Radio Polarisation Study of High Rotation Measure AGNs - How to Distinguish Intrinsic from External Sources of Rotation Measure?

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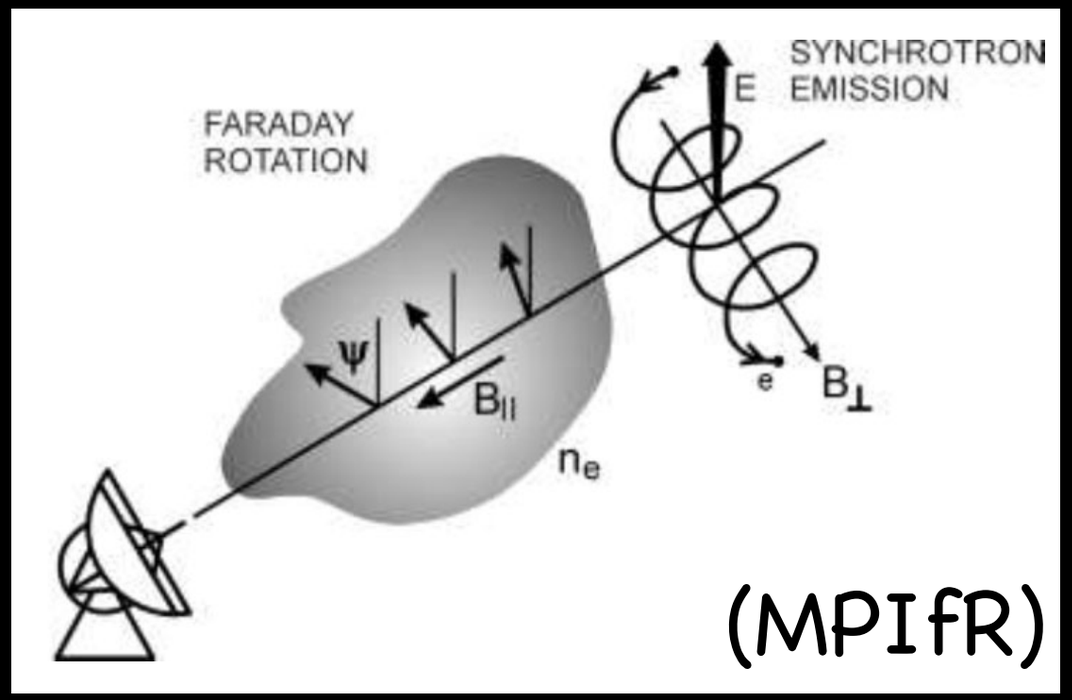
RM as the Probe of Foreground Physical Environments

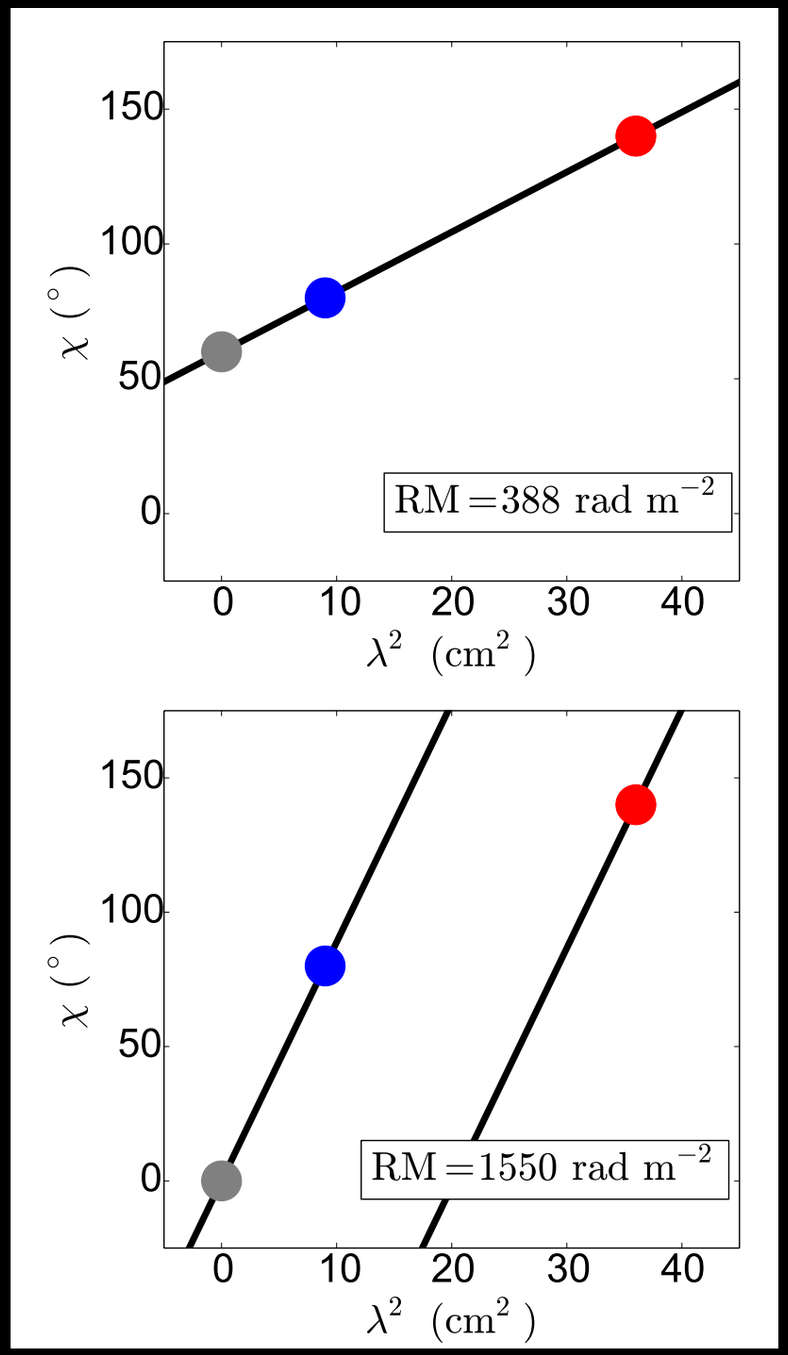
$$\Psi = \Delta\chi = 0.81\lambda^2 \int_{\ell}^{0} n_e(s) B_{||}(s)\,\mathrm{d}s \equiv \mathrm{RM}\lambda^2$$

- Info about the physical environments in the foreground (e.g. AGN jet, NLR, ICM, Milky Way…) is encrypted in RM



(MPIfR)

Determination of RM



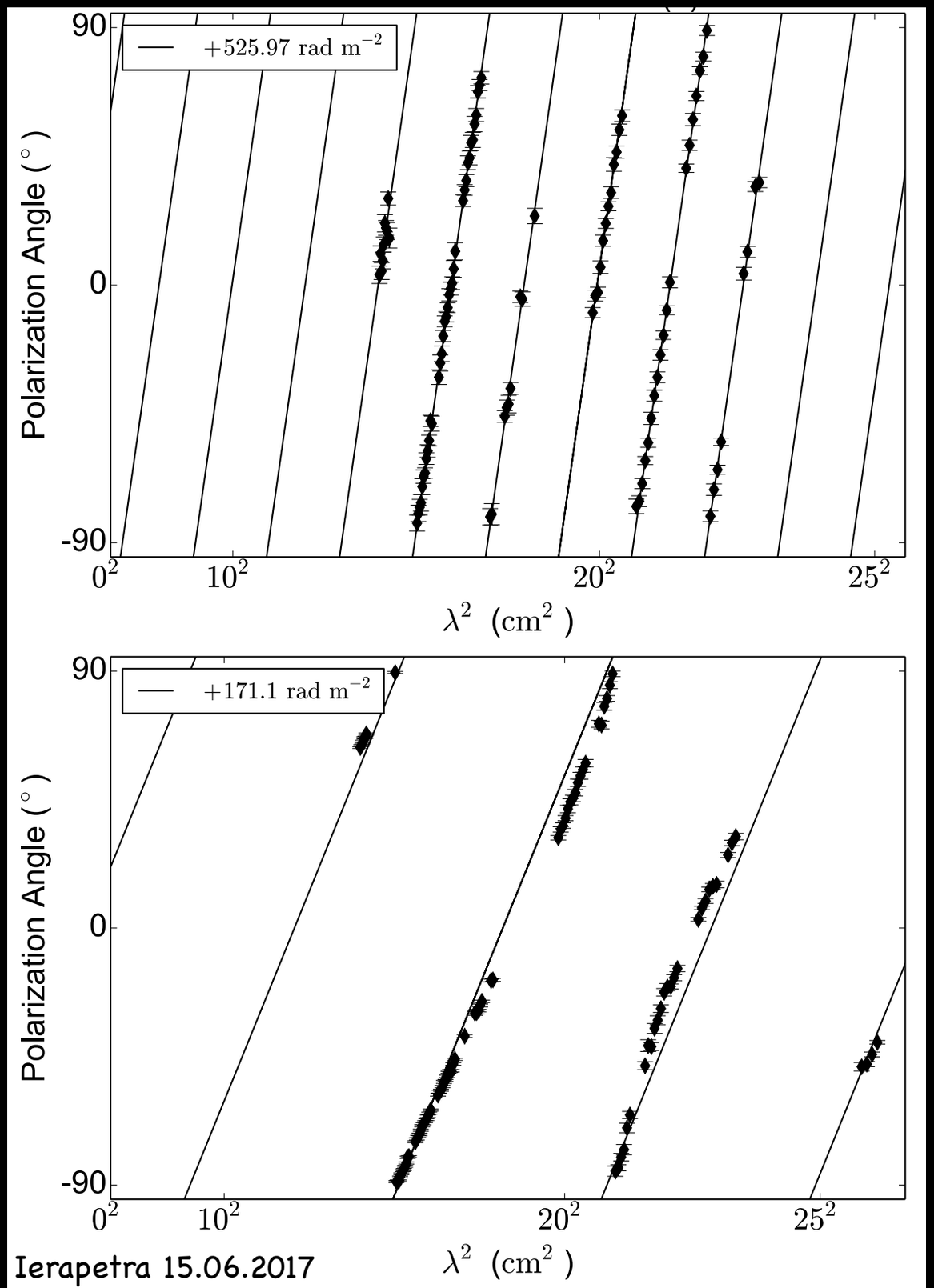
(from Ma 2015 Master thesis)

- Two (or more) PAs at different λ needed to get RM
- λ^2-fit: $PA(\lambda^2) = PA_0 + RM\ \lambda^2$
- Problems:
- Relative rotation between two bands could be $\pm n\pi$ radians more / less than simple (upper) picture

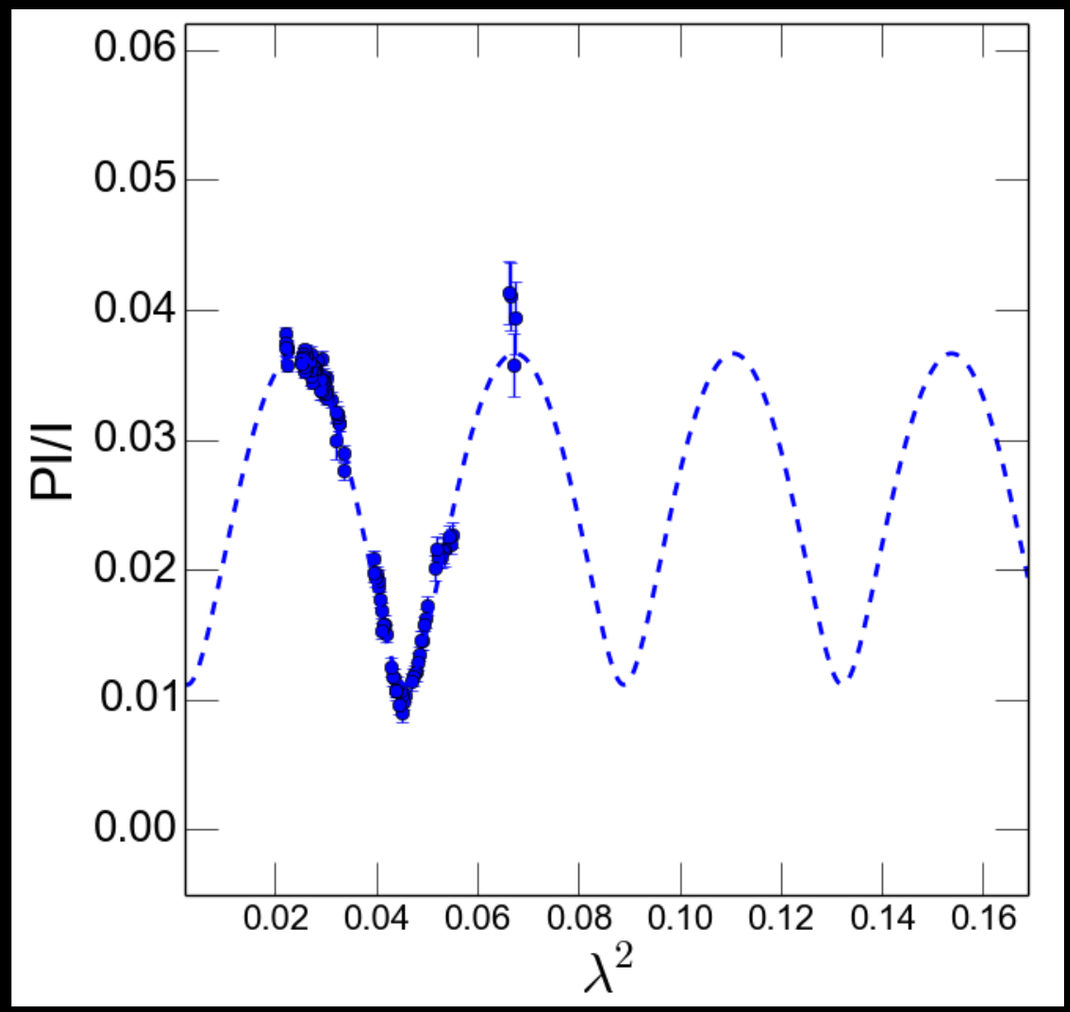
nπ-ambiguity!

- Also ignores "Faraday complexity" (deviation of PA from λ^2-law, and/or de/re-polarisation signature)

Determination of RM



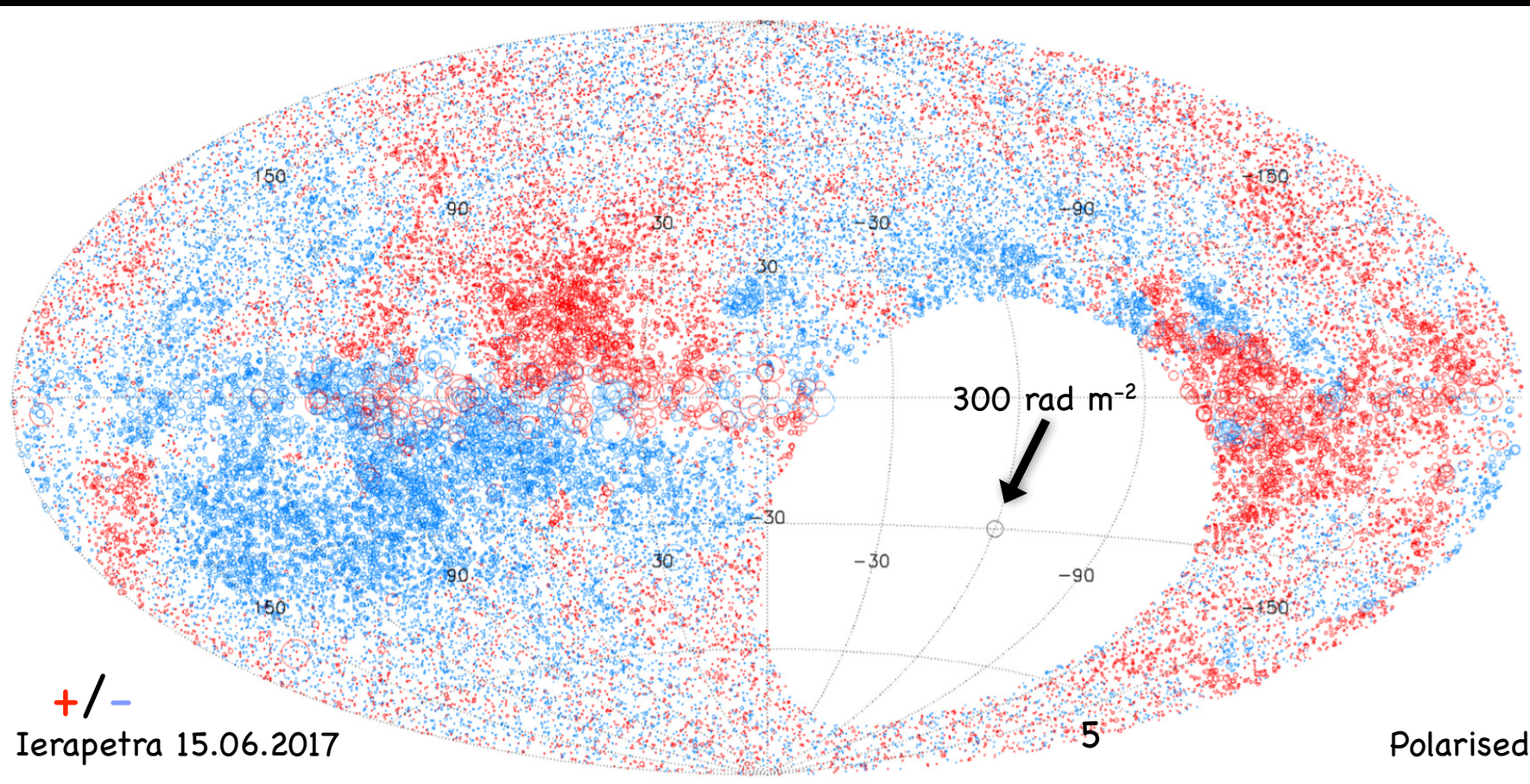
The power of broadband polarisation observations!!



(See also: talks by Talvikki Hovatta, Craig Anderson, & Alice Pasetto)

NVSS RM Catalogue

- RM of 37,543 sources! Excellent sample of background probes of, e.g., Milky Way magneto-ionised medium
- Old L-band: 1364.9 & 1435.1 MHz (bw: 42 MHz each)
- They devised an algorithm in attempt to minimise nπ-ambiguity… But how effective is it??

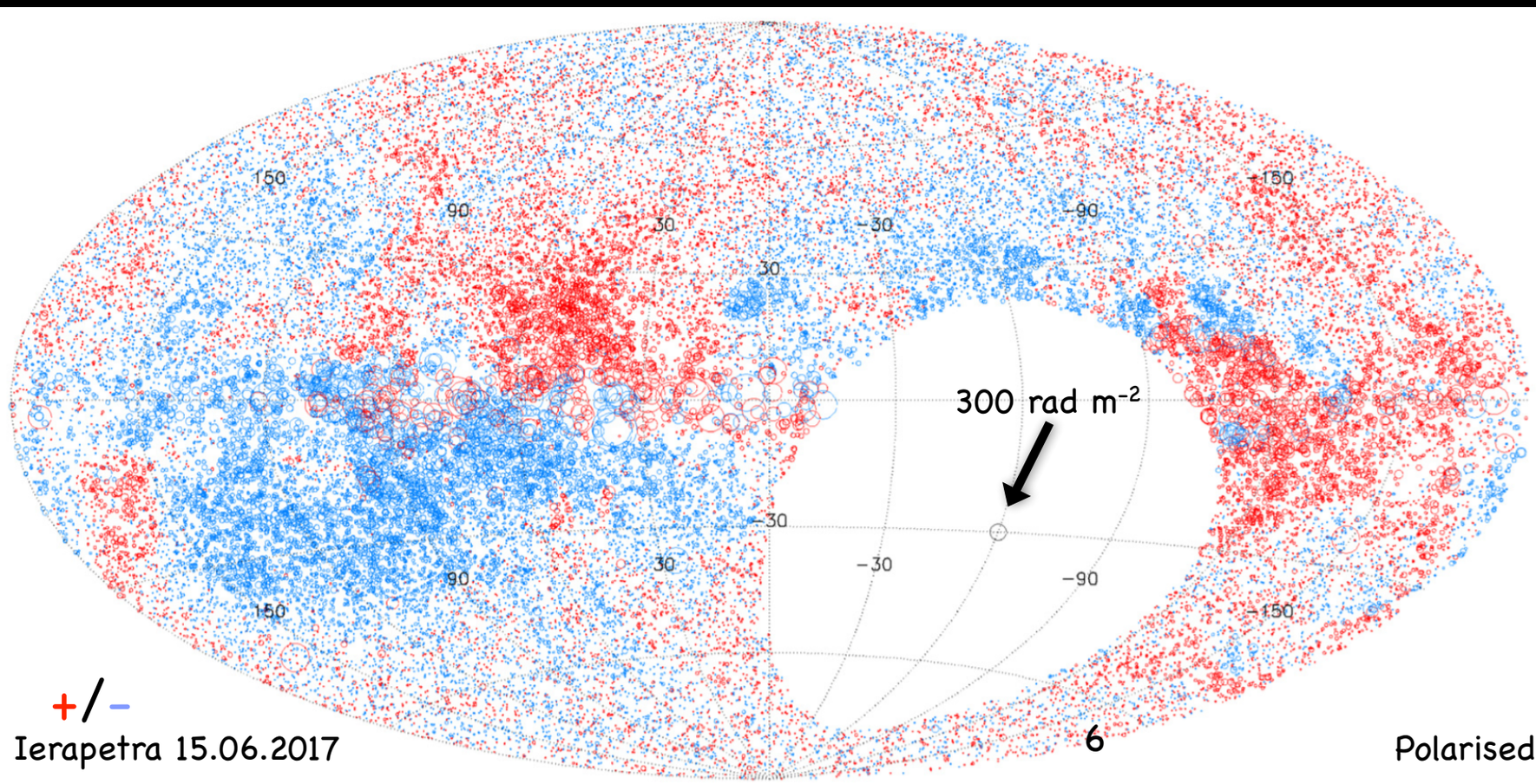


(Taylor+2009)

+/−

High RM Sources in NVSS RM Catalogue

- At |b| > 10°:
  - almost 99% have $|RM_{NVSS}| < 150$ rad m^{-2}
  - ~20 with $|RM_{NVSS}| \gtrsim 300$ rad m^{-2}!!



(Taylor+2009)

High RM Sources in NVSS RM Catalogue

	NVSS RM is erroneous [Impostors!]	NVSS RM is correct [(Statistical) Outliers]	
Causes	nπ-ambiguity	High RM intrinsic to the sources	Sources lying on special sightlines (behind magnetised clouds in intergalactic medium / Milky Way?)
Why interesting?	May affect foreground RM experiments (e.g. Harvey-Smith+2011; Oppermann+2012; Purcell+2015)	Exotic sources! Unique probe of immediate vicinity of those sources	Identification of magnetised clouds (e.g. Gum Nebula, Smith's Cloud, Sh2-27...)

Broadband observations can give RM free of ambiguity

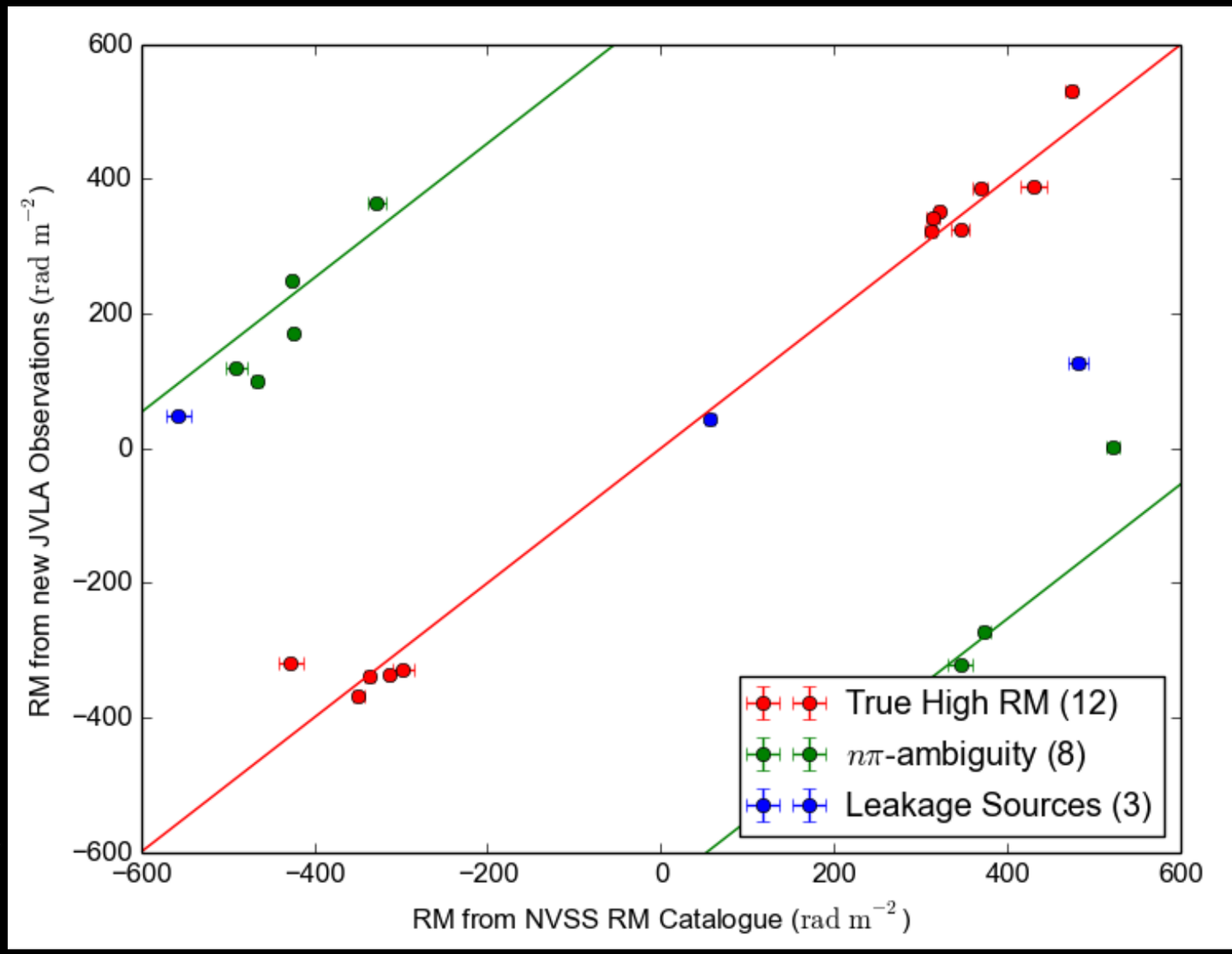
Broadband observations + RM synthesis & QU-fitting can give us insights

New Broadband Observations

- Karl G. Jansky Very Large Array (JVLA) in Jul 2014
- L-band (1-2 GHz; 1 MHz channel)
- D array configuration (angular resolution ~ 45″)
- Typical rms: 400 μJy/beam

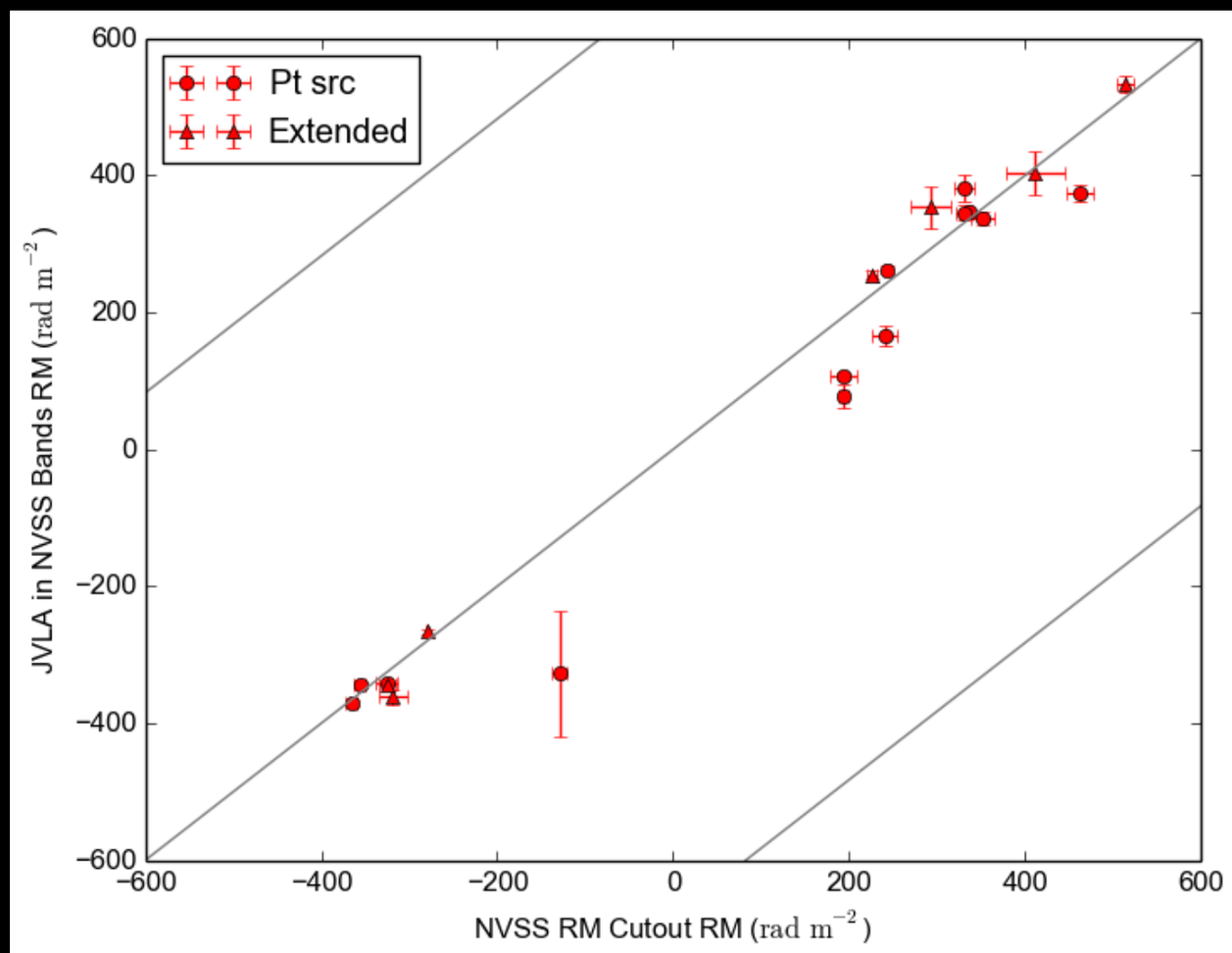
NVSS RM nπ-ambiguity

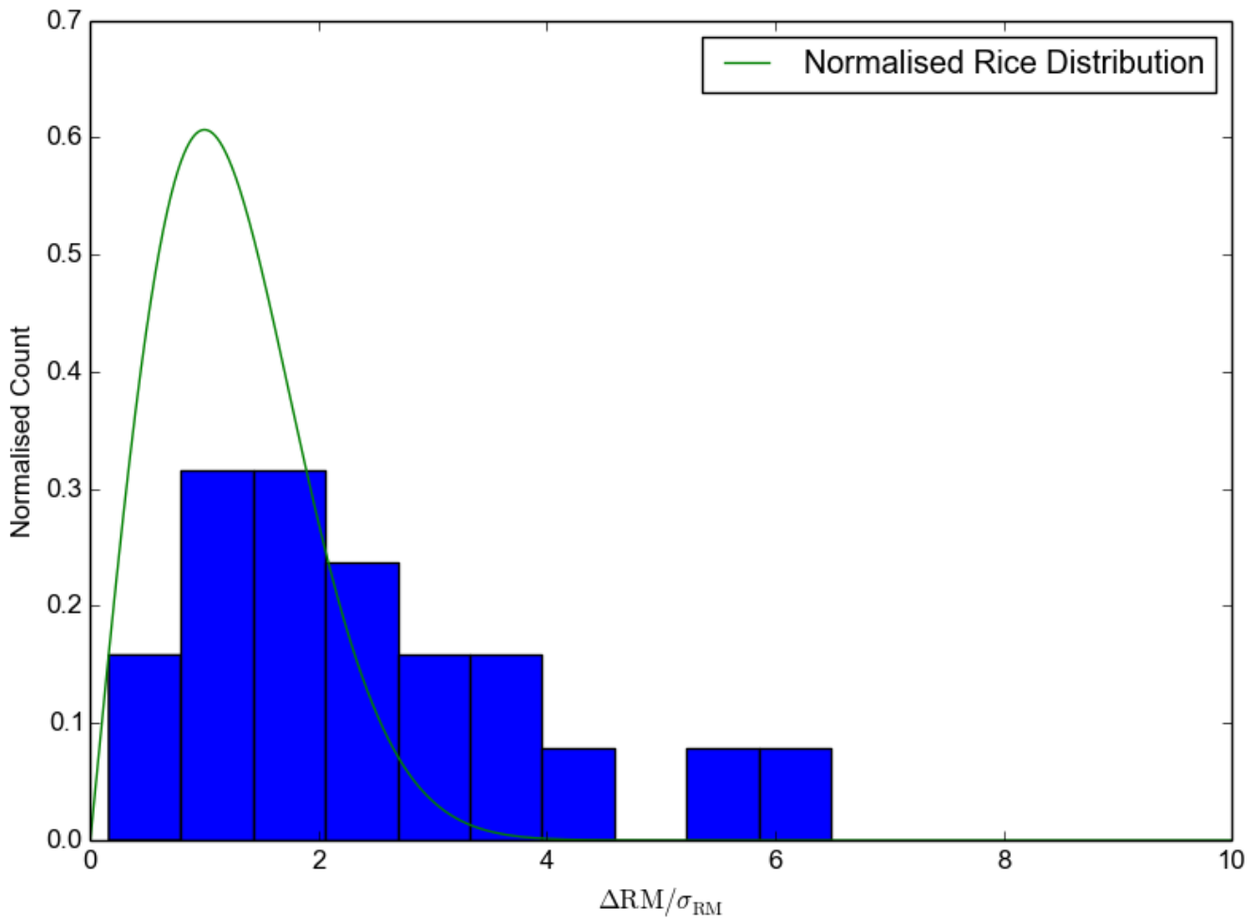
- 8 out of 20 sources **(40%)** suffered nπ-ambiguity in NVSS RM Catalogue!
- Questions to be answered:
  - Why the Taylor+2009 algorithm did not work for some sources?
  - What types of sources are more prone to this nπ-ambiguity?
- My suggestion: Do **NOT** fully trust the NVSS RM values of individual sources (e.g., do not use them to de-rotate your PA)



RM Variabilities

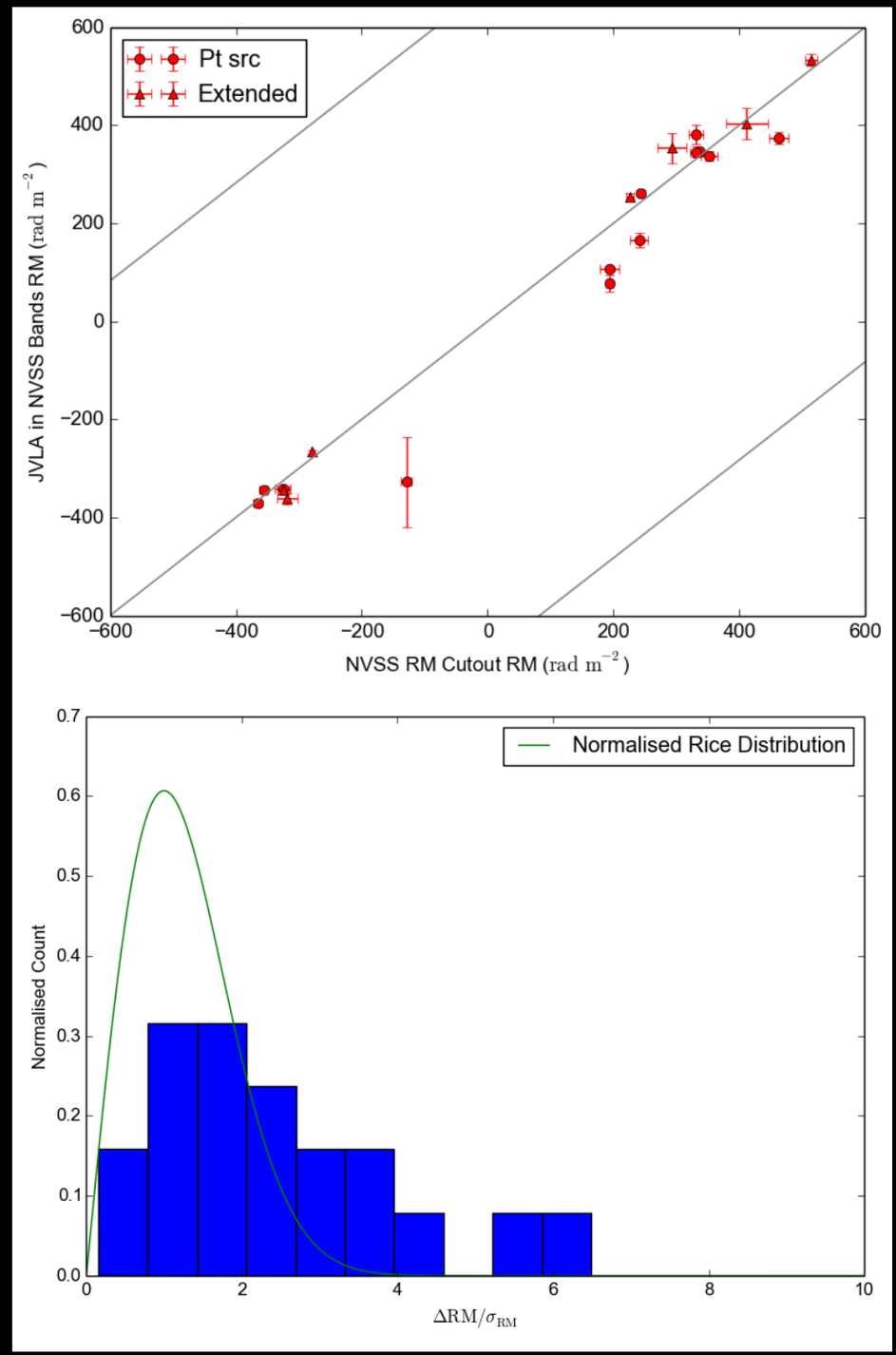
- Our new JVLA data: formed "images in NVSS bands"
- Compared with NVSS RM cutout images: apples to apples





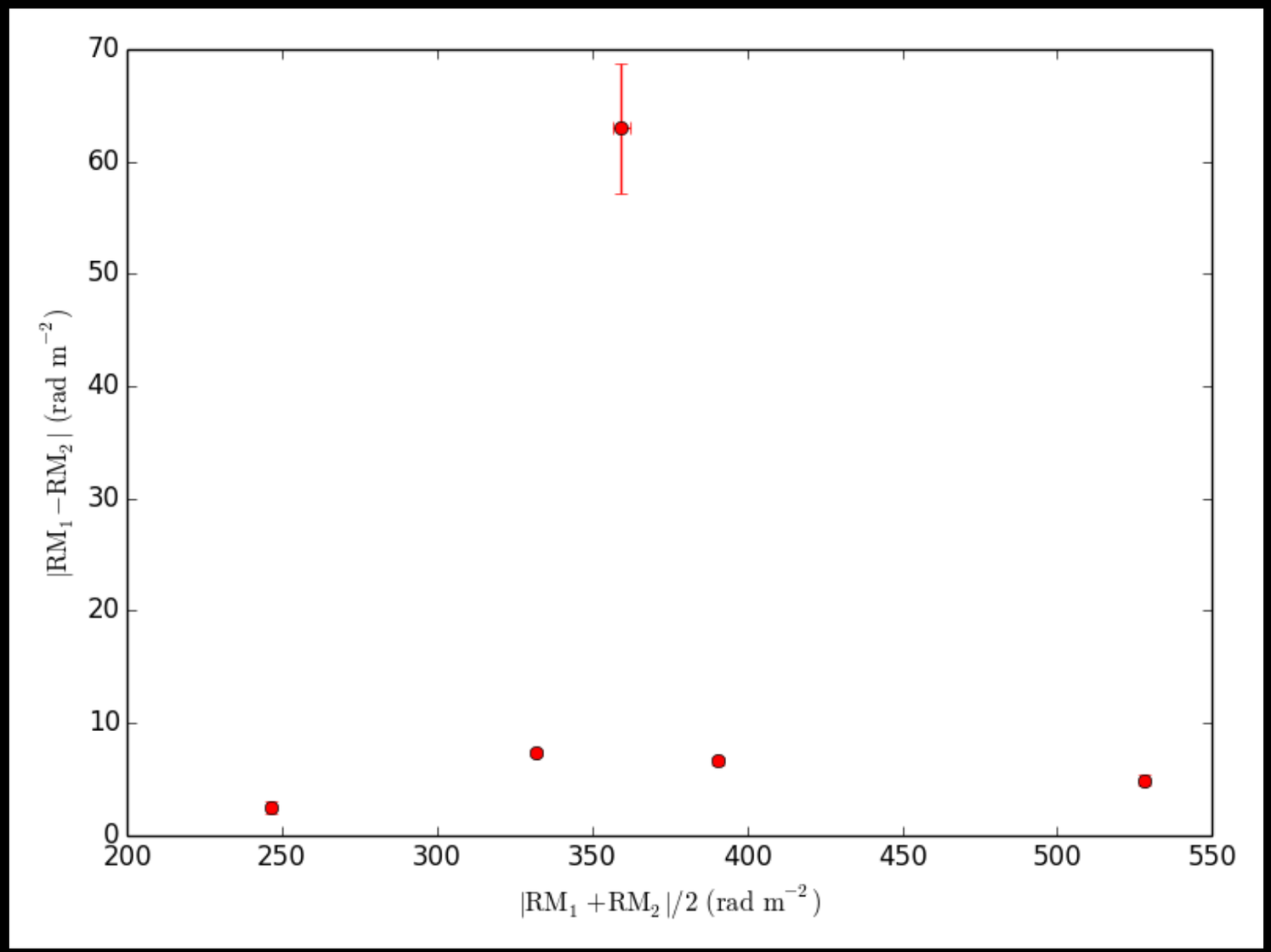
RM Variabilities

- Similar to RM variabilities seen in VLBI observations? (e.g., 3C273, 3C279; Zavala & Taylor 2001)
- Possible systematic effects (e.g., NVSS off-axis polarisation leakage)
- New JVLA observations last month: to confirm & characterise RM variabilities with broadband data (~ 3 years cadence)
- Broadband study as alternative / supplementary way to study RM variabilities of AGNs (vs VLBI)!!



Probing AGN Vicinities with RM

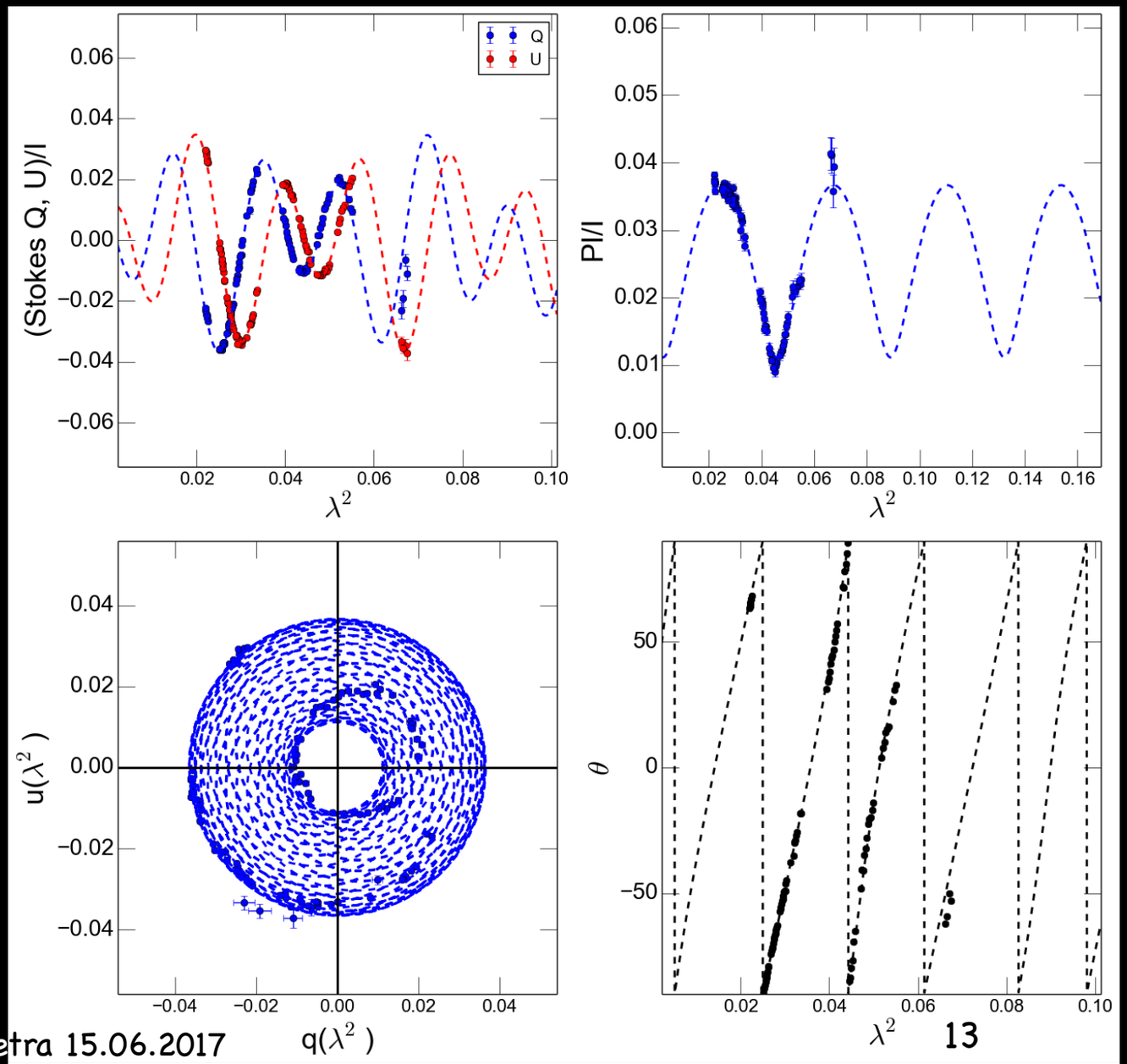
- Use AGNs composed of two point sources (two radio lobes?)
- ΔRM = RM_1–RM_2 (Laing-Garrington effect)



- Can also study by RM gradients of extended sources (e.g., see talks by Tuomas Savolainen, Sebastian Knuettel, & Evgeniya Kravchenko)

Probing AGN Vicinities with RM

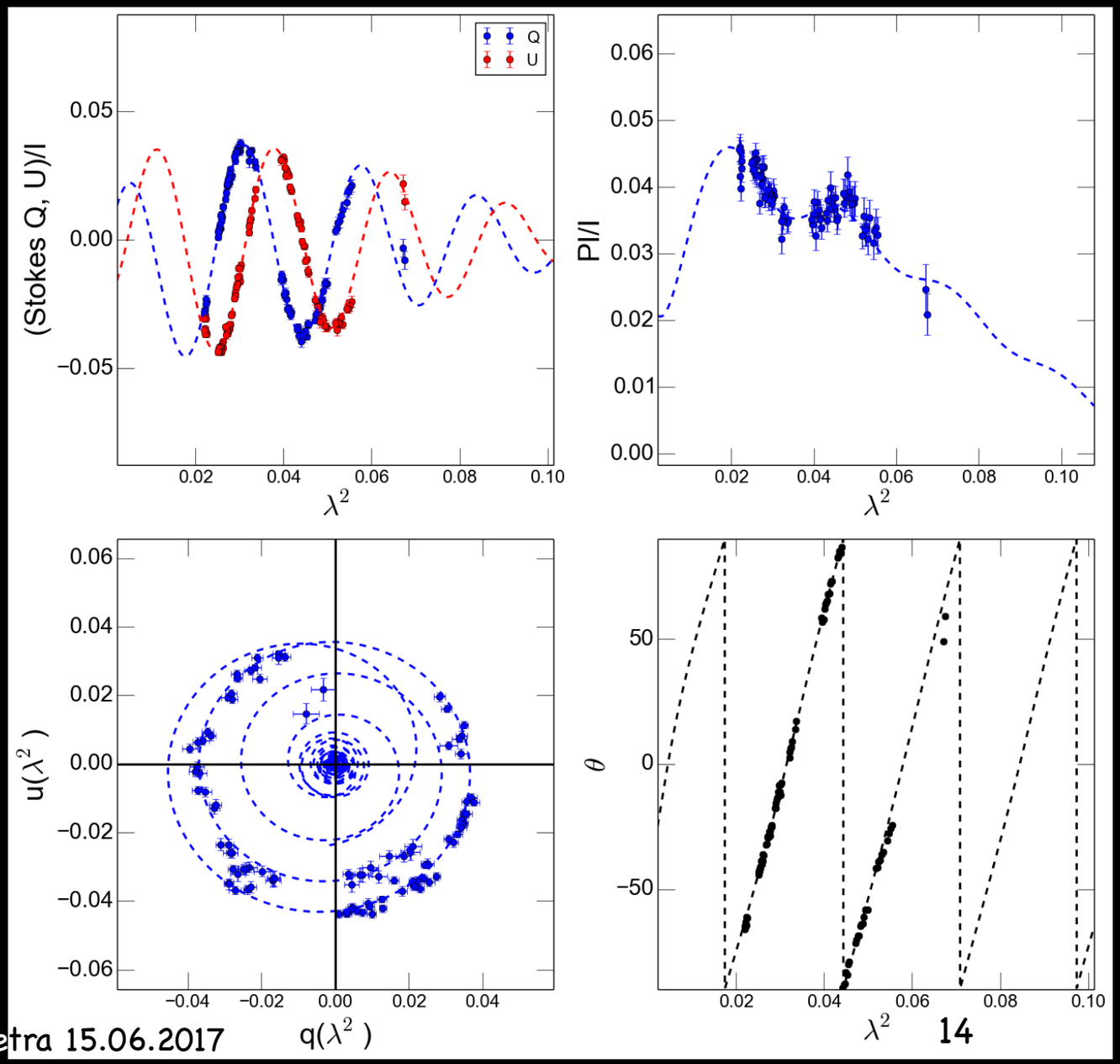
- Unresolved sources can host multiple Faraday components!
- Broadband observations can "resolve" spatially unresolved sources (QU-fitting: O'Sullivan+2012)



- Two Faraday-thin components:
- Component 1:
  pol = 1.27 ± 0.01%
  RM = +95.1 ± 1.0 rad m^{-2}
- Component 2:
  pol = 2.39 ± 0.01%
  RM = +167.9 ± 0.5 rad m^{-2}
- ΔRM = 72.8 ± 1.1 rad m^{-2}

Probing AGN Vicinities with RM

- QU-fitting can also recognise more complex polarisation signature
- e.g. Burn slab* (Internal Faraday rotation; Burn 1966), or foreground RM gradient, both probe physical conditions of AGNs



- Double Burn slab*
- Component 1:
  pol = 19.9 ± 0.6%
  FD = +106.7 ± 0.5 rad m^{-2}
- Component 2:
  pol = 22.0 ± 0.6%
  FD = +131.8 ± 0.5 rad m^{-2}

*Not distinguishable from foreground RM gradient

Summary

- Broadband studies of high |RM| sources away from Galactic plane
- At least some sources from the NVSS RM Catalogue (40% of my sample) suffers nπ-ambiguity
  - Be skeptical about the listed RM values of individual sources!!
- We noted RM variabilities of our sources when compared with NVSS RM (~ 20 years cadence)
  - Obtained new broadband data last month (~ 3 years cadence), to confirm + characterise the RM variabilities
- Broadband data + QU-fitting can be used as a tool to study the magnetised medium in / around AGN jets