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Evidence for Toroidal B-Field Components in AGN jets on Kiloparsec Scales

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Helical Magnetic Fields

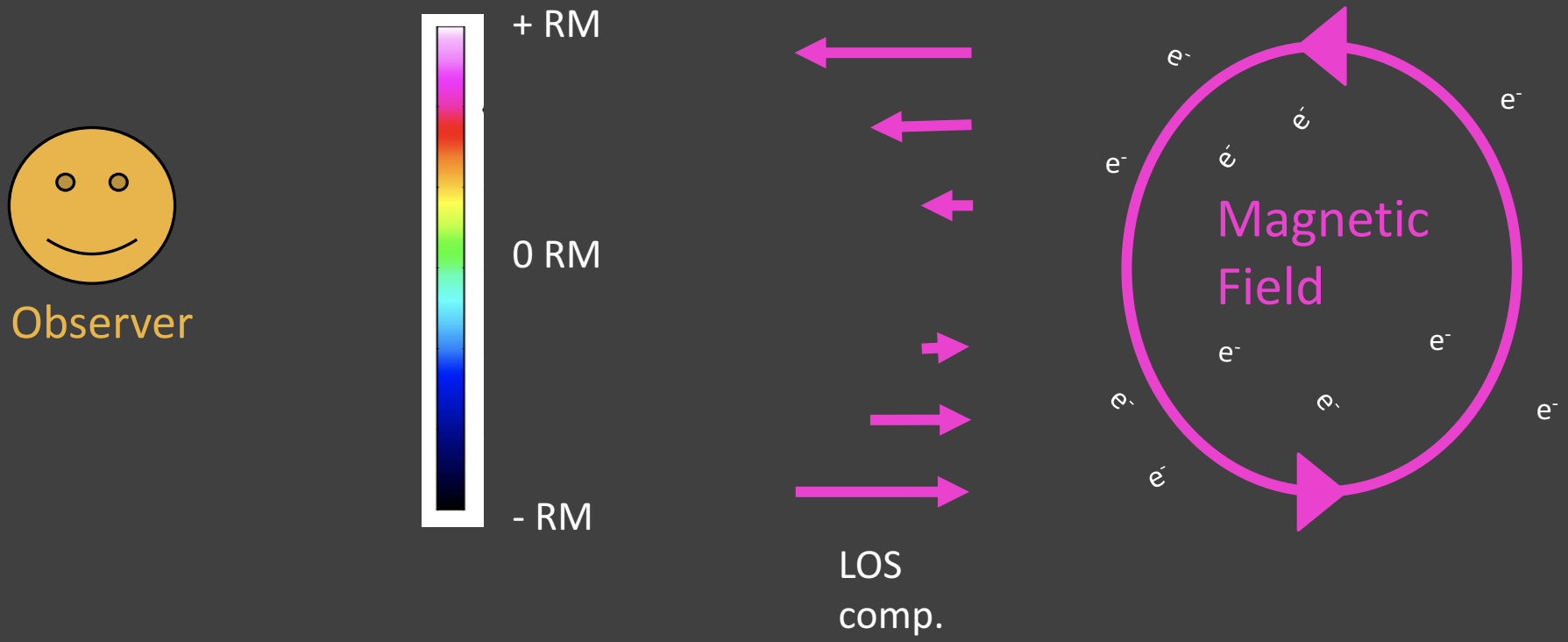
The confinement of jets by a helical or toroidal B-field is a plausible model for the confinement of the charged particles making up the jet.

These fields can be inferred by the existence of a transverse gradient in the Faraday Rotation Measure (RM) across the jet

$$\mathrm{RM} \propto \int_0^d n_e \vec{B} \cdot \mathrm{d}\vec{l}$$

Faraday Rotation Measure (RM) Gradients

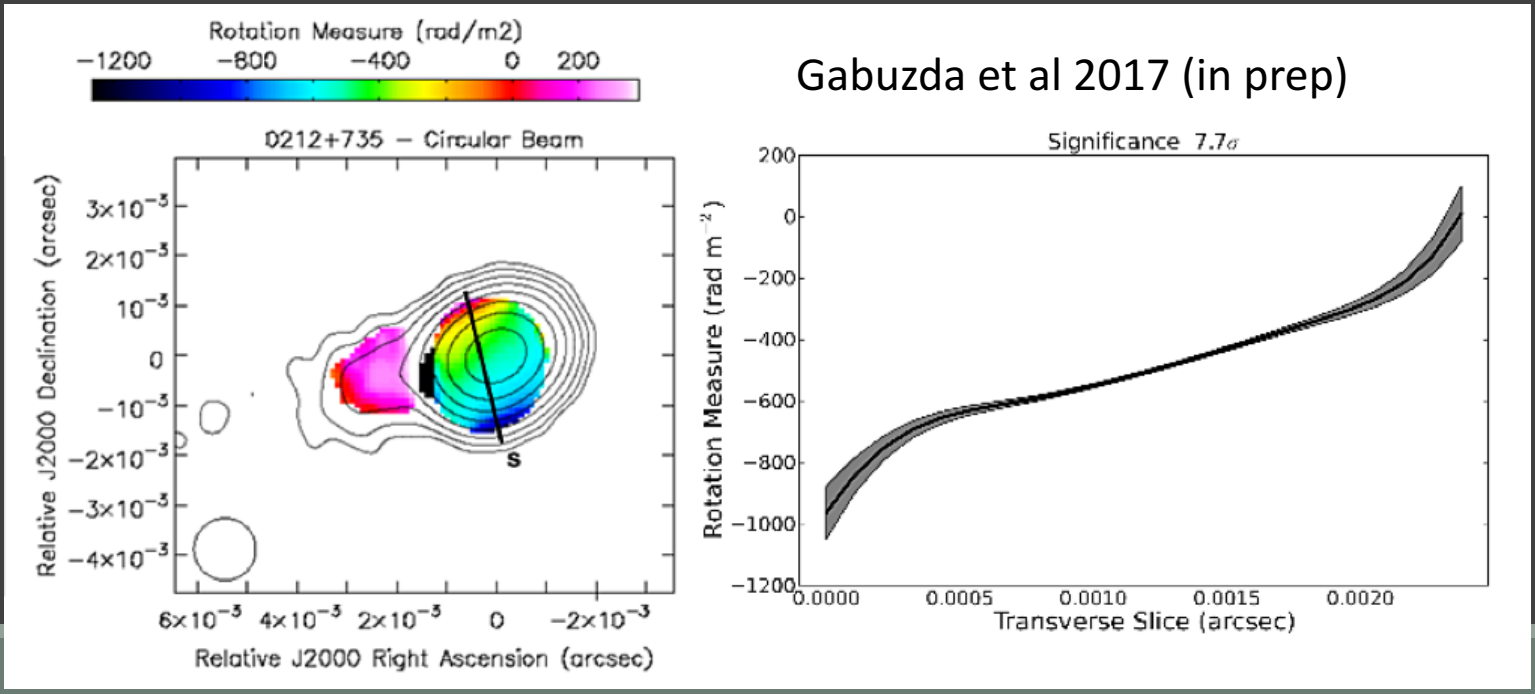
Gradients in the RM infer a similar behavior for the line-of-sight Magnetic field component.



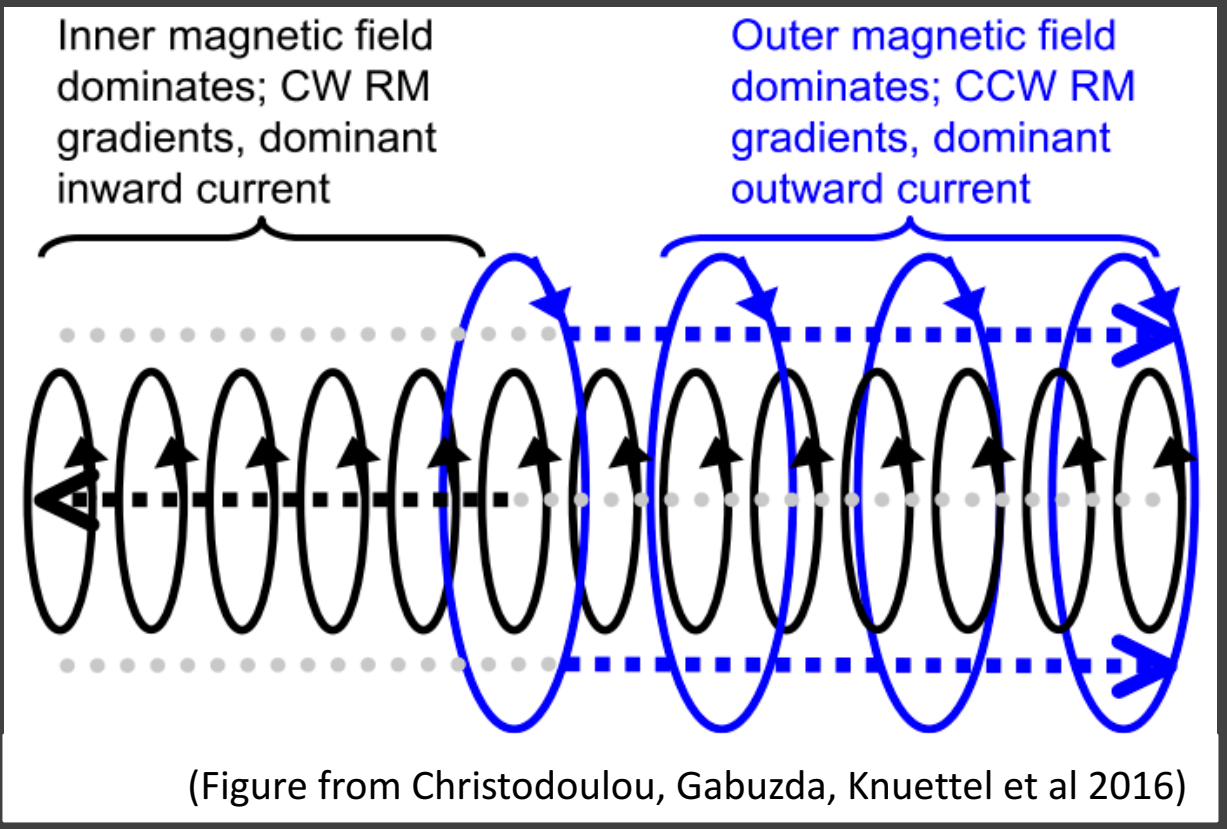
Previous Work

Many transverse RM gradients on the parsec scale, which were observed using the VLBA have been published.

The focus of my work is to try and detect such gradients on larger scales with the VLA.



Cosmic Battery Model



(Figure from Christodoulou, Gabuzda, Knuettel et al 2016)

This predicts the jet will carry electric currents consistent with a set of nested helical magnetic fields.

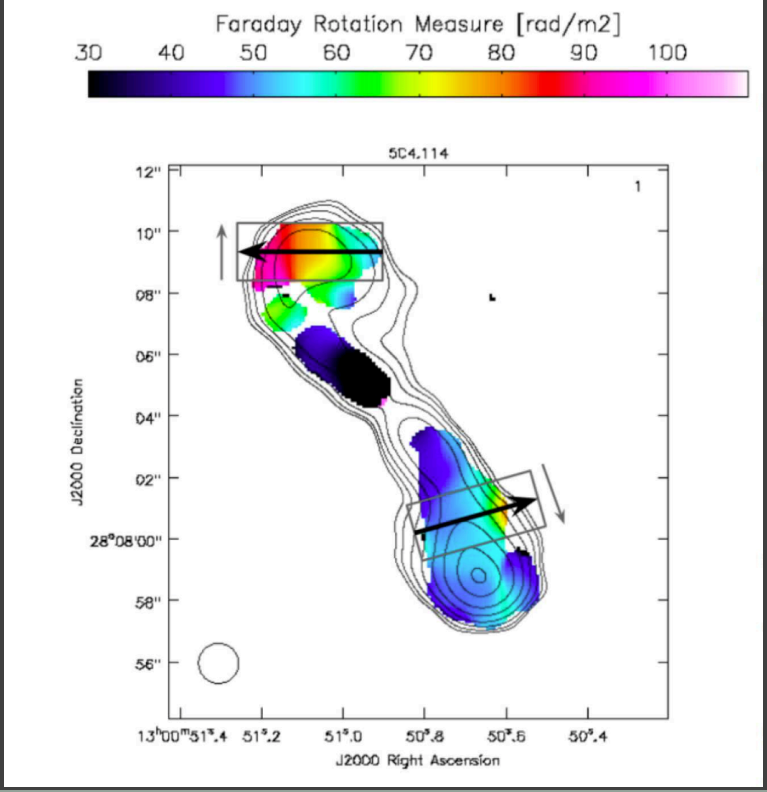
An inward current is expected to dominate on the small scale near the jet base.

An outward current is expected to dominate on larger scales in the outer parts of the jet.

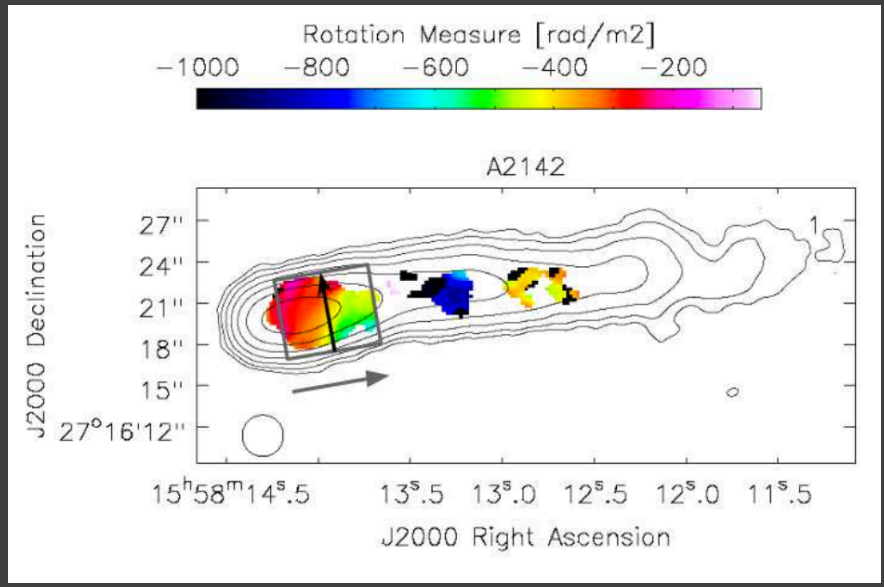
We have all seen this configuration before!

Already published Results

5C4.114 (Gabuzda, Knuettel, Bonafede 2015)



A2142 (Christodoulou et al 2016)



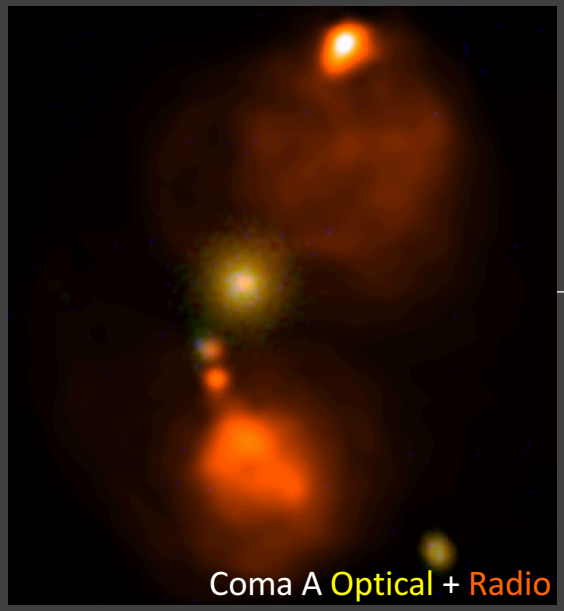
Difficulties

Due to the large scales and distances involved there is some difficulty in detecting gradients on such large scales.

- Random magnetic field components
- Turbulence in the Jet

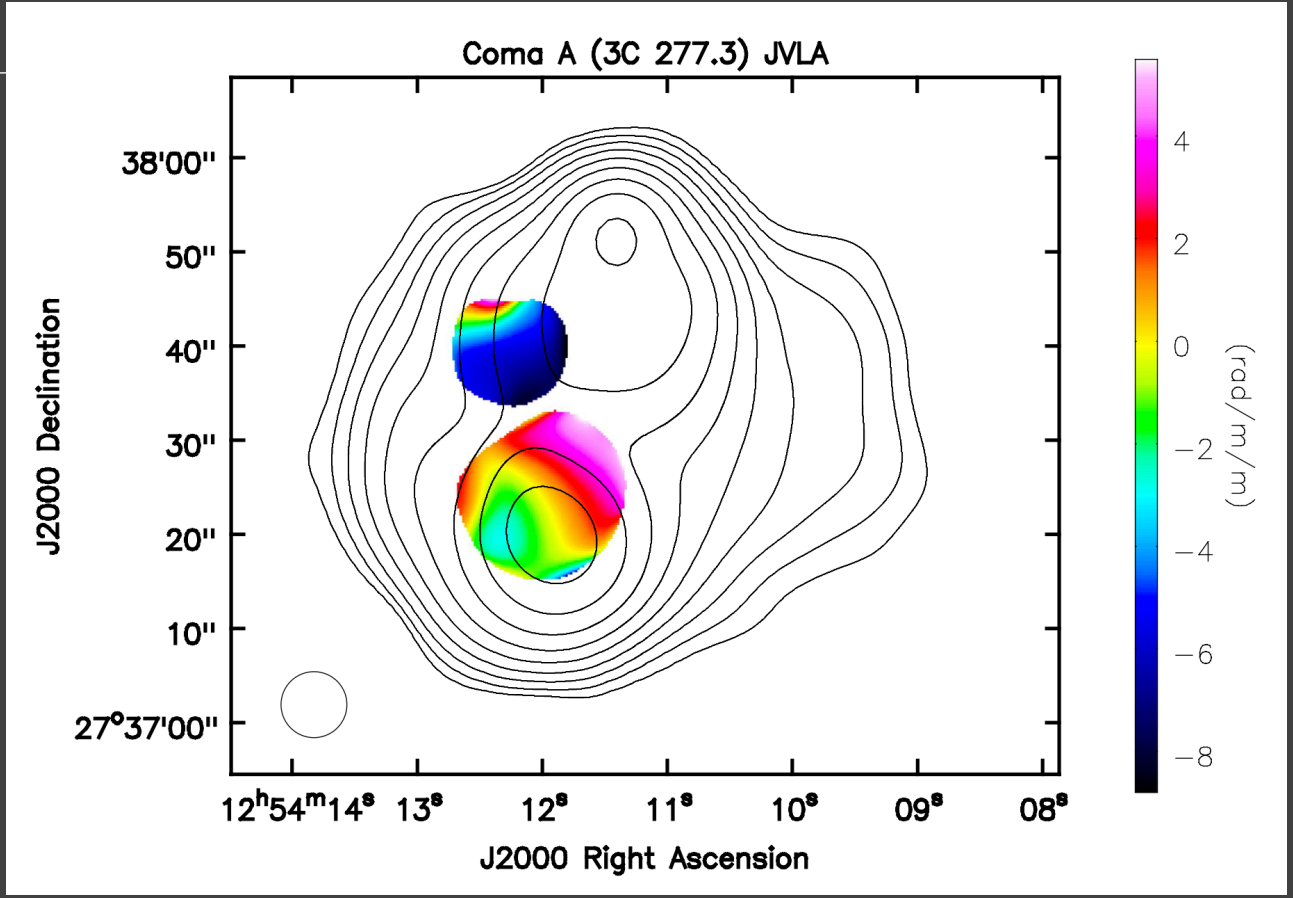
New Results

Coma A (3C 277.3)
JVLA Observation at L Band

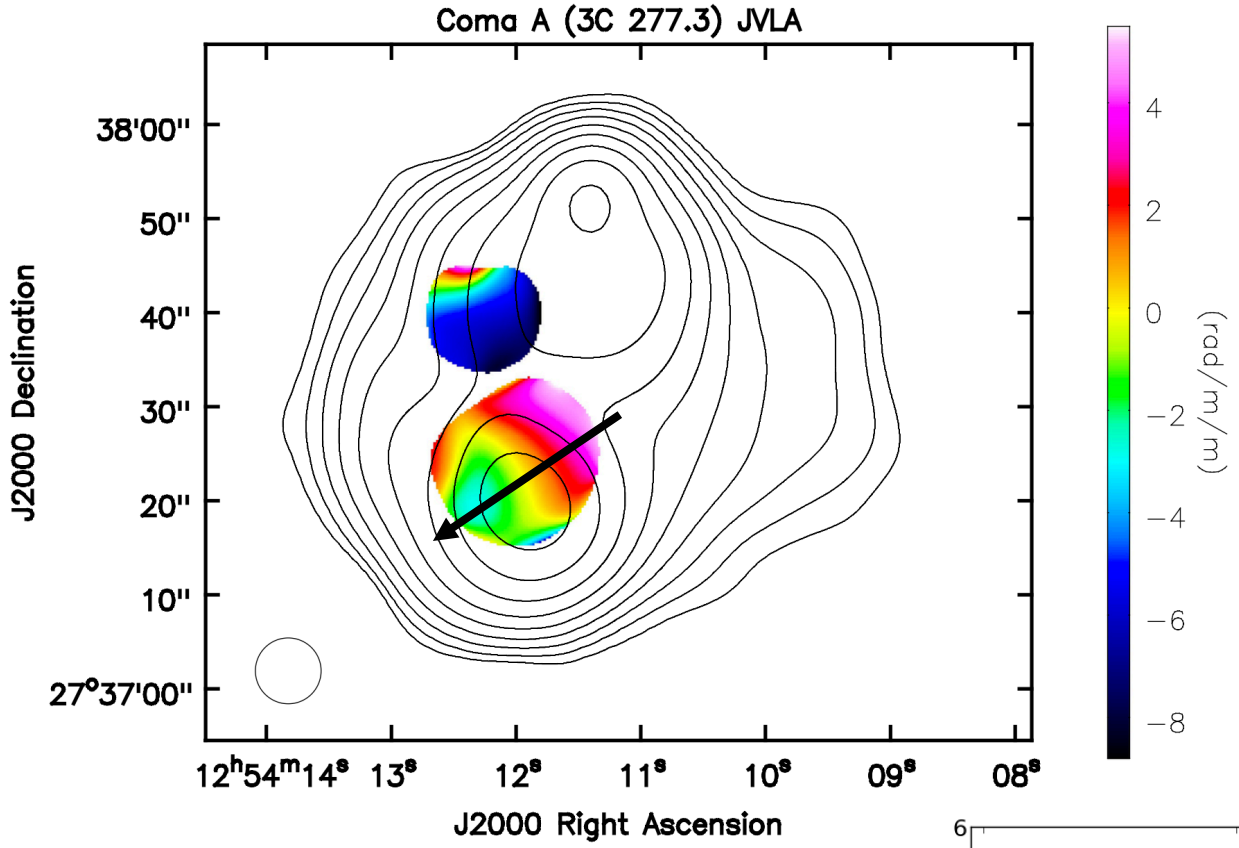


The RM gradient structure is still visible in the 1-2GHz range.

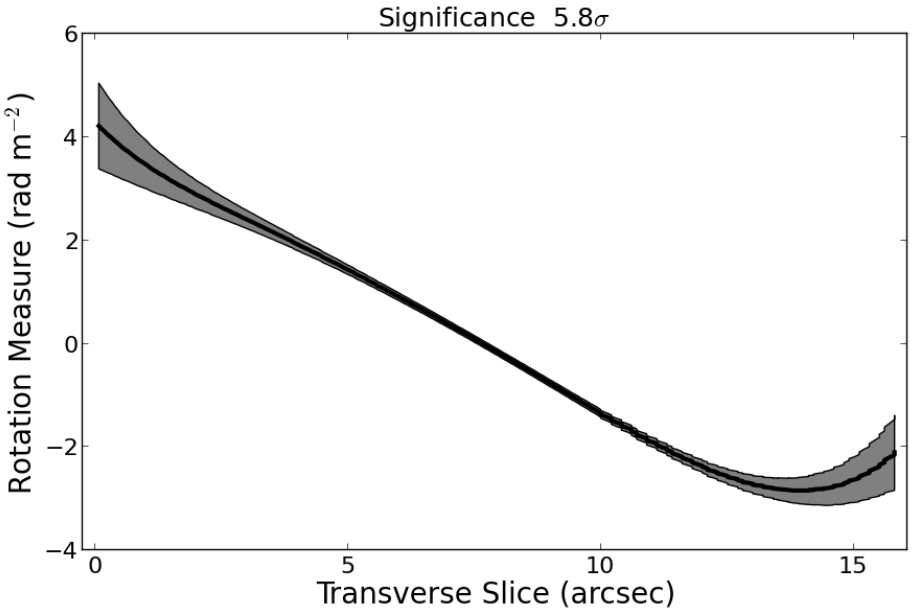
This was obtained fitting χ vs λ^2 for 16 frequencies between 1 and 2GHz.

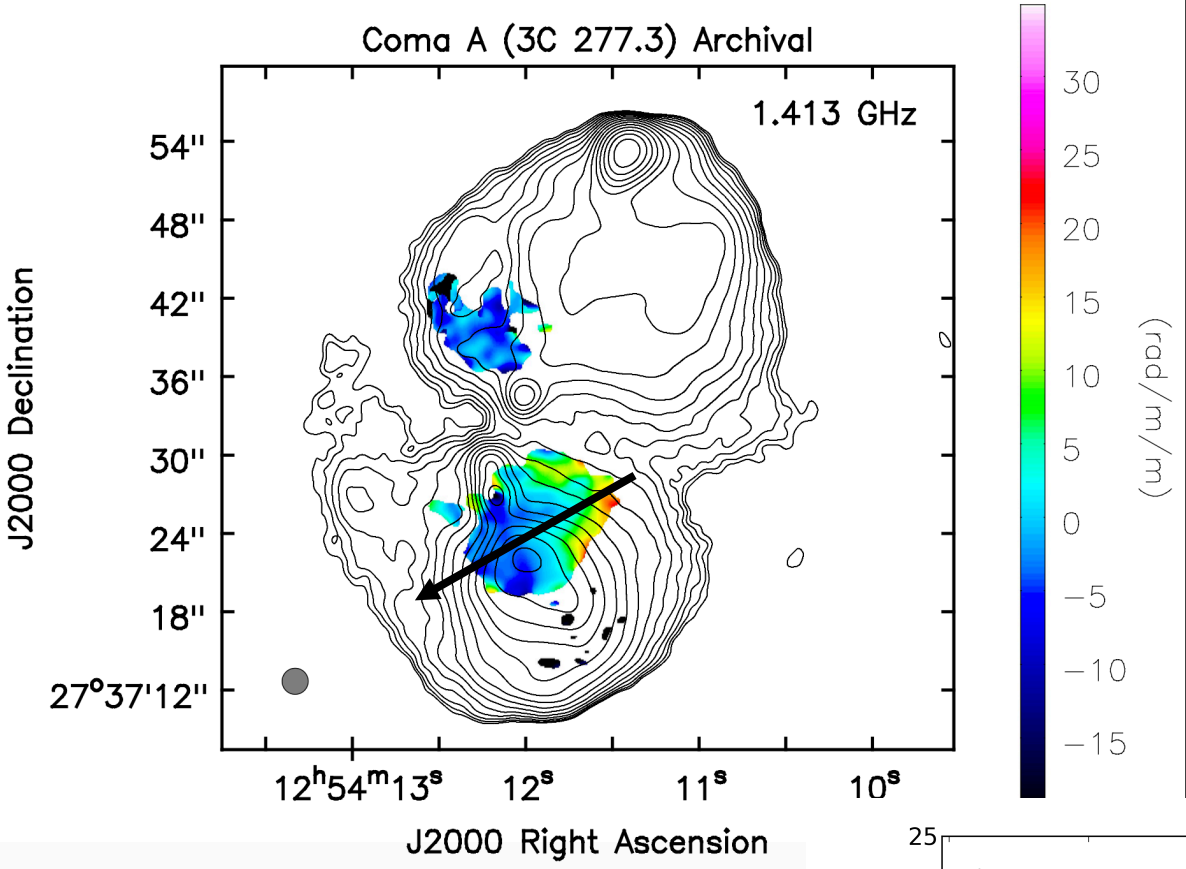


JVLA observation



The arrow indicates the path along which the slice is taken.

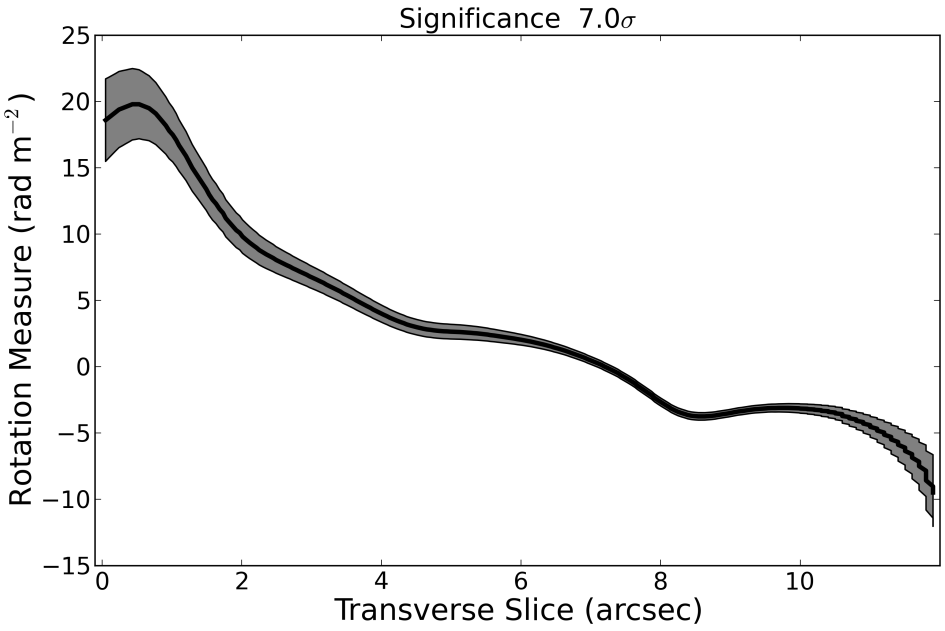




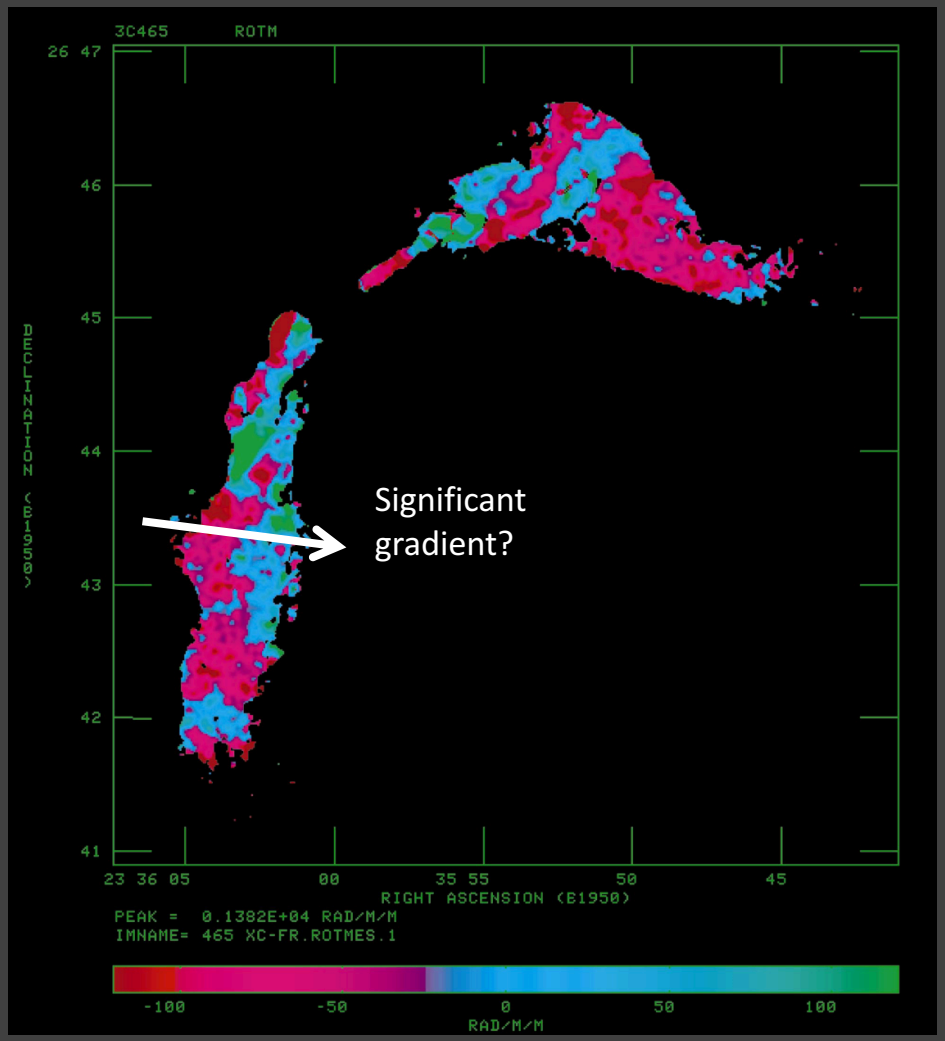
Archival VLA data

Observations at 1.4, 4.9 and 15GHz at A, B and C configurations respectively ensure matching resolutions

Similar gradient structure can be found in this archival data.



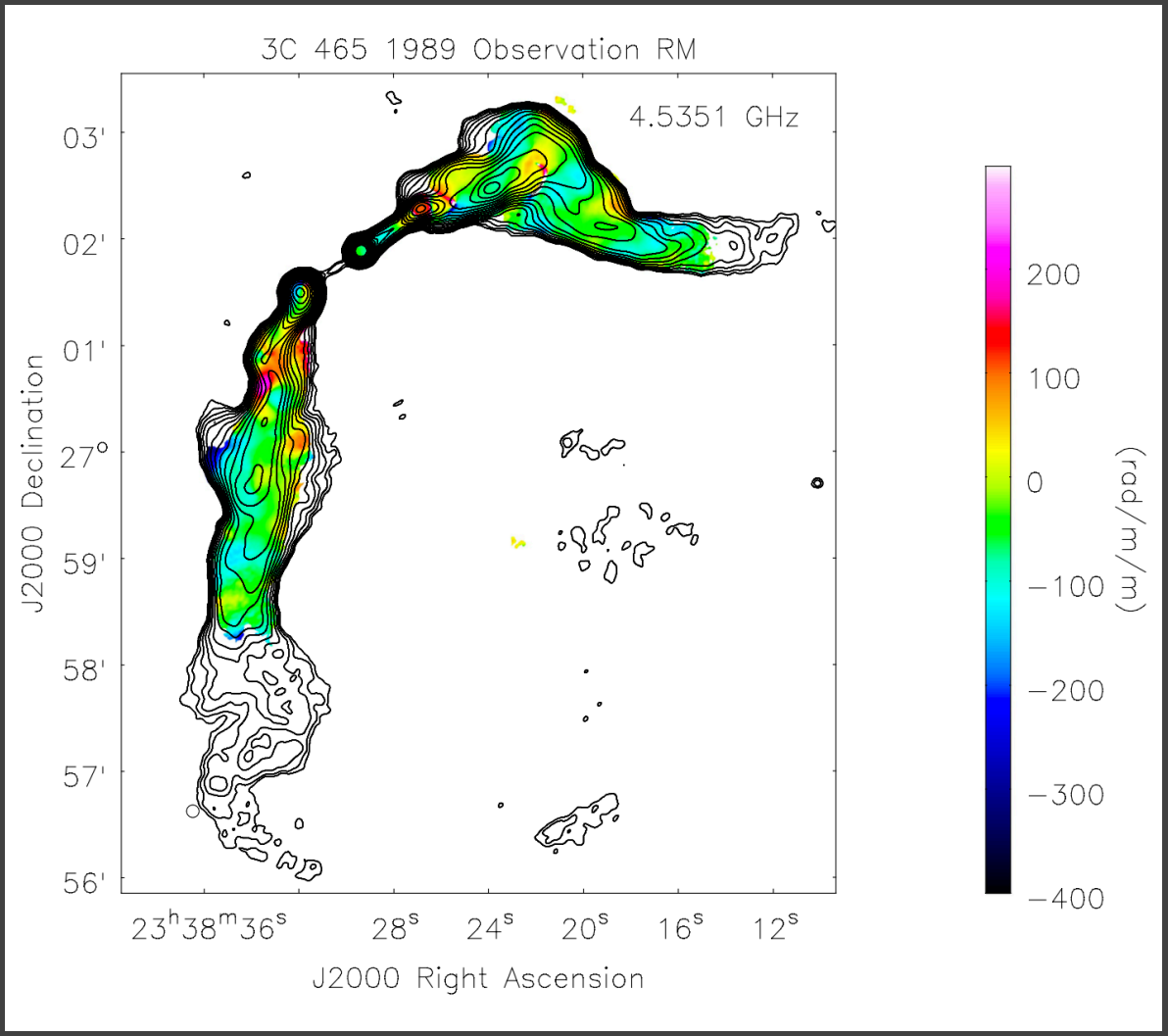
3C 465



(Original RM image taken from Eilek & Owen 2004.)

The data were observed in 1989 and originally published in Eilek & Owen 2004.

This RM map motivated further study into the Faraday rotation structure of this source



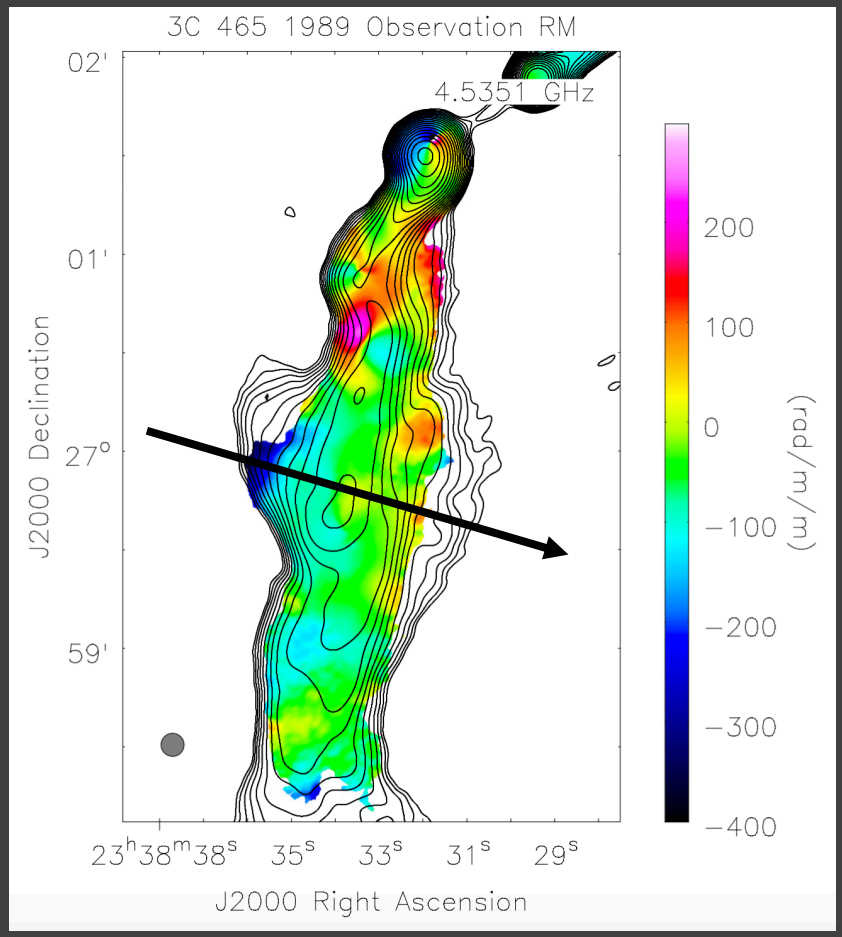
3C 465

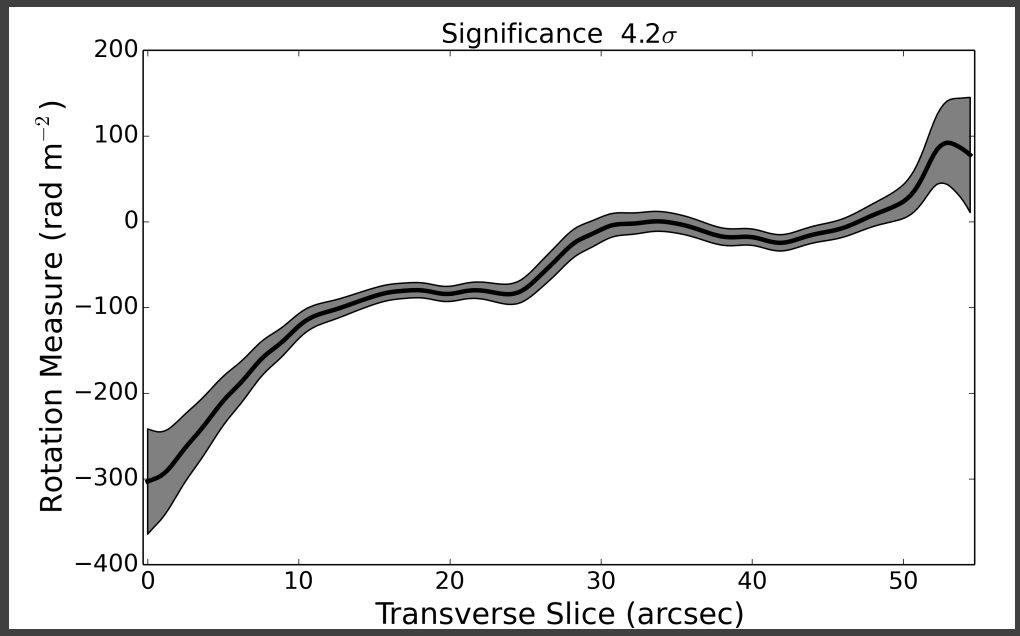
The data were observed in 1989 and originally published in Eilek & Owen 2004.

The original data are available on the VLA archive and were calibrated again and shown here.

The data is in the 4-8GHz range

The Southern Jet





There is a lot of RM in the Jet here

To Summarize

Faraday rotation measure gradients are good indicators of toroidal/helical B-field components.

The preferred direction of these gradients supports a “cosmic battery” model.

Significant RM gradients have been found on kiloparsec scale observations.

Work is ongoing to find more gradients in VLA archival data.

No. (1)	Object name (2)	z (3)	RM gradient direction (4)	Projected distance from core (pc) (5)
				Firm Gradients,
1	0716+714	0.127	CCW*	3–35
2	0923+392	0.695	CCW*	20
3	5C4.114 (N)	$> 0.023^a$	CCW	> 2000
4	5C4.114 (S)	$> 0.023^a$	CCW	> 1500
5	A2142A	0.091	CCW	to $\simeq 10,000$
6	1652+398	0.034	CCW	20
7	1749+701	0.77	CCW*	75–100
8	3C380	0.692	CCW	70–210
9	2037+511	1.687	CCW*	40

+1 Result From Coma A

Probability of this being by chance < 0.1% !!!

Table from Christodoulou et al 2016