PROPER MOTION OF COMPONENTS OF THE QUASAR 3C 345+

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ABSTRACT

From five sets of VLBI observations spaced between 1972 and 1981, we estimated the positions of components of the superluminal quasar 3C 345 relative to the position of the single component of the quasar NRAO 512. The relative proper motion of the easternmost component of 3C 345, believed to be the "core", was found to be 0.02±0.02 mas/yr. This result is consistent with the "core" being stationary and the "jet" components moving with respect to NRAO 512.

INTRODUCTION

The radio brightness distribution of the quasar 3C 345 (1641+399) has been reported to have several components of milliarcsecond size. Since 1971 several VLBI groups have measured increases in the separation between these components of up to 0.4 mas/yr (e.g., Wittels et al. 1976, Unwin et al. 1983). If the quasar lies near its redshift distance (z=0.595), some of these increases require apparent superluminal transverse motion of the components relative to each other. Our goal was to determine the motion of these components with respect to an external reference.

METHOD

The right ascension and declination of a radio source can now be determined via VLBI with an uncertainty of a few milliarcseconds (see, for example, Ma et al. 1981), likely too high to detect the proper motion of any component of 3C 345 within a few years. Much higher accuracy can be achieved in the determination of the relative position of two sources, if their separation on the sky is sufficiently small: most systematic errors tend to cancel and, further, the fringe phase can be used as the observable (see Shapiro et al. 1979). For two sources separated by, say, half a degree or less, one can interleave observations of them and determine the difference in their sky positions with an uncertainty below 1 milliarcsecond (mas). With present intercontinental VLBI arrays, to achieve a precision of ∿0.1 mas in the measurement of the relative position of two such sources, certain geodetic and astrometric parameters have to be known with sufficiently

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high accuracy. Approximate accuracies (within a factor 3) for such parameters are given in Table 1; for comparison we show the accuracies now obtainable from "geodetic" VLBI experiments.

TABLE 1
Required Accuracy of Astrometric and Geodetic Parameters to Determine Relative Positions to within 0.1 mas for Two Sources Separated by 0.5 deg on the Sky

Parameters	Required Accuracy (approximate)	Obtainable Accuracy (approximate)	References
1. Baseline lengths	10 cm	5 cm	Rogers *et al.* 1983
2. Position on sky of reference source	5 mas	5 mas	Ma *et al.* 1981
3. Earth orientation (equivalent length on surface)	50 cm	40 cm	Robertson *et al.* 1983
4. Ionospheric delay	10 cm	1 cm	Herring 1983
5. Tropospheric delay	10 cm	10 cm	educated guess

To make use of such precision when at least one of the sources is partially resolved, the position must refer to a well-defined point in each source. Our estimates of position refer to the center of brightness of the easternmost component of 3C 345. The positions of the other compact components are determined from knowledge of the components' separation, obtained, for example, from hybrid maps.

OBSERVATIONS

Interleaved observations of 3C 345 and the nearby source NRAO 512 (1638+398), with redshift z=1.67 and a single compact component, were made at λ3.8 cm in the early and mid 1970's using the Mark I VLBI system, and at λ3.6 cm and λ13 cm (simultaneously) since 1980 using the Mark III VLBI system. Data from five epochs are discussed here.

RESULTS

The difference in right ascension between the easternmost compact component (the putative "core" component) in 3C 345 and the single compact component in NRAO 512 is given in Figure 1 for five epochs. (We omit the declination because changes in declination are nearly orthogonal to the motion of interest, and because our relative position estimates are subject to larger errors in declination than in right ascension.) If the individual observations are assigned standard errors equal to the root-mean-square of the postfit residuals, the statistical standard error in the estimate of the relative position of the two sources is about 0.1 mas for the first two epochs and 0.02-0.03 mas for the last three; in all cases the fractional uncertainties are less than 1 part in 10^7.

To display the positions of the "jet" components, a ten times larger scale for the right ascension is used in Figure 2. This figure includes relative positions of "jet" components previously reported by other VLBI groups; estimated errors are also shown. The positions are plotted with respect to the mean from all five epochs of the separation between the easternmost component of 3C 345 and the single component of NRAO 512. Although it is not clear whether specific "jet" components can be traced for the whole decade from 1972 to 1982 (see, e.g., Schraml 1981), one component can be traced from 1972 to 1976 and two from 1979 onwards. Within at least these periods proper motions of the "jet" components are apparent.

CONCLUSION

Our results show that the "core" of the superluminal quasar 3C 345 is stationary (0.02±0.02 mas/yr) and the "jet" components are moving with respect to the external reference, NRAO 512.

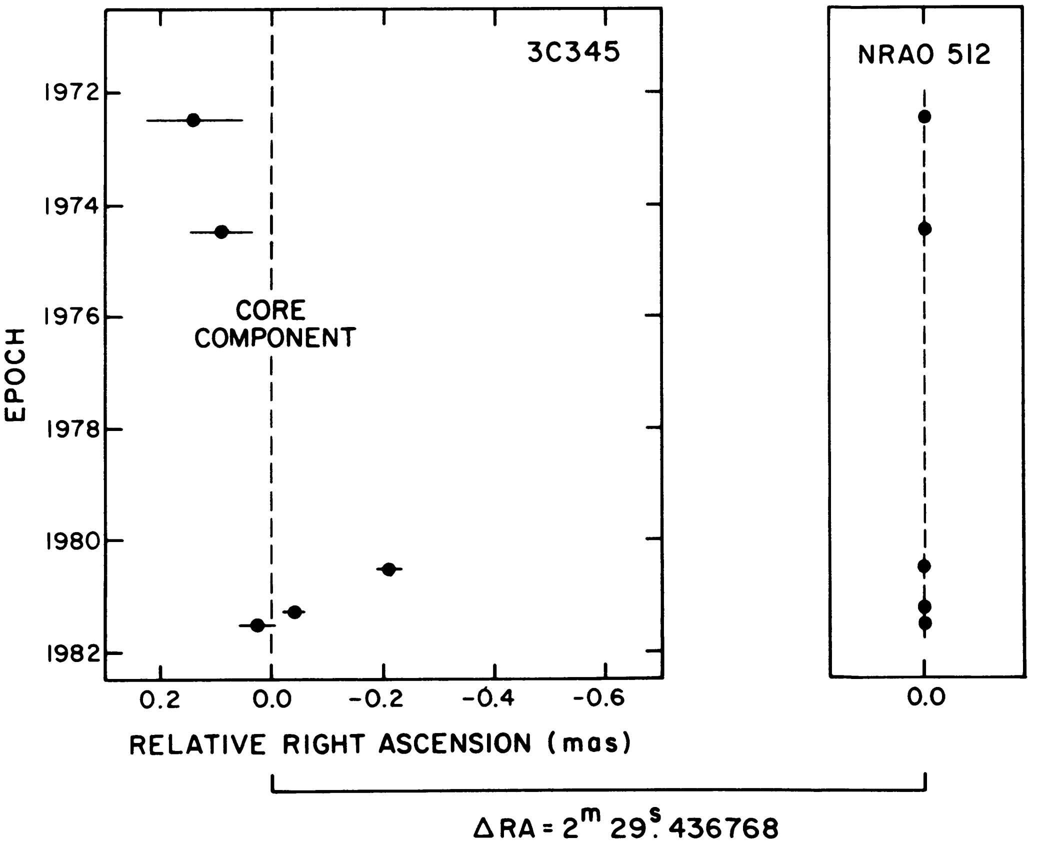

Figure 1: The differences in right ascension between the "core" component in 3C 345 and the single compact component in NRAO 512 for each of five epochs. The left dashed line marks the mean of these differences. Statistical standard errors are shown.

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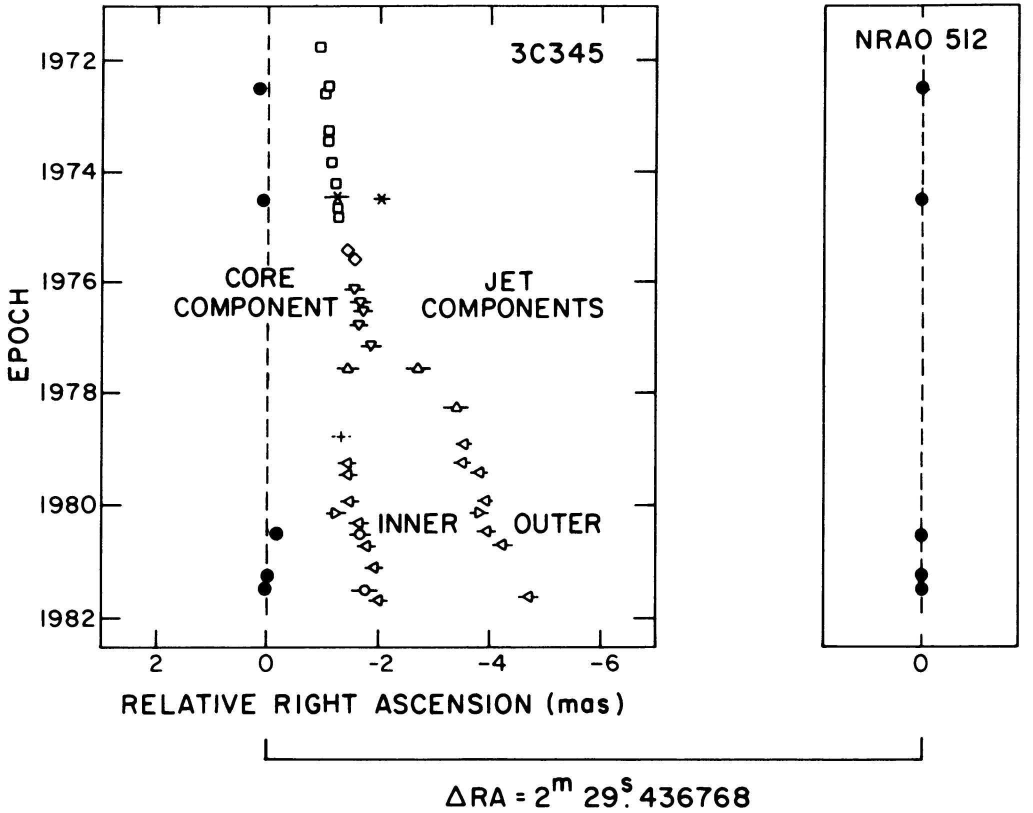

Figure 2: Same as Figure 1, but a ten times larger scale. Additional symbols mark positions of inner and outer jet components relative to the dashed line. Data are from: + Baath et al. 1981, ◇Cohen et al. 1977, Δ Cohen et al. 1981, x Cotton 1980, ∇ Seielstad et al. 1979, ▷ Spencer et al. 1981, ◁Unwin et al. 1983, □Wittels et al. 1976, ● and ○ this paper.

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