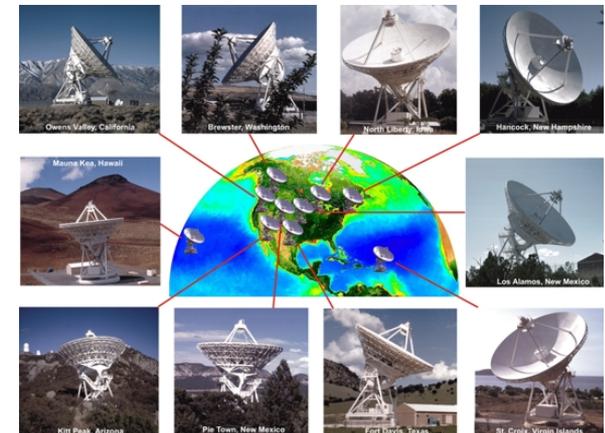
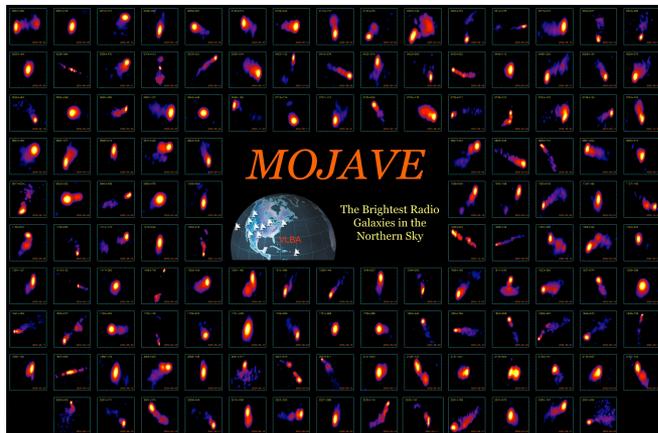


Faraday rotation in pc-scale AGN jets

Talvikki Hovatta

Aalto University, Metsähovi Radio Observatory, Finland



MOJAVE Collaboration

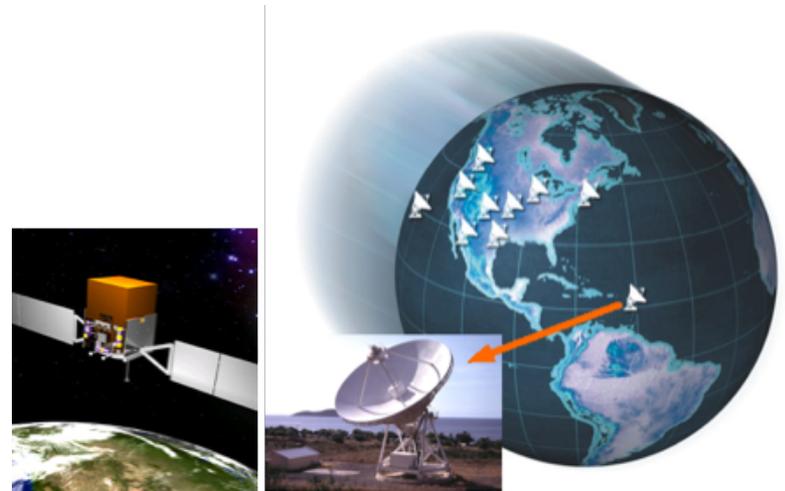
- M. Lister (P.I.), J. Richards (Purdue)
- T. Arshakian, A. Lobanov, E. Ros, J. A. Zensus (Max Planck Inst. for Radioastronomy)
- M. and H. Aller (Michigan)
- M. Cohen (Caltech)
- D. Homan (Denison)
- T. Hovatta, T. Savolainen (Aalto U.)
- M. Kadler (U. Wuerzburg)
- P. Kharb (Indian Institute of Astrophysics)
- K. Kellermann (NRAO)
- Y. Kovalev (ASC Lebedev)
- A. Pushkarev (Crimean Astrophysical Observatory)

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talvikki.hovatta@aalto.fi

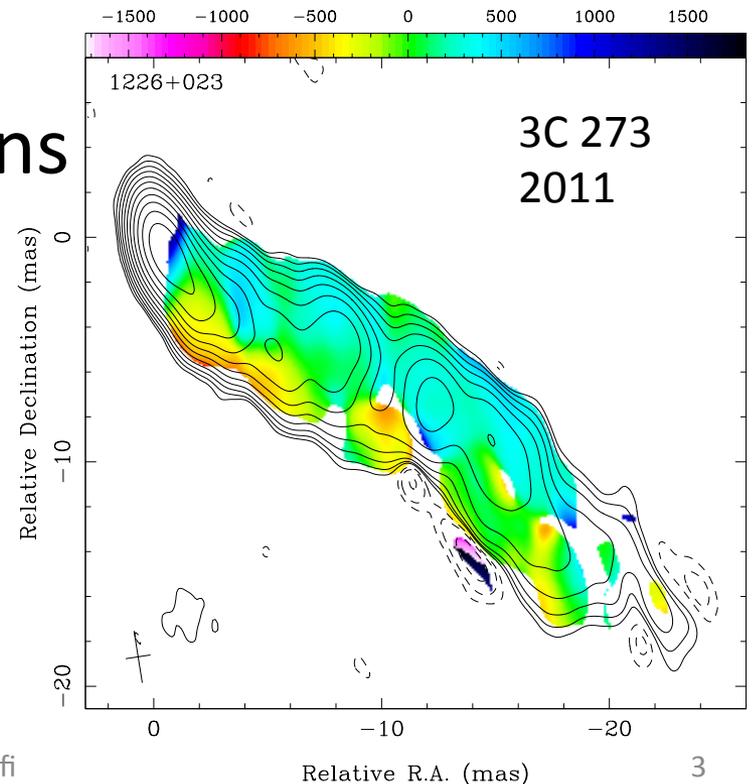
Monitoring Of Jets in Active Galaxies with VLBA Experiments

The MOJAVE Program is supported under NASA Fermi Grant 11-Fermi11-0019 and NSF grant 0406923-AST.



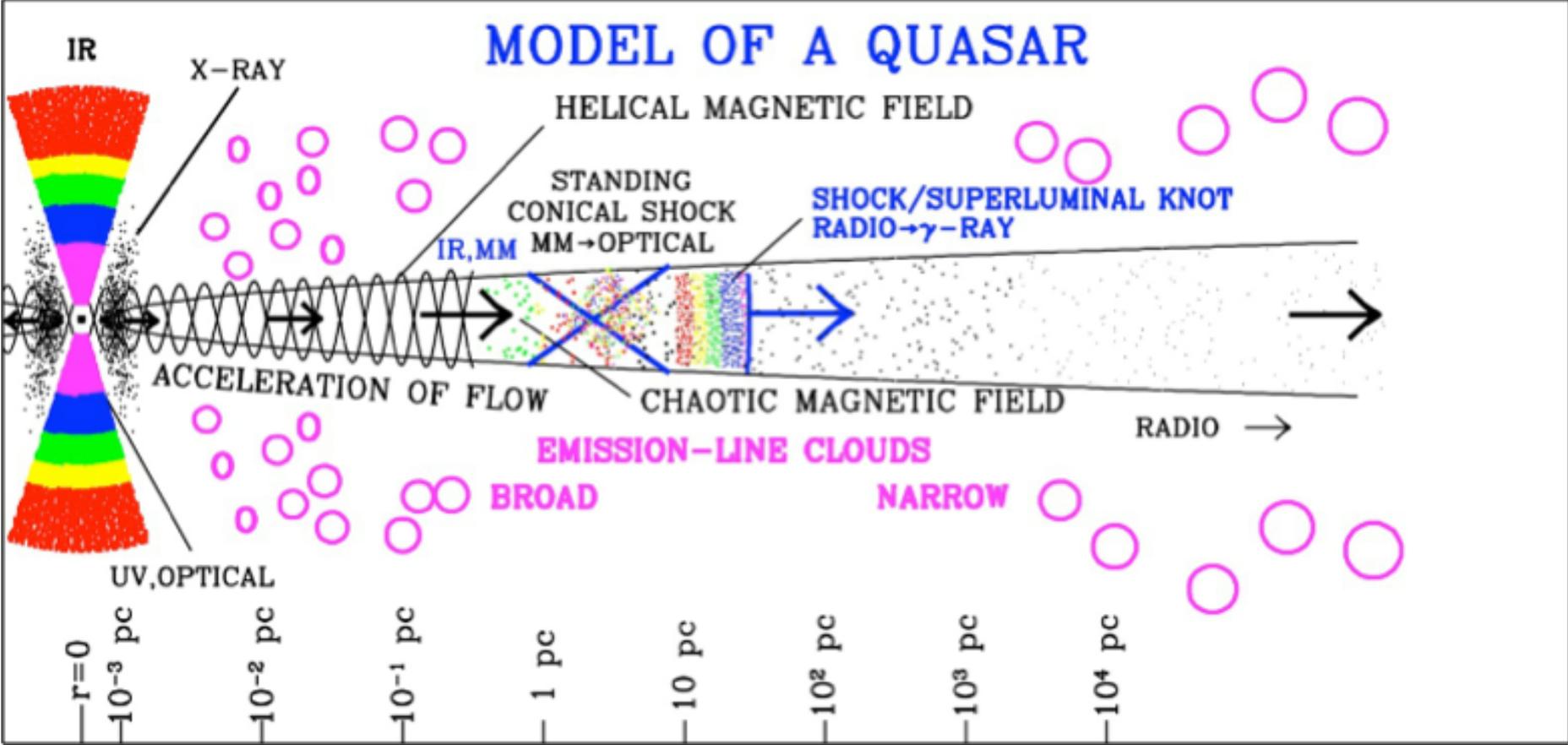
Outline

- Motivation
- Statistical view from MOJAVE
- Preliminary new results from follow-up observations
- Summary



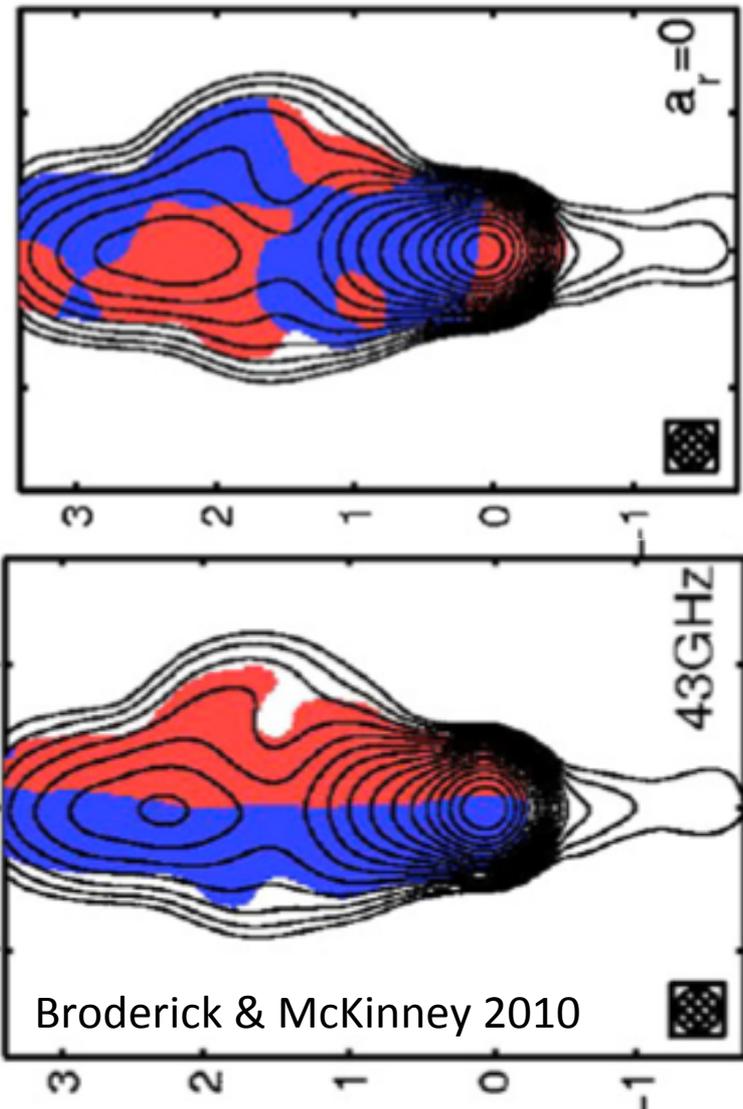
Magnetic field structure on pc-scales?

Credit: A. Marscher



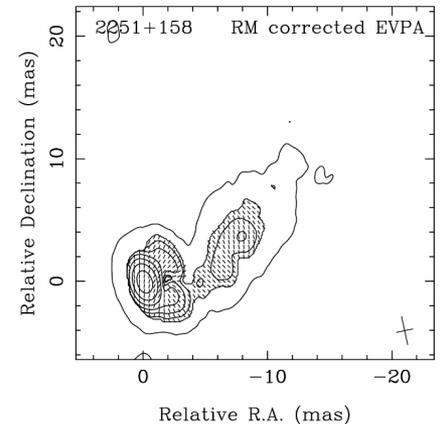
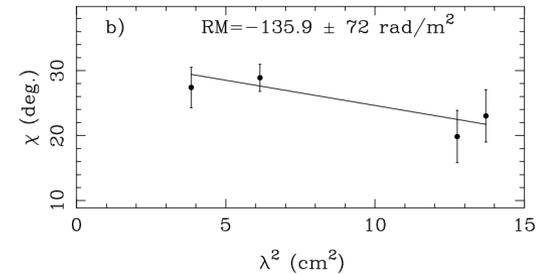
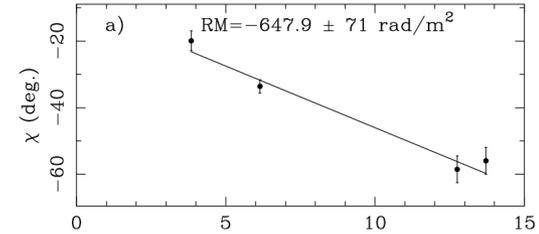
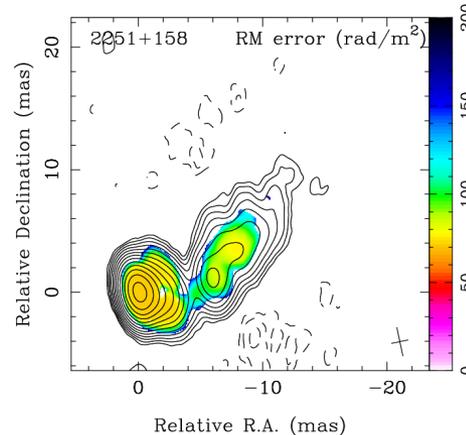
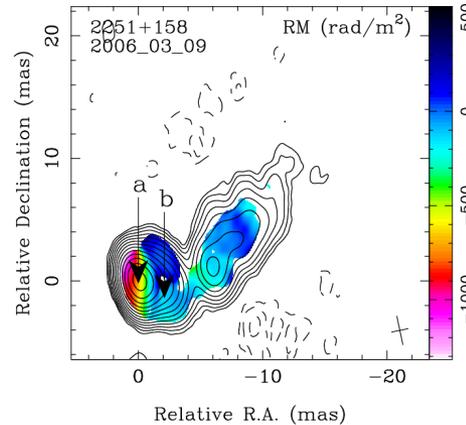
What does Faraday rotation tell us?

- $RM \sim \int n_e B_{||} dl$
- True direction of the B-field
 $X_{obs} = X_0 + RM \lambda^2$
-> RM of 500 rad/m² rotates the EVPA by $\sim 10^\circ$ at 15 GHz and by 40° at 8 GHz
- Direction of the line of sight component of the B-field in the rotating plasma
- Amount of Faraday depolarization
 - internal or external screen?
- Distance dependence
 - Denser environment / higher B-field closer to the core?



Statistical view

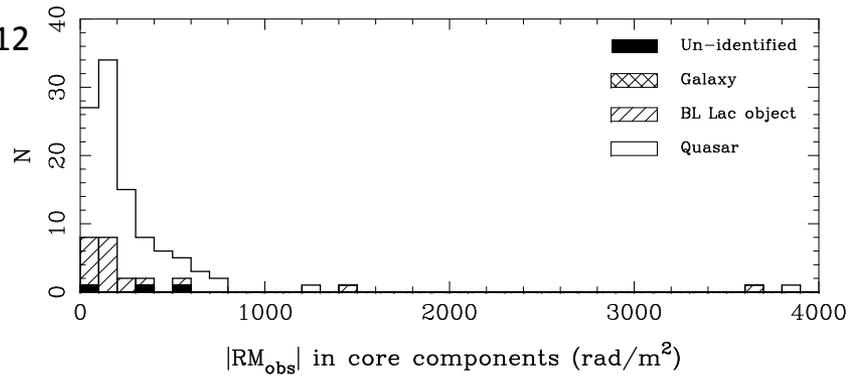
- 191 sources from the MOJAVE program
- 12 epochs with VLBA in 2006
- 8.1, 8.2, 12 and 15 GHz
- 211 observations
- 159 maps with detected RM



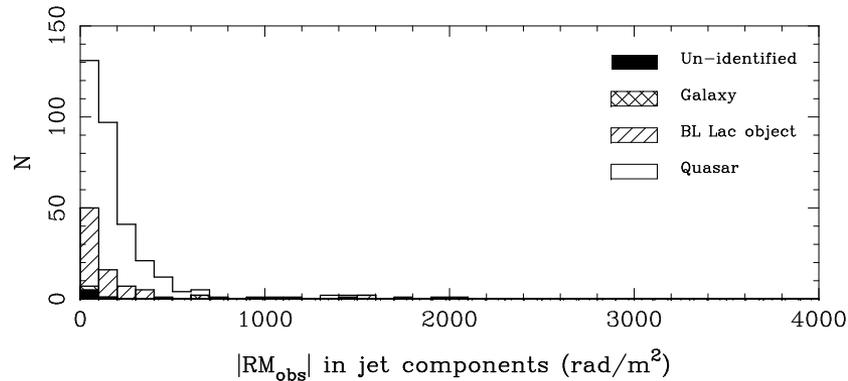
MOJAVE VIII = Hovatta et al. 2012, AJ, 144, 105

Faraday rotation in the core vs. jet

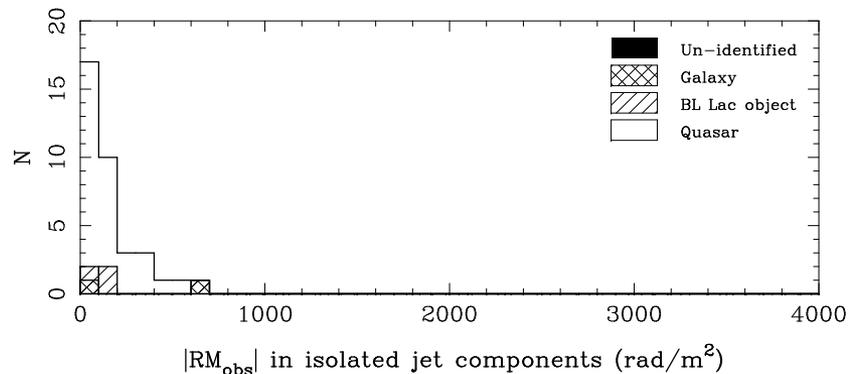
Hovatta et al. 2012



FSRQ core median $183 \text{ rad}/\text{m}^2$
BL Lac core median $134 \text{ rad}/\text{m}^2$



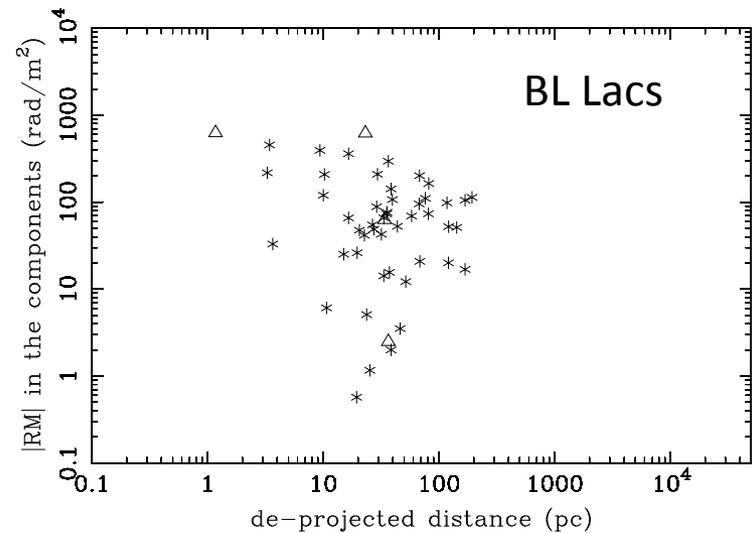
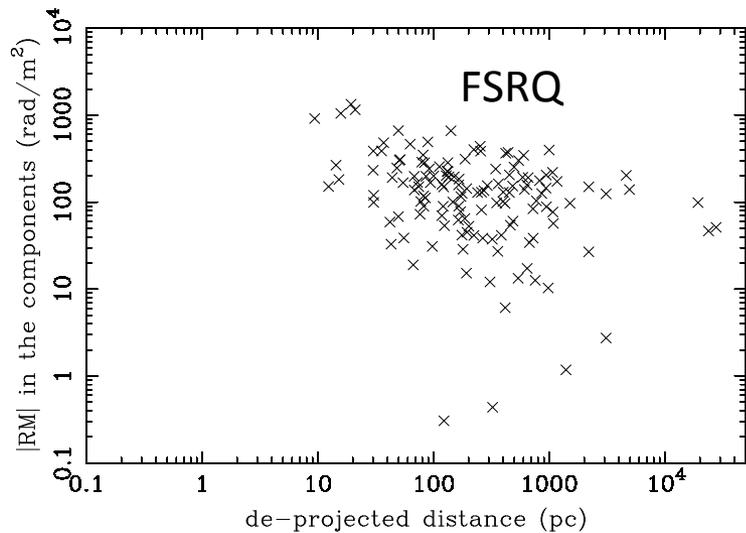
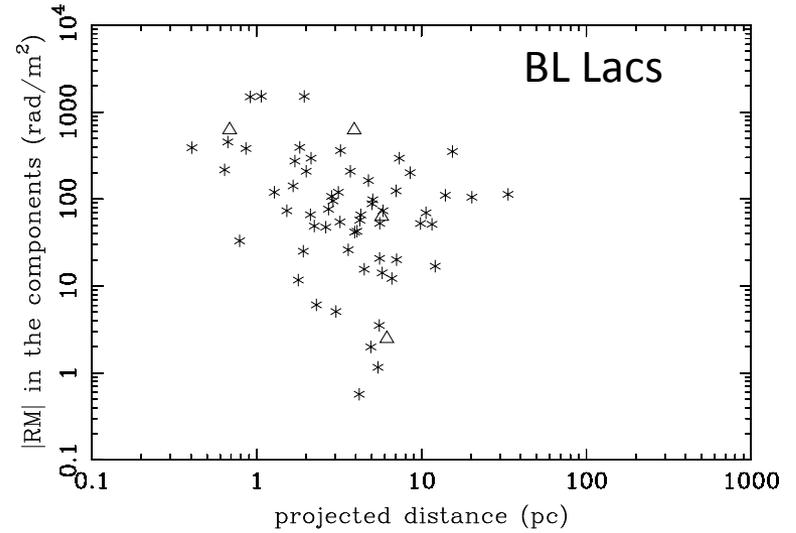
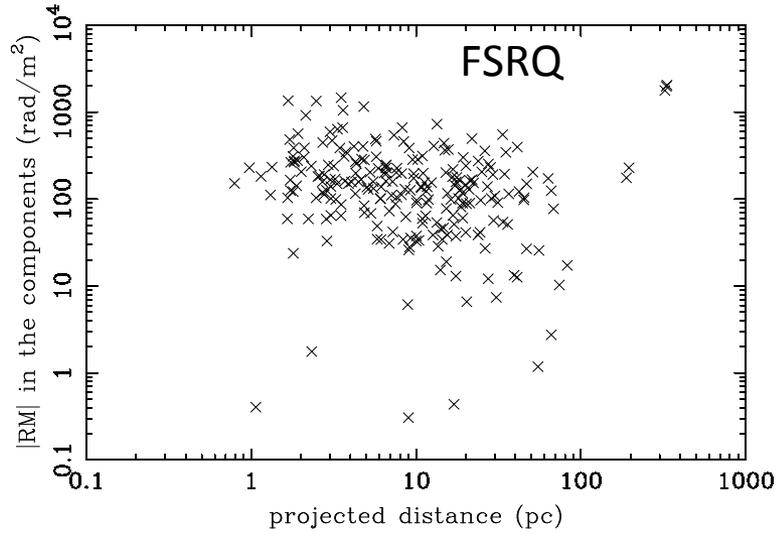
FSRQ jet median $144 \text{ rad}/\text{m}^2$
BL Lac jet median $71 \text{ rad}/\text{m}^2$



Similar results as in
Zavala & Taylor 2003, 2004

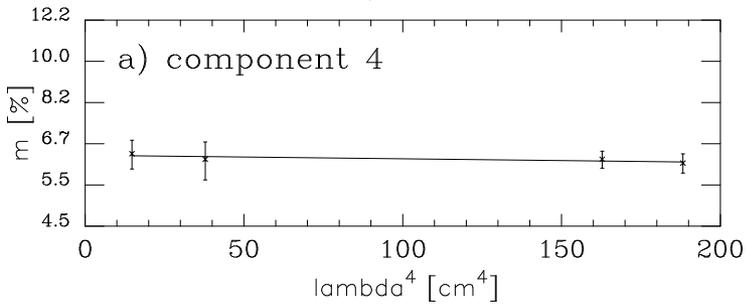
Distance dependence

Hovatta et al. 2012



Internal or external Faraday screen?

0003-066 epoch 2006_07_07



Internal Faraday depolarization

$$m_{\text{obs}}(\%) = m_{\text{max}} \left| \frac{\sin(2\lambda^2 \text{RM})}{2\lambda^2 \text{RM}} \right|$$

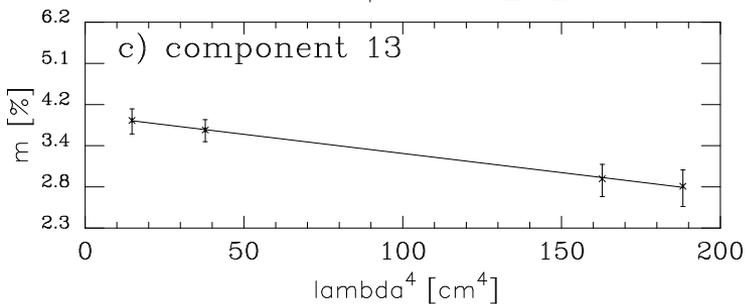
External Faraday depolarization

$$m_{\text{obs}}(\%) = m_{\text{max}} e^{-2\sigma^2 \lambda^4}$$

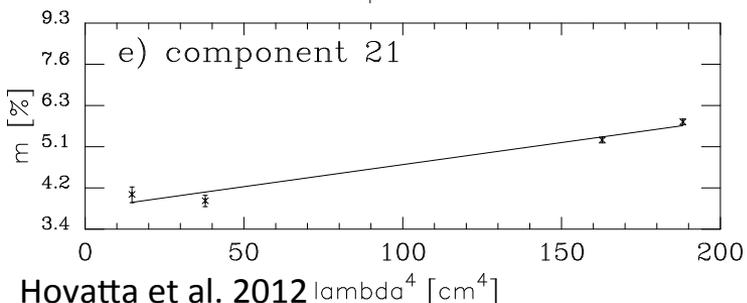
Fitted function (valid up to ~ 800 rad/m²)

$$\ln m = \ln m_0 + b\lambda^4$$

0430+052 epoch 2006_05_24



1226+023 epoch 2006_06_15



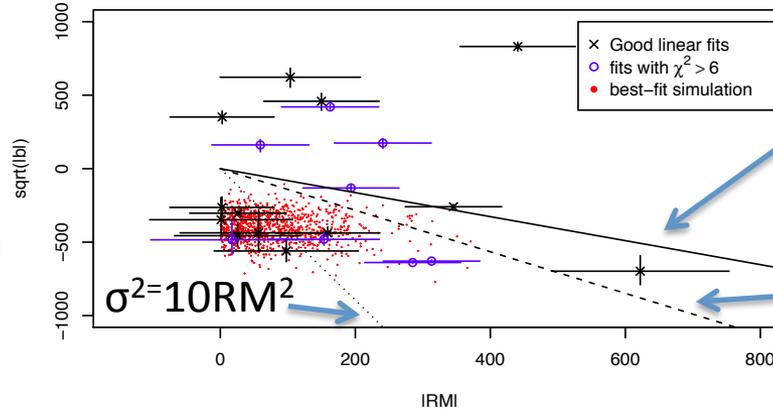
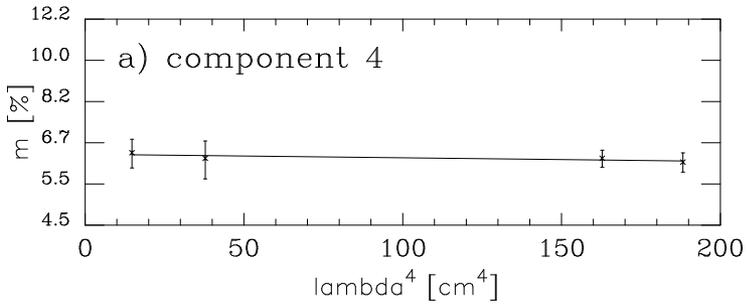
Hovatta et al. 2012 λ^4 [cm⁴]

Jets 2016, Malaga

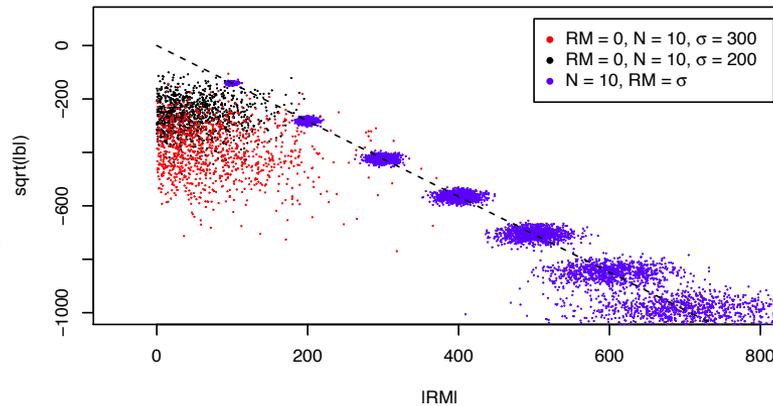
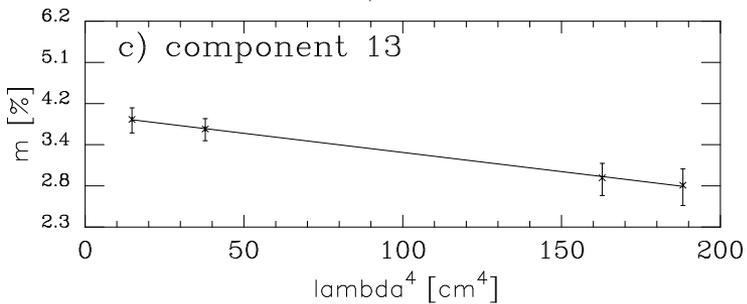
talvikki.hovatta@aalto.fi

Internal or external Faraday screen?

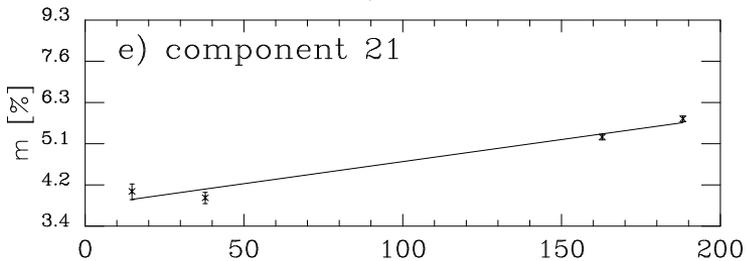
0003-066 epoch 2006_07_07



0430+052 epoch 2006_05_24



1226+023 epoch 2006_06_15



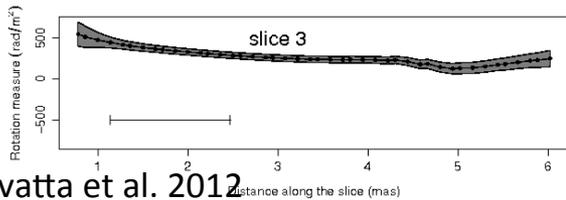
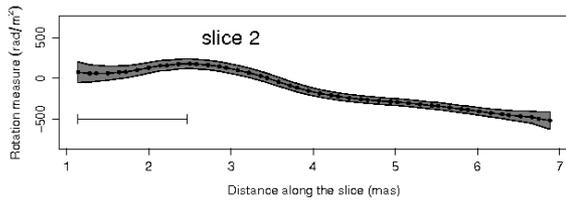
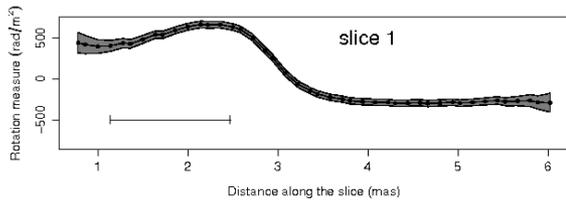
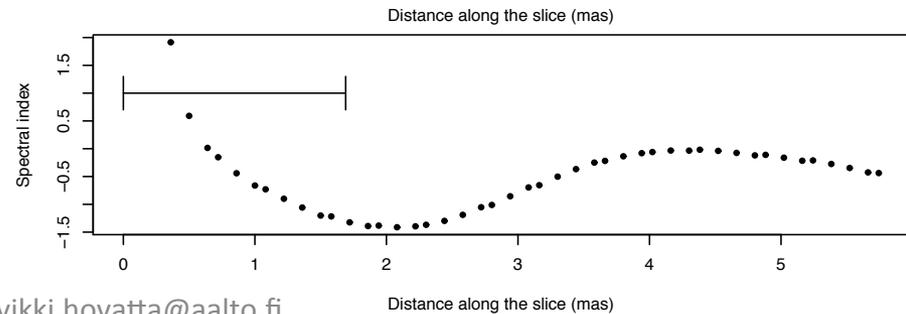
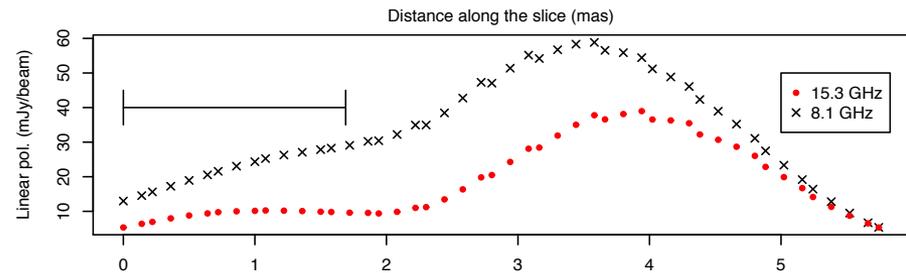
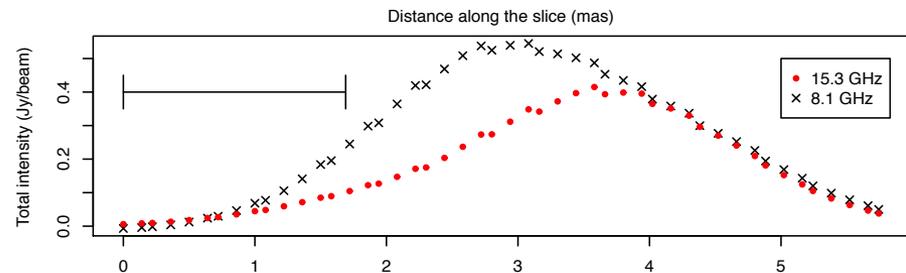
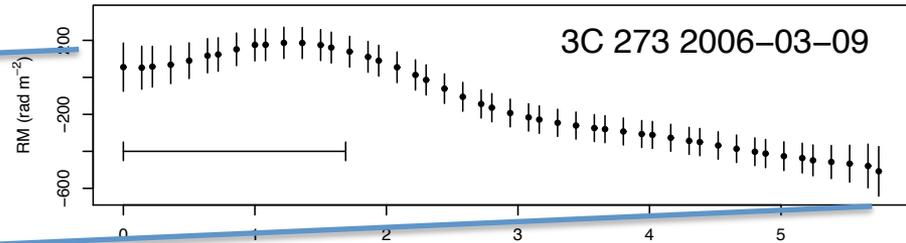
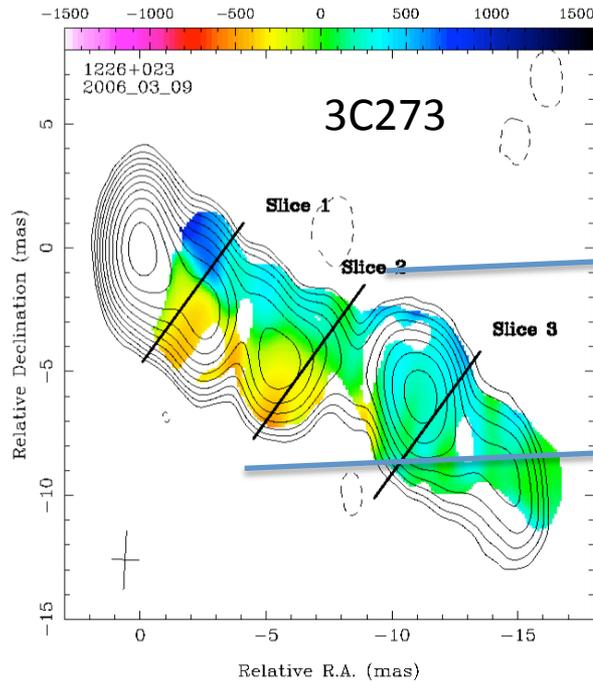
Random foreground screen works for most of the sources

Hovatta et al. 2012 λ^4 [cm⁴]

Jets 2016, Malaga

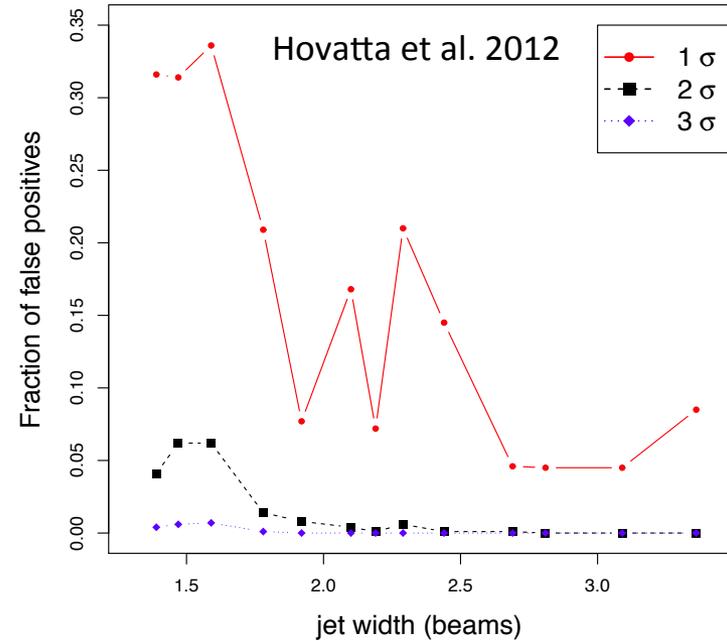
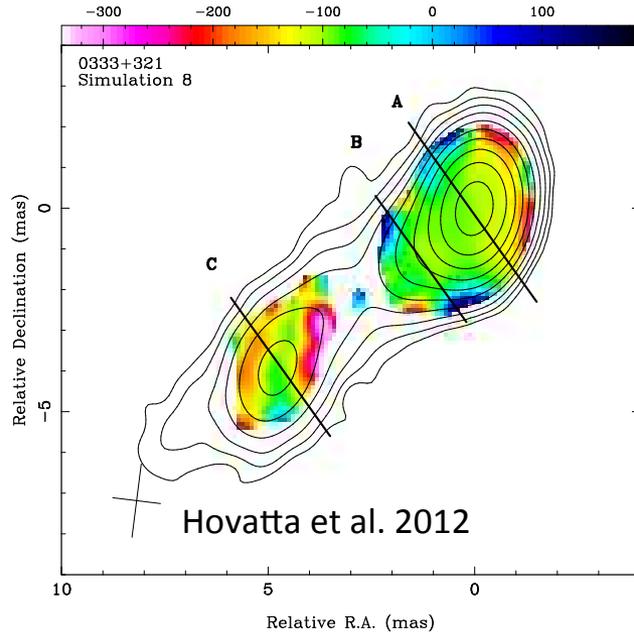
talvikki.hovatta@aalto.fi

Transverse RM gradients

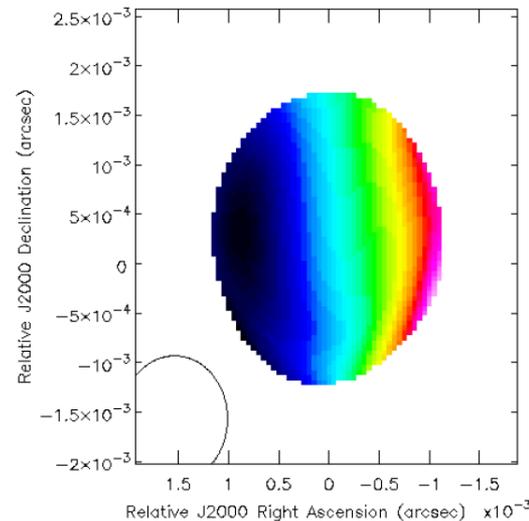
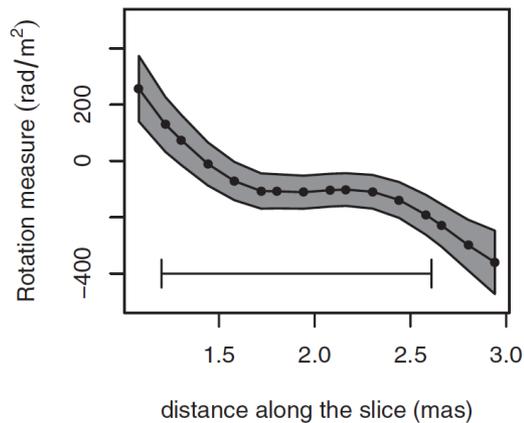


Significance of gradients

Simulated map without input gradient with added noise



0333+321 slice C



Simulated map with input gradient without added noise

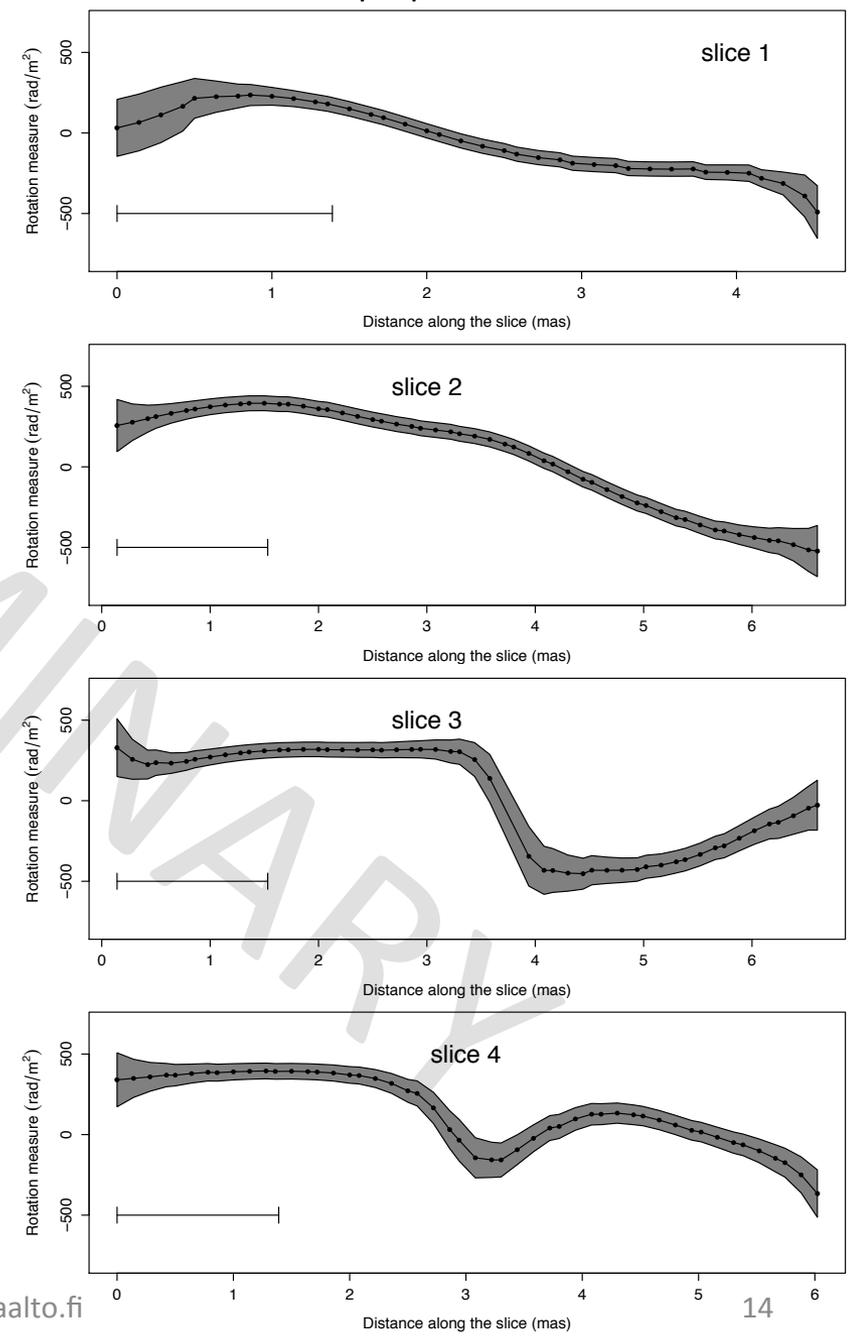
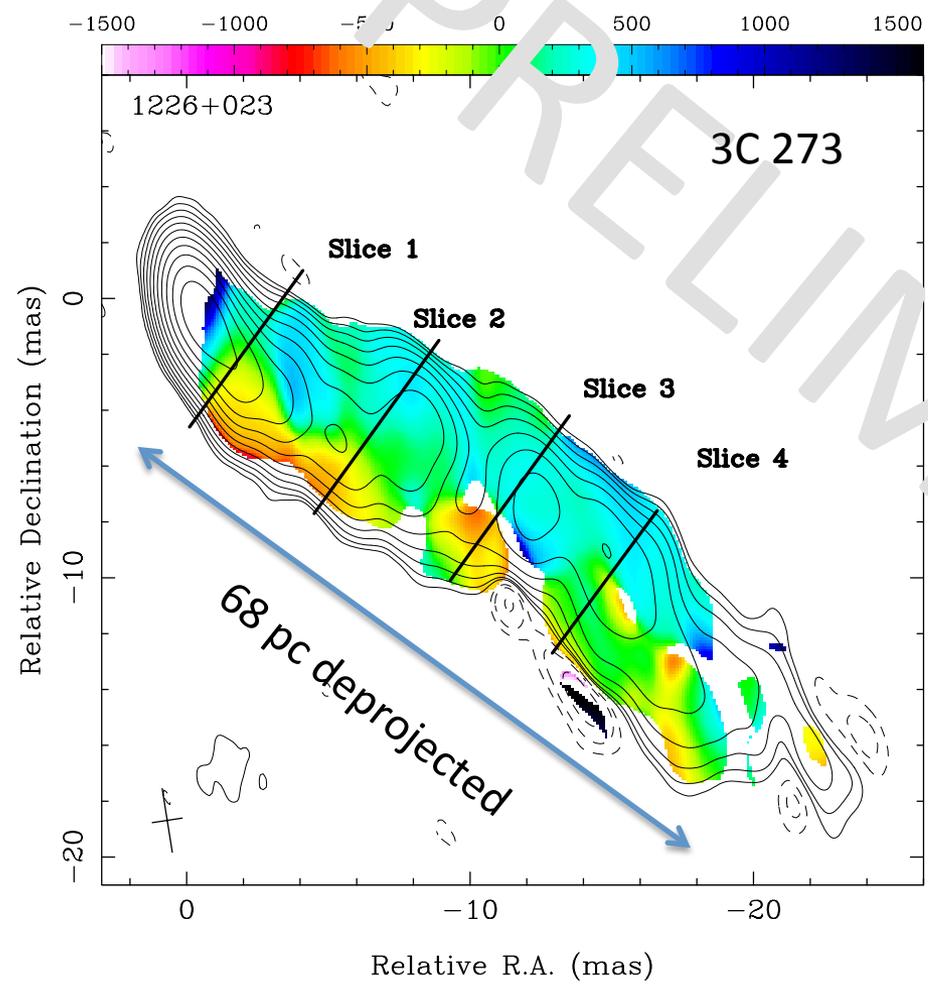
Mahmud et al. 2013,
Murphy & Gabuzda, 2013

Follow-up observations

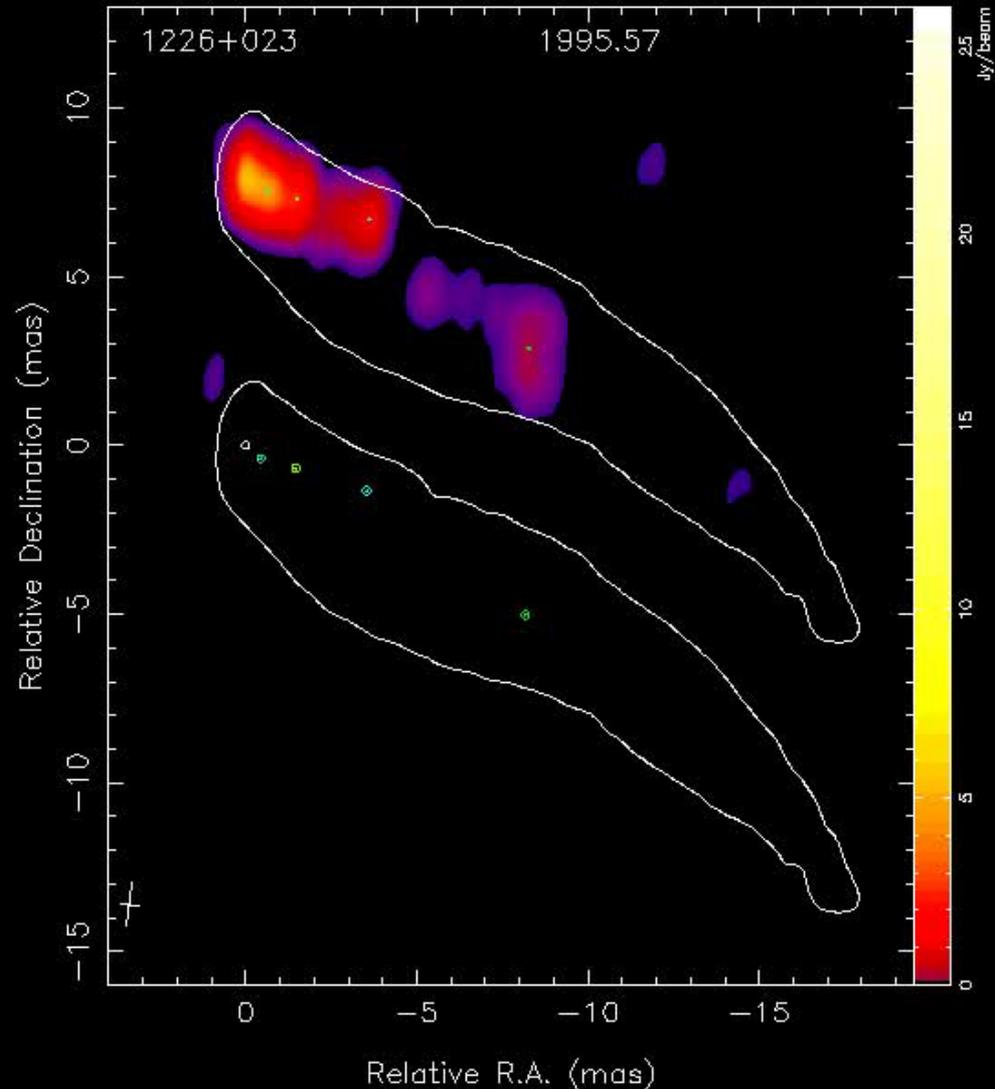
- In Hovatta et al. 2012 we found 4 sources with $> 3\sigma$ gradients and 3 more with 2σ gradients
- Follow-up observations of all 7 sources
 - Obtained in 2011
 - 10 frequency bands (5 reduced so far, 8-15 GHz)
 - Improved sensitivity

3C273 in 2011

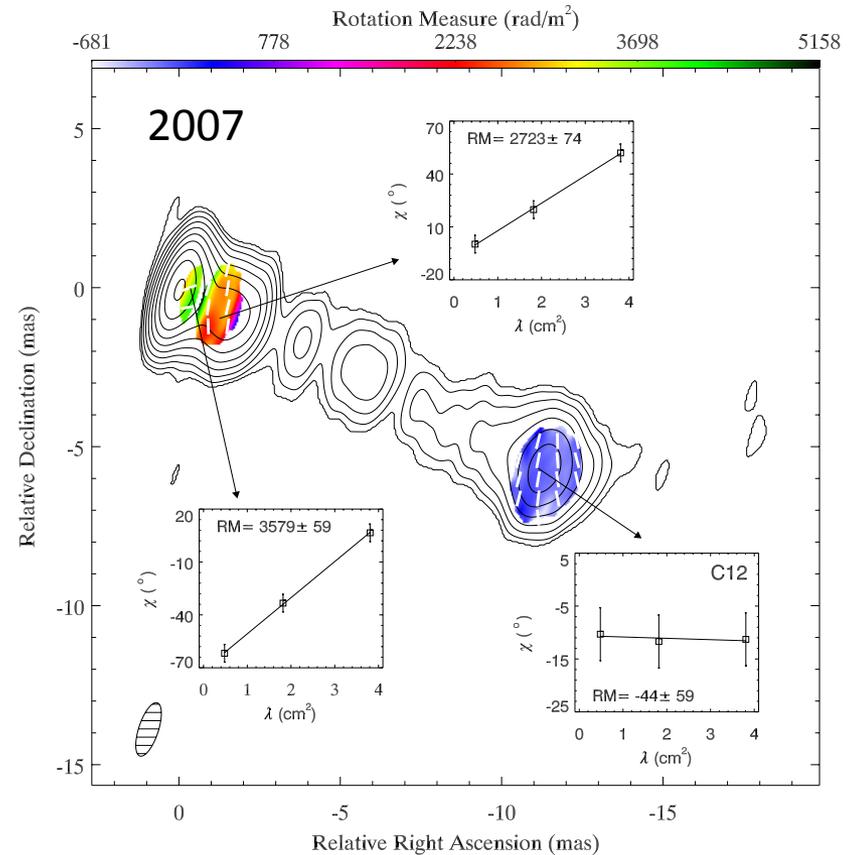
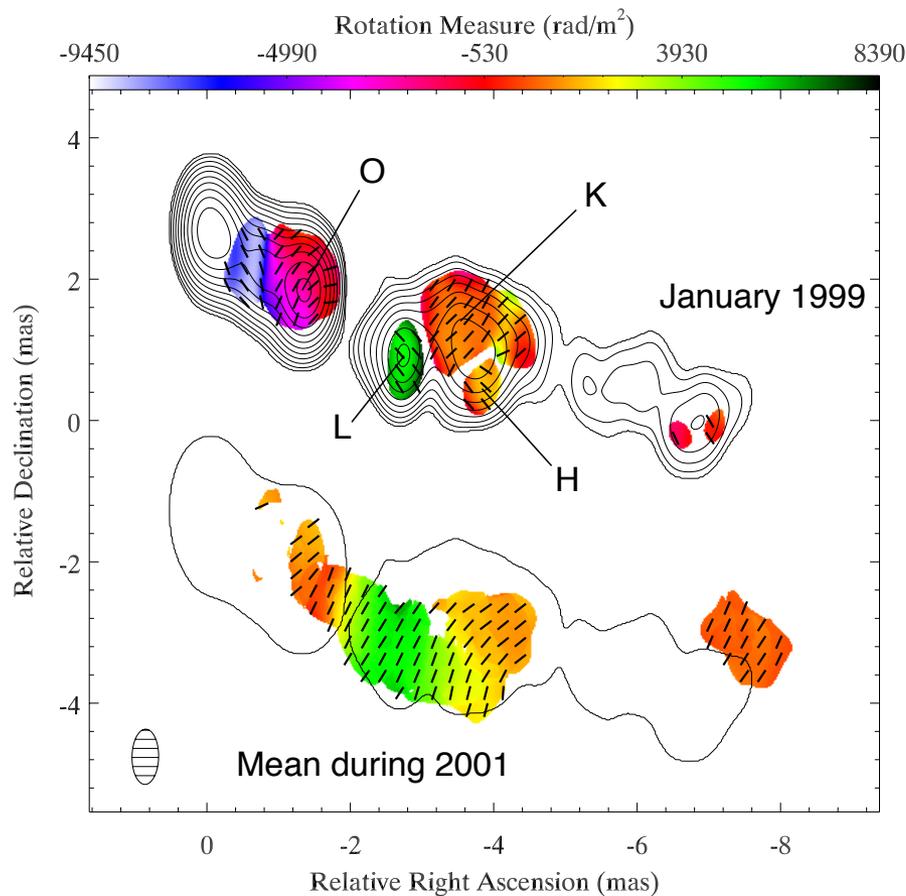
Hovatta et al. in prep.



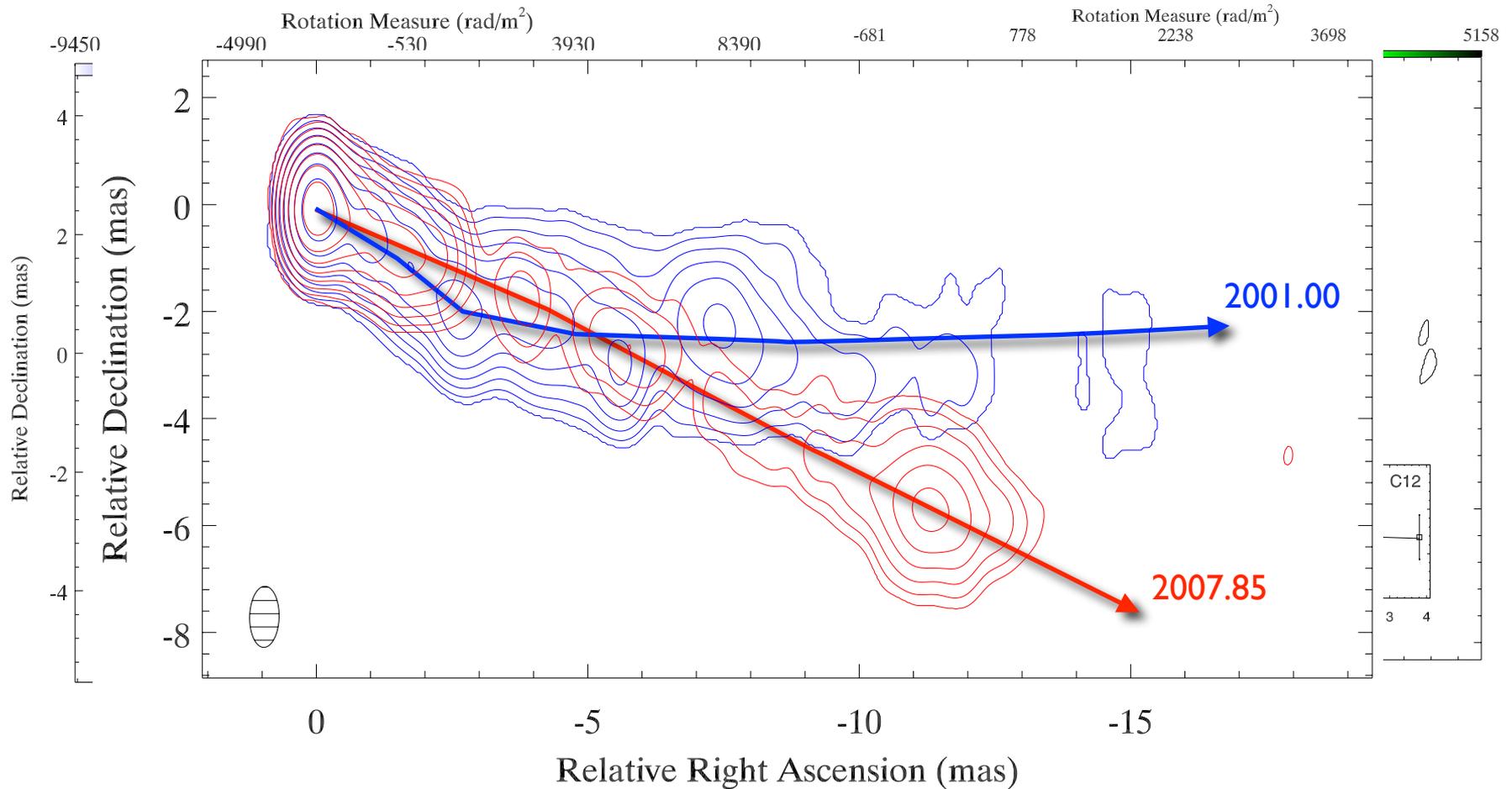
Only small part of jet seen at a single epoch!



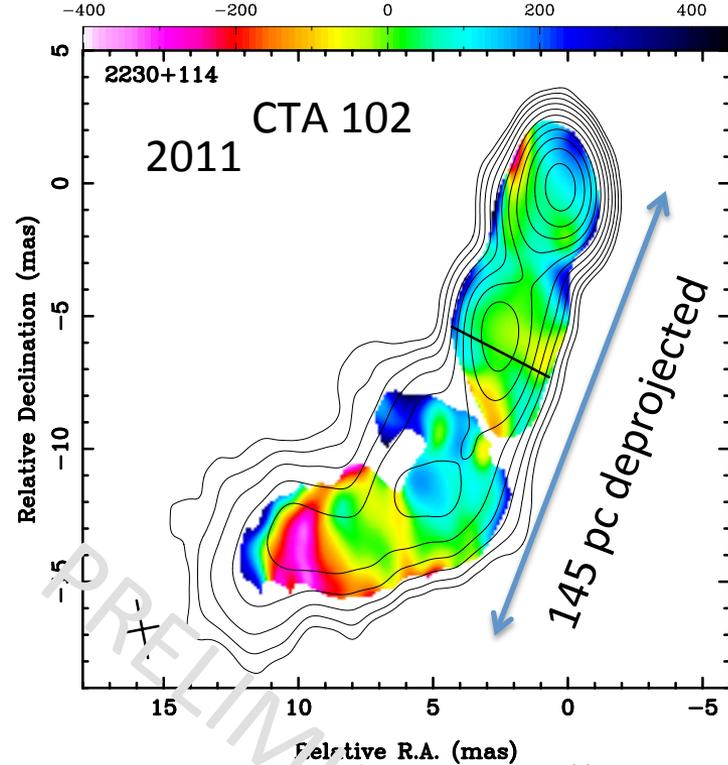
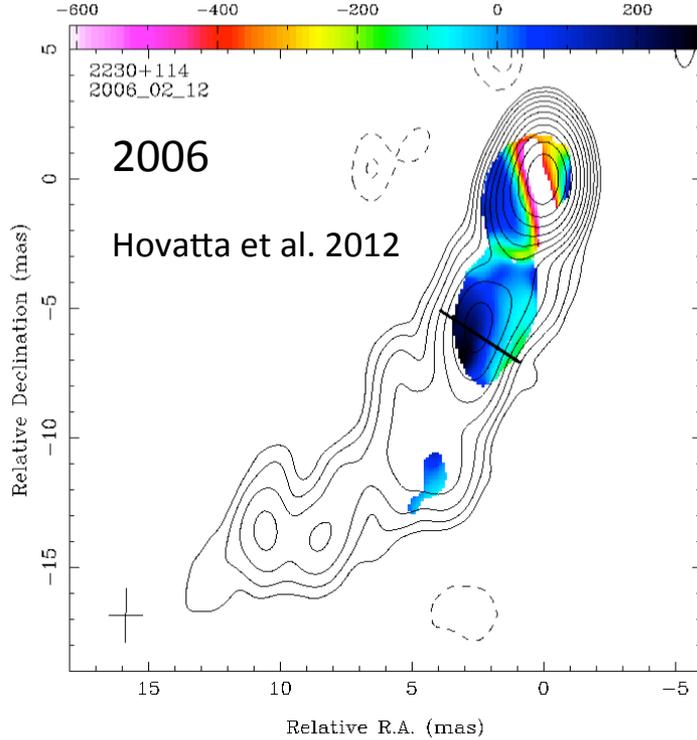
3C120 by Gomez et al. 2008 / 2011



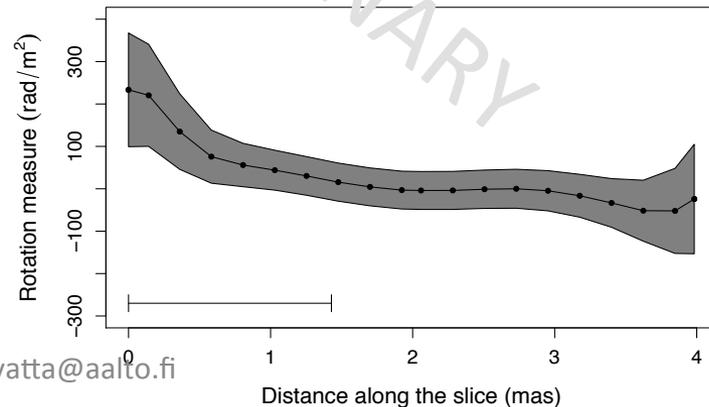
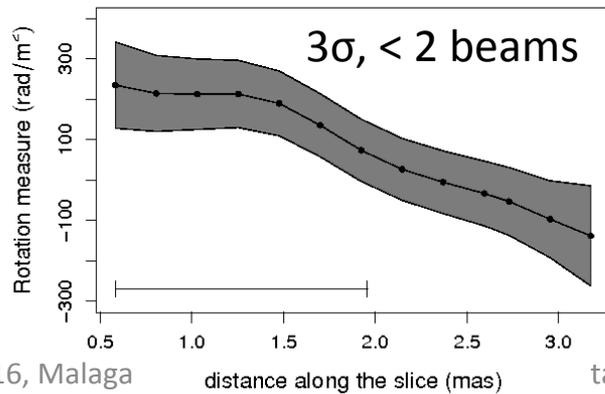
3C120 by Gomez et al. 2008 / 2011



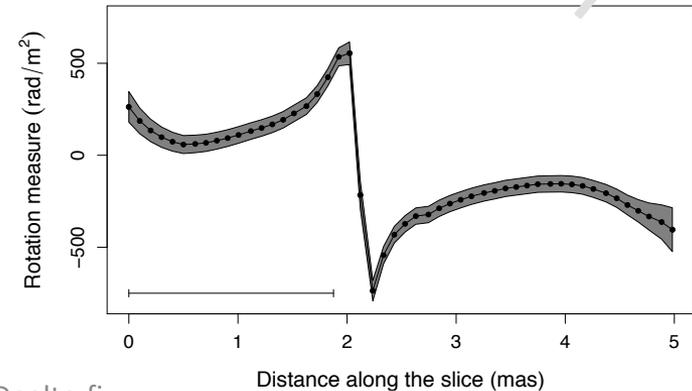
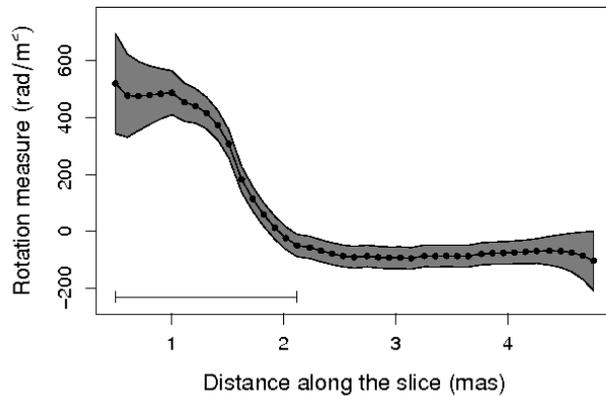
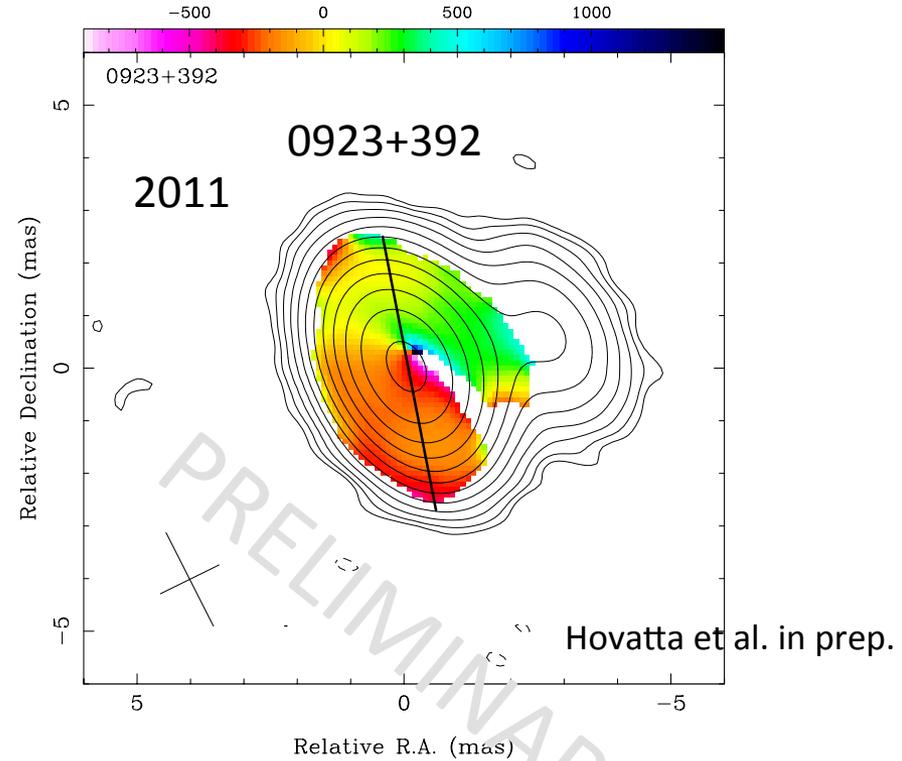
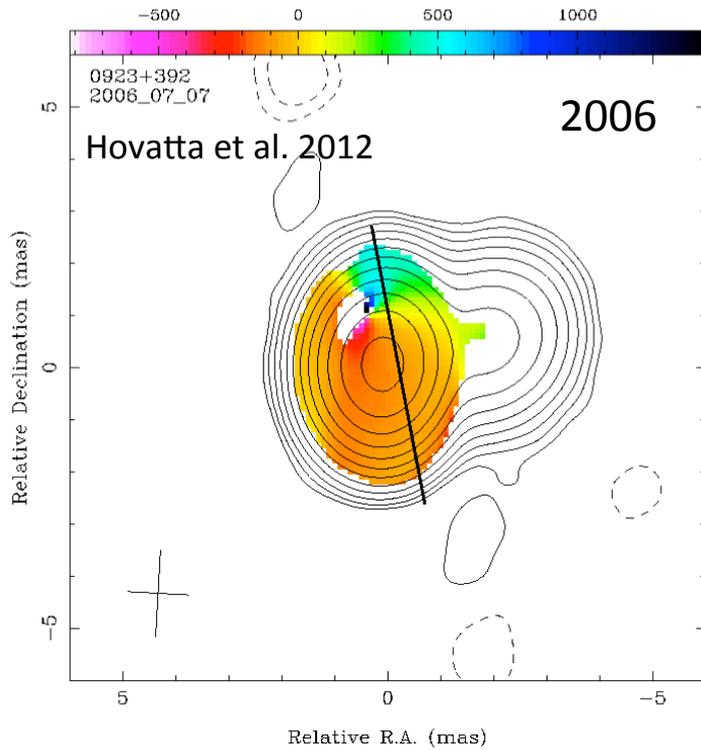
Other follow-up sources



Hovatta et al. in prep.



Other follow-up sources



Summary

- Faraday rotation gets smaller as a function of distance
 - > larger electron density / B-field in the core
- Depolarization behavior in most sources can be explained with a random external screen
- RM gradients are seen in a handful of sources
 - Resolution is a problem (need multiple epochs)
 - Different projected distance depending on redshift
- The full jet cross-section is not seen at single epoch images!