SUPERLUMINAL MOTION IN WEAK QUASAR CORES

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ABSTRACT

The importance of studying the statistics of the occurrence of superluminal motion in an unbiased sample of radio sources is stressed, and methods for selecting such samples are reviewed. The weak radio cores of quasars exhibiting extended, double-lobed emission can be used for this purpose. Recent studies of the superluminal motion in the core of 3C 179, a quasar selected from such a sample, are described.

INTRODUCTION

The observation of apparent superluminal motion by VLBI in a number of strong, compact radio sources poses an intriguing problem for astronomers. While many explanations of the phenomenon have been proposed, the most popular ones invoke highly relativistic motion of the radio components, at a small angle to the observer's line of sight. In the relativistic jet model (Blandford and Königl, 1979; Scheuer and Readhead, 1979), this motion is in a collimated beam of energetic particles emanating from the central energy source, which energises the outer, extended radio-emitting regions. The ingredients of the model are the angle, θ, with respect to the line of sight, and the Lorentz factor, $\gamma(=(1-\beta)^{-1/2}$, $\beta = v/c$). To produce an observed faster-than-light velocity, $\beta' = v_{obs}/c$, then $\theta \simeq 1/\beta'$ and $\gamma \simeq \beta'$.

Whilst this mechanism explains many of the observed properties of the superluminal sources, it is obviously important to try and find independent evidence for the high values of γ and small values of θ. Marscher and Broderick (1981, 1982) have drawn attention to the (redshift-independent) evidence for high γs from the lack of inverse-Compton X-ray emission from some radio sources. Using this argument they suggested, and indeed found, superluminal motion in the quasar NRAO 140. If superluminal sources are really at small θ, one would expect i) the size of any outer structure to be smaller, on average, by a factor of sin θ (but see Schilizzi and de Bruyn, 1983), and

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ii) the superluminal effect in samples of sources with unbiased θ should be rare, about 1 in every γ^2 sources.

DEFINING AN UNBIASED SAMPLE

For the purpose of such statistical studies, it is clear that one cannot use a sample of quasars selected on the basis of the core flux density, because of the associated "Doppler Boosting" of the flux density when θ is small. Optically selected quasars could, in principle, provide a suitable sample free of orientation bias, but the radio emission from such quasars is typically very weak (e.g. Strittmatter et al., 1980; Kellermann et al., 1983) and is below the sensitivity of present VLBI. X-ray selected quasars are not suitable because if the X-ray emission is produced by the inverse Compton effect in the jet, it, too, will be Doppler Boosted. Selecting quasars on the basis of the flux density in their extended radio emission seems to be an ideal method. Firstly, for the case of double-lobed sources, Longair and Riley (1979) have

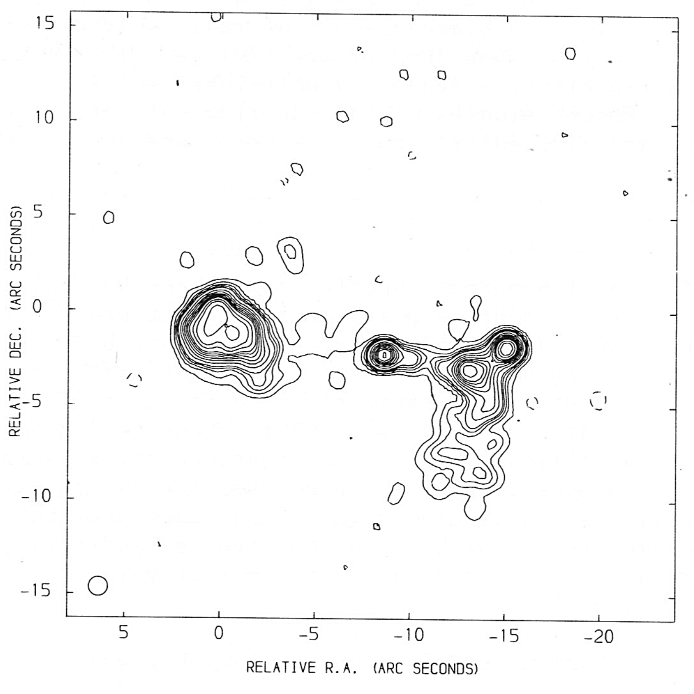

Figure 1: 408 MHz MERLIN map of the arc second scale structure of 3C 179, June, 1981. Restoring beam is 1.0 x 1.0 arcsec. Contour levels 2, 4, 6, 8, 10, 15, 20, 25, 30, 35, 40, 50, 60, 80 percent of the peak.

argued that the expansion speed of the lobes is low, because of the symmetric way they straddle the central object. Thus the lobe flux density cannot be boosted, and flux density limited samples of classical double quasars should have an unbiased distribution of θ. Secondly, nearly all such quasars have a detectable radio core, many in the range 50 - 300 mJy (Owen et al., 1978; Owen et al., 1982) and hence are observable by VLBI.

OBSERVATIONS OF 3C 179

We have undertaken VLBI observations of such a sample of quasars, selected from the Jodrell Bank 966 MHz survey. The selection criteria are described by Porcas (1981, 1982). Zensus and Porcas (this volume) report on first epoch Mark III observations of a number of the sources. One quasar from the sample, 3C 179 (Fig. 1), has been observed since 1979 at 10.7 GHz using Mark II VLBI, and superluminal motion was found from the first two observing epochs (Porcas, 1981). A number of subsequent observations have been made in order to confirm and to investigate further, the superluminal behaviour. Fig. 2 shows an "expansion graph" of the motion, and it is clear that the separation of the milli-arc-second components has continued to increase in a roughly linear fashion. Most of the values of the separation are derived from model-fitting to the

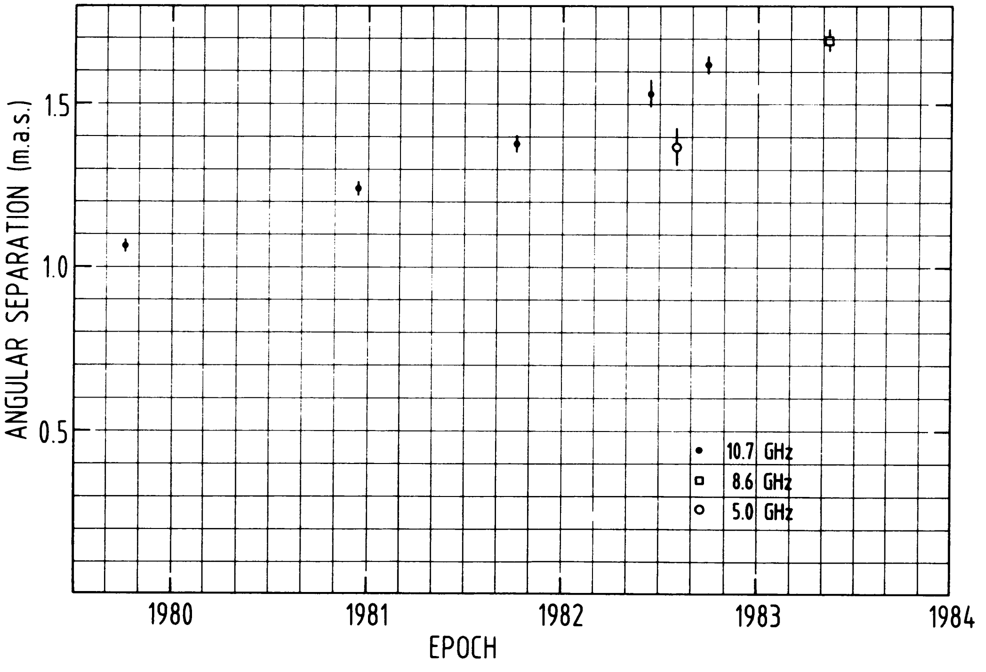

Figure 2: Expansion graph of the superluminal motion in the core of 3C 179.

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visibility functions, since the radio core is very weak, and, indeed, has decreased in flux density since 1980. However, it has been possible to make hybrid maps for two epochs: for December 1980 (when the 10.7 GHz flux density was at a maximum) and for May 1983, from 8.6 GHz data, obtained using a sensitive VLBI array consisting of the 100 m Effelsberg antenna and the two 64 m DSN dishes at Madrid and Goldstone (in collaboration with A. Rius). These maps are shown in Fig. 3, plotted on the same angular scale and with the same CLEAN restoring beams. At both epochs the

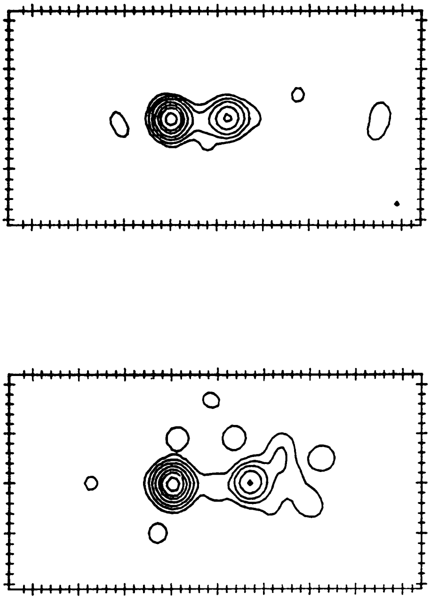

Figure 3: Hybrid maps of the core of 3C179 at December 1980 (10.7 GHz) and May 1983 (8.6 GHz). Restoring beam is 0.45 x 0.45 mas. Contour levels 2, 5, 10, 20, 35, 50, 80 percent of the peak. Tick interval is 0.2 mas.

source structure is dominated by two components, whose separation has changed from 1.24 mas to 1.70 mas over the 2.4 year interval. Taking $H_0 = 55$ km s^{-1} Mpc^{-1} and $q_0 = 0.05$, this corresponds to an apparent expansion velocity of 10 c.

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