Relativistic Beaming and the Nuclei of Double-lobed Radio Quasars

D. H. Hough
Jet Propulsion Laboratory, 238-700, Pasadena, CA 91109

A. C. S. Readhead
California Institute of Technology, 105-24
Pasadena, CA 91125

ABSTRACT

We have defined a complete sample of double-lobed 3CR quasars with minimal orientation bias. Properties of these objects on the >kpc scale are consistent with the simple beaming model for their nuclei. VLBI maps of six nuclei reveal "core-jet" structures. Both nuclei mapped at multiple epochs are modestly superluminal (3C245, 3.1c; 3C263, 1.3c; H_0=100 km/s/Mpc, q_0=0.5). The distribution of apparent velocities in this sample will provide a stringent test of beaming.

The simple relativistic beaming model (Scheuer and Readhead 1979; Blandford and Königl 1979) predicts a strong dependence of source properties on the orientation of the beam axis to the line of sight, θ. In order to test such physical theories, we require a sample for which the distribution in θ is known. Thus we have defined a complete, flux density-limited sample of 26 steep-spectrum, double-lobed 3CR quasars (taken from Laing, Riley, and Longair 1983), which should be randomly oriented. For details, see Hough (1986) and Hough and Readhead (1987).

The statistics of >kpc-scale properties of these quasars are consistent with the assumption of random orientations and simple beaming. We find anticorrelations of projected linear size L with both nuclear strength R (=ratio of nuclear to extended emission at 5 GHz, emitted) and outer lobe misalignment angle C; there is a correlation between R and C. Others have found similar correlations (e.g., Kapahi and Saikia 1982), which could also be explained by interactions with the surrounding medium. Even if there is some bias in θ by our selecting quasars, the sample clearly covers a considerable range in θ. Further, even if Doppler-boosting effects are small and these nuclei are intrinsically far weaker than dominant cores, we can study the dependence of v on intrinsic luminosity.

We have mapped the nuclei of six objects at 10.7 GHz using the Mark III system. The sources are 3C207, 3C212, 3C245, 3C249.1, 3C263, and

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3C334. Each object exhibits a double or extended structure, which may be interpreted as a "core-jet". The pc-scale jets are aligned with >kpc-scale, one-sided jets, and the small- and large-scale jets lie on the same side of the compact core.

Thus far, two nuclei have been mapped at multiple epochs. We find superluminal expansion in 3C245 (Hough and Readhead 1987) with an apparent velocity v=3.1c (z=1.029) and in 3C263 (Zensus, Hough, and Porcas 1987) with a smaller v=1.3c (z=0.656). Since 3C245 has relatively large R and small L, it may be aligned at smaller θ than 3C263, which has moderate R and large L. Given a difference in orientation, the different v's are consistent with simple beaming using a bulk Lorentz factor $\gamma \geq 3$.

Porcas (1981) has argued that, based on superluminal motion in 3C179, simple beaming requires a typical $\gamma \geq 5$ for the nuclei of double-lobed quasars, not $\gamma \leq 2$ (Scheuer and Readhead 1979). Our observations of 3C245 further support the case for $\gamma \geq 2$. The three objects in this class (3C179, 3C245, 3C263) have an average $v \sim 3$c. The beaming interpretation for superluminal sources in general is supported by the larger average $v \sim 5$c for nine of the better-studied strongly core-dominated objects (see references in Hough and Readhead 1987). However, Barthel *et al.* (1986) point out that some of the core-dominated superluminals have quite large deprojected linear sizes.

The most direct test of beaming is the measurement of the v distribution in these nuclei (e.g., Scheuer 1984), and at least 85% of our sample is within reach of current VLBI sensitivity.

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