X-RAY EMISSION FROM BL Lac OBJECTS: COMPARISON TO THE SYNCHROTRON SELF-COMPTON MODELS

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As one part of our joint study of the X-ray properties of BL Lac objects, we compare the measured X-ray flux densities with those predicted using the synchrotron self-Compton (SSC) formalism (Jones et al., 1974). Naive application of the formalism predicts X-ray fluxes from 10^{-3} to 10^{5} those observed. We therefore ask what we can learn by simply assuming the SSC mechanism, and looking for ways to reconcile the observed and measured X-ray fluxes. This paper reports our investigation of beaming factors due to relativistic ejection of a radiation source which is isotropic in its own rest frame. We conclude that large Lorentz factors, $\Gamma \gtrsim 10$, do not apply to BL Lac objects as a class.

Our present study (Table 1) is based on 16 sources for which a VLBI size has been measured by Weiler and Johnston (1980) and which have been observed (15 detected) in X-rays with the Einstein Imaging Proportional Counter. The X-ray data have been reduced in the manner described by Zamorani et al. (1981), except that we assume a steeper energy spectrum, of index 1.5. We use equation 4 of Jones et al. (1974) to predict the X-ray flux density S_x'(Jy) at 1 keV.

TABLE 1 Distribution of Beaming Factors

Object	S_x'(Jy)	S_x(Jy)	δ	Object	S_x'(Jy)	S_x(Jy)	δ
0048-097	1.3E-3	2.2E-7	8.8	1101+38	3.2E-7	1.4E-5	0.39
0219+438	8.8E-9	1.5E-7[1]	0.49	1219+28	3.2E-6	4.8E-7	1.6
0235+164	1.0E-1	1.6E-7	28.0	1308+326	2.1E-1	2.7E-7	30.0
0735+178	4.6E-5	2.4E-7	3.7	1400+162	1.9E-10	1.6E-7[1]	0.18
0754+100	3.6E-5	2.0E-7	3.6	1538+149	1.9E-5	1.3E-7	3.5
0818-128	3.9E-6	<1.4E-7	>2.3	1652+398	2.1E-7	1.2E-5	0.36
0829+046	1.8E-7	1.9E-7	0.98	2201+04	8.9E-8	2.6E-7	0.76
0851+202	3.4E-4	2.3E-6	3.5	2254+074	8.1E-9	1.2E-7[1]	0.51

[1]From Maccagni and Tarenghi.

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We consider a model where the radio source is ejected with a Lorentz factor Γ, at an angle θ away from a line toward us. If we define the beaming factor $\delta = 1/\Gamma\ (1-\beta\cos\theta)$, then a Lorentz transformation gives $S_x = S_x'\delta^{-2(\alpha+2)}$. In Table 1 we have assumed ν_m = 1 GHz and α = 0. Calculating with ν_m = 0.3 or 5 and α = 0.2 or 0.5 changes S_x' by a large factor; however, since S_x depends on δ to a power similar to the dependence on the radio size, synchrotron absorption frequency ν_m and radio flux density S_m, δ is determined within a factor of a few.

If the predicted S_x' were all within a factor of 10 or 100 from the measured S_x, it could be evidence for a single component SSC model. Instead, we must find a way to reconcile at least the cases where the predicted X-ray flux density greatly exceeds that observed. The assumption of relativistic beaming is sufficient and furthermore is reasonable in the sense that a quasi-isotropic distribution of θ, and relatively small Γ are required.

We may predict the intrinsic distribution of δ for a set of objects if the Lorentz factors have a probability density function $\rho(\Gamma)$:

$$\rho(\delta) = \frac{1}{2\delta^2}\int_{\Gamma_{min}}^{\infty} \frac{\rho(\Gamma)\ d\Gamma}{\sqrt{\Gamma^2 - 1}} \qquad (1)$$

where the minimum $\Gamma_{min} = (1+\delta^2)/2\delta$. From this equation we can immediately see qualitatively that for a δ-function distribution of Γ, values of Γ_0 = 2 to 5 would suffice to span most of the range of observed δ factors, from 0.1 to 10. A power law $\rho(\Gamma)\propto\Gamma^{-2}$ would span this same range. On the other hand, for $\Gamma \geqslant 10$, the overwhelming majority of sources would have $\delta \ll 1$, which is not what we observe.

Suppose we only recognize an object as a "BL Lac" if it is beamed toward us within some angle θ_m. In this case we can only integrate equation (1) up to some Γmax at which $\delta \geqslant 1/\Gamma_{max}\ (1-\cos\theta_m\ \sqrt{1-1/\Gamma_{max}^2})$, and the normalization factor 2 changes to $1-\cos\theta_m$. For the delta function distribution, $\theta_m = 1/\Gamma_0$, and it is easy to see that for $\Gamma_0 \geqslant 10$ we do not expect any $\delta \leqslant 10$. We conclude that although some extreme values of Γ may occur for specific sources, the general distribution is dominated by $\Gamma \lesssim 5$.

REFERENCES

Jones, T.W., O'Dell, S.L., and Stein, W.A. Astrophys. J. 192, 261 (1974).

Maccagni, D. and Tarenghi, M. Astrophys. J. 243, 42 (1981).

Weiler, K.W. and Johnston, K.J. M.N.R.A.S. 190, 269 (1980).

Zamorani, G. et al. Astrophys. J. 245, 357 (1981).

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