The Decaparsec Scale Radio Structures of BL Lac Objects

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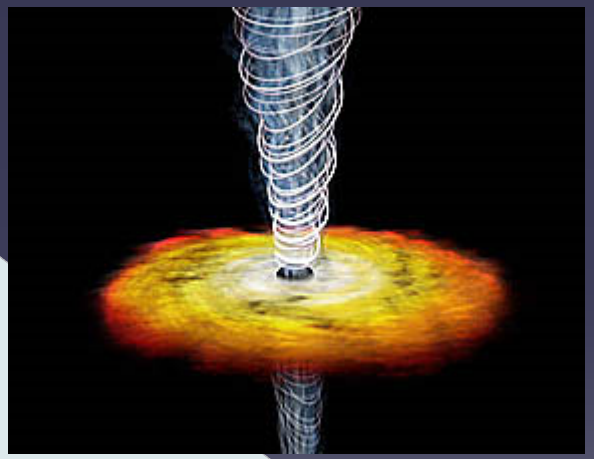
Outline

- Introduction
  - Objects
  - Observations
    - Two epoch, multi-frequency
    - Decaparsec scales
    - Spine – sheath Polarization
    - Farady rotation
- Results
    - Polarization structure
    - Rotation measure
    - Fractional Polarization

BL Lacs

Properties

- Jet appears close to our line of sight
- Beaming with high Doppler factors
- Variable
- Faint optical line emission
- Synchrotron emission
  - Linear polarization

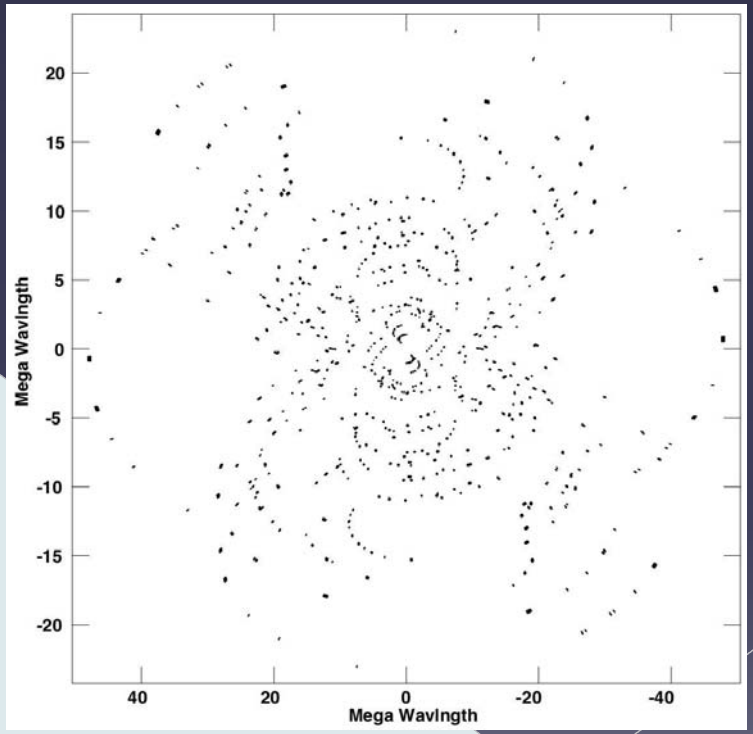


The Sample

- The sample of 34 northern BL Lac objects selected from the 1JY Catalogue by Kühr and Schmidt (1990).
- Flux > 1Jy at 5 GHz.
- Lack of line emission in the optical band.
- Sample includes BL-Lac and many sources are part of MOJAVE.

Observations

- 16-17 January 2004
  - V.L.B.A. Data
  - 4 wavelengths between 18 and 22 cm
- 13 December 1999
  - V.L.B.A. Data
  - 18 and 13 cm
- Good UV coverage
- Data calibrated and imaged using A.I.P.S.

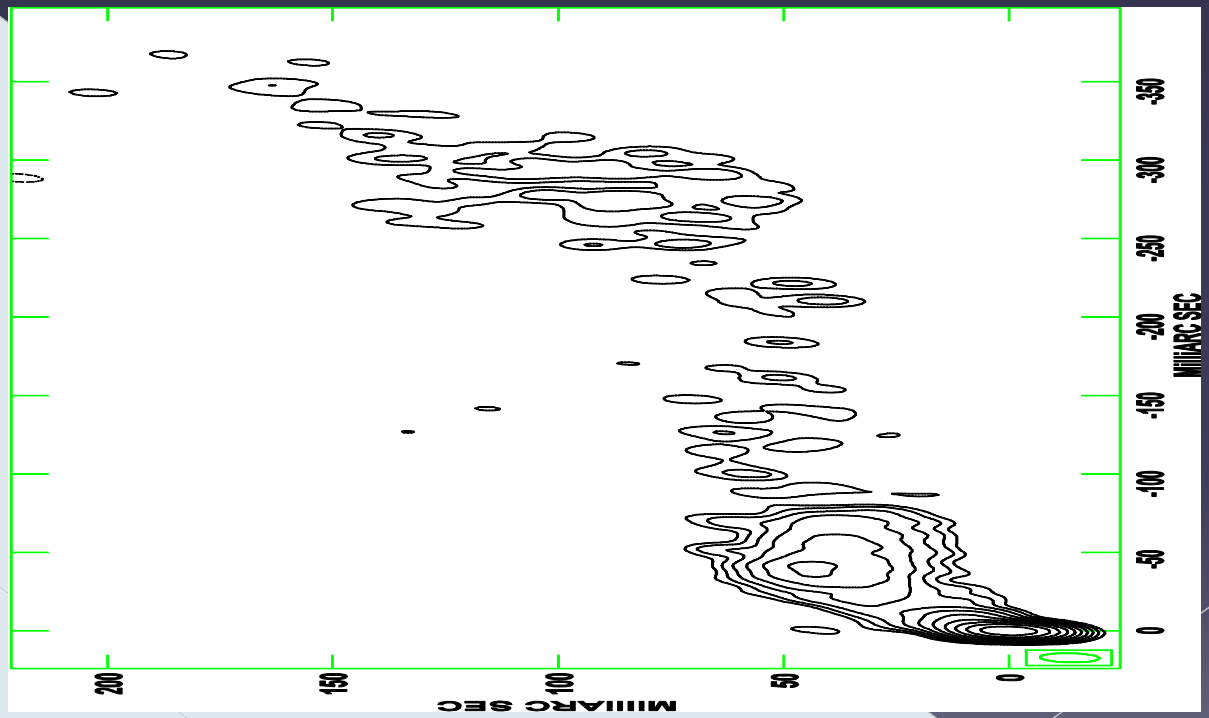


General Trends

- Morphology
  - Jet extends from tens to hundreds of mas
  - Jet emission out to 0.7 kpc
- Polarization Structure
  - Interested primarily in the jet polarization
  - Core lacks resolution
- Rotation Measure distribution
  - Electron density and B field along line of sight
- Evidence for helical magnetic fields

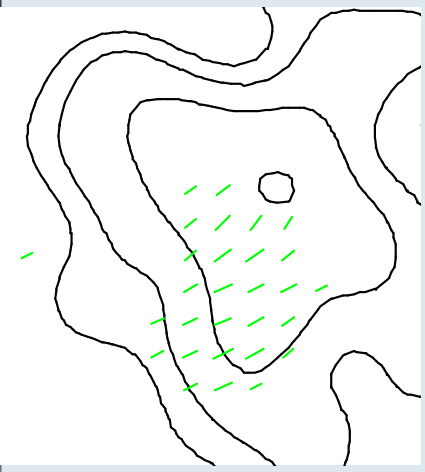
Large scale structure

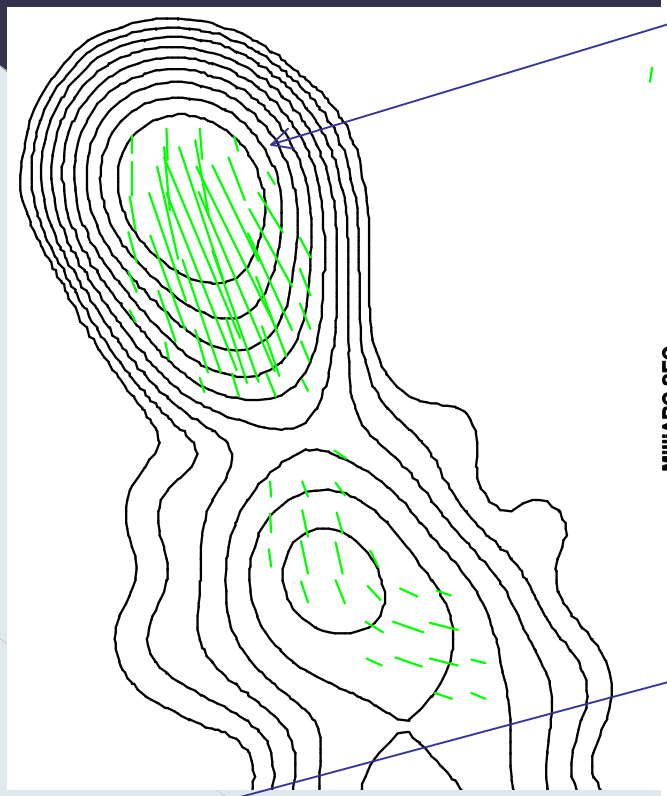
- 1538+149
  - Extended
  - Signs of Jet instability

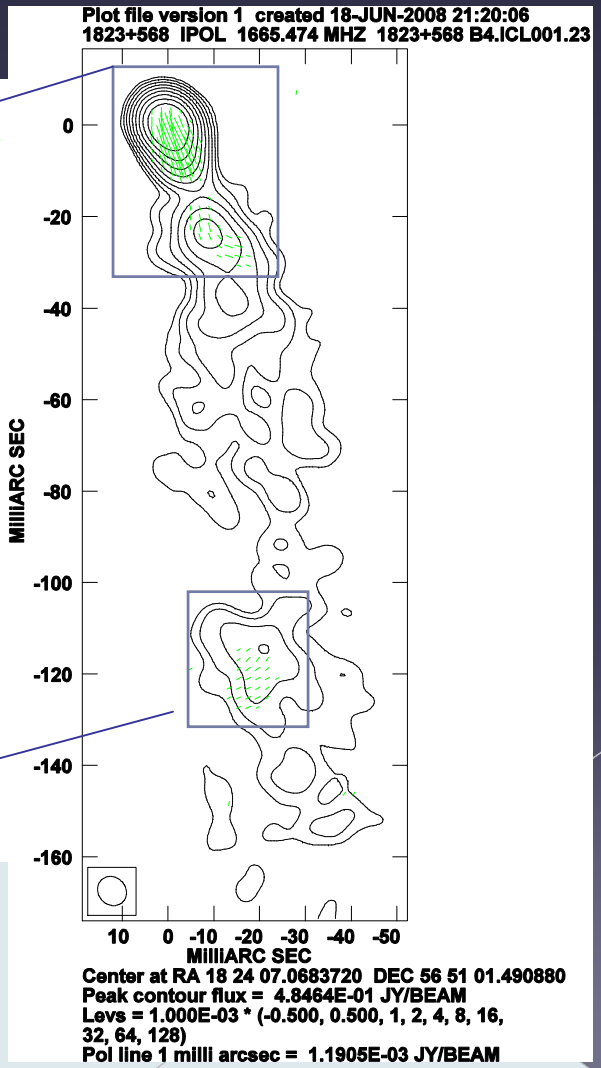


Large scale structure

- 1823+568
  - Extended
  - Polarized knot in Jet





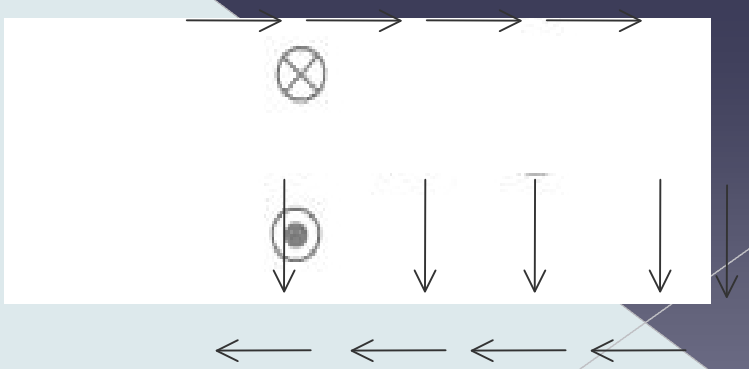


Evidence for Spine-Sheath structure

- What is it?
  - Observed tendency for E field to align with Jet direction (Parallel and Perpendicularly)
- Optical Depth
  - E relative to B
- Implications
  - Helical B Field

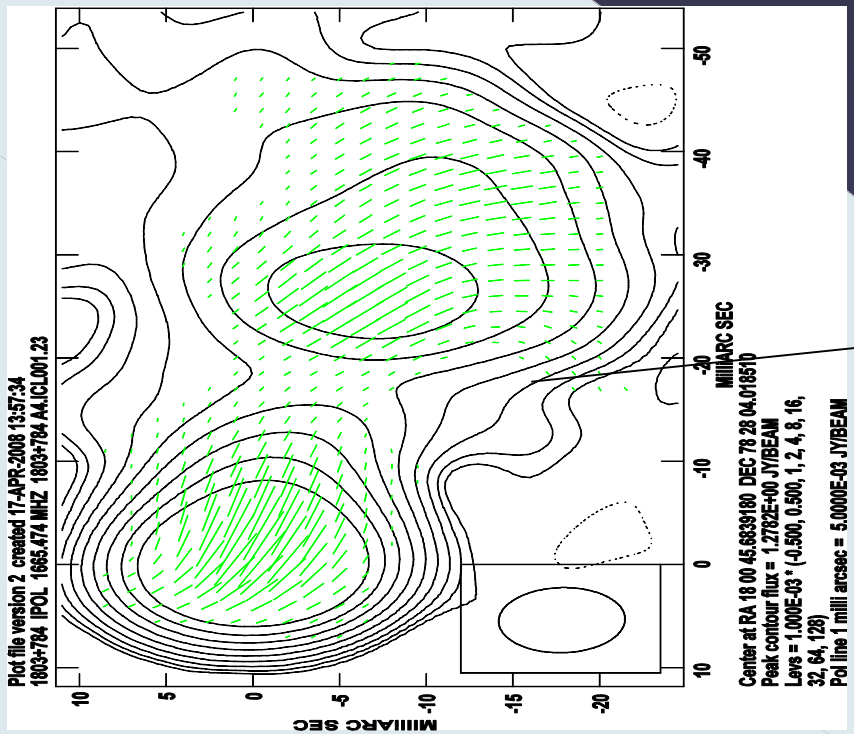
Left: Observed polarization

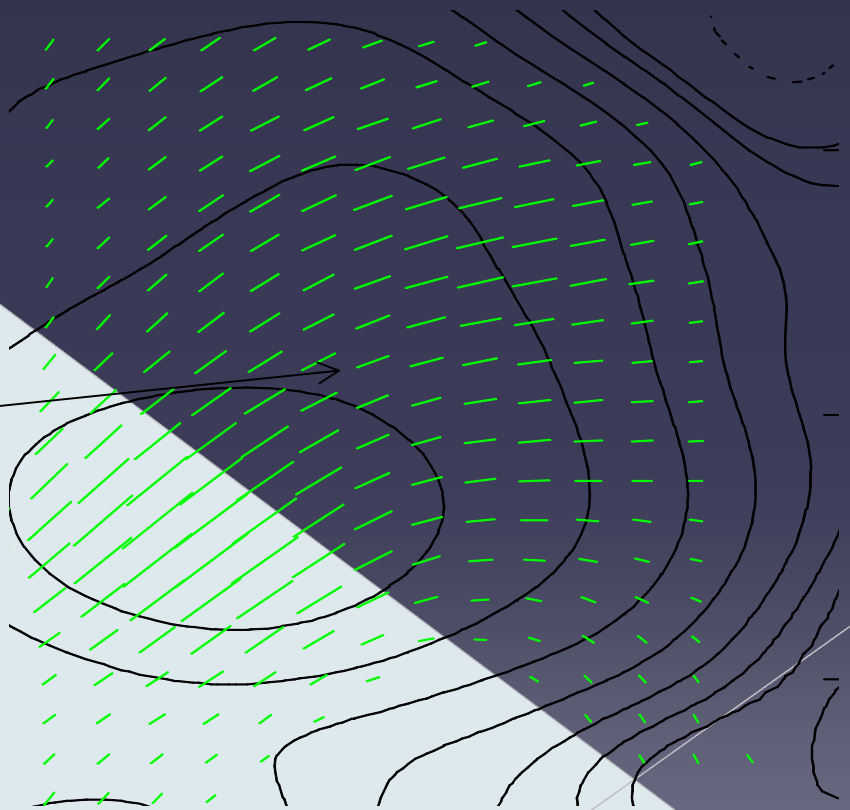
Below: Magnetic Field



Polarisation structure

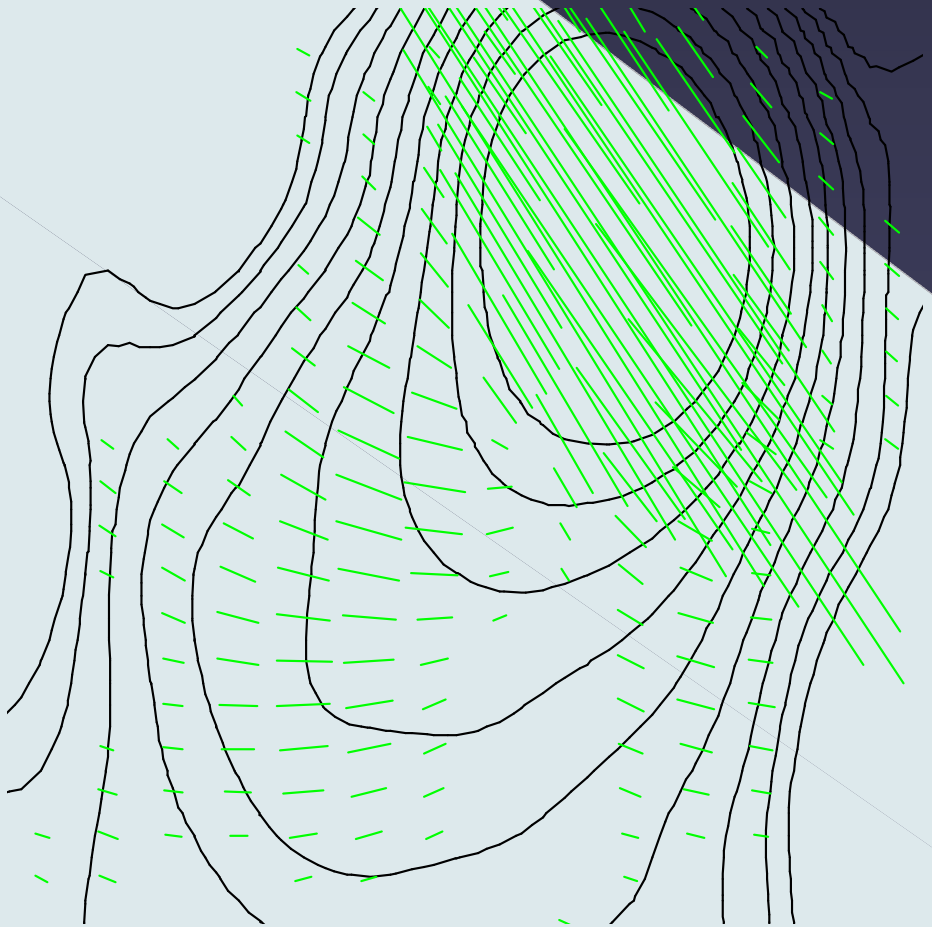
- 1803+784

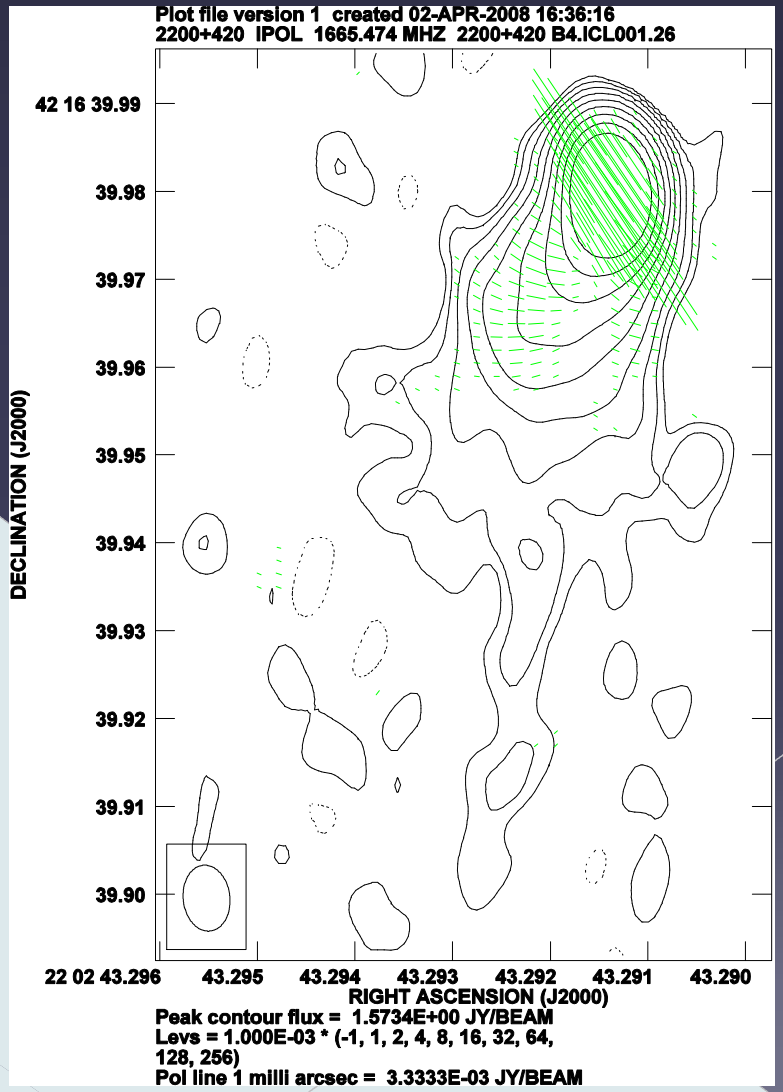




Polarisation structure

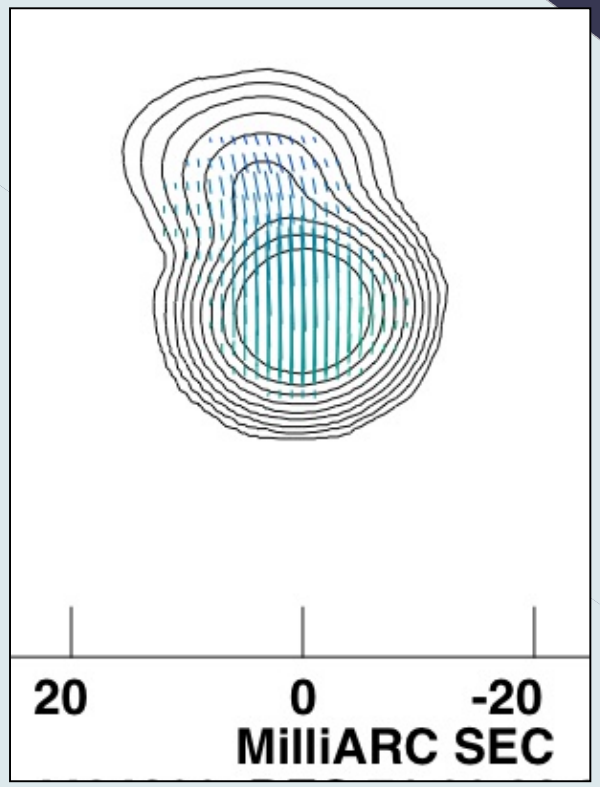
- BL-Lac

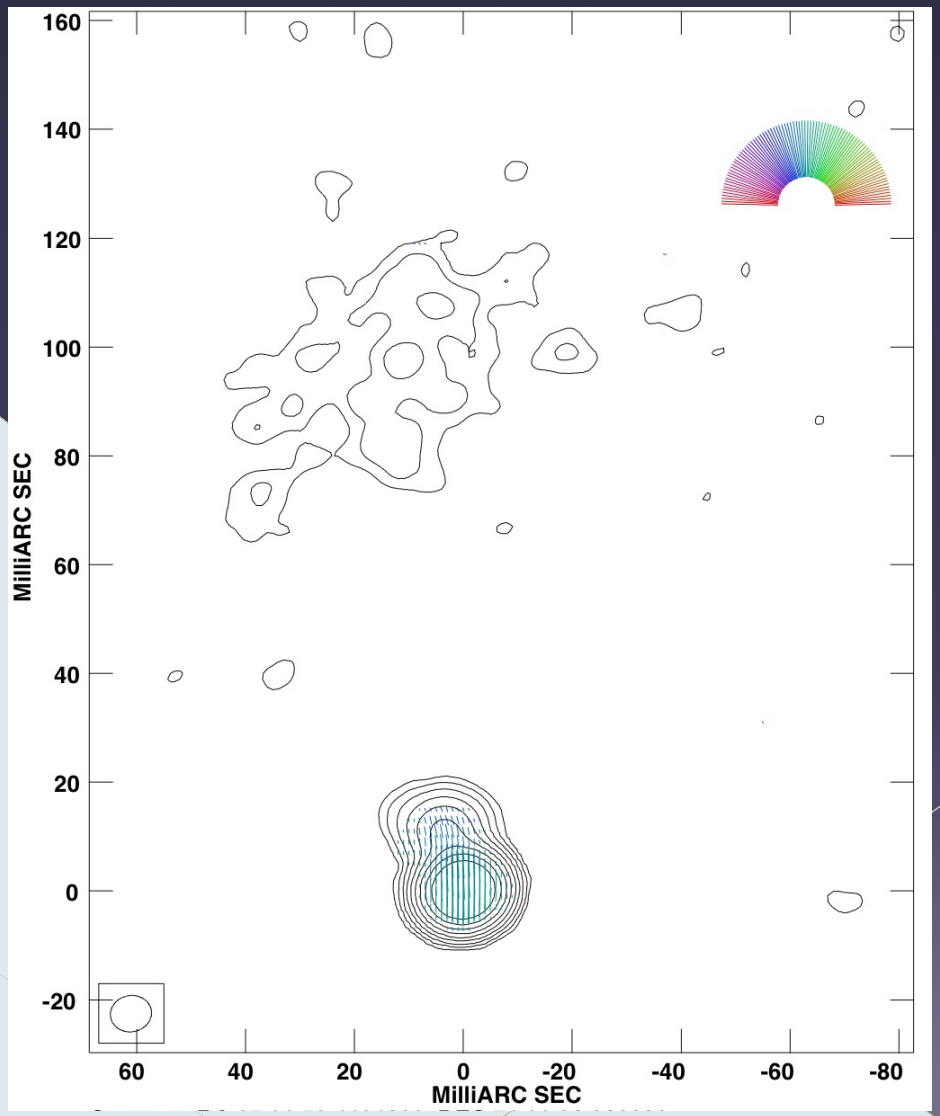




Polarisation structure

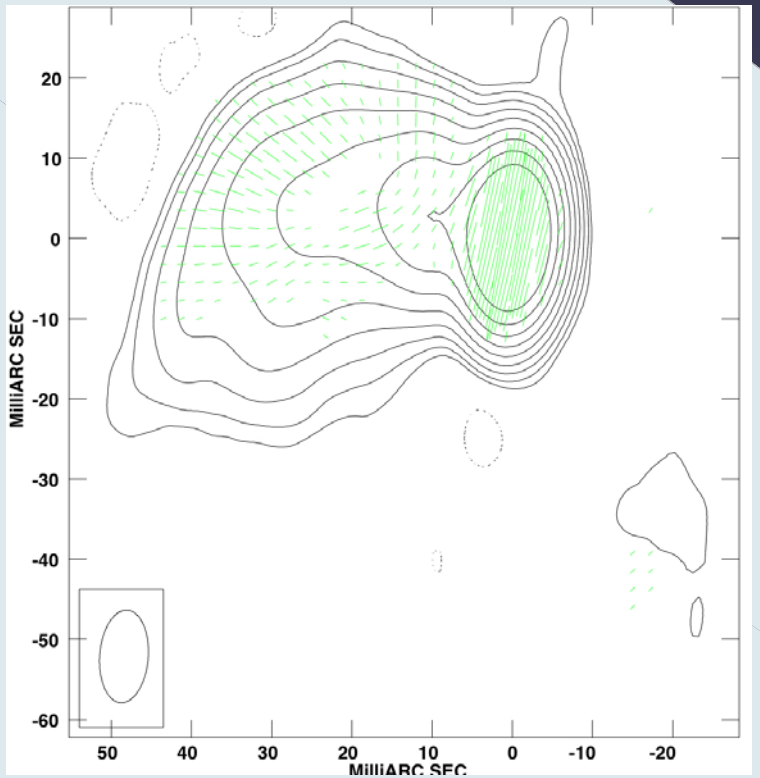
- 0716 + 714
  - 2004 18cm

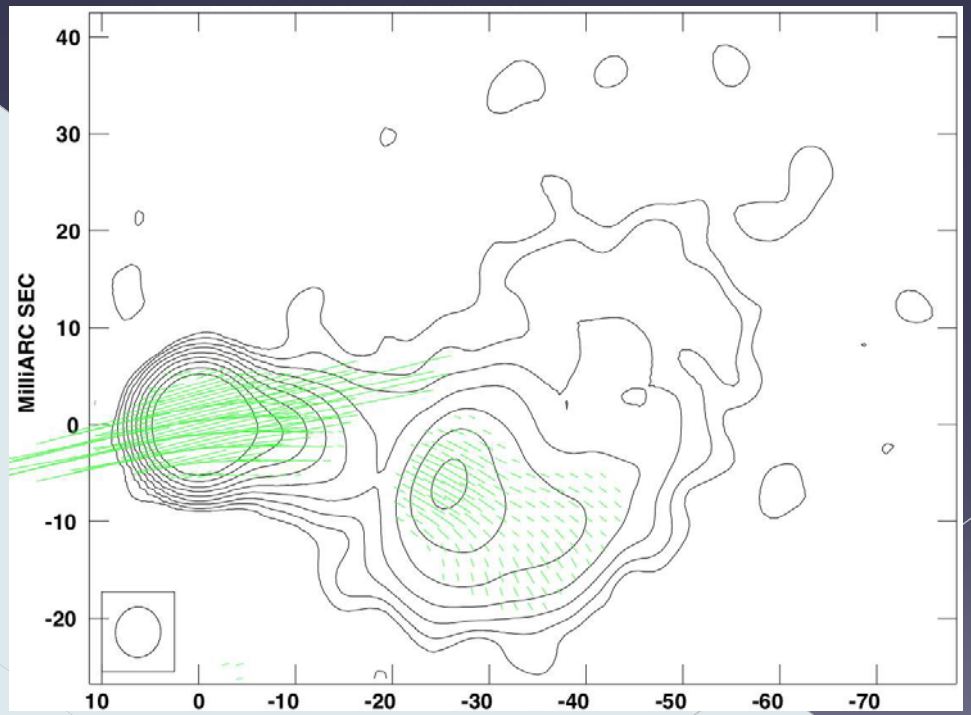




Multi-Epoch Observations

- 0735+178
- 13 cm, 1999
- 1803+784





Faraday Rotation

- Rotation of the plane of linear polarization.
- RCP and LCP have different velocity in the plasma.

$$\chi_{obs} = \chi_0 + RM\lambda^2$$

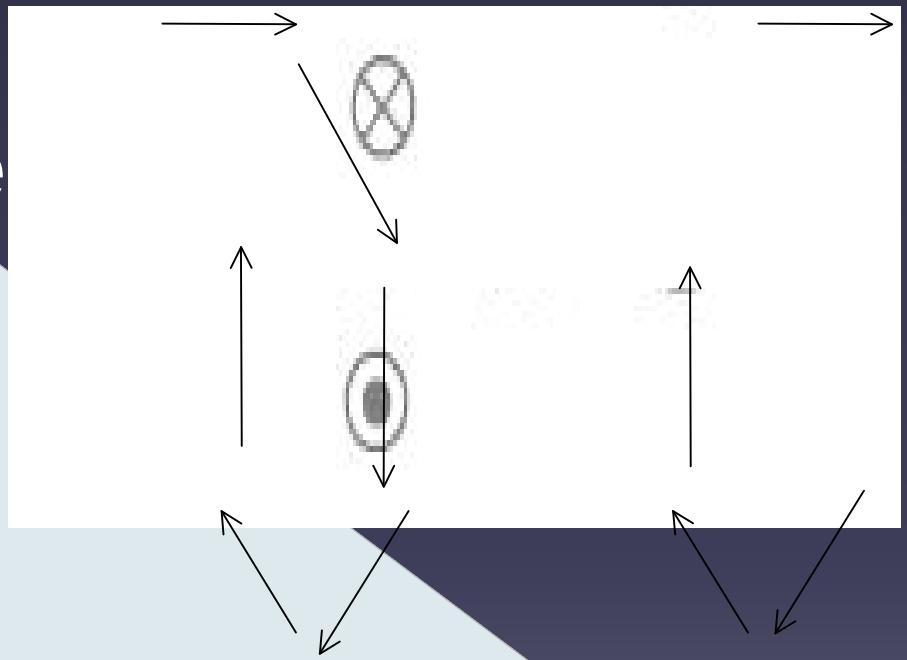
- Lambda squared dependence
- Dependant on magnetic field and free electron population.

Faraday Rotation effects

- Due to ISM in our own galaxy
- Pushkarev (2001)
- VLA observations (18 – 22 cm)
- Lambda squared dependence
- An RM of just 20 can cause rotations of up to 50 °

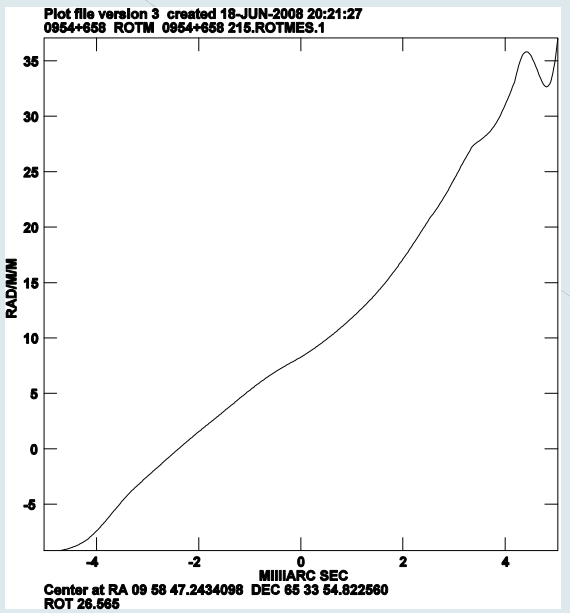
Rotation Measure Gradients

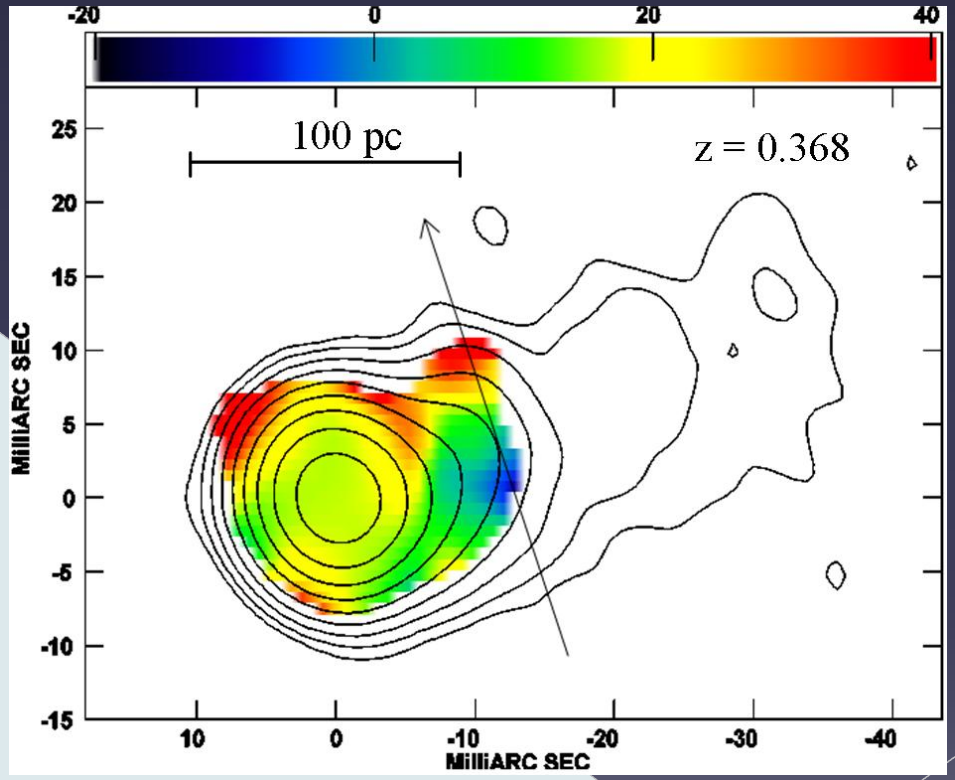
- Gradients due to the changing line of sight B field



RM Intrinsic to the source

- 0954+658
  - Observed at other VLBA frequencies too.

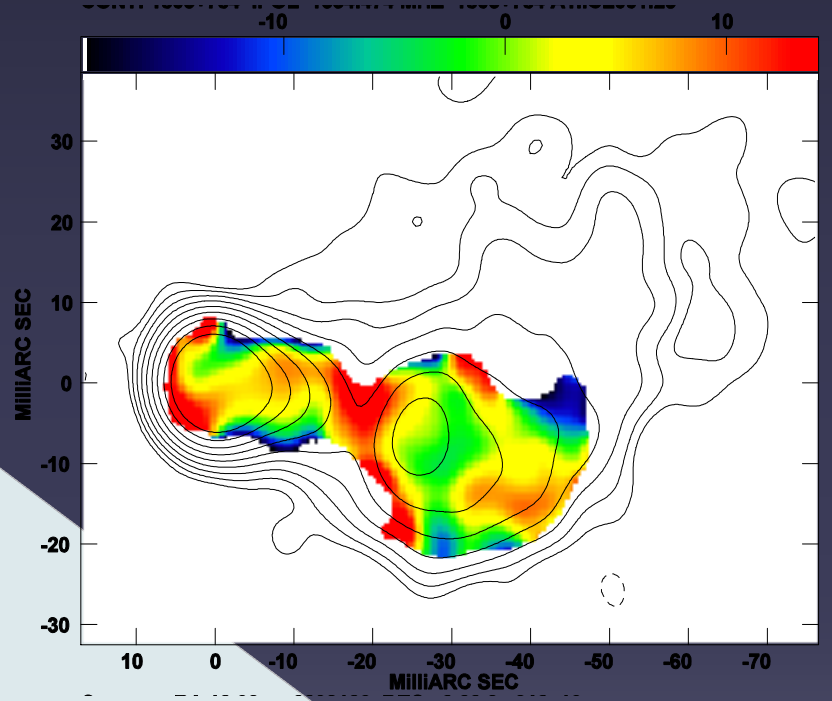




Above: 2004, 18 - 22cm RM
Left: Slice as shown by arrow
RM from -9 to +35 Rad / m^2

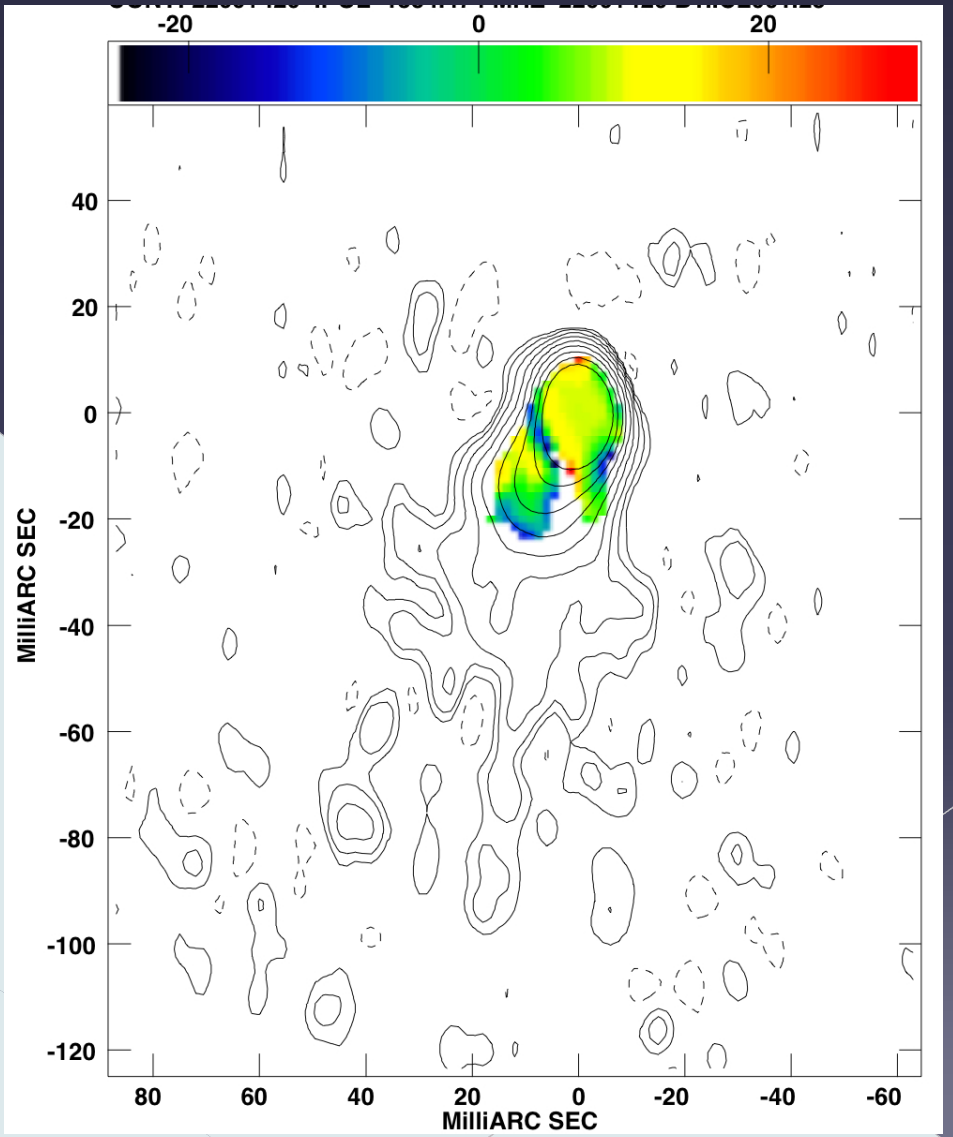
RM Intrinsic to the source

- 1803+784
  - Also observed at other VLBA frequencies.
  - Plenty of structure
  - Possible gradients
  - Needs further investigation and error analysis



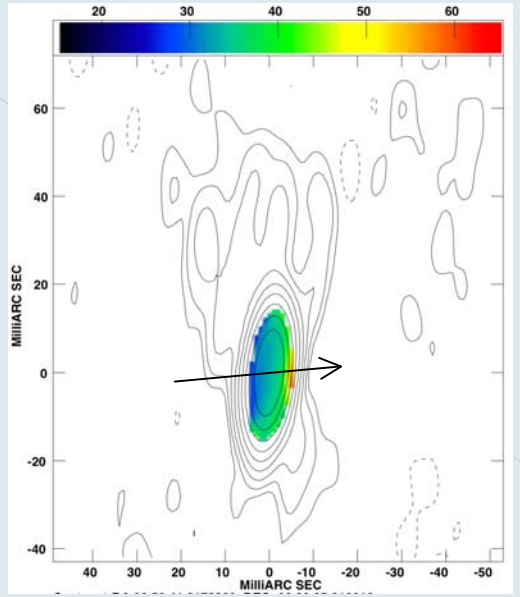
RM Intrinsic to the source

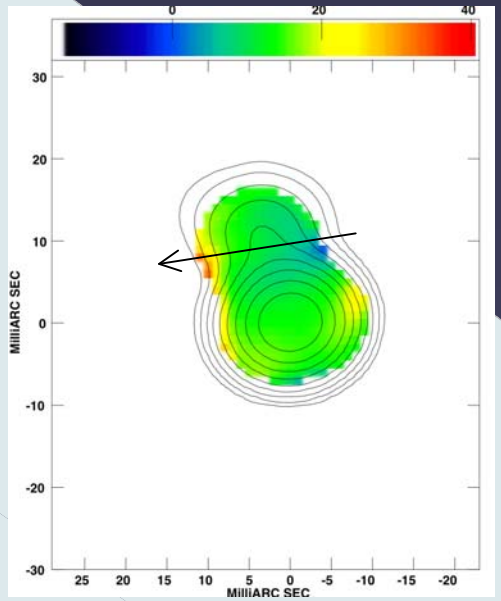
- Bl Lac
  - Weak gradient across inner jet.
  - Modest faraday rotation from ISM of our galaxy, but weak RM at the source

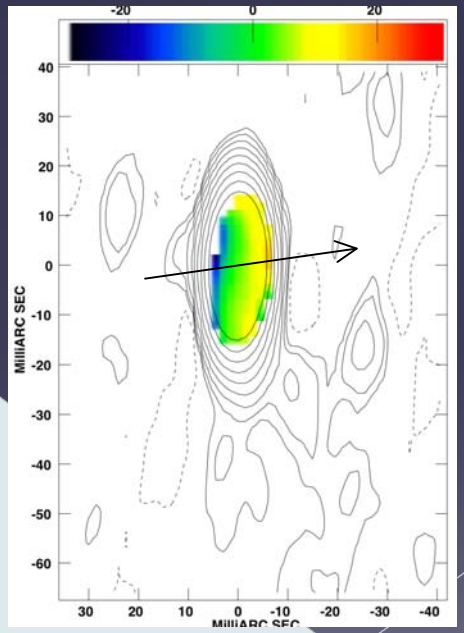


RM Intrinsic to the source

- 0048-097
- 0716+714
- 2155-152



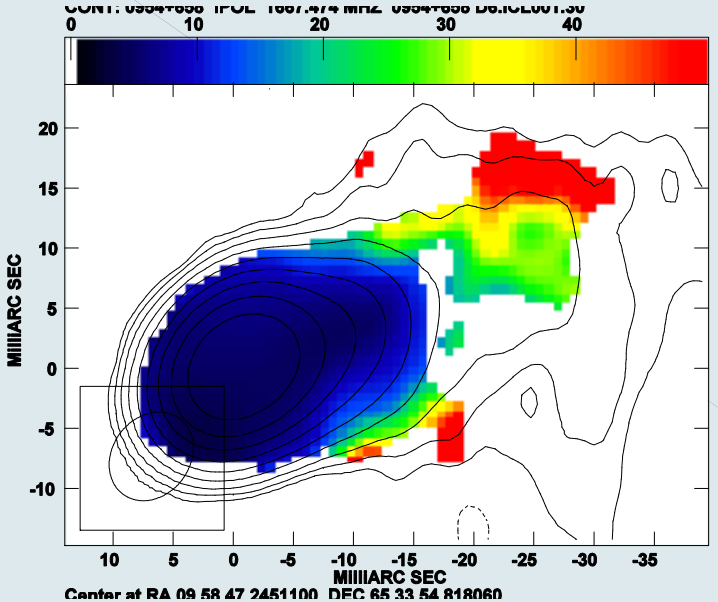


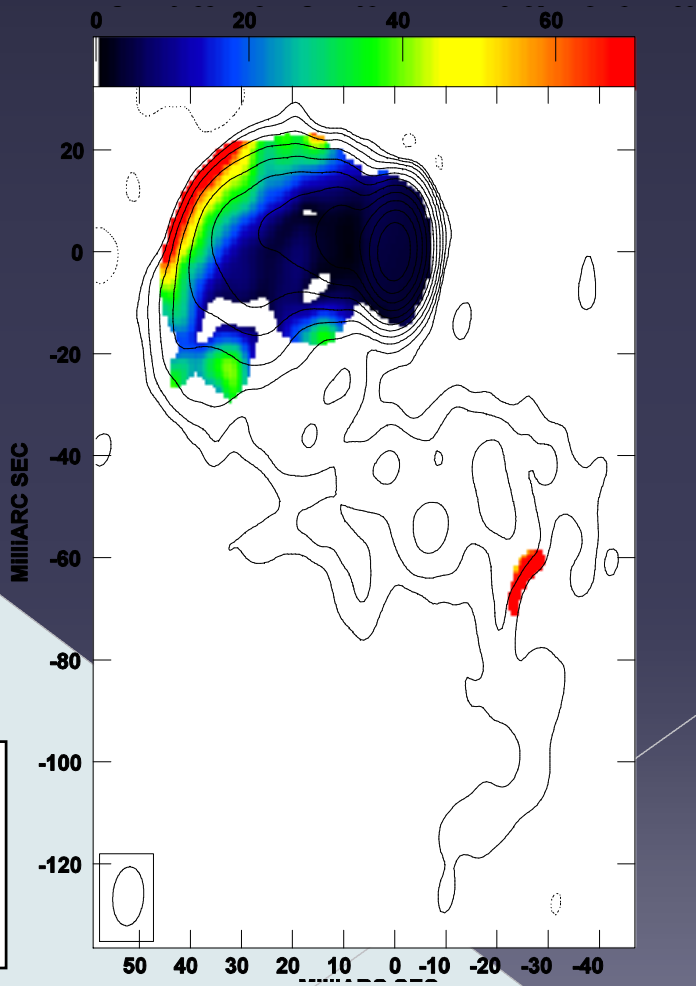


- Both 0716+714 and 2155-152 gradients are in same direction as higher frequency observations of Mahmud

Fractional Polarisation Maps

- Further evidence for helical fields, cf Lyutikov (2005).





Left: 2004, 18 cm 0954+658
Right: 1999, 18 cm 0735+178

Project Status

- Imaging just completed for all data.
- Rotation measure maps needed for all sources from 2004 data.
- Rotation measure maps between 13 and 18cm from 1999 possible
- Categorise sources due to morphologies or polarisation structure.

Summary

- Decaparsec scale observations
- Rich structure
- Spine - sheath polarisation structures
- RM gradients
- Evidence for Helical Magnetic fields
  - Ordered polarization structures

Acknowledgments

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