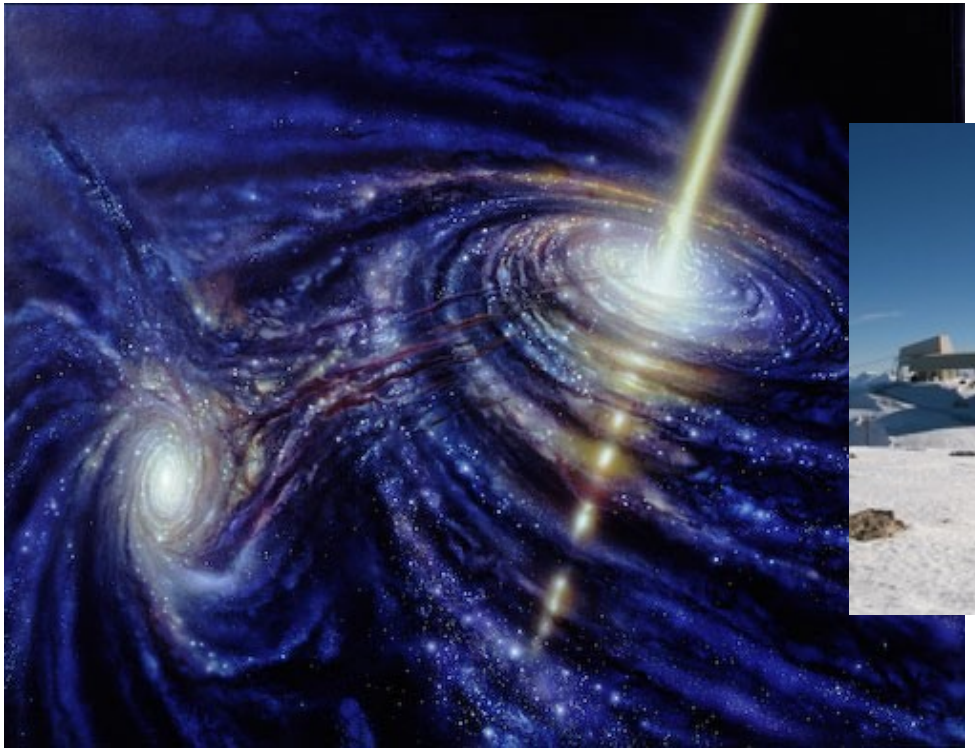
Probing the mm/radio Polarization of Active Galactic Nuclei



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This is the work of many people

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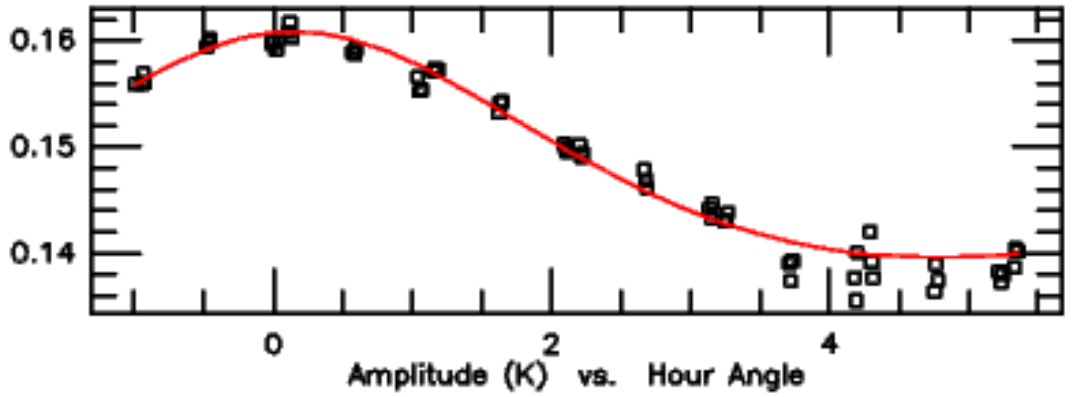
The Plateau de Bure Interferometer

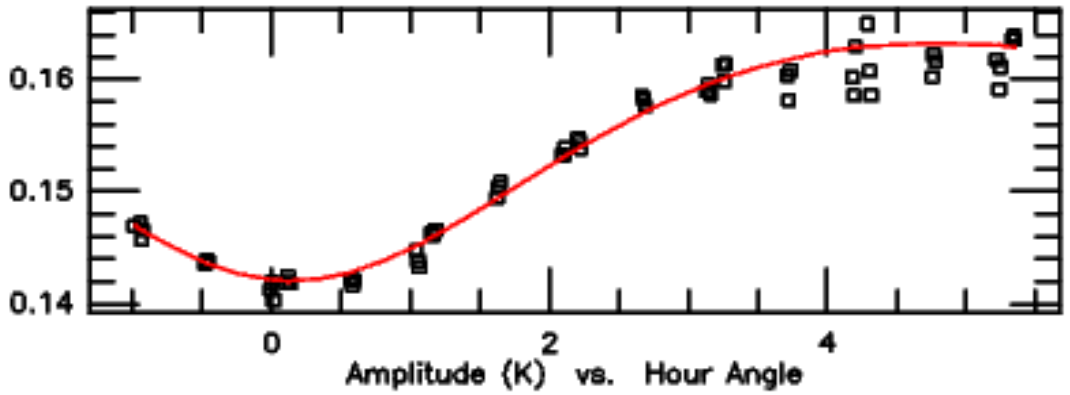
- located in the south-east of France
- six 15-m antennas at 2560 m a.s.l.
- dual-polarization single-band receivers
- one narrow-, one wide-band correlator
- frequency range 80 – 371 GHz
- maximum baseline 760 m
- angular resolutions ~0.2" – 7"
- spectral bandwidths 20 – 3600 MHz
- spectral resolutions 39 kHz – 2 MHz
- 2 worldwide calls for proposals per year

Each PdBI observation collects polarization information on calibration quasars

(since 2007)



Vertical (w.r.t. antenna)

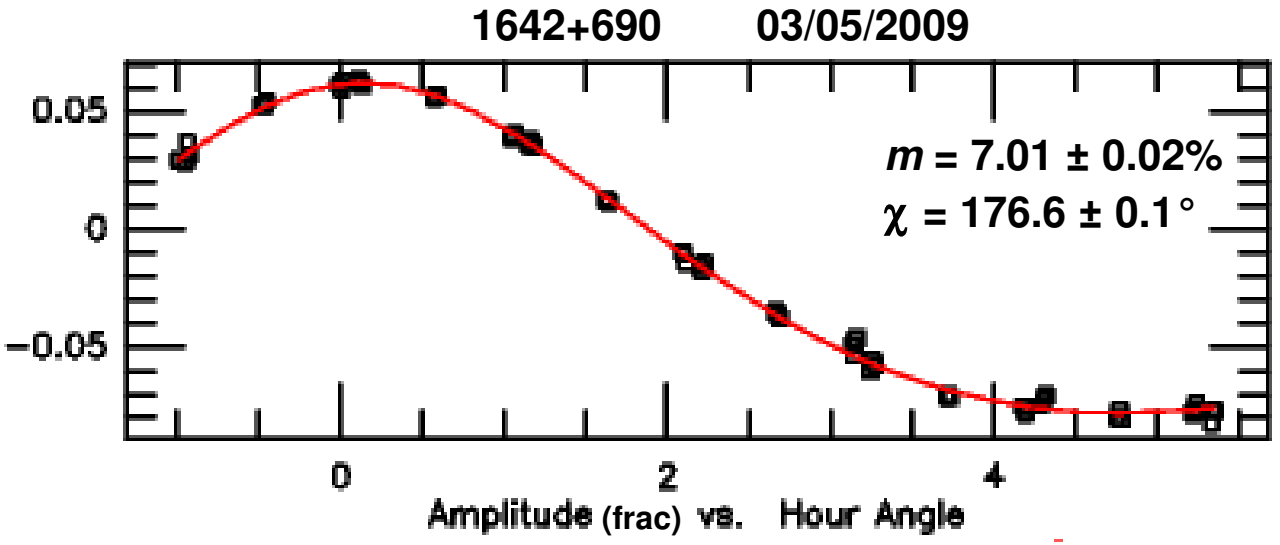


Horizontal (w.r.t. antenna)

Large survey at 1.3 / 2 / 3 mm with 1000s of hours “for free”!

Earth rotation polarimetry provides all we need

$$q(h) = \frac{V-H}{V+H}(h) =$$



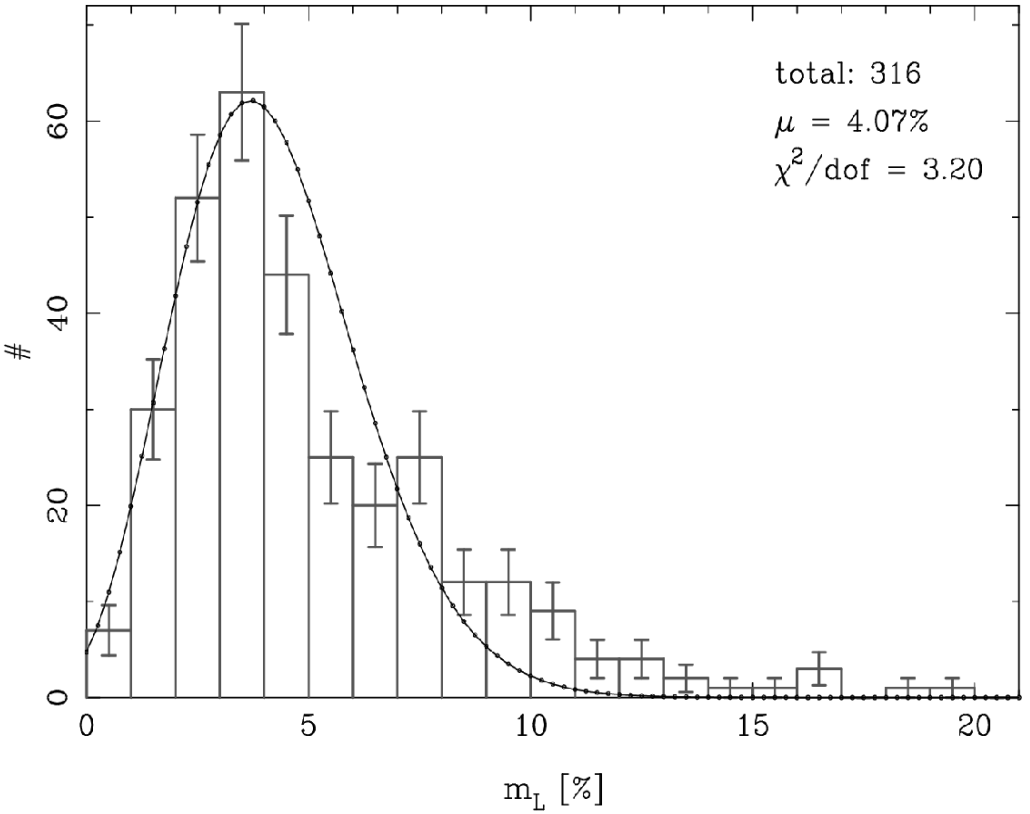
$$q(\psi) \equiv m \cos[2(\psi-\chi)]$$

h: hour angle
ψ: parallactic angle

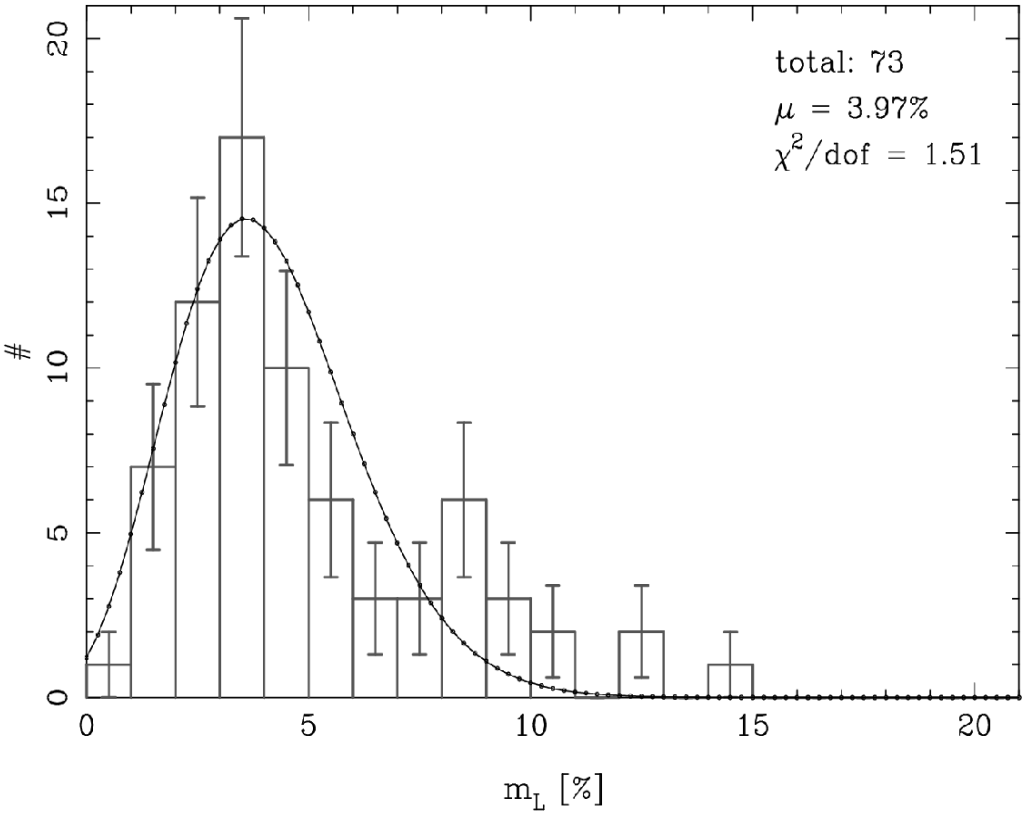
m: polarization fraction
χ: polarization angle

We see polarization (almost) everywhere

all measurements

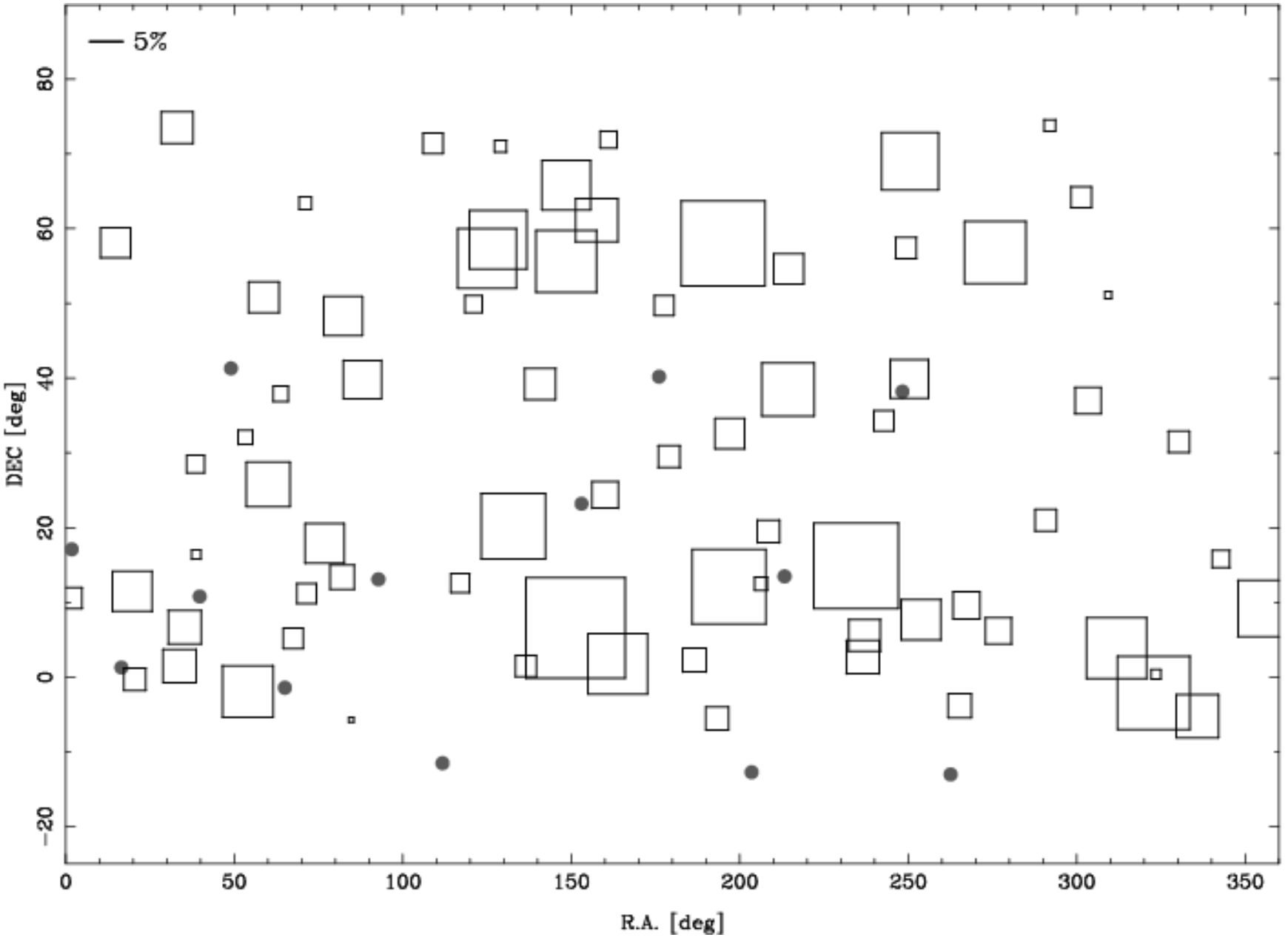


one value per target

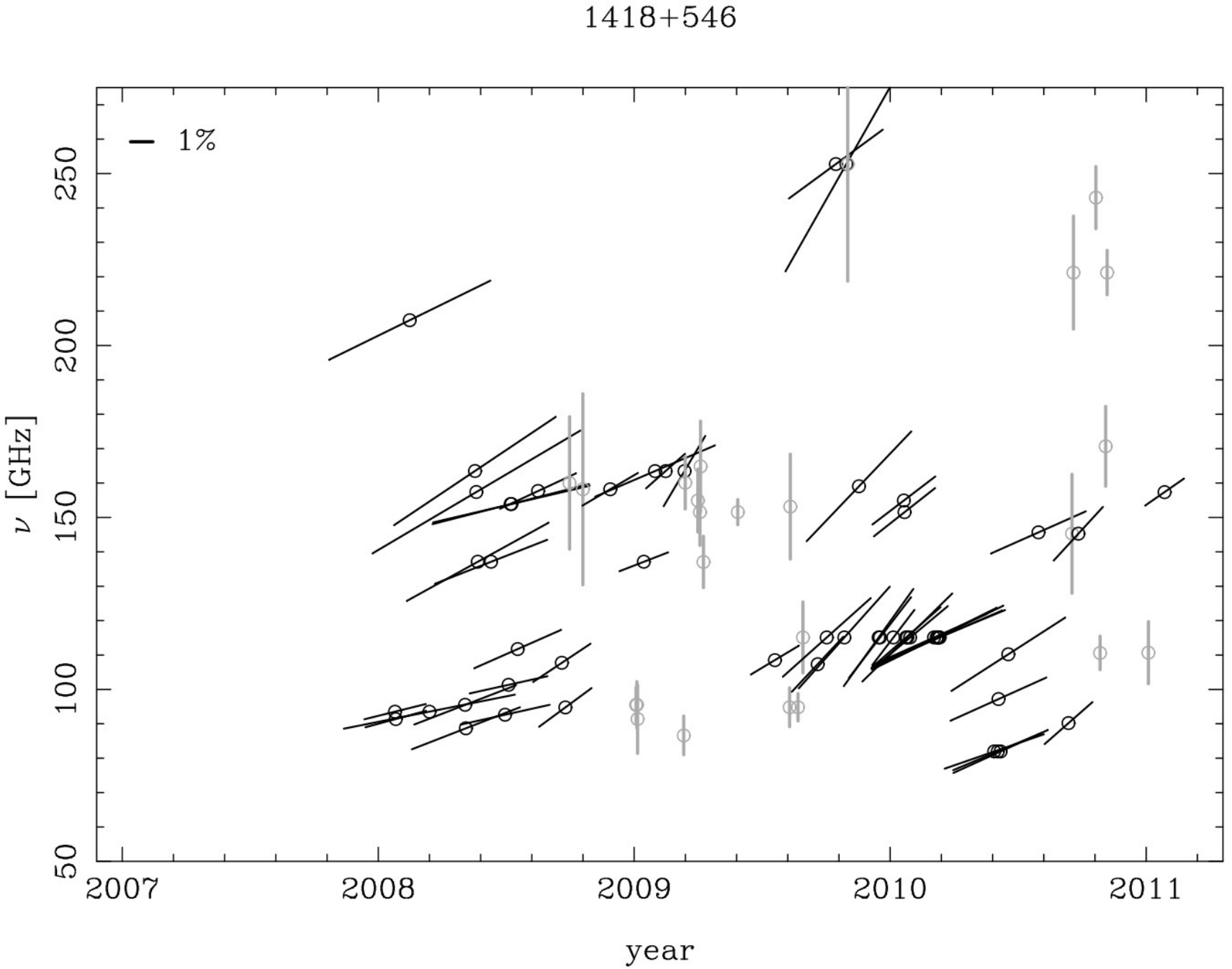


316 out of 441 measurements (73 out of 86 QSOs) detect polarization

We see polarization (almost) everywhere



Strong activity in polarization



Flux variability ↔ polarization variability

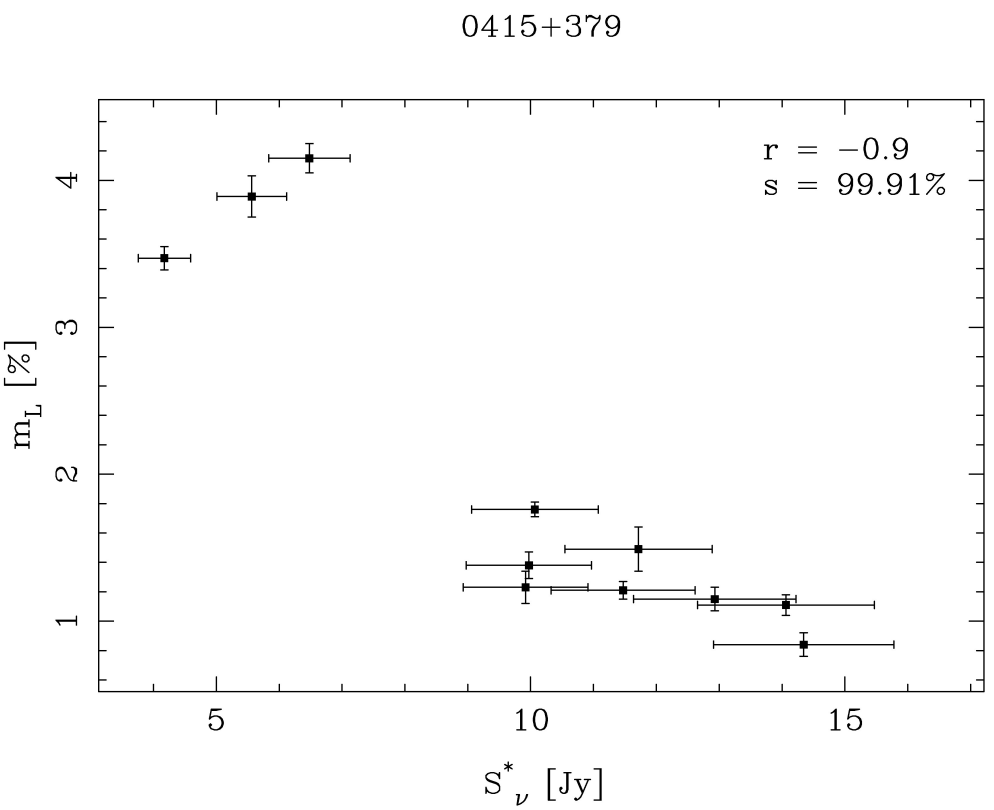
Object	N_{obs}	N_{det}	$\langle m_L \rangle$ [%]	σ_m [%]	ξ_m [% d^{-1}]	$\xi_m/\langle m_L \rangle$ [d^{-1}]	$\langle S_\nu \rangle$ [Jy]	ξ_S [Jy d^{-1}]	$\xi_S/\langle S_\nu \rangle$ [d^{-1}]	ρ
0415+379	34	17	2.3	1.5	0.09±0.01	0.041±0.005	7.5	0.7	0.1	0.4
0507+179	22	21	7.4	2.5	0.36±0.05	0.048±0.007	1.0	0.07	0.07	0.7
0528+134	32	18	3.2	1.2	0.33±0.04	0.104±0.014	3.5	1.1	0.3	0.3
0954+658	37	35	7.4	3.9	0.50±0.02	0.067±0.003	1.2	0.1	0.08	0.8
1418+546	76	52	5.0	2.0	0.28±0.02	0.056±0.004	0.8	0.04	0.05	1.1
1637+574	26	17	3.0	1.0	0.16±0.01	0.053±0.003	1.2	0.2	0.1	0.4

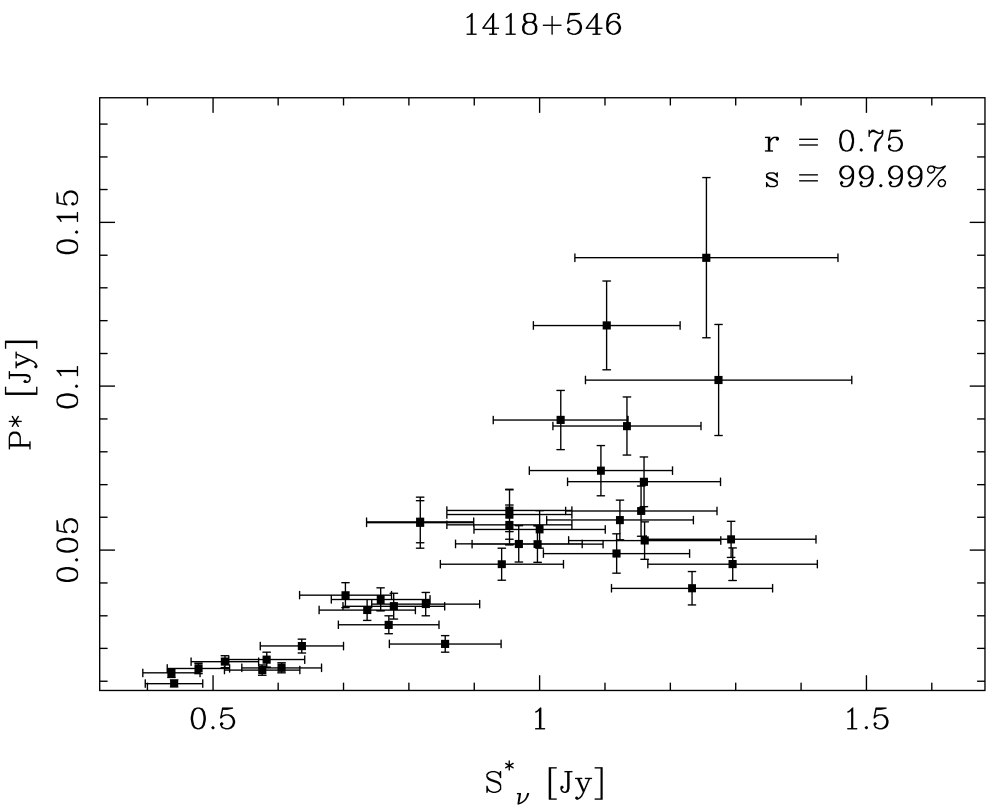
$$\xi_x = \frac{1}{N}(1+z)\sum_{i=1}^{N-1}\left|\frac{x_{i+1}-x_i}{t_{i+1}-t_i}\right|$$

$$\rho = \frac{\xi_m/\langle m_L \rangle}{\xi_S/\langle S_\nu \rangle}$$

- Fast variability in flux and polarization
- Almost identical fluctuation rates → similar spatial scales probed

P / m_L – S_ν correlations → # of components





(At least) 2 components:

1 with high polarization
1 with low polarization

1 (predominant) component

Polarization variability → shock parameters

Shocks in magnetized plasma reduce linear polarization by a factor

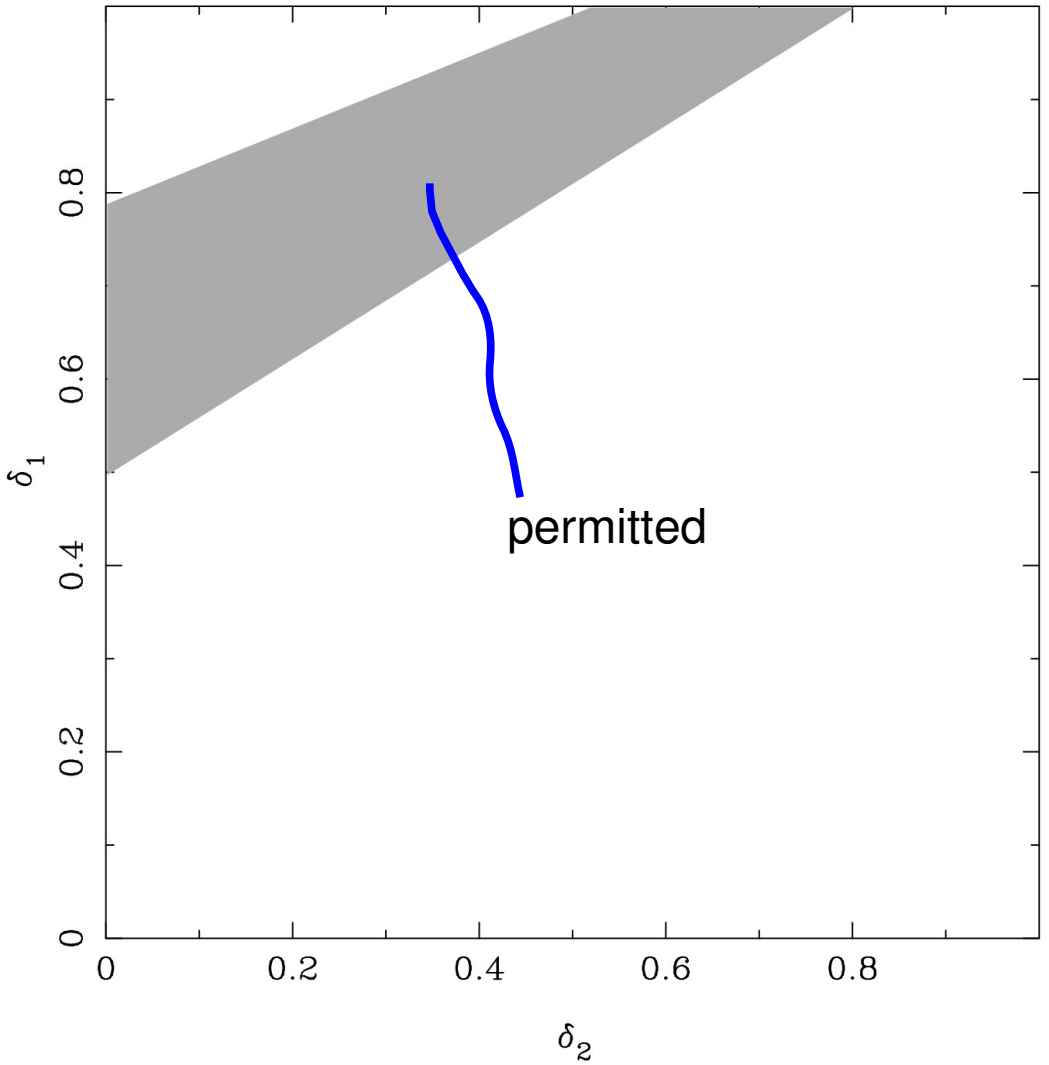
$$\mu = \frac{\delta}{2 - \delta}$$

with the shock parameter

$$\delta = (1 - k^2)\cos^2 \epsilon$$

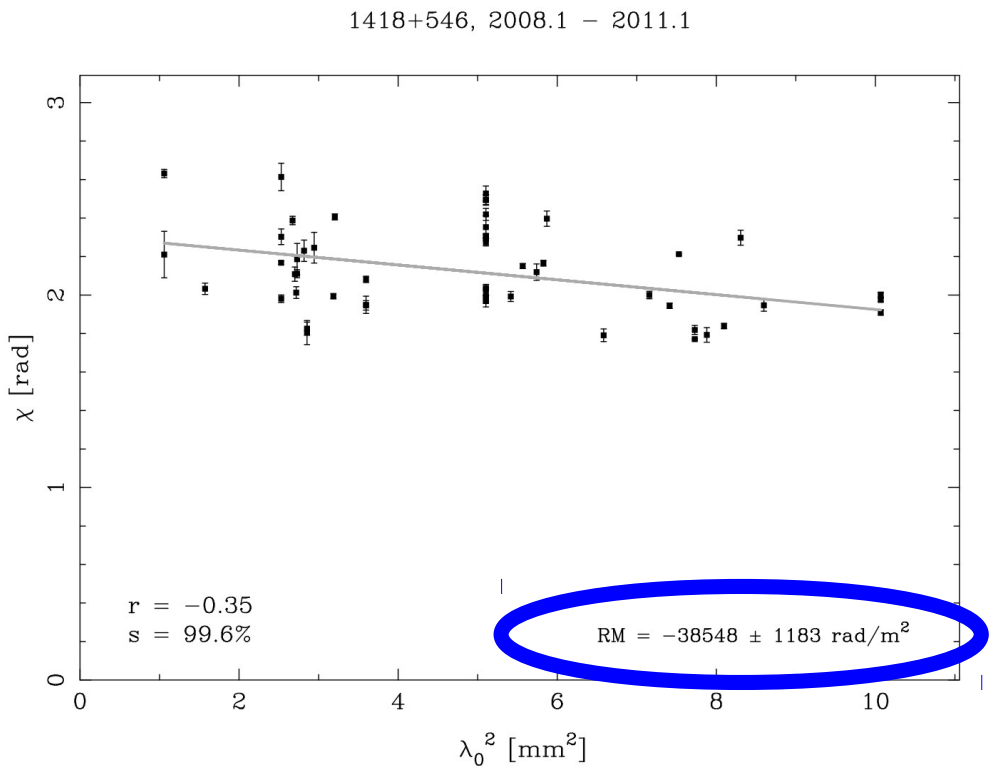
$$\Delta\mu \approx \frac{\sigma_m}{\langle m_L \rangle}$$

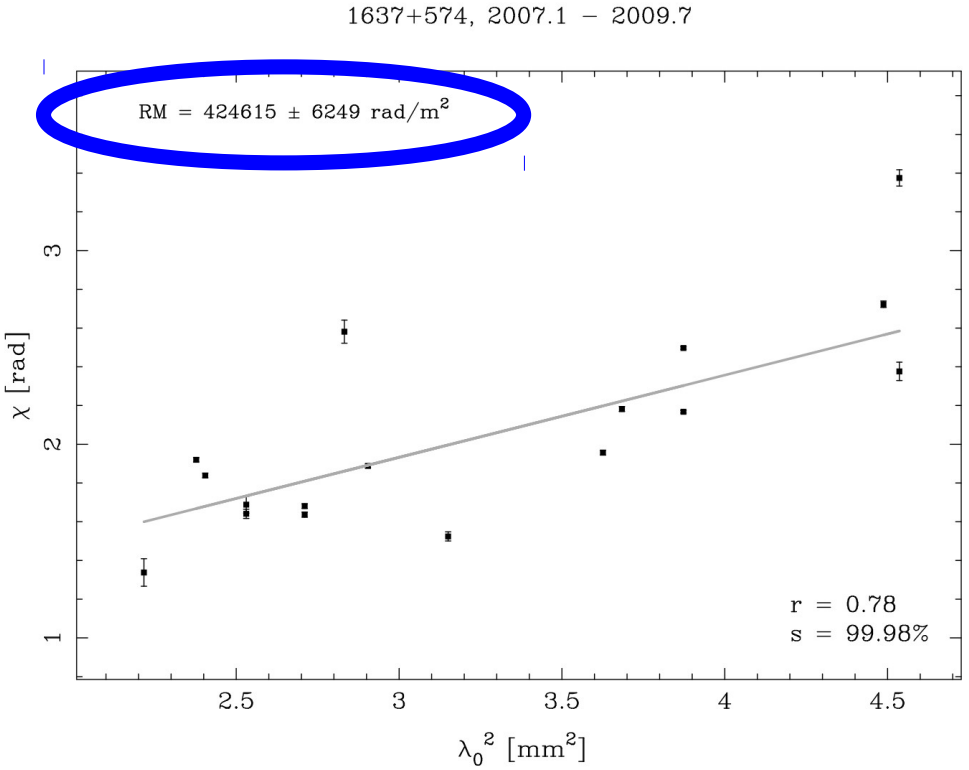
$$\Delta\mu = \mu_1 - \mu_2 = \frac{\delta_1}{2 - \delta_1} - \frac{\delta_2}{2 - \delta_2} = \frac{2(\delta_1 - \delta_2)}{(2 - \delta_1)(2 - \delta_2)}$$



- $k < 0.9$ and/or $\epsilon > 10$ degrees

Very high rotation measures





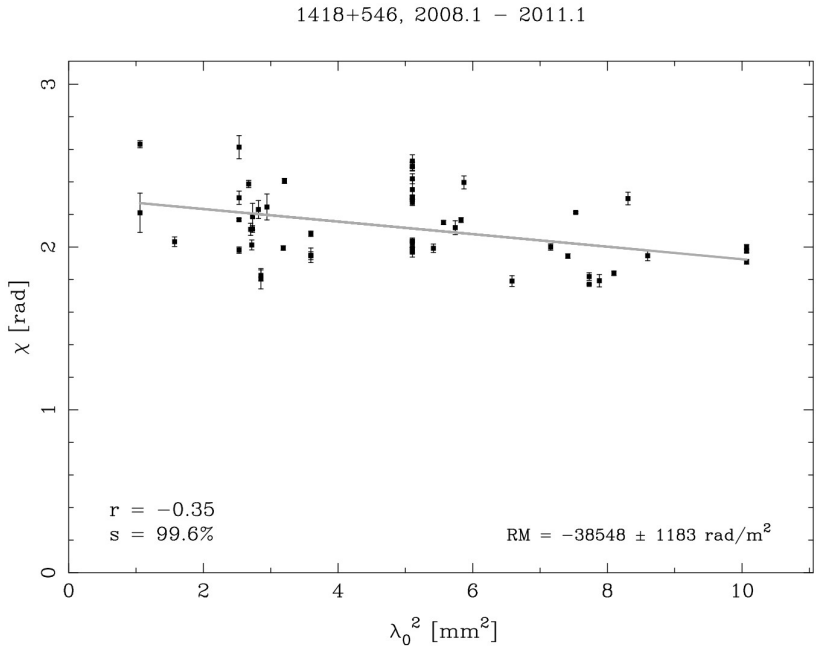
$$\chi = \mathrm{RM} \times \lambda_0^2$$

where RM is the rotation measure

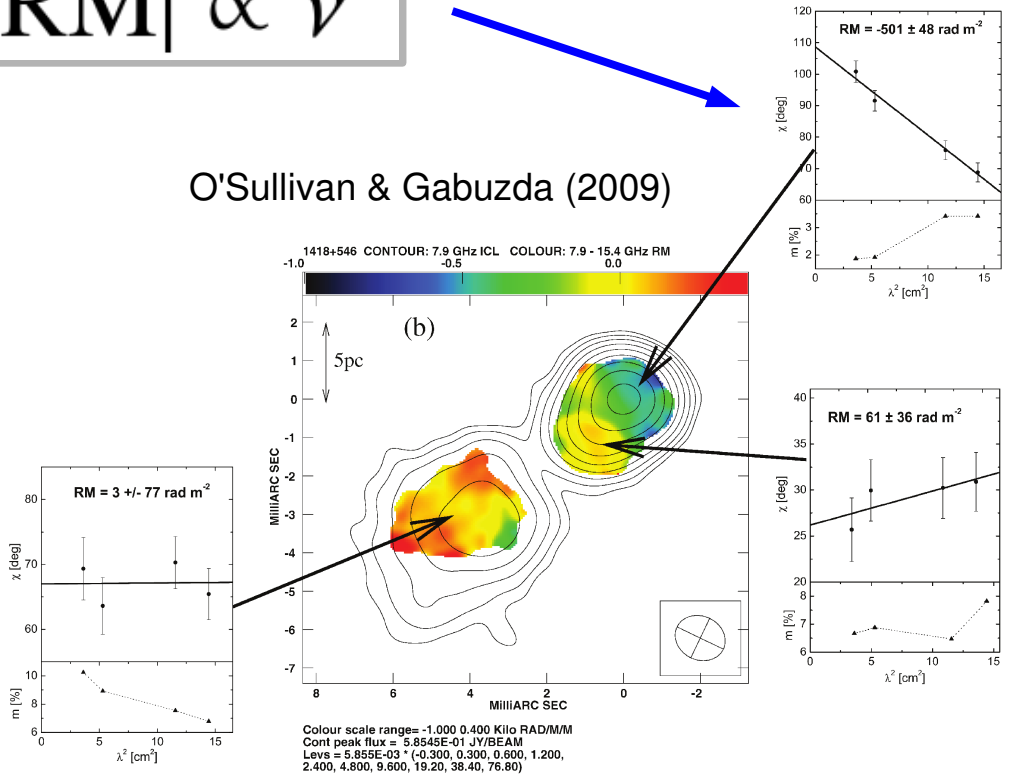
$$\frac{\mathrm{RM}}{\mathrm{rad\,m^{-2}}} = 8.1 \times 10^5 \int_{\mathrm{l.o.s.}} \left(\frac{B_\parallel}{\mathrm{G}}\right)\left(\frac{n_e}{\mathrm{cm^{-3}}}\right)\mathrm{d}\left(\frac{l}{\mathrm{pc}}\right)$$

Rotation measures → outflow geometries

$$|\mathrm{RM}| \propto \nu^{a}$$



O'Sullivan & Gabuzda (2009)



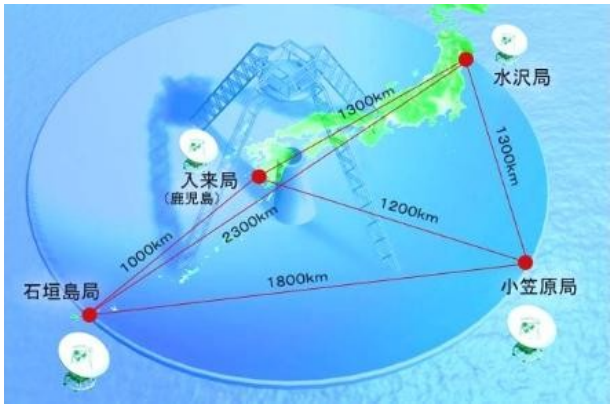
a ≈ 2 → spherical / conical outflow geometry

Summary

- We have exploited 4 years of polarization monitoring data of AGN
- Linear polarization on the order of ~5% (synchrotron theory: up to ~70% expected)
- Polarization is highly variable on the same time (and spatial?) scales as the flux
- Polarization variations indicate strong shocks
- Rotation measures up to ~400,000 plus indication for spherical/conical outflows
- Overall: data prefer “discrete shock zone” scenarios at scales of parsecs

Trippe et al. 2010, A&A, 515, A40
Trippe et al. 2012, A&A, 540, A74

Coming soon:
KVN+VERA: deep polarimetric imaging



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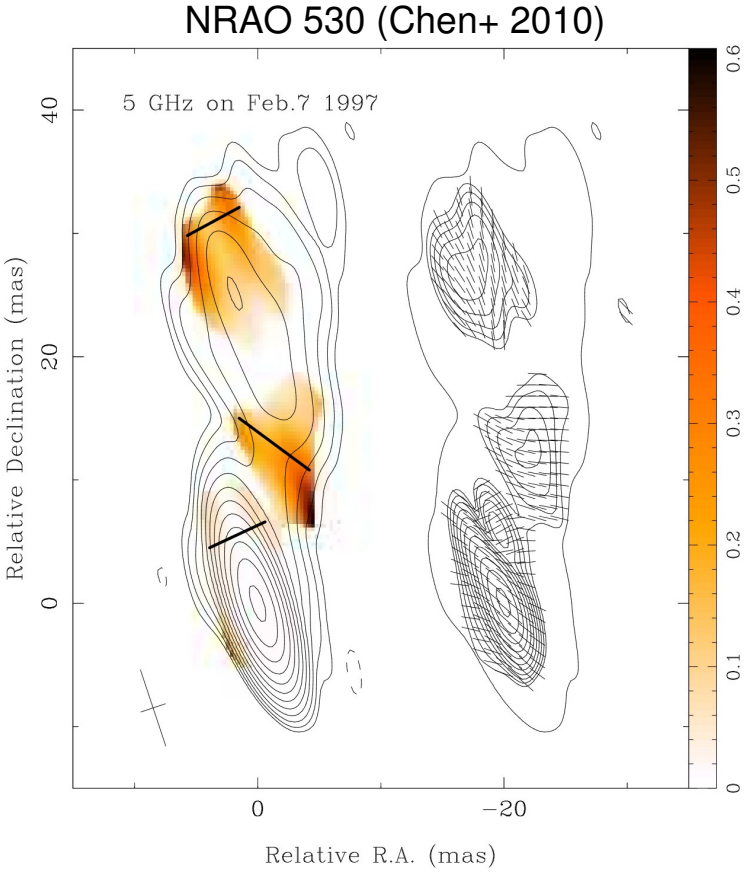

- 7 antennas = 21 baselines
- Five (?) stations with dual polarization receivers at 22+43 GHz