Red synchrotron jets in Parkes Quasars.

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Abstract. Models of synchrotron emission are fitted to broadband optical to near-infrared photometry of Parkes Half-Jansky Sample quasars. Most of the sources show evidence for the presence of a synchrotron component peaking in the near-infrared. The results are compared with ROSAT observations, as well as emission line measurements, and the implications of these are discussed, particularly for BL Lacs.

1. Introduction

The Parkes Half-Jansky Sample (Drinkwater et al. 1997) is a complete subsample of the Parkes Catalogue, and consists of 323 objects that are radio loud ($S_{2.7\ \mathrm{GHz}} > 0.5$ Jy), and have a flat radio spectrum ($\alpha_{2.7/5.0} > -0.5$, $S(\nu) \propto \nu^{\alpha}$). Of these sources, 14 have been classified as BL Lacs, and 6 as BL Lac Candidates, according to Padovani & Giommi (1995).

Webster et al. (1995) showed that quasars in the Parkes Half-Jansky Sample have much redder optical colours than typical optically–selected quasars (such as LBQS quasars). Two alternatives have been proposed for the cause of this reddening: extinction by dust somewhere along the line of sight; or the presence of an additional red synchrotron component. In this paper we investigate the synchrotron hypothesis by fitting models to optical and near-infrared photometry, and look at how the results compare to X-ray and emission line observations.

2. Observations

We have complete photometry in B,V,R,I,J,H and K bands for 129 sources from the Parkes Half-Jansky sample, with the observations complete in some R.A. ranges, thereby removing bias effects. Of these sources, 6 are classified as BL Lacs, and 2 as BL Lac Candidates. The photometry is quasi-simultaneous, that is, both the optical and infrared observations were taken within a few days of each other. This minimises any effect that intrinsic source variability might have on the relative strength of the different wave-band fluxes.

3. Models

To test the synchrotron hypothesis, a two-component model is used, based on the assumption that all quasars have the same underlying continuum, and that these “red” quasars have an additional synchrotron component superimposed over this. This underlying component, representing the “Big Blue Bump”, is modelled with a power law extending from the UV to the optical, defined by $f_\nu \propto \nu^{-0.3}$, or $f_\lambda \propto \lambda^{-1.7}$. This index, -0.3, was found by Francis et al. (1991) to be the average value for the optically selected quasars in the LBQS. It is also consistent with that expected from free-free emission due to hot gas (Barvainis 1993).

The synchrotron component is calculated from the single particle luminosity, integrated over a power law distribution of electron energies, up to some cut-off energy, which preserves the angular dependence of the radiation. This synchrotron spectrum has a rapid fall-off for wavelengths shorter than the peak, and a more gradual fall-off at longer wavelengths.

To fit to the data, seven template synchrotron functions were made, each peaking in one of the wave-bands B through K. Each of these was used with the power law to make a least-squares fit to the data, and the best (i.e. minimum χ^2) fit out of the seven was chosen, generating a peak synchrotron wavelength for each source.

4. Results of fitting

The distribution of peak wavelengths is shown in Table 1. The remaining fifteen sources not included in Table 1 had average B-to-K slopes that were steeper than the big blue bump power law slope of -1.7, and so need a slightly steeper (in f_λ) power law to fit the models to them. (Adding a synchrotron component to the power law has the effect of flattening the slope of the big blue bump component.) A little over half of them could be fit using a $\lambda^{-1.8}$ power law, and a $\lambda^{-1.9}$ power law fitted all but two of them.

It can be seen from Table 1 that most of the observed synchrotron peak wavelengths lie in the infrared region, with a sharp cutoff around the I band. This sharp cut-off indicates that there are no sources with observed peaks in the UV. In terms of the quasar rest frame wavelength (i.e. the emitted wavelength), this translates into a cut-off around 0.3μm, with most sources falling in the region between 0.5μm and 1μm.

5. X-ray data

The X-ray properties of the Half-Jansky Sample have also been investigated (see Siebert et al. (1998) for a full analysis of the Half-Jansky Sample), using data from the ROSAT All-Sky Survey, as well as from archival pointed PSPC observations. For the 163 sources that were detected, a $0.1 - 2.4$ keV flux was derived, whilst the remaining 160 sources have 2σ upper flux limits. Also, separate mean photon indices were derived for each of the different classes of objects in the sample (quasars, galaxies and BL Lacs), enabling the rest-frame fluxes to be calculated for each object.

These X-ray fluxes were compared with the synchrotron fluxes resulting from the model fitting, to see if there was a correlation. If the X-ray emission is due to a process related to the synchrotron component, such as inverse Compton scattering of lower energy photons by the synchrotron-emitting electrons, then one would expect some correlation between the two fluxes. However, when the rest frame fluxes are considered (see Fig. 1), there is no significant correlation present.

6. Equivalent widths

If one assumes that the synchrotron flux does not ionise the broad line region (BLR), then an increase in the synchrotron flux relative to the continuum would reduce the equivalent width of the emission lines from the BLR. So, we compared the equivalent widths of six emission lines (Lyα (0.1216 μm), CIV (0.1549 μm), CIII] (0.1909 μm), MgII (0.2798 μm), [OII] (0.37273 μm), and Hβ (0.48613 μm)) with the ratio of synchrotron to continuum flux at the line wavelength, to see if an anti-correlation is present.

The Hβ line (see Fig. 1) shows a significant anti-correlation between the synchrotron strength and the equivalent width. However, this is the only one of the six lines examined to do so. This is to be expected, since the emitted peak wavelength of the synchrotron for most sources lies at longer wavelengths than the Hβ line. This means that the Hβ line is closest to the synchrotron peak, and so, due to the rapid fall-off of the synchrotron emission short-wards of the peak, it has the strongest synchrotron flux, and therefore the greatest amount of "masking" of the underlying emission.

7. Discussion

It can be seen from the two-model fitting that there is strong evidence for synchrotron emission in many of the Parkes quasars. The synchrotron models that give the good fits mostly peak around the I to H bands, as measured in the observer's frame. When the redshift of the sources is taken into account, the peak emission wavelengths range up to around 0.2μm, which is into the ultra-violet region of the spectrum.

The lack of correlation of the X-ray measurements with the model synchrotron fluxes may have a number of different explanations. It could imply that the X-ray and synchrotron emissions are unconnected, coming from unrelated processes. Alternatively, it could be possible that the X-ray and synchrotron processes are indeed connected, but the lack of simultaneity in the respective observations has destroyed any correlation that would have been present.

The equivalent width results have implications for BL Lacs. A common explanation for the lack of emission lines in BL Lacs has long been that the emission line flux was being swamped by a beamed synchrotron flux from a jet directed towards us (Blandford & Rees 1978). However, only the longest wavelength emission line (Hβ) shows any reduction with synchrotron flux, so for a synchrotron jet to swamp the other lines, the synchrotron component needs to be peaking at much shorter wavelengths (i.e. closer to the rest-frame wavelength of the lines). This means that the lack of significant emission lines in LBLs (that is, low-frequency peaking BL Lacs) in particular can not be explained simply by the presence of a beamed synchrotron component. Further discussion of these results will be found in our upcoming paper (Whiting et al. 1998).

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References

Barvainis R. 1993, ApJ, 412, 513

Blandford R.D. & Rees M.J. 1978, in Pittsburgh Conference on BL Lac Objects, ed. A. N. Wolfe (Pittsburgh, University of Pittsburgh Press), p. 328

Drinkwater M.J. et al. 1997, MNRAS, 284, 85

Francis P.J. et al. 1991, ApJ, 373, 465

Padovani P. & Giommi P. 1995, MNRAS, 277, 1477

Siebert J. et al. 1998, MNRAS, in press

Urry C.M. & Padovani P. 1995, PASP, 107, 803

Webster R.L. et al. 1995, Nature, 375, 469

Whiting M.T. et al. 1998, in preparation

band	$\lambda_0 (\mu m)$	number	number with $\chi^2 \leq \chi^2_{0.99}$
B	0.44	4	0
V	0.55	2	1
R	0.7	5	1
I	0.88	5	3
J	1.3	22	15
H	1.6	32	26
K	2.1	44	28

Table 1. Distribution of (observed) peak wavelengths of the synchrotron models, showing the "good fits" (99% C.L.).

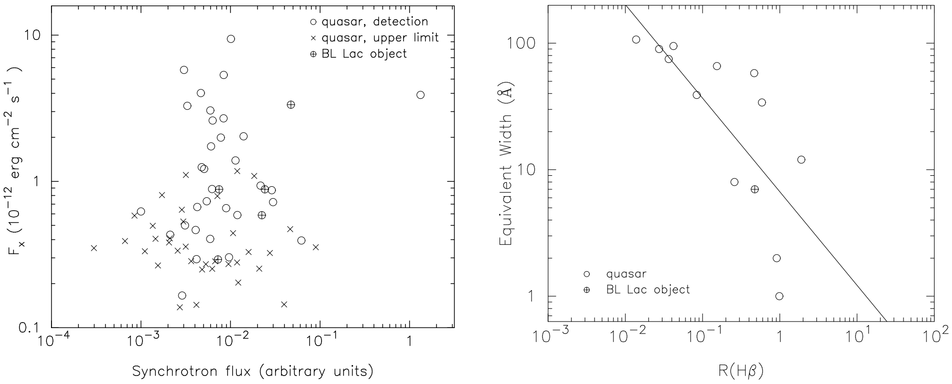

Figure 1. (l) Rest frame peak synchrotron flux vs. 0.1-2.4 keV flux transformed into rest frame. (r) Equivalent width of Hβ line vs. ratio of synchrotron to power law component at the Hβ line, with line of best fit.