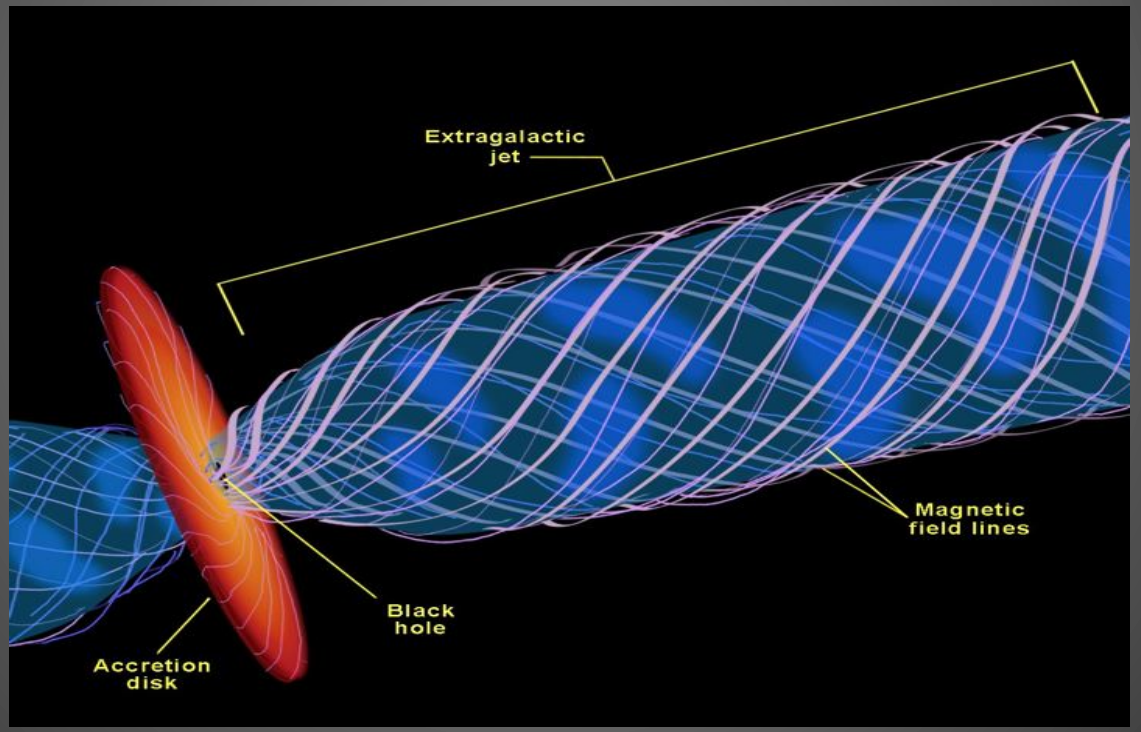
Gleaning Secrets from Transverse Profiles of AGN

Eoin Murphy (UCC), Dr. Denise Gabuzda (UCC), Dr. Tim Cawthorne (UCLan)

EVN Symposium 2010, Manchester



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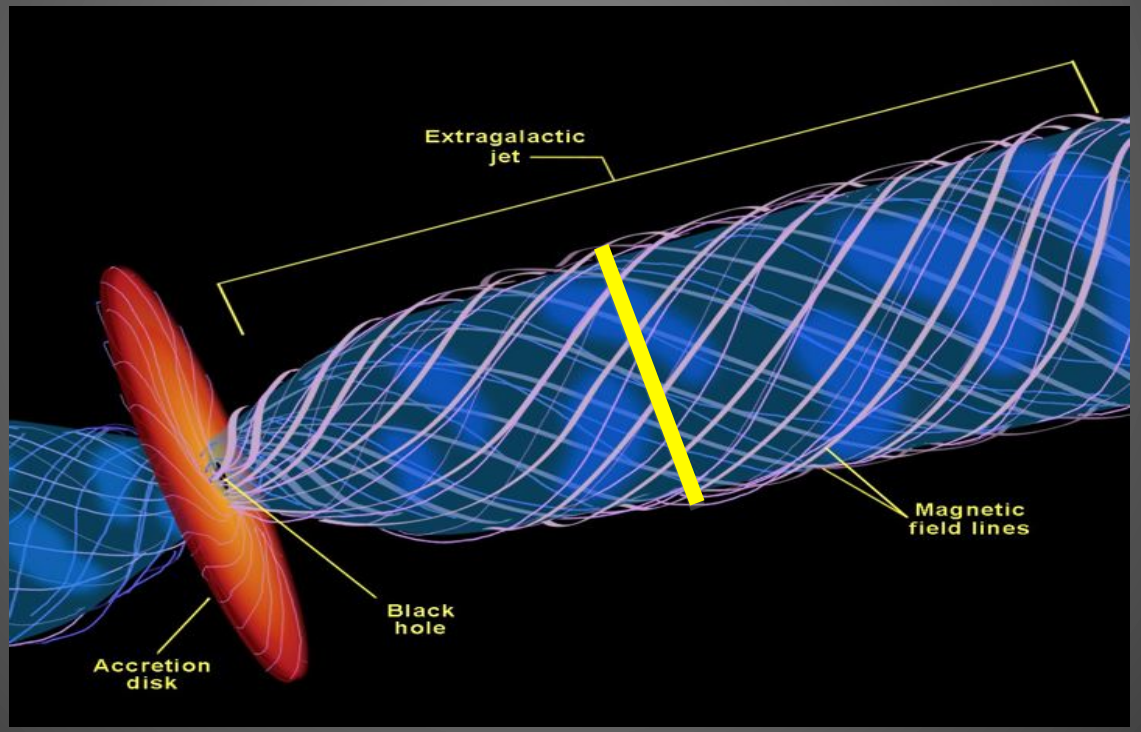

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Evidence for Helical Magnetic Fields

There are primarily 3 different observations that support Helical Magnetic Fields threading the jets of AGN.

- Systematic Faraday Rotation Measures gradients across jets
- Asymmetric profiles of both intensity and polarization across jets.
- Magnetic field angle orientation changing from longitudinal to transverse within a given jet profile.

Evidence for Helical Magnetic Fields

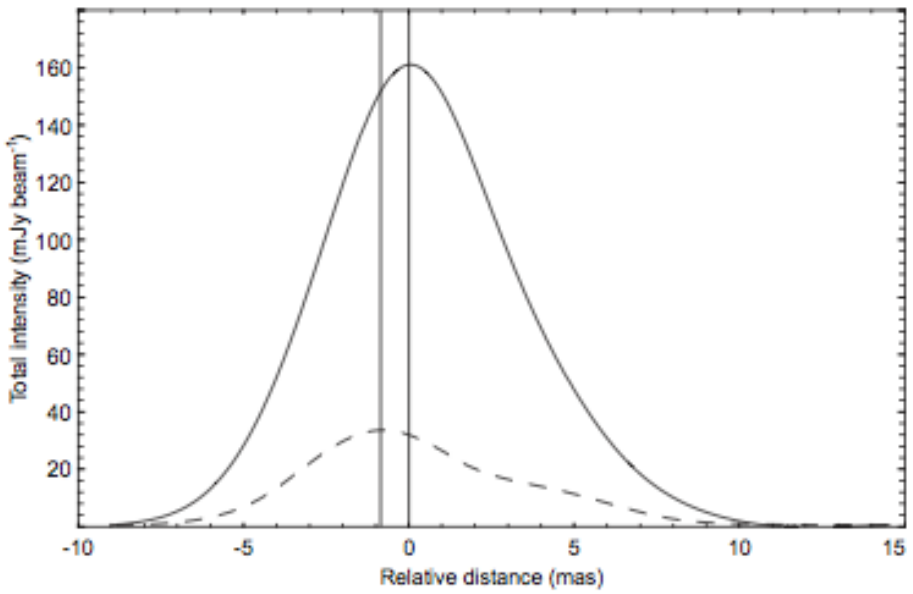

Figure 2. 1.6 GHz total and polarized intensity transverse profile of the jet in 3C 380, 16 mas away from the core. The convolution beam is ~ 4 mas. Solid line corresponds to total intensity, dashed line corresponds to polarized intensity.

Papageorgiou (2005)

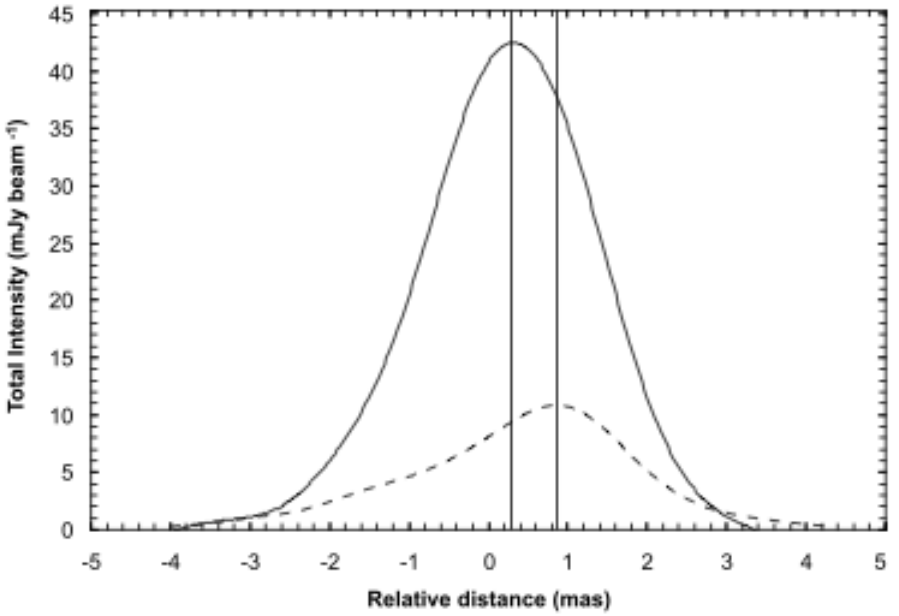

Figure 1. 8 GHz total and polarized intensity transverse profile of the jet in 4C 71.07 (epoch 1997.89), 6 mas away from the core. The convolution beam is ~ 1.5 mas. Solid line corresponds to total intensity, dashed line corresponds to polarized intensity.

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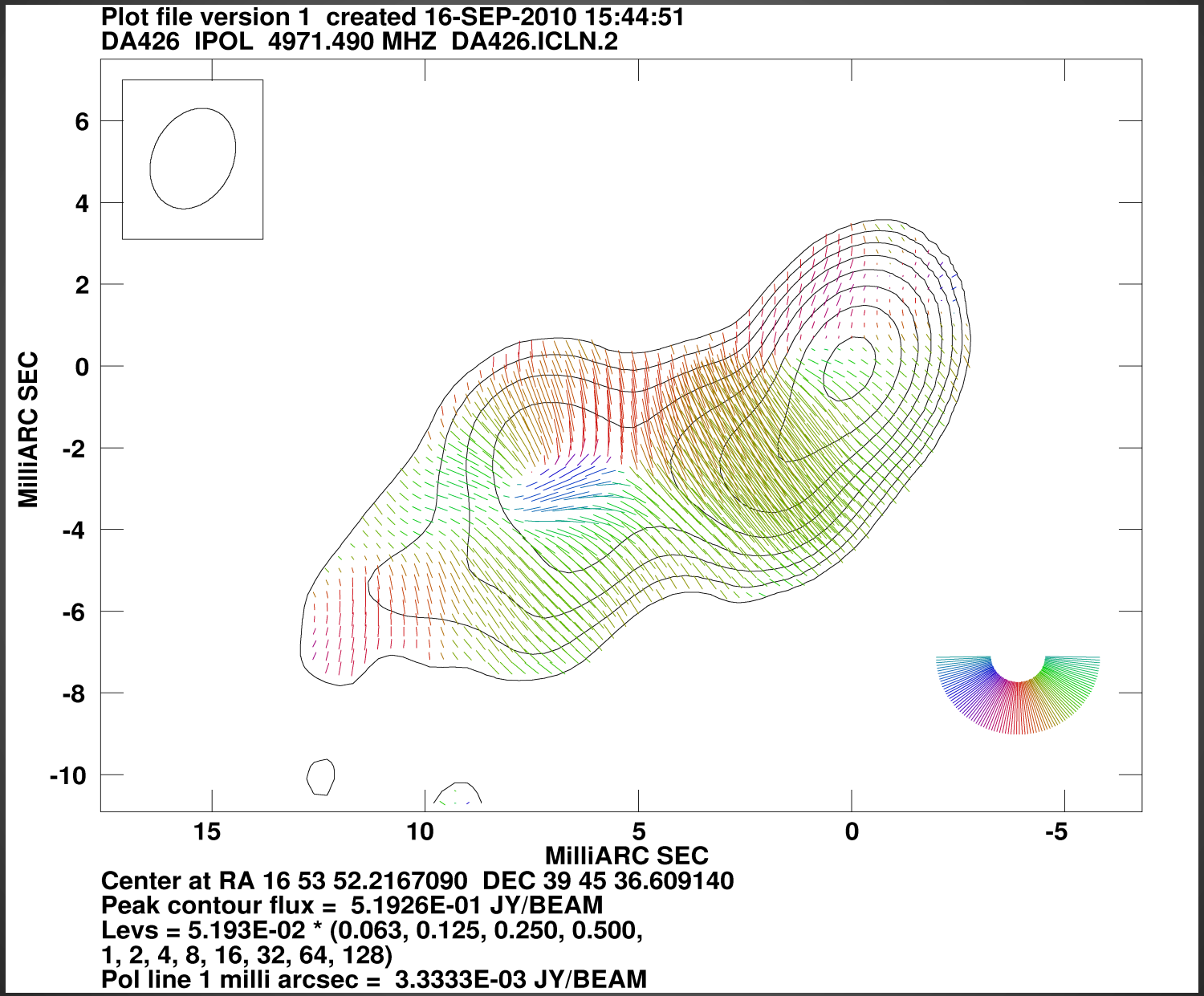

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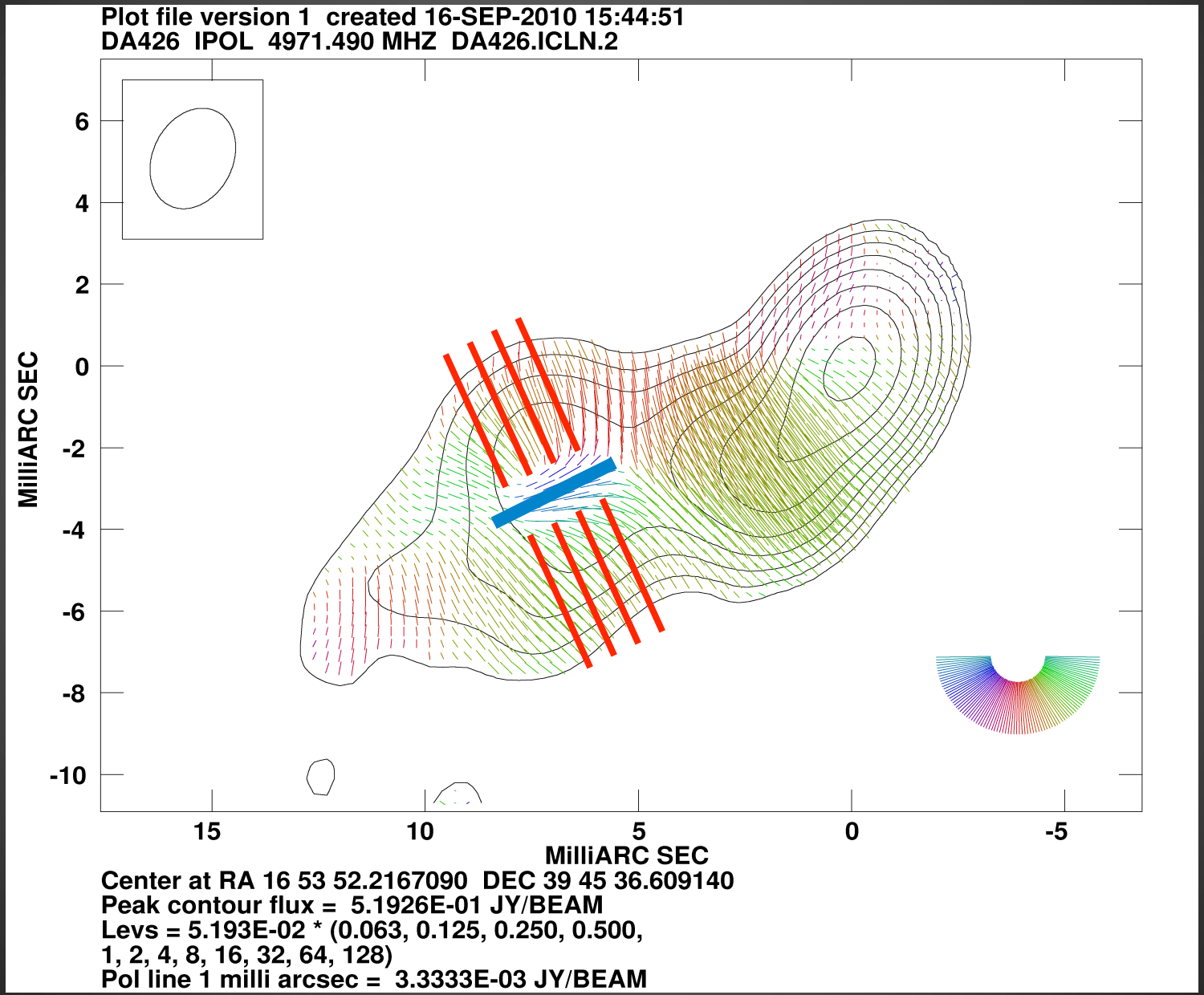
Pushkarev et al. (2005)

Evidence for Helical Magnetic Fields



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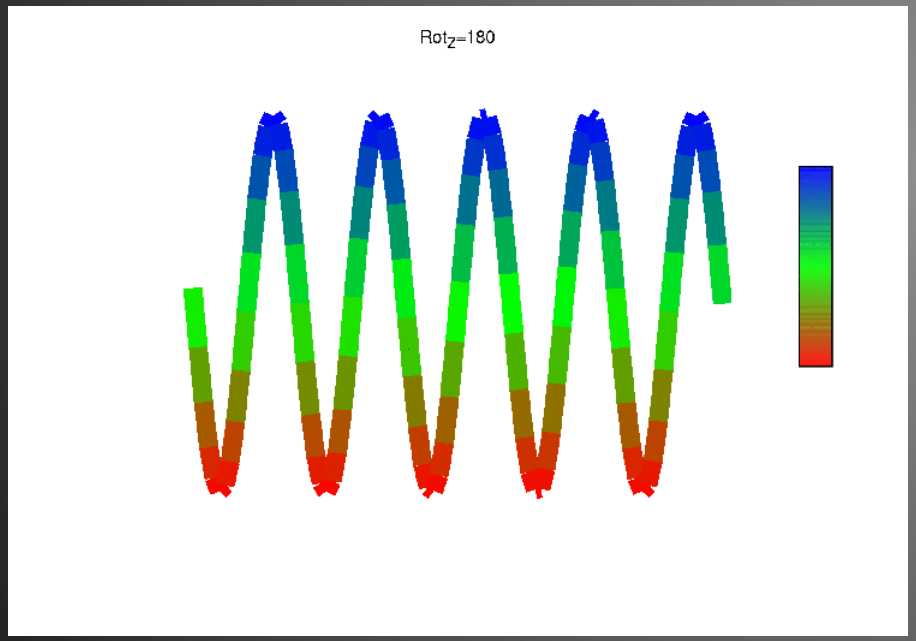
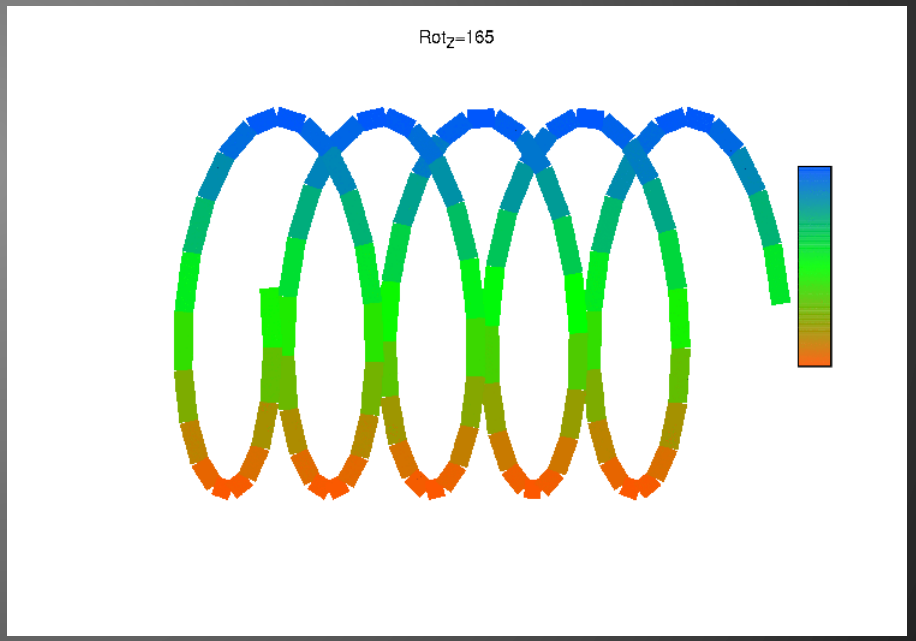
Helical Magnetic Fields Models

In the simplest case, a helical field model can be described using 2 parameters:

- The line of sight (viewing) angle delta (δ)

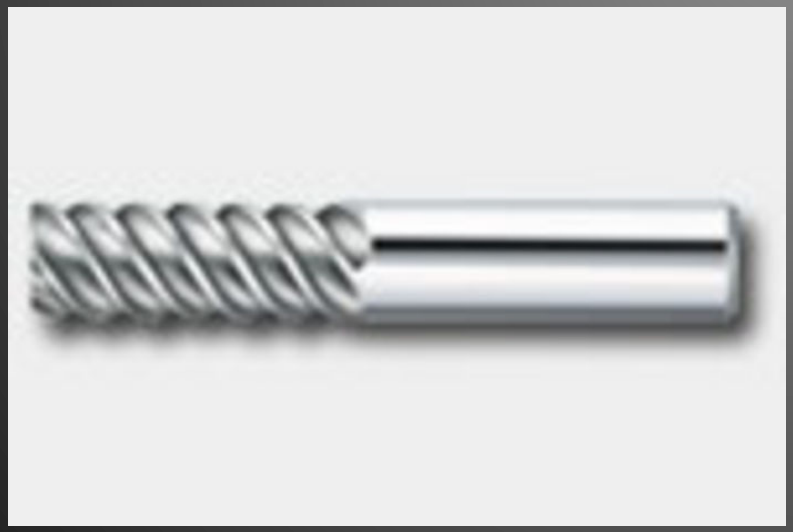




Helical Magnetic Fields Models

- The pitch angle (γ) of the helix threading the jet

Pitch Angle (γ) = 45



Pitch Angle (γ) = 60

Helical Magnetic Fields Model

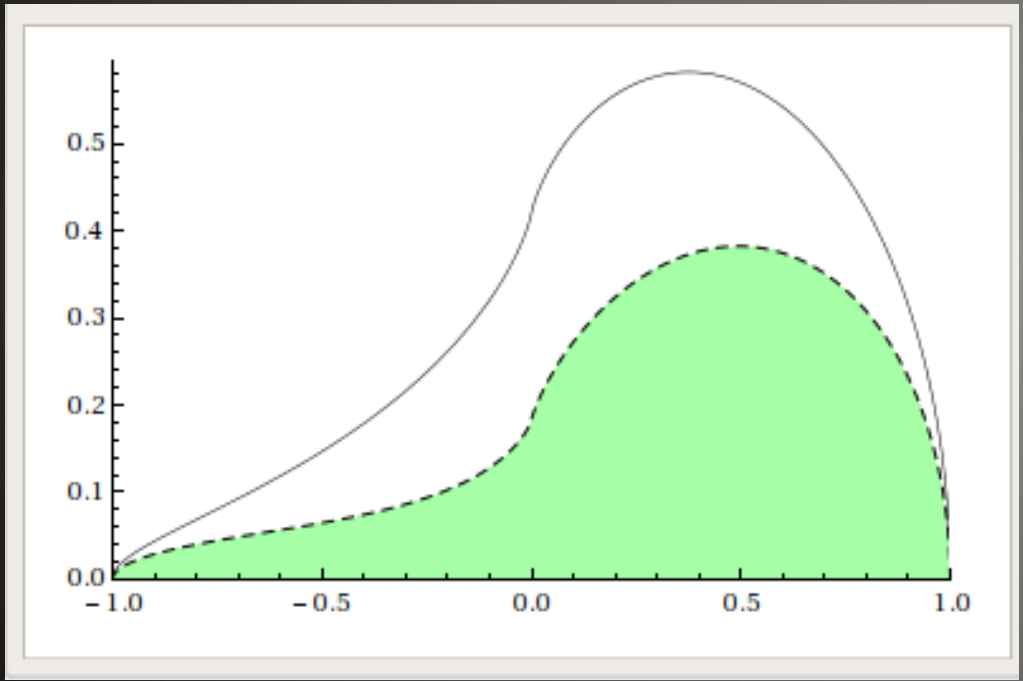
This model I am using to generate theoretical transverse profiles was first determined by R.A Laing (1981) and further developed by Andreas Papageorgiou (2005).

- Jet is modelled as a cylinder of radius 1.
- Magnetic Field is confined to thin shell at edges of this cylinder.
- A constant pitch angle is assumed throughout the jet.
- Spectral index of 1 is assumed throughout the jet.

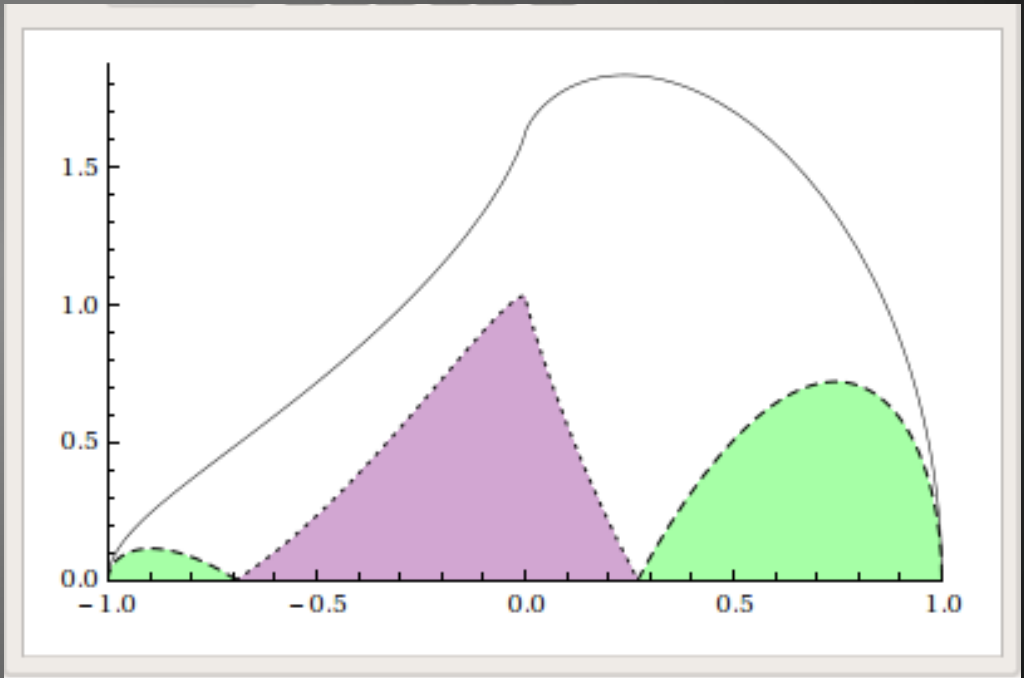
Helical Magnetic Field Model Profiles

Using this model transverse profiles (slices) can be generated.

Green :Longitudinal Magnetic Field Purple: Transverse Magnetic Field



Pitch Angle (γ) = 10
Viewing Angle (δ) = 20



Pitch Angle (γ) = 60
Viewing Angle (δ) = 30

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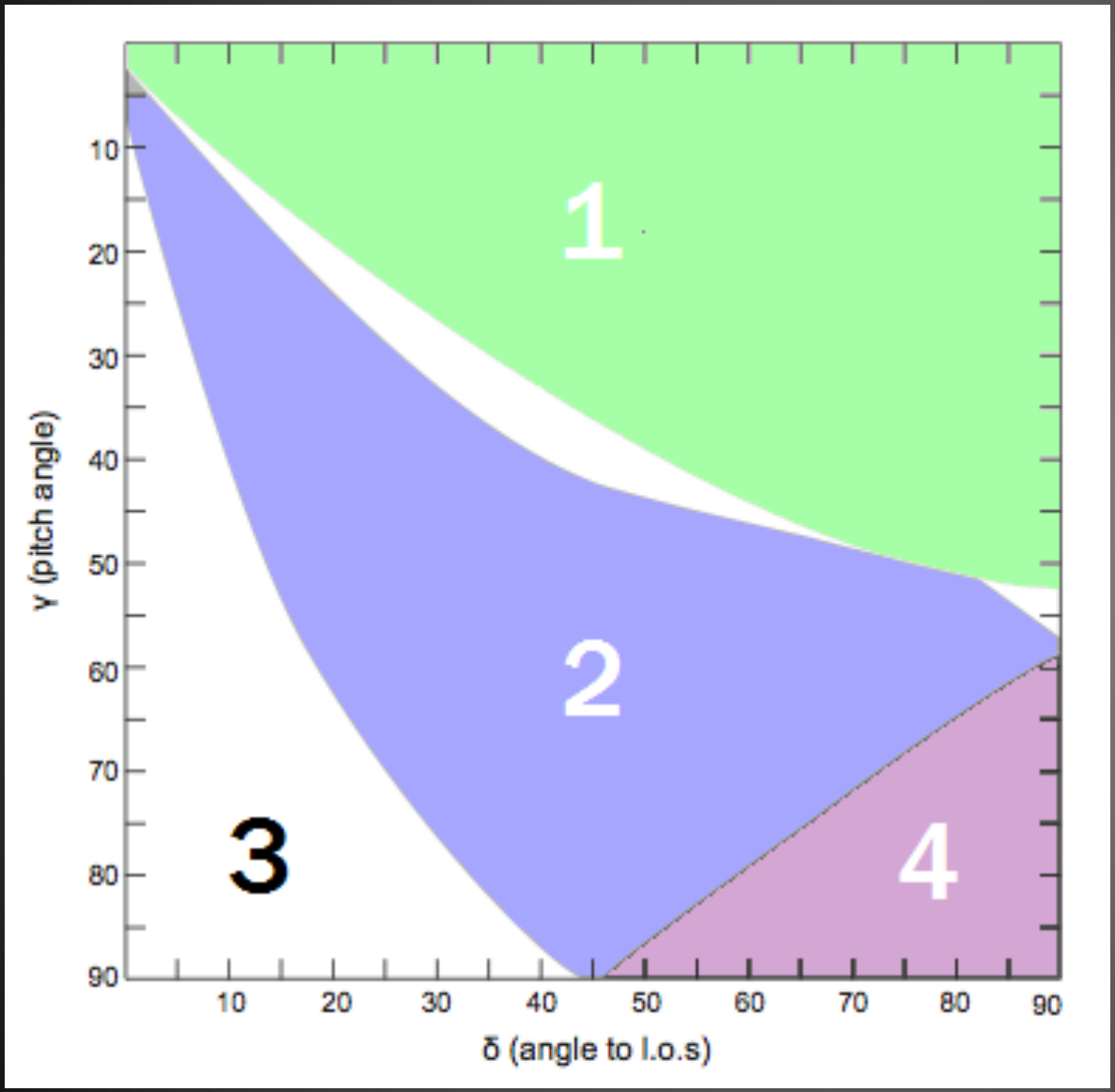
Helical Magnetic Field Model Profiles



1. Longitudinal all across the jet.
2. Longitudinal on one side and Transverse on the other side.
3. Longitudinal at the edges and Transverse at the centre.
4. Transverse all across.

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Degree of Entanglement

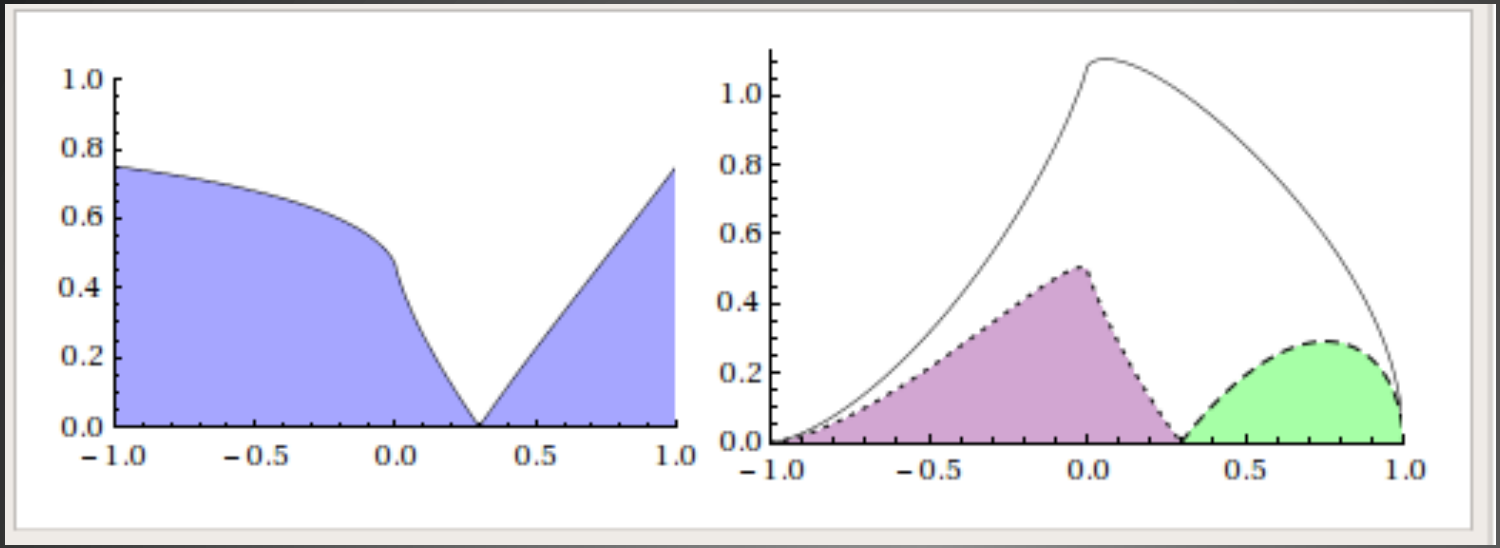
Comparisons between this model and observations showed that the model produced a much higher percentage polarization than was observed.

In order to reduce the percentage polarization of the model a third parameter is introduced, the degree of entanglement, f.

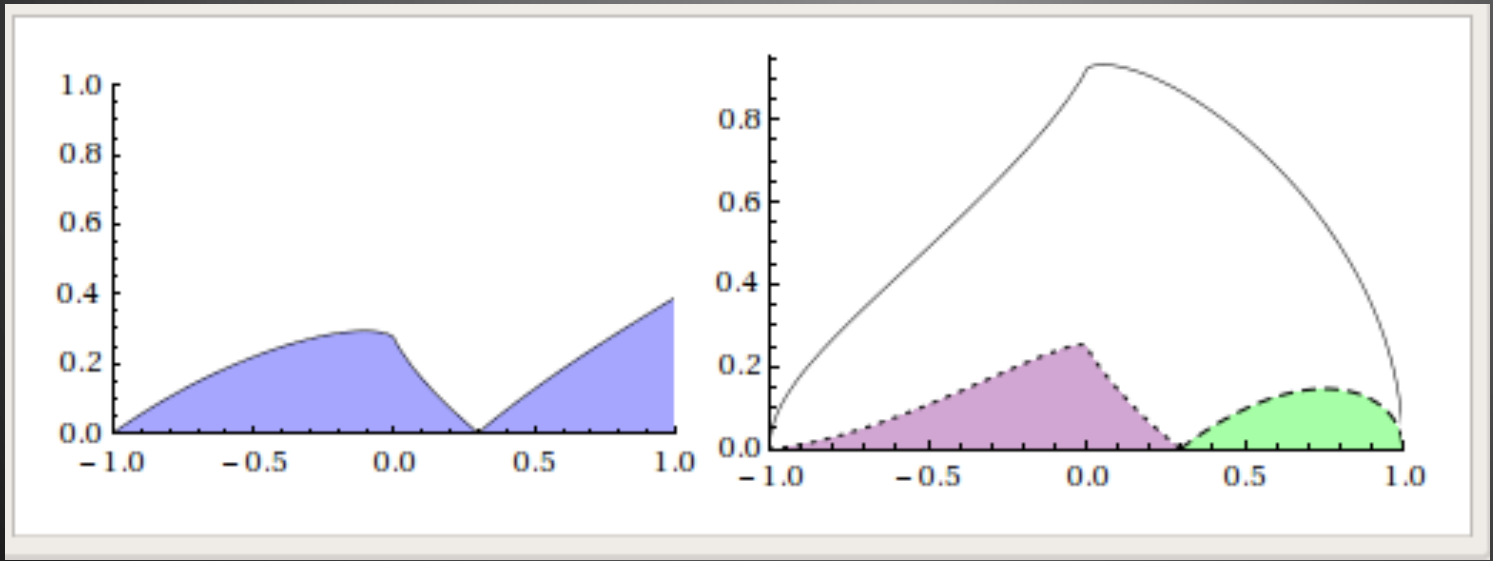
$$f = \frac{\langle B_T{}^2 \rangle}{\langle B_H{}^2 \rangle + \langle B_T{}^2 \rangle}$$

Increasing f also decreases asymmetries in the model profiles.

Degree of Entanglement



f = 0



f = 0.5

Method of Comparison

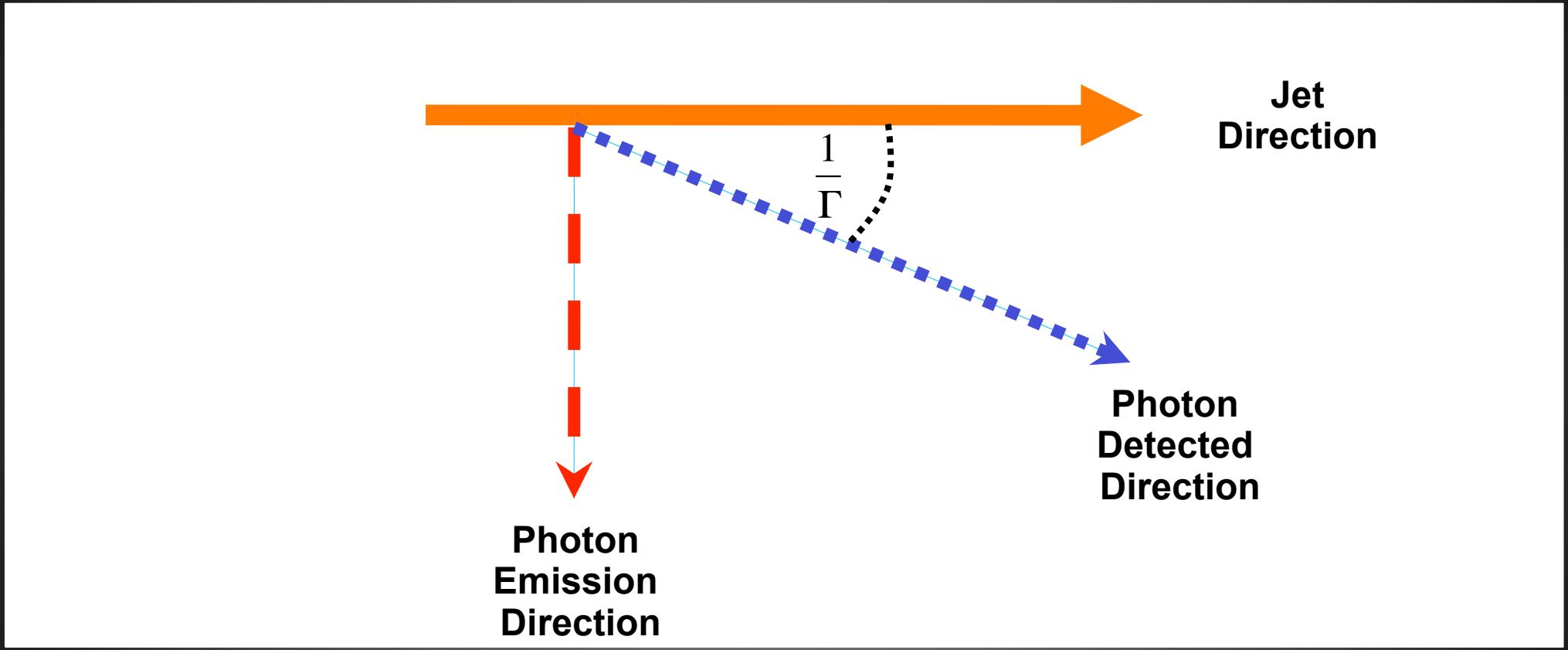
Comparisons are made by comparing observed profiles to a database of profiles generated using the model.

In order to compare the observed profiles to the model profiles the model profiles are scaled such that the maximum Total Intensity is equal for both profiles.

Not only does this method allow one to quickly compare multiple profiles for a source but it provides an objective way to fit profiles

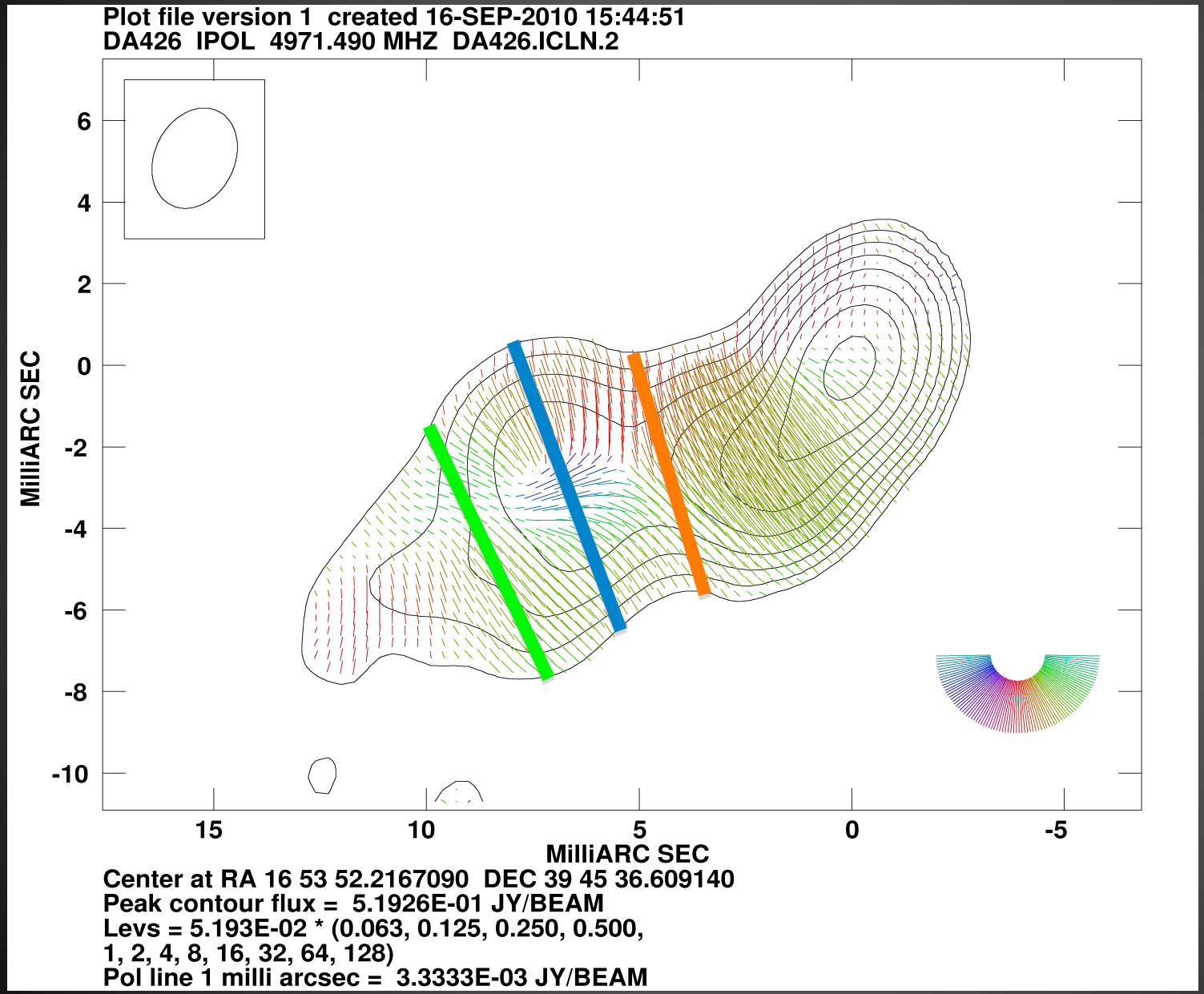
Both the determined Pitch angle and the Viewing angle are in the rest frame of the jet.

Method of Comparison



Both the determined Pitch angle and the Viewing angle are in the rest frame of the jet.

Markarian 501



Slice 1

Slice 2

Slice 3

6cm VLBA image
February 1997

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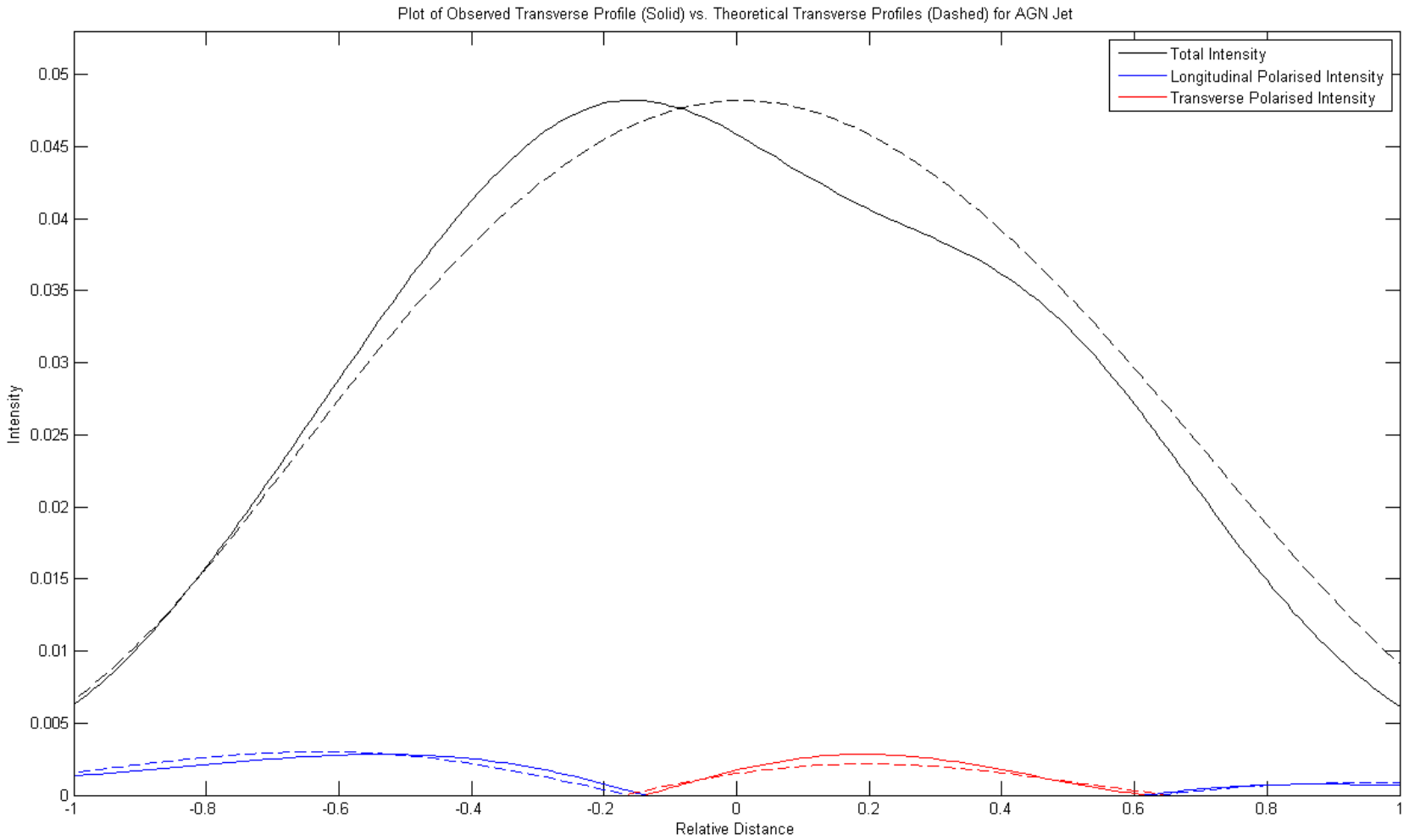
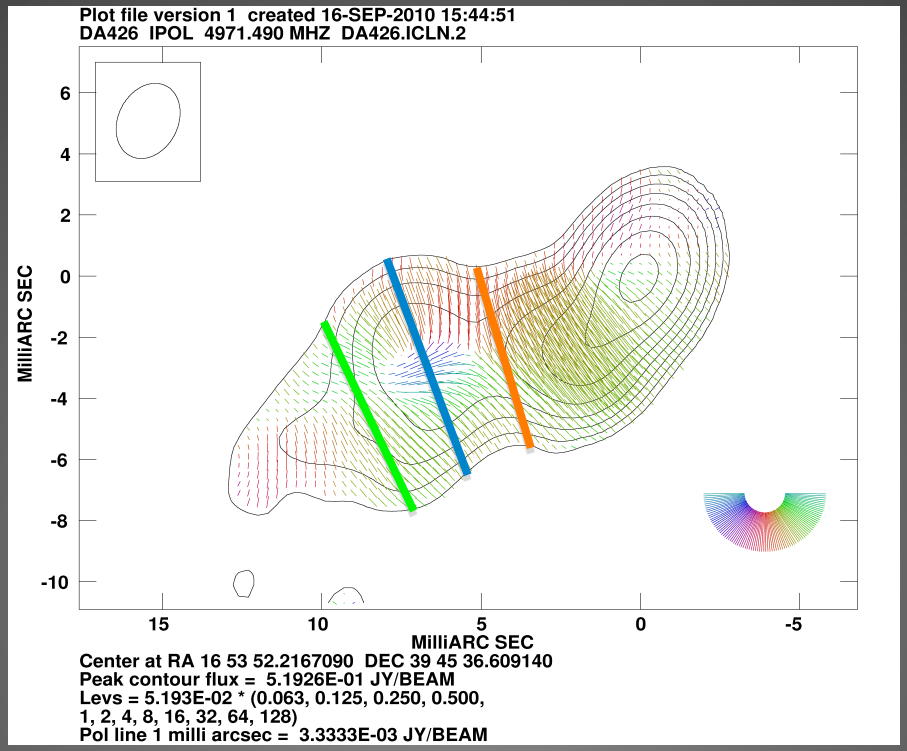
Slice 2



Slice	γ	δ	f
Slice 2	53 Degrees	80 Degrees	.4

Markarian 501



Slice	Pitch Angle	Viewing Angle	Entanglement
Slice 1	49 Degrees	78 Degrees	.4
Slice 2	53 Degrees	80 Degrees	.4
Slice 3	58 Degrees	78 Degrees	.8

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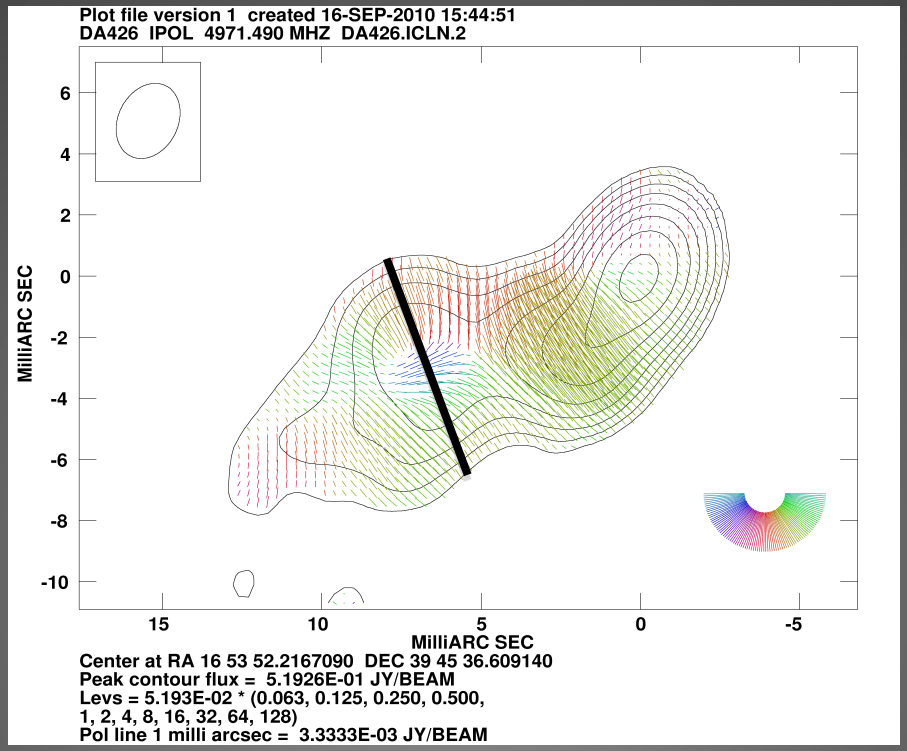
Markarian 501



Slice	Pitch Angle	Viewing Angle	Entanglement	Epoch
4 cm	53	83	.4	February 1997
6 cm	53	80	.4	February 1997
13 cm	54	87	.3	May 1998
18 cm	53	86	.45	May 1988

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Conclusions

Many sources demonstrate polarization structure in their jets that can be described using a simple Helical Magnetic Field model.

Comparing observed transverse profiles to theoretical profiles can provide information on the viewing angle and helical pitch angle of the magnetic field threading the jet.

Derived parameters for Mrk501 are consistent, both for multiple slices across 6cm jet and for slices in the same region of the jet observed at 4cm, 6cm, 13cm and 18 cm (at two different epochs)

Tentative evidence that pitch angle and degree of entanglement increases with distance from the core.

Future Work

Apply this method to different sources.

Devise a way of ensuring the profiles are close to perpendicular to the local jet direction.

Improve the model!

Continue work on modeling the expected Faraday Rotation Measure gradients resulting from this model.

Any Questions?