CALCULATIONS OF THE LINEAR POLARIZATION OF INHOMOGENEOUS RELATIVISTIC JETS

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ABSTRACT. We have performed exact numerical calculations of the Stokes parameters I, Q, and U for optically and Faraday thick inhomogeneous relativistic jets. We consider how changes in Faraday depth, as well as in the observer-jet geometry, change the resolved and unresolved properties of the jet.

1. INTRODUCTION

The standard model for relativistic jets in compact radio sources (Blandford and Königl 1979; Königl 1981) portrays jets as being conical regions of small semi-angle carrying a convected magnetic field in a strongly relativistic bulk flow of synchrotron emitting particles. The direction of motion makes a small angle to the line of sight.

We have generalized their model to include *radial* bulk motion (rather than motion strictly *parallel* to the jet axis) and internal Faraday rotation. The effect of the former is to give different Doppler factors for different parts of the jet. The Faraday rotation partially depolarizes the jet, as suggested by recent observations of very low degrees of polarization in some cores (Wardle *et al.* 1986). We also calculate lines of sight making small angles to the jet axis, and even those which lie inside of the jet cone itself (this may be necessary to explain observations of BL Lac objects). We are also able to treat arbitrary magnetic field models, and velocity gradients between the axis and boundary of the jet.

2. RESULTS

In the present calculations we assume $B(r) \sim r^{-2}$, $K(r) \sim r^{-2}$, $N(\gamma_e) \sim \gamma_e^{-2}$, and $\gamma_j = 5$ (in the notation of Königl 1981). For simplicity we take the magnetic field to be everywhere parallel to the bulk velocity.

Figure 1 shows the behavior of the integrated fractional polarization, m, as a function of the observer inclination angle θ. The jets here are *Faraday thin.* The three curves correspond (from top to bottom) to jet semi-angles ϕ of 2°, 5°, and 8° respectively. Note that the polarization in all three cases is largely independent of inclination angle when the observer is *outside* of the jet, but strongly dependent on inclination angle when the observer is *inside* the jet. This is just due to the projection onto the sky of the radial field lines.

Figure 2 shows the integrated fractional polarization, m, as a function of the Faraday depth ξ_1 at the $\tau = 1$ surface for the case $\phi = 3°$ and $\theta = 10°$. This was generated simply by varying the lower energy bound of the relativistic electron spectrum (Jones and O'Dell

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1977). The end points on the curve correspond to $\gamma_{e,lower}$ of 100 and 10 respectively. Even in the Faraday thick case the *integrated* polarization is still almost 12%. To Faraday depolarize a jet which would otherwise be highly polarized thus requires an *extremely* small value of $\gamma_{e,lower}$ (or an extremely high density of thermal electrons). This is because the jets always become Faraday thin downstream.

Figure 3 shows how the separation (here called $\Delta_{I,P}$) of the peaks of the I and P strip distributions (normalized by the distance of the $\tau = 1$ surface from the apex) varies as a function of the Faraday depth at the $\tau = 1$ surface. At low Faraday depths $\Delta_{I,P}$ is constant at about 0.3, but it rises sharply as the inner parts of the jet are depolarized. Depending on the jet geometry and model, this may provide a new observational means of putting bounds on the Faraday depth of a source.

Figure 1.

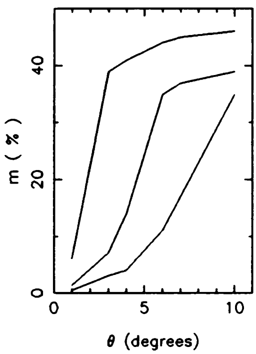


Figure 2.

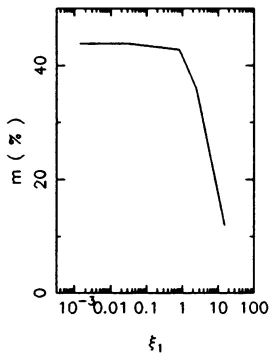
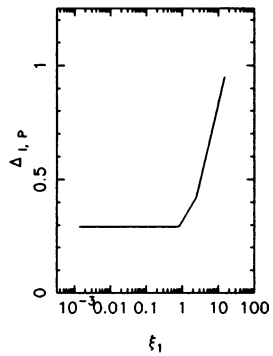


Figure 3.



3. DISCUSSION

We wish to emphasize the preliminary nature of these results. We have just begun to investigate the enormous variety of models with which our code is capable of dealing. Nevertheless, we show that polarization observations can give useful constraints on the jet-observer geometry as well as on Faraday depth. In particular, internal Faraday rotation is not very efficient at depolarizing these jets because they always become Faraday thin further downstream.

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