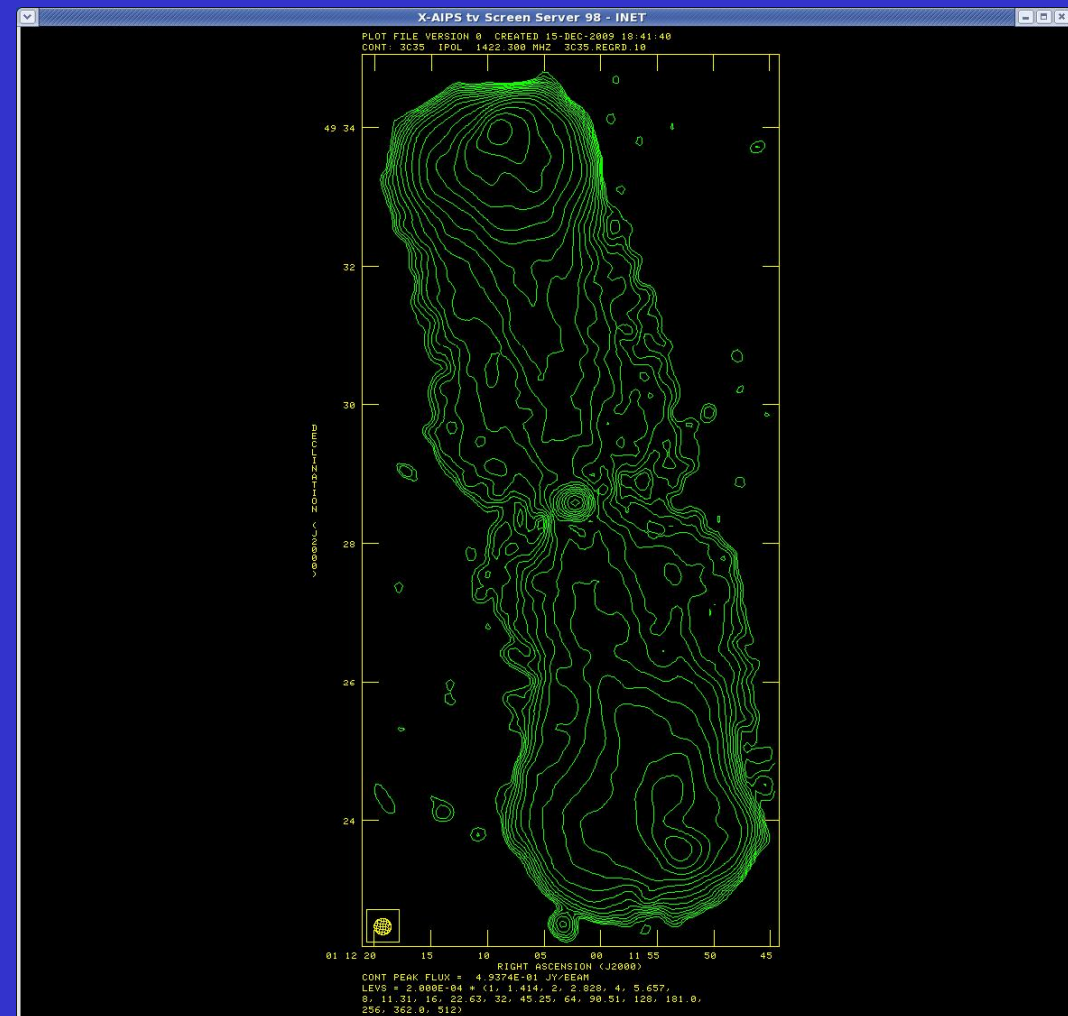


Image making

Final step: fix the
coordinates.

B1950 to J2000
conversion (rotation
of axes).

Change from standard
projection used in
radio astronomy to
standard used by
everyone else (sine-
to tangent-plane).

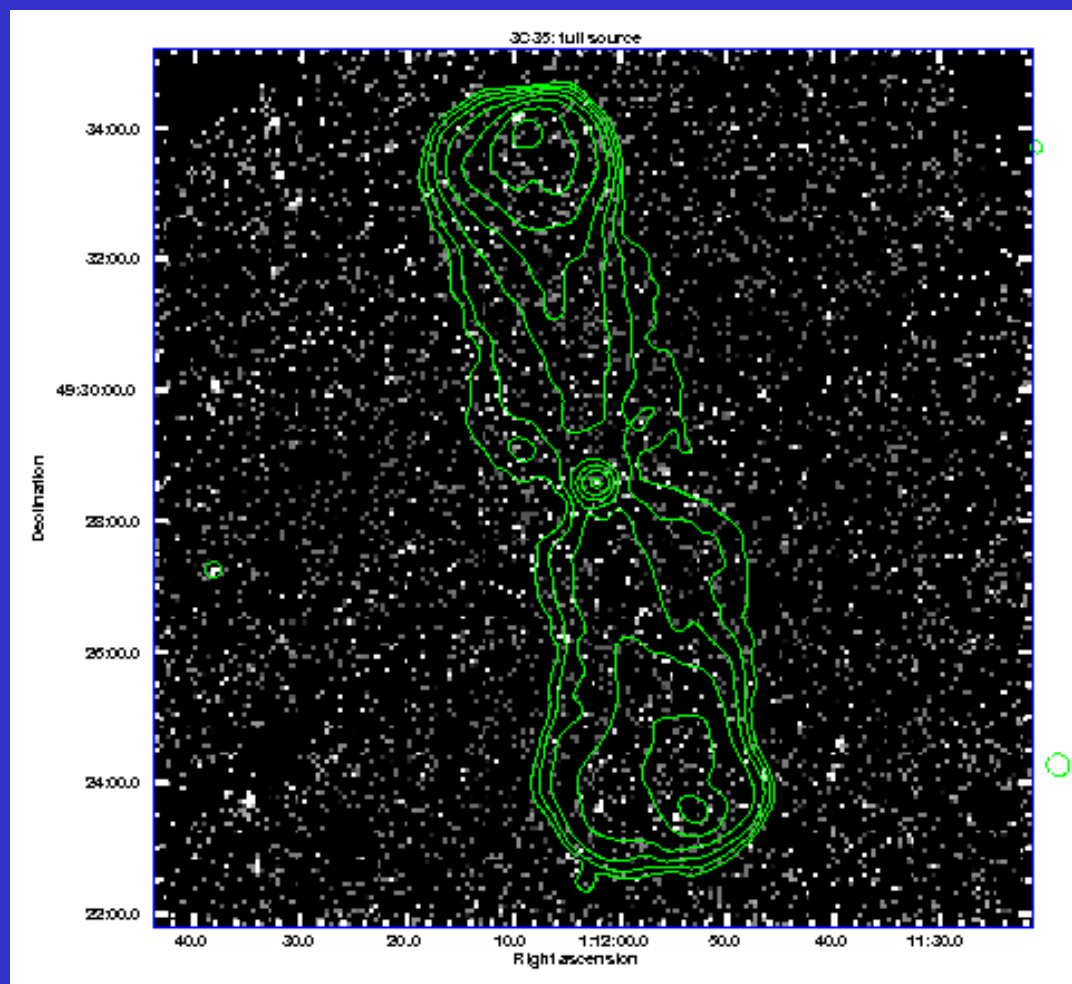


Putting the story together

Interesting part of field: radio contours from our L-band map on X-ray 0.5-2.5 keV image.

Core, source at north not associated (pity).

Hint of something ...

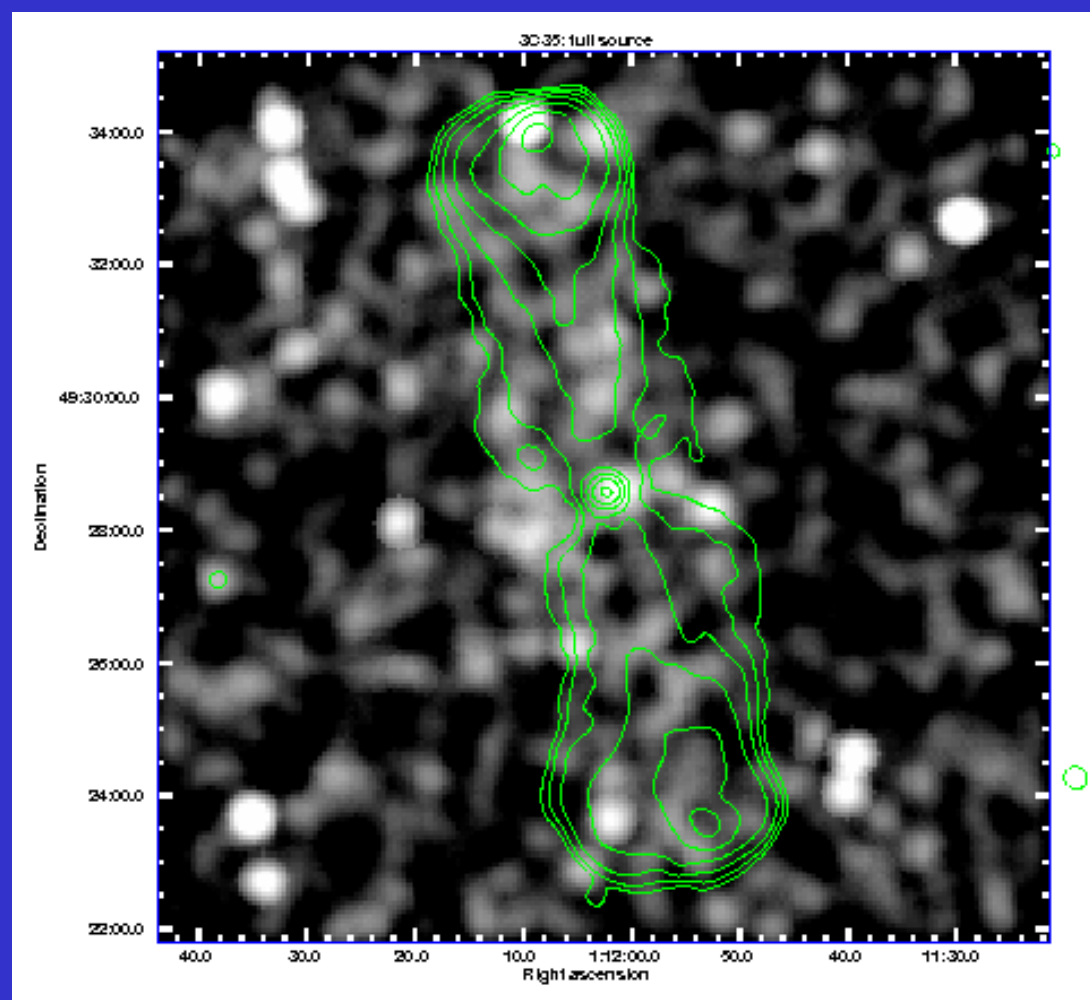


Putting the story together

Same, after smoothing
X-ray image.

X-rays brighter under
the lobes: inverse-
Compton emission,
allows a measure of
energy content.

Central “bar”??



Science at last!

- The X-ray core is absorbed but not completely: gives idea that there's a lot of central gas. Often seen in double sources of this type.
- There is no X-ray jet: nothing that indicates how the source is being powered
- The lobes are faint X-ray emitters by the inverse-Compton process: they are not “particle-dominated”, and are close to minimum energy
- There is no external gas to hold the lobes together, apparently.