

Spectroscopic observations of southern N-galaxy candidates

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Received 1982 November 11

Summary. In an attempt to discover new broad-line radio galaxies (BLRG), spectra were taken of a sample of southern radio sources identified as N galaxies. Twenty candidates were observed and 12 redshifts were measured, yet only one probable and one possible broad-line galaxy were discovered. Fourteen other radio sources identified as galaxies were also observed; 10 redshifts were measured.

1 Introduction

Studies of radio galaxies with emission lines in their spectra have shown that these objects can be divided, on the basis of the widths of their spectral lines, into two classes: broad-line radio galaxies (BLRG) and narrow-line radio galaxies (NLRG). This division is more or less similar to the division of Seyfert galaxies into Types 1 and 2, respectively (Osterbrock, Koski & Phillips 1975). Furthermore, this spectroscopic classification corresponds very well with a morphological classification of radio galaxies, since nearly all BLRG are N galaxies while nearly all NLRG are cD, D or E galaxies (Grandi & Osterbrock 1978).

The class of BLRG/N galaxies (which we will consider equivalent for the present) has some very interesting properties. They tend to be X-ray sources, have relatively weak non-thermal continua, have prominent galactic absorption spectra, have very broad, very complex and very variable Balmer-line profiles, and have steeper Balmer decrements, smaller Fe II/H β ratios and much weaker 3000-Å bumps than classic Seyfert 1 galaxies (Osterbrock *et al.* 1975; Marshall *et al.* 1978; Grandi & Osterbrock 1978; Miller, French & Hawley 1980). In other words, while BLRG are to first approximation very similar to Seyfert 1 galaxies and to quasars, they can be distinguished from their active-galactic-nucleus (AGN) cousins by having lower-luminosity power sources, and emission-line cloud ensembles that are both moving faster and are closer to the central powerhouse.

Unfortunately, there are only a relatively small number of BLRG known; Grandi & Osterbrock (1978) list 15. The detection of more such objects would lead to further information about how all types of AGN interrelate, as well as providing new objects

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interesting in themselves. I therefore undertook a programme to identify new BLRG by spectroscopically observing radio sources that have been optically identified as N galaxies.

2 Observations

Objects in the under-observed southern hemisphere were chosen from sources in the Parkes, and the Parkes 2700-MHz, radio surveys that are optically identified as N galaxies. Also chosen, as programme fillers, were sources from the same surveys that were identified as other types of galaxies.

Spectroscopic observations were made in 1977 June with the SIT Vidicon attached to the Cassegrain spectrographs of the Cerro Tololo Inter-American Observatory 4- and 1.5-m reflectors (Atwood *et al.* 1979). The useful spectral range of the SIT scans was approximately $\lambda\lambda$ 4300 to 6900 (although the system response dropped rapidly beyond λ 6500). Unfortunately, [O II] λ 3727 could therefore not be observed, even for moderately redshifted galaxies, but the survey was designed to detect the strong, broad H β lines characteristic of BLRG. Each pixel in a SIT scan represents approximately 6 Å, so the resolution is approximately 12 Å.

Table 1. SIT observations of radio sources identified as N galaxies.

Objects with measured redshifts

Object	Reference	m	z	Identified lines
PKS 0053 – 016	3	16.4	0.042	4306, 5178, 5891
PKS 0053 – 015	3	16.7	0.041	4306, 4861, 5178, 5891
PKS 1005 + 007	3	16.9	0.099	3933, 3968, 4306, 5178, 5891 EM: 4959, 5007
PKS 1304 – 215	1	17.5	0.126	3933, 4306, 5178, 5891 EM: 4959, 5007
PKS 1340 + 05	2	17.8	0.136	3933, 4306, 5178 EM: 4340, 4861, 4959, 5007
PKS 1342 – 314	5	17	0.143	3933, 3968, 4306, 4861, 5178, 5891
PKS 1601 – 00	3	17.5	0.034	4861, 5178, 5891
PKS 2159 – 335	5	17.5	0.152	3933, 3968, 4306, 4384, 5178
PKS 2206 – 237	1	17	0.086	5178 EM: 4340, 4861, 4959, 5007, 6300, 6363
PKS 2242 – 297	6	17.5	0.166	3933, 3968, 4306, 5178
PKS 2309 – 416	7	16	0.088	3935, 4306, 4861, 5178
PKS 2333 – 318	5	16	0.060	4306, 4861, 5178, 5891

Objects with uncertain spectra

Object	Reference	m	Observed lines
PKS 2005 – 489	6	16.5	5047
PKS 2117 – 269	1	18	5709
PKS 2153 – 219	3	17.2	5680
PKS 2225 – 308	5	16.5	6237, 5790, 5337

Objects with zero or near-zero redshifts

Object	Reference	m	Identified lines
OP 282	4	17	4306, 4861, 4178, 5891
OQ 151	4	17	4306, 5178, 5891
PKS 1437 – 153	1	17.5	4306, 4861, 5178, 5891
PKS 2258 – 619	7	15	4861, 5173, 5891, 6562

References

1. Bolton *et al.* (1975). 2. Clarke *et al.* (1966). 3. Merkelijn & Wall (1970). 4. Radovich & Kraus (1971).
5. Shimmins & Bolton (1974). 6. Savage *et al.* (1977). 7. Wall & Cannon (1973).

Table 2. SIT observations of other radio sources.

Objects with measured redshifts

Object	Reference	Galaxy type	m	z	Identified lines
PKS 0013 – 240	6	S	17.0	0.063	EM: 5007, 6562
PKS 1258 – 321	4	E	13	0.017	4306, 4861, 5178, 5891
PKS 1323 – 271	2	E	15	0.044	4306, 4861, 5178, 5891
PKS 1407 – 425	1	E	15.5	0.053	3968, 4306, 5178, 5891
PKS 1444 – 301	4	E	15	0.014	4306, 5178, 5891
PKS 1833 – 77	5	E	14.5	0.018	4306, 5178, 5891
PKS 1935 – 526	7	D	16	0.030	4306, 4861, 5178, 5891
PKS 1941 – 554	7	E	14	0.014	4861, 5178, 5891
PKS 2027 – 308	4	S	16.5	0.021	EM: 4861, 6562
PKS 2128 – 388	1	E	14.5	0.016	4306, 4861, 5178, 5891

Objects with uncertain spectra

Object	Reference	Galaxy type	m	Observed lines
PKS 2031 – 359	1	E	15.5	5292

Objects with zero or near-zero redshifts

Object	Reference	Galaxy type	m	Identified lines
PKS 1617 – 235	2	E	16.5	TiO
PKS 1814 – 63	3	E	16	4861, 5891, 6562
PKS 1926 – 359	7	E	15	4101, 4340, 4861, 6562

References

1. Bolton & Shimmins (1973). 2. Bolton *et al.* (1975). 3. Hunstead *et al.* (1971). 4. Shimmins & Bolton (1974). 5. Savage *et al.* (1977). 6. Wall *et al.* (1976). 7. Wall & Cannon (1973).

The spectroscopic observations of radio sources identified as N galaxies are summarized in the three sections of Table 1: objects with measured redshifts, objects with uncertain spectra and objects (presumably stars) with zero or near-zero redshifts. Entries for each object include the object name, the reference number of the optical identification and finding chart, the optical magnitude, the redshift (if known) and a list of identified or observed lines. For the identified lines the following codes are used: 3933 refers to the Ca II K line, 3968 refers to the Ca II H line, 4306 refers to the *G* band, 4340 refers to H γ , 4861 refers to H β , 4959 and 5007 refer to the [O III] lines, 5178 refers to the Mg I *b*-band, 5891 refers to the Na I D line, 6300 and 6363 refer to the [O I] lines and 6562 refers to H α . Lines listed after 'EM:' were detected in emission. The observations of the other radio sources identified as galaxies are listed in Table 2 in the same manner as in Table 1. Notes on individual objects listed in Tables 1 and 2 follow.

3 Radio sources identified as N galaxies

3.1 OBJECTS WITH MEASURED REDSHIFTS

3.1.1 PKS 0053 – 016 and 0053 – 015

These two galaxies, both members of Abell cluster A119, lie within the radio source structure of PKS0053 – 01. Schilizzi (1975) refers to PKS0053 – 016 as galaxy a and PKS

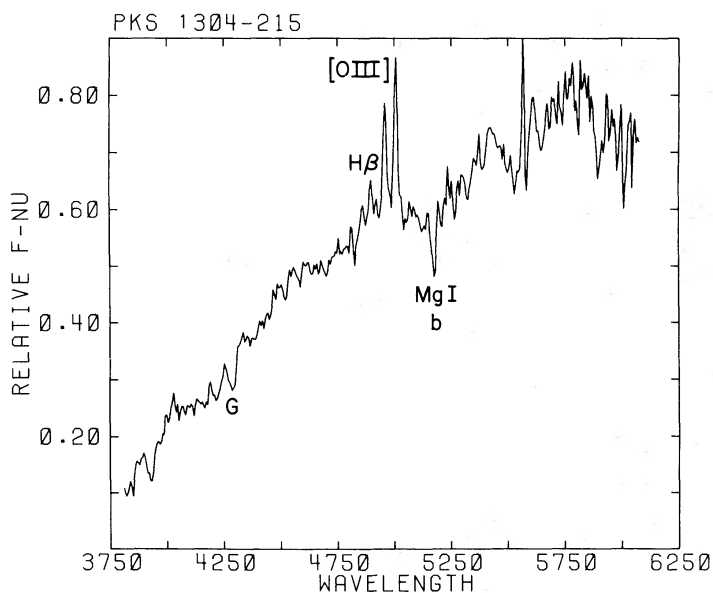


Figure 1. CTIO SIT scan of the possible BLRG PKS 1304 – 215. Relative F_{ν} is plotted against unredshifted wavelength.

0053 – 015 as the southern member of the pair d. Danziger & Goss (1979) observed Schilizzi's galaxy c and found it to be a narrow-line emission galaxy with a redshift of $z = 0.0414$ and therefore probably the correct optical identification for PKS0053 – 01. Apparently PKS0053 – 016 and 0053 – 015 are chance coincidences with the peak emissions of the two lobes of PKS0053 – 01. Also note that Schilizzi (1975) and Wall, Shimmins & Merkelijn (1971) both list PKS0053 – 016 and 0053 – 015 as E galaxies rather than N galaxies as identified by Merkelijn & Wall (1970).

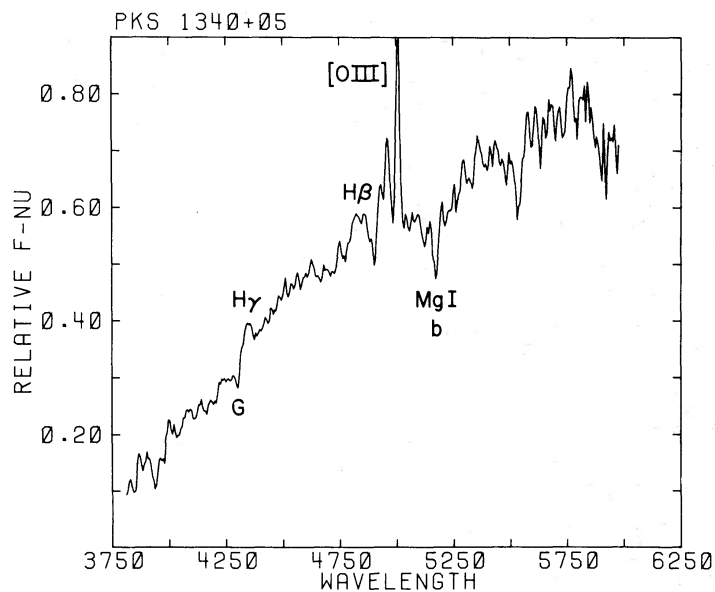


Figure 2. CTIO SIT scan of the probable BLRG PKS 1340 + 05. Relative F_{ν} is plotted against unredshifted wavelength.

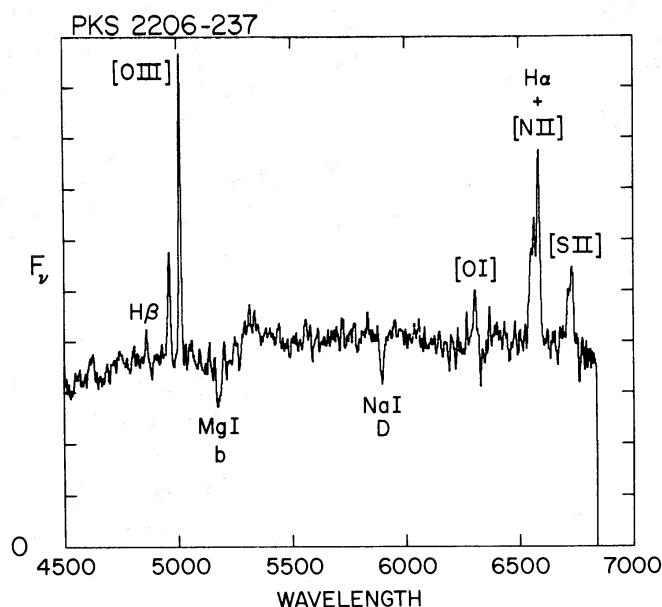


Figure 3. Lick Observatory ITS scan of the NLRG PKS 2206 – 237. Relative F_v is plotted against unredshifted wavelength.

3.1.2 PKS 1304 – 215

This galaxy is possibly a BLRG (see Fig. 1). The [O III] lines are prominent and weak, and broad H β emission is possibly present. Unfortunately, H α at a redshift of 0.126 occurs at λ 7390 which is beyond the range of the SIT observations.

3.1.3 PKS 1340 + 05

This galaxy is probably a BLRG (see Fig. 2). Broad H γ and H β are present, as are strong, narrow [O III] $\lambda\lambda$ 4959, 5007. Also present are prominent galactic absorption lines. PKS 1304 + 05 was previously observed by Burbidge (1967) who determined a redshift $z = 0.1334$ (from Ca II *H* and *K* absorption and narrow [O II] λ 3727 emission). Once again, H α falls outside the range of the SIT observations.

3.1.4 PKS 2206 – 237

This galaxy is a NLRG with a spectrum much like those shown in Costero & Osterbrock (1977). A red spectrum taken on 1977 July 11 with the Robinson–Wampler image-tube scanner (ITS) attached to the 3-m Shane telescope of Lick Observatory shows the [N II] + H α complex and the [S II] blend (see Fig. 3).

3.2 OBJECTS WITH UNCERTAIN SPECTRA

3.2.1 PKS 2005 – 489

This object, which was observed to be much brighter than the tabulated magnitude, has a continuous spectrum with no obvious lines. Savage, Bolton & Wright (1977) suggest that ‘this object could possibly be a planetary nebula’, a possibility that now appears untenable.

4 Other radio sources

4.1 OBJECTS WITH MEASURED REDSHIFTS

4.1.1 PKS 0013 – 240

This object shows [O III] λ 5007 and H α emission, both apparently narrow. H β is possibly present. Wall *et al.* (1976) note that PKS 0013 – 240 is in a small cluster and has a blue stellar nucleus.

4.1.2 PKS 1941 – 554

Wall & Cannon (1973) note that this object has a radio spectrum which suggests the presence of a compact high-frequency component, but no emission lines were found on their Mt Stromlo plates. Danziger & Goss (1979) confirm the absorption-line redshift listed in Table 2; they also report the presence of weak [O III] λ 5007 emission (which is not confirmed by the SIT scan) and prominent H α + [N II] and [S II] emission lines (both of these features are to the red of the useful sensitivity range of the SIT).

4.1.3 PKS 2027 – 308

Shimmins & Bolton (1974) note that this galaxy is very blue and suggest that it is a possible Seyfert galaxy. While prominent H α and weak H β emission lines are seen in the SIT scan and [S II] emission is seen on a red scan taken on 1977 July 8 with the Lick Observatory ITS, the strong [O III] lines typical of a Seyfert galaxy are not observed. Rather, PKS 2027 – 308 is probably a member of the class of very-narrow-line emission galaxies.

4.2 OBJECTS WITH ZERO OR NEAR-ZERO REDSHIFTS

4.2.1 PKS 1617 – 235

The bright ‘nucleus’ reported for this object is obviously a superimposed M star: the spectrum rises toward the red and shows the very prominent TiO bands characteristic of such a star.

4.2.2 PKS 1814 – 63

This object, whose SIT scan shows only absorption lines at zero redshift, has also been discussed by Danziger & Goss (1979). Their data, with a better signal-to-noise ratio and extending further to the red, show [O III], H α , [N II] and [S II] emission at a redshift of 0.063. Apparently a foreground star contaminates the spectrum.

4.2.3 PKS 1926 – 359

The SIT scan of this object shows prominent *blueshifted* Balmer absorption lines. From the measured location of H β , the ‘cleanest’ line, a velocity shift of approximately -750 km s^{-1} is present. Since this shift corresponds to little more than one resolution-element in the scan and could conceivably be caused by peculiar placement of the object within the spectrograph slit, PKS 1926 – 359 should be re-observed. It was identified by Wall & Cannon (1973) as an E galaxy.

5 Discussion

As is obvious from the observations listed above, the results of the search for new BLRG were disappointing. The question that needs to be answered is: Why was the expectation that a sample of N galaxies should yield a rich lobe of BLRG so mistaken? After all, previous work indicates that most radio galaxies show reasonably strong emission lines in their spectra (Smith, Spinrad & Smith 1976) and that most emission-line radio galaxies morphologically classified as N galaxies show the broad permitted lines typical of BLRG (Grandi & Osterbrock 1978).

I can suggest two possible answers to this dilemma, neither very probable or satisfactory. First, it is at least conceivable that the morphological criteria used to classify the members of my sample as N galaxies differ from the criteria used by earlier investigators. Secondly, most of the N galaxies in my sample were discovered in the Parkes 2700-MHz survey whereas practically all of the N galaxies previously discovered to be BLRG were first catalogued in low-frequency surveys. Indeed, the one probable BLRG in my sample, PKS 1340+05, is a low-frequency source. However, analysis of the fraction of the high-frequency sources that turn out to be galaxies indicate that they are quite similar to low-frequency radio galaxies (Longair 1980). As a final note, the absence of any emission lines, broad or narrow, in most of the radio galaxies in my sample can be naturally explained by noting that $[\text{O II}] \lambda 3727$, which is the most commonly observed emission line in the spectra of radio galaxies, is too blue to be observed in any of the SIT scans.

Acknowledgments

I wish to acknowledge the encouragement of Dr D. E. Osterbrock and the financial support of the Lick Observatory and the National Science Foundation (under grant AST 76-18440) towards the research reported in this paper.

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