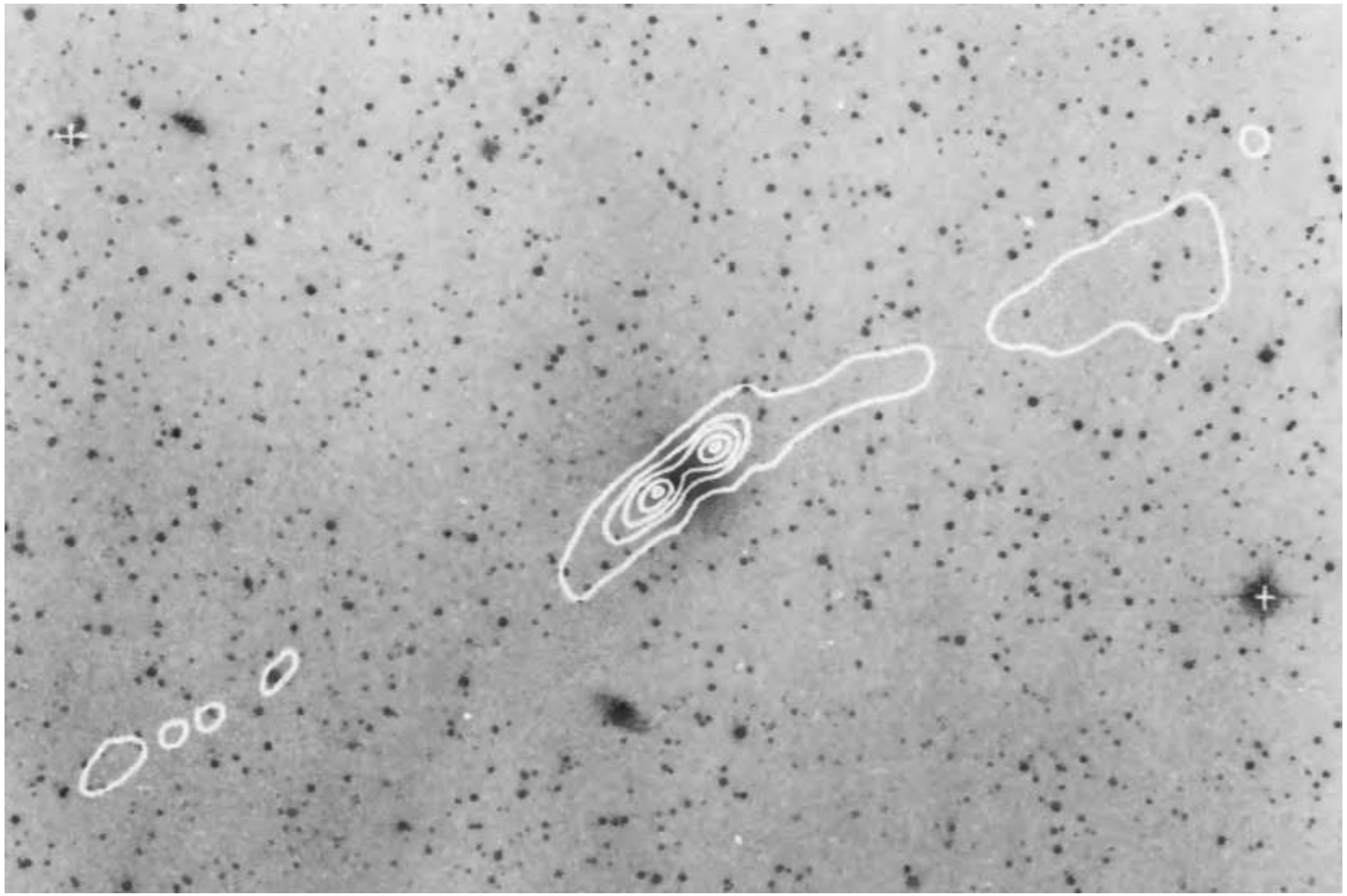
The importance of polarization in double-double radio galaxies

Vijay Mahatma

Martin Hardcastle, Emmanuela Orru, Luigina Feretti

Double-double radio galaxies

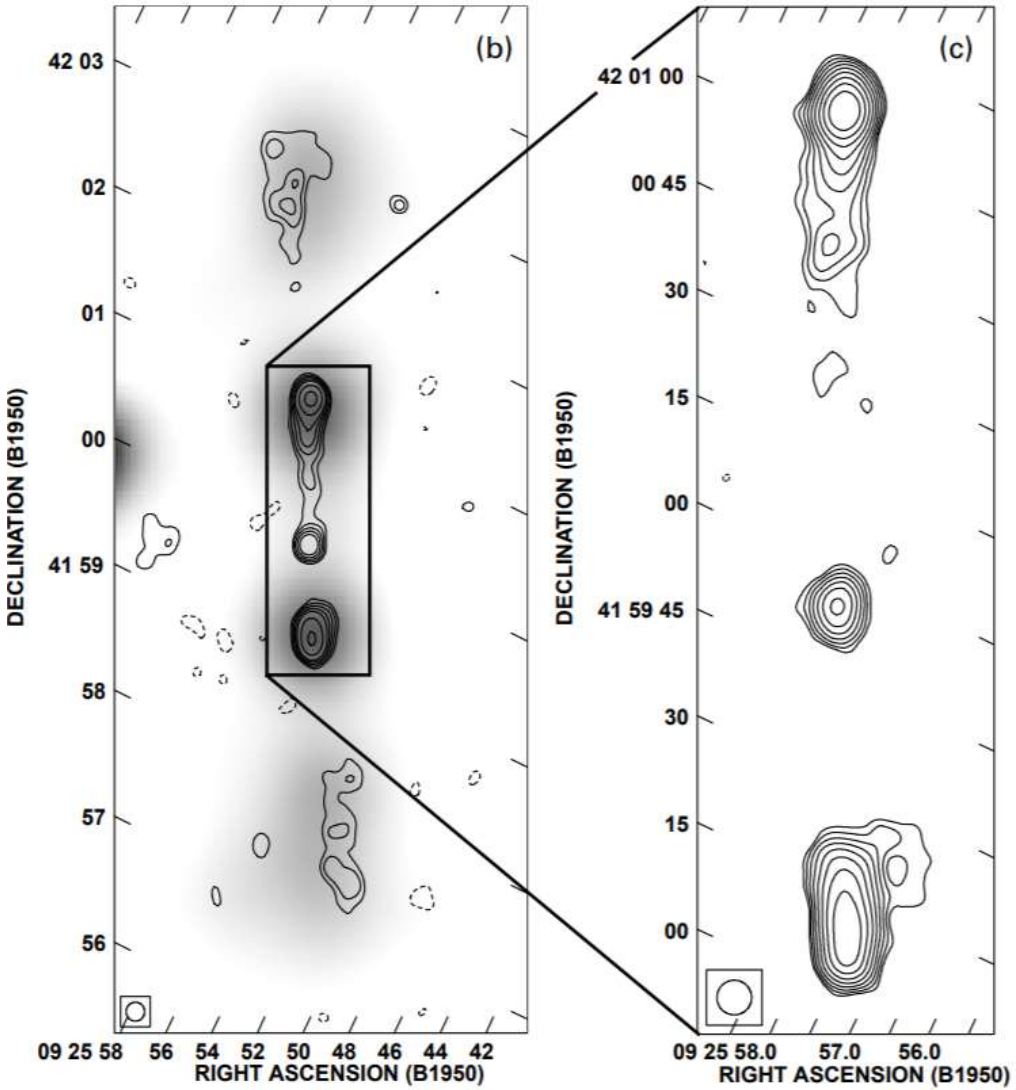


IC 4296; Goss et al. (1977)

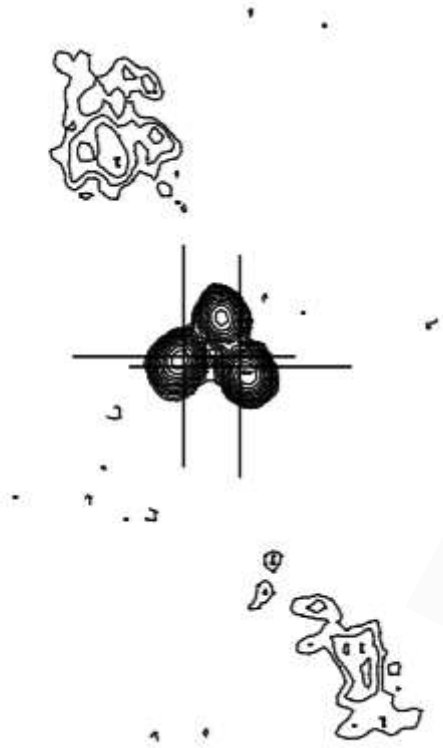
Double-double radio galaxies

Schoenmakers et al. (2000)

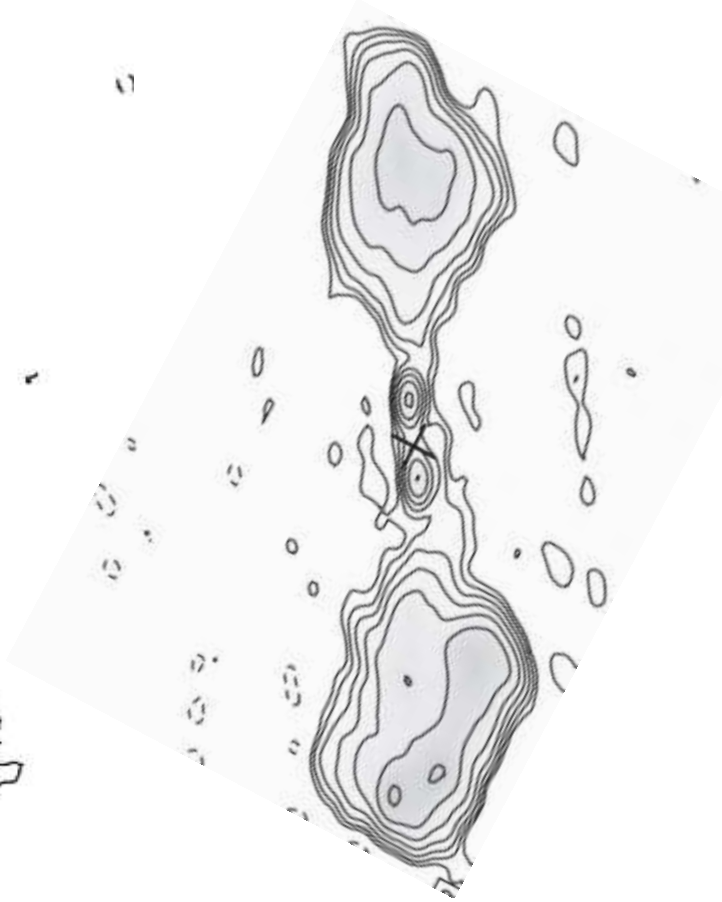
- Definition: Pair of radio lobes along the same projected jet axis (Schoenmakers et al. 2000)
- Most likely explanation being interruption of jet activity: birth of new jets
- Must be short interval between death of old jets and birth of new jets (due to short synchrotron cooling time)
- Quiescent phases are usually a small fraction of the active phase (Konar et al. 2012,2013)
- Short duty cycle – ‘interrupted’ activity not ‘recurrent’
- Short duty cycle suggests radio-quiet phase not significant in AGN feedback for these sources



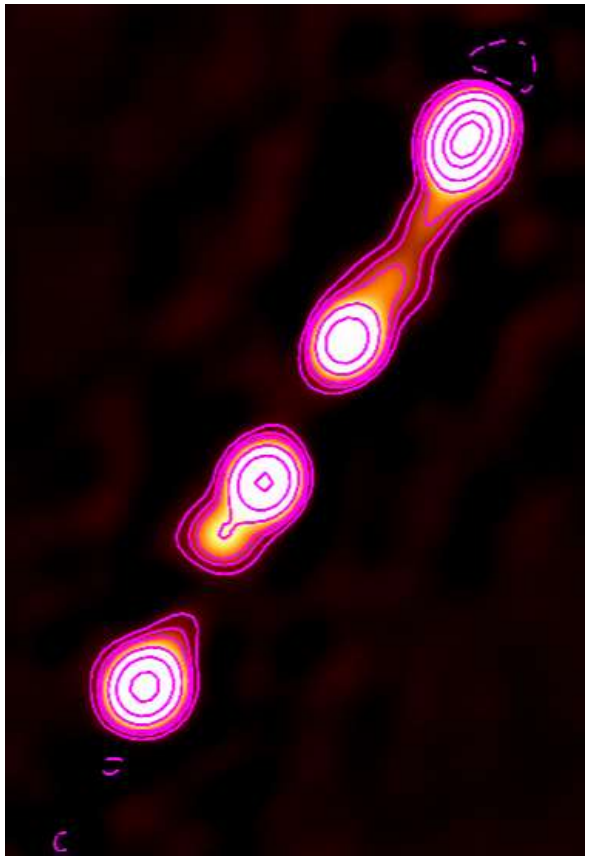
Double-double radio galaxies



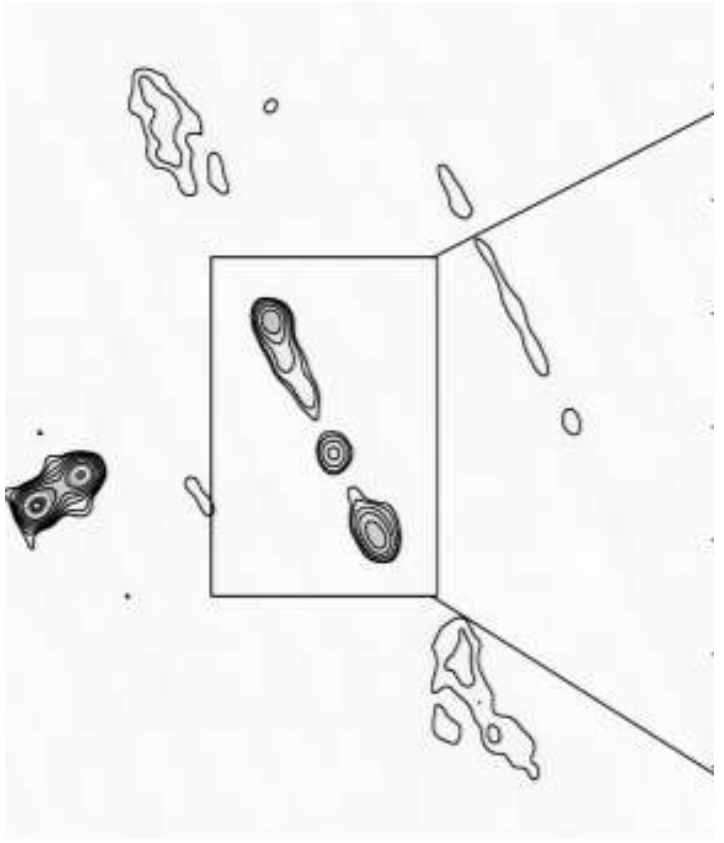
Marecki et al. (2021)



Nandi et al. (2019)

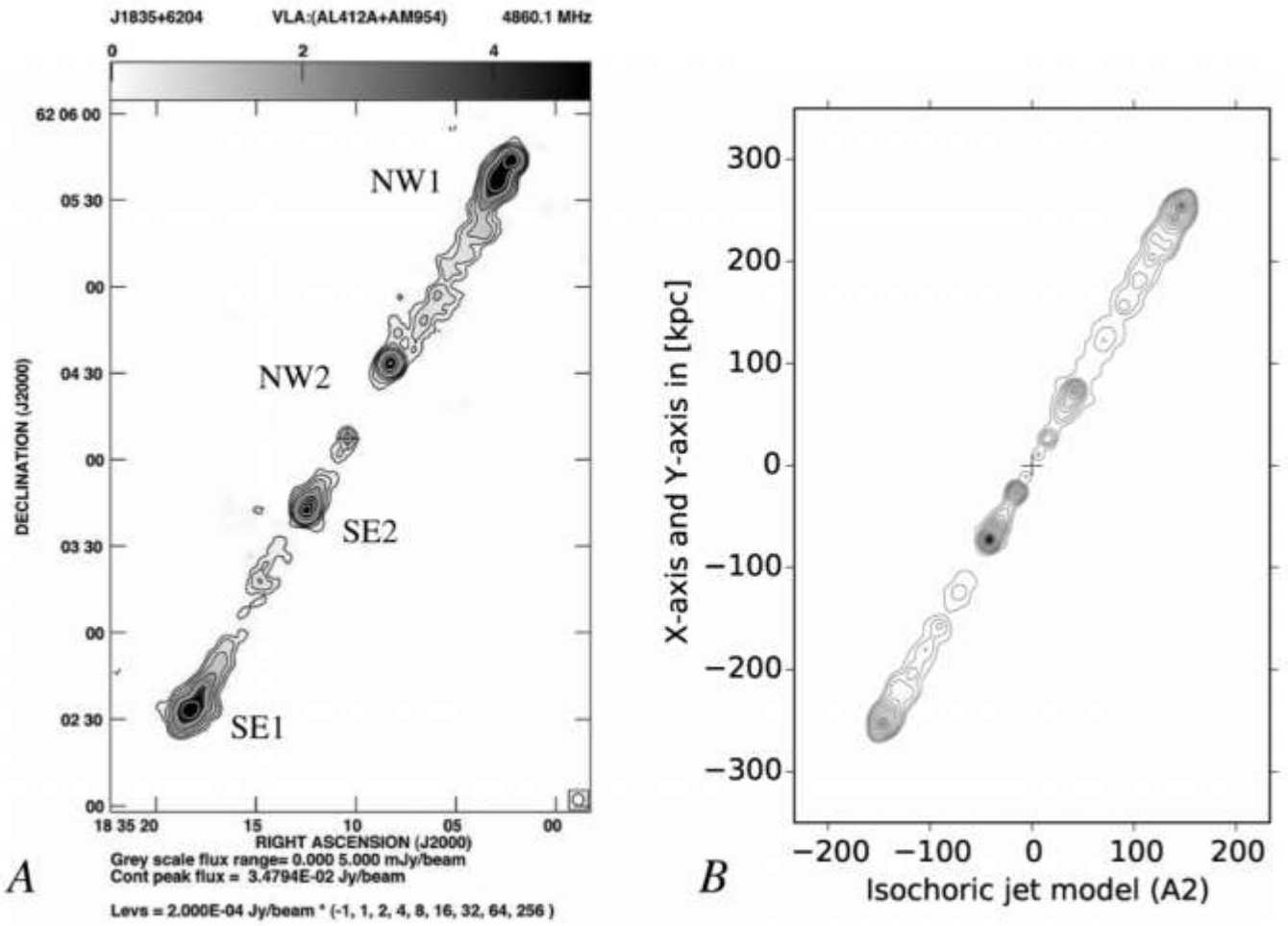


Orru et et al. (2015)



Brocksopp et et al. (2007)

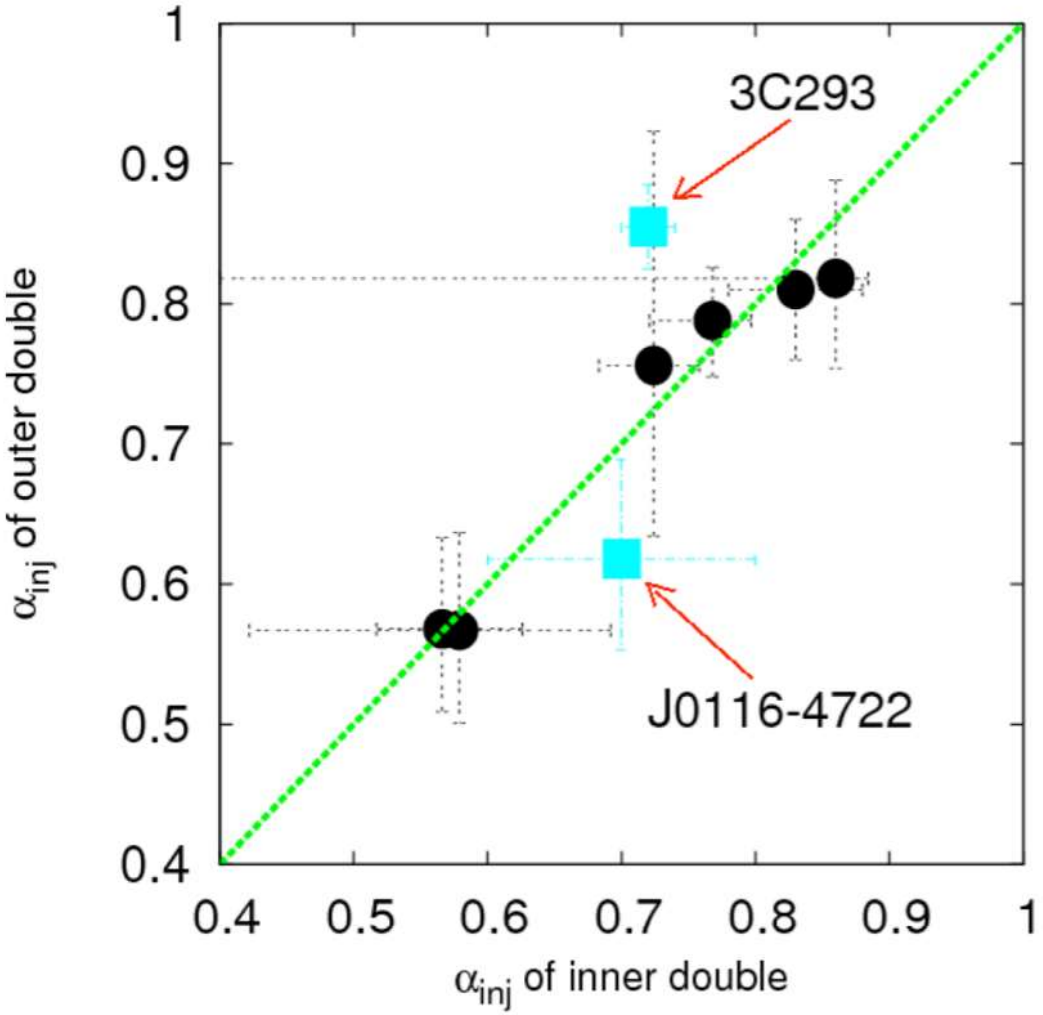
Simulations of DDRGs



Walg et al. (2020)

- Synthesized radio maps allow an inference of observational properties of known DDRGs
- Spectral ageing tends to become significant at ~300 MHz or greater – requires 150 MHz data to fully observe outer lobes
- New jets must emerge within <10% of the lifetime of the old jets

Energetics of DDRGs



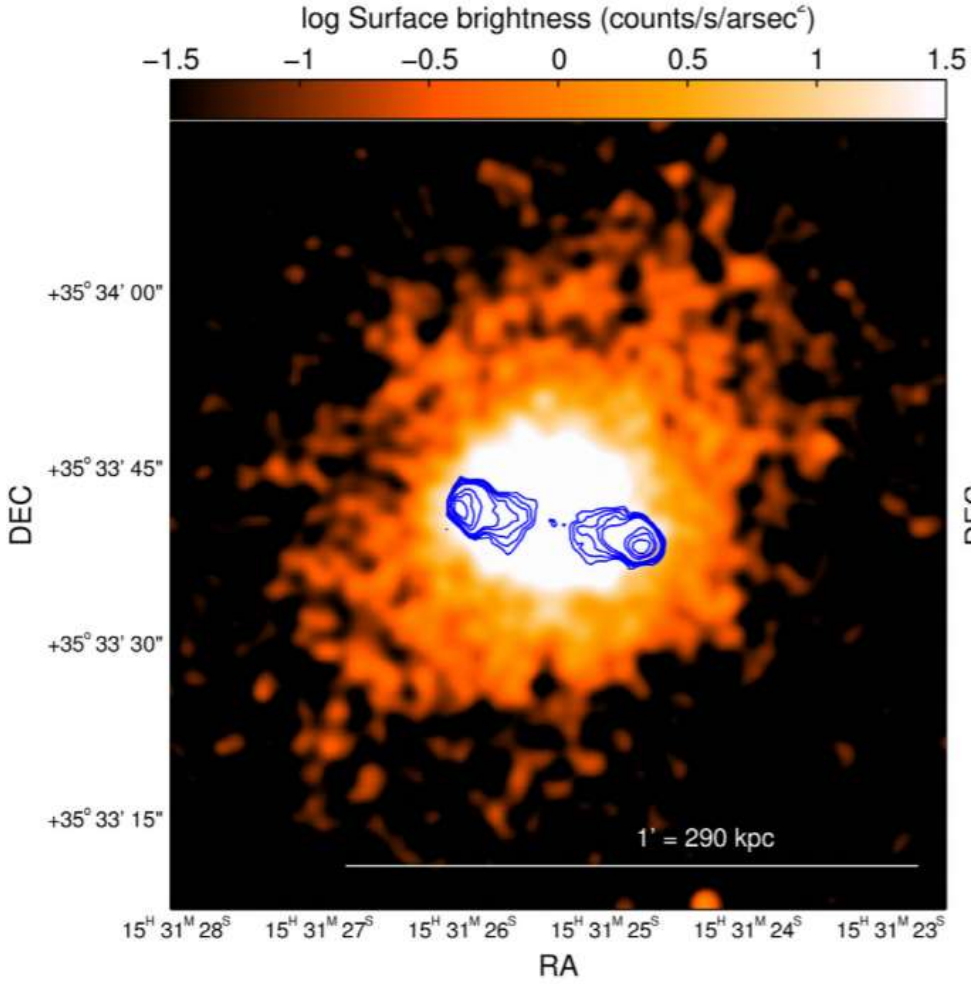
Konar et al. (2013)

- Spectral index measurements show a remarkable correlation between injection properties of inner and outer doubles
- Suggests similar jet powers of old and restarted jets
- Suggests that the dominant process driving the observed hotspots of the inner double is particle acceleration of the restarting jet (classical FR-II model), rather than re-acceleration of the old plasma through which the new jet is driving through (bow-shock model).
- Kaiser et al. (2000) suggest thermal particle content in outer lobes – need observational evidence!

Outstanding questions

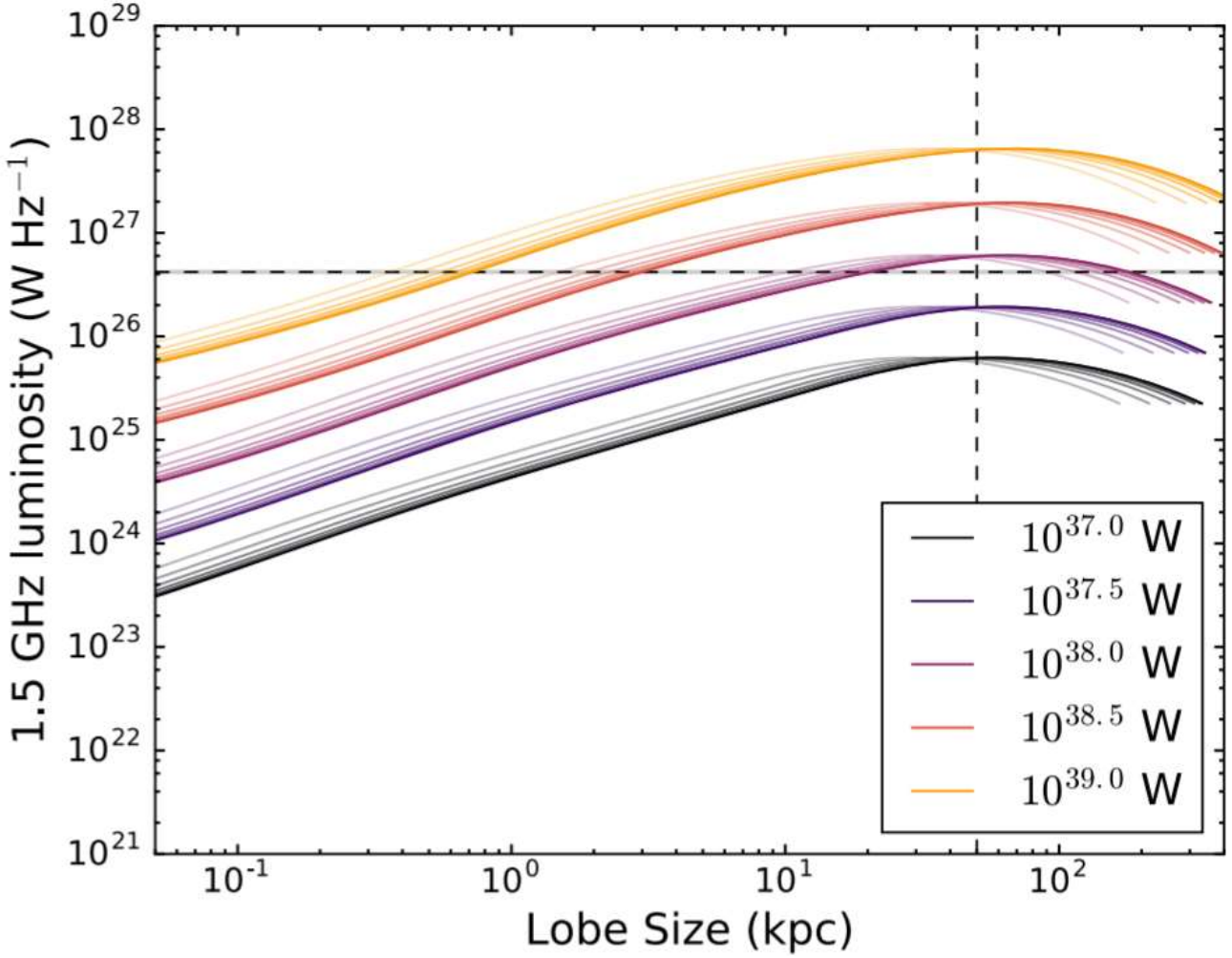
- Why do the jets get disrupted?
- What sets the timescale for new jets to begin
- Do jets really switch off or switch to a low jet power?
- Do the properties of DDRGs apply to other classes of restarted radio galaxies?
- Are the inner hotspots a consequence of jet termination shock or bow shock driving into old plasma?
- What is the particle composition of the inner and outer lobes
  - Without knowing composition, we don’t know the true kinetic output of radio galaxies

Clues for thermal content in radio galaxy lobes



- Use of analytic model calibrated by observations of 3C sources to determine jet dynamics (Mahatma et al. 2020)
- New modelling shows that thermal proton content is non-zero (Mahatma et al. in prep)

Clues for thermal content in radio galaxy lobes



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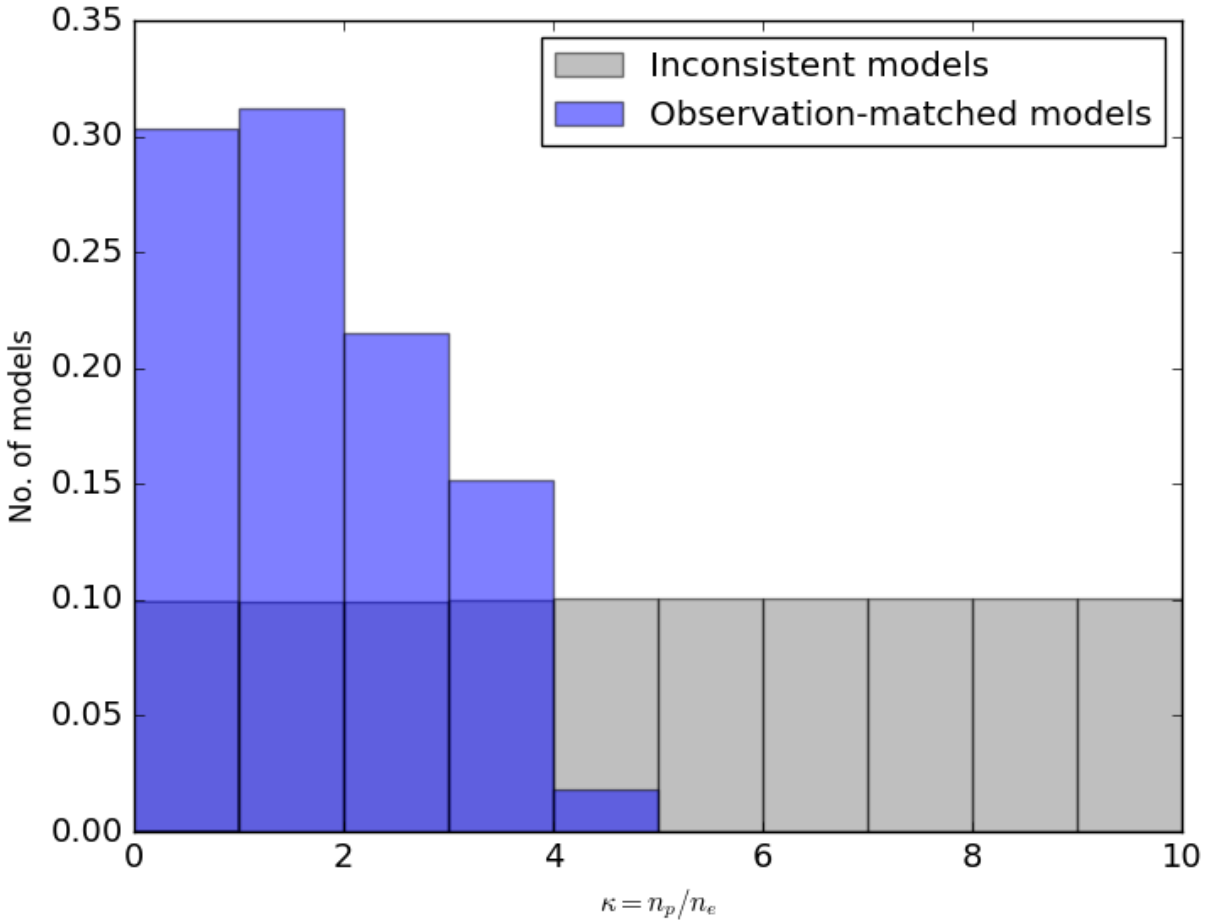

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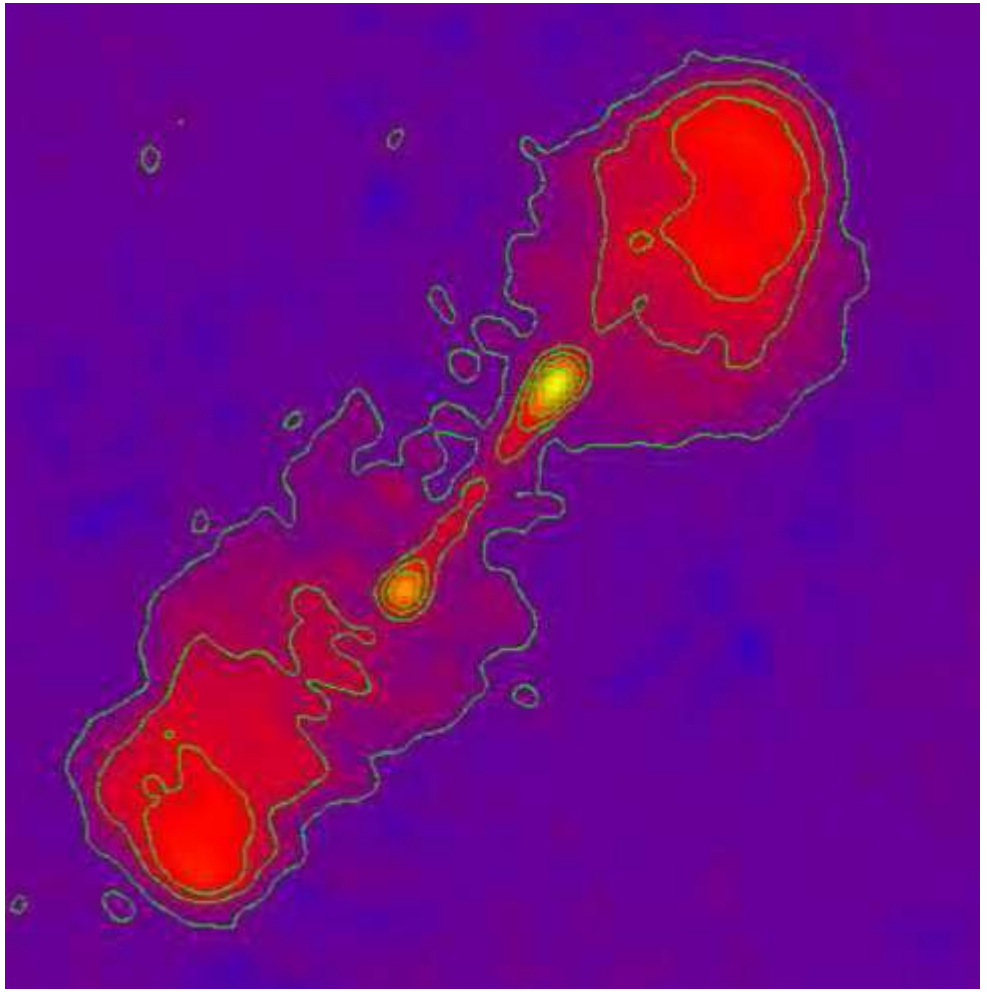
Aims

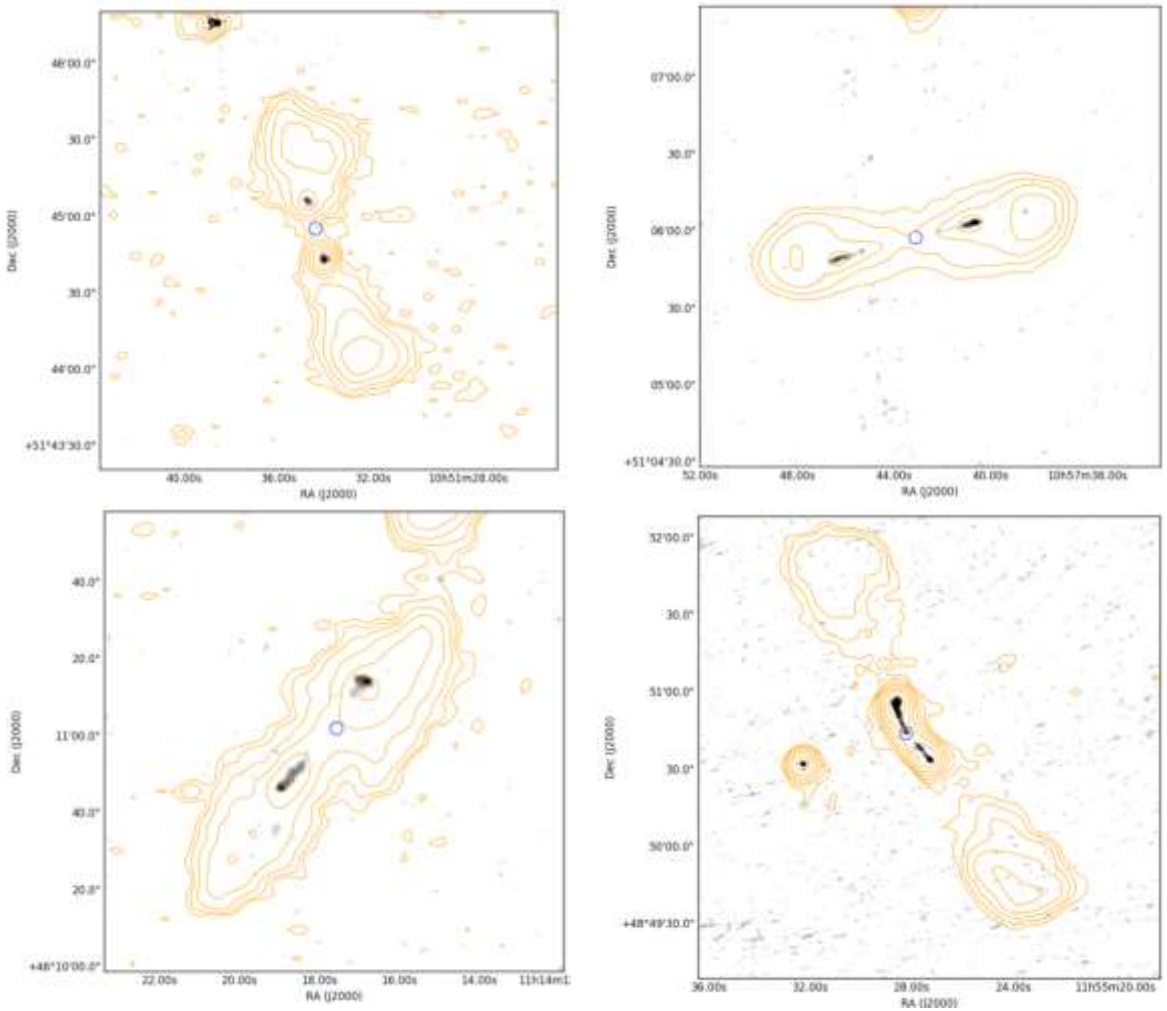
- What are the properties of DDRGs that are depolarized?
- If the inner lobes are depolarized relative to outer lobes, then we can trace the thermal particle content in the outer lobes.
- This can constrain models where inner hotspots are seen due to their impact with thermal material left behind by outer lobe plasma
- Use RM/depolarization to constrain thermal particle content

$$\mathrm{RM} = C \int n_{\mathrm{th}} B_{\parallel} \mathrm{d}z \ \mathrm{rad\ m^{-2}}$$



Konar et al. (2013)

DDRG sample



- ‘Candidate’ DDRGs identified by visual inspection in the HETDEX field using LOFAR (orange contours; LoTSS DR1 survey)
- 33 ‘confirmed’ as DDRGs using VLA high res observations showing inner hotspots (greyscale)
- Host galaxies typical of the population of radio galaxies

Mahatma et al. (2019)

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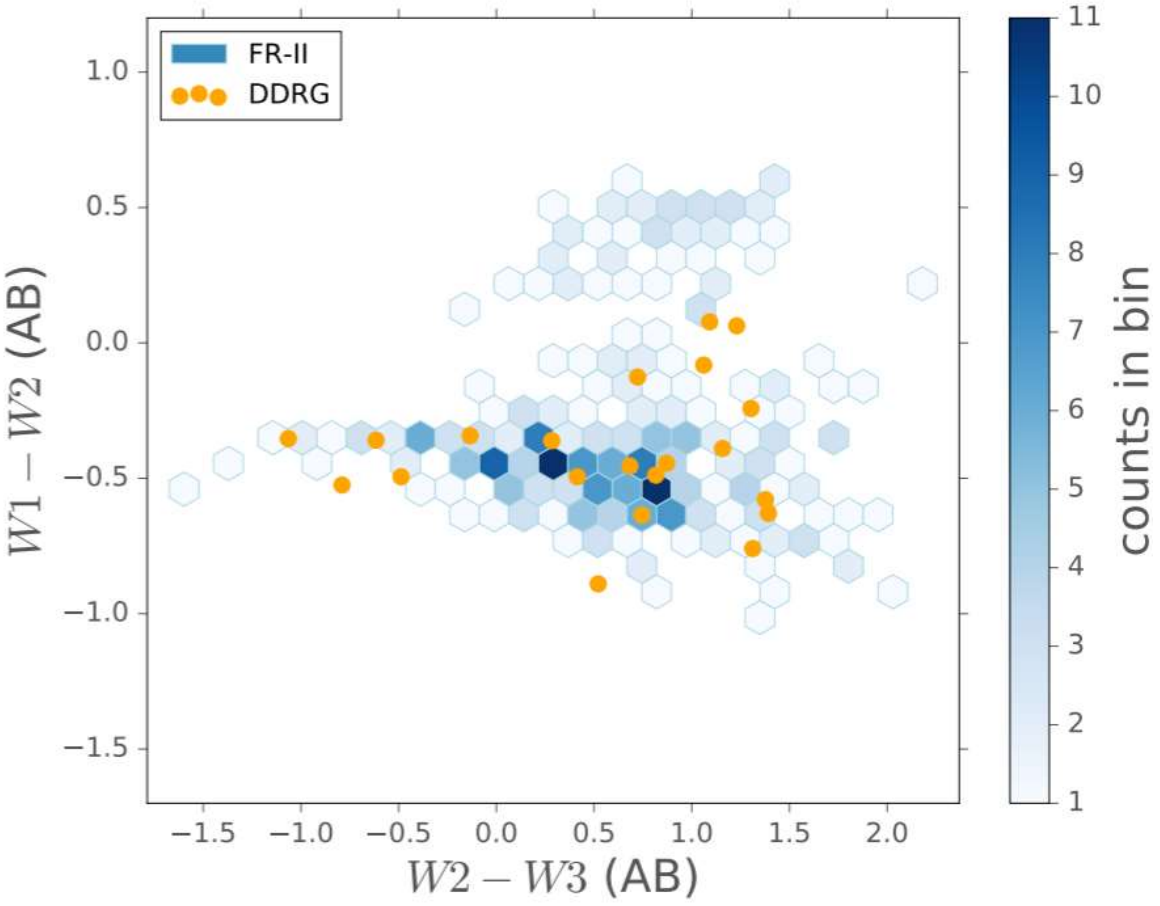

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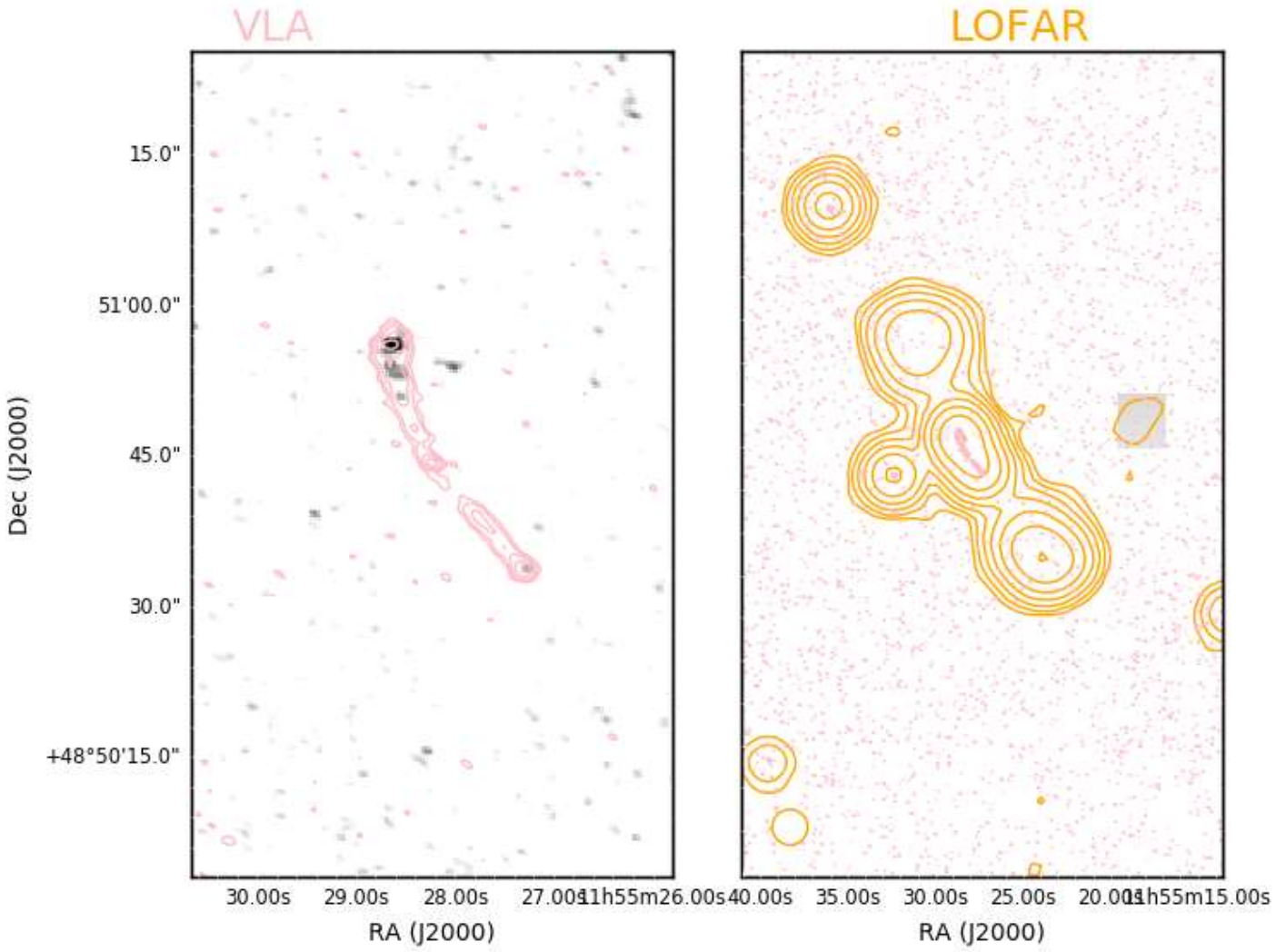
VLA 1.4 GHz linear polarization

- Observations made in full polarization mode
- Polarization calibration performed with 3C286 to calibrate cross-hand delays and phases
- Complex gain calibrators used to calibrated leakages (assuming low level of polarization)
- Q and U images produced in CASA and combined
- Preliminary linear polarization images..

VLA 1.4 GHz polarization images



- VLA 1.5” image (left panel) and LOFAR image 20” (right panel)
- Greyscale showing polarized emission
- ~7/33 polarized in our sample
- Inner doubles almost exclusively polarized over outer doubles
- No detection of both inner and outer doubles in polarization (sensitivity limitation of VLA snapshots)

Mahatma et al. (in prep)

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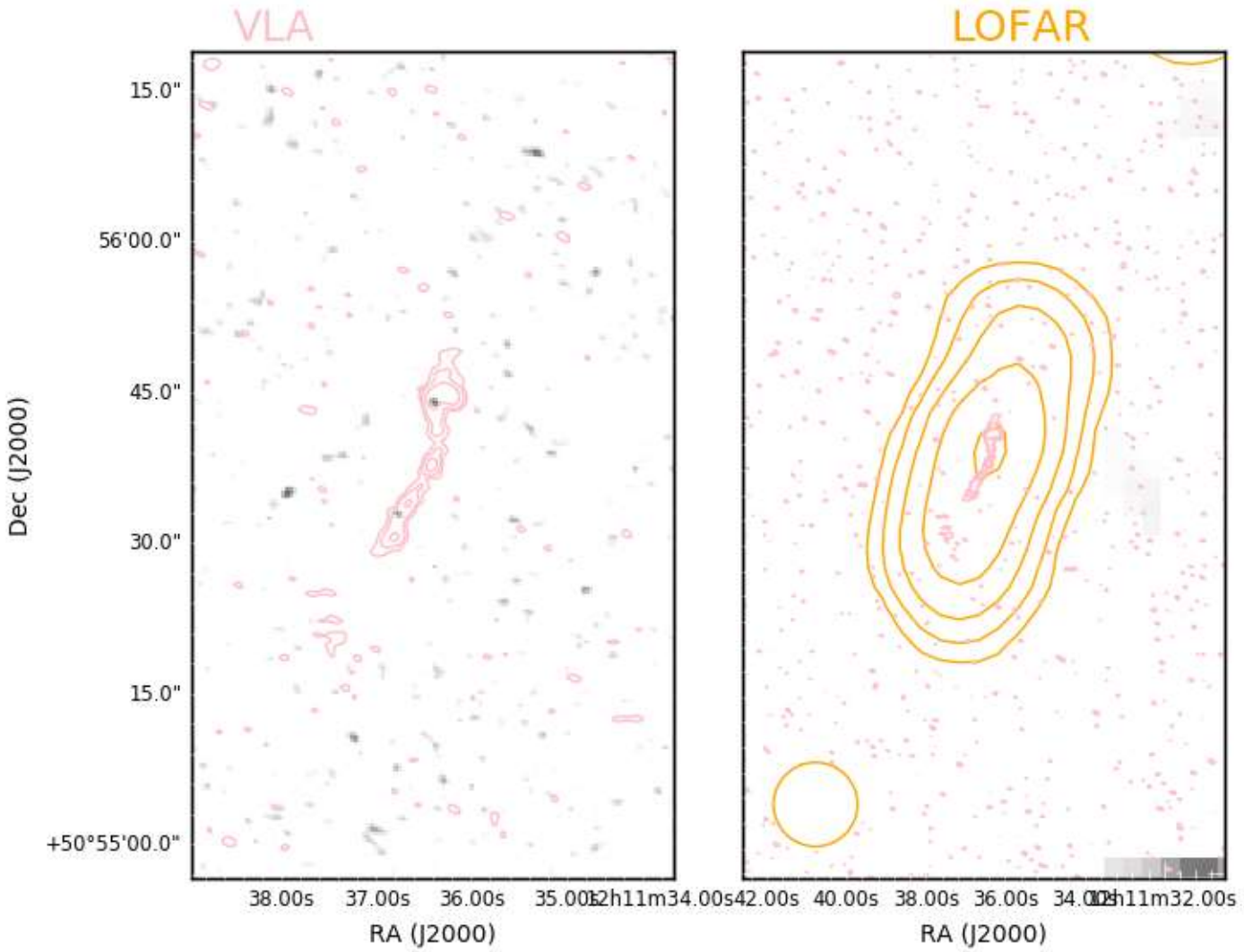

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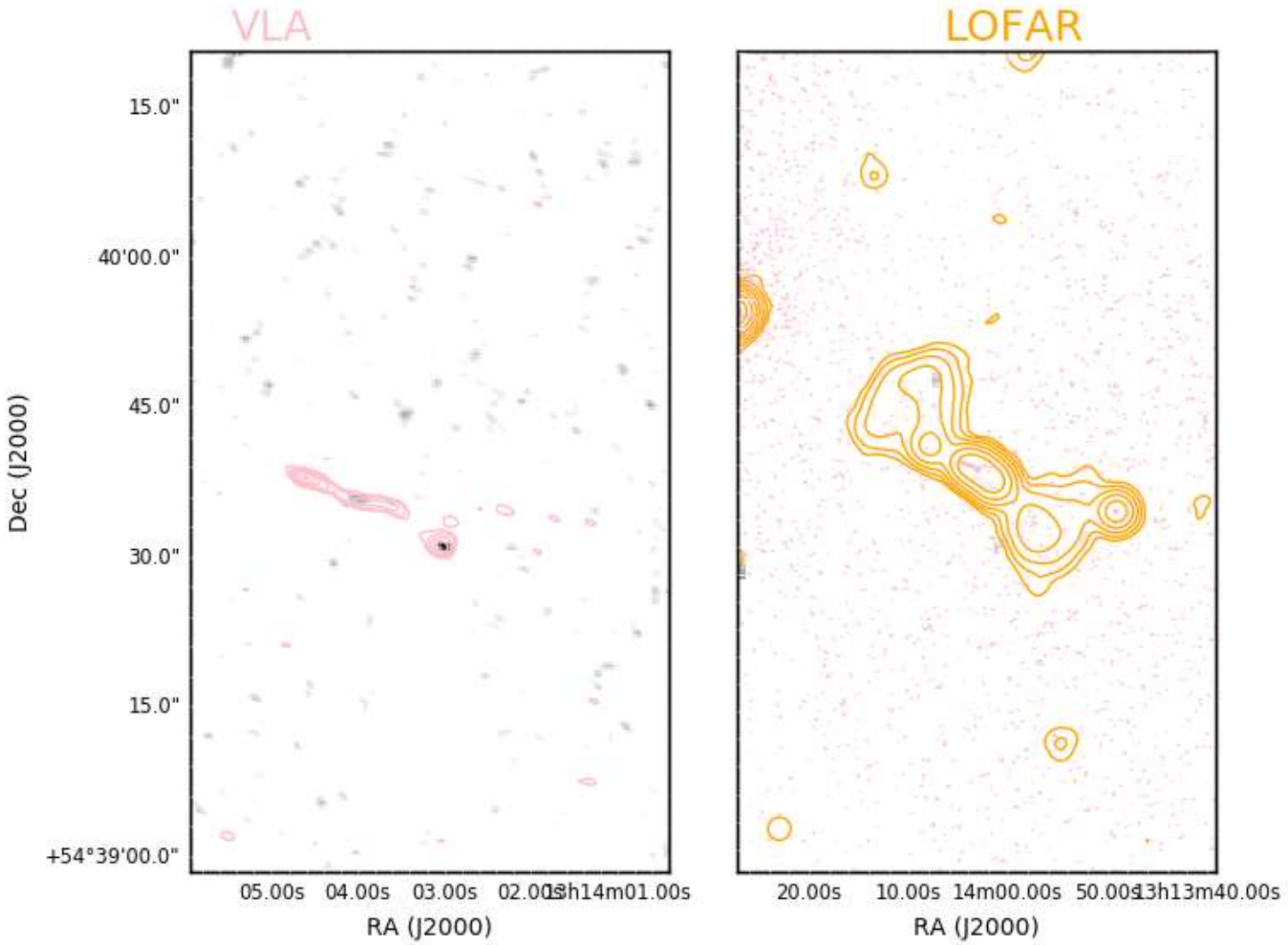

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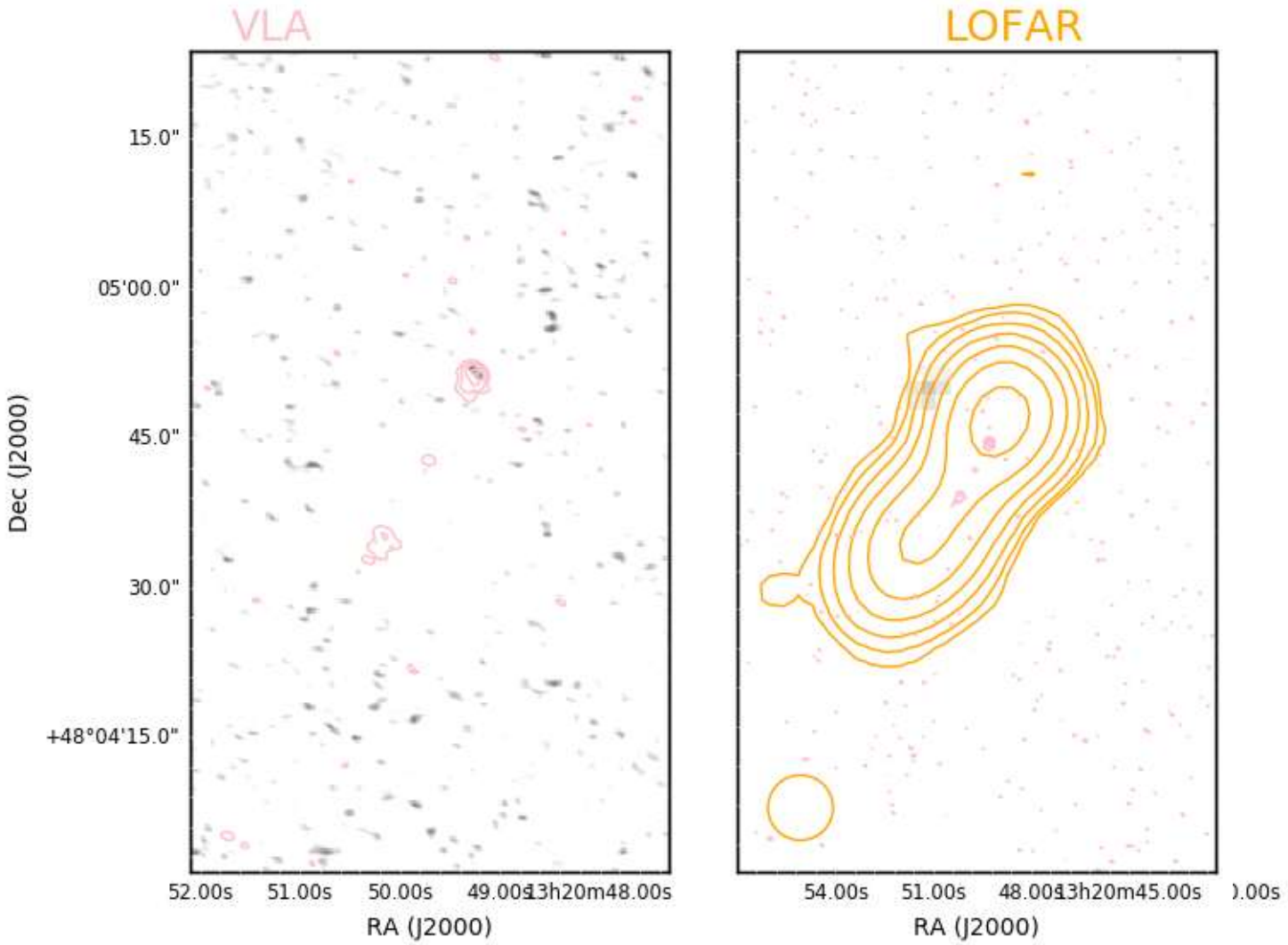

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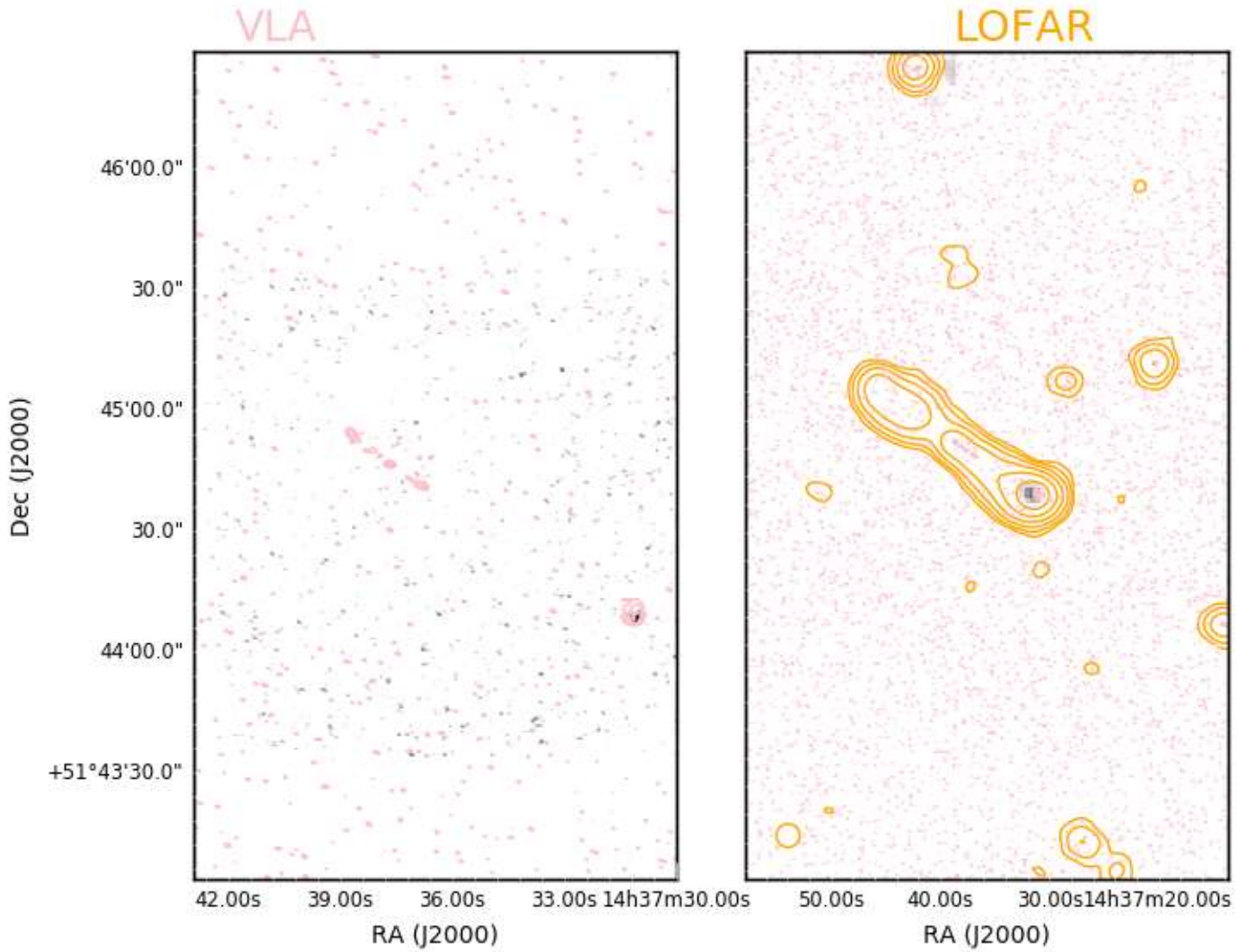
Polarization in outer lobes



- Outer lobe polarization seen in only 2 sources, but inner lobes depolarized at 150 MHz and 1.4 GHz
- ‘Excess’ Faraday rotation in inner lobes in these sources due to foreground or thermal material in outer lobes
- Can constrain limits on thermal particle content (in progress)
- New polarized DDRG found through reanalysis of VLA data

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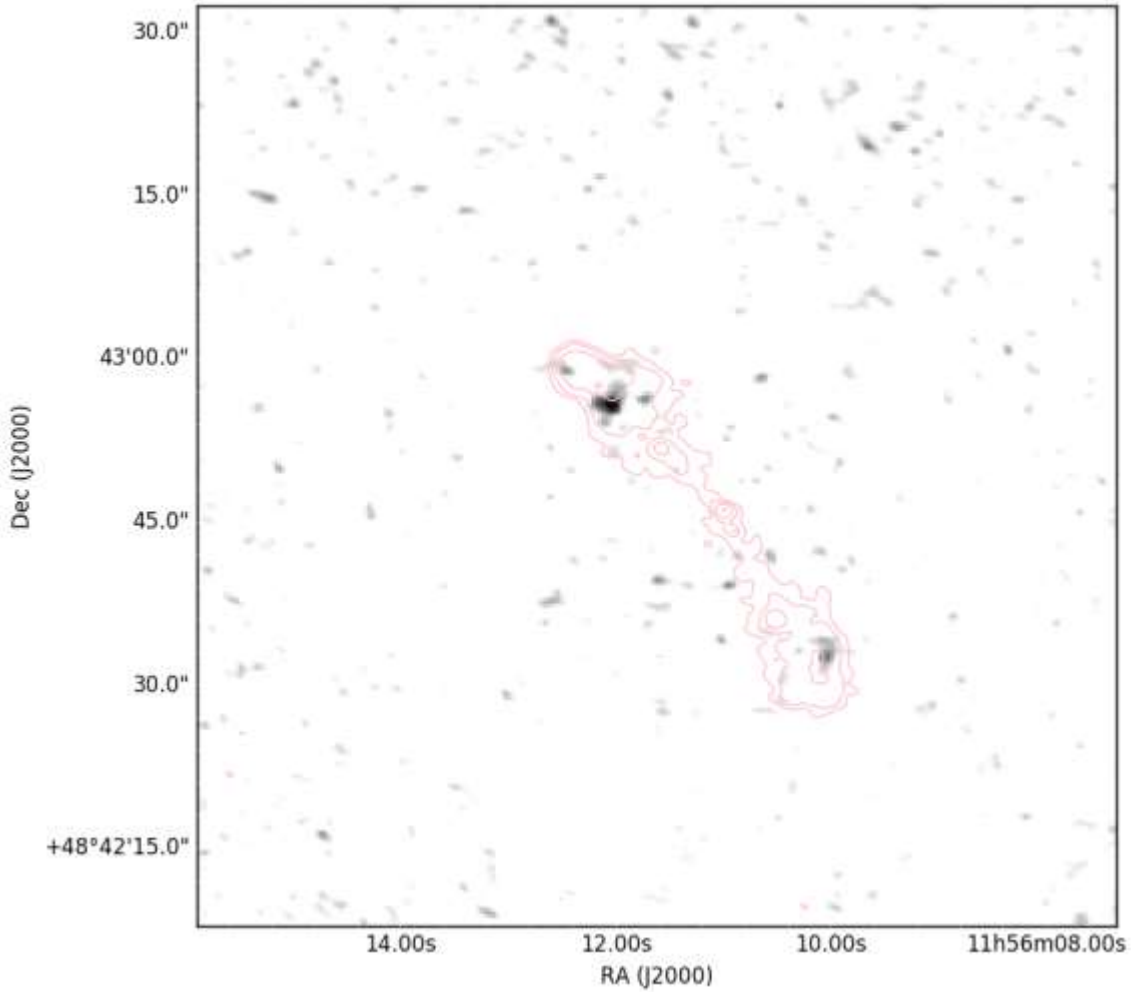

- Outer lobe polarization seen in only 2 sources, but inner lobes depolarized at 150 MHz and 1.4 GHz
- ‘Excess’ Faraday rotation in inner lobes in these sources must be due to thermal material in outer lobes
- Can constrain limits on thermal particle content (in progress)
- New polarized DDRG found through reanalysis of VLA data

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Caveats/summary

- Find polarization in ~8/34 sources. Only two show polarization in outer lobes
- We will constrain limits on the thermal matter, but will be limited by the unknown foreground Faraday rotation..
- ..but we can attempt to statistically model the foreground RM as performed on the polarized radio galaxy sample analysed by Mahatma et al (2021)
- Limits on thermal particle content will provide new insights into the dynamics of FR-II radio galaxies and their interaction with the ambient medium