Multi-wavelength VLBI Circular Polarisation Measurements of AGN

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Radio Emission of AGN is synchrotron radiation due to motion of relativistic electrons through region with magnetic field.

Synchrotron radiaton can be highly linearly polarised, up to 75% in uniform B field.

The observed polarisation angles χ depend on:

- underlying B field direction
- optical depth (thick: $\chi \parallel B$, thin: $\chi \perp B$)
- Faraday rotation along line of sight

If Faraday rotation is measured, and optical-depth regime is known, can infer underlying B field direction.

Intrinsic degree of circular polarisation (CP) of synchrotron radiation is low, < 1% for B fields ~ 1 G.

More efficient mechanism: Faraday conversion of linear to circular polarisation when linearly polarised EM wave passes through magnetised plasma.

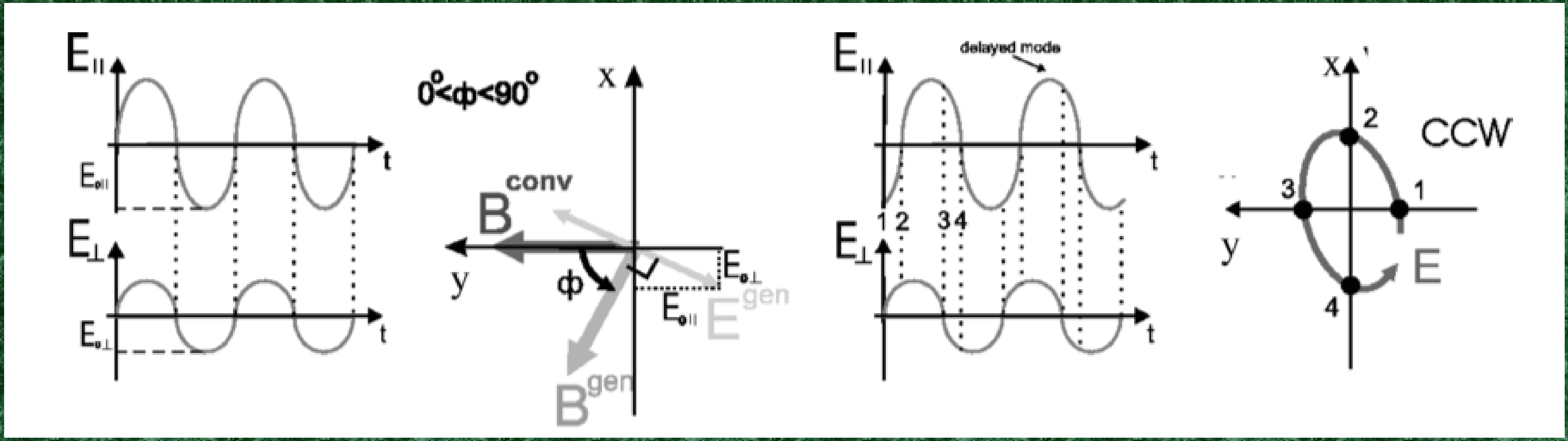
Physical basis of Faraday conversion:

— Describe wave's E field using components parallel to ($E_{||}$) and orthogonal to ($E_{\perp}$) magnetic field in medium B_{med}

— Free charges in medium can be accelerated by $E_{||}$, but not by $E_{\perp}$: $E_{||}$ is absorbed+re-emitted (delayed) while $E_{\perp}$ is not $\Rightarrow$ circular polarisation

Delaying one E component relative to the other is equivalent to introducing a circularly polarised

component



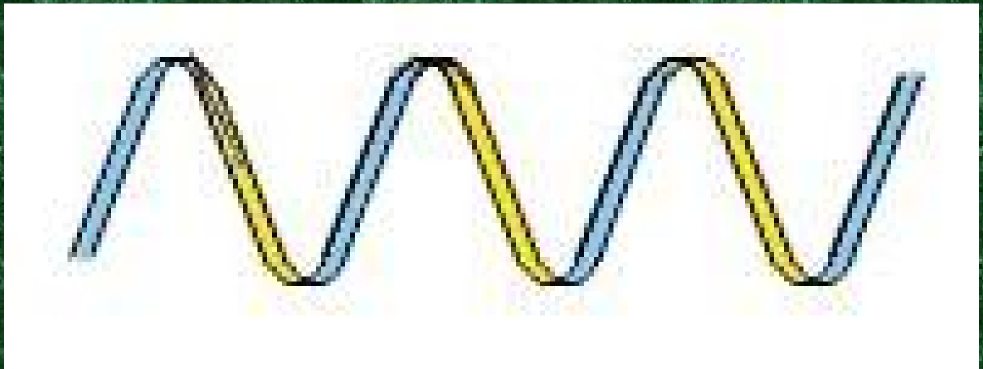
No Faraday conversion when plane of linear polarisation (E) is

— fully orthogonal to B_{med} (electrons in medium cannot move orthogonal to Bmed, E not absorbed)

— fully parallel to B_{med} (total E is absorbed and re-emitted)

Best situation for Faraday conversion: E_{synch} not too close to parallel or orthgonal to B_{med} .

Favourable geometry for conversion provided by a helical B field:



Linear polarisation from far side of jet can be converted to circular polarisation when passes through near side of jet.

Although “intrinsic” synchrotron CP can yield degrees of CP ~ a few tenths of a percent at cm wavelengths for B fields of ~1 G, Faraday conversion is much more efficient (could yield m_c an order of magnitude greater)

$\Rightarrow$ Faraday conversion taken to be more likely mechanism

Expected spectrum for degree of CP in simplest case of uniform source:

— $\nu^{-0.5}$ for intrinsic ("synchrotron") CP from homogeneous, optically thin synchrotron source

— ν^{-3} for Faraday conversion in homogeneous source

Until recently very few multi-frequency CP measurements available, virtually none simultaneous in time.

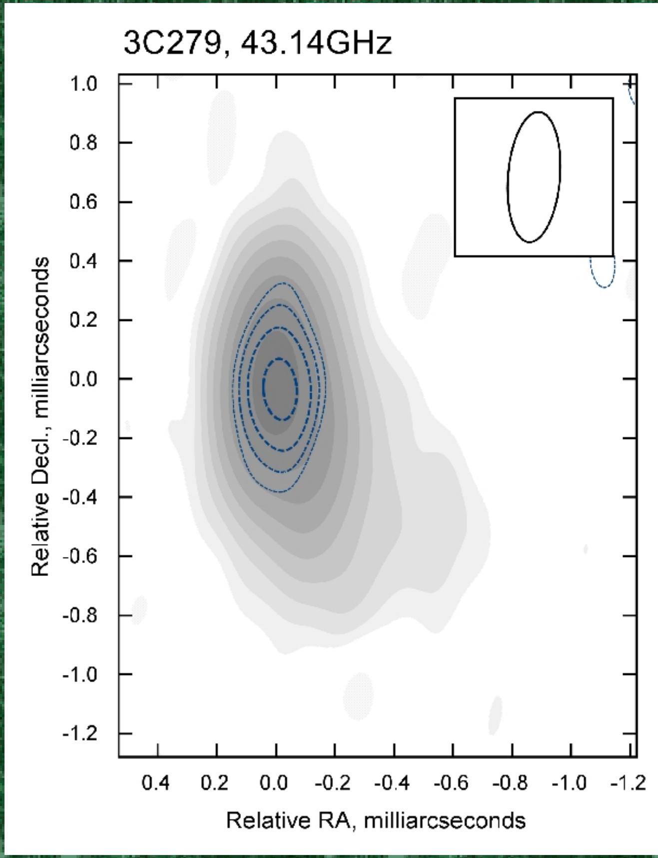
* New multi-frequency VLBA CP measurements for roughly 40 AGN at 15, 22 and 43 GHz (Vitrishchak, Gabuzda et al. 2008, MNRAS in press; astro-ph) !

Circular-polarisation measurements require accurate relative calibration of R and L gains (Homan & Wardle 1999).

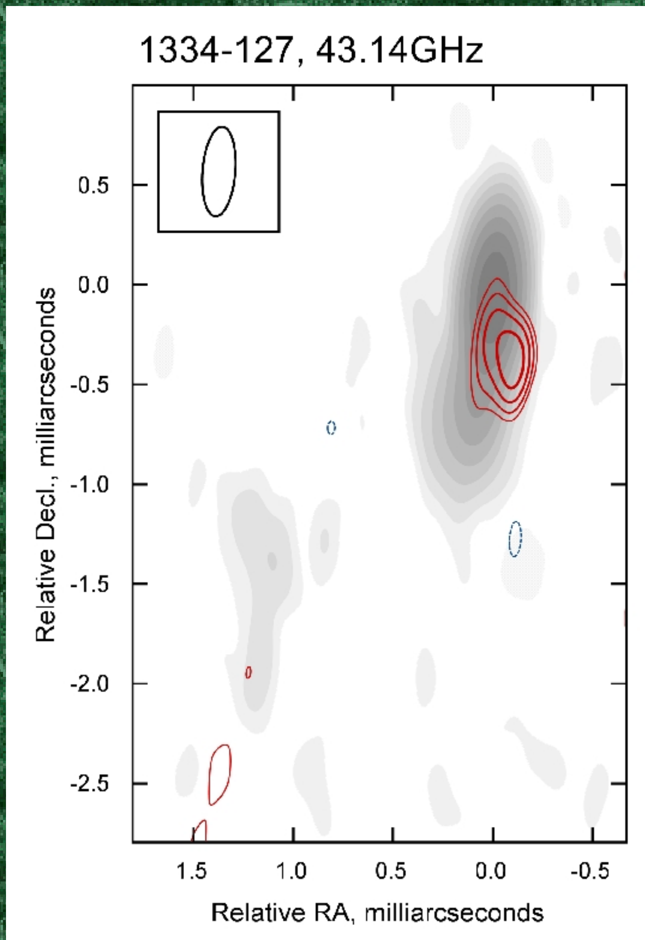
We applied “classic” technique of Homan & Wardle: R/L gain ratios estimated as function of time using calibrators with zero CP, interpolated and applied to data for targets (“gain-transfer” method).

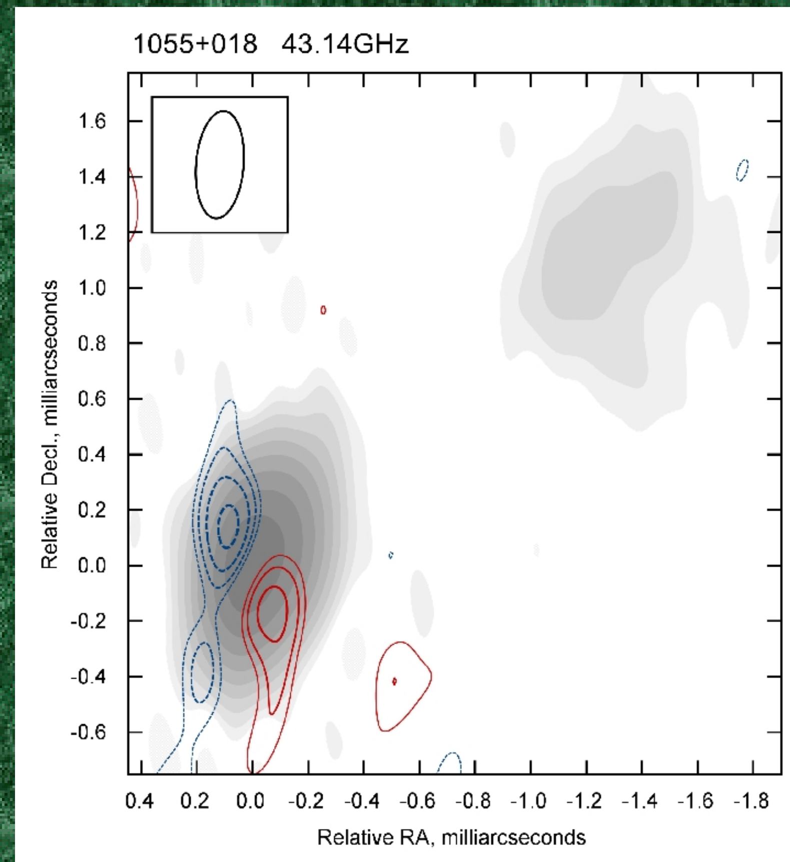
Results: first parsec-scale CP measurements at 43 GHz!

- Measured CP at ~2σ level or higher in core region of about half a dozen AGN.
- Degrees of core CP at 43 GHz range from ~ 0.3% to ~ 2.8%!
- Degree of core CP typically higher at 43 GHz than at 22 and 15 GHz.

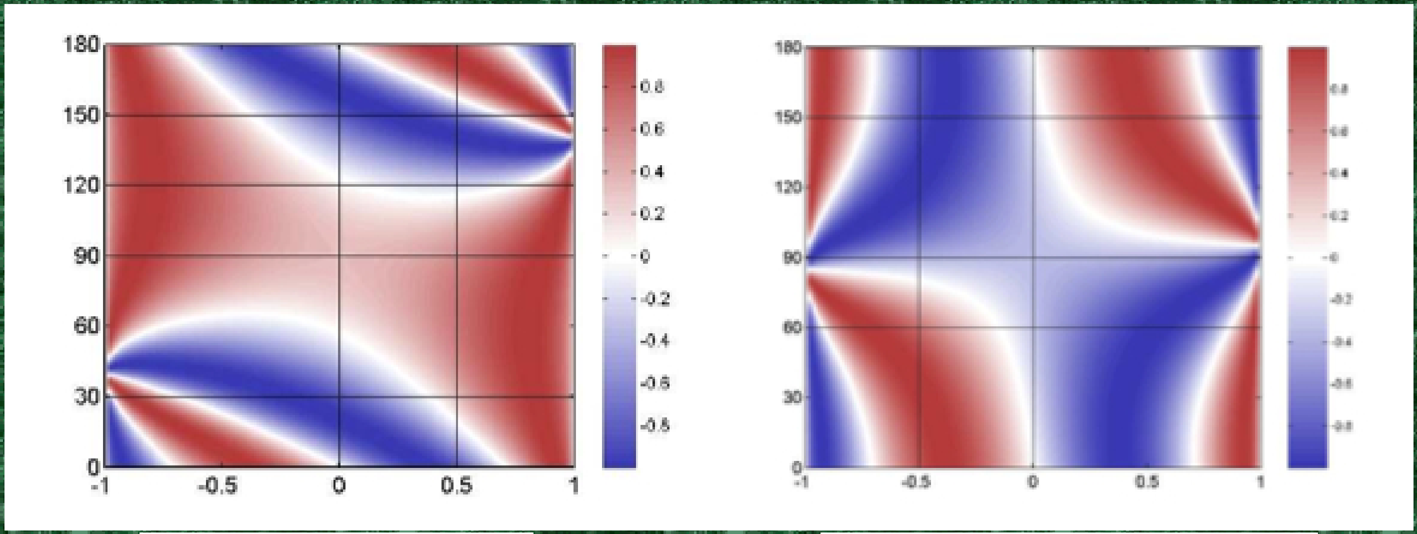


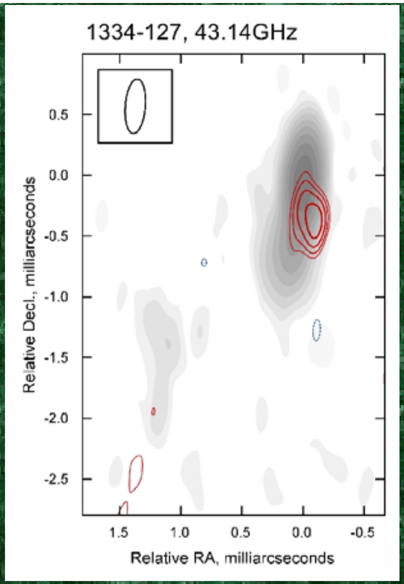
Tentative detection of transverse CP structure in several objects:

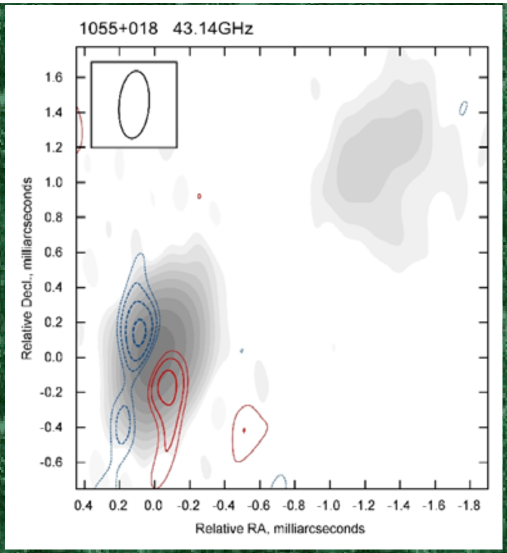




Transverse CP structure consistent with CP generated in helical jet B-field geometry:







Core-region CP measured at 2 or 3 wavelengths in 9 sources

Table 5. CP spectra ($|m_c| \propto \nu^{\alpha_c}$)†

Source	15 GHz m_c (%)	22 GHz m_c (%)	43 GHz m_c (%)
0133+476	-0.32 ± 0.09	–	-0.33 ± 0.19
0851+202	-0.19 ± 0.08	-0.20 ± 0.13	$+0.55 \pm 0.26$
1055+018	$+0.52 \pm 0.10$	$+0.27 \pm 0.17$	*
1253−055	$+0.83 \pm 0.10$	$+0.62 \pm 0.25$	$+1.21 \pm 0.37$
	$+0.26 \pm 0.09$	$+0.20 \pm 0.15$	-1.03 ± 0.16
1334−127	$+0.28 \pm 0.09$	$+0.40 \pm 0.24$	*
1510−089	–	$+0.44 \pm 0.19$	-2.43 ± 0.40
1633+382	-0.34 ± 0.06	-0.83 ± 0.17	–
2145+067	-0.45 ± 0.09	-0.34 ± 0.13	–
2230+114	-0.61 ± 0.08	-1.26 ± 0.21	–

Degree of CP at 43 GHz always > degree of CP at 22, 15 GHz; no clear trend between 15 and 22 GHz

Expectation for CP from synchrotron mechanism and Faraday conversion: m_c should decrease with increasing frequency — opposite to observed trend!

Possible explanations?

— Several regions with different CP signs contribute to observed “core” CP [e.g., 43 GHz map of 1055+018, 15 and 22 GHz maps of 3C84 (Homan & Wardle 2005)]

— Reflects intrinsic inhomogeneity of “Blandford-Konigl” type jet; BK scaling of B and n_e with distance along jet ($B \propto r^{-1}$, $n_e \propto r^{-2}$) predicts $m_c \propto \nu^{+1}$ (Wardle & Homan 2003)

$\Longrightarrow$ May be fruitful to search for CP at relatively high frequencies!

SUMMARY

• First VLBI CP measurements at 43 GHz, CP detected in core regions of about half a dozen AGN; degrees of core CP at 43 GHz range from ~ 0.3% to ~ 2.8%

• Transverse CP structure consistent with CP generated in helical jet B-field geometry is observed in several AGN

• Have measured pc-scale CP spectrum in 9 AGN:

— Results contrary to expectation - degree of CP higher at 43 GHz than at 15 and 22 GHz, possibly due to complex CP structure on smaller scales or intrinsic inhomogeneity of jet structure.

— Further multi-wavelength CP measurements needed, including at 43 GHz!