Fine Structure in the Jets of 3C 219

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Abstract

VLA observations at 2 and 3.6 cm of the "partial" jet and counterjet in 3C219 at resolutions of 0.18 to 0.4 arcseconds have revealed fine structure with important implications for jet models. Both jets abruptly end at bright, compact features, dropping from the maximum to zero intensity in less than 100 pc. There is no evidence of bow shocks in advance of either jet. The jet tips are of similar size and brightness, and are aligned with the core with a bend angle of less than 0.2 degrees. Sinusoidal (and thus possibly helical) oscillations in the ridge lines of both jets are found, with inverted symmetry. The jet edges are remarkably linear, despite internal variations in structure, and are limb-brightened. There is evidence for a previously unknown nuclear jet of length $\sim$ 2 kpc, pointed towards the main (SW) jet. The 2cm-3.6cm spectral index of the main jet is very high, exceeding 1.0 in most places.

1. Introduction

3C219 is a moderately luminous ($P_{1.4} = 3 \times 10^{26}$ W Hz^{-1}) FRII radio galaxy with a bright jet that extends for 18 arcsec to the SW from the nucleus, and a fainter counter-jet that extends to about 5 arc sec from the nucleus to the NW. The jet is of particular interest because it disappears abruptly despite the presence of a bright hotspot some 60 arcseconds from the nucleus which presumably signifies a continuation of an active jet somewhere beyond the apparent point of disappearance. Clarke *et al.* (*Ap.J.*, **385**, 173, 1992) proposed two models to explain the observed structure of 3C219:

(a) Symmetric, relativistic, restarting jets, with the brightness asymmetry of the jets being due to Doppler favoritism and the length asymmetry being being due to the difference in light travel time to the observer from the approaching jet and receding counter-jet. In this model, outward-moving shocks at the leading edges of

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the jets decelerate them and make the counter-jet tip visible by reducing a previously unfavorable Doppler factor.

(b) A continuous, two sided jet, whose emissivity is enhanced close to the galaxy through lateral compression from X-shocks caused by the adjustment of the supersonic flow to the declining external pressure gradient. The emission is quenched when the jet comes into pressure equilibrium with the atmosphere. In this model, the brightness asymmetry is ascribed to a side-to-side aysmmetry in the pitch angle of the magnetic field (higher pitch angle in the counter-jet) and the geometrical asymmetry is random.

Both models can account for some aspects of the large scale structure, but both contain *ad hoc* assumptions. The sensitive high resolution observations reported here were made in an attempt to discriminate further between the models.

Two eight-hour sessions with the VLA were used to observe 3C219 at 3.6 and 2cm in the **A**-configuration in Sept. 1991. The image shown in Fig. 1 reveals the following new features: (1) The emission drops from the maximum of 12 mJy/sq. arcsec to zero within 100 pc of each jet tip. A wider-field image shows there is no compact emission anywhere between the jet tips and the hotspots. (2) The tips of the jet and counter-jet are remarkably similar to each other in size and brightness. (3) A line drawn from the jet tip through the nucleus passes through the counter-jet tip within 0.05 arcseconds, so the maximum bend angle is 0.2 degrees. (4) Sinusoidal structures are present in both jets, with inverted symmetry. (5) The edges of the main jet are linear, despite variations in its substructure, and are limb brightened in many places. In addition, a core-subtracted image reveals a 2 kpc nuclear jet which is aligned with the main jet and which points toward it. (The tip of this inner jet is just visible in Figure 1.) Comparison of 0.4 arcsecond images shows that the 3.6 to 2cm spectral index of the SW jet exceeds 1.0 in most places, while the jet tips have spectral indices of 0.5 to 0.7.

2. Discussion

The abrupt ends and bright tips of the jet and counter-jet pose a strong challenge to the continuous flow/field-compression model, which cannot readily reproduce such rapid quenching of the emissivity. In contrast, the rapid drop in emissivity and the similarity in structure and brightness of the tips of the jet and counter-jet are predicted by the restarting jet model, as is the inverted symmetry of the internal structures. Does this mean the restarting jet model is favored, and the continuous flow/field decompression model is now to be rejected? Not necessarily.

A supersonic restarting jet propagating through the lobes of a radio source must drive ahead of it a bow shock which travels in a radio-emitting plasma and so must significantly enhance the radio emissivity of the lobe medium. No traces of such bow-shock