Investigating the Effects of Finite Resolution

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1. Introduction

Both the emission properties and evolution of Active Galactic Nuclei (AGN) radio jets are dependent on the magnetic fields that thread them. Faraday Rotation gradients are a very important way of investigating these magnetic fields, and can provide information on the orientation and structure of the magnetic field in the immediate vicinity of the jet; for example, a toroidal or helical field component should give rise to a systematic gradient in the observed Faraday rotation across the jet, as well as characteristic intensity and polarization profiles.

However, real observed radio images have finite resolution, usually expressed via convolution with a Gaussian beam whose size corresponds to the central lobe of the point source response function. This will tend to blur transverse structure in the jet profile, raising the question of how well a jet must be resolved in the transverse direction in order to reliably detect transverse structure.

We present the results of simulated intensity, polarization and Faraday rotation images designed to directly investigate the effect of finite resolution on observed transverse jet structures.

2. Rotation Measure Map

3. Effects of Finite Resolution on Faraday Rotation Measure Gradients

Faraday Rotation occurs when an electromagnetic wave propagates through a charged plasma threaded by a Magnetic Field. Faraday Rotation rotates the angle of polarization, χ of an electromagnetic wave following the equation

$$\chi = \chi_0 + RM\lambda^2$$

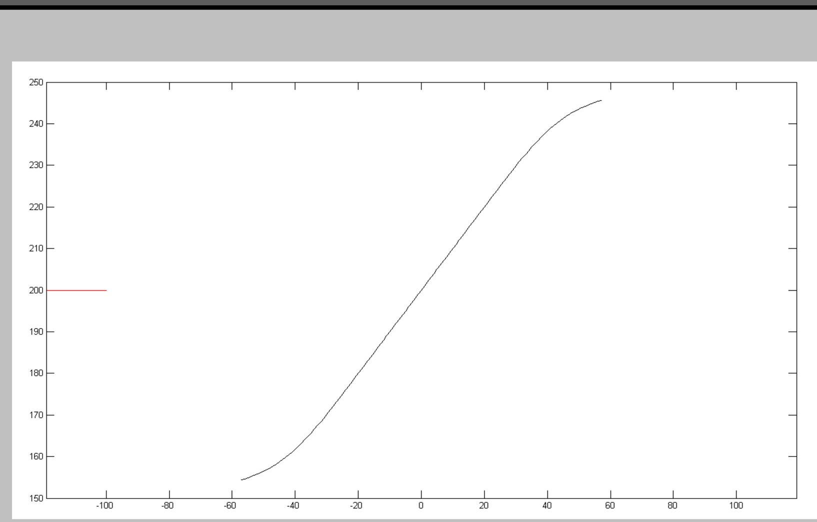
Due to the λ^2 dependence Faraday Rotation is only really observed at radio wavelengths. The rotation measure is given by

$$RM = \frac{e^3}{8\pi\varepsilon_0 m_e^2 c^3} \int n_e B \bullet dl$$

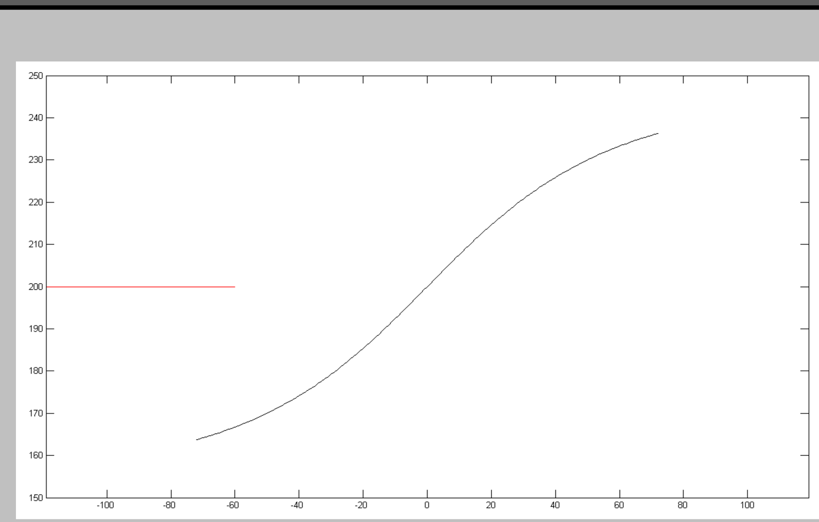
As B • dl changes across a Helical Magnetic Field we would expect the Rotation Measure to change if a Helical Magnetic Field thread the jet.

In order to observe the effects of finite resolution on the Rotation Measure Gradients an infinite resolution rotation measure gradient was applied to an infinite resolution jet at 4 different frequencies. This jet was then convolved with different Gaussian beams and the rotation measure gradient of the then finite resolution jet was determined. The infinite resolution gradient applied to the jet ranged from 150 to 250 and had a slope of 1.

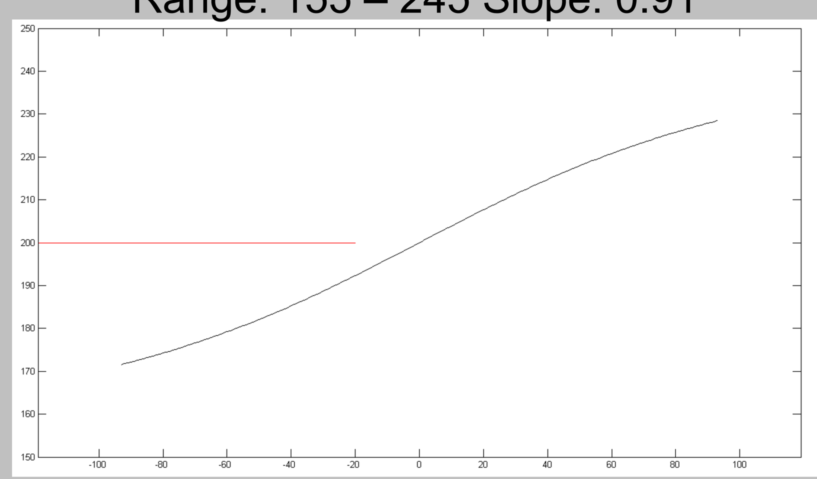
The finite resolution Rotation Measure Gradients for 4 different beam sizes are shown on the right. While increasing the gaussian beam size has a significant effect on both the slope and the range the gradient is still visible even with very large beams.



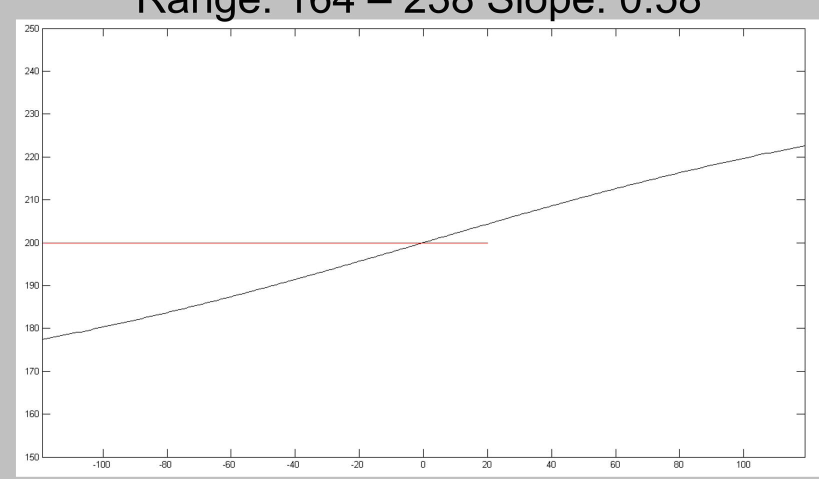
FWHM of Beam = 0.2 Intrinsic Jet Width
Range: 155 – 245 Slope: 0.91



FWHM of Beam = 0.6 Intrinsic Jet Width
Range: 164 – 238 Slope: 0.58



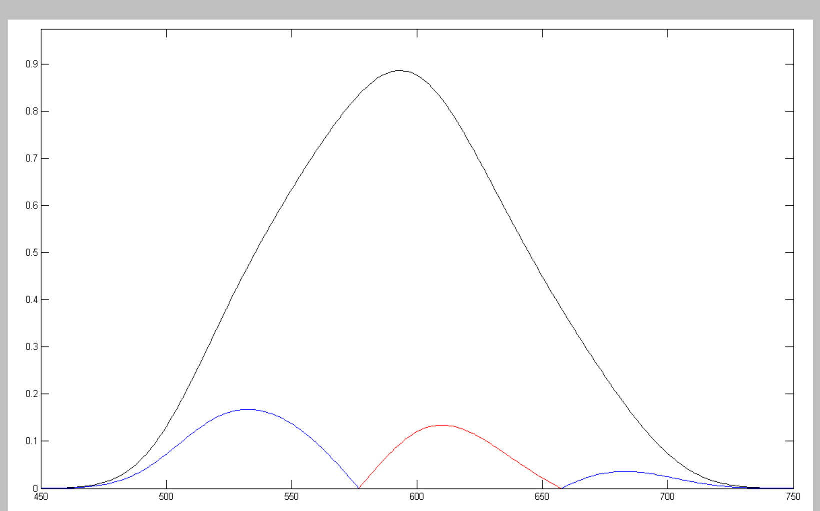
FWHM of Beam = 1.0 Intrinsic Jet Width
Range: 172 – 227 Slope: 0.33



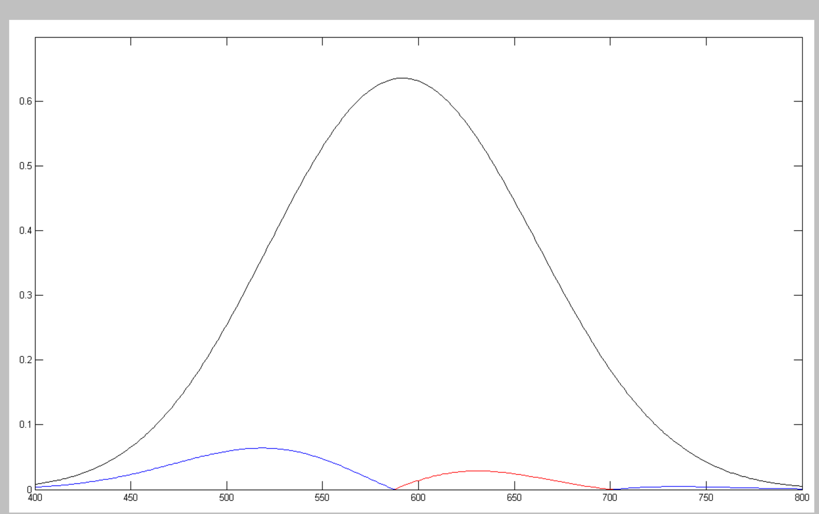
FWHM of Beam = 1.4 Intrinsic Jet Width
Range: 178 – 223 Slope: 0.20

4. Effects of Finite Resolution on Transverse Intensity and Polarization Profiles

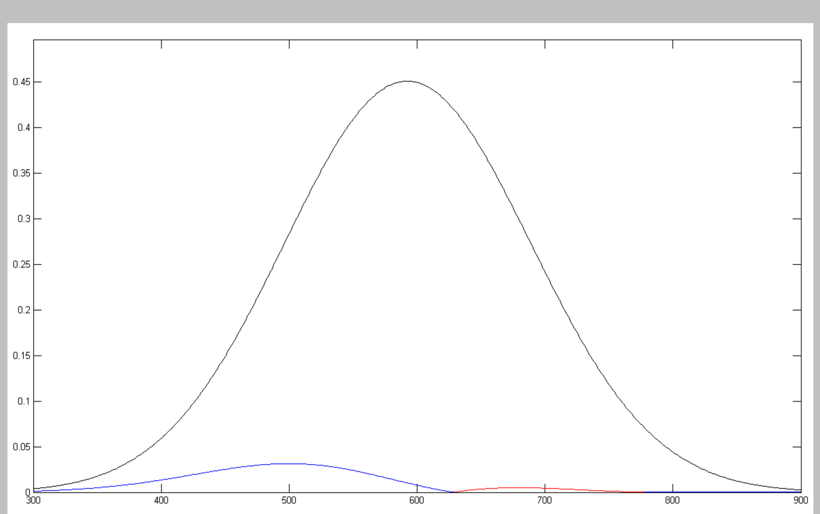
Black: Total Intensity
Red: Transverse Magnetic Field **Blue: Longitudinal Magnetic Field**



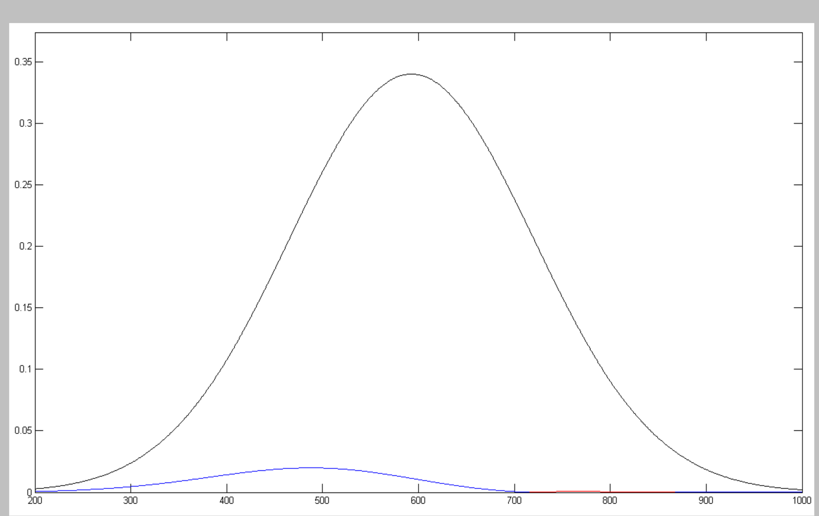
FWHM of Beam = 0.2 Intrinsic Jet Width



FWHM of Beam = 0.6 Intrinsic Jet Width



FWHM of Beam = 1.0 Intrinsic Jet Width



FWHM of Beam = 1.4 Intrinsic Jet Width

If a helical magnetic field threads the jet of an AGN then there are 2 observations we expect to observe

- Asymmetric Total Intensity and Polarized Intensity Profiles in which the position of maximum total intensity isn't aligned with the position on maximum polarized intensity.
- Magnetic field angle orientation changing from longitudinal to transverse within a given jet profile.

In order to observe the effects of finite resolution on transverse jet profiles infinite resolution intensity and polarization maps where generated using a simple helical jet model and then convolved with larger and larger beams.

The model we have used consists of a helical B field of constant pitch angle and uniform flux density threading a cylindrical jet. This model geometry was first proposed by Laing [2] and further investigated by Papageorgiou [3]. This model predicts the total and polarized intensity distributions across a jet as functions of the helical pitch angle γ and viewing angle δ.

Transverse profiles for Total Intensity and Polarized Intensity for 4 different gaussian beam sizes are shown on the left. Convolution with a gaussian beam rapidly reduces the asymmetry in jet profiles while reducing the asymmetry expected in polarization configurations less rapidly. Convolution can also drastically change the expected magnetic field orientations across a profile.

However, even after convolution with a very large beam, the position of maximum intensity and maximum polarized intensity are still very misaligned.

5. Conclusions

Convolution with a Gaussian beam rapidly reduces the asymmetry in jet profiles while reducing the asymmetry expected in polarization configurations less rapidly. Convolution has little effect on the visibility of Rotation Measure Gradients. However convolution can significantly change the observed values of a Rotation Measure Gradient. Asymmetric Polarization and Rotation Measure Gradients remain visible with beams significantly larger than the width of the jet.

6. References

[1] RM Map Reference

[2] Laing R. A., 1981, ApJ, 248, 87

[3] Papageorgiou A, 2005, PhD. Thesis

Understanding Relativistic Jets, Kraków, Poland. 23rd – 26th May 2011

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