Unravelling Active Galactic Nuclei

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Abstract

A complete flat-spectrum radio-loud sample of AGN includes a significant fraction of Seyfert-like AGN including a NLS1. Analysis of their optical spectra suggests that the reddest continuum colours are either associated with AGN in nearby resolved galaxies, or distant quasars showing relatively narrow permitted emission lines.

Key words: galaxies: active; quasars: general; quasars: radio-loud

1 Introduction

The relationship between Seyfert galaxies and radio-loud galaxies has not been explored in detail. However, a complete sample of flat-spectrum radio-loud AGN contains a significant fraction of Seyfert-like sources, including one which would be classified as a narrow-line Seyfert 1 (NLS1).

To understand the physical mechanisms responsible for producing the different characteristics of AGN, a multiwavelength approach is needed. Correlations between properties at different wavelengths can be used to reject and refine physical models of the central regions of AGN. The Parkes Half-Jansky Flat-Spectrum Sample (PHFS) (1) is interesting in this context because it is a radio-selected sample. The selection criteria are as follows:

- Radio-loud: 2.7GHz flux > 0.5 Jy.
- Flat-spectrum: $\alpha_{2.7/5.0} > -0.5$, where $S_\nu = \nu^\alpha$
- Galactic latitude: $|b| > 20^\circ$
- $-45^\circ < \text{Dec(B1950)} < +10^\circ$

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This sample contains 323 sources with a wide range of properties which can be quite different to AGN selected by optical colours. The PHFS AGN have a large range in optical luminosities, with more than 50 objects having absolute magnitudes in the Seyfert luminosity range ($M_B >-23$). Another interesting characteristic is the large dispersion in optical colours of this sample compared with optically selected samples such as the Large Bright Quasar Survey (10; 3).

2 Spectra of the Parkes Quasars

The mechanism responsible for producing the large dispersion in optical colours, especially the significant number of red sources in the sample, is not at all well established. There have been suggestions of dust reddening (10), reddening due to the underlying galaxy spectrum (5) and synchrotron reddening (11). We consider two questions:

(1) Are the reddened continuum colours associated with changes in the emission lines of the AGN?
(2) Can we identify the reddening mechanisms contributing to each AGN?

We have low resolution optical spectra of an unbiased subsample of the PHFS. This subsample was divided into three equal colour bins based on the B-K colours of the objects: blue (B-K < 3), intermediate (3 < B-K < 4.4) and red (B-K > 4.4). A composite spectrum of the objects in each bin was made (see (4) for a description of the technique used). The results are plotted in Figure 1. It should be noted that the continuum has been normalised to the same slope for each bin to compare the emission line properties over the range of colours. The LBQS composite spectrum is also shown as a comparison with an optically selected sample (2).

There are clear differences between the different composites. The width of H$\beta$ line decreases as redness increases and OIII(3727Å) is only seen in the red composite. The MgII(2800Å) line is also quite broad in the blue and intermediate composites, and much narrower in the red composite. Further analysis of the spectra in the red bin shows there are two different types of spectra in this bin: (1) low redshift galaxy-type spectra, and (2) higher redshift quasar spectra.

Several very red objects in the Parkes sample seem to appear red owing to a large contribution from a galactic component. The 4000Å break in the spectrum of the galactic light reduces the amount of light in the blue filter giving a B-K colour which is quite red. These objects are at low redshifts and are generally resolved. Masci (5) has fitted an evolved elliptical galaxy SED to the PHFS spectra, showing that these objects have a high proportion of galactic light in their spectra. These objects also have the steepest radio spectrum
with values of $\alpha \sim -0.5$. The composite spectrum of these resolved sources is fairly typical of a galaxy with no H$\beta$ emission.

The second group of red objects in the sample are higher redshift quasar/Seyfert-type objects. They show the strong emission lines characteristic of quasars and have flatter radio spectral indices. Whiting et al. (11) have modelled the reddening by synchrotron emission using broad band SEDs. They show that these objects tend to have a strong component of synchrotron emission which is responsible for their red continuum. These quasars would be missed in a traditional blue-selected quasar sample. The composite of these unresolved sources has a completely different shape, with narrow permitted emission lines at CIV(1549Å), CIII$\lambda$(1909Å) and MgII(2798Å) superimposed on a fairly smooth continuum. Thus it appears that the red AGN have relatively narrow emission lines. A fuller description of these results will appear in Oshlack et al. (7).

![Composite optical spectra](image)

**Fig. 1.** Composite optical spectra generated from the PHFS as a function of optical (B-K) colour. The LBQS composite is also shown for an optically selected comparison. Each composite is normalized to the same continuum slope to compare emission lines. The plot shows the rest wavelength in angstroms, and the flux in arbitrary units.

### 3 A NLS1 in the Parkes Sample

In examining the spectra from the Parkes sample we have identified a NLS1 candidate, PKS 2004-447 (Figure 2). One model for NLS1s suggests they are AGN oriented towards us, so that the doppler broadening of a disk-like Broad Line Region would naturally produce narrower emission lines (6). An
extremely radio-loud NLS1 could provide an independent test of such physical models of NLS1s, and AGN unification in general.

Fig. 2. Low resolution spectrum of PKS 2004-447, a candidate radio-loud NLS1.

A low resolution spectrum of this source shows an H\(\beta\) width of \(\sim 2000\) km s\(^{-1}\). There is some indication of FeII emission on the blueward side of H\(\beta\) and the source has been detected at X-ray energies \(^{(8)}\). This object is extremely radio-loud with a radio to optical flux ratio (R) exceeding 7000. The colour of PKS 2004-447 is very red, in contrast with the previously discovered radio-loud NLS1, RGB J0044+193 which was quite blue \(^{(9)}\). The radio spectrum of PKS 2004-447 is also quite steep, with recent measurements of the (contemporaneous) radio spectral index giving \(\alpha_R = -0.67\), consistent with radio indices of radio-quiet NLS1s (Moran, these proceedings). A higher resolution spectrum of PKS 2004-447 will be obtained, to confirm its identity.

References

[1] M.J. Drinkwater, R.L. Webster, P.J. Francis, J.J. Condon, S. Ellison, D. Jauncey, J. Lovell, B.A. Peterson, A. Savage, MNRAS, (1997), 284, 85.
[2] P.J. Francis, P.C. Hewett, C.B. Foltz, F.H. Chaffee, R.J. Weymann, S.L. Morris, ApJ, (1991), 373, 465.
[3] P.J. Francis, M.T. Whiting, R.L. Webster, PASA, (2000), in press.
[4] P.J. Francis, P.C. Hewett, C.B. Foltz, F.H. Chaffee, R.J. Weymann, S.L. Morris, ApJ, (1991), 373, 465.
[5] F.J. Masci, R.L. Webster, P.J. Francis, MNRAS, (1998), 301, 975.
[6] D. E. Osterbrock, R. W. Pogge, ApJ (1985), 297, 166.
[7] A.Y.K.N. Oshlack, R.L. Webster, M.J. Drinkwater, M.T. Whiting, PASA, (2000), submitted.
[8] J. Siebert, W. Brinkmann, M.J. Drinkwater, W. Yuan, P.J. Francis, B.A. Peterson, R.L. Webster, MNRAS, (1998), 301, 261.
[9] J. Siebert, K.M. Leighly, S.A. Laurent-Muehleisen, W. Brinkmann, T. Boller, M. Matsuoka, A&A, (1999), 348, 678.
[10] Webster, R. L., Francis, P. J., Peterson, B. A., Drinkwater, M. J., Masci, F. J., *Nature*, (1995), *375*, 469.

[11] M.T. Whiting, R.L. Webster, P.J. Francis, *MNRAS*, (2000), submitted.