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

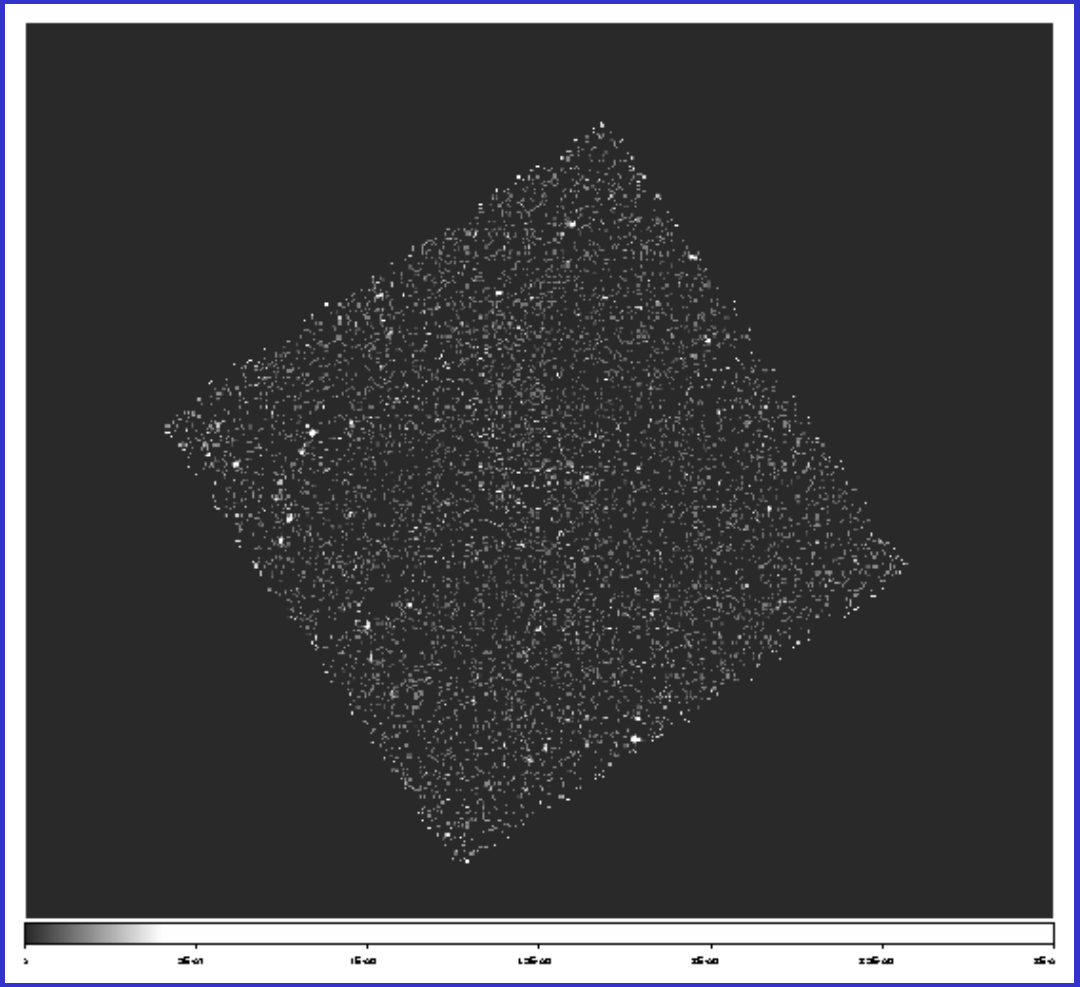
Example source: 3C35

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

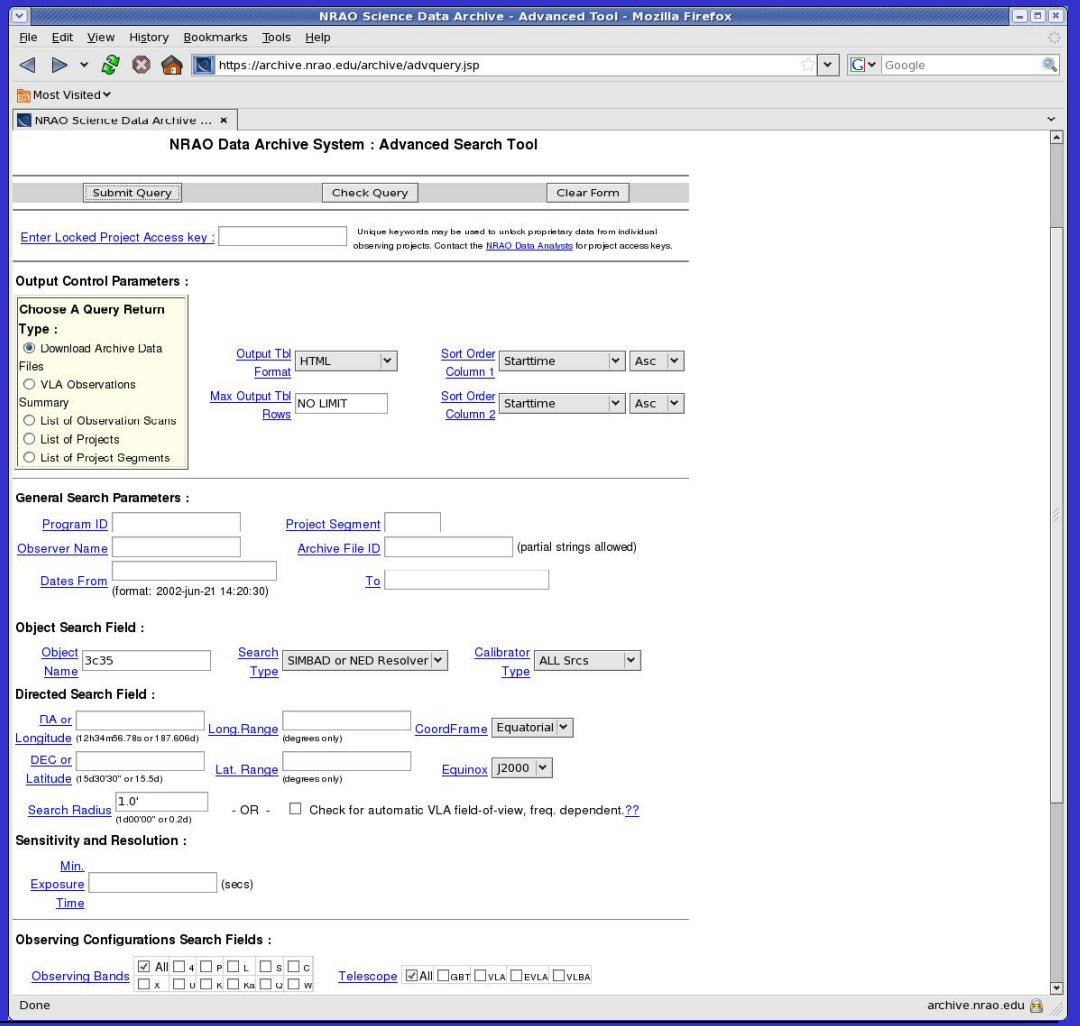
VLA

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"

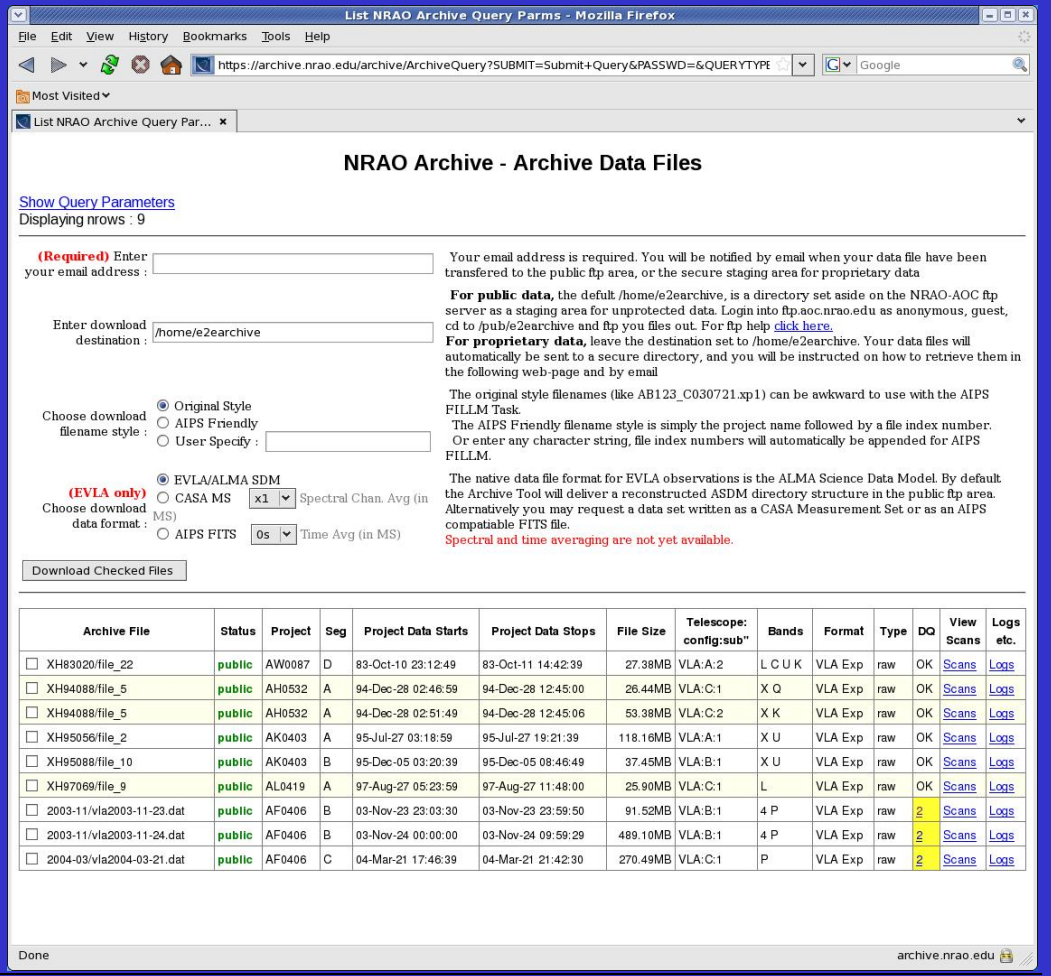


The VLA archive

Search result: there are data that can be used.

But are any of them useful?

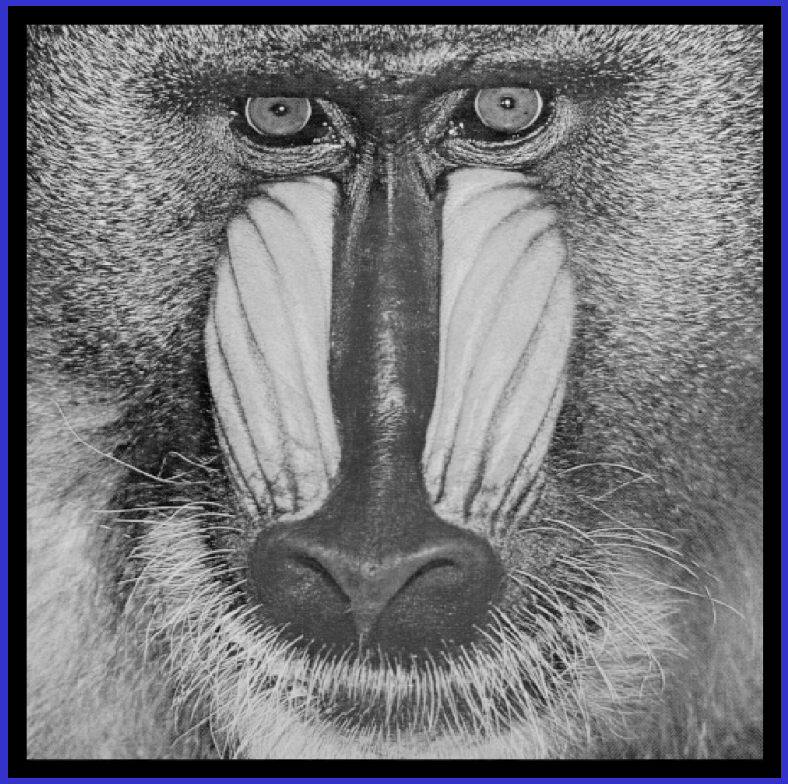
What do I need?



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/vla2003-11-23.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/vla2003-11-24.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/vla2004-03-21.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

Editing and calibration

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



AIPS = Astronomical Image Processing System

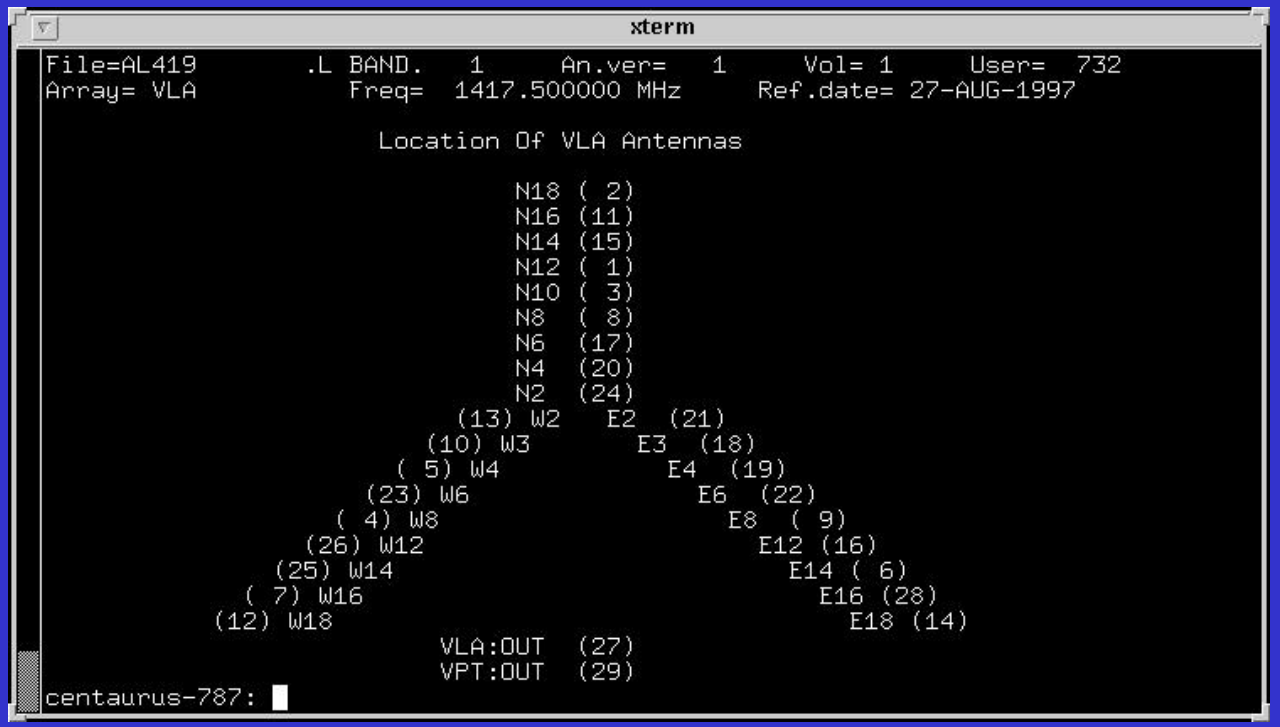
Now replaced by something better (?) CASA

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

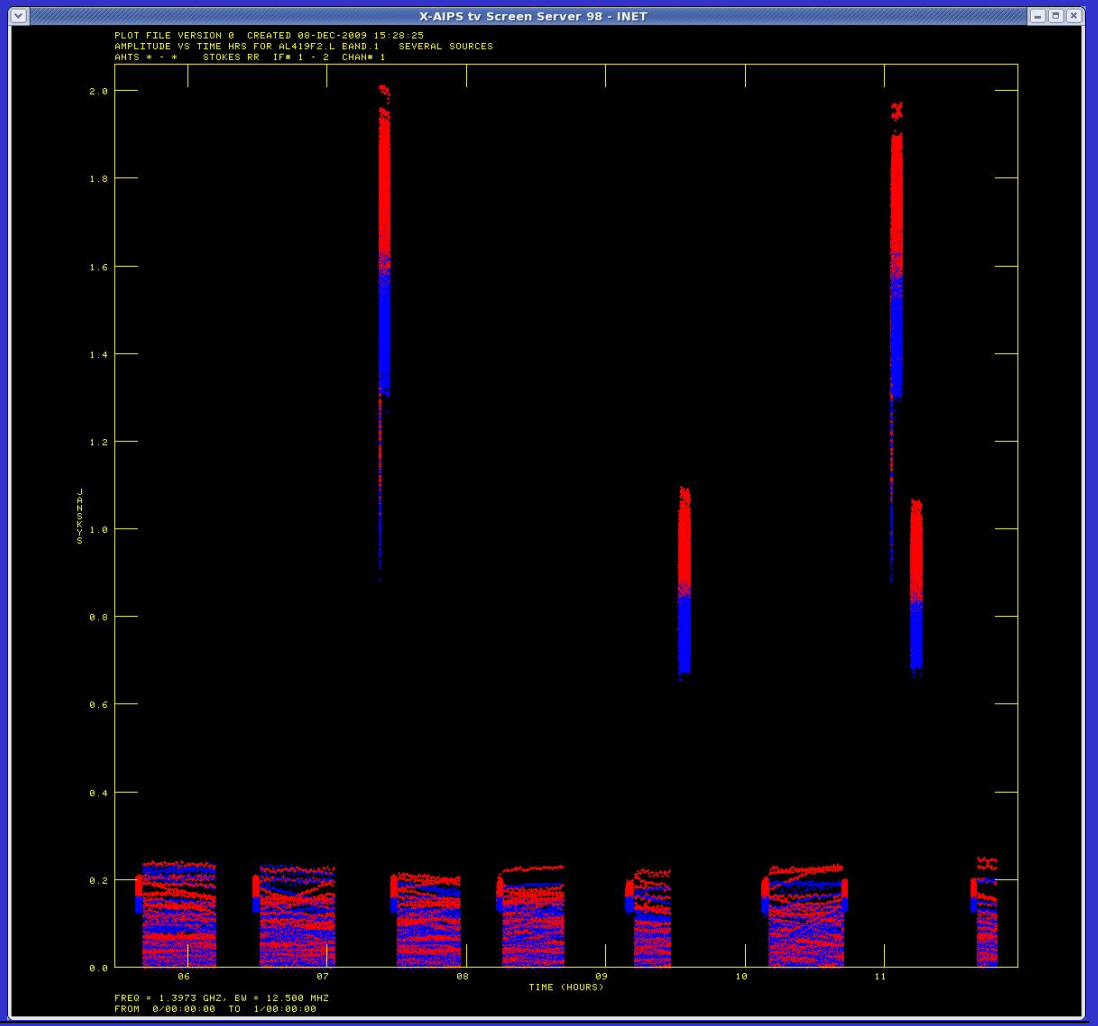
Diagram arranged to look like the antenna layout on the ground.

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.

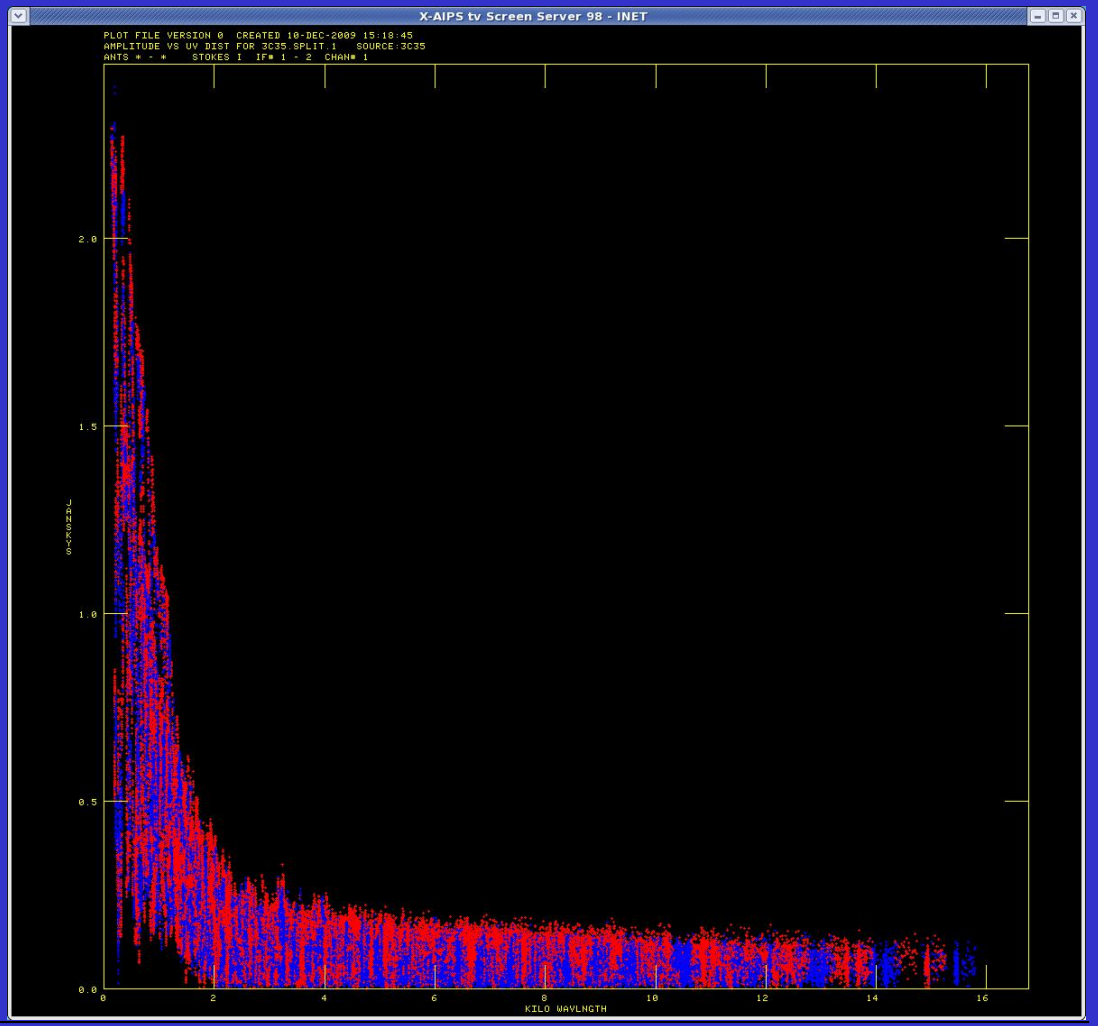


Image making

- 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.

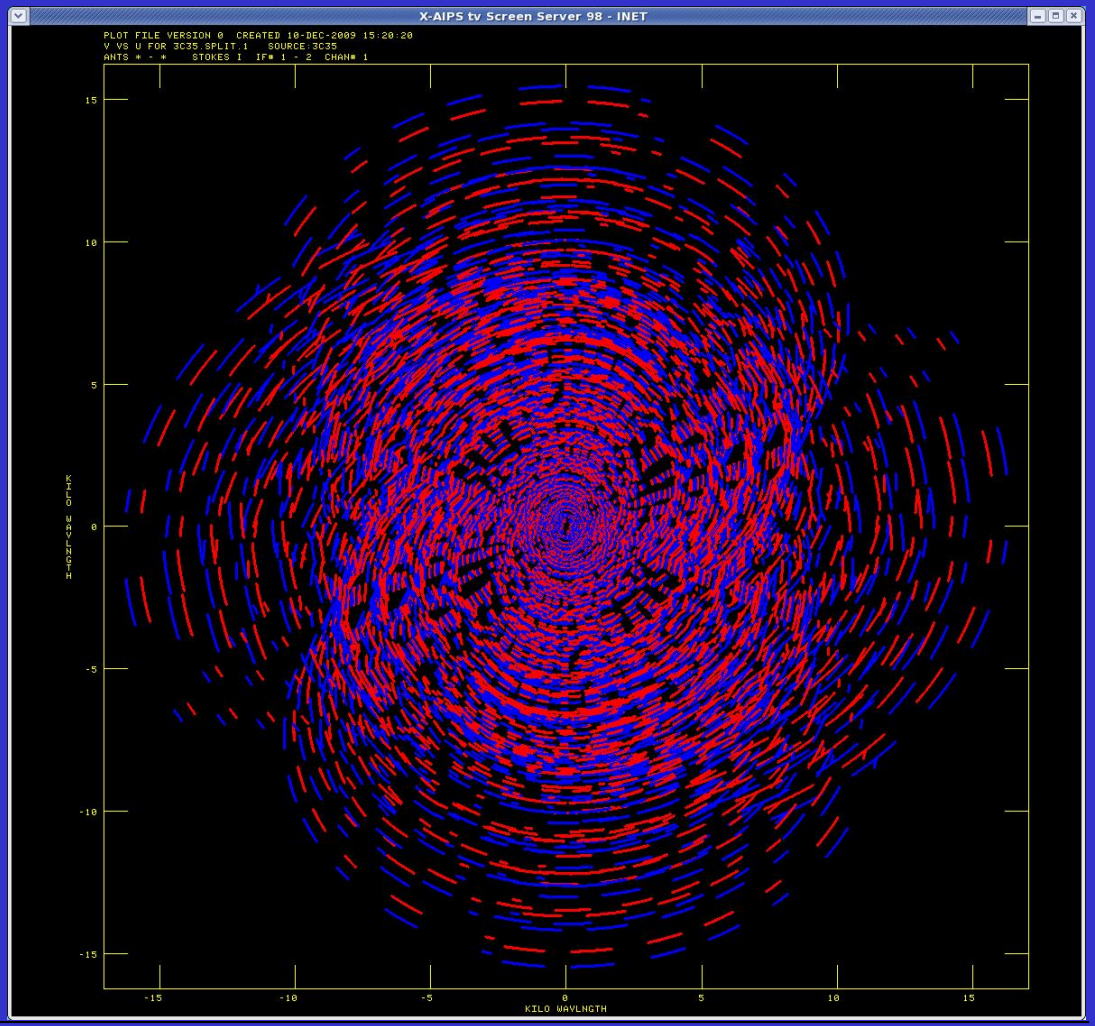


Image making

First map: basic Fourier transform

Grey-scale range -10 to +10 mJy

See major features: double structure, bright core

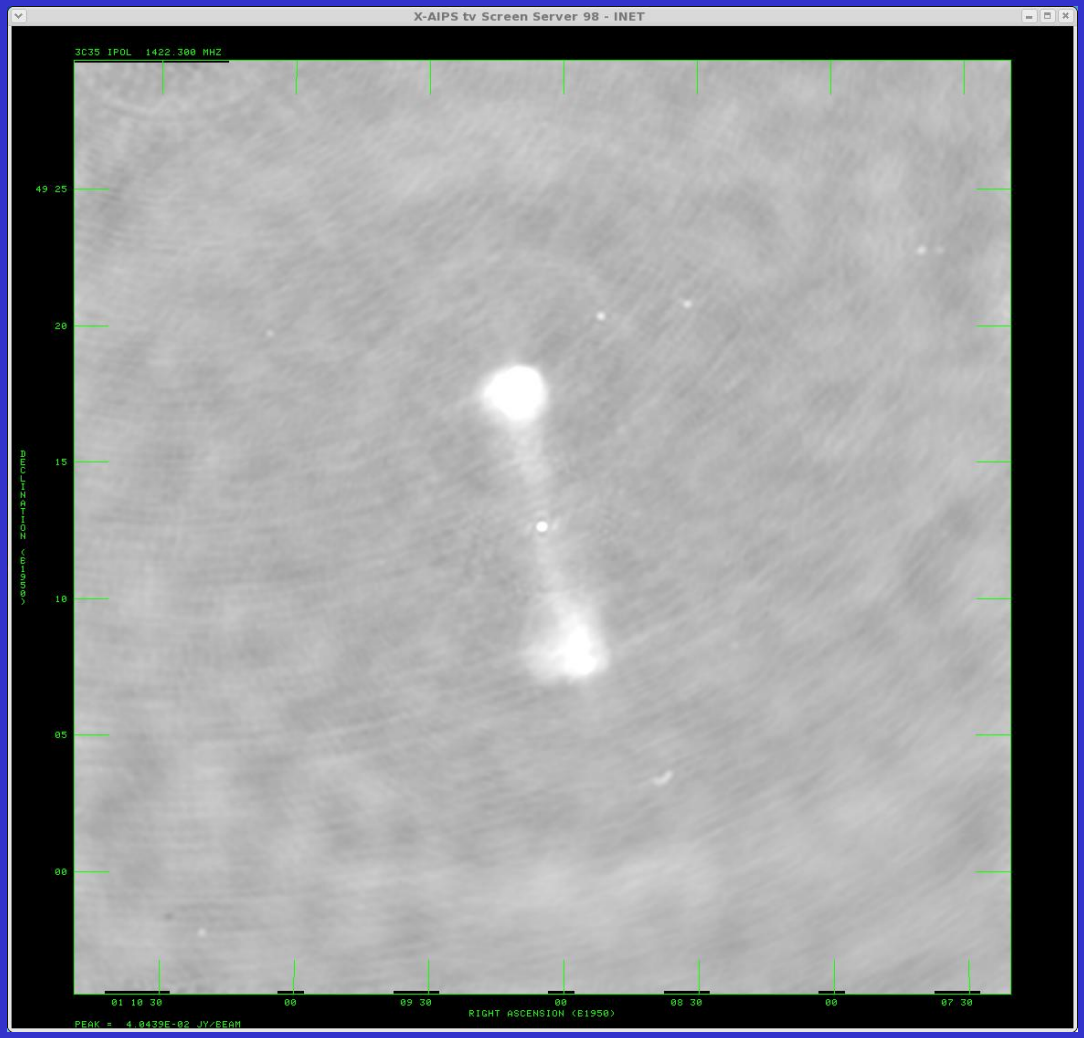


Image making

First map: basic Fourier transform

Grey-scale range -10 to +10 mJy

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

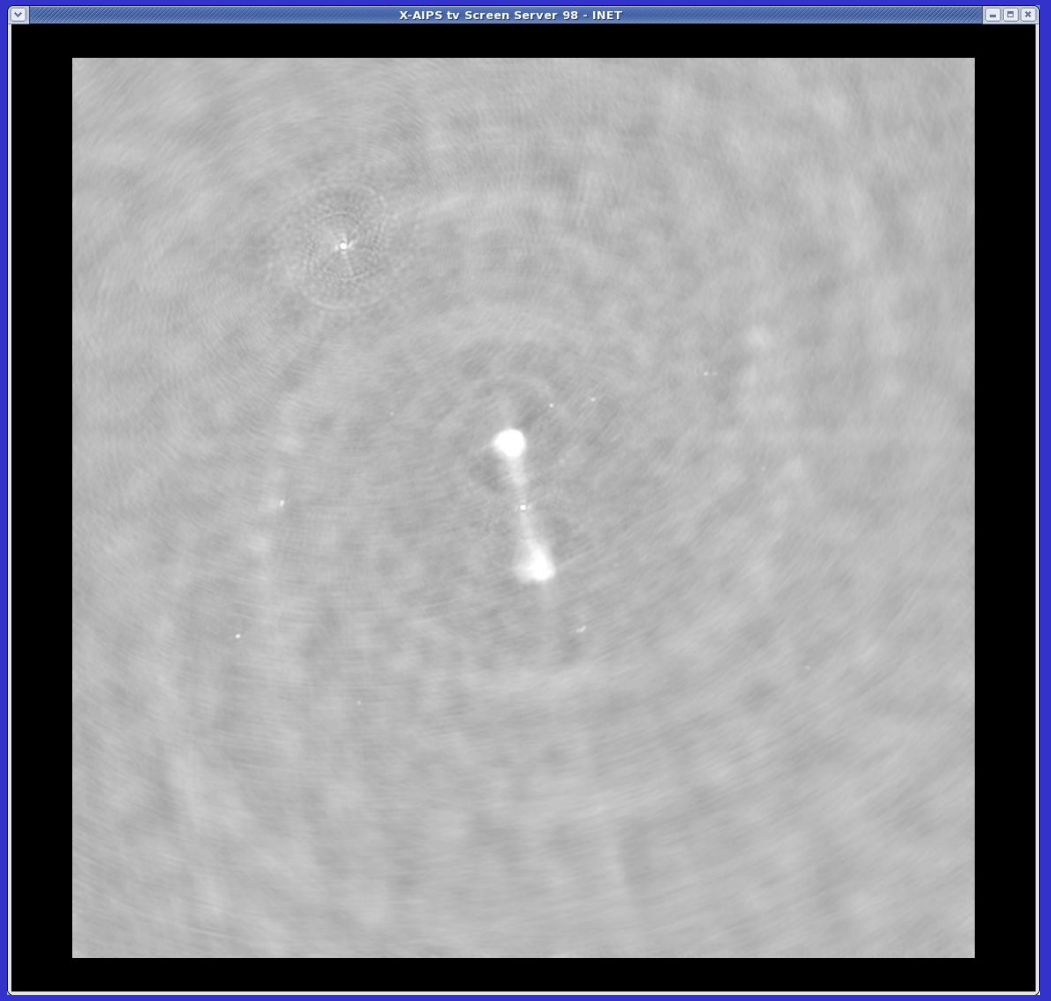


Image making

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

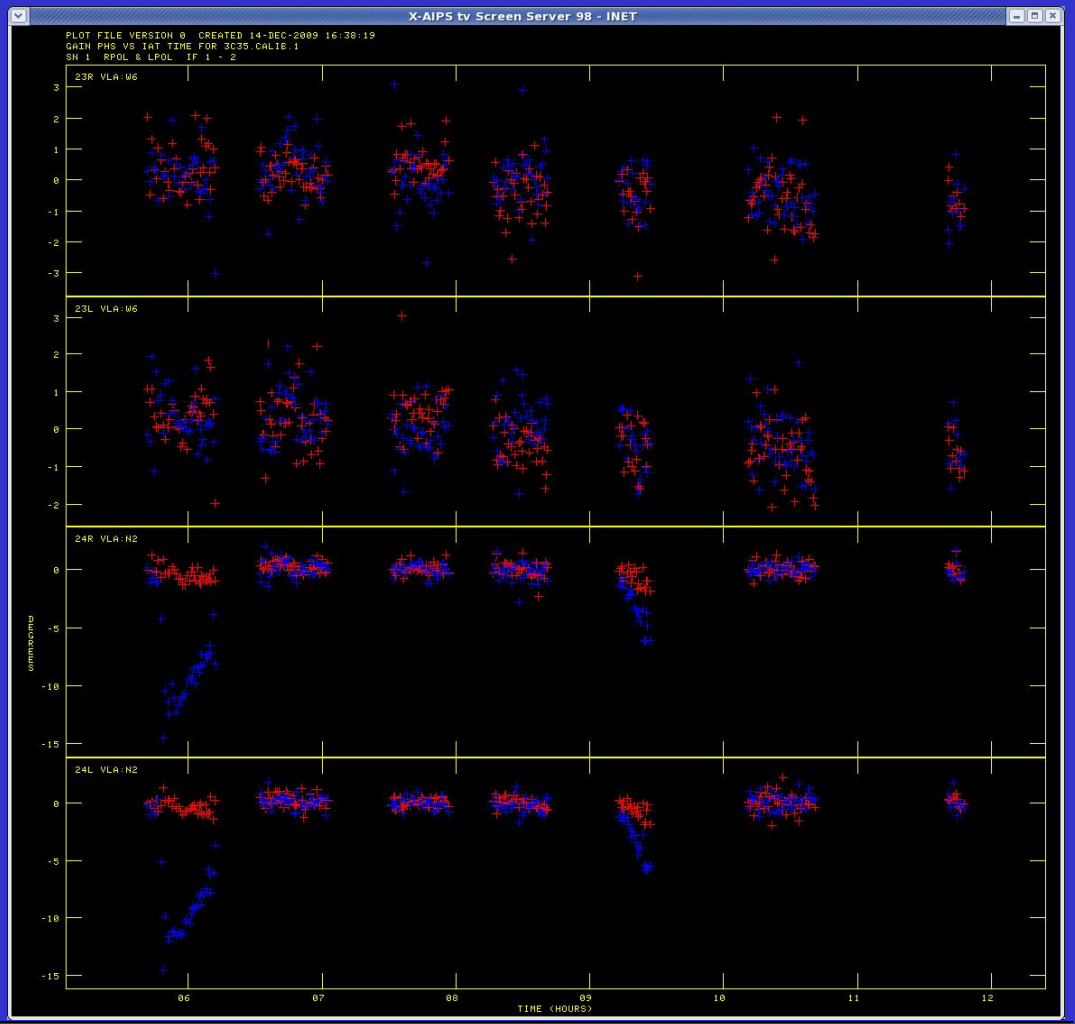


Image making

Repeat 10 times … or more.

Correct for the primary beam of the VLA antennas

Final result (central noise 40 μJy)

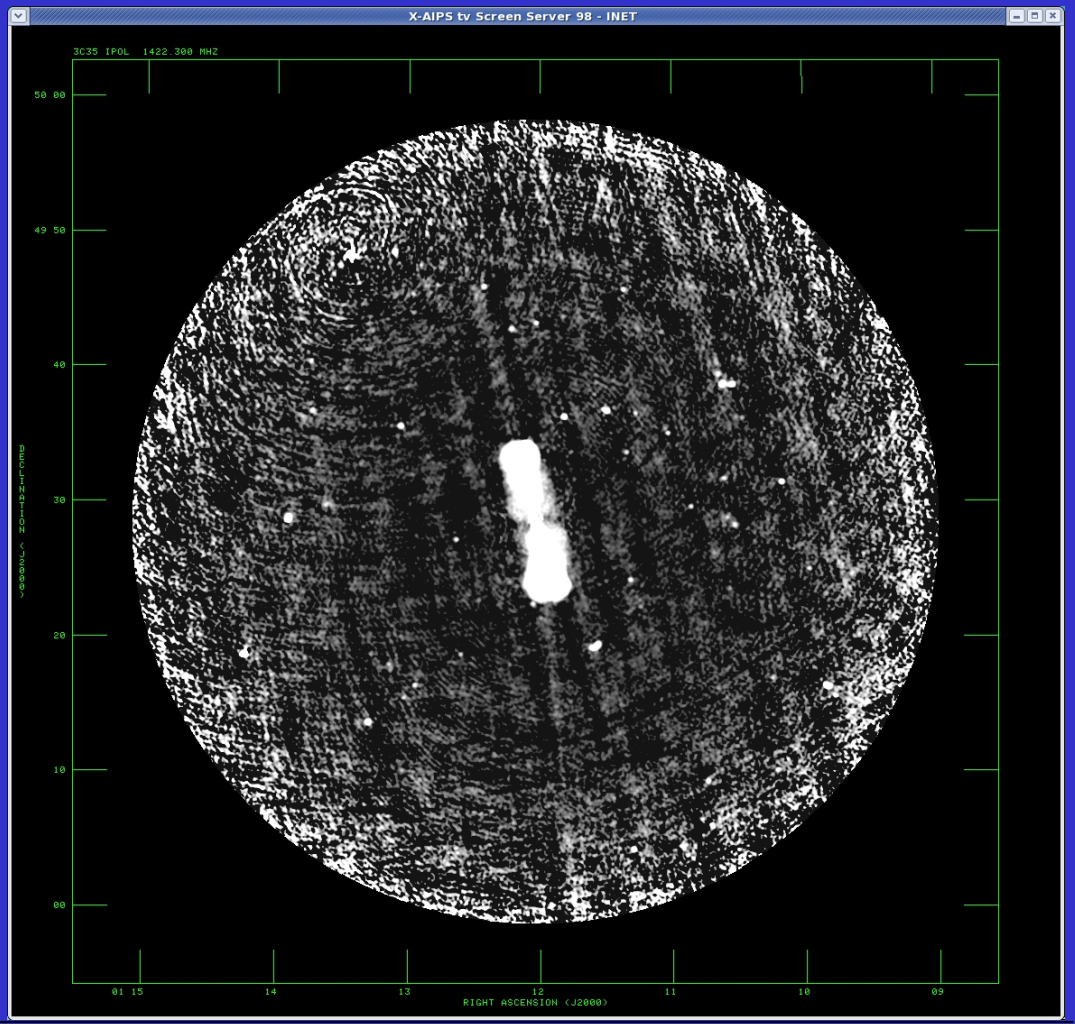


Image making

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.

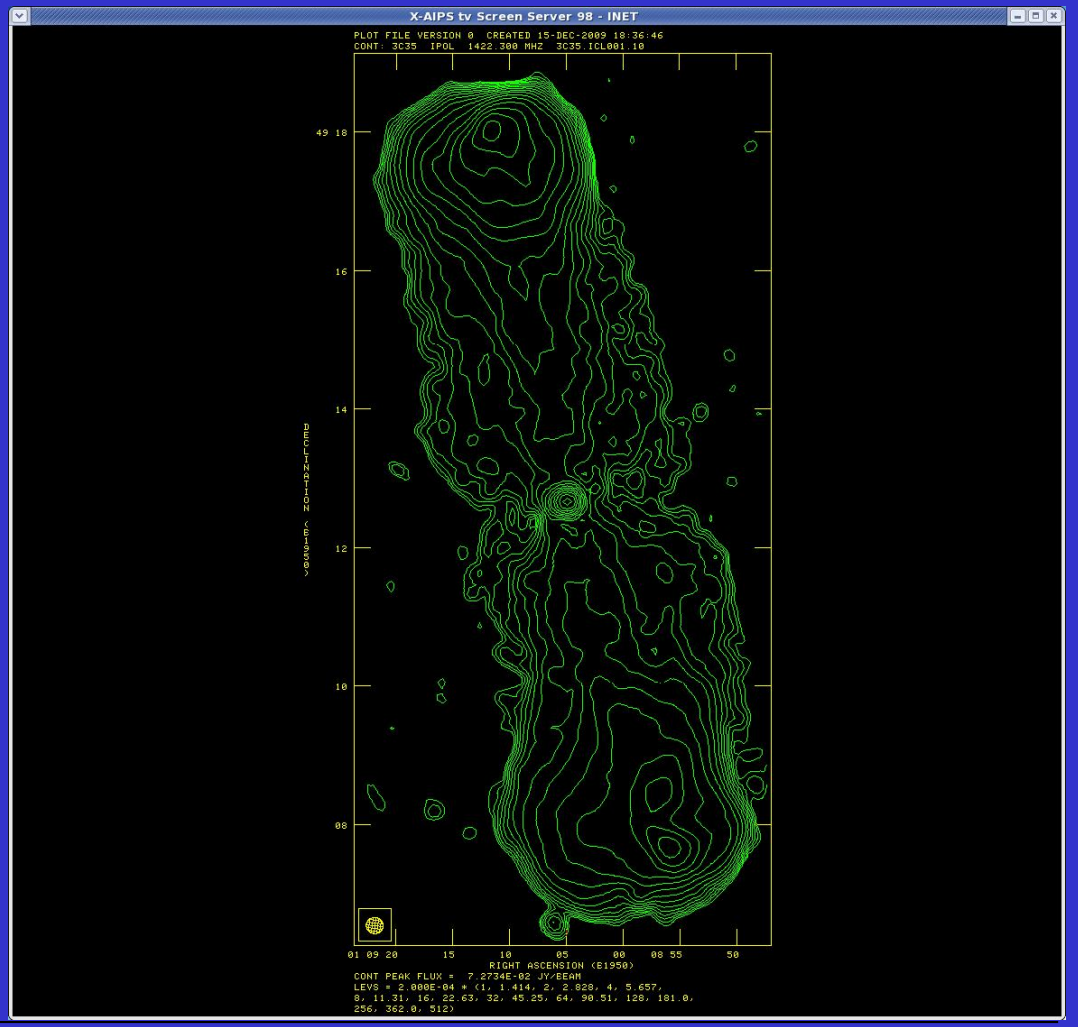
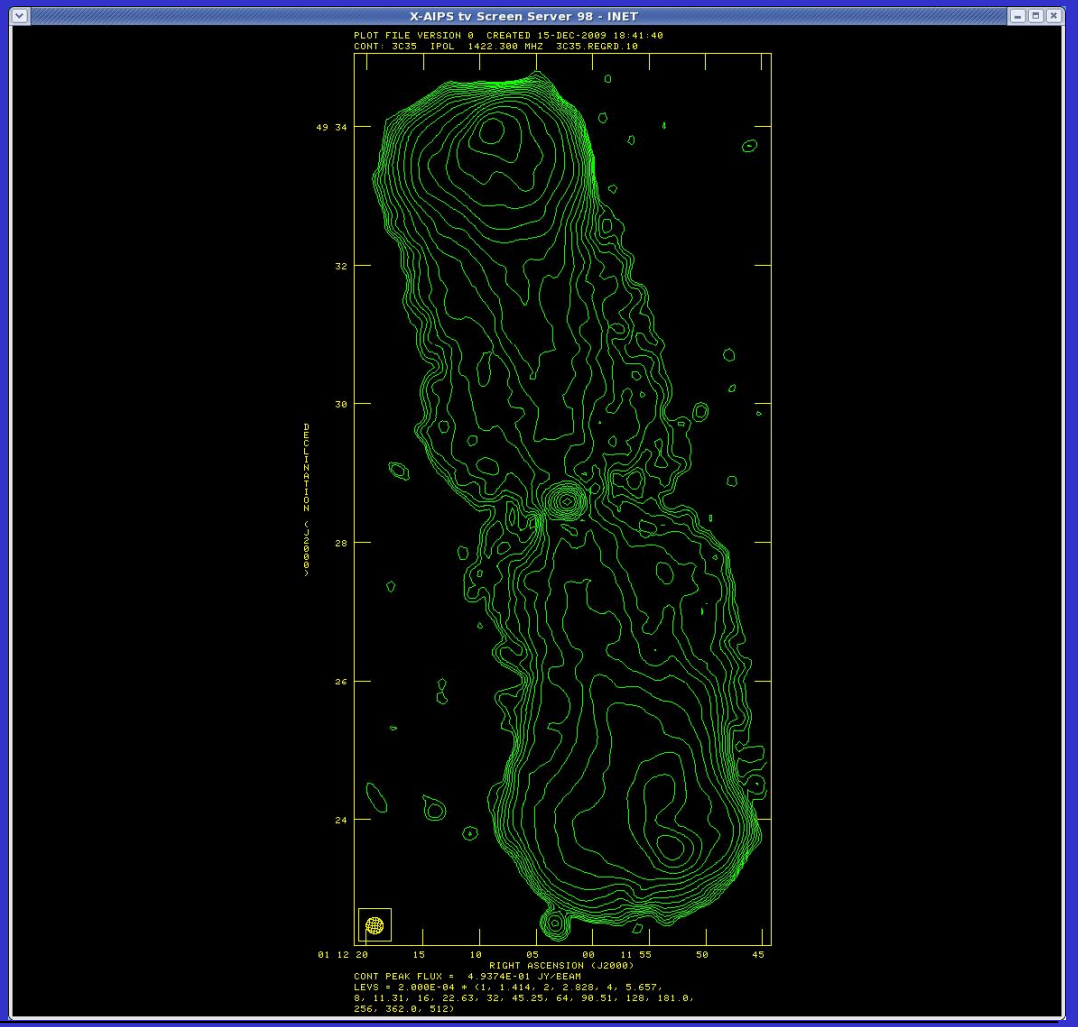


Image making

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).

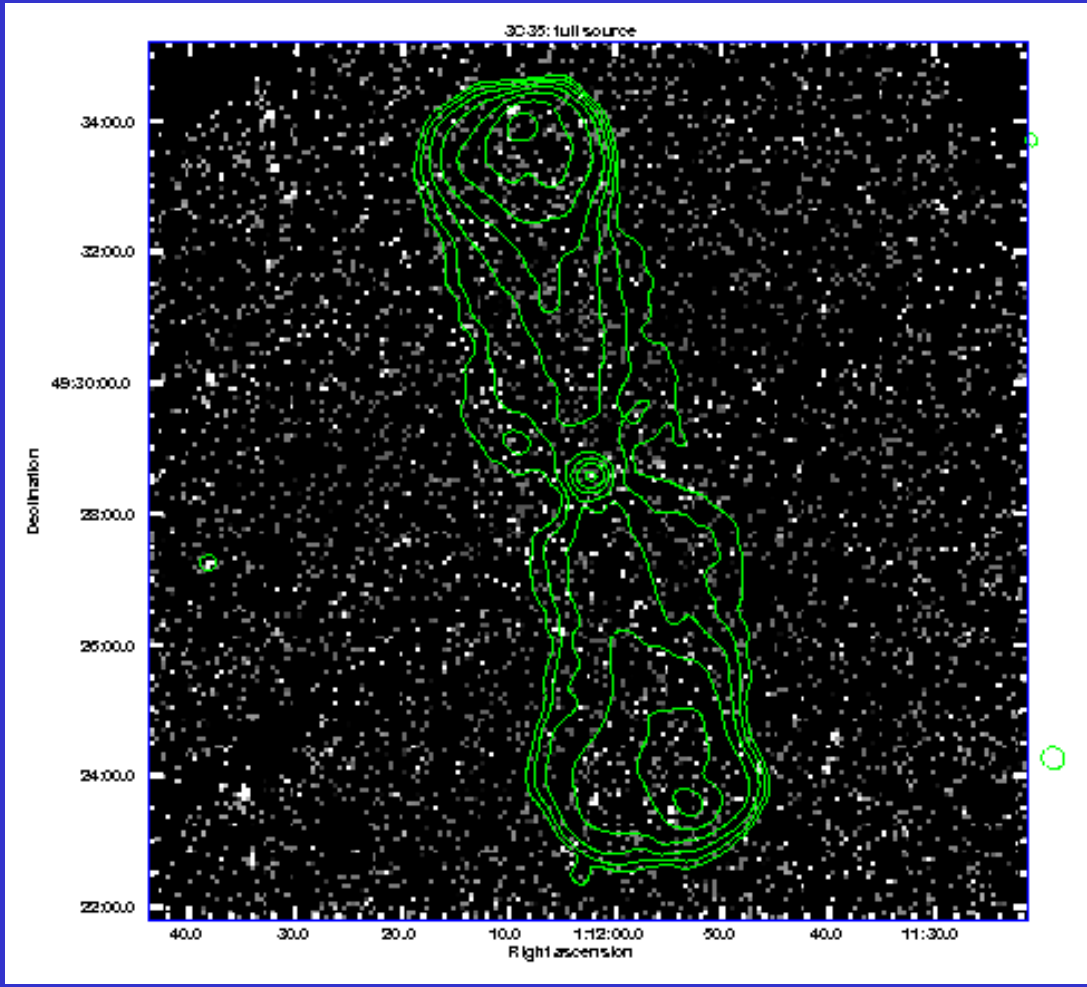


Putting the story together

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 ...

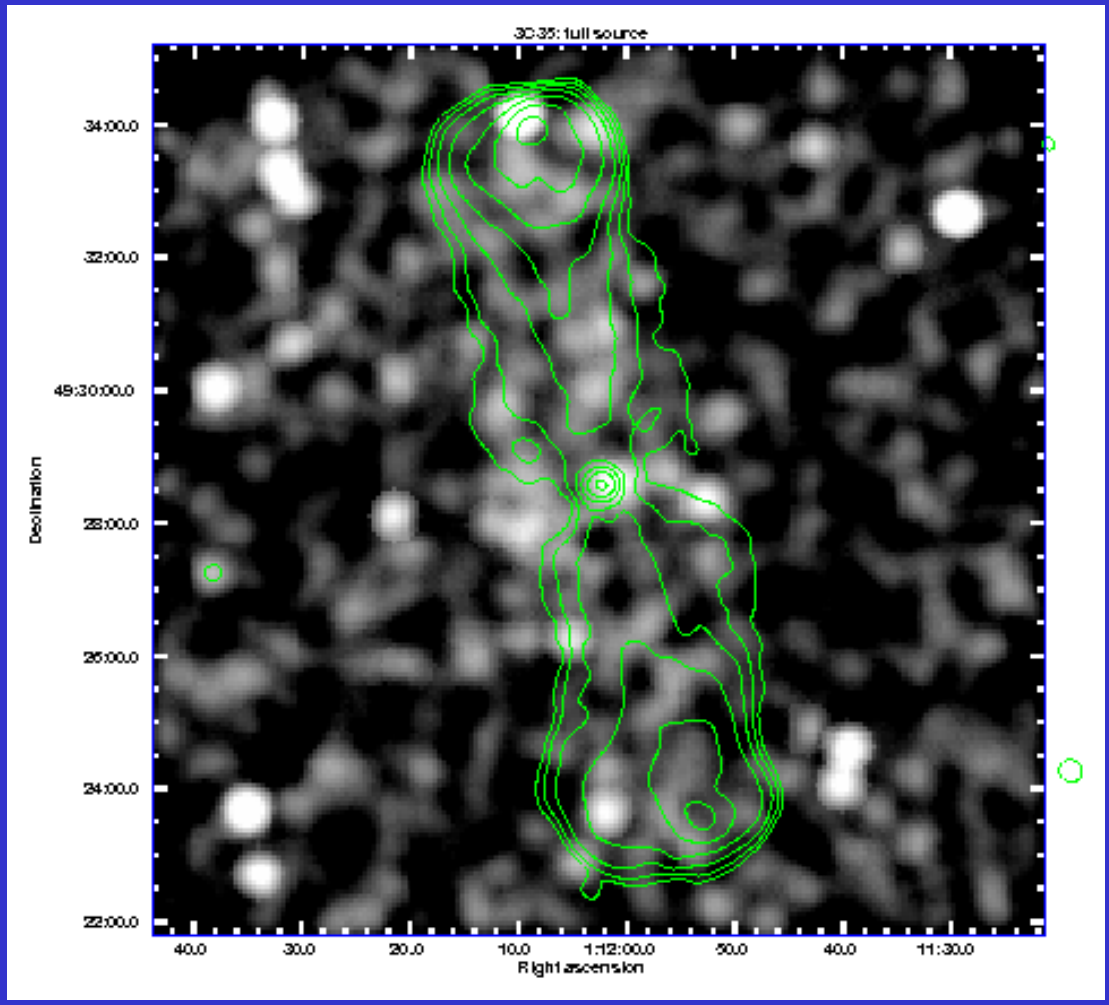


Putting the story together

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.