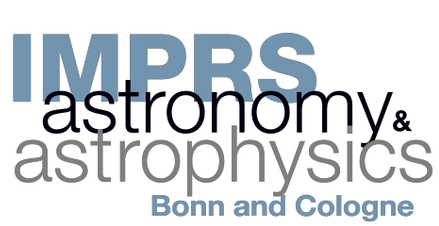
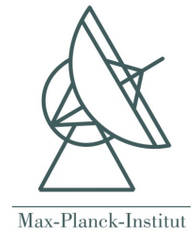
Physics of gamma-ray loud AGN jets

through high cadence, multi-frequency polarization monitoring

Ioannis Myserlis

E. Angelakis, L. Fuhrmann, A. Kraus, V. Pavlidou, D. Blinov, V. Karamanavis, J. A. Zensus



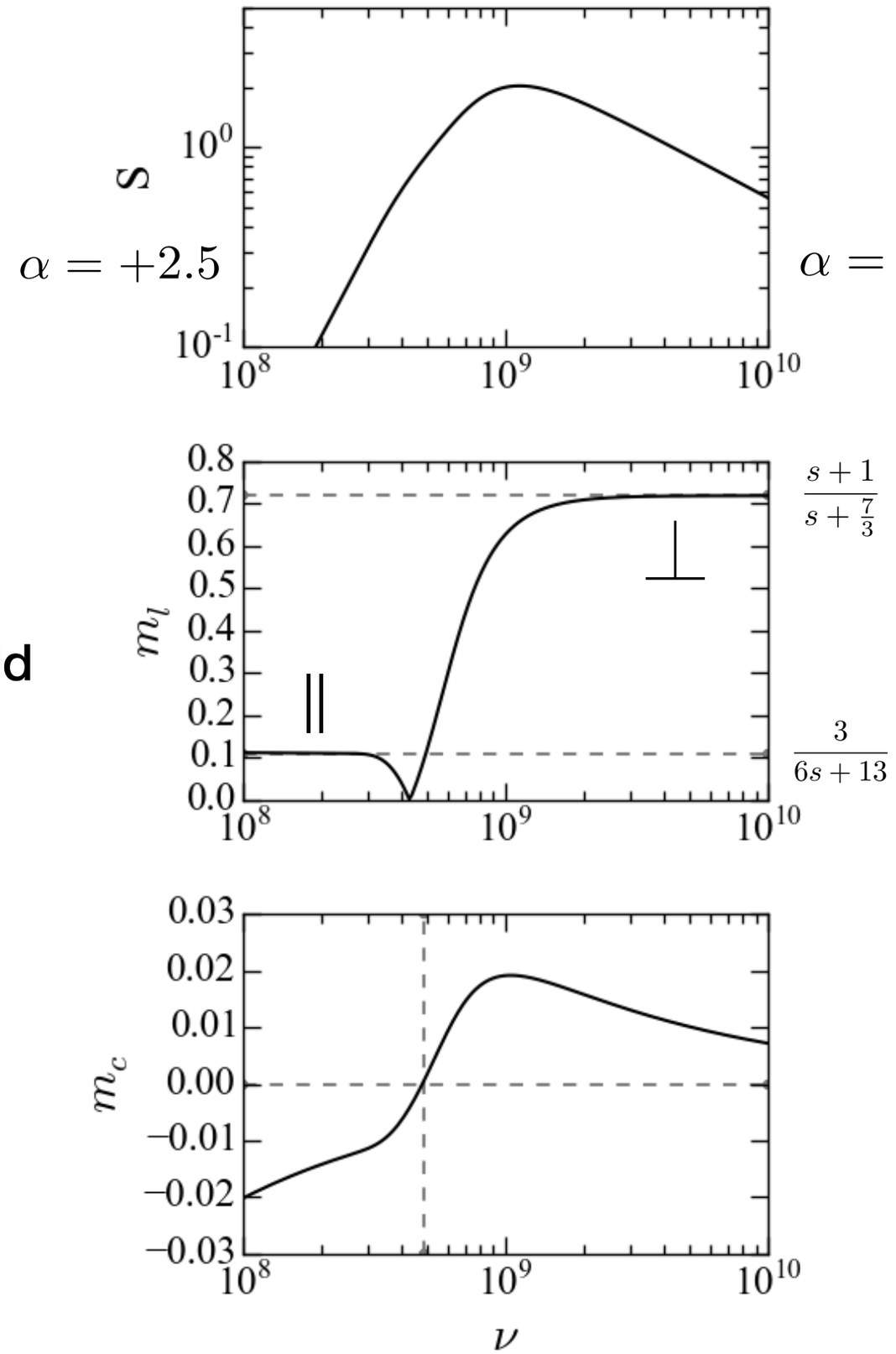


Synchrotron polarization

Energy distribution

$$N(E)dE = \kappa E^{-s} dE$$

$$S(\nu) \propto \nu^{\alpha}$$



χ parallel to projected ***B*-field**

χ perpendicular to projected ***B*-field**

based on Pacholczyk (1977)

High precision linear and circular radio polarimetry

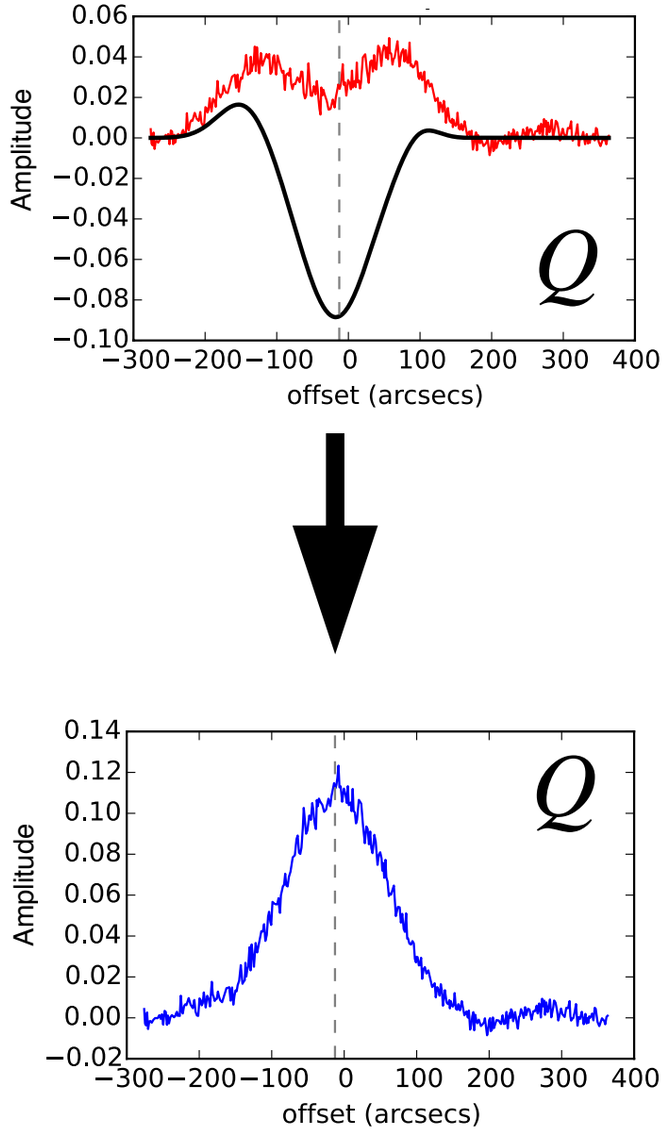
Realistic parametrization of the telescope response

Instrumental polarization removal

- LP: Instrument model
- CP: Zero-level using unpolarized and polarized sources

Post-measurement corrections

- Atmospheric opacity
- Gravitational deformations of the telescope's surface



- ✓ Standards Stokes parameter stability: 1-2%
- ✓ m_l and m_c uncertainties: 0.1-0.2%
- ✓ χ uncertainty: 1-2º
- ✓ Tables with linear and circular polarization parameters of standard sources

Myserlis et al. (in prep.)

The radio dataset

Part of the *F-GAMMA* dataset
Fuhrmann et al. (2007), Angelakis et al. (2008)

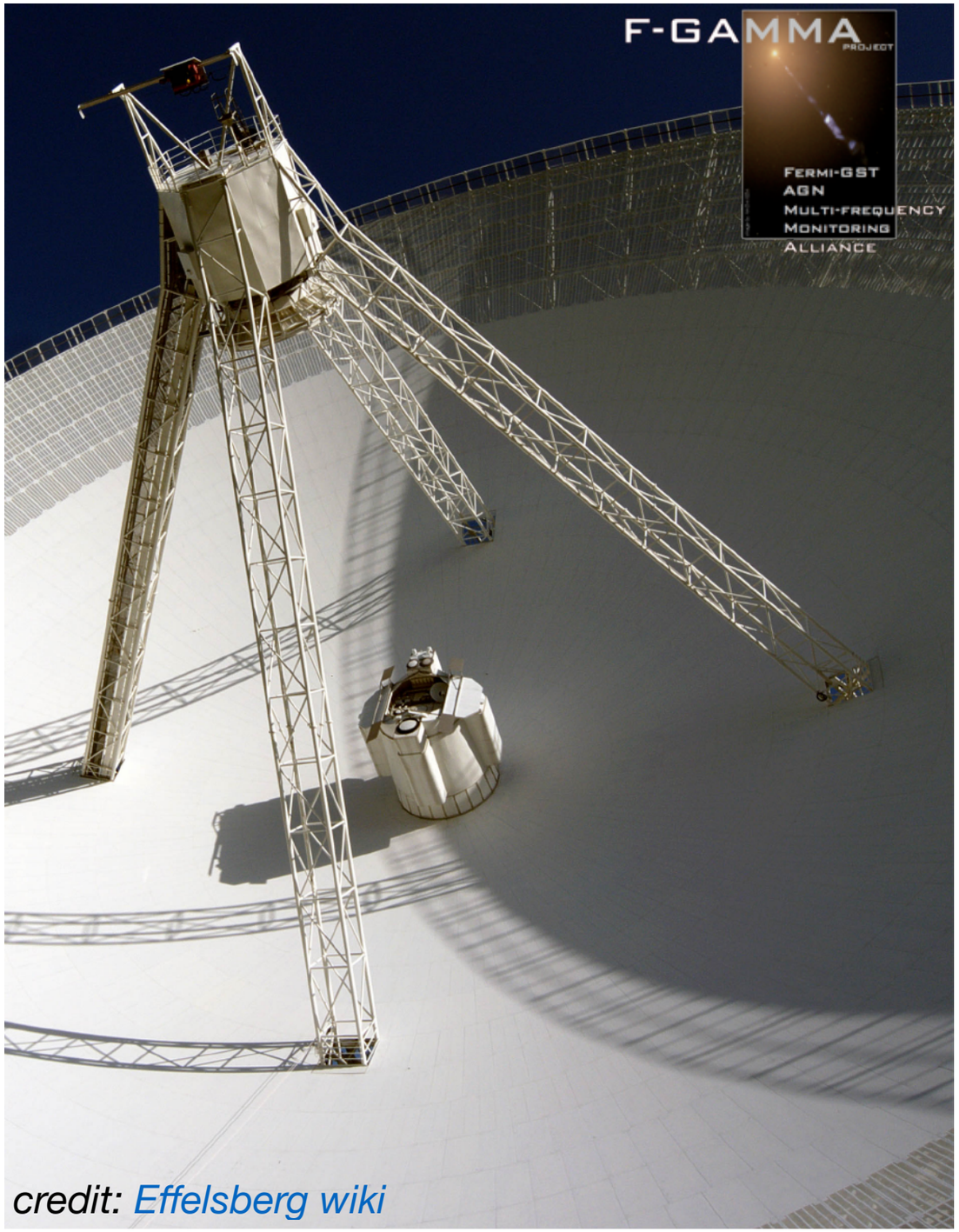
87 sources

July 2010 - January 2015

Cadence: 1.6 months

Linear polarization
2.64, 4.85, 8.35, 10.45 GHz

Circular polarization
4.85, 8.35 GHz



credit: Effelsberg wiki

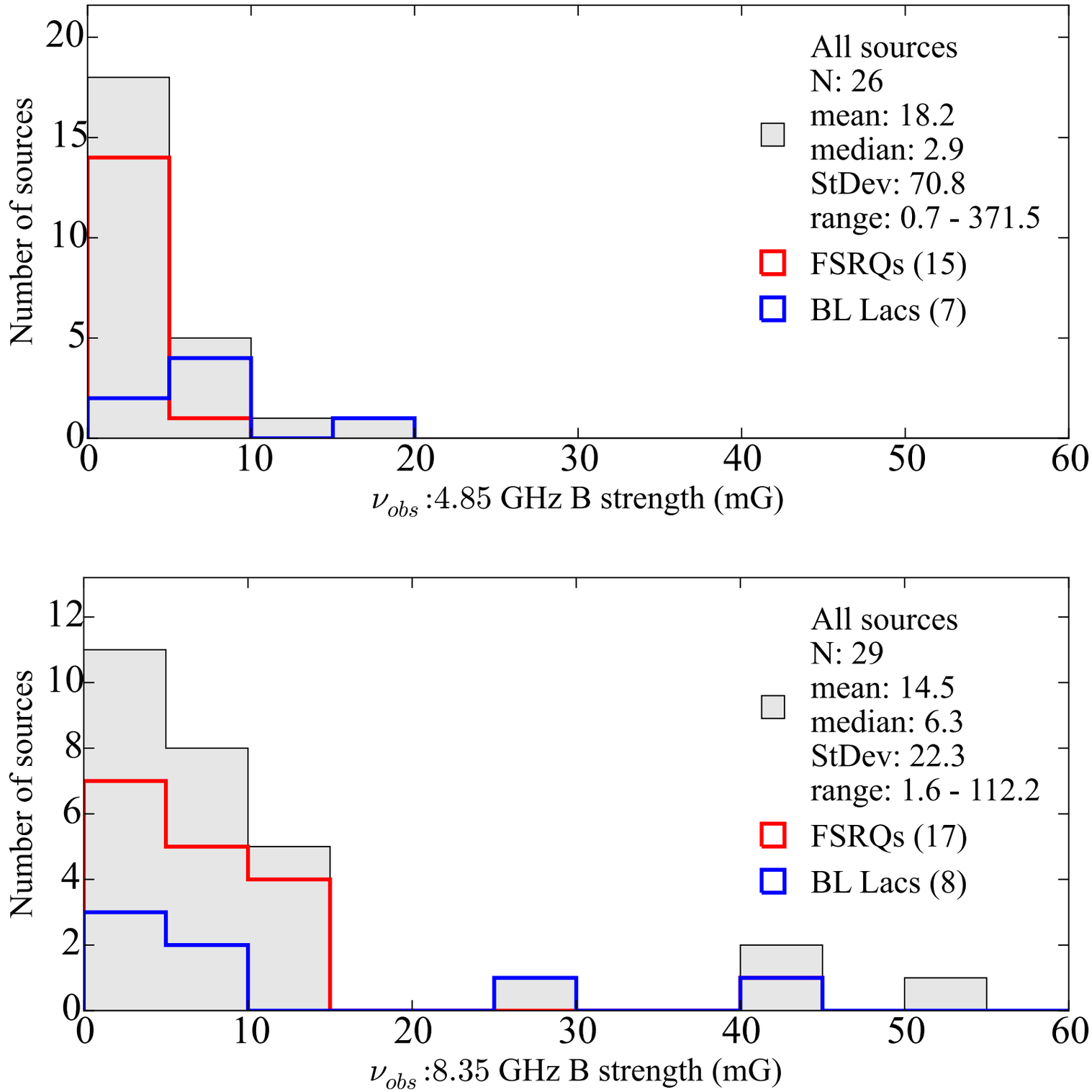
Magnetic field strength

Assumptions

- Synchrotron circular polarization
- One particle population, e.g. e^- or e^+
- Uniform magnetic field

$$B \sim \frac{m_c^2 \nu_{\rm obs}(1+z)}{2.8D}$$

Homan et al. (2009)



Myserlis et al. (in prep.)

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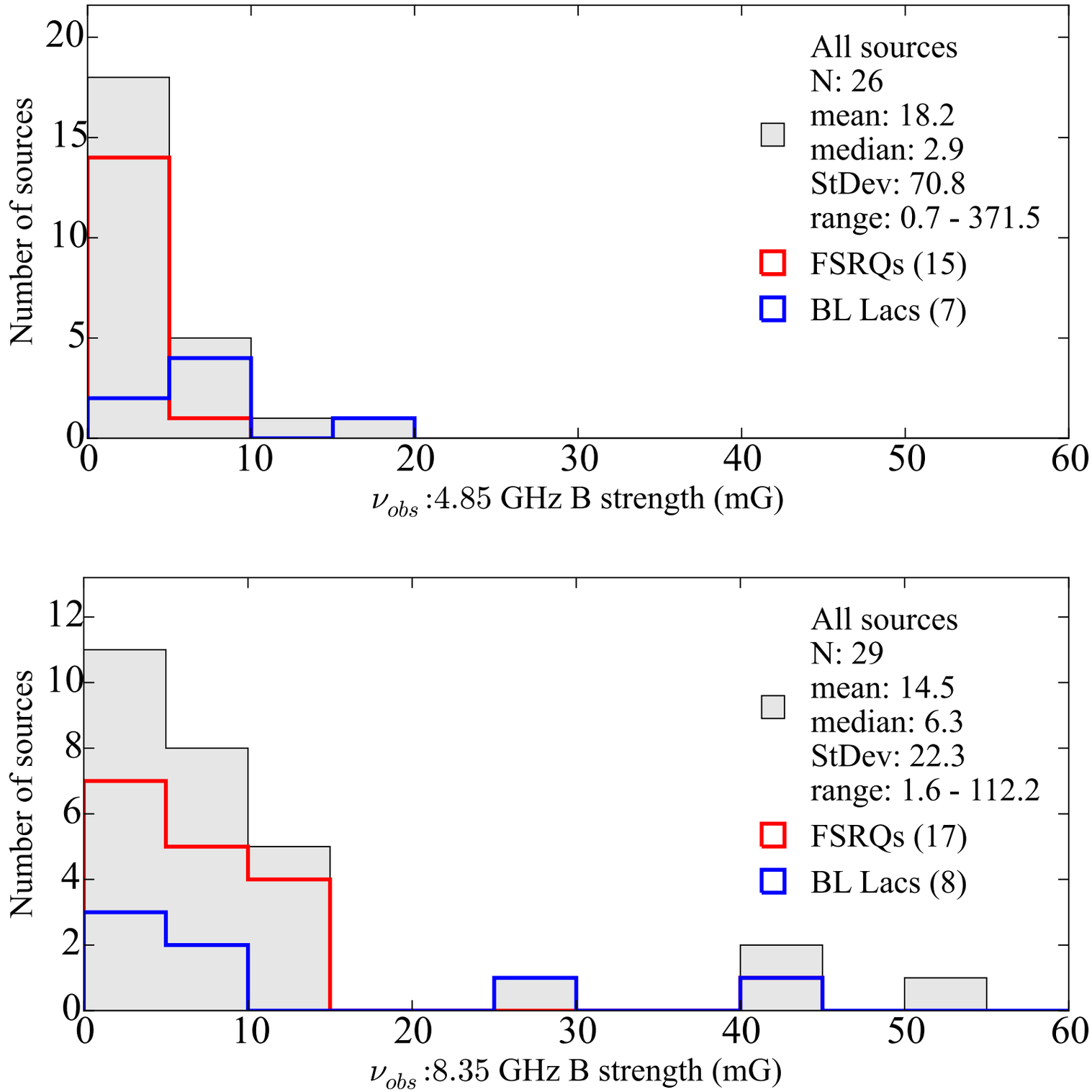
Homan et al. (2009)

➡ Median B: 3-6 mG



Myserlis et al. (in prep.)

Jet plasma composition

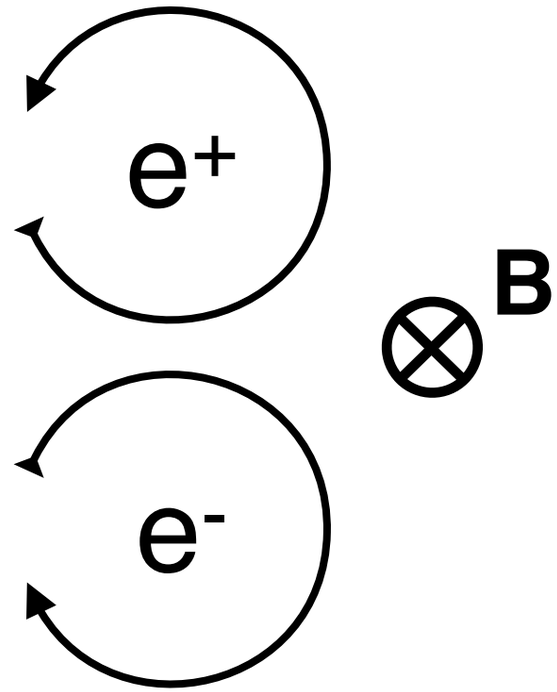
Magnetic field strength

- Predicted: 10-100 mG
  O'Sullivan & Gabuzda (2009a)
- Observed: 3-6 mG

e^- - e^+ admixture

Lepton number $\ell = \dfrac{n_- - n_+}{n_- + n_+}$

Homan et al. (2009)



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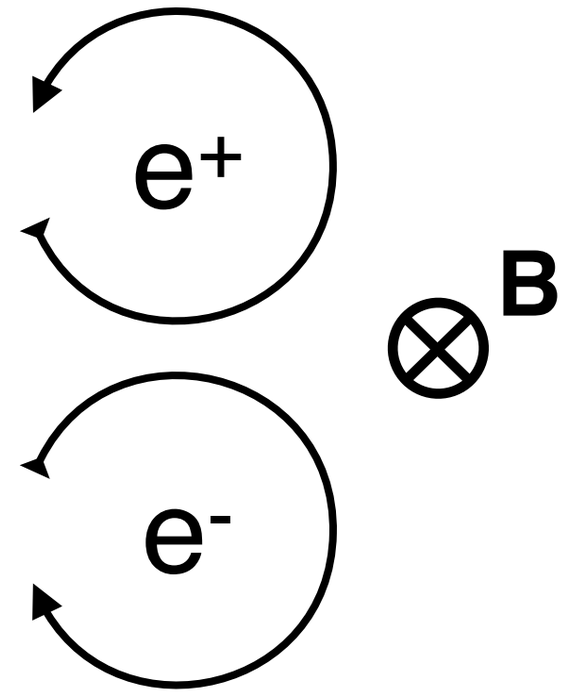


➡ ℓ ~ 0.2-0.5

➡ Admixture 1:1.5-2

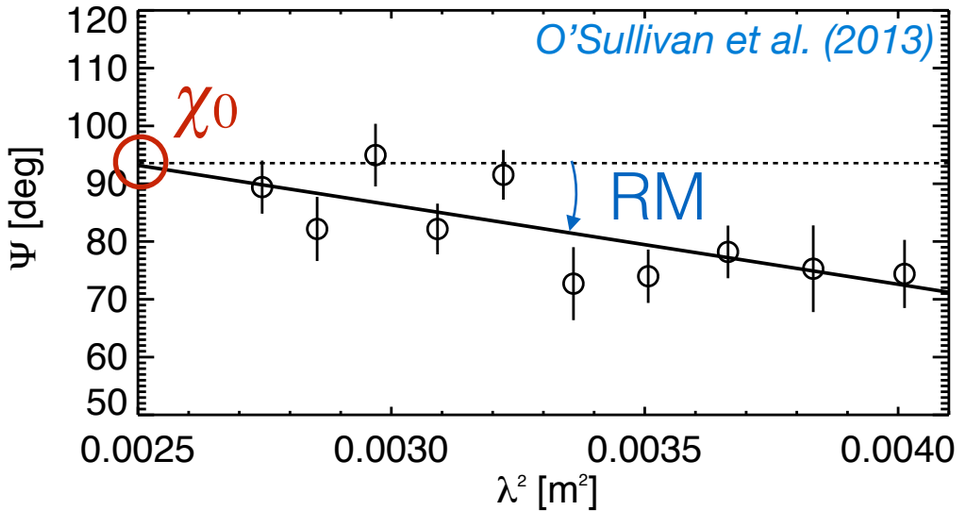
Myserlis et al. (in prep.)

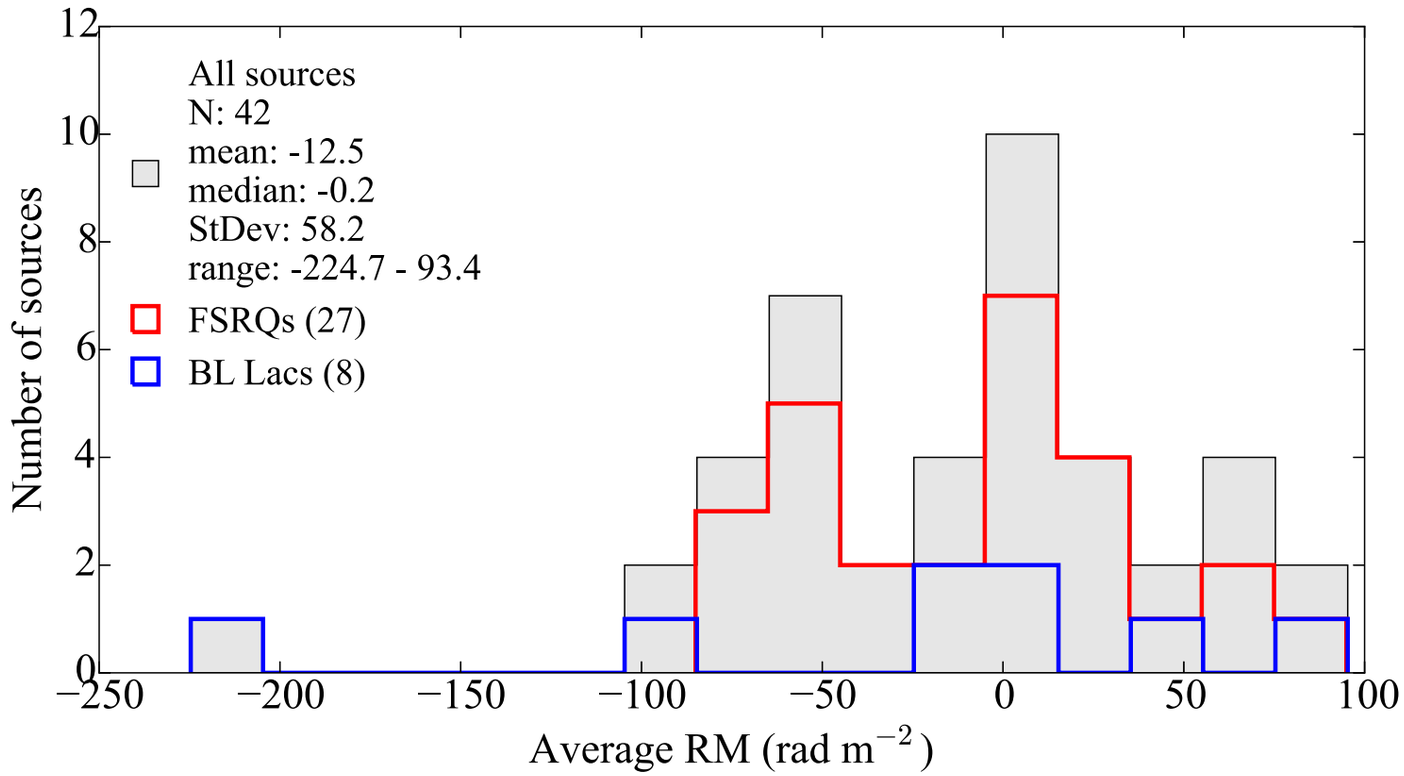
Low energy magnetized plasma content

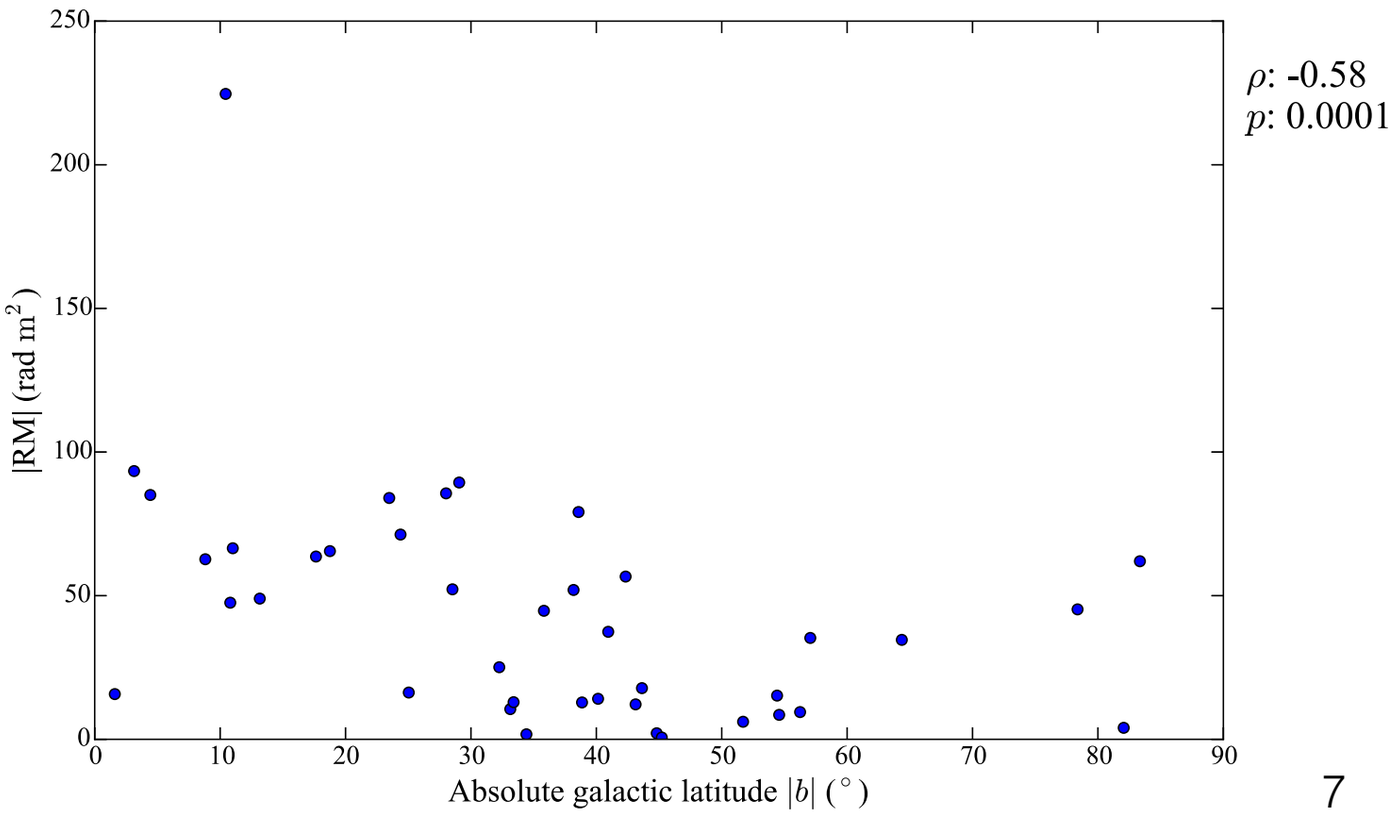
Faraday rotation $\Delta\chi$

$$\Delta\chi = \mathrm{RM}\lambda^2$$

$$\mathrm{RM} = \frac{e^3}{2\pi m^2 c^4}\int_0^d n_e(s) B_{\parallel}(s) ds$$







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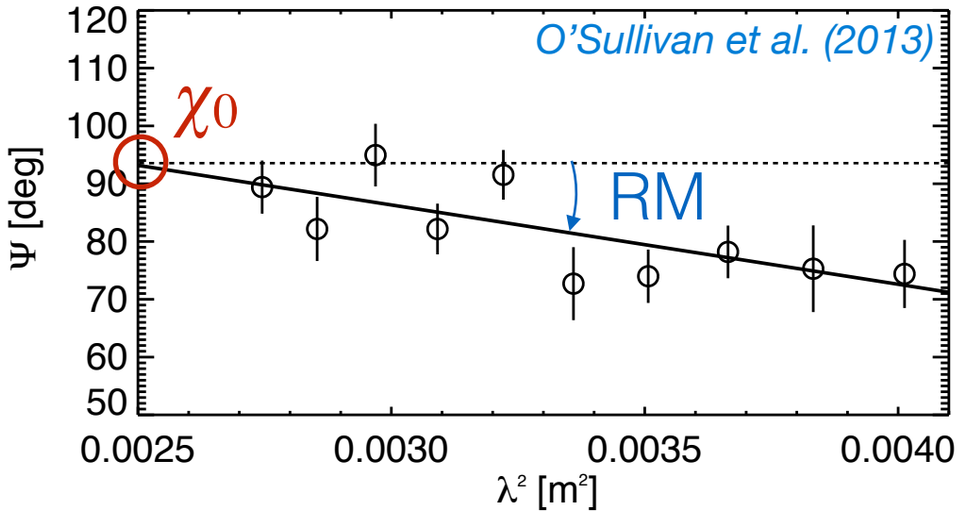
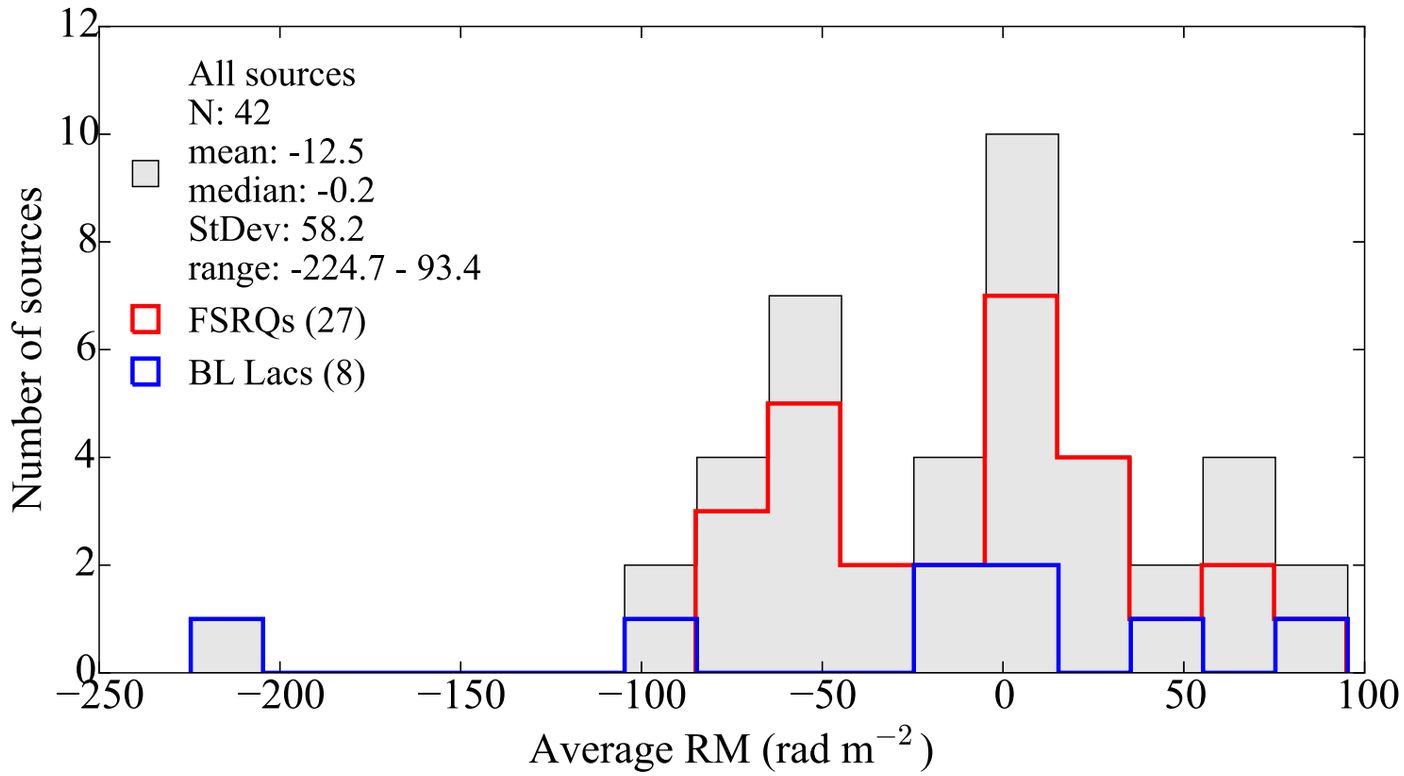
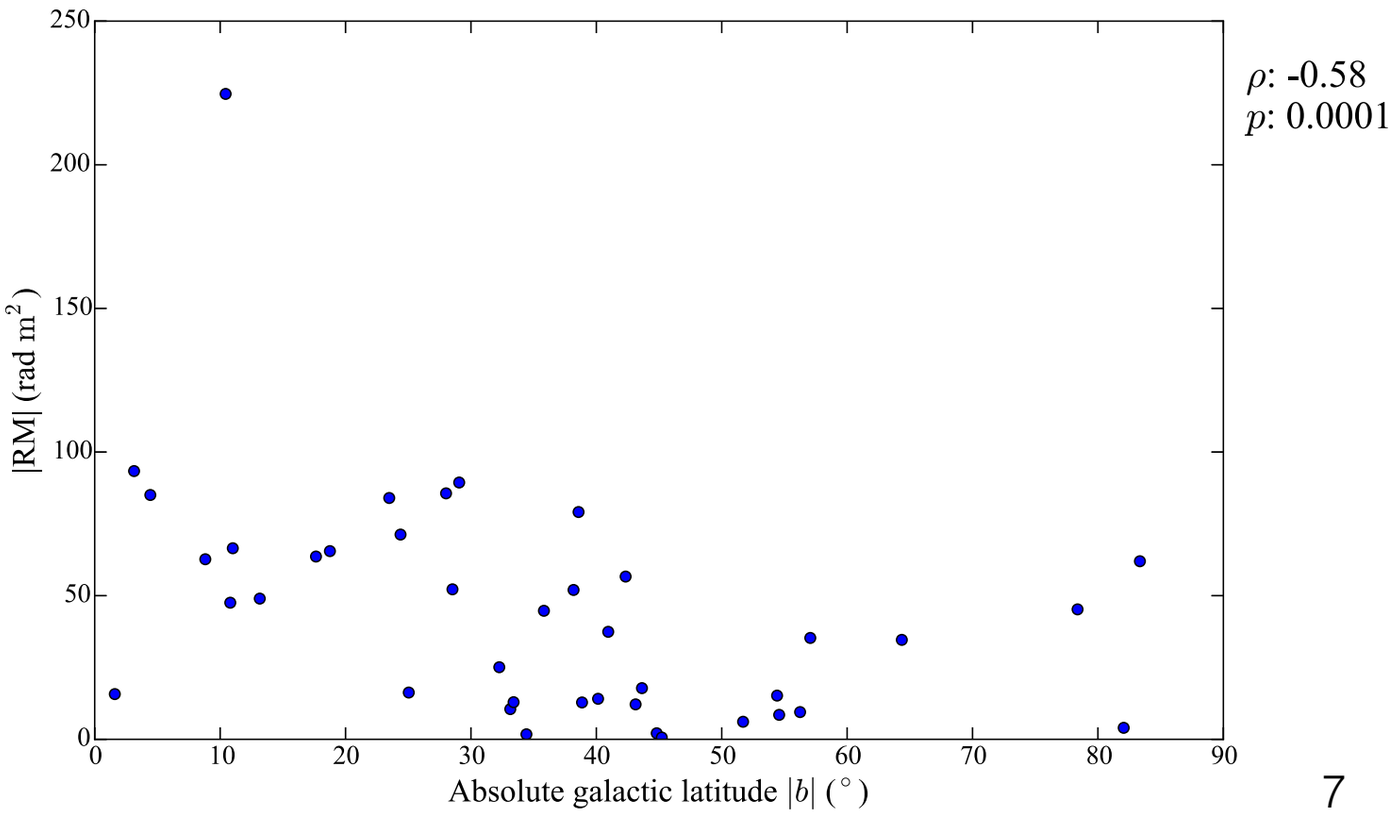


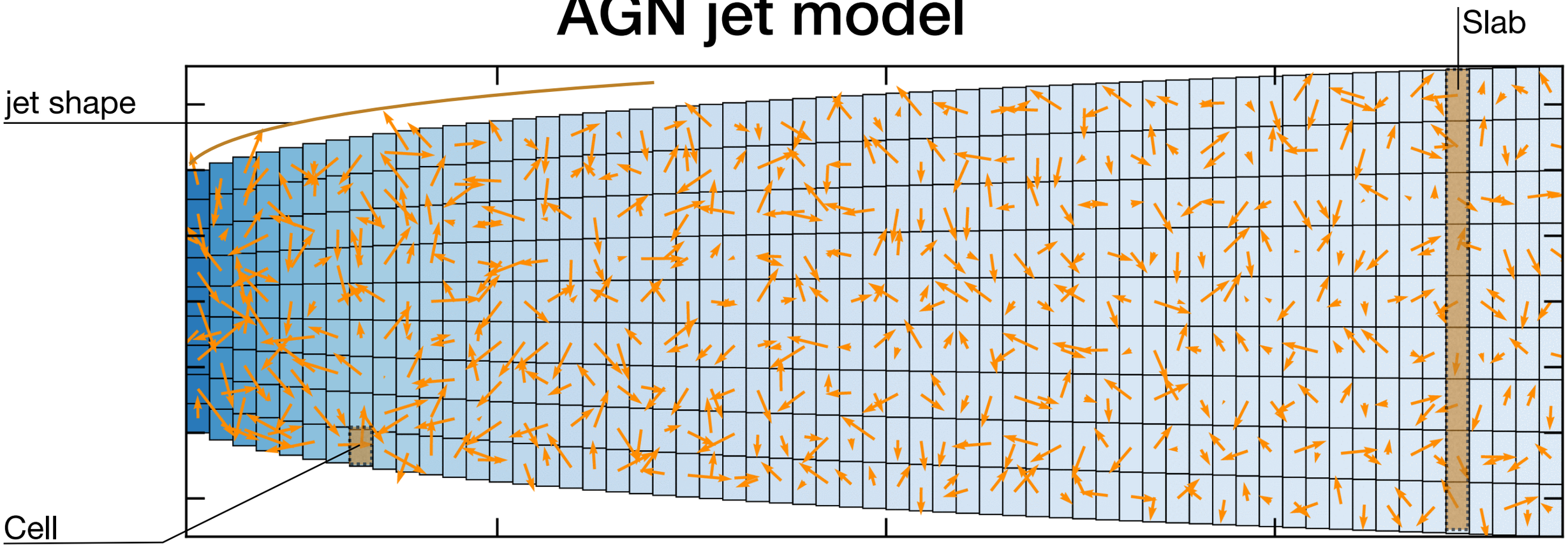


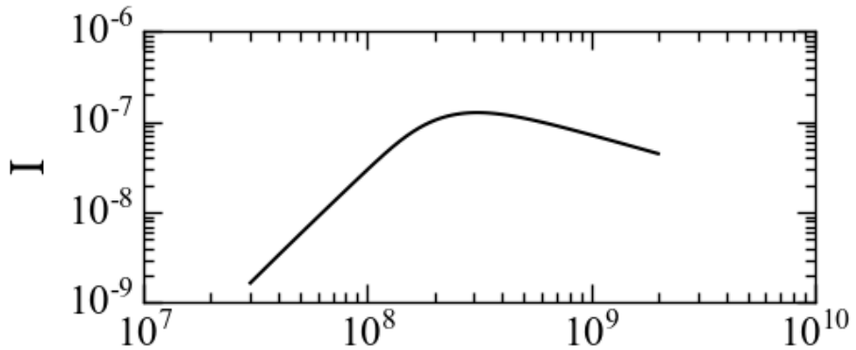


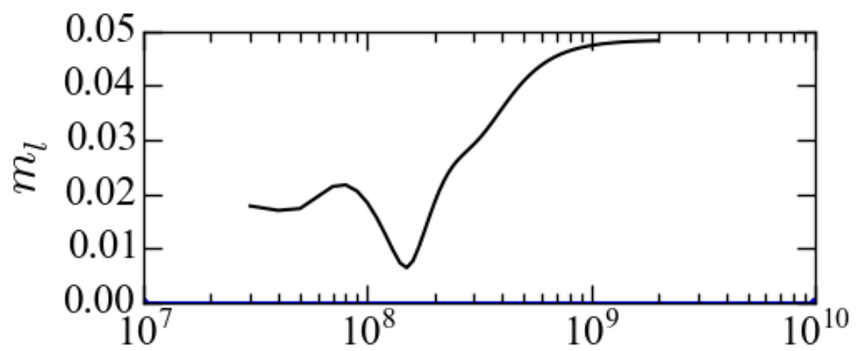
- ➡ Galactic origin of RM
- ➡ No low energy plasma at the source

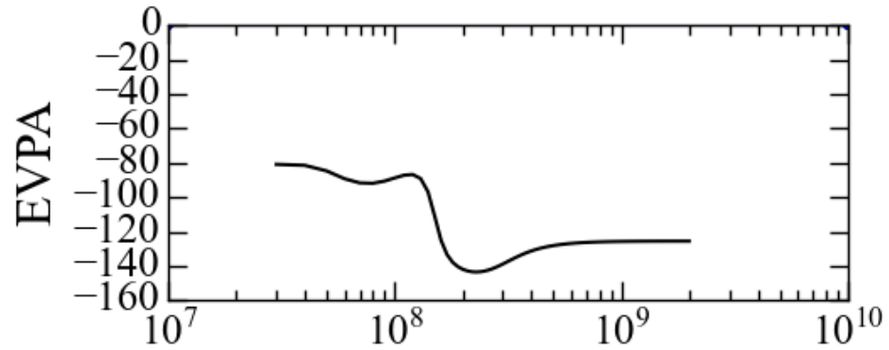
Myserlis et al. (in prep.)

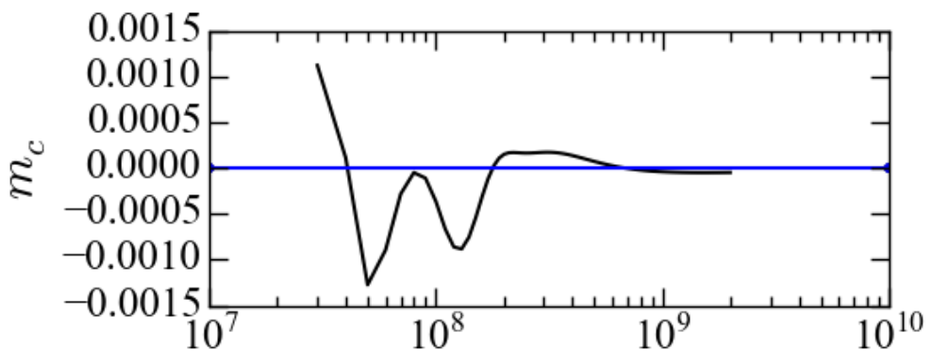
AGN jet model







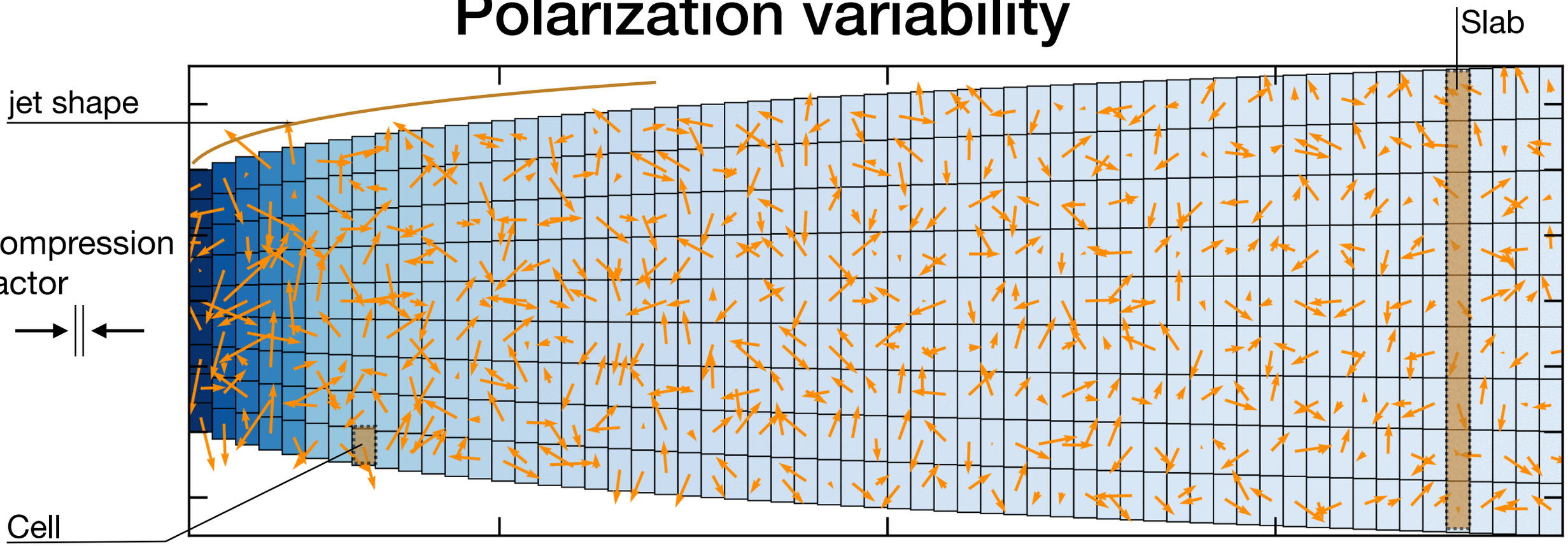




Line of sight

Myserlis et al. (in prep.), based on Hughes et al. (1989)

Polarization variability



Density

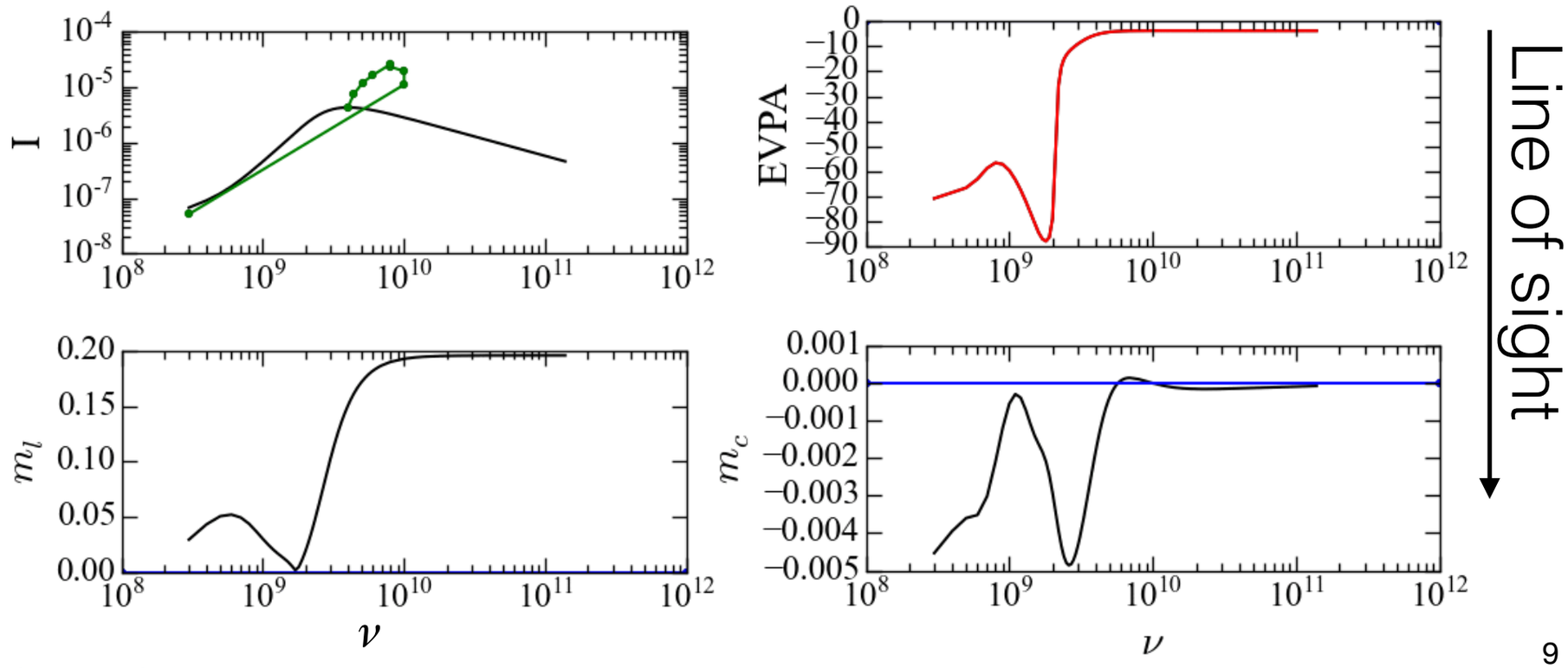
$$n_0' = n_0 k^{-\frac{s+3}{6}}$$

Lower energy cutoff

$$E'_{\rm min} = E_{\rm min} k^{-\frac{1}{3}}$$

B-field strength

$$B' \sim kB$$



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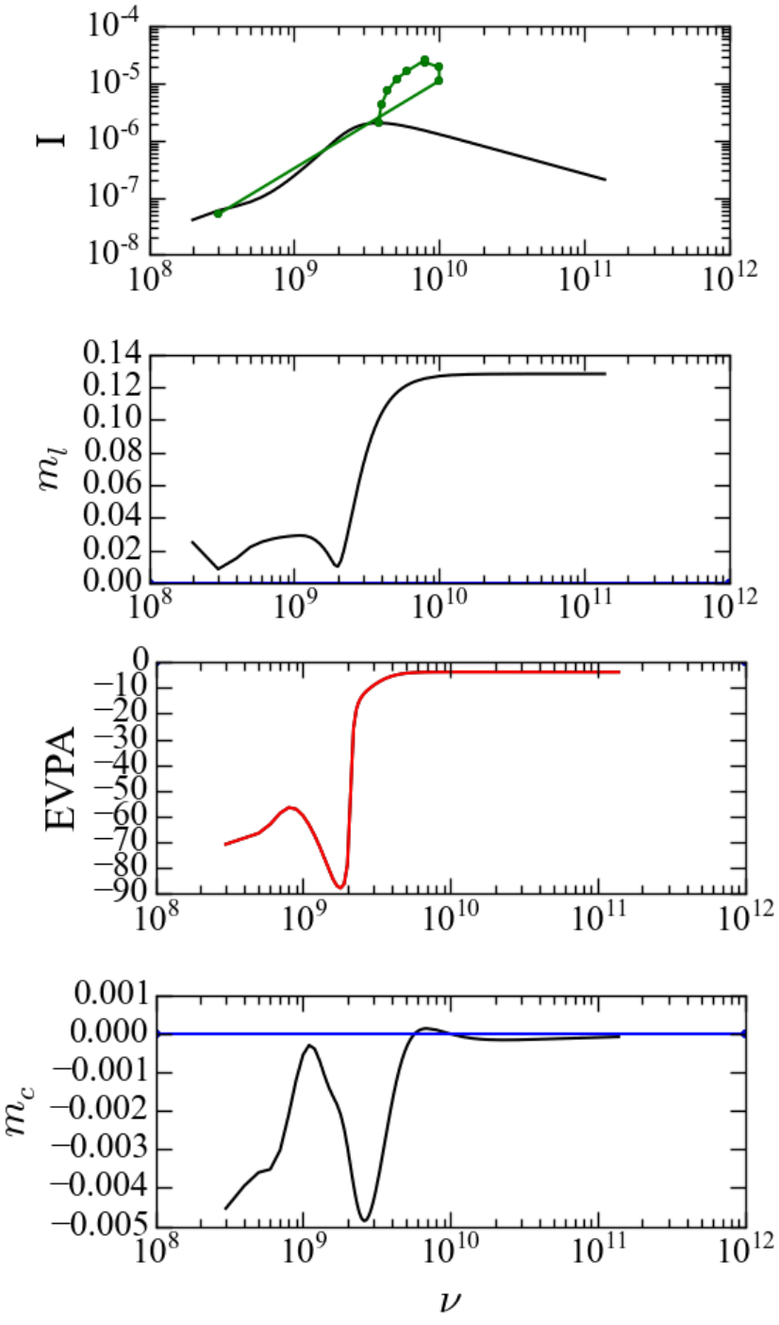
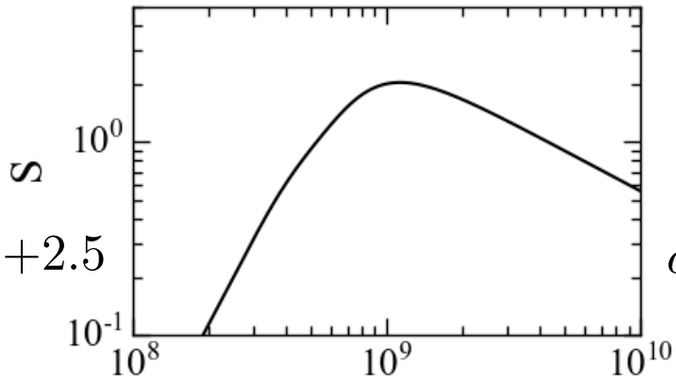
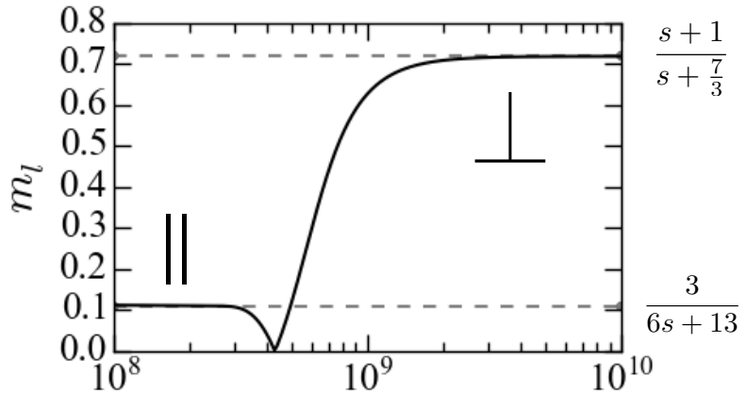
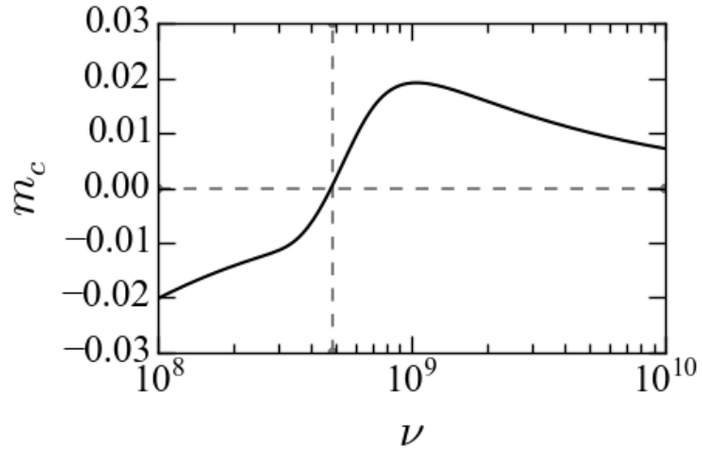


$\alpha = +2.5$



$\alpha = -\frac{s-1}{2}$





optical depth

χ 90°-flip

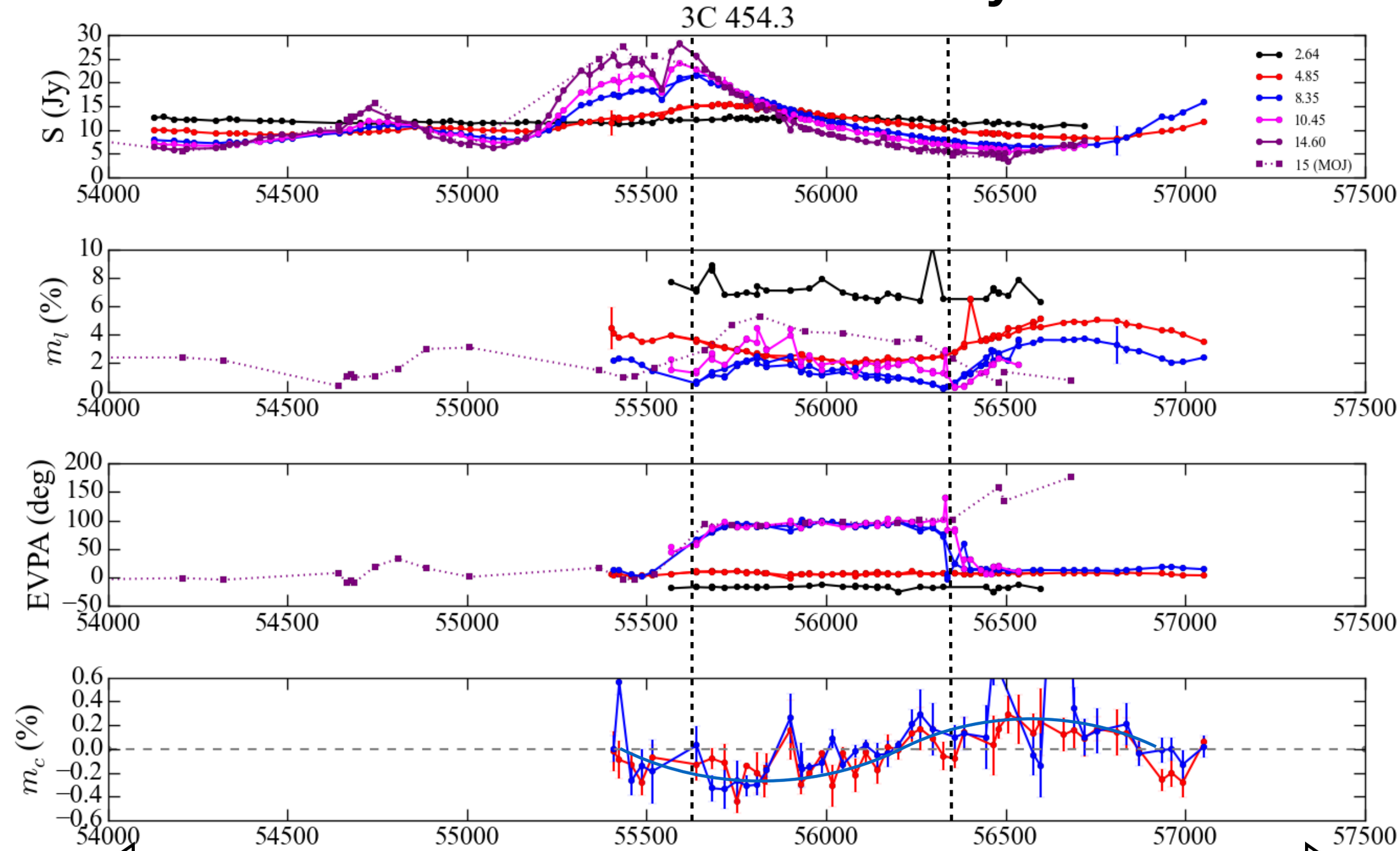
$m_l \rightarrow 0$

$m_c \rightarrow 0$

$S \rightarrow S_{max}$

frequency, time

Polarization variability



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Myserlis et al. (in prep.)

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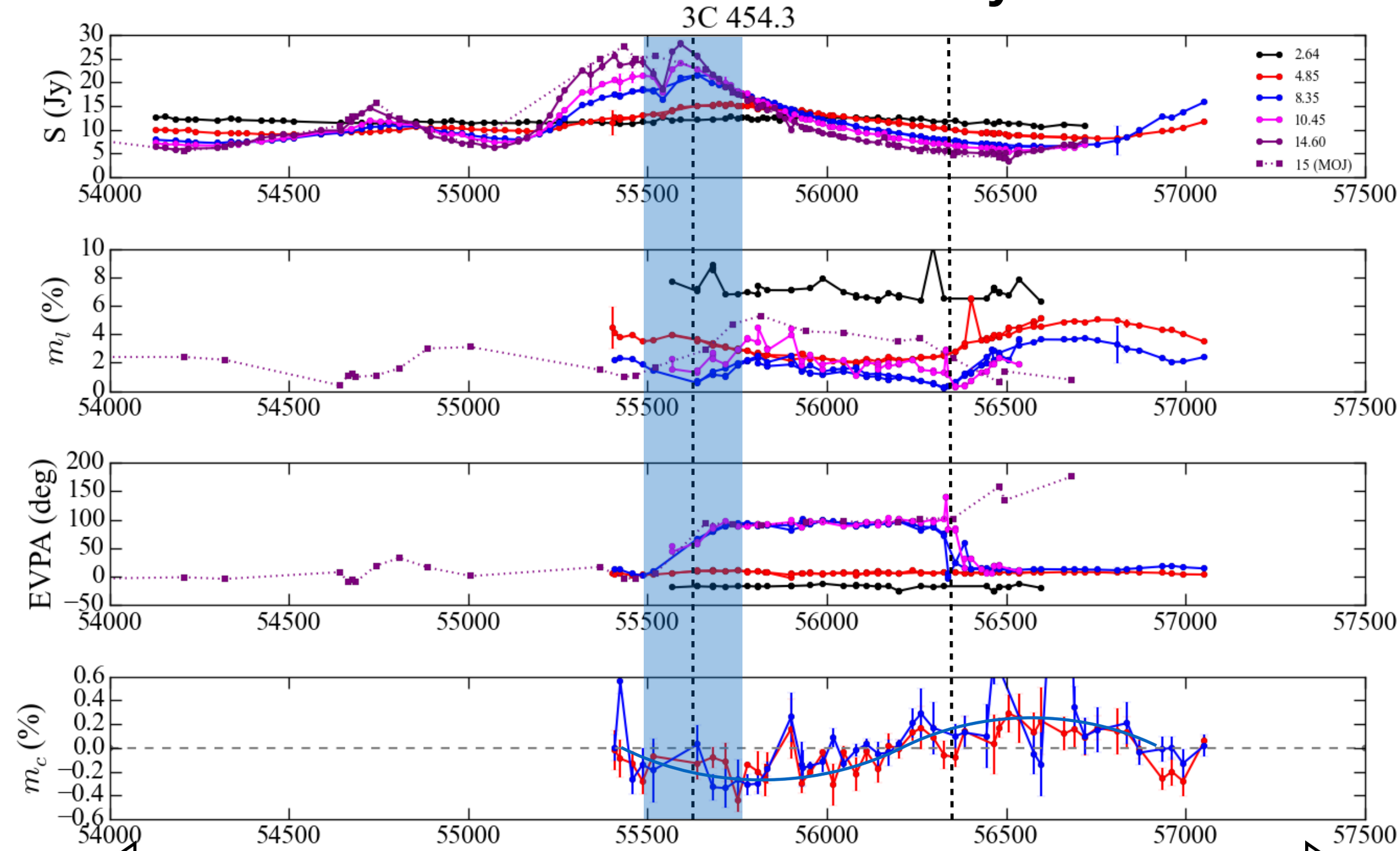

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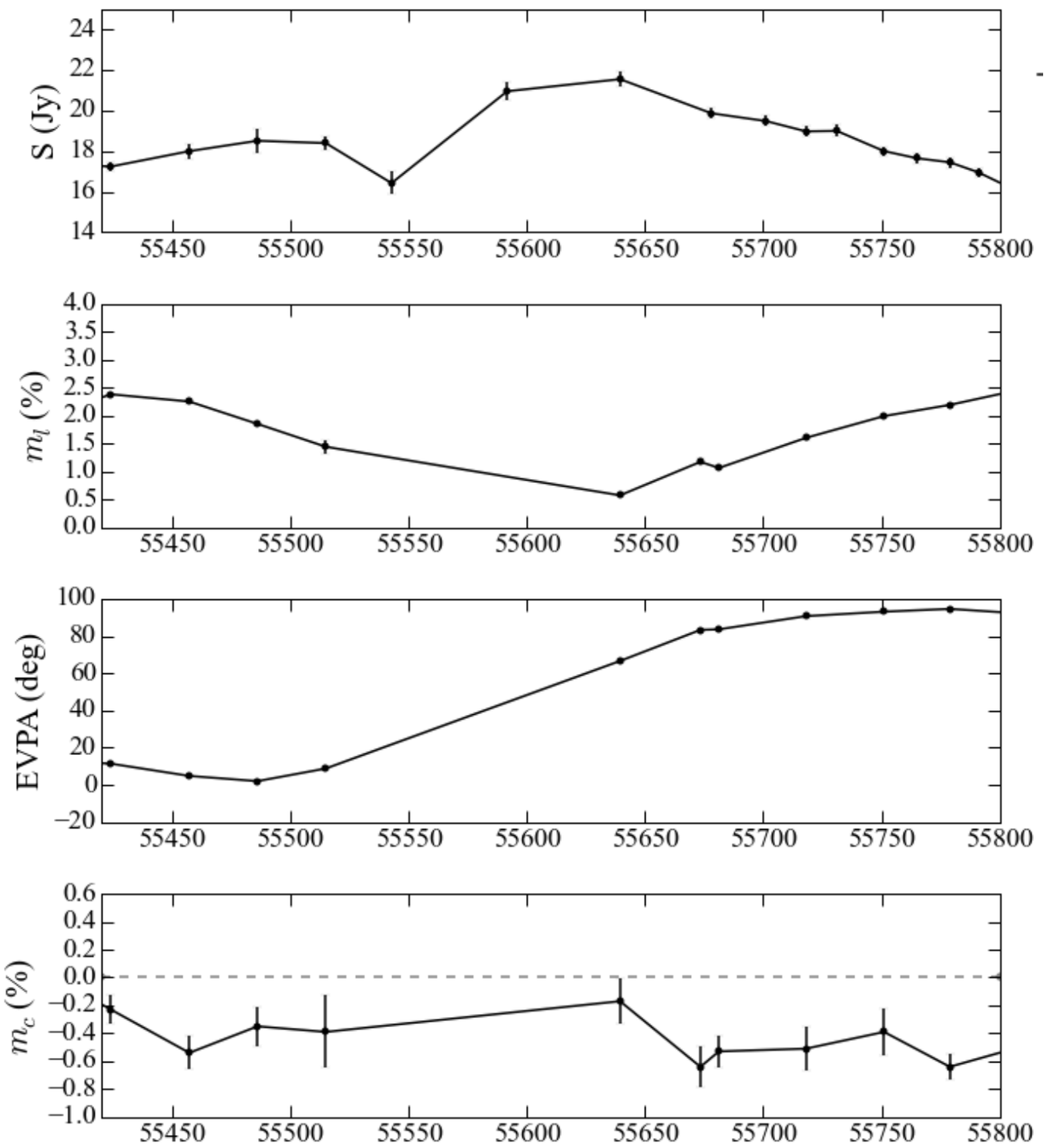
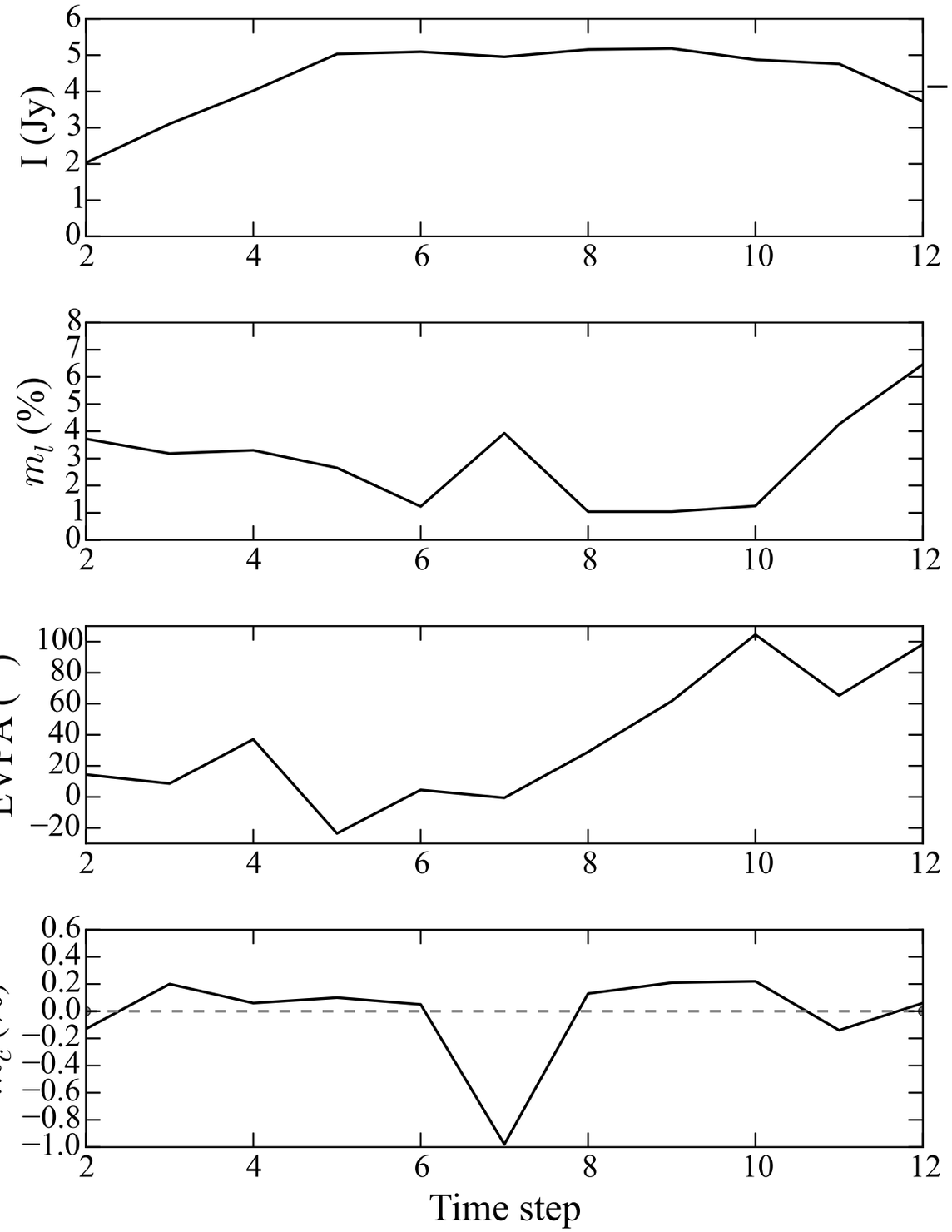
Data



Simulation



Myserlis et al. (in prep.)

The study case of 3C 454.3

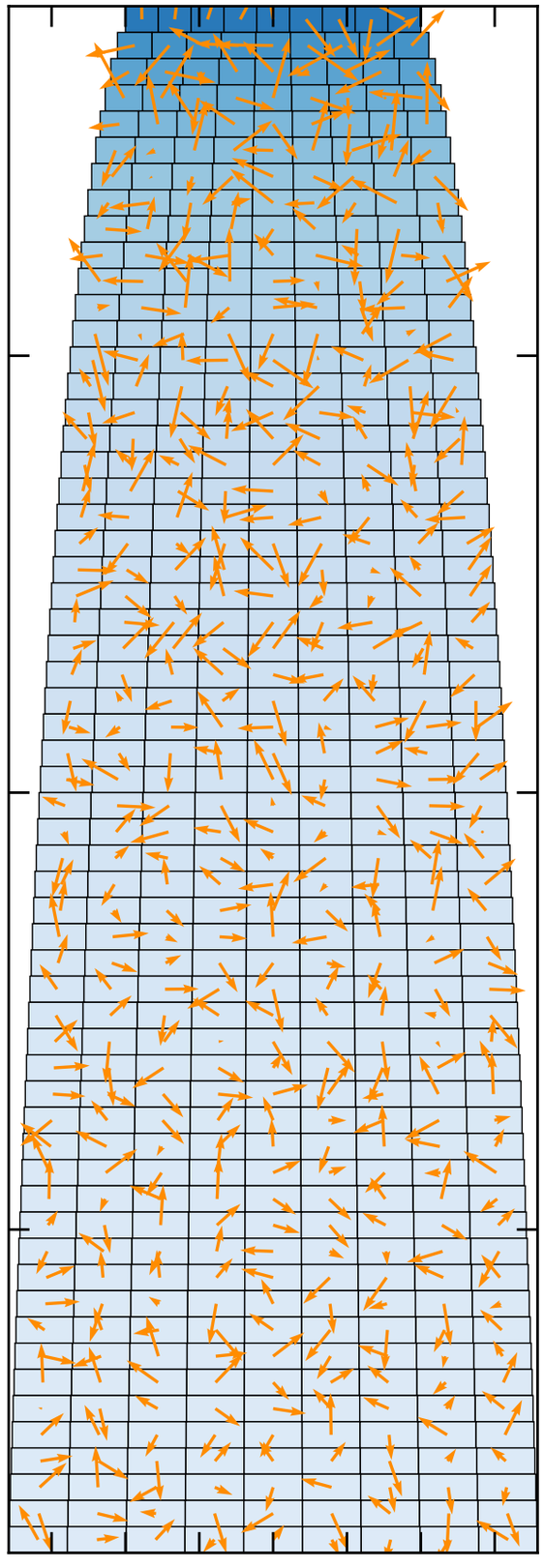
Shock parameters

- Compression factor: $k = 0.8$
- Doppler factor: $D \sim 30$

  Consistent with D_{var} at 37 GHz
  Hovatta et al. (2009)

Jet plasma parameters

- Density: $n_0 = 10^1 - 10^2$ cm^{-3}
- Magnetic field coherence length: 9 pc



Myserlis et al. (in prep.)

Conclusions

Novel data analysis pipeline

➡realistic parametrization of the telescope response

➡instrument model for spurious LP correction

➡polarization standards stability: 2%

➡m_l and m_c uncertainty: 0.2%

➡LP and CP standards' catalogues of m_l, χ and m_c

Physical conditions

➡***B***-field strength: 3-6 mG

➡plasma composition: for e^--e^+ plasma: 1:1.5-2

➡galactic origin of RM: no low energy plasma

Conclusions

Modeling the variability

➡full-Stokes radiative transfer code accounting for all propagation effects

➡reproduce all observables and their variability

➡study case: 3C 454.3

➡reproduce full-Stokes variability

➡physical conditions:

➡shock compression factor: $k = 0.8$

➡Doppler factor: $D \sim 30$

➡plasma density: 10 - 100 cm^{-3}

➡Magnetic field coherence length: 9 pc