X-RAY PROPERTIES OF COMPACT EXTRAGALACTIC RADIO SOURCES

D.M. Worrall
Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, U.S.A.

I. OBSERVATIONS

A good correlation is known to exist between the X-ray and radio luminosity of flat-spectrum, core-dominated radio sources (*e.g.,* Owen, Helfand and Spangler 1981). Worrall (1987) presents a logarithmic plot of spectral luminosity in the source frame at 2 keV versus that at 5 GHz for a variety of QSOs, Highly Polarized QSOs (HPQs), and BL Lac Objects. Friedmann cosmology with $H_o = 100h$ km s^{-1} Mpc^{-1}, $q_o = 0$ is assumed. Exclusion of objects which are optically or X-ray selected, or in which the radio emission is not dominated by a flat-spectrum compact core, gives a sub-sample consisting of 50 QSOs, 20 HPQs, and 10 BL Lacs, of which 5,4,3, respectively, are known superluminals. The dispersion of these data about the log-log correlation (assuming a Gaussian distribution), is $\sigma_{obs} = 0.44 \pm 0.06$ (90% confidence errors for one interesting parameter).

II. COMPARISON WITH MODEL RESULTS

It is assumed that compact flat-spectrum radio sources are selected by preferential beaming towards the observer from a population undergoing relativistic motion of Lorentz factor γ. The Doppler factor is $\delta = [\gamma(1-\beta\cos\theta)]^{-1}$, where θ is the angle of motion to the line of sight. The enhancement of the radio luminosity relative to isotropically-emitted luminosity will be $\delta^{p+\alpha_r}$, where α_r is the spectral index of the radio emission, and $p = 3$ or 2 depending on whether or not emission is from discrete blobs (see Phinney 1985). Calculations below assume $p + \alpha_r = 2.5$. If the dispersion of $\sigma_{obs} = 0.44$ is less than the dispersion implied by projection effects of $\delta^{p+\alpha_r}$, then we must conclude that the X-ray emission is fully or partly beamed like the radio.

The dispersion in δ will depend on the following:

(a). The distribution of γ. A clue to this is available from the 12 superluminals in the sample. The transverse velocities measured for these objects suggest a likely range of γ between $4h^{-1}$ and $16h^{-1}$.

(b). The θ-distribution of the sources. Because the sources are radio selected and core dominated, they are presumably oriented between θ_{min} and θ_{max} such that $\theta_{max} < 180°$. Impey(1987) presents evidence that the optical radiation of compact flat-spectrum QSOs, HPQs and BL Lacs is a composite of beamed and isotropic radiation. Low-polarization QSOs are in the majority in the sample used here, suggesting $\theta_{max} \gtrsim 20°$, and the presence of BL Lac objects suggests $\theta_{min} \simeq 0°$.

Assuming that the X-ray emission is unbeamed and the radio emission is beamed, an expected value for σ can be calculated. If it exceeds σ_{obs}, the assumption of unbeamed X-ray emission is proved to be invalid.

M. J. Reid and J. M. Moran (eds.), The Impact of VLBI on Astrophysics and Geophysics, 109–110.

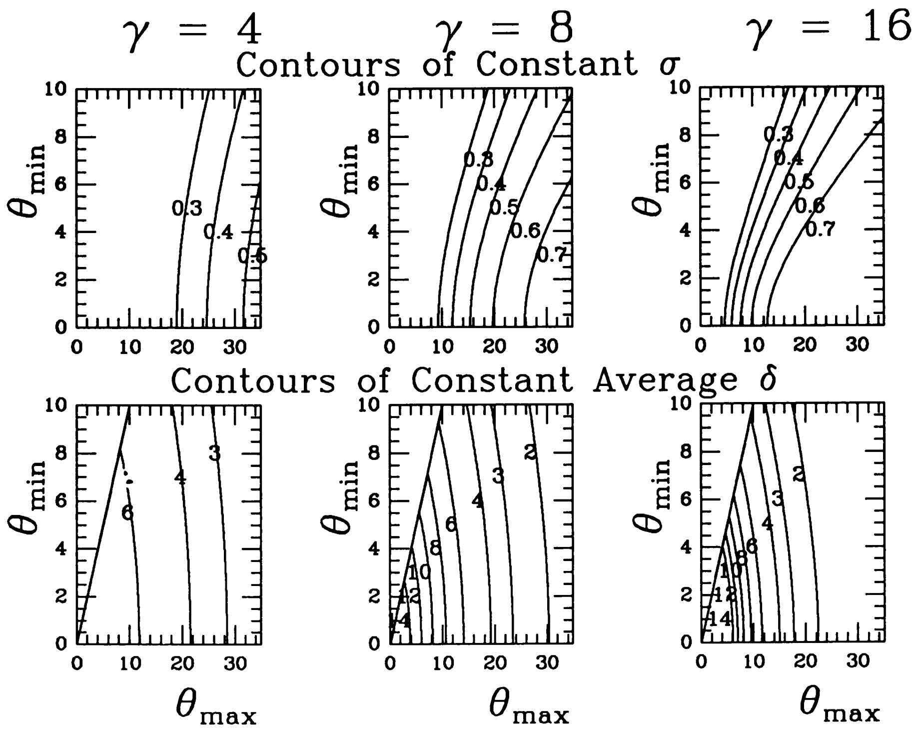

Figure 1. Calculations of σ and average value of δ, for three values of γ, as a function of the minimum and maximum angles of orientation of sources with respect to the line of sight, θ_{min} and θ_{max}. The model assumes that the radio emission is beamed and the X-ray emission is unbeamed, and that sources are oriented at random between θ_{min} and θ_{max}.

Likely parameters for the present sample (for which $\sigma_{obs} = 0.44$) are $4 \geq \gamma \leq 16$, $\theta_{min} = 0°$, and $\theta_{max} \gtrsim 20°$ [see (a) and (b) above]. For such parameter values, Figure 1 shows model predictions which prefer $\sigma > 0.44$. The discrepancy between the predicted σ and σ_{obs} becomes larger under the assumption that some of σ_{obs} is intrinsic or due to variability.

Results are necessarily weak due to the incompleteness of the sample and the uncertainty in the distributions for γ and θ. The best conclusion is that there is a *suggestion* that at least some of the X-ray emission must be beamed.

This work was supported by NASA Contract NAS8-30751 and Smithsonian Institutional funds.

REFERENCES

Impey, C. 1987, in *Superluminal Radio Sources*, ed. J.A. Zensus, and T.J. Pearson (Cambridge: Cambridge University Press), p. 233.

Owen, F.N., Helfand, D.J., and Spangler, S.R. 1981, *Ap.J. (Letters)*, **250**, L55.

Phinney, E.S. 1985, in *Astrophysics of Active Galaxies and Quasi-Stellar Objects*, ed. J.S. Miller (Mill Valley: University Science Books), p. 453.

Worrall, D.M. 1987, in *Superluminal Radio Sources*, ed. J.A. Zensus, and T.J. Pearson (Cambridge: Cambridge University Press), p. 251.