Probing the Magnetized Medium of AGNs using Wideband Radio Polarimetry

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IMPRS astronomy & astrophysics Bonn and Cologne

Max-Planck-Institut für Radioastronomie
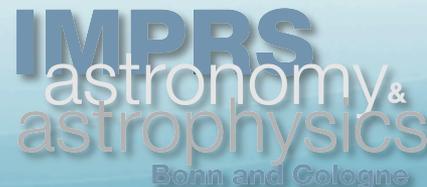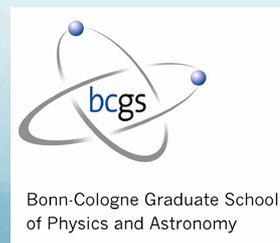
The targets

- **77 Polarized Extragalactic Radio Sources** (|b| >10°)

- Radio galaxies / AGNs

- **Selected from NVSS** (NRAO VLA Sky Survey)
  - 1.4 GHz
  - 45" resolution
  - Full polarization
  - 1.7M radio sources!

- **Unresolved** in NVSS

- **Highly polarized** (>30%) in NVSS

Motivation

- Origin of ordered magnetic fields
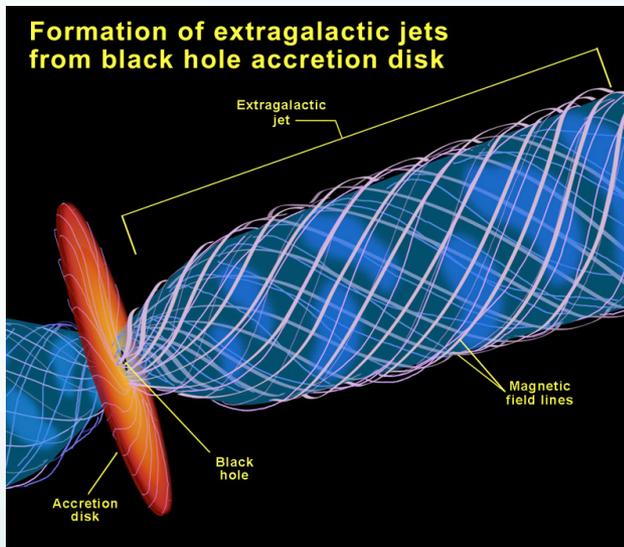
Credit: NASA and Ann Field (Space Telescope Science Institute)

- Probes of magnetism in foreground objects
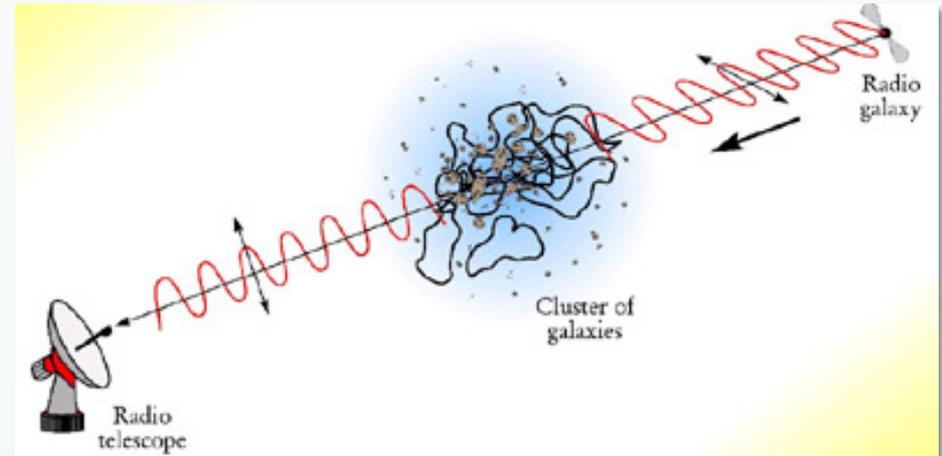
Credit: P. Kronberg, *American Institute of Physics*

- Brand new class of objects?

The project

- Unusual **highly polarized** point sources
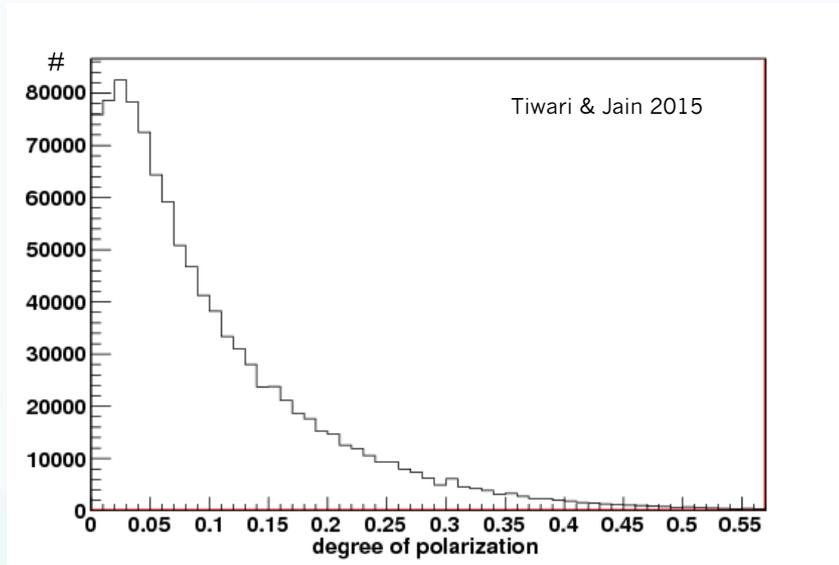
Tiwari & Jain 2015

NVSS: p ≥ 30 %

Credit: NASA

- Reason?
  1) Intrinsically ordered magnetic fields?
  2) Less depolarization?
  3) Selection bias by low signal-to-noise in NVSS?

The project

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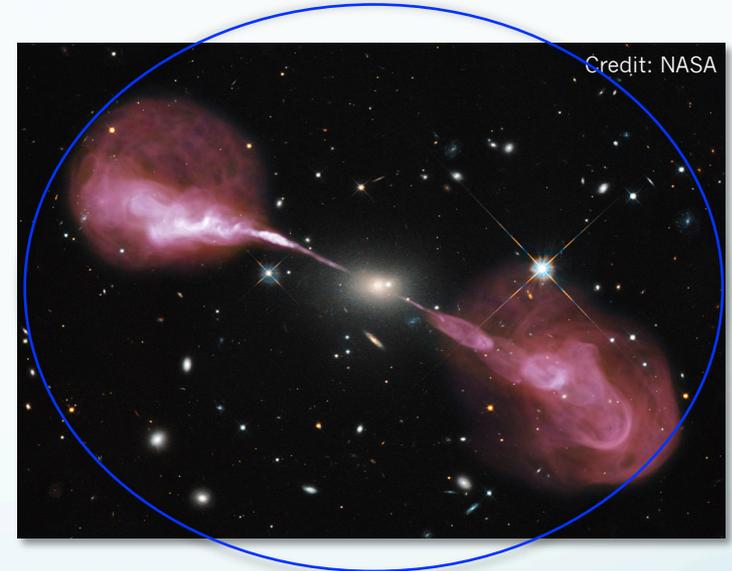
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Observation

- High resolution polarization survey of 77 NVSS sources with p ≥ 30%

- JVLA
  - L band (1-2 GHz) with Θ ≥ 15"
  - Snapshot mode

- Wideband

- RM-Synthesis

RM-Synthesis from data

$$\mathbf{P}(\lambda^2) = \int\limits_{-\infty}^{\infty} \mathbf{F}(\phi)e^{2i\phi\lambda^2}\mathrm{d}\phi$$

- Polarized signal in 3-dimensional data cubes

- After applying RM-synthesis the third axis gives the Faraday depth along one line of sight (**RM$\equiv\phi$**)

- The Faraday spectrum shows the polarized flux density at different Faraday depths

Q Credit: George Heald **U**

λ^2 λ^2

RM Synthesis

Q U

ϕ ϕ
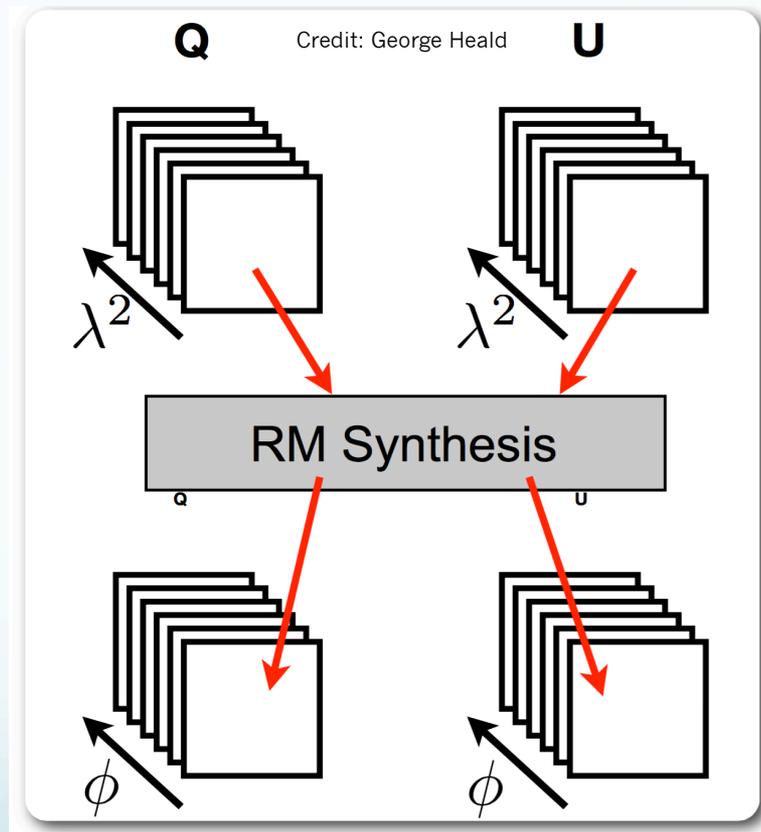
FT

$$\mathbf{F}(\phi) = \int\limits_{-\infty}^{\infty} \mathbf{P}(\lambda^2)e^{-2i\phi\lambda^2}\mathrm{d}\lambda^2$$

Polarized Intensity Images
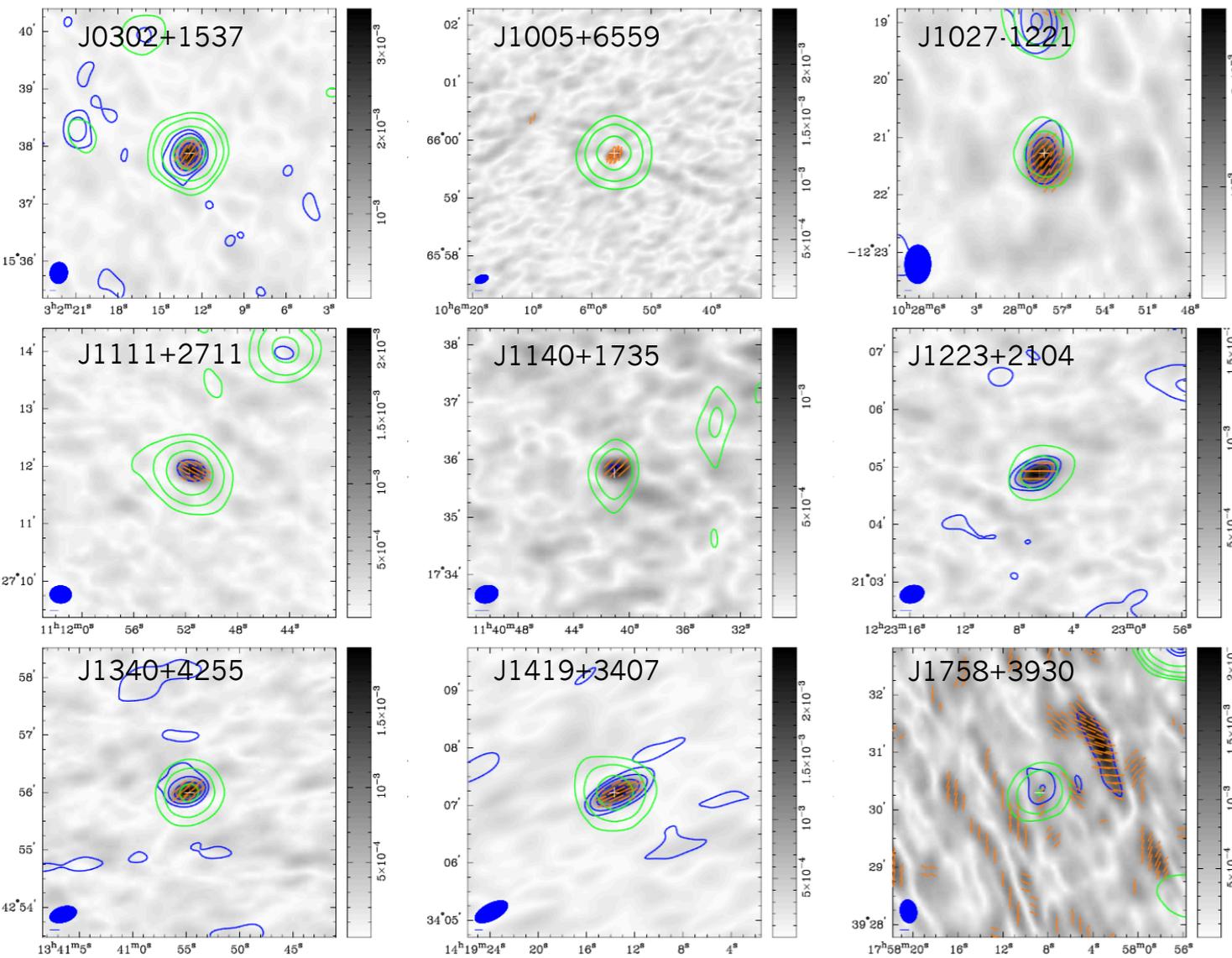
Background: PI
Blue: Stokes I (~15'')
Green: Stokes I NVSS (45'')

Contour levels: (3,6,12,24)*rms

PAs clipped at 3σ; rotated by 90°

Line segment in lower left corner represents 1mJy in PI

9

Faraday Spectra from RM-Synthesis

9 sources with S/N > 10 in PI

Black line: distribution of polarized flux density

Blue lines: clean components from RM-Synthesis

Green line: rms in ϕ-space (average of all data 3*FWHM away from peak)

FWHM ~ 123 rad/m^2
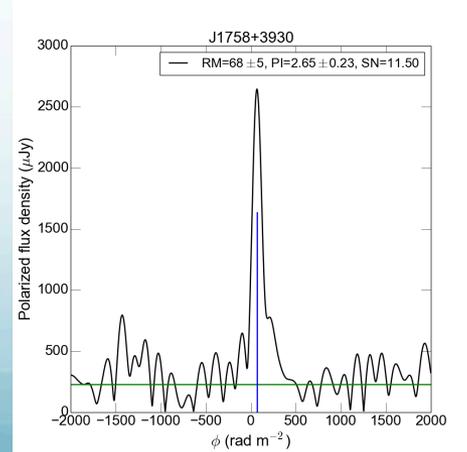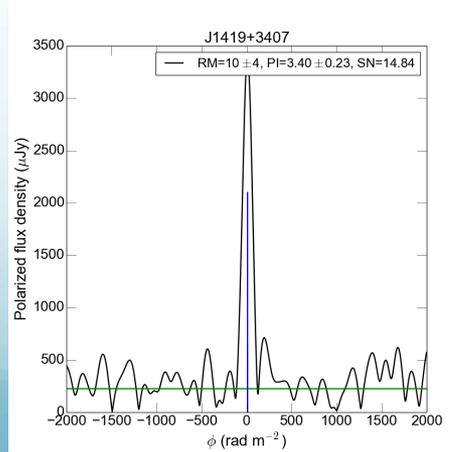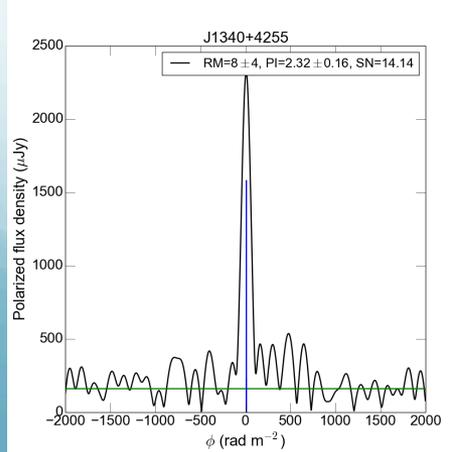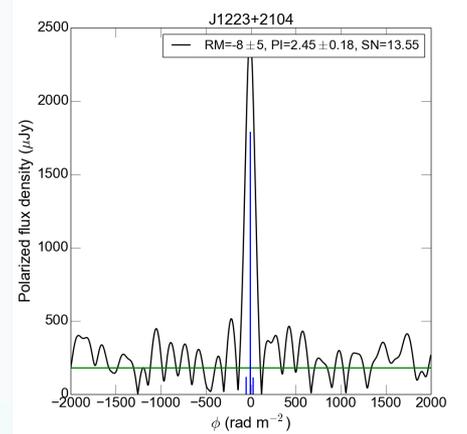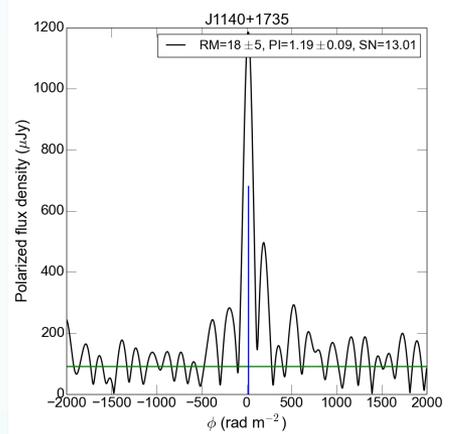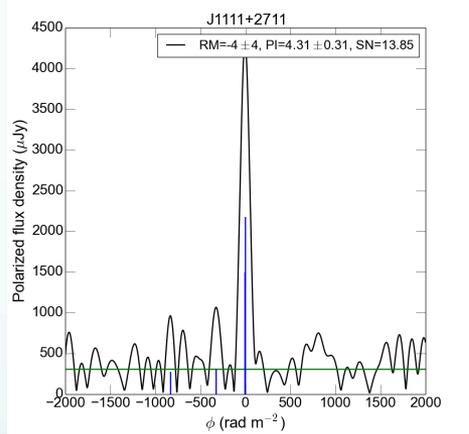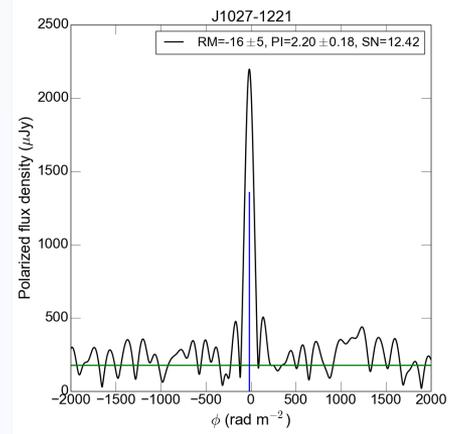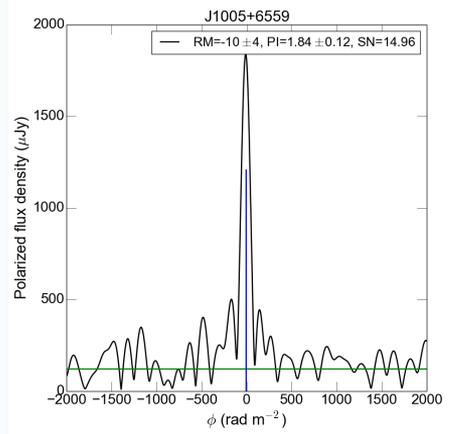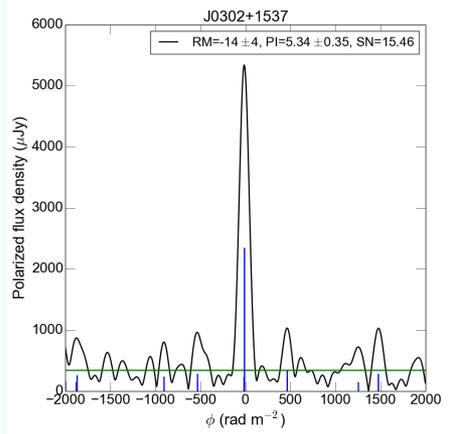
Results from RM-Synthesis

- 77 observed

- 11 non detections in Stokes I

- 49 sources with S/N ≥ 4 in PI

- 39 (out of the 49) sources with S/N ≥ 4 in Stokes I

- 9 sources with S/N ≥ 10 in PI

Source	RM (rad m^{-2})	PI (mJy)	p (%)	α
J0302+1537	−14 ± 4	5.3 ± 0.4	37.6 ± 1.3	−0.67 ± 0.37
J1005+6559	−10 ± 4	1.8 ± 0.1	51.1 ± 20.4	2.55 ± 1.65
J1027-1221	−16 ± 5	2.2 ± 0.2	60.7 ± 8.9	−1.20 ± 0.99
J1111+2711	−4 ± 4	4.3 ± 0.3	48.4 ± 2.9	−0.71 ± 0.31
J1140+1735	+18 ± 5	1.2 ± 0.1	38.6 ± 20.3	0.39 ± 0.67
J1223+2104	−8 ± 5	2.5 ± 0.2	42.3 ± 2.6	−0.29 ± 0.30
J1340+4255	+8 ± 4	2.3 ± 0.2	29.8 ± 1.9	−1.5 ± 0.51
J1419+3407	+10 ± 4	3.4 ± 0.2	36.4 ± 1.9	−1.23 ± 0.28
J1758+3930	+68 ± 5	2.65 ± 0.2	46.1 ± 8.6	−2.62 ± 0.47

Degree of polarization

- Broad band fractional polarization less than original selection criteria?

Distribution of fractional polarizations

bin width=3.01
mean_calc=32.08±0.23
sigma_calc=14.92±1.31
median=28.81

Comparison of p in JVLA and NVSS measurements
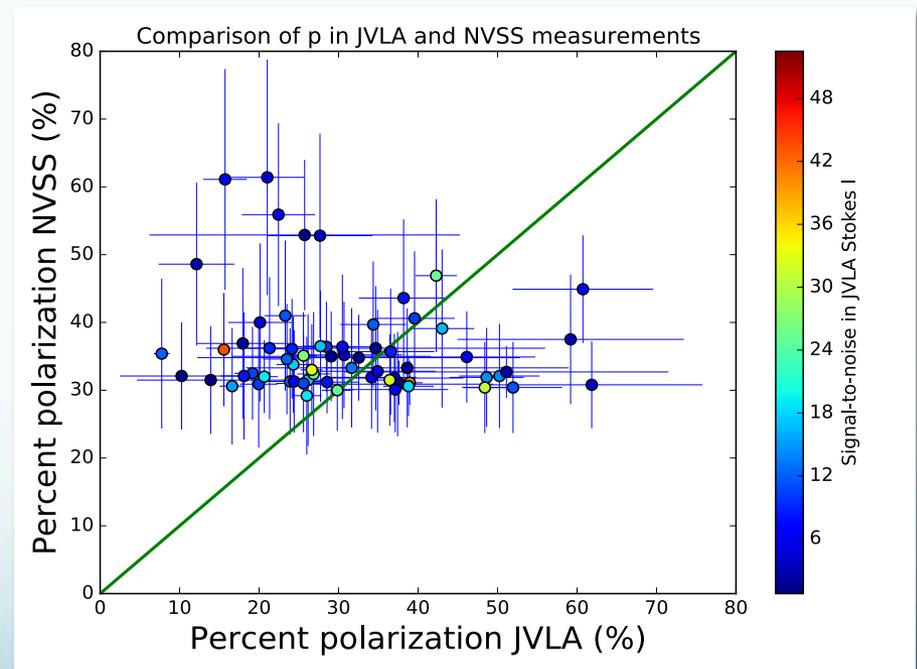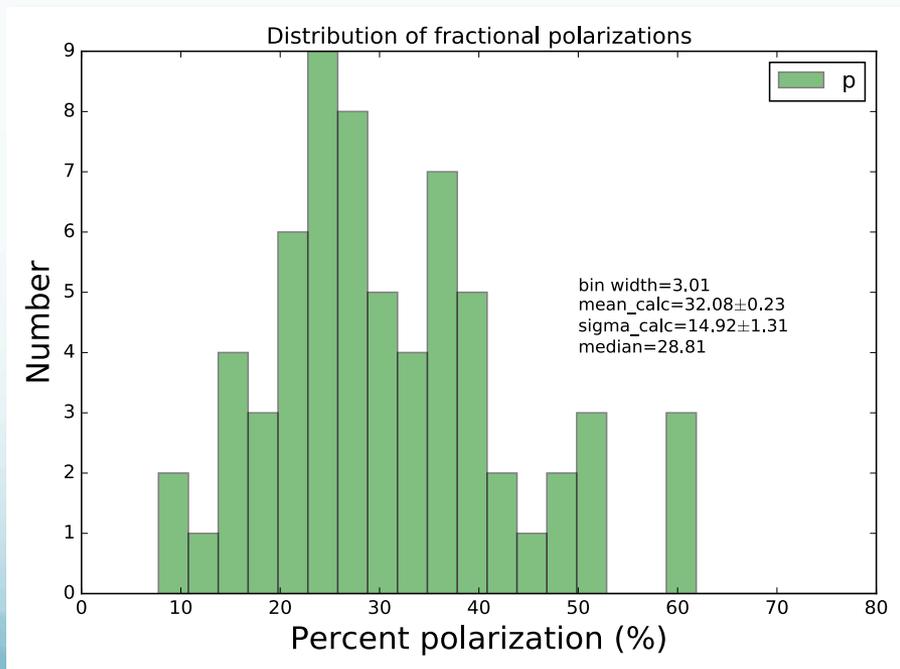
Rotation measures

- New broad band RM values!

- Not included in Taylors RM catalog due to low S/N
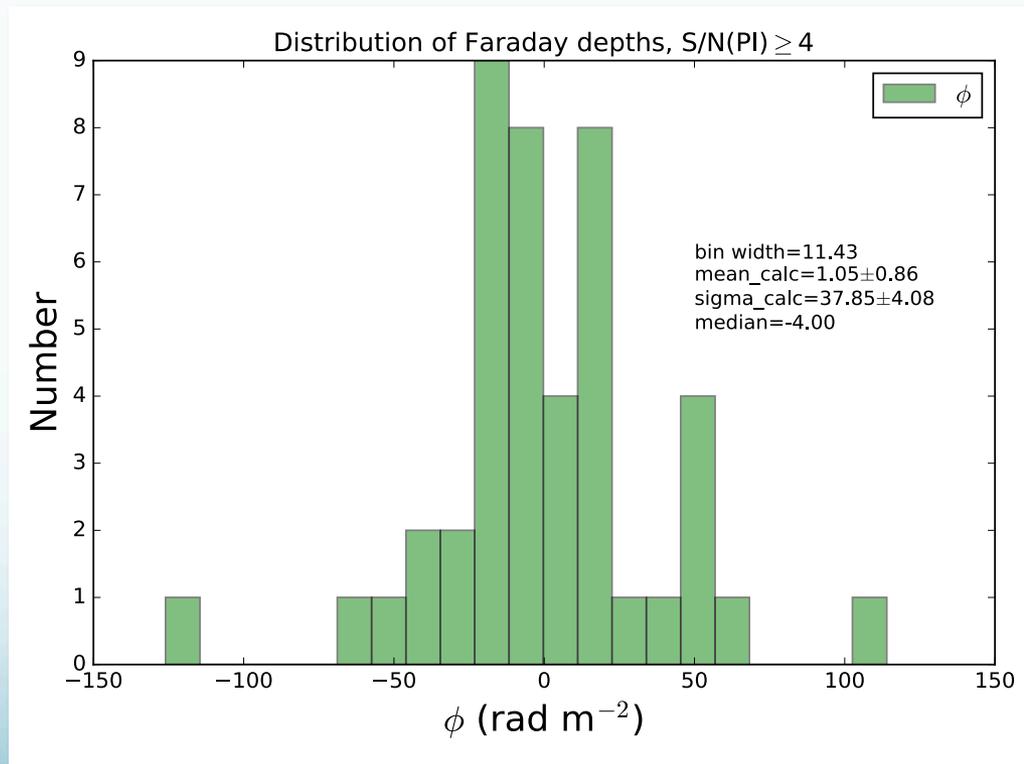
Spectral index

- Highly polarized sources show both steep and flat spectral indices

Distribution of Stokes I spectral indices

bin width=0.26
mean_calc=-0.77 ± 0.01
sigma_calc=0.96 ± 0.08
median=-0.82
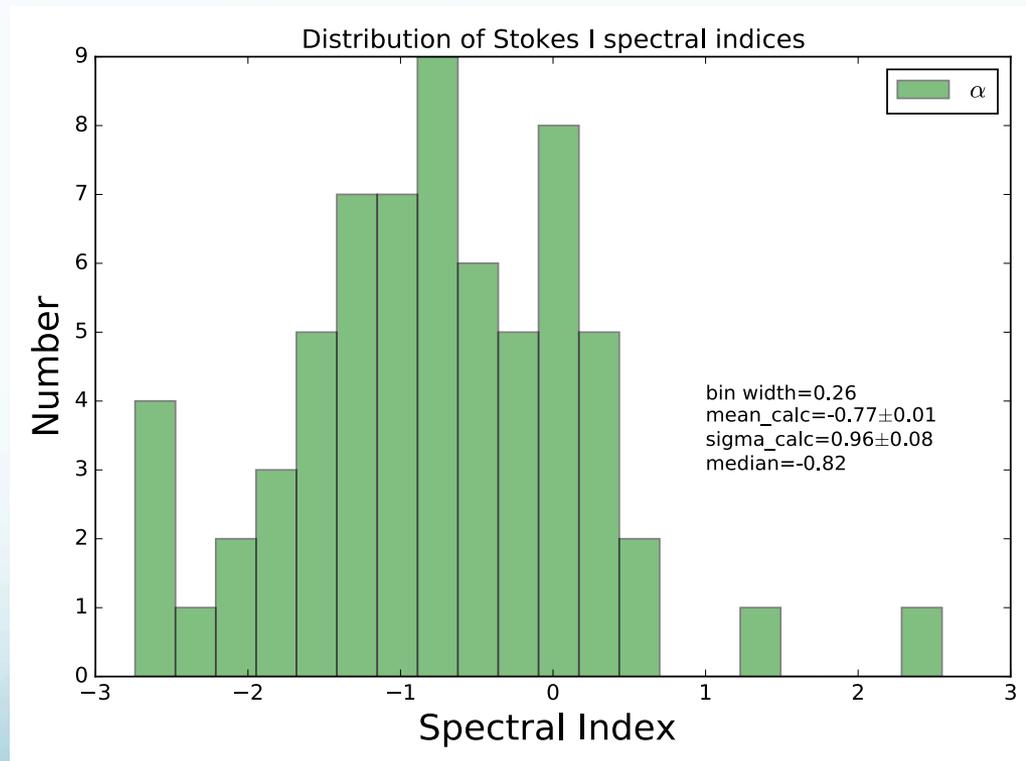
What else?

$$p, \quad RM, \quad \#, \quad \alpha, \quad z$$

Fractional polarization
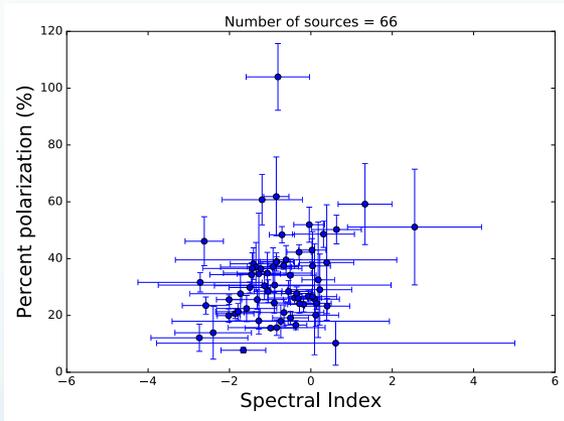
Rotation Measure

Majority with small RMs?
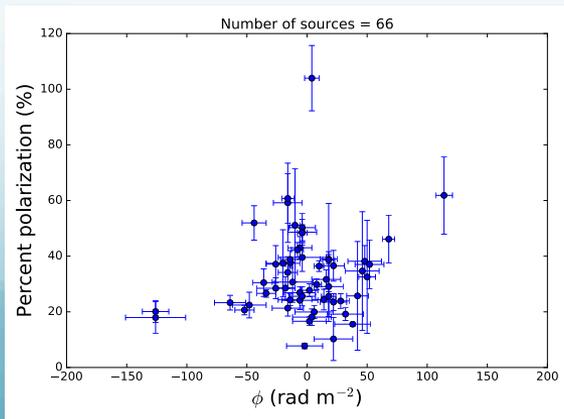
Number of Faraday components

Only single components detected

Spectral Index

Broad distribu-tion?

Redshift
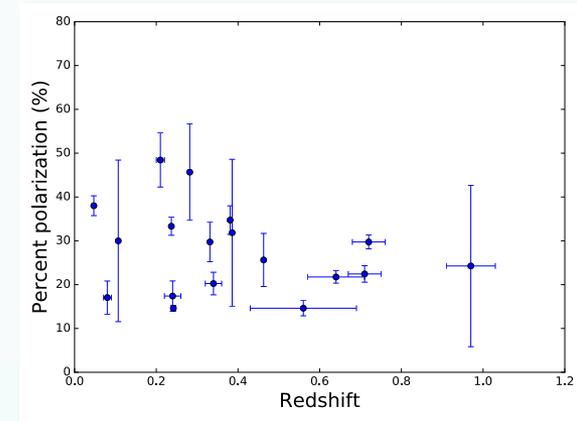
Summary

- New survey of 77 unresolved sources with unusual high degree of polarization (≥ 30 %)

- Degrees of polarization lower than NVSS but still unusual high

- Found simple Faraday spectra and low RMs

- Found no trend in spectral indices

- Technical methods:

  - Polarimetry

  - RM-Synthesis

- Goal:

  - Understanding origin of high degree of polarization

  - Understanding nature of well-ordered magnetic fields