Supplement to *J. Astrophys. Astr.* (1995) **16**, 185–188

Aspect Dependent Optical Continuum Emission in Radio Quasars

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Abstract. We have defined a new, complete, low-frequency selected sample of southern radio quasars, the Molonglo Quasar Sample, with the aim of studying the aspect dependence of the radio and optical emission. As a test for enhancement of the optical continuum, we find that the narrow [O II] and [O III] emission line equivalent widths decrease systematically with radio core dominance. This effect is consistent with the optical continuum being relativistically boosted at angles close to the line of sight. However, such an interpretation seems to be in conflict with the aspect independent behaviour of the broad lines, most notably Hβ.

Key words: Quasars: emission lines—optical spectroscopy—radio sources—active galaxies.

1. Introduction

Statistical studies have suggested that radio core-dominated quasars are on average over one magnitude brighter in the optical than their lobe dominated counterparts (Browne & Wright 1985; Kapahi & Shastri 1987; Wills *et al.* 1992). Since radio core dominance is believed to arise from Doppler boosting of a forward-directed relativistic jet seen at small angles to the line of sight, such a difference in optical magnitudes can be understood if the optical continuum also depends on viewing angle and is enhanced along with the radio core emission. If so, then virtually all existing QSO samples will contain a significant orientation bias. We have attempted to minimize this bias by selecting a new sample at low radio frequency, where the flux density is dominated by the unbeamed extended emission, and by ensuring that optical identifications are complete down to the limit of deep sky survey Schmidt plates.

2. The Molonglo Quasar Sample (MQS)

Initially, ~ 700 sources with $S_{408} > 0{\cdot}95$ Jy, in a $10°$ declination strip ($-30° < \delta < -20°$) and in the RA ranges 20^h–06^h and 09^h–14^h, were selected from the 408 MHz Molonglo Reference Catalogue (Large *et al.* 1981). The sources were mapped at 843 MHz with the Molonglo Observatory Synthesis Telescope in snapshot mode, and optical identifications of stellar counterparts were made from the UK Schmidt IIIaJ plates, complete down to the limiting magnitude $B_J \sim 22{\cdot}5$. Follow-up radio imaging has been undertaken at the VLA at 5 GHz for all the QSO candidates. Optical spectroscopy at the Anglo-Australian Telescope has provided us with redshifts ($0{\cdot}1 < z < 2{\cdot}9$), continuum slopes and emission line data.

3. The equivalent width test

A widely used test for the enhancement of the optical continuum has been the comparison of narrow emission line equivalent width, W_λ, with radio core dominance parameter, R (Wills & Browne 1986); R is usually defined as the ratio of core to extended flux density at a given emitted frequency (we use 10 GHz). If the optical continuum is brighter in quasars viewed at small angles to their radio jet axis then, for an isotropically emitted line, W_λ will decrease with increasing R. This has been observed by Browne & Murphy (1987) for a collection of X-ray selected quasars using the narrow [O III] λ5007 line. The same effect is observed with the MQS (Baker *et al.* 1993). However, Jackson & Browne (1990) presented evidence, from a comparison of [O III] luminosities for a matched set of radio galaxies and quasars, that the [O III] line is significantly stronger in the quasars and may not be emitted isotropically.

Recent studies suggest that, unlike [O III], the distribution of [O II] λ3727 luminosity is the same for both radio galaxies and quasars (Bremer *et al.* 1992; Hes *et al.* 1993), consistent with the quasar-radio galaxy unification picture (Barthel 1989). This suggests that [O II] might be emitted more isotropically than [O III] and, therefore, be a better line to use as a benchmark.

Our preliminary plot of W_λ[O II] against R is shown in Fig. 1(a). A strong decrease in W_λ with R is evident, spanning four orders of magnitude, and is remarkably

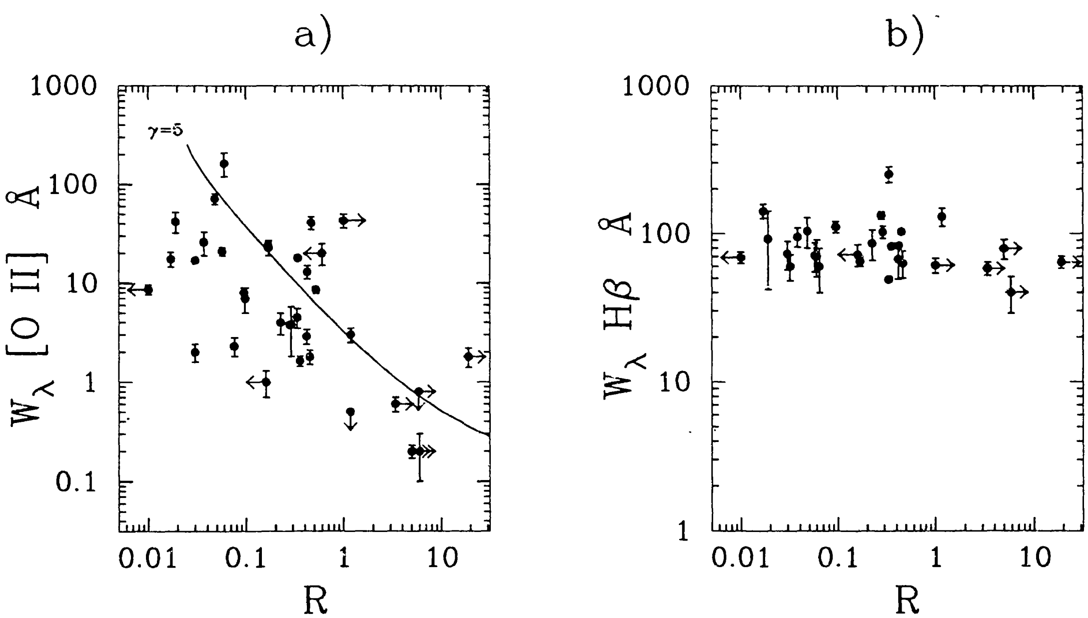

Figure 1. Preliminary plots of W_λ versus R for (**a**) [O III] λ3727 showing a strong anticorrelation consistent with the $\gamma = 5$ Doppler boosted continuum model shown (Browne & Murphy 1987), and (**b**) Hβ λ4861 showing W_λ to be independent of R.

consistent with a simple relativistically beamed continuum model (Browne & Murphy 1987). Such a strong anticorrelation cannot be attributed solely to a decrease in [O II] line luminosity, which has a range of only one order of magnitude, comparable with the scatter. We therefore believe that the trend is most readily explained by a progressive enhancement of the optical continuum emission with increasing R.

4. Broad line equivalent widths

In contrast to the narrow line results, we observe little or no anticorrelation between W_λ and R for the broad lines C IV and C III]. Perhaps Mg II shows a weak anti-correlation, although the scatter is large. The lack of a strong trend for the broad lines can be understood in terms of partial obscuration of the BLR, leading to anisotropy in the line emission.

The result for Hβ is intriguing (Fig. 1b), the equivalent width being independent of R over the range $R = 0{\cdot}01-10$, with very little dispersion. The narrow range in equivalent width can be interpreted alternatively as a direct proportionality between the Hβ line and continuum luminosity, a correlation which appears to hold for all kinds of AGN except BL Lac objects (Yee 1980; Miller *et al.* 1992). The tightness of this correlation (and its wide applicability) suggests that it is telling us something fundamental about the emission mechanism.

Hβ itself cannot be relativistically beamed, because it is not observed to be blue-shifted with respect to the narrow forbidden lines. Could the line-to-continuum proportionality imply that aspect dependence is in fact caused by obscuration and not relativistic beaming? It appears as though Hβ emanates from a region with precisely the same opening angle as the optical continuum. On the other hand, the [O II] plot in Fig. 1(a) seems to show very strong orientation effects and these are difficult to explain with current geometric models.

5. Conclusions

We have presented evidence that, on the one hand, the optical continuum of radio quasars is strongly aspect dependent and consistent with a simple Doppler beaming model. On the other hand, this straightforward interpretation appears inconsistent with the narrow distribution of Hβ equivalent width over a wide range in R, which suggests a common angular dependence for the Balmer lines and optical continuum. It is hoped that these apparently conflicting results will stimulate further theoretical work on modelling the physics and geometry of quasar emission regions.

Acknowledgements

JCB is grateful for a postgraduate scholarship from the Research Centre for Theoretical Astrophysics, Sydney University, and RWH acknowledges financial support from the Australian Research Council.

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