5 YEARS OF VLBI AND X-RAY OBSERVATIONS OF NRAO 140

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ABSTRACT. The author and his collaborators have observed NRAO 140 twice at X-ray energies and numerous times with multifrequency VLBI. The VLBI observations reveal a knotty jet structure with superluminal motion of the innermost two knots relative to the core. The VLBI core decreased by about a factor of 2 in flux density between 1980 and late 1984. The X-ray flux also declined by about the same factor during this period. Monitoring at 18 cm during periods of low-frequency variability has revealed pronounced changes in the relative brightnesses of the components of the source while the total flux density has varied by $\lesssim$ 10%.

1. INTRODUCTION.

Advances in our understanding of the quasar phenomenon have been accomplished through both statistical studies of large samples of objects and detailed analyses of the emission from single objects. The quasar NRAO 140 (z=1.26) is a particularly good choice for the latter type of investigation, since it is among the strongest X-ray quasars and exhibits many interesting of radio properties apparent superluminal motion, core-jet morphology, and variability at both high and low frequencies. The author and his collaborators have been observing NRAO 140 with X-ray satellites and VLBI arrays since 1980. The results impact our current thoughts on how to explain the X-ray and radio emission from quasars.

2. X-RAYS.

The author has observed NRAO 140 in 1980 (with *HEAO 2*) and 1985 (with *EXOSAT*). Upon combining these results with the X-ray measurements by other authors, it is evident that the X-ray flux density decreased by a factor of 2 between 1978 and 1985. This is coincident with a similar decline in the intensity of the radio core flux density at 2.8 cm (see below). This behavior is consistent with inferences drawn from the previously reported strong correlation between high-frequency radio flux density and X-ray flux in compact radio sources (*e.g.*, Owen, Helfand, and Spangler 1981). One would not, however, expect a one-to-one correspondence between X-ray and radio core flux density if the X-rays originate through inverse Compton scattering in the core except under special circumstances (Marscher 1987a).

The absorption column density (expressed in terms of the amount of cold

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hydrogen gas along the line-of-sight), as determined by the low-energy cutoff in the X-ray spectrum, is consistent with the galactic value of $2 \times 10^{21}\mathrm{cm}^{-2}$ in 1979 and 1985. In 1980, however, it exceeded $6 \times 10^{21}\mathrm{cm}^{-2}$ (90% confidence limit) (Marscher 1987b). The excess absorption could have been produced either by a solar-system sized globule of density $\sim 10^{9}\mathrm{cm}^{-3}$ or by a cloud in the quasar, with the latter case requiring a column density 9 times greater owing to the strong energy dependence of the absorption cross-section and the redshift of the quasar. The former interpretation is made more plausible by the fact that NRAO 140 lies behind the outer edge of a giant molecular cloud in Perseus.

3. VLBI.

The 6 cm VLBI observations reveal that the quasar has a core-jet structure, with 6 components evident on the map. The opening half-angle of the jet is $\sim 3°$, which implies a true opening half-angle less than half a degree if the jet is pointing nearly along the line-of-sight. Superluminal motion of the innermost knots is revealed at 2.8 cm. The core at 2.8 cm decreased in flux density by about a factor of 2 between 1980 and late 1984. A spectral dissection using multifrequency VLBI performed in mid-1981 and 1984 illustrates how the various self-absorbed components contribute to an overall flat spectrum. Analysis of two of the components reveals a "Compton problem," which refers to an excess of self-Compton X-ray flux predicted over that observed (Marscher and Broderick 1981; Marscher *et al.* 1987a).

NRAO 140 is a well known low-frequency variable, with an outburst which peaked in mid-1981. The author and his collaborators have observed NRAO 140 using VLBI at 18 cm in 1981, 1984, and 1986. Changes in the visibilities indicate that a particular component decreased significantly in brightness at 18 cm between the first two epochs, as the low-frequency outburst faded (Marscher *et al.* 1987a). The 1986 map (Marscher *et al.* 1987b) shows that the southeastern half of the source declined further in brightness while the northwestern half increased in flux density. The total flux density at 18 cm fluctuated only slightly (by ±0.15 Jy) during this period. The "mid-frequency gap" in variability seems therefore to be another conspiracy, in this case resulting in nearly constant total flux density at 18 cm while the flux densities of the individual components fluctuate considerably. It is not clear whether the refractive scintillation model can explain the near constancy of the total flux density at 18 cm. Also, the size of the variable component measured at 6 cm indicates that it has a "Compton problem" which implies the existence of relativistic motion, which by itself can also explain the low-frequency variability.

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