Mon. Not. R. astr. Soc. (1983) **202,** 703–715

Optical spectroscopy of 28 southern radio galaxies

I. J. Danziger *European Southern Observatory, Karl-Schwarzschild Str. 2, D-8046 Garching bei München, West Germany*

W. M. Goss *Kapteyn Astronomical Institute, 9700 AV Groningen, The Netherlands.*

Received 1982 June 8; in original form 1982 May 6

Summary. The results of an optical spectroscopic survey of 28 southern radio galaxies including redshifts and descriptions of their spectra are presented. One of these objects is a quasar, while five of the remainder involve fields where more than one galaxy has been observed because of the complex radio structure or uncertain identification. A Fleurs synthesis telescope map at 21 cm of PKS 0114 – 47 and a VLA map at 6 cm of PKS 0843 – 33 are also presented and discussed.

1 Introduction

During the period 1976–77 we initiated a spectroscopic survey of southern radio sources at the AAT. In general this was an attempt to define better the spectroscopic characteristics of steep-spectrum Parkes radio sources identified with galaxies. However, this was not a strictly defined sample, and a particular bias toward galaxies with emission-line activity was introduced whenever there was some indication in the literature of this phenomenon. The justification for this arises from the fact that earlier spectroscopic work, lacking the simultaneous sky subtraction properties and red response of new modern detectors on a larger telescope, could not elucidate the subtle and important properties associated with the spectra of many objects. This is exemplified by the spectrophotometric study of Pictor A by Danziger, Fosbury & Penston (1977).

The results of some of this work have already been published (Danziger, Goss & Frater 1978; Danziger & Goss 1979; Danziger, Goss & Wellington 1981) and the results for several other galaxies will be published elsewhere. We present here results for a somewhat heterogeneous selection of radio galaxies.

2 Observations

Almost all of the optical observations presented here were obtained with the image-dissector-scanner attached to the Boller and Chivens spectrograph mounted at the Cassegrain focus of the 3.9-m telescope of the Anglo-Australian Observatory. A diaphragm size of 3.5 arcsec combined with a 600 groove mm^{-1} grating resulted in an effective resolution of ~ 9 Å. The small diaphragm size was such as to prevent good absolute spectrophotometry, but in most cases reasonably accurate photometry relative to a flux at a given wavelength was possible. These fluxes were obtained by observing Oke's (1974) white dwarf standards on the same night and calibrating the system response in the usual way.

3 Results

We present in Table 1 a summary of quantitative data derived from the optical galaxies associated with the radio source. The columns in this table are mainly self-explanatory. Column 8 provides references to earlier identification work. Our discussion is based on an assumed Hubble constant $H_0 = 50\ \mathrm{km\ s^{-1}\ Mpc^{-1}}$.

In what follows we provide further descriptions of the sources that may be of particular interest.

0018 – 19

The identified galaxy has a sharp emission-line spectrum of high excitation but small equivalent width due to a strong stellar component. It lies midway between an unequal double (9:1) radio source having a linear size of 0.7 Mpc.

0114 – 47

This galaxy was discussed briefly by Danziger *et al.* (1978), who identified it as a giant radio galaxy of linear size 1.8 Mpc. Its spectrum contains narrow emission lines of small equivalent width and stellar absorption lines. It has been observed with the Fleurs synthesis telescope at 1.4 GHz and the resulting map is shown in Fig. 1. It has a spectral index $\alpha = 0.6$ ($S \propto \nu^{-\alpha}$). The structure suggests a radio jet from the galaxy towards the south-east lobe. There are two

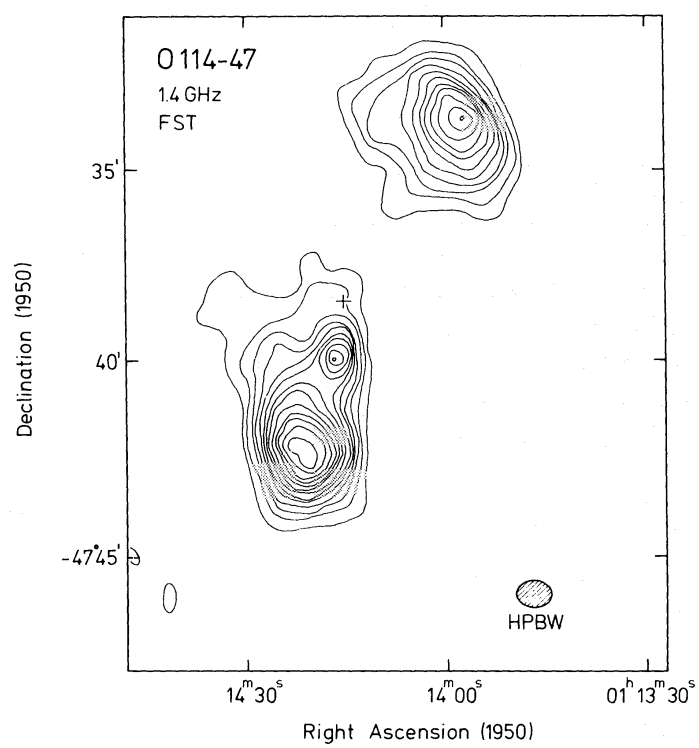

Figure 1. A map of the giant radio galaxy PKS 0114 – 47 at 1.4 GHz obtained with the Fleurs synthesis telescope. The HPBW of 55 × 45 arcsec² is indicated. The contour intervals are 25, 50, 75 ... 325 mJy/beam where 25 mJy/beam corresponds to 6.7 K in beam brightness. The galaxy is indicated by a cross.

Table 1. Properties of 28 southern radio galaxies.

Name PKS	α 1950 h m s	δ 1950 ° ′ ″	m m	z	Lines: Absorption	Lines: Emission	References
0018-19	00 18 35.8	-19 26 44	17 E	.0952 ± .0004	G, Mg, MgH, D	[OIII], [NII]	1
0114-47	01 14 14.9	-47 38 29	16.5 E	.146 ± .001	H, K, G, Mg, D	[OII], Hβ, [OIII], [OI], [NII]	1, 2
3C40							1,3
NGC 541	01 23 11.2	-01 38 21	12.7 E	.0168 ± .0004	Mg, D		
NGC 545	01 23 26.1	-01 36 00	11.9 db	.0172 ± .0004	Mg, D		
NGC 547	01 23 27.6	-01 36 19		.0174 ± .0004	Mg, D		
0202-76	02 02 01.1	-76 34 33	16 QSO	.3896 ± .0003		[OIII], [OII]	4, 5
0214-48	02 14 52.8	-48 03 01	14.5 D	.0640 ± .0006	Mg, MgH, D		1
0427-53							1,6
IC 2082(C)	04 27 58.9	-53 56 10	13 db	.0385 ± .001	G, Mg, MgH, D		
IC 2082(D)	04 27 57.6	-53 56 06		.039 ± .002	Mg, D		
IC 2082(B)	04 28 10.0	-53 55 28	14.5 E	.039 ± .003	H, K, G, Mg		
IC 2082(A)	04 28 17.7	-53 56 06	15 E?	.039 ± .001	G, Mg, D		
0625-53	06 25 18.0	-53 39 27	15.4 db	.054 ± .001	Mg, D		7
0800-09							1
a(i)	08 00 12.0	-09 49 16	17.5	Star? z∿0			
a(ii)	08 00 12.6	-09 49 14	17 g	.0699 ± .0005	Mg, D		
b	08 00 16.2	-09 49 44	17.5 g	.0865 ± .0005	Mg, MgH, D		
0819-30	08 19 24.7	-30 01 27	18 g	.086 ± .001	Mg, D	[OI]?, [NII], Hα?	1
0833-01 NGC 2616	08 33 03.0	-01 40 42	13.9 E	.0300 ± .0004	Mg, MgH, D		8
0843-33 NGC 2663	08 43 08.0	-33 36 55	12.3 E	.0066 ± .0004	Mg, MgH, D, G	[NII]	
0915-11 Hydra A	09 15 41.2	-11 53 04	14.8 D	.0548 ± .0003	Mg, D	[OIII], [OI], [NII], Hα, Hβ	9
1146-11	11 46 33.6	-11 47 53	18 g	.117 ± .001	Mg, D		1
1216-10	12 16 03.4	-10 03 56	16 D	.0874 ± .0003	Mg, D	[OIII], [OII], [NII], Hα, Hβ	1
1234-72	12 34 05.1	-72 19 02	14.5 E	.0246 ± .0004	G, Mg, D		1
1331-09	13 31 40.1	-09 54 08	17.5 E	.081 ± .003	Mg, D		1, 14
1358-11	13 59 01.3	-11 21 58	15 E	.0367 ± .0004	K, G, Mg, MgH, D	[NII]?	1
1514+00	15 14 05	+00 26	16.5 E	.0518 ± .0003	Mg, D	[OIII], [OI], [NII], Hα, Hβ	10
1602-63	16 02 06	-63 21 36	17.5 db	.0588 ± .0007	G, Mg, D	[OIII]	6
1610-60							6
A	16 10 43.2	-60 46 54	13 E	.0170 ± .0004	Mg, D		
C	16 10 49.3	-60 45 57	15.5 S	.0217 ± .0004	Mg, D		
D	16 11 25.3	-60 47 38	13 E	.0117 ± .0004	Mg, D		
E	16 11 13.2	-60 32 25	14 E	.0157 ± .0004	Mg, D		
G	16 11 29.6	-80 40 38	13.5 E	.0109 ± .0004	Mg, D		
1637-77	16 37 06	-77 10 06	16.0 D3	.024 ± .002	Mg, MgH, D		13
1846-63	18 46 06.4	-63 07 59	15 E	.0148 ± .0004	Mg, D		1
2006-56							1, 15
(a)	20 06 19.8	-56 39 02	16.5 SO	.058 ± .001	G, Mg, D		
(b)	20 06 22.1	-56 36 51	16.5 E4	.0576 ± .0007	Mg, D		
(d)	20 07 27.5	-56 53 04	16 E2	.053 ± .001	Mg, D		
2014-55	20 14 06.1	-55 48 52	15.5 EO	.0600 ± .0003	Mg	[OIII], [OII], [OI], Hα, Hβ	1
2152-69	21 52 57.8	-69 55 40	13.8 E(D)	.0285 ± .0003	Mg, D	[OIII], [OII], [OI], Hβ	1
2300-18	23 00 23	-18 57 30	18.3 N	.1290 ± .0003		[OIII], [OII], [OI], [NII] Hα, Hβ	11
2349-01	23 49 23	-01 26	17.5 N	.174 ± .0005		[OIII], [OII]	12
2356-61	23 56 29.4	-61 11 41	16 E3(D)	.0958 ± .0003	Mg	[OIII], [OII], [NII], Hα, Hβ	1

References

1. Schilizzi & McAdam (1975), Schilizzi (1975).
2. Danziger, Goss & Frater (1978).
3. Schilizzi, Lockart & Wall (1972).
4. Ekers (1970).
5. Anguita & Pedreros (1977).
6. Christiansen *et al.* (1977).
7. Wall, Shimmins & Bolton (1975).
8. Wall, Shimmins & Merkelijn (1971).
9. Matthews, Morgon & Schmidt (1964).
10. Bolton, Shimmins & Merkelijn (1968).
11. Bolton & Ekers (1966a).
12. Bolton & Ekers (1966b).
13. Ekers (1970).
14. Chen *et al.* (1982).
15. Goss *et al.* (1982).

faint sources in the field with the following positions (1950) and flux densities:

$$\alpha\, 01^h 12^m 32^s.6 \pm 0^s.3, \delta\, -47° 43' 30'' \pm 3'', S = 175 \pm 20\,\text{mJy}; \quad (1)$$

$$\alpha\, 01^h 15^m 16^s.6 \pm 0^s.3, \delta\, -47° 23' 53'' \pm 3'', S = 320 \pm 30\,\text{mJy}. \quad (2)$$

There is no obvious optical identification with (2) on the UK Schmidt IIIa-J survey brighter than 21 mag. For (1) there is a 17-mag stellar object within 5 arcsec of the radio position.

0123 – 01 (3C40)

NGC 541, 545/7 lie in the central region of the cluster A 194. There is an intergalactic bridge between NGC 541 and 545/7 which has been discussed by Simkin (1976). Emission lines are not apparent in the spectra of any of these objects. The complex radio structure has been discussed by Schilizzi & McAdam (1975) and references therein.

0202 – 76

This 17-mag QSO has been discussed by Jauncey *et al.* (1978). In Fig. 2 the spectrum for the narrow emission-line region can be seen to be of high excitation. The broad Balmer emission lines are asymmetric with a pronounced redward extension, and Hβ has a full width at zero intensity in the rest frame of > 17 000 km s^{-1}. An absorption feature at 7195 Å corresponds to the Mg stellar absorption feature in galaxies at 5175 Å in the rest frame. The radio angular size is < 0.4 arcmin and the spectral index, 0.9 ± 0.1 from 408 to 5000 MHz is quite steep.

0214 – 48

This is a D galaxy without emission lines. The north–south extension of the double-double radio structure (Christiansen *et al.* 1977) implies a linear size of 1 Mpc.

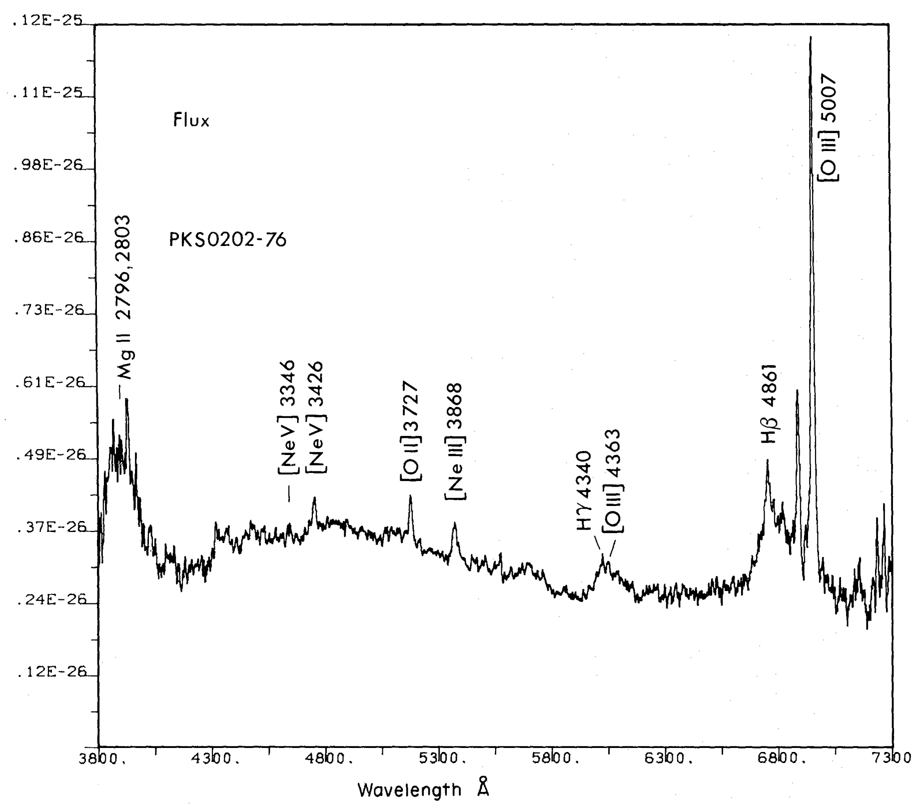

Figure 2. The spectrum of PKS 0202 – 76 calibrated in frequency units (erg cm^{-2} s^{-1} Hz^{-1}).

0427 – 53

The nomenclature for the four galaxies discussed here is that used by Christiansen *et al.* (1977) who suggest that galaxy B may be the active galaxy for a head–tail source. Optical emission lines have not been detected in the spectra of any of these objects.

0625 – 53

The optical identification of this source was made by Bajaja (1970). It has a steep radio spectral index (0.9).

0800 – 09

Schilizzi (1975) proposes three possible optical identifications. We find *a*(i) is a star, and *a*(ii) and *b* are galaxies differing in redshift by 5000 km s^{-1}. They are therefore probably unrelated. Neither have emission lines so there is no preferred choice for the active galaxy. The source is a large double of size 0.85 or 1.1 Mpc, depending on which galaxy is the correct identification.

0819 – 30

The identification by Schilizzi (1975) is with a very red galaxy which has narrow weak emission lines as well as stellar absorption lines. It has a double radio structure of dimension 0.68 Mpc.

0833 – 01

This bright E galaxy has no emission lines. The radio spectral index from 85 to 5000 MHz is 0.8.

0843 – 33

This E galaxy (NGC 2663) has [N II] emission lines as well as stellar absorption features. The flux density at 11 cm is 1.5 Jy. At 6 cm the VLA map shown in Fig. 3 reveals a compact nucleus (< 1.5 arcsec) of 135 ± 40 mJy and a jet structure approximately 70 arcsec long at

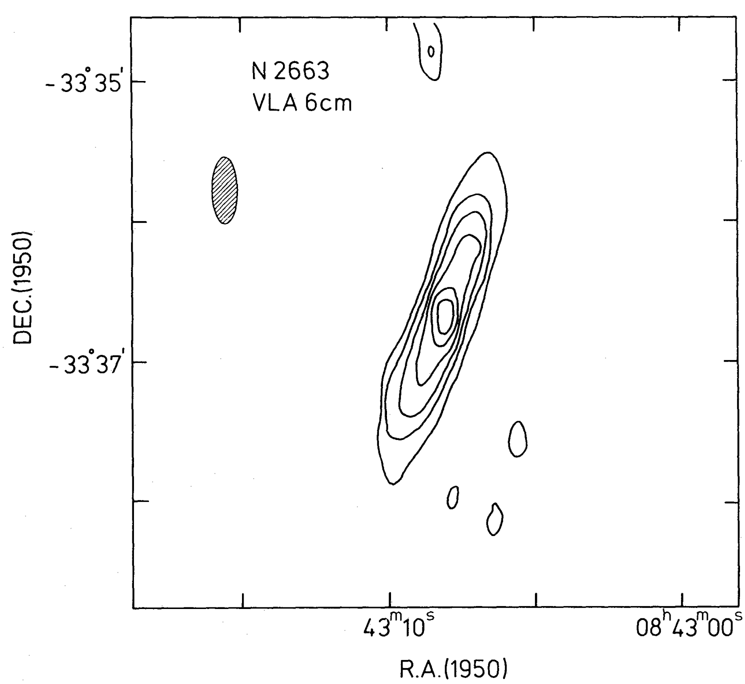

Figure 3. A VLA map of PKS 0843 – 33 (NGC 2663) at 6 cm. The beam size is 10 × 28 $arcsec^2$ and the contours correspond to 16, 31, 47, 78, 109, 140 mJy/beam area.

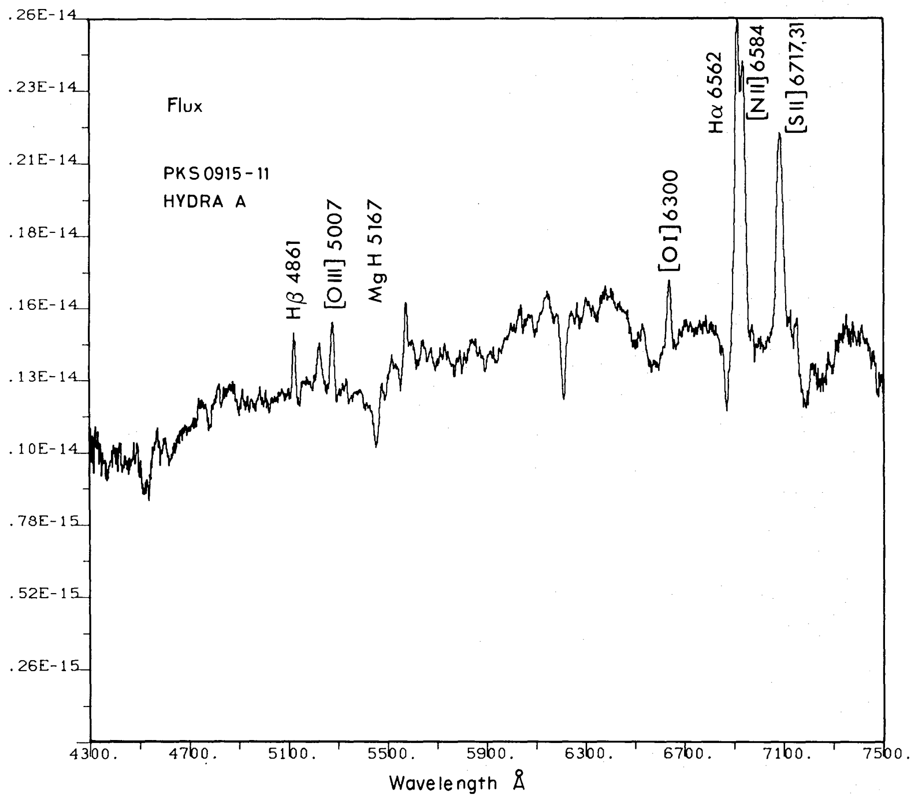

Figure 4. The spectrum of PKS 0915 – 11 (Hydra A) calibrated in wavelength units (erg cm^{-2} s^{-1} Å^{-1}).

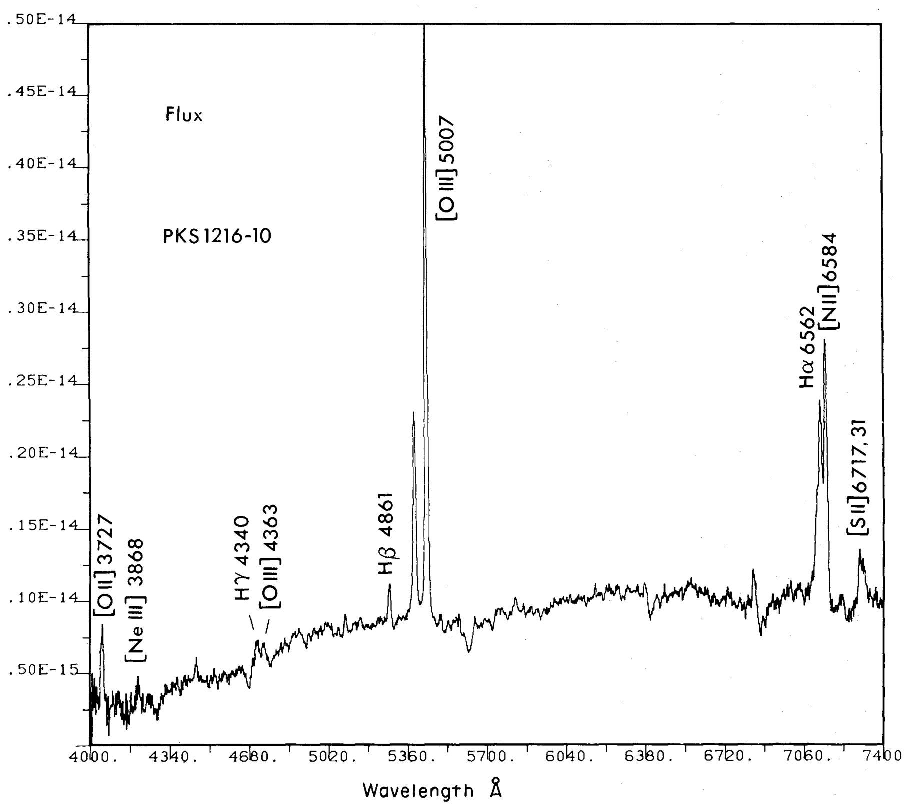

Figure 5. The spectrum of PKS 1216 – 10 calibrated in wavelength units.

position angle $-20°$. The total single-dish (Parkes) flux density at 6 cm is 950 mJy; but the total VLA flux is 650 mJy. This implies that the source is larger than is shown in Fig. 3. The VLA map was made in 1979 September with the incomplete VLA with 17 antennas.

0915 – 11 (Hydra A)

The spectrum of this D galaxy was first discussed by Matthews, Morgan & Schmidt (1964). Our spectra shown in Fig. 4 reveal a low-excitation emission-line spectrum superimposed on a strong stellar continuum. The radio structure is discussed by Ekers & Simkin (1982).

1146 – 11

Only stellar absorption lines are visible in the spectrum. It has a double radio structure with a dimension of 0.68 Mpc.

1216 – 10

The spectrum shown in Fig. 5 reveals the characteristic narrow high-excitation emission lines, including He II 4686, superimposed on the stellar absorption lines. The radio double structure has a dimension of 0.76 Mpc.

1234 – 72

The identification and redshift have been given by Tritton & Schilizzi (1973). There are no visible optical emission lines. The dimension of this extended source is 0.4 Mpc.

1331 – 09

This red E galaxy has no visible emission lines. The most recent radio map has been made with the Fleurs synthesis telescope by Chen *et al.* (1982) who point to similarities of the double radio structure with Cygnus A. It has a size of 1.9 Mpc.

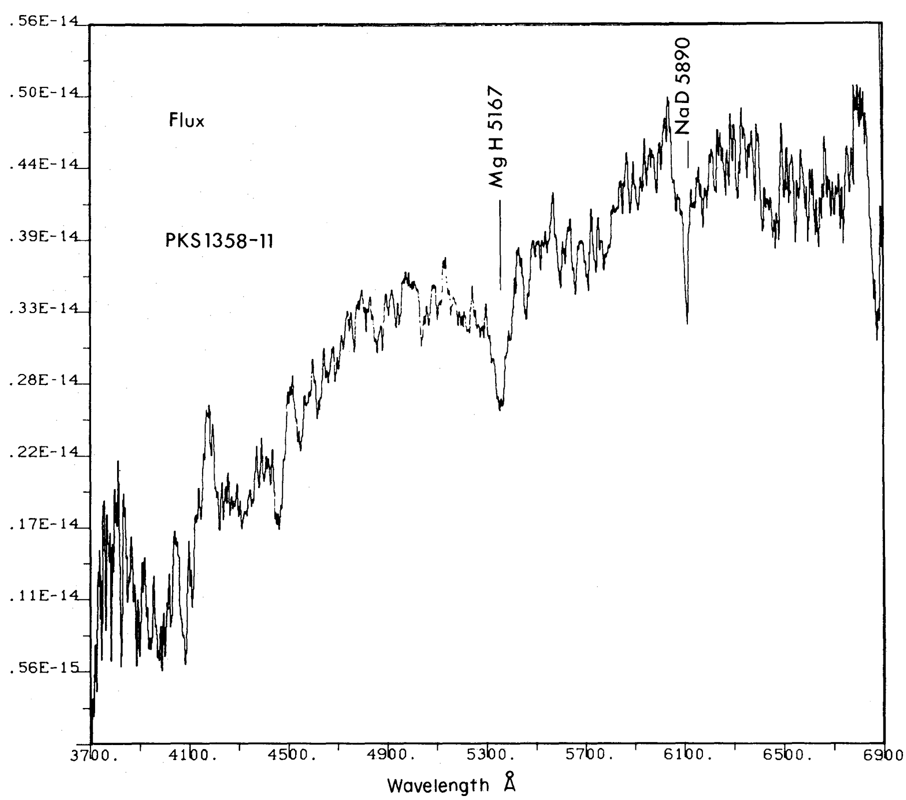

Figure 6. The spectrum of PKS 1358 – 11 calibrated in wavelength units.

1358 – 11

Searle & Bolton (1968) obtained a redshift $z = 0.026$ by measuring apparent emission lines of [O III]. There is some evidence in our spectra in Fig. 6 that these may be high points in a stellar continuum. Our redshift $z = 0.0367$ comes from absorption lines and [N II] emission. This double radio source lies in the cluster Abell 1836 and has a size of 0.34 Mpc.

1514 + 00 (4C 0.56)

The optical spectrum in Fig. 7 shows it to be of intermediate excitation with the [O III] lines resolved. This could be due to rotational motion. It has a triple structure (Fomalont 1971) with a size of 0.4 Mpc and spectral index 0.6 ± 0.1.

1602 – 63

This db galaxy has weak emission lines superimposed on the stellar absorption-line spectrum. An FST map of this double radio source has been published by Christiansen *et al.* (1977). The size is 0.75 Mpc.

1610 – 60

Five galaxies all having only stellar absorption lines were measured in a loose group in the area of the two radio sources 1610 – 60.8 and 1610 – 60.5 (Christiansen *et al.* 1977). Galaxy A is the identification for the double 1610 – 60.8 proposed by Ekers (1970), and E is the identification for 1610 – 60.5. The mean velocity for this group of five galaxies 4618 ± 1309 km s^{-1} compares closely with the mean value for 19 galaxies in the group of 4600 ± 1000 km s^{-1} obtained by Ekers & Pickles (private communication).

1637 – 77

This galaxy appears to have weak emission lines of [O I] 6300 and Hα superimposed on a stellar absorption-line spectrum.

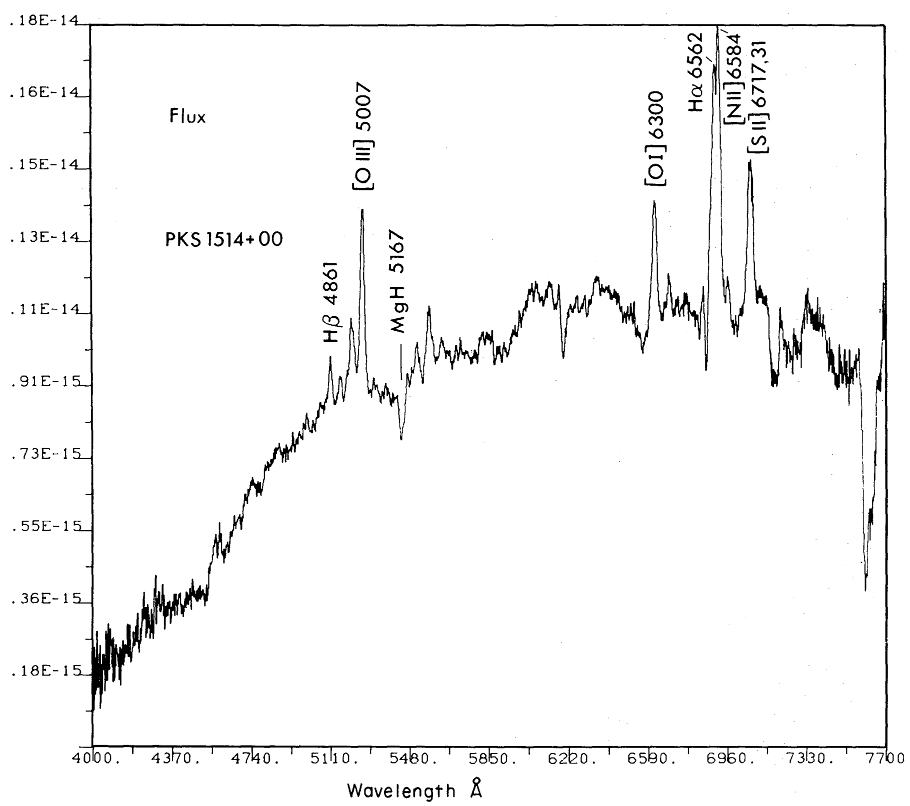

Figure 7. The spectrum of PKS 1514 + 00 calibrated in wavelength units.

1846 – 63

Tritton & Schilizzi (1973) have proposed the identification of the 15-mag E galaxy close to the northern component of this double radio source. Emission lines are not apparent in the spectrum. If this identification is correct the source is a small (0.13 Mpc) radio galaxy of low luminosity (10^{23} W Hz^{-1} sr^{-1} at 1.4 GHz).

2006 – 56

This complex radio source has been mapped with the FST by Goss *et al.* (1982). Galaxy b may be the active galaxy for a head–tail structure. Galaxy d is the most obvious identification for the source 2007 – 569, probably quite independent. None of the galaxies has emission lines.

2014 – 55

A very-high-excitation emission-line spectrum is evident in Fig. 8. The radio size is 1.2 Mpc. This object is known to have extended emission lines which will be studied in more detail.

2152 – 69

Another example shown in Fig. 9 of a high-excitation emission-line spectrum in which the [O III] lines are resolved as a result of large-scale systematic motions. The dynamics of the extended emission line region will be discussed in separate papers. An FST map by Christiansen *et al.* (1977) shows the galaxy situated at the centre of a somewhat elongated radio structure.

2300 – 18

The optical spectrum of this N galaxy is shown in Fig. 10. It is characterized by a high-excitation narrow emission-line spectrum together with a broad Balmer-line spectrum which

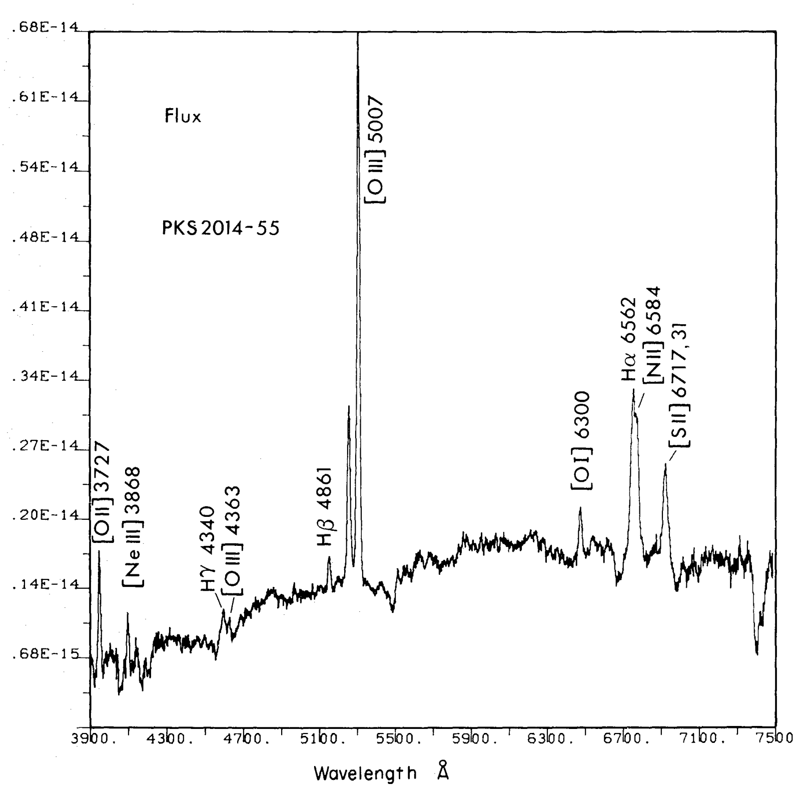

Figure 8. The spectrum of PKS 2014 – 55 calibrated in wavelength units.

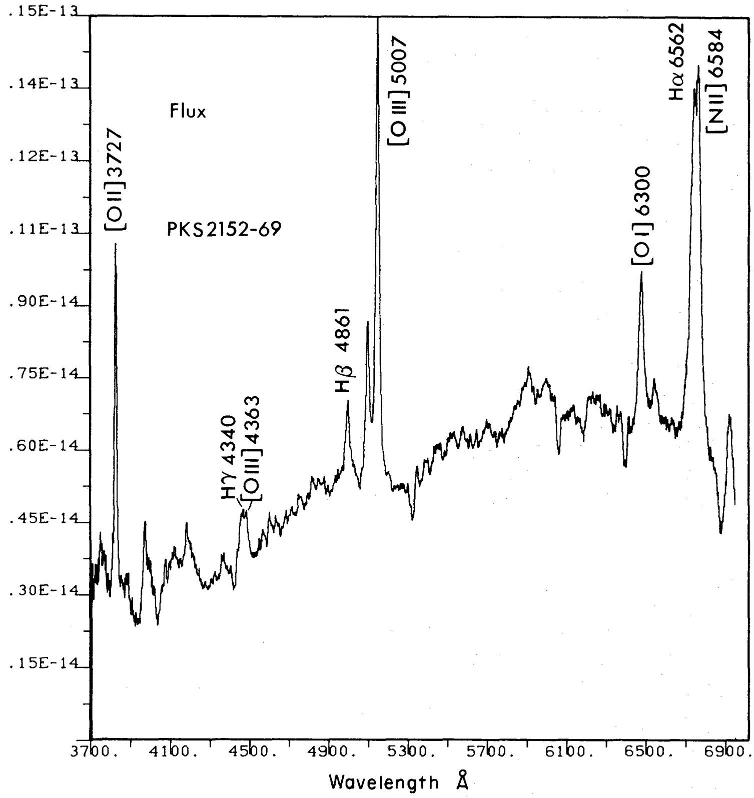

Figure 9. The spectrum of PKS 2152 – 69 calibrated in wavelength units.

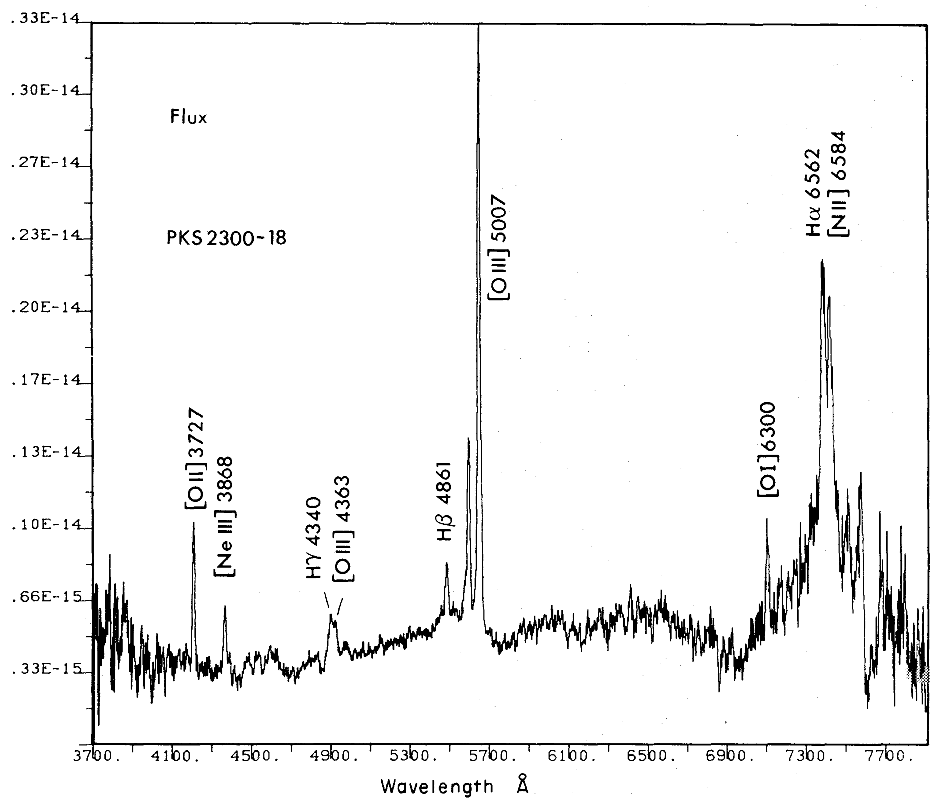

Figure 10. The spectrum of PKS 2300 – 18 calibrated in wavelength units.

has a steep decrement. The full width at zero intensity of Hα could be > 40 000 km s^{-1}. There is evidence for an underlying old stellar component, a fact apparently evident in other N galaxies (Miller 1981). Nothing is known about the radio structure. It has an inverted radio spectrum with spectral index + 0.9 at low frequencies and 0.1–0.2 in the 11–6 cm range.

2349 – 01

This broad-line N galaxy has been discussed by Osterbrock (1978). The angular size of the radio source is 17 arcsec according to McEwan, Browne & Crowther (1975) and the radio spectral index between 85 and 5000 MHz is 0.7 ± 0.1.

2356 – 61

The emission-line spectrum shown in Fig. 11 is of extremely high excitation with [O III] and He II 4686 very strong as is [Ne V] 3426. The Balmer decrement is not steep. There is an underlying stellar absorption spectrum. The known extended emission from this object is being studied. The radio structure has a double-double shape where the inner double may well be two asymmetric jets (discussed by Christiansen *et al.* 1977). The overall dimension of the outer radio double is 1.0 Mpc.

4 Discussion

A detailed list of emission-line strengths and a discussion of an astrophysical interpretation of the emission-line spectrum of individual objects is not given here because we believe that the simple model given for PKS 0634 – 20 and 0211 – 47 by Danziger *et al.* (1978) applies to galaxies in the present list. That model, proposed by others as well, and widely applicable,

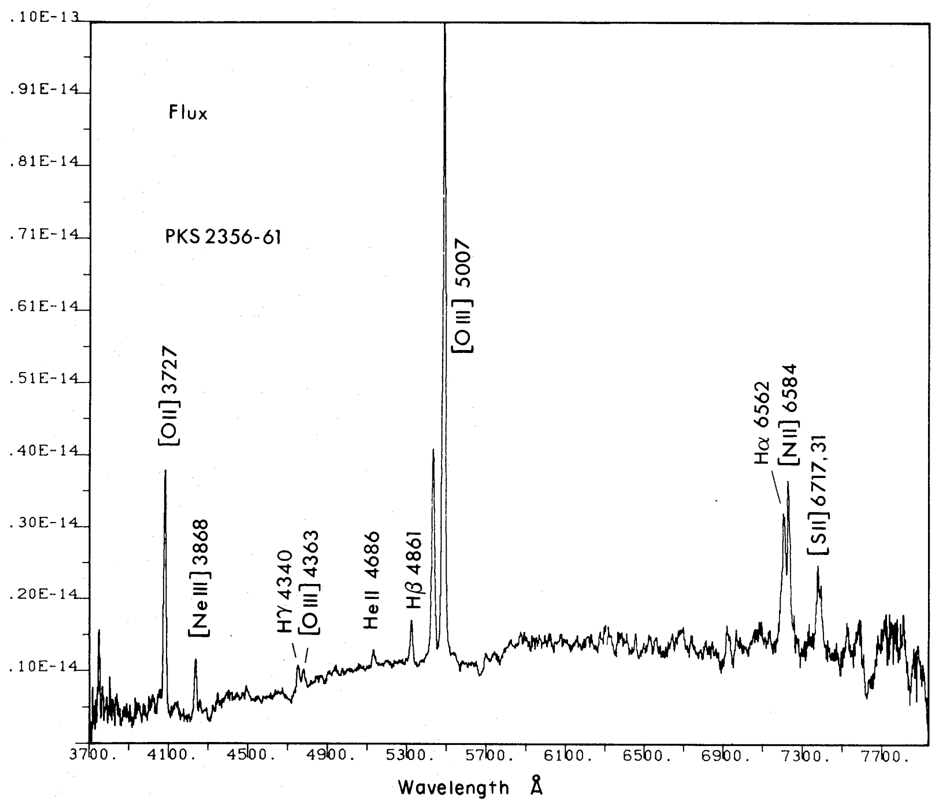

Figure 11. The spectrum of PKS 2356 – 61 calibrated in wavelength units.

requires a very compact non-thermal source at the centre of the galaxy, photoionizing and exciting a larger surrounding volume of gas.

Some further support for such a model can be gained by reference to the diagnostic diagrams published by Baldwin, Phillips & Terlevich (1981). These diagrams show relationships between emission lines that depend upon the cause of the ionization. It is clear, by reference to our spectra published here and those diagrams, that the narrow-line regions of PKS 0202 – 76, 1216 – 10, 2014 – 55, 2300 – 18, 2356 – 61 all result from photoionization by a non-thermal source. The O III (5007)/Hβ ratio and the relative weakness of O I(6300) both attest to this conclusion. PKS 1514 + 00 lies in an intermediate position between photoionization and shock heating as the source of excitation. Unfortunately, the very important line O II(3727) has not been measured in this galaxy so a stronger conclusion is difficult. O II(3727) is strong in PKS 2152 – 69, as is O I(6300). But, because O III(5007)/Hβ is also strong, this galaxy is not a clear-cut case. Perhaps the most interesting case is PKS 0915 – 11(Hydra A) whose spectrum, particularly the O III(5007)/Hβ ratio and the strength of O I(6300), clearly places its gas in the domain of shock excitation. The signal-to-noise ratio in the spectrum in Fig. 4 is not sufficiently high to allow a reliable determination of the O III(4363) line strength, which might indicate whether a very high temperature existed there. Unfortunately, O II(3727) has not been measured. We lack any further information which would suggest why the conditions in the gas of this galaxy are different from the others.

We re-emphasize, however, that there is a wide range of emission line strengths and equivalent widths in radio galaxies which do not appear to correlate with the size or form of the extended radio-emitting regions. This once again raises questions concerning the relationship between the central compact source, the optical line-emitting regions, the compact and extended radio emission and the broad-line region (if any). The material presented here provides a further basis for speculation concerning lifetimes, recurrence and fuel for the active nuclear sources. Our data also support the conclusion of Osterbrock (1978) that most radio galaxies are narrow-lined if they do have emission lines, that they are almost always E or D galaxies, and that any N galaxies that do occur tend to have broad emission lines.

Acknowledgments

We thank Dr J. V. Wall for providing detailed information and references to work on many of these sources. The work at the Fleurs Radio Observatory is financed by the University of Sydney and the Australian Research Grants Committee. We thank D. Skellern for assistance with the FST observations.

The very large array of the National Radio Astronomy Observatory is operated by Associated Universities Inc. under contract with the National Science Foundation. WMG thanks the Netherlands Organization for the Advancement of pure Research (ZWO) for a travel grant to the VLA.

References

Anguita, C. & Pedreros, M., 1977. *Astr. J.,* **82,** 102.
Bajaja, E., 1970. *Astr. J.,* **75,** 667.
Baldwin, J. A., Phillips, M. M. & Terlevich, R., 1981. *Publ. Astr. Soc. Pacific,* **93,** 5.
Bolton, J. G. & Ekers, J., 1966a. *Aust. J. Phys.,* **19,** 559.
Bolton, J. G. & Ekers, J., 1966b. *Aust. J. Phys.,* **19,** 713.
Bolton, J. G., Shimmins, A. J., Merkelijn, J. K., 1968. *Aust. J. Phys.,* **21,** 81.
Chen, J-S., Liang, B-L., Cui, Z-X., Zen, Z-L., Su, H-J., 1982. *Acta Astrophys. Sinica.,* **2,** 19.

Christiansen, W. N., Frater, R. H., Watkinson, A., O'Sullivan, J. D., Lockhart, I. A., Goss, W. M., 1977. *Mon. Not. R. astr. Soc.,* **181**, 183.
Danziger, I. J., Fosbury, R. A. E., Penston, M. V., 1977. *Mon. Not. R. astr. Soc.,* **179**, 41P.
Danziger, I. J. & Goss, W. M., 1979. *Mon. Not. R. astr. Soc.,* **186**, 93.
Danziger, I. J., Goss, W. M. & Frater, R. H., 1978. *Mon. Not. R. astr. Soc.,* **184**, 341.
Danziger, I. J., Goss, W. M. & Wellington, K. J., 1981. *Mon. Not. R. astr. Soc.,* **186**, 845.
Ekers, R. D., 1970. *Aust. J. Phys.,* **23**, 217.
Ekers, R. D. & Simkin, S. M., 1982. *Astrophys. J.,* in press.
Fomalont, E. B., 1971. *Astr. J.,* **76**, 513.
Goss, W. M., Ekers, R. D., Skellern, D. J., Smith, R. M., 1982. *Mon. Not. R. astr. Soc.,* **198**, 259.
Jauncey, D. L., Wright, A. E., Peterson, B. A., Condon, J. J., 1978. *Astrophys. J.,* **219**, L1.
Matthews, T. A., Morgan, W. W. & Schmidt, M., 1964. *Astrophys. J.,* **140**, 35.
McEwan, N. J., Browne, I. W. A. & Crowther, J. H., 1975. *Mem. R. astr. Soc.,* **80**, 1.
Miller, J. S., 1981. *Publ. Astr. Soc. Pacific,* **93**, 681.
Oke, J. B., 1974. *Astrophys. J. Suppl.,* **27**, 231.
Osterbrock, D. E., 1978. *Phys. Scripta.,* **17**, 137.
Schilizzi, R. T., 1975. *Mem. R. astr. Soc.,* **79**, 75.
Schilizzi, R. T., Lockhart, I. A. & Wall, J. V., 1972. *Aust. J. Phys.,* **25**, 545.
Schilizzi, R. T. & McAdam, W. B., 1975. *Mem. R. astr. Soc.,* **79**, 1.
Searle, L. & Bolton, J. G., 1968. *Astrophys. J.,* **154**, L101.
Simkin, S. M., 1976. *Astrophys. J.,* **204**, 251.
Tritton, K. P. & Schilizzi, R. T., 1973. *Mon. Not. R. astr. Soc.,* **165**, 245.
Wall, J. V., Shimmins, A. J. & Bolton, J. G., 1975. *Aust. J. Phys. Astrophys. Suppl.,* **34**, 55.
Wall, J. V., Shimmins, A. J. & Merkelijn, J. K., 1971. *Aust. J. Phys. Astrophys. Suppl.,* **19**, 1.