Aspects of radio galaxies and lifecycles

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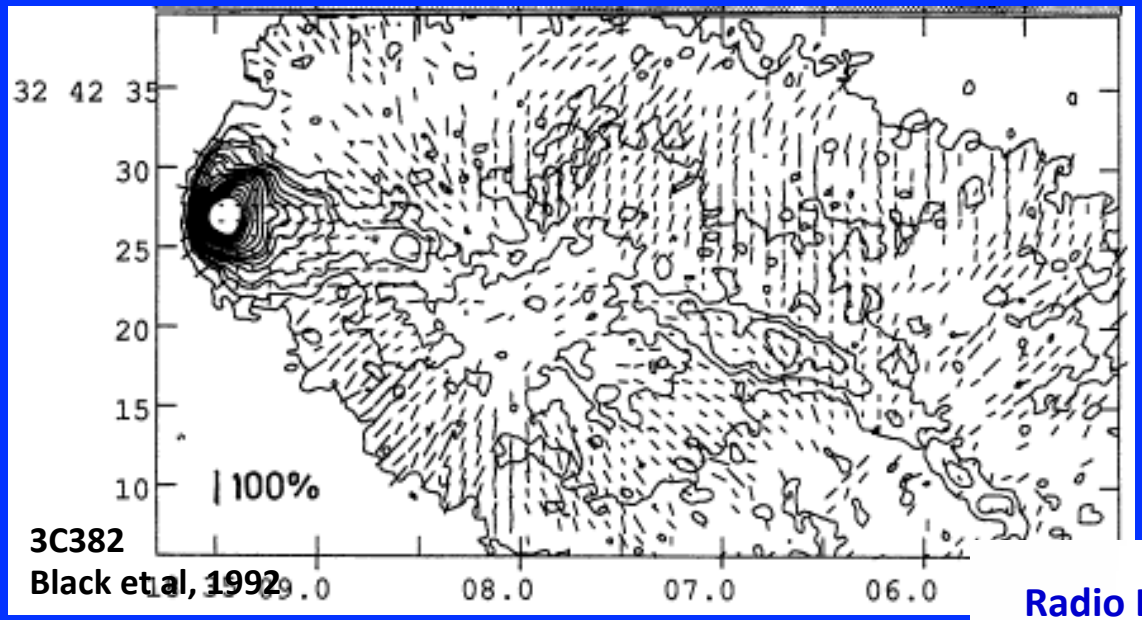
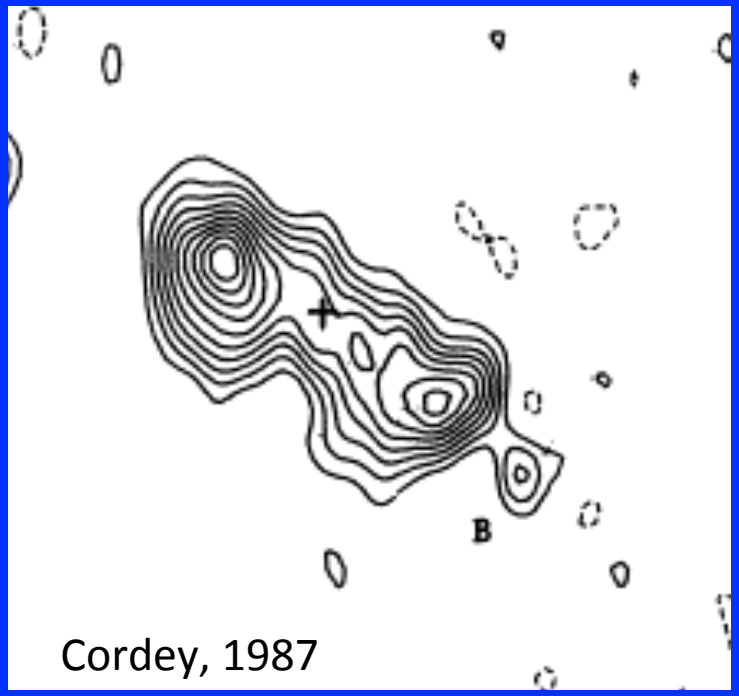
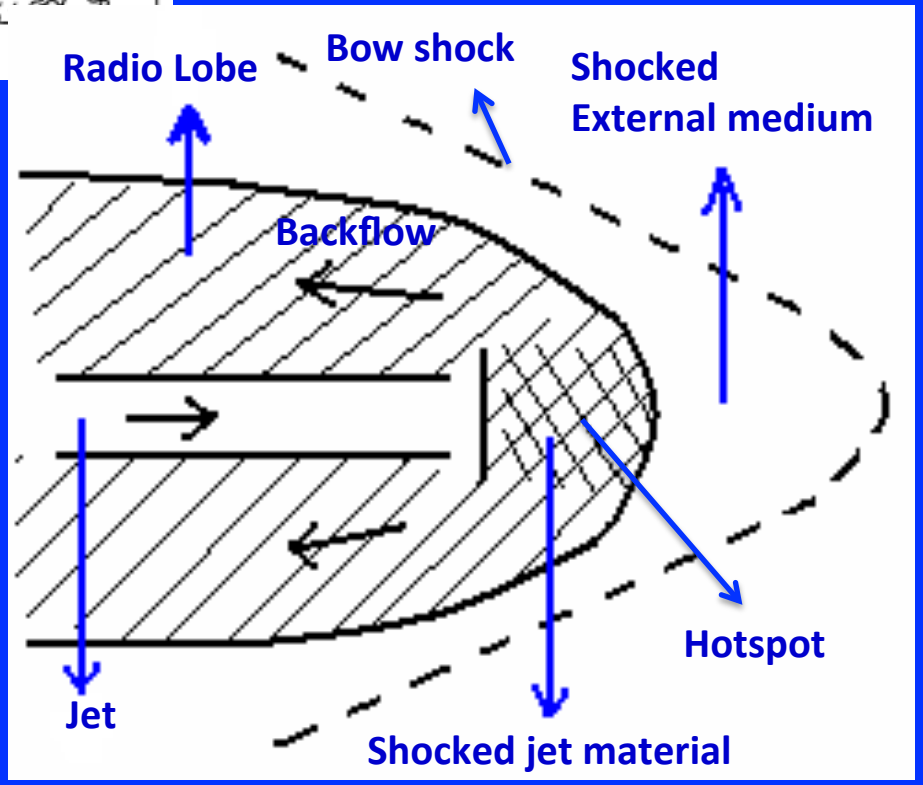
Beam model for double radio sources



3C382
Black et al, 1992



Cordey, 1987



- As sources grow

  - Consequences for lobes are many:
    - Synchrotron losses $\longrightarrow$ $-\mathbf{dE/dt} \sim B^2 \beta^2 \gamma^2$
    - Expansion losses $\longrightarrow$ $-\mathbf{dE/dt} \sim \gamma$
    - Magnetic field dilution $\longrightarrow$ $B' = B / f^2$
    - Inverse-Compton losses $\rightarrow$ $-\mathbf{dE/dt} \sim U_{cmb} \beta^2 \gamma^2$

Kaiser, Alexander & Dennett-Thorpe, 1999; Blundell, Rawlings & Willott, 1999

- Dead AGN expected

- Where are the dead quasars? Bower et al 1993

  "A search for dead quasars among nearby luminous galaxies"

- Rarity recognized early on

Several attempts, several techniques

- Based on morphology (Cordey, 1987; Saripalli et al, 2005)
- Steep radio spectra (Parma et al, 2006, Dwarakanath & Kale,2009; van Weeren et al, 2009)
- AGN emission line ratios (Capetti et al, 2011)
- Inverse-Compton X-rays (Fabian et al, 2008)
- Low fractional core powers (Giovannini et al, 1988)

- Mostly ~a few percent or much lower

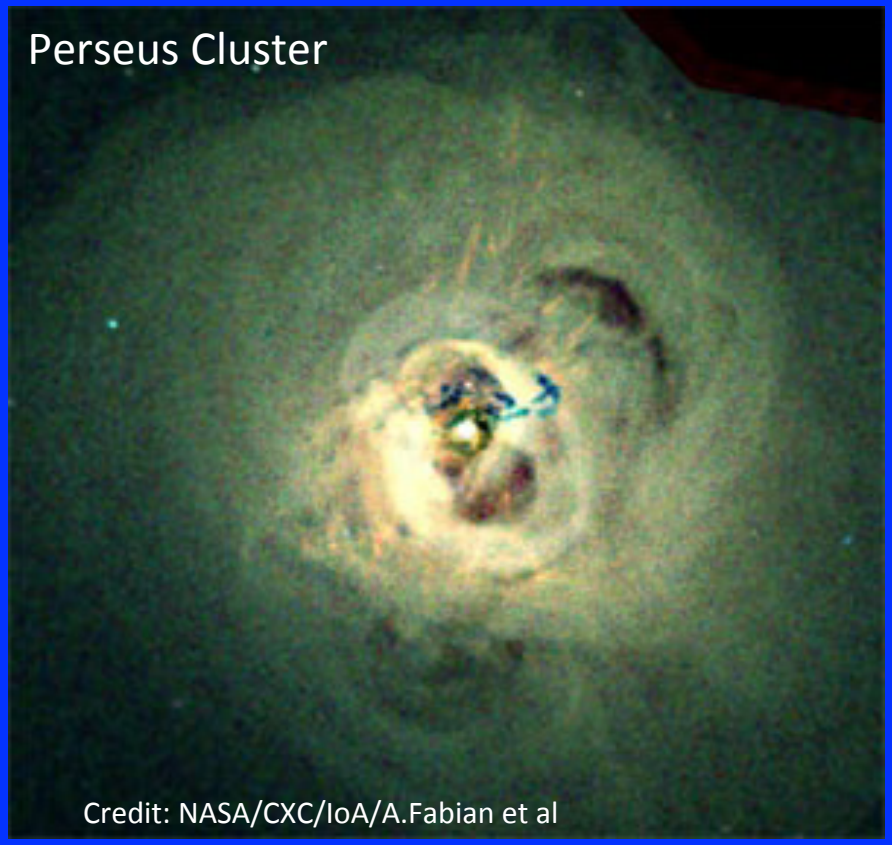
- What kind of sources are these searches really after?

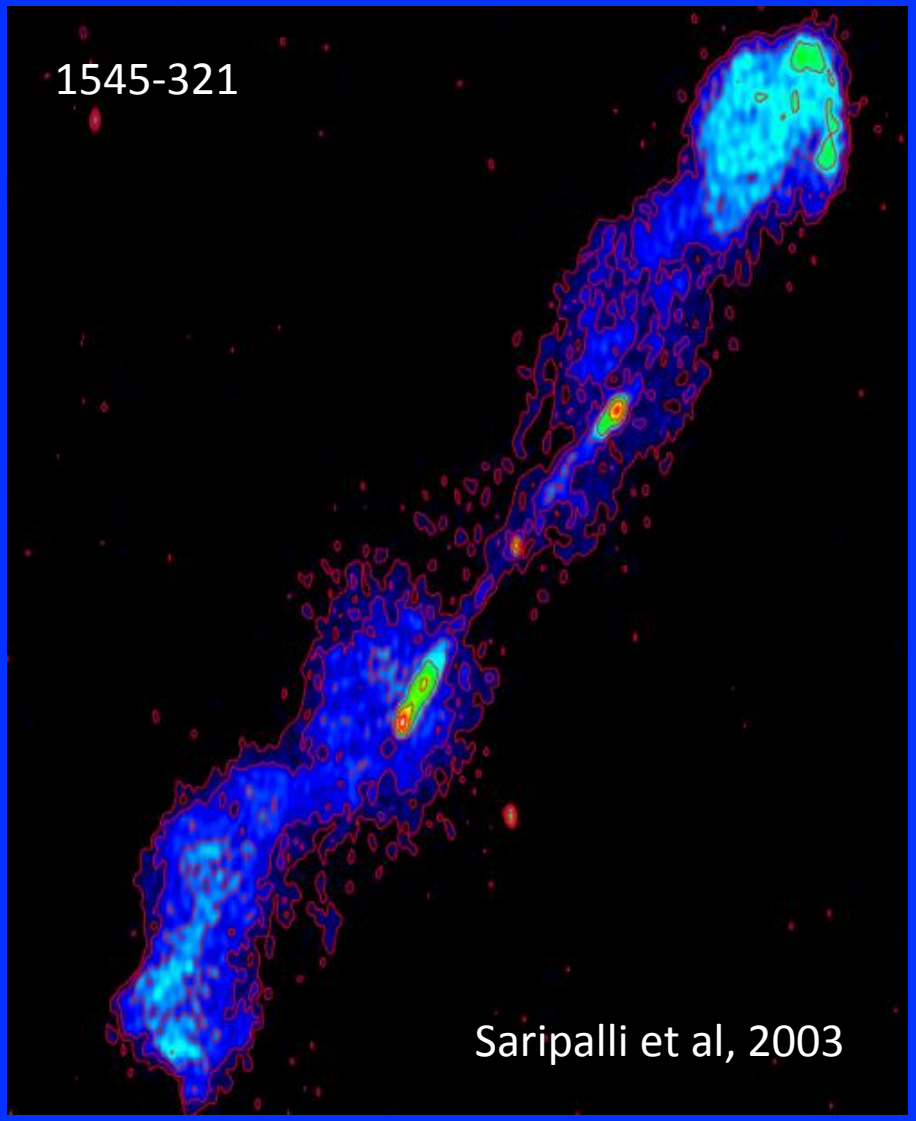
Restarted radio galaxies

- Not anticipated (like dead radio sources were)
- No concerted searches (like for dead radio sources)
- Only serendipitous discoveries (Clarke & Burns, 1991, Roetigger et al, 1994; Subrahmanyan et al, 1996; Schoenmakers et al, 1999)
- Now expected (e.g. Scarpa & Urry, 2001; Best et al, 2005)

- Several examples in clusters – FR-I type
- Several examples outside clusters – FR-II type

Restarted radio galaxies

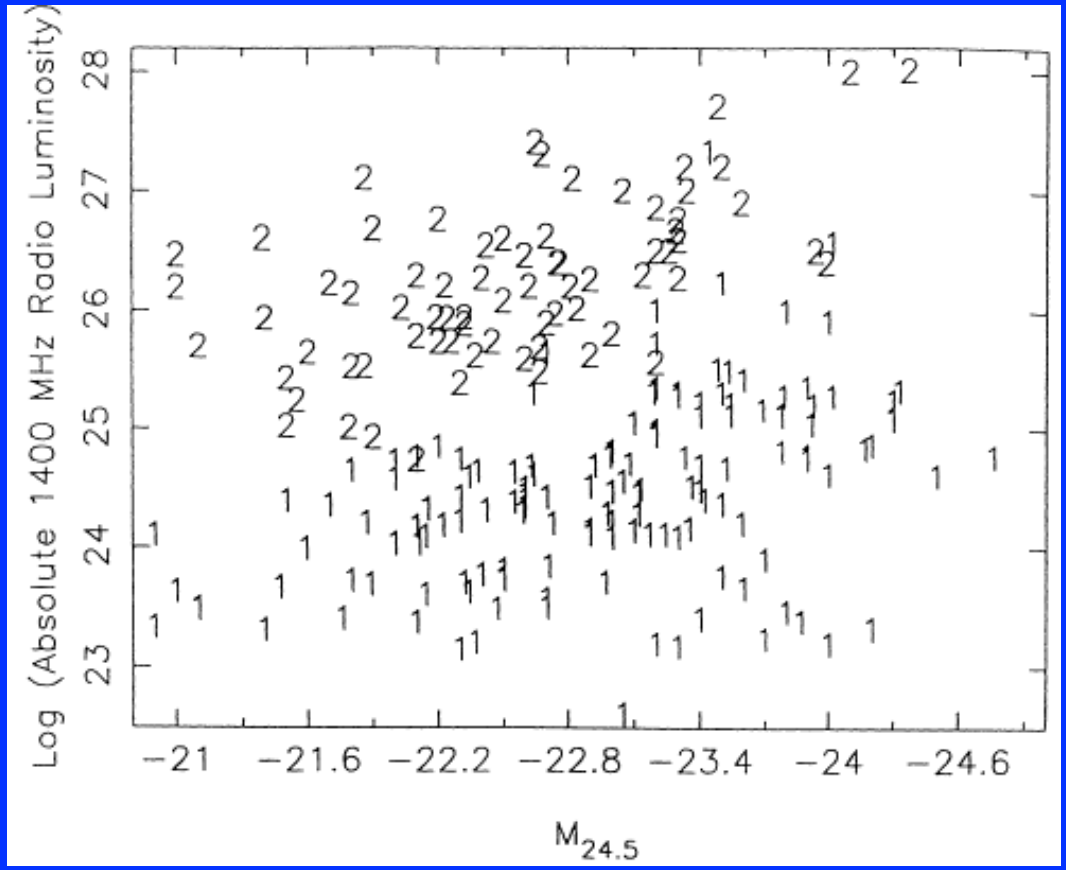




- Different
  - Beam powers
  - Accretion processes
  - Modes of accretion

For FR-I and FR-II sources

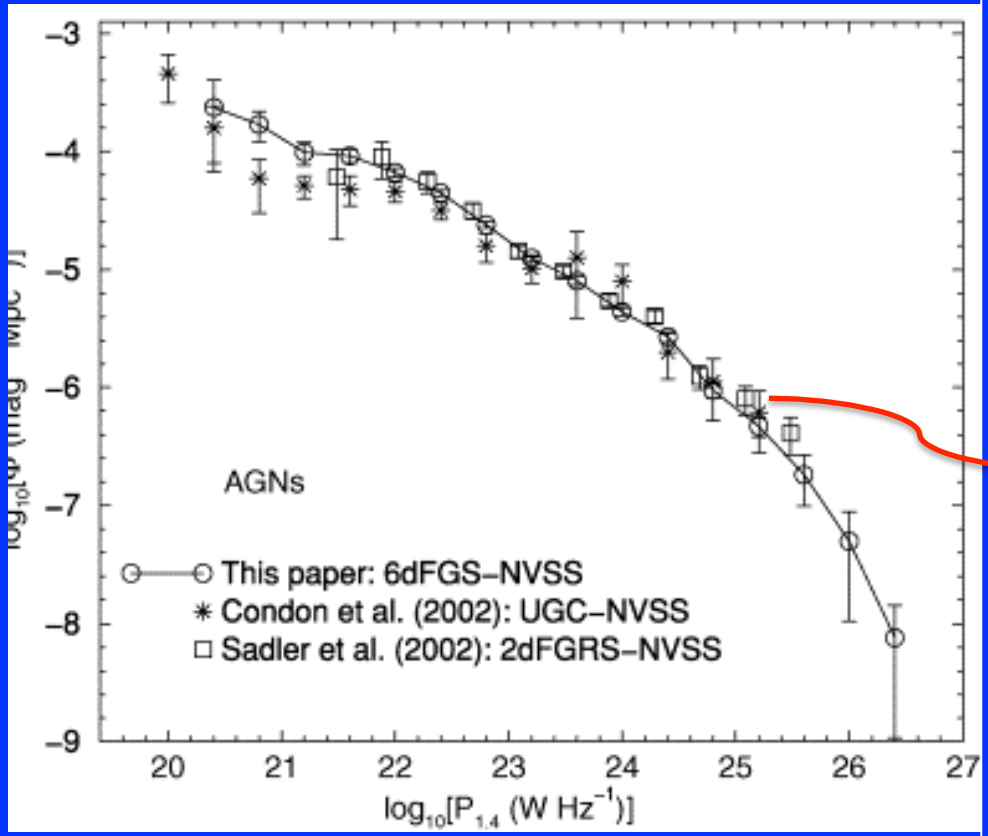
  - Duty cycles?



Owen & Ledlow, 1994

Searches for relics

Radio luminosity function



Mauch & Sadler 2007

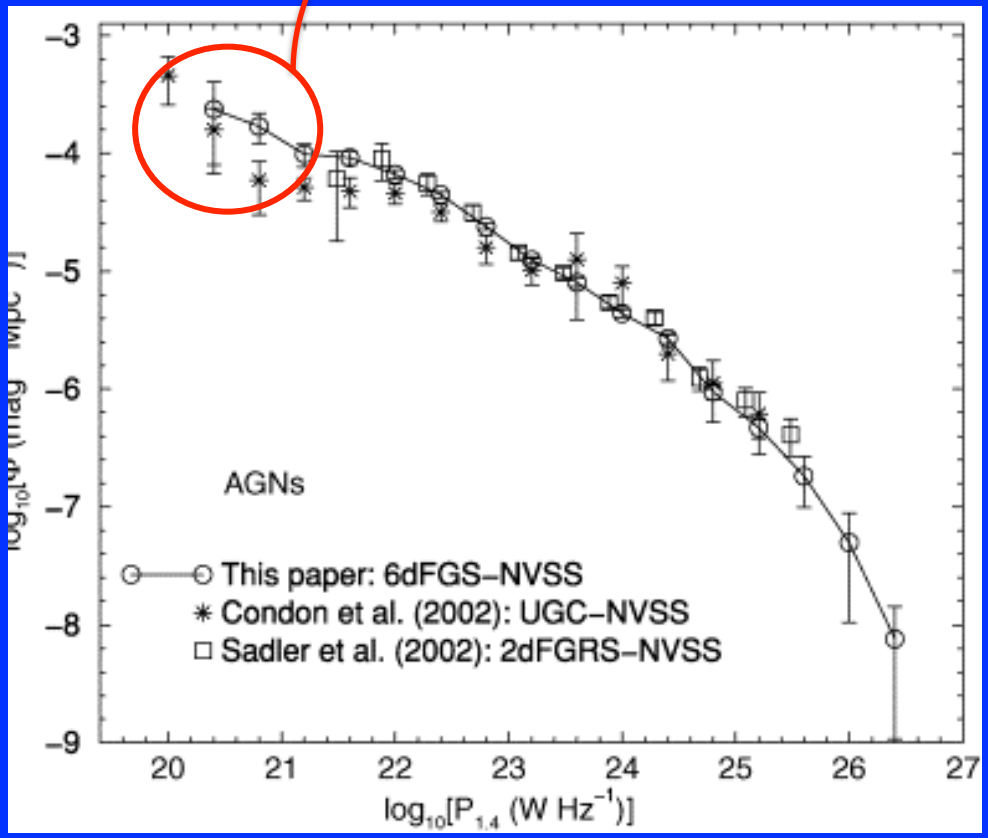
- Searches for dead FR-IIs that have *remained inactive*
- Searches for a fraction of a small fraction of radio source population
- Largely associated with isolated, lower mass ellipticals (at least in nearby universe!)

- What about dead FR-Is (dead FR-Is that have not restarted)?
- More massive hosts
- Continuous fuel from stellar mass loss + corona

- Shorter quiescent phases? (also Shabala et al, 2008)

‘Radio quiet’

Radio luminosity function



Mauch & Sadler 2007

Large fraction (≥ 40%) of massive ellipticals are LLAGNs

LLAGNs are almost always associated with radio jets
(Falcke et al, 2000; Nagar et al, 2001)

Jets are everywhere!
‘Silent majority’

Relation to FR-Is? Dead QSOs?

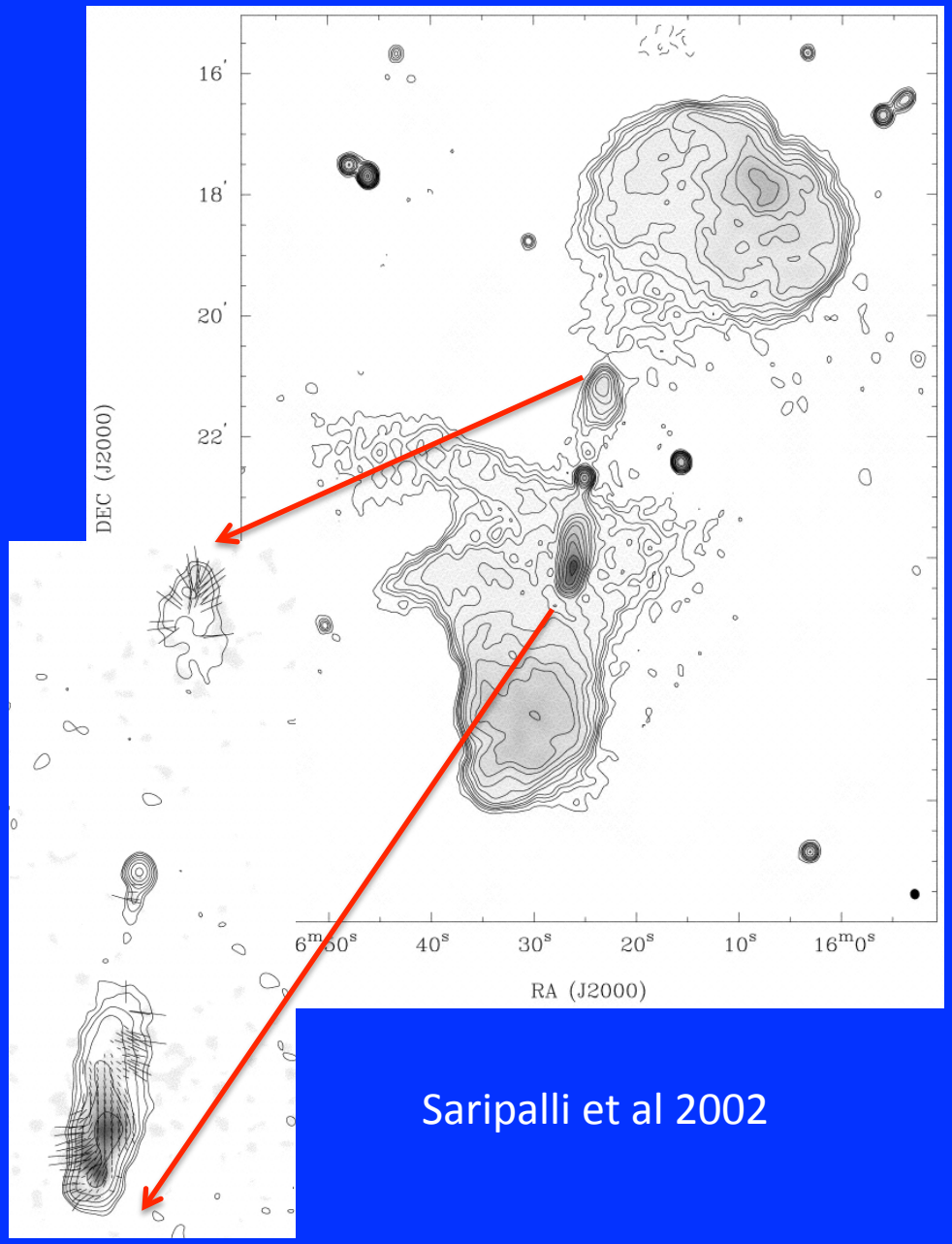
The very fact that new activity epochs were recognized implies dead FR-2 lobes do exist.

Why *do* we see dead FR-II lobes??

A way to determine AGN life cycles?

Re-energized? (Safouris et al, 2008, Brocksopp et al, 2010)

Denser environment?



Saripalli et al 2002

The ATLBS radio continuum survey

Collaboration

Ravi Subrahmanyan (Raman Research Institute)
Lakshmi Saripalli (Raman Research Institute)
Ron Ekers (CSIRO Astronomy & Space Sciences)
Elaine Sadler (University of Sydney)
Richard Hunstead (University of Sydney)
Helen Johnston (University of Sydney)
Kshitij Thorat (Raman Research Institute)

- Main Survey:

  Array configurations 750A, 750B, 750C and 750D.

  Configurations provided complete u-v coverage up to 750m

  19 pointings, cycled every 19x20 sec

  Beam=50”, rms noise = 80 μJy

  Lone 6 km antenna provided separate 5” images

- Follow up radio data

  Array configurations 6A, 6B, 6C, and 6D.

  Total time: 96 hrs

  Beam = 6”, rms noise = 72 μJy

  Full structural information

K-band & Optical data

- IRIS2 K-band imager on the 3.9-m AAT
- 700 pointings with median seeing about 1”
- completeness down to 19 mag

- MOSAICII imager on the CTIO NOAO 4-m Blanco telescope
- g, r, z imaging; 90% completeness to r = 22.5

- AAOmega on AAT spectroscopy (ongoing)

ATLBS Survey details

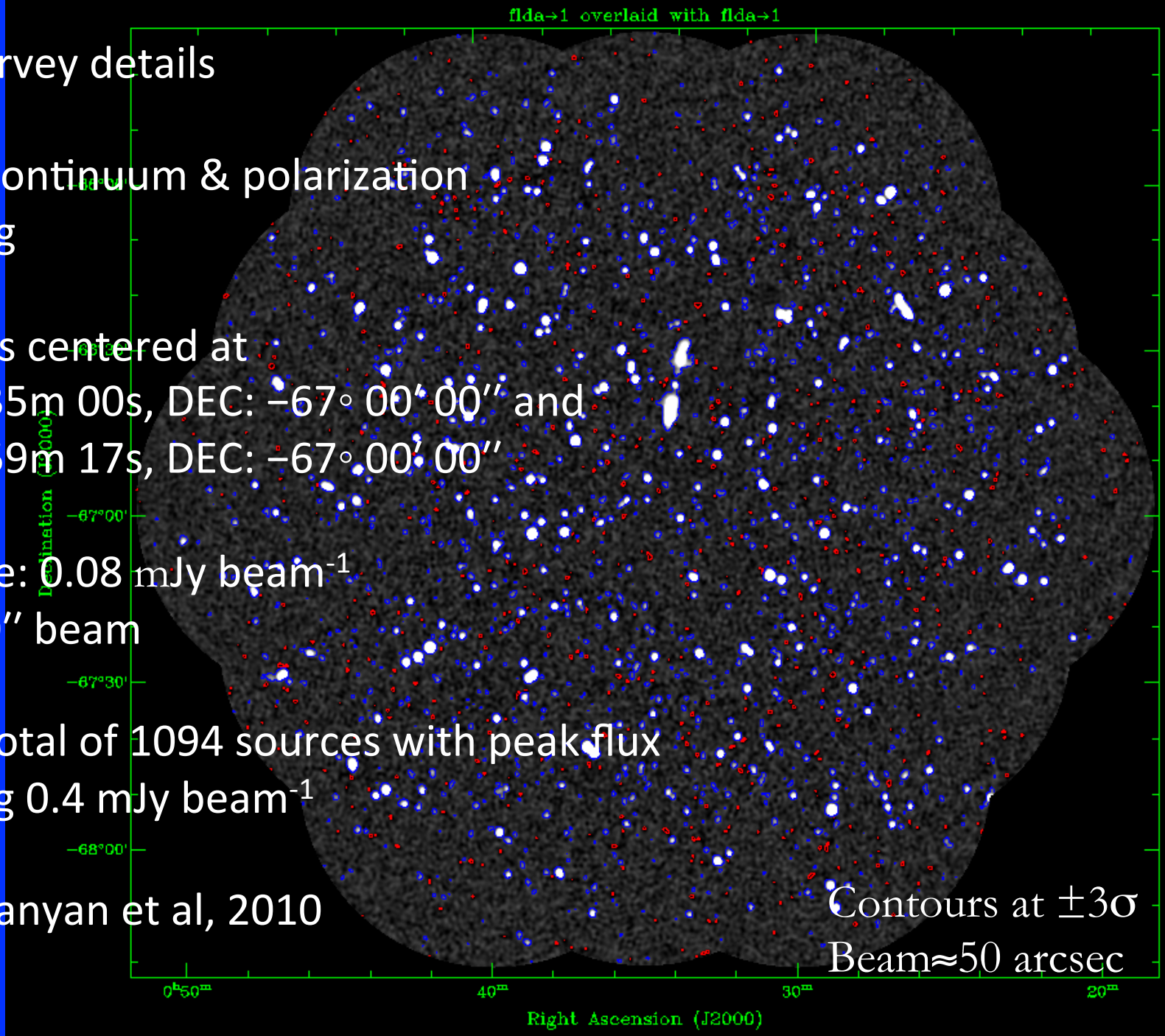
1.4 GHz continuum & polarization
8.4 sq deg

Two fields centered at
RA: 00h 35m 00s, DEC: –67◦ 00‘ 00’’ and
RA: 00h 59m 17s, DEC: –67◦ 00‘ 00’’

Rms noise: 0.08 mJy beam^{-1}
Beam: 50’’ beam

Detects total of 1094 sources with peak flux exceeding 0.4 mJy beam^{-1}

Subrahmanyan et al, 2010



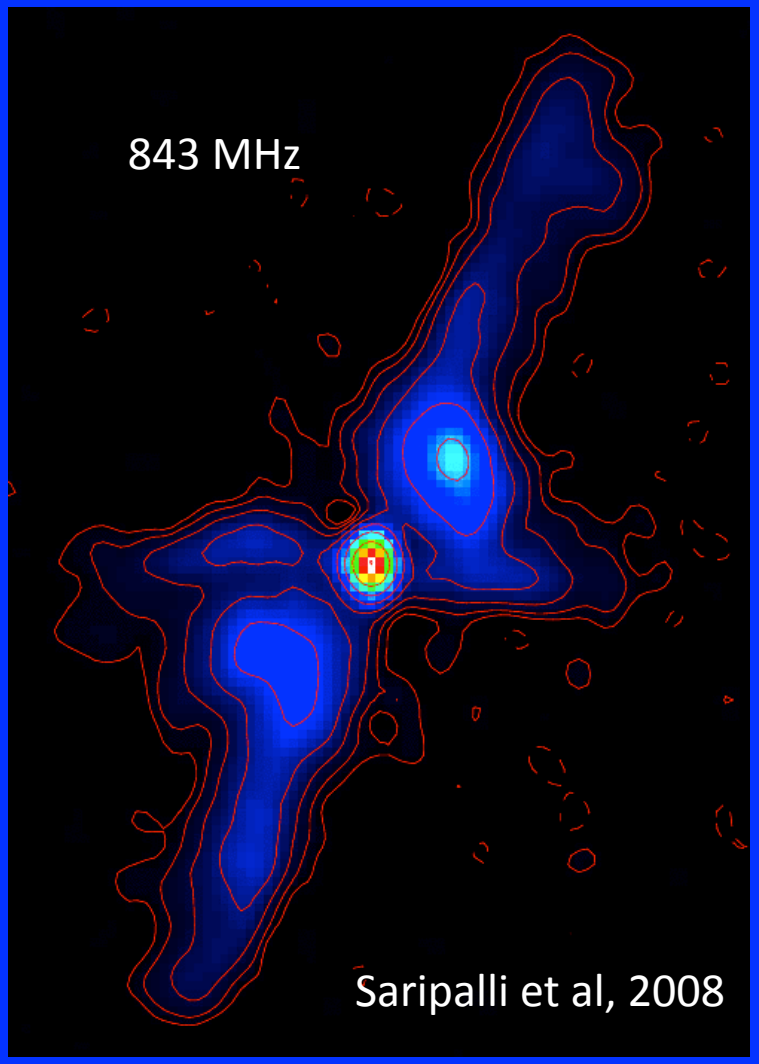
The extended source sample

- All sources from original survey with
  50”/5” Flux ratio > 1.5: 260 sources
- Each examined individually using maps from follow up radio data
- Total 119 sources with LAS > 30”
- Source characterization using 10” smoothed images

- Exquisite structural information

FR-Is - many questions

- Morphologies more than one type: 3C31 type, lobe-type (Parma et al, 1996; Eilek 2001)
- Origin not clear – can also be dying FR-IIs! (Ledlow, 1994; Baum et al, 1995; Saripalli et al, 2009)
- Evolution with z not known



A restarted, giant, X-shaped FR-I

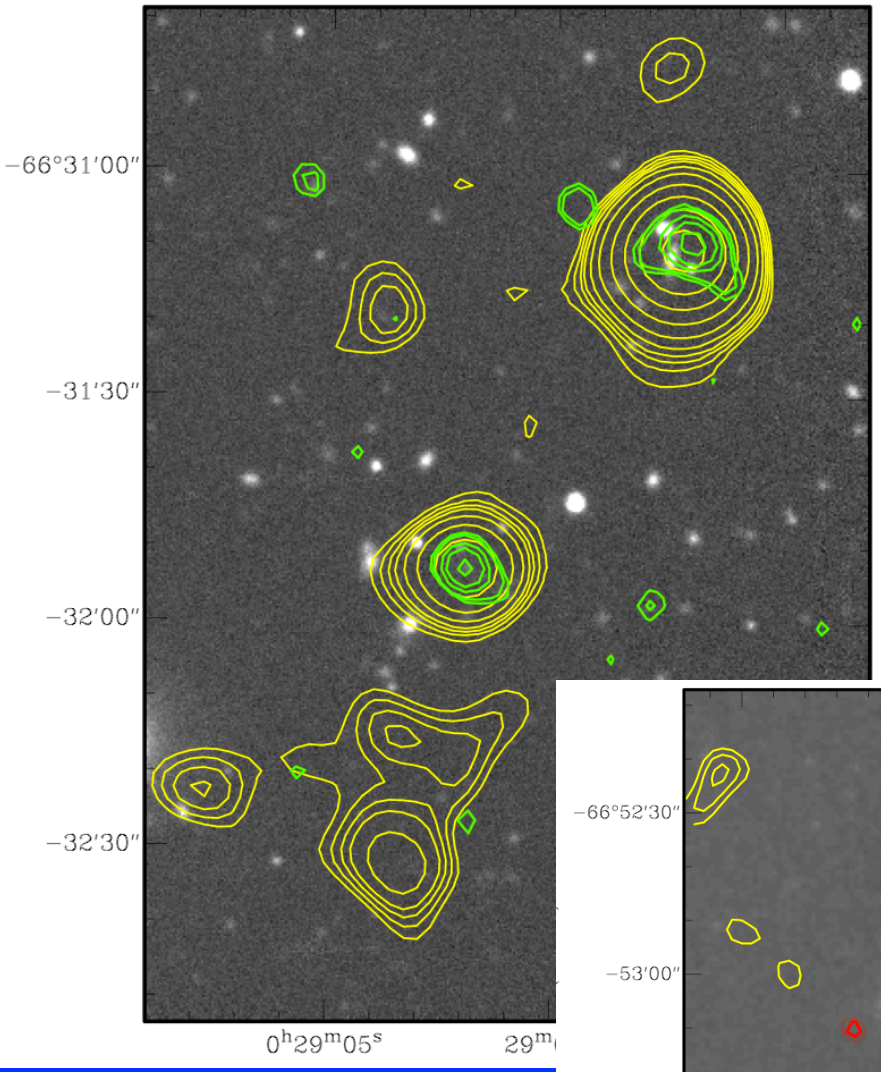
- low numbers and conflicting results that report
  - no evolution (Clewly & Jarvis, 2004) to
  - moderate evolution (Rigby et al, 2007) to
  - significant evolution (Sadler et al, 2007).
- Radio morphologies recognized to be key in sorting the issues.
- High surface brightness surveys much to offer

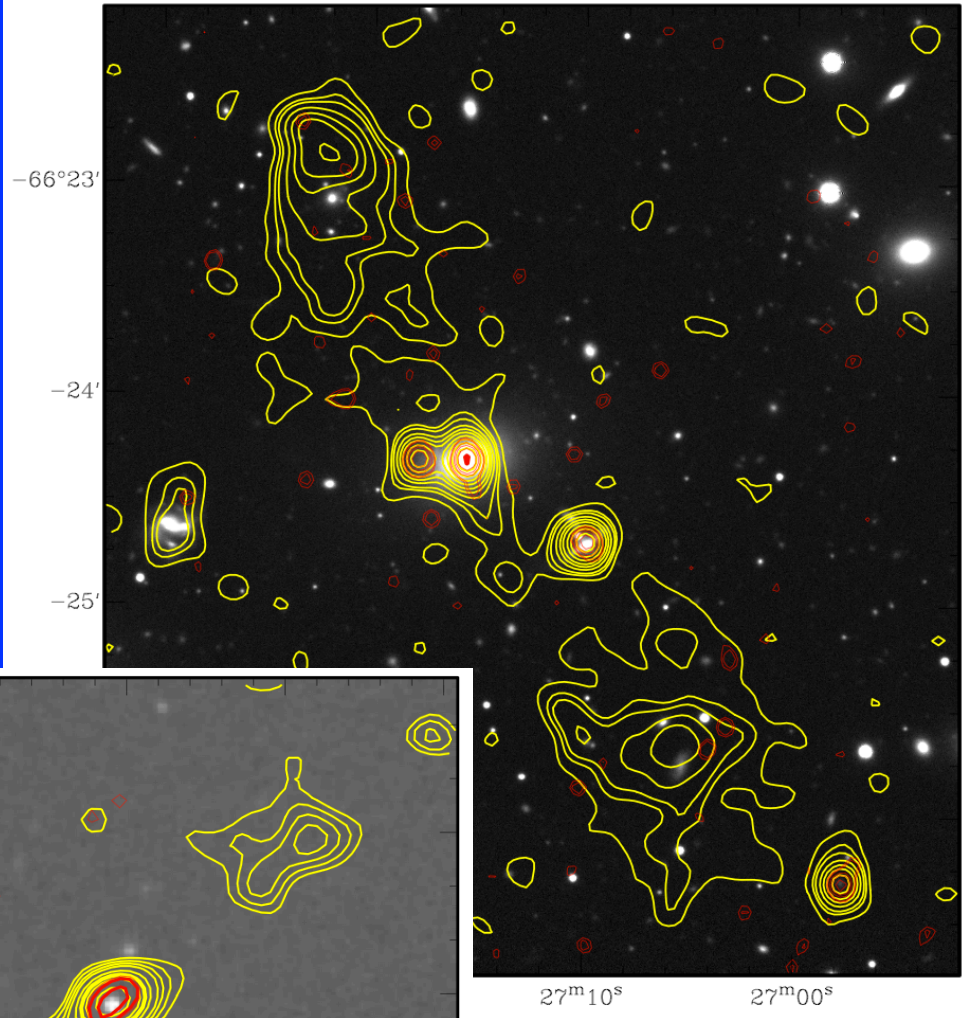
Main results

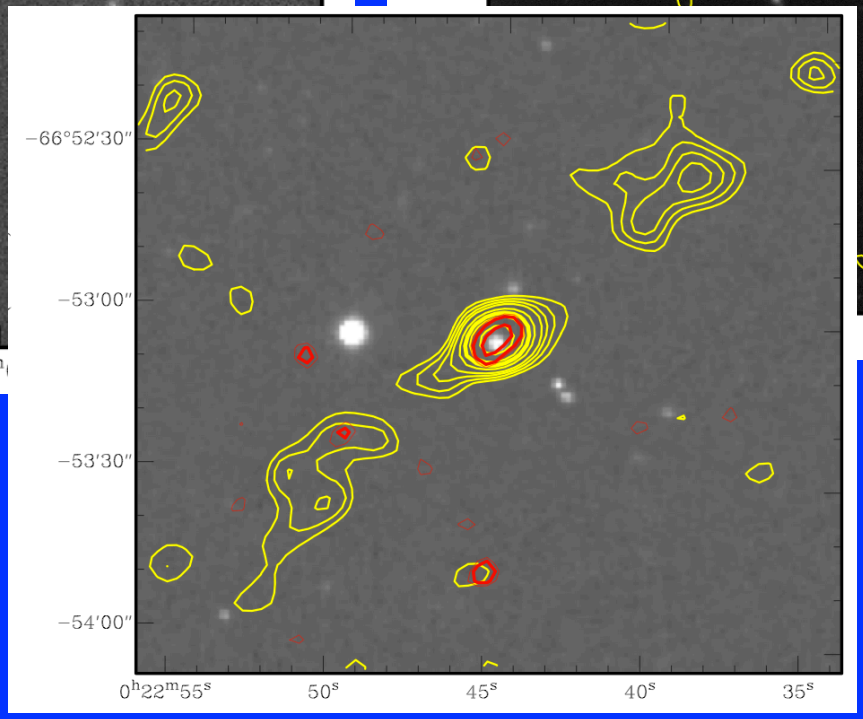
- almost equal fractions of FR-I (46%) and FR-II (54%) radio galaxies
  - fraction of sources with FR-I type appears to increase with decreasing flux density
- Large number (40%) of relatively high-redshift $z > 0.5$, FR-I sources.
- 13 giant radio galaxies (linear size > 700 kpc)
- 11 likely to be at redshifts, $z > 1$.
  - Giant radio sources not less common at high redshifts

Main Results

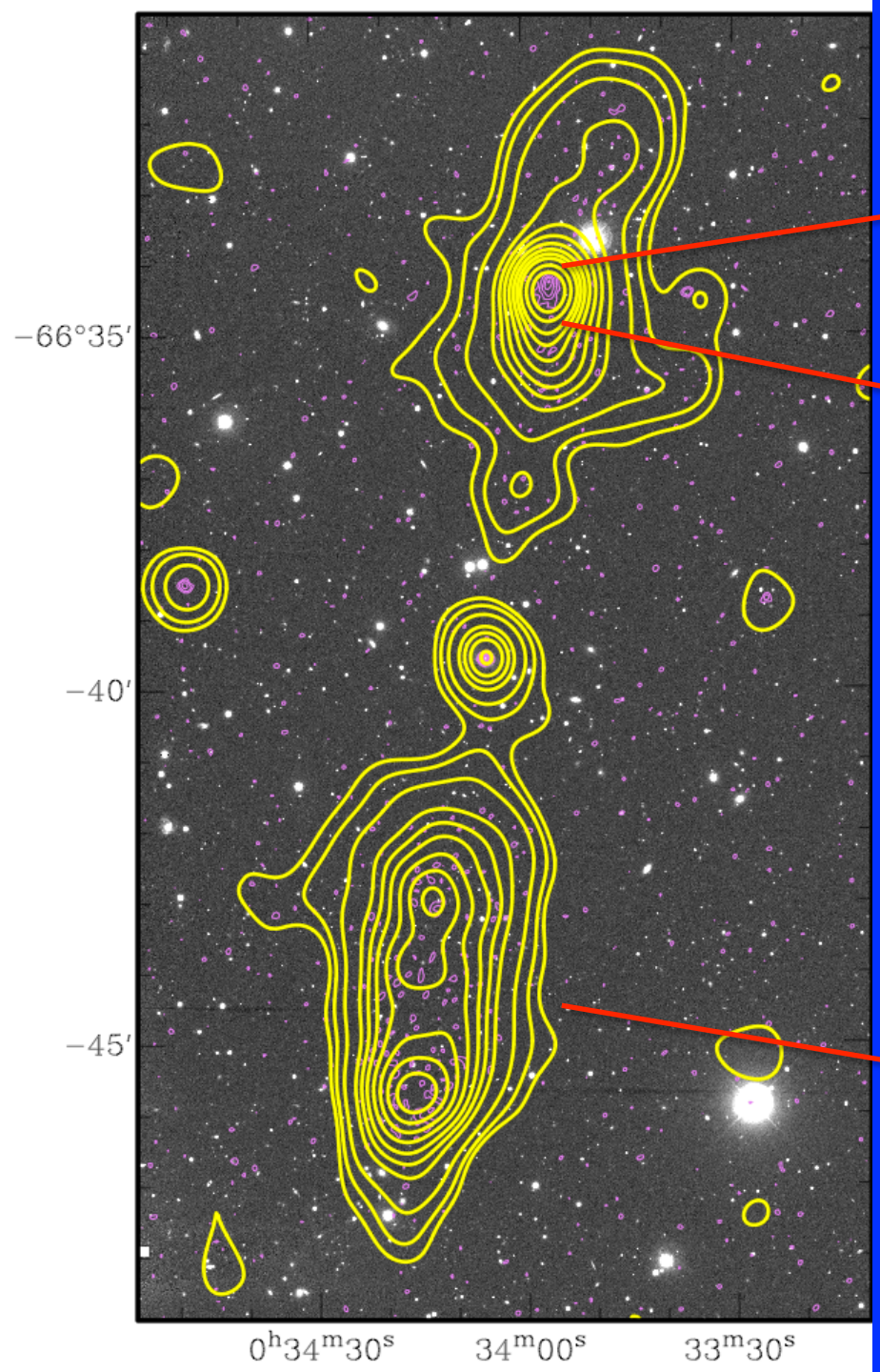
- Radio lobes with surface brightness down to ~ 1 mJy arcmin^{-2}
- Large number of restarted source candidates
  - Nearly 1 in every four may have restarted AGN activity
- Relic radio galaxies: they remain rare at 3%!

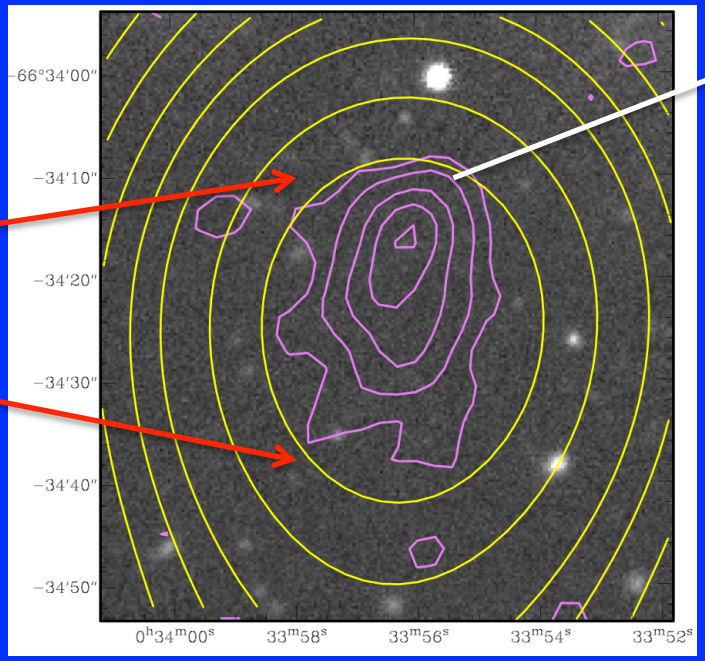






FR-II
Restarted
sources





Inner lobe head

The only compact feature in this lobe

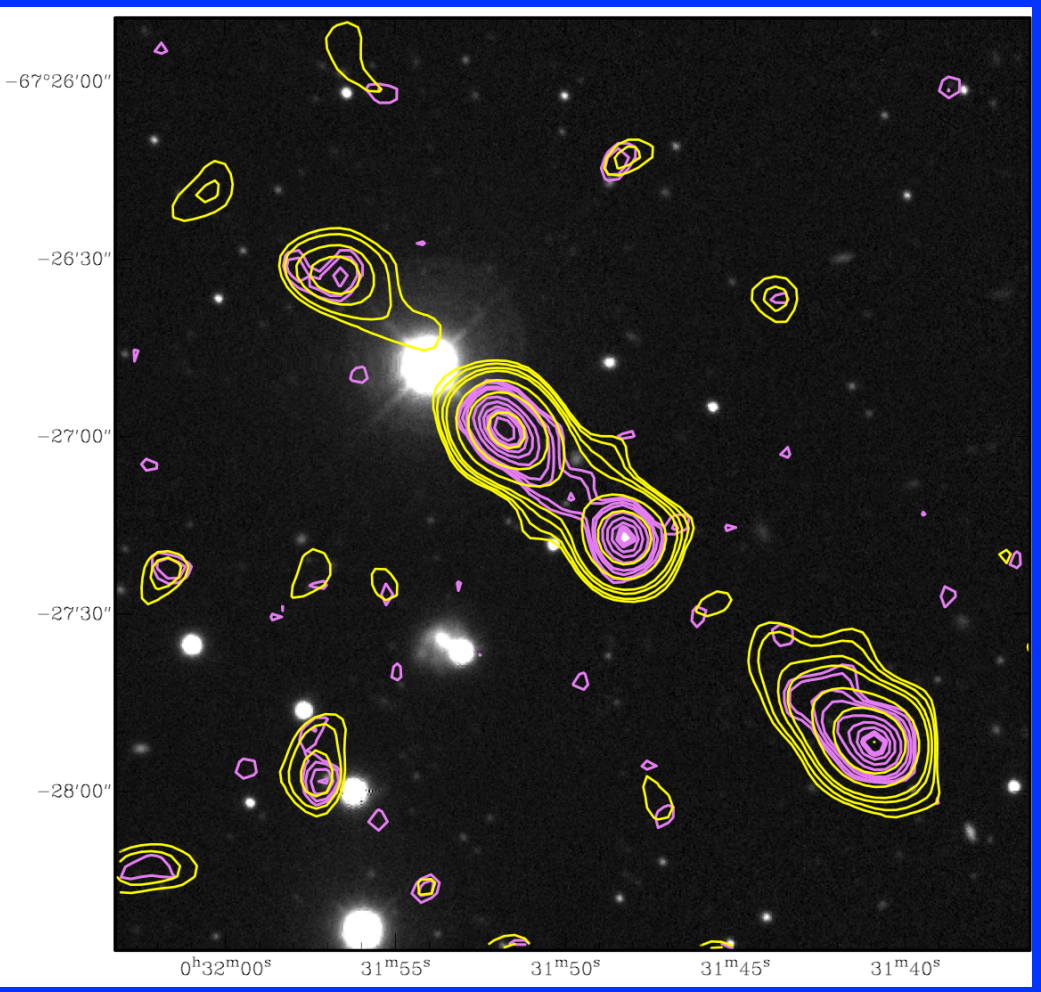
2 Mpc , z=0.11

FR-II Restarted AGN

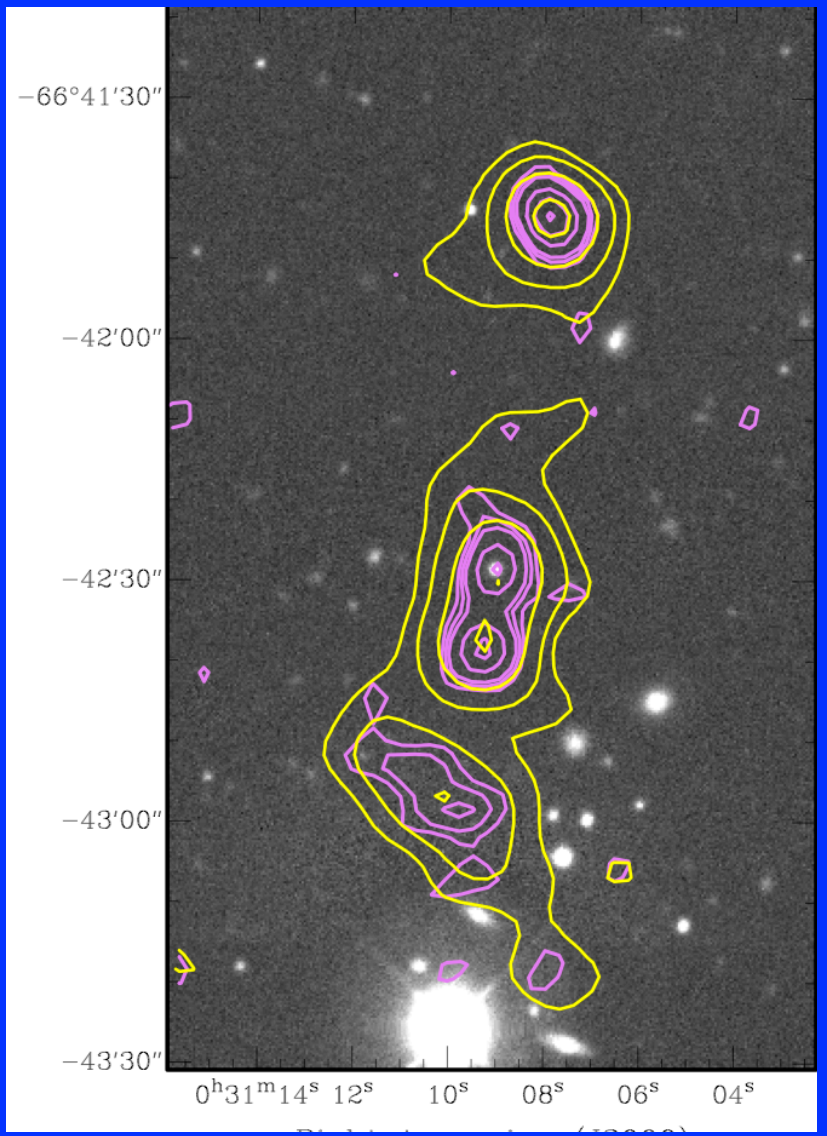
No compact source any where in the lobe

Faint lobes:
~ 1 mJy arcmin^{-2}

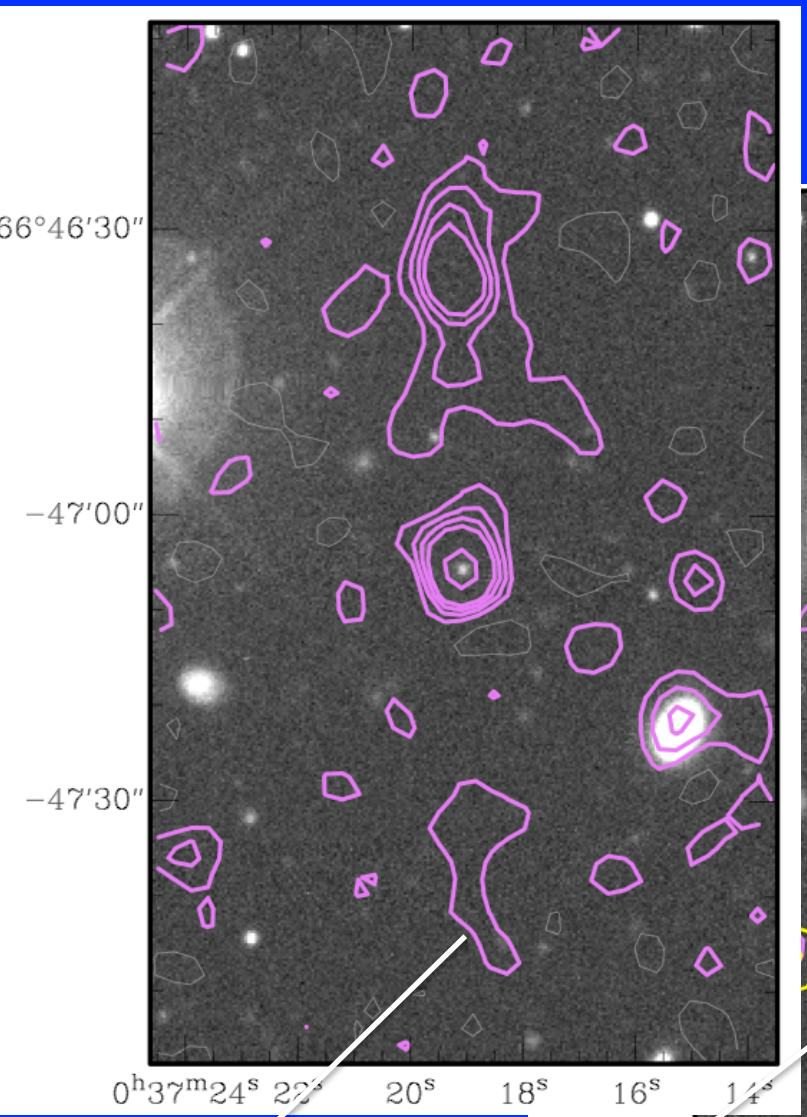
z = 1.156
Restarted quasar

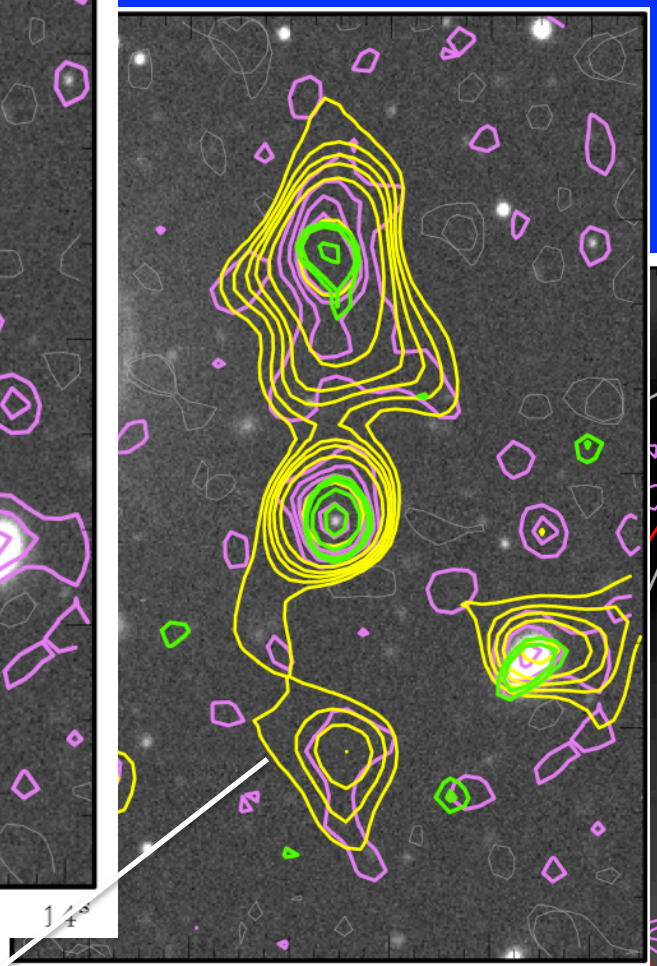


Possible quasar
Restarted AGN?



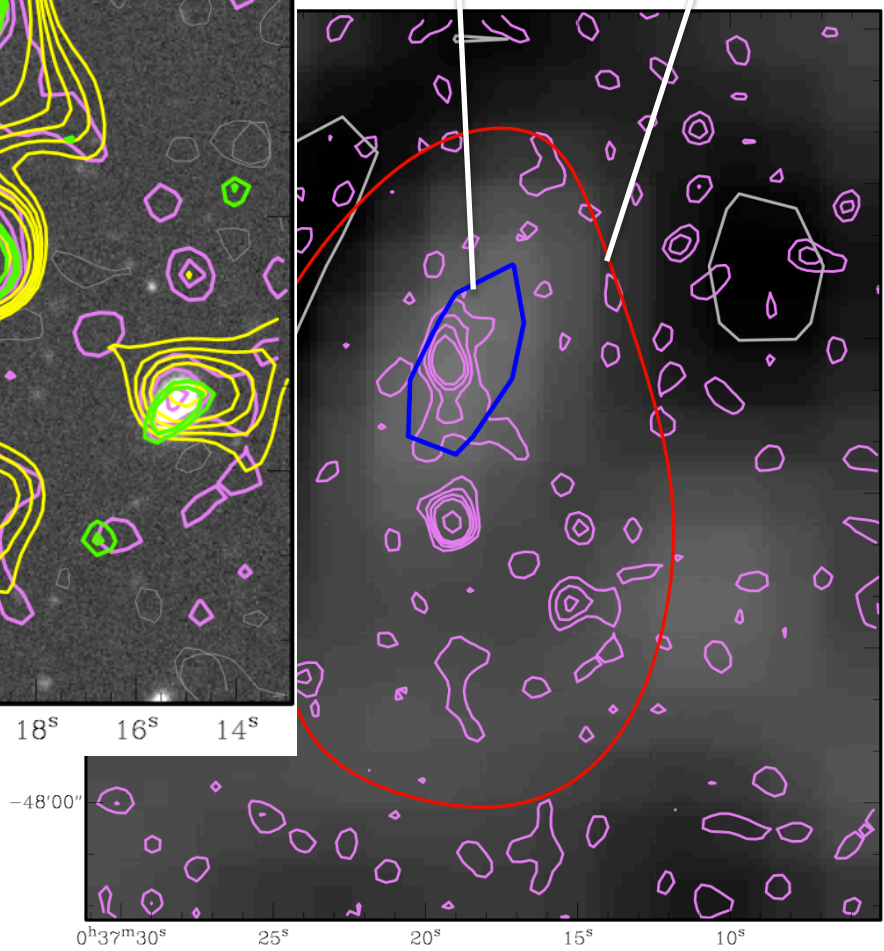
FR-II Restarted AGN





SUMSS
45” beam, 3σ

Original ATLBS
50” beam, 3σ

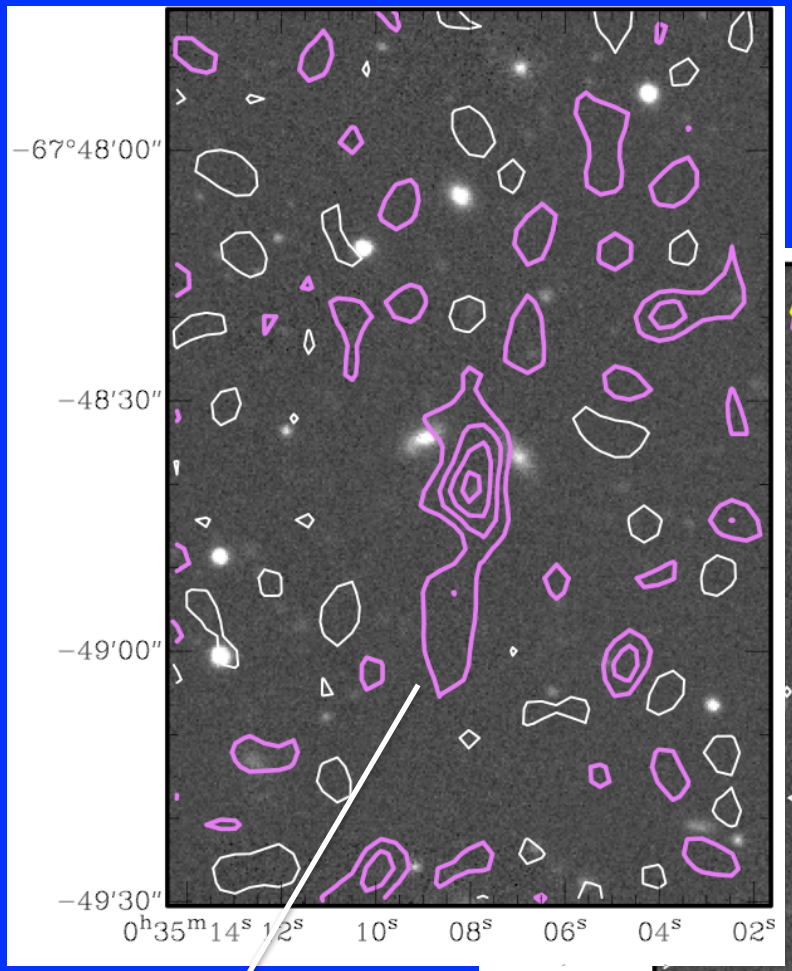


6” beam, 1.5σ

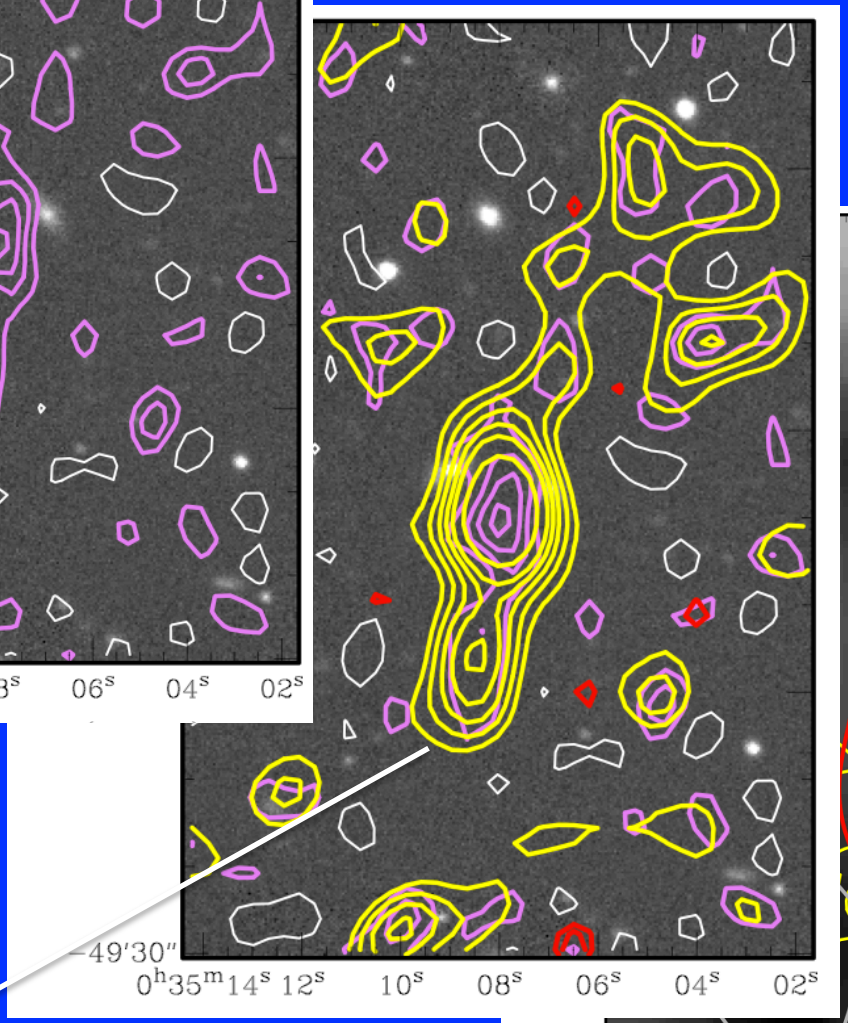
10” beam, 2σ

estimated z > 0.5, FR-I relic

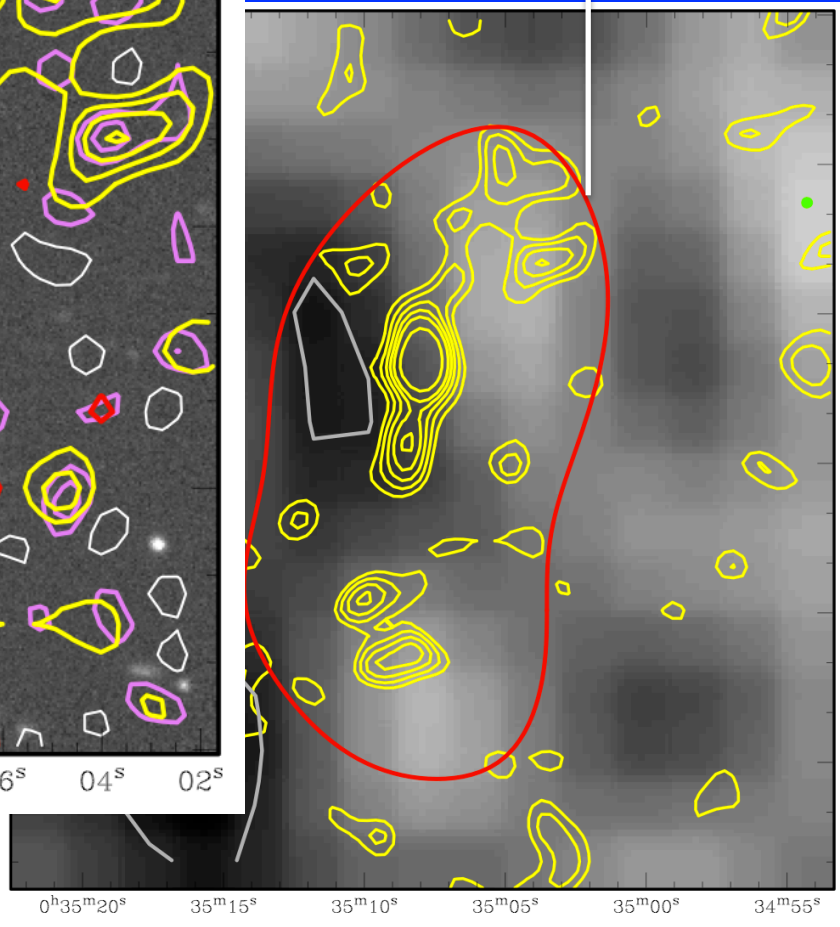
Original ATLBS 50” beam, 3σ.
Not seen at (SUMSS) 843 MHz



6” beam, 1.5σ



10” beam, 2σ
No compact structure anywhere



Thank you.