RELATIVISTIC BEAMING AND QUASAR STATISTICS

I.W.A. Browne and M.J.L. Orr
Nuffield Radio Astronomy Laboratories
Jodrell Bank, Macclesfield, Cheshire

ABSTRACT

The predictions of a scheme which attributes the observed differences between flat and steep spectrum quasars to projection and the effects of relativistic beaming are explored. We conclude that the statistical properties of quasars are entirely consistent with such a scheme provided the mean Lorentz factor in the central components of quasars is $\sim$5.

INTRODUCTION

Many maps of core-dominated sources have been shown by Peter Wilkinson and Rick Perley at this conference. One possible interpretation of these maps is that what we are seeing in core-dominated sources are just normal doubles viewed along their axes. If this is so the statistics of flat spectrum (core-dominated) and steep spectrum (normal double) sources are not independent. In this contribution we use a simple model of a quasar consisting of a compact relativistically beamed core, spectral index zero, and unbeamed lobes, spectral index -1, to predict the proportion of flat spectrum sources in flux limited samples selected at different frequencies. Also using the same model quasar we construct the flat spectrum number/flux density counts from the observed steep spectrum counts. Our aim is 1) to see if quasar statistics are consistent with such a unified scheme of flat and steep spectrum objects, and 2) to see if we can put useful constraints on the Lorentz factors in quasar cores. This work is described in more detail in Orr & Browne (1981).

THE QUASAR MODEL

We will neglect the contribution of jets because at high frequencies they are nearly always very much weaker than the cores. It will be assumed that the core emission is Doppler boosted with a Lorentz factor

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γ and that the rest of the emission (i.e. that from the lobes) is unbeamed.

We take the ratio

$$R_T = \frac{\text{Core strength perpendicular to the line of sight}}{\text{Lobe strength}}$$

to be a constant. In any particular source the observed ratio

$$R = \frac{\text{Core strength at angle } \theta \text{ to the line of sight}}{\text{Lobe strength}}$$

will depend on θ and γ (Scheuer & Readhead, 1979).

RESULTS

The distribution of R in a sample of sources selected without reference to beamed properties can be predicted, since in such a sample θ will be randomly distributed. 3CR quasars approximate closely to such a sample, and from the distribution of R amongst these we deduce that $R_T \simeq 0.025$. The distribution of R for a small sample of quasars is, however, not a good way to determine γ (c.f. Scheuer & Readhead, 1979). This is because predicted distributions for various γs, only differ significantly for sources with high values of R and these are expected to be very rare, requiring a high degree of alignment.

A better way to estimate γ is by predicting the expected numbers of flat and steep spectrum quasars in flux limited samples selected at different frequencies and comparing the predictions and reality. Such predictions are possible because the condition for a quasar to have a flat spectrum can be re-expressed as a condition on R. In other words if $R > R_C$, some critical value, the overall radio spectrum will be flat. Table I shows the observed fraction of flat spectrum quasars in various surveys and the Lorentz factors required to produce that fraction. It is clear from the table that $\gamma \sim 4.5$ is consistent with the statistics of nearly all the samples.

Another way in which our simple quasar model can be used to check the consistency of the unified scheme is to predict the number/flux density counts of flat spectrum quasars from those of steep spectrum quasars. (We make the assumption that quasar counts at 408 MHz are essentially free from the effects of beaming). Fig. 1 shows the 5 GHz differential source counts for flat spectrum quasars and the predicted counts for γ = 4, 5 and 6. No one value of γ gives a perfect fit, but considering the simplicity of the model and the uncertainties in the starting 408 MHz counts, we think the agreement is encouraging. In particular the overall shape is roughly right and the very small number of flat spectrum quasars at low flux densities (Condon & Ledden, 1981) is successfully predicted.

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Table I The fraction (F) of flat spectrum quasars in various surveys and the core Lorentz factor (γ) required to predict F. ν is the frequency and S_0 the flux density limit of the survey.

Sample	ν(MHz)	S_0(Jy)	F	γ
3C	178	10	8 ± 4	3.2 ± 0.9
4C	178	2	17 ± 6	5.8 ± 0.8
Bologna(B2)	408	0.9	18 ± 5	4.9 ± 0.7
Jodrell Bank	966	1.0	21 ± 4	3.7 ± 0.3
Parkes	2695	0.35	60 ± 8	5.2 ± 0.5
Kuhr et al.	5000	1.0	82 ± 6	5.3 ± 0.3
NRAO Deep Survey	5000	0.1	56 ± 18	4.5 ± 1.1

A number of trials were conducted using a distribution of γ rather than a constant value. In practice it was found that approximately the same predicted curves were produced as for a constant γ provided the centre of gravity of the distribution $\bar{\gamma} \simeq \gamma$.

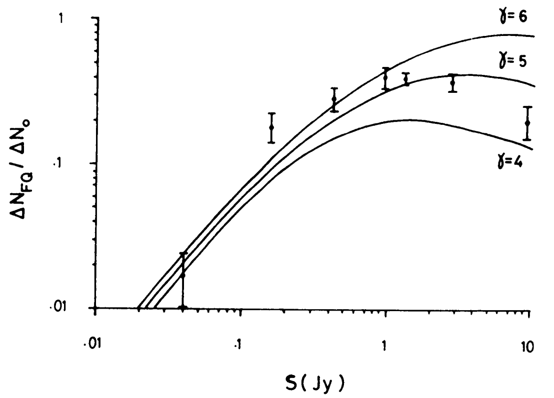

Fig. 1 The observed and predicted differential number counts of flat spectrum quasars

DISCUSSION AND CONCLUSION

Independent estimates of γ can be obtained from observations of superluminal sources (see contribution by M. Cohen). These all come out to be in the range 3 to 10 (if $H_0 \sim 100$ km s^{-1} Mpc^{-1}) and are within the range of the present results.

We conclude that a simple relativistic beam model of quasars (with $\gamma \simeq 5$) is entirely consistent with the statistical properties of quasars.

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Discussion

J.F.C. Wardle. Does your model predict $\left\langle \frac{V}{V_m} \right\rangle \sim 0.5$ for flat spectrum quasars?

I.W.A. Browne. Yes it does predict $\left\langle \frac{V}{V_m} \right\rangle \sim 0.5$ for intermediate flux density quasars. For the strongest quasars the predicted Log N/Log S slope is steeper than the Euclidian value indicating $\frac{V}{V_m} > 0.5$. This has what has been found to happen in reality by Peacock and his collaborators.

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