INVESTIGATIONS OF 3C345

J. A. Biretta
Harvard - Smithsonian Center for Astrophysics

M. H. Cohen
California Institute of Technology

The well known superluminal source 3C345 is associated with a 16th magnitude quasar at z=0.595. The optical continuum is highly polarized and shows violent variations. At x-ray frequencies it is a weak source; while at radio frequencies it is bright and variable. The radio structure consists of a 200 kpc halo, a 20 kpc jet, and a very bright pc scale region which shows superluminal motion. Recent MkII VLBI monitoring (Biretta, Moore, Cohen 1986) at 2, 5, 11, and 22 GHz has provided accurate spectra, sizes, expansion rates, velocities, and trajectories for the superluminal knots and the "core." Here we consider physical conditions in the emission regions and models for the kinematics.

To derive physical conditions in the emission regions, and properties of the jet, we apply a synchrotron self-Compton model to observations. We assume the radio emission is incoherent synchrotron emission, and that inverse Compton scattering will produce x-rays. The "core" component is modeled as an inhomogeneous conical jet (Königl 1981) with magnetic fields and relativistic electron densities varying smoothly as $B(r) = B(r_o)\, r^{-m}$ and $N(E,r) = KE^{-p} r^{-n}$, where r is the distance along the jet. The superluminal knots are modeled as homogeneous spheres with a uniform electron density and (well tangled) magnetic field. For the "core" we assume the conical pattern is fixed relative to the "central engine" and the fluid moves with a Lorentz factor γ; for the knots we assume both the spherical pattern and fluid move with γ (Lind and Blandford 1985). The model is constrained by the radio spectra and component sizes, and by the total x-ray flux.

Results of the model can be summarized as follows. Each of the emission regions must have a relativistic Doppler shift factor δ significantly greater than unity, or the model x-ray flux will exceed the observed x-ray flux. The "core" has the largest limit $\delta \gtrsim 10$ and knot C3 has the smallest $\delta \gtrsim 3$. This is evidence for relativistic motion in the source, and is independent of the observed superluminal motions. The magnetic fields can be estimated from the turnover in the synchrotron spectrum for knots C4, C3, and C2, and we find that the magnetic field falls off as $B \propto r^{-1.0\pm0.5}$ along the jet. For the "core" component we cannot derive the magnetic field and particle density functions independently. However, if

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we assume the number of relativistic particles is conserved along the jet ($n = 2$) we then find $m = 1$ ($B \propto r^{-1}$) in the "core" as well. The pressures in the knots appear to exceed the external (narrow line region) pressures, unless the Doppler shift factor $\delta \sim 15$, which is much larger than the minimum values. Also, the particle energy densities exceed those of the magnetic field, unless $\delta \gtrsim 15$. This model predicts that the position of the "core" will shift with frequency. At any given frequency the "core" will be brightest at the optical depth $\tau \sim 1$ point; at high frequencies this point occurs near the apex of the jet (near the central engine), whereas at low frequencies it occurs farther from the apex. While we do not have absolute positions for the "core," we can measure its position relative to the knots. For example, the model predicts that "core" will be 0.27mas farther from the knots at 5 GHz than at 11 GHz, and in fact we observe that knot C3 is 0.30 ± 0.04mas farther from the "core" at 5 GHz than at 11 GHz. This and a similar agreement found between 22 and 11 GHz lends support to this model.

The superluminal knots in 3C345 display interesting kinematics which have not yet been seen in other sources. Knot C4 was observed to change position angle from −135° to −87° relative to the "core" as it moved 0.3 to 0.8 mas away from the "core." Components C3, C2, C1, and the 3" jet continue the northward curvature, and are at position angle −86°, −74°, −64°, and −31°, respectively. Component C4 accelerates from v/c=1.3 to 6.5 as it moves away from the "core," while knots C3 and C2 have v/c = 6.0 and 9.5, respectively.

Precession of the central engine (Begelman, Blandford, and Rees 1980) has been proposed to explain the curvature seen in mas scale jets, but this mechanism fails in 3C345 since it cannot explain the changing position angle and acceleration of C4. Furthermore, the required rapid precession would be difficult to obtain (Biretta, *et al.* 1985). The kinematics can instead be explained as a bending or twisting of the jet by an external medium. If the jet has a non-relativistic equation of state, its bulk velocity will remain approximately constant as it move through the external medium. The observed kinematics could then be explained by a $\gamma \sim 10$ jet which is initially aligned at an angle $\theta \lesssim 1/2°$ to the line of sight, and then bends away from the line of sight to $\theta \sim 4°$. The bending might result from a large pressure gradient in the external medium, or from a Kelvin-Helmholtz instability (Hardee, 1987). However, such a trajectory seems improbable since the initial θ is so small. A larger initial θ is possible if the jet has a relativistic equation of state. Such a jet would probably consist of electrons and positrons, and would accelerate as the external pressure decreased (Smith and Norman 1981). A possible trajectory might have $\gamma \sim 5$ and $\theta \sim 2°$ near the "core" and then accelerate to $\gamma \sim 10$ with $\theta \sim 4°$. This has the advantage that the initial θ need not be very small, and the jet can be bent by smaller pressure gradients. Further study of hydrodynamic acceleration in relativistic jets is needed.

References

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