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SPECTROSCOPY OF RADIO SOURCES FROM THE THIRD BOLOGNA SURVEY

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ABSTRACT

We present long-slit CCD spectroscopy of eleven optical candidates for selected radio sources from the third Bologna survey (B3). One object (0141+398) is a probable misidentification, a foreground star. The remaining ones are a mixture of quasars and active galaxies, ranging in redshift from 0.11 to 0.85. B3 0219+443 is a steep-spectrum quasar. B3 1141+374 is identified with an interacting galaxy pair, with the southern component harboring an active nucleus.

Key words: galaxies: redshifts–quasars–redshifts–spectroscopy

The third Bologna radio survey (B3; Ficarra, Grueff, and Tomassetti 1985) consists of a complete sample of 13,354 sources brighter than 0.1 Jy at 408 MHz, in the interval $37°15' < \delta < 47°37'$. A subset of 1103 sources in five flux bins was defined by narrowing the survey strip in δ and restricting it to high galactic latitudes. VLA maps were then obtained for all sources in this subsample (B3VLA). More details were given by Vigotti *et al.* (1989). The survey spans an intermediate range in radio flux (from 0.1 Jy up, at 408 MHz), thus filling the gap between the 3CR and other high-flux samples and the mJy-level samples. About 400 sources have optical identifications proposed so far, but only ~ 100 of them have measured redshifts.

We are conducting a program of optical identifications and spectroscopy of the B3VLA sources at Palomar Observatory and elsewhere. Our purpose is to form a complete sample of moderate-power radio sources at cosmologically interesting redshifts, for studies of galaxy evolution and radio source counts, evolution of radio source properties (e.g., linear size, morphology) with redshift, comparisons of galaxies with a wide range of radio power at similar redshifts, a search for extremely distant clusters of galaxies, steep-spectrum quasars, other unusual types of objects, and so on. Here we present the spectroscopic results on some of the higher objects observed to date at Palomar. The radio information and optical identifications proposed for the sources observed in this work were published by Vigotti *et al.* (1989).

The observations reported here were done on UT 1988 January 10 and 11 and March 10 and 11 using the Double Spectrograph (Oke and Gunn 1982) mounted at the Cassegrain focus on the Hale 200-inch (5-m) telescope. The conditions were mostly nonphotometric, with variable transparency, and the seeing was never better than about 2 arc sec (FWHM). The slit width used was 2 arc sec and the effective spectral resolution (FWHM) was about 10 Å. The wavelength range covered was different for different nights, but typically was 3700 Å–7400 Å or 3600 Å–9000 Å; on UT 1988 January 10 there was a gap of about 500 Å in the coverage between the blue and the red sides of the spectrograph. The exposure times were in the range of 600–2500 sec. Exposures of arc lamps were used to obtain the dispersion solutions, giving a wavelength calibration rms of ~ 1 Å. Dome flat fields and exposures of standard stars from Oke and Gunn (1983) were used to correct for the instrumental response and to provide a crude flux calibration, and we estimate the zero-point uncertainties to be of the order of $0^m.5$. The data were reduced using standard procedures.

A total of eleven sources were observed, of which two turned out to be quasars, five narrow emission-line galaxies, two galaxies with a weak or absent line emission, one apparently interacting galaxy pair, and one galactic star (probably a misidentification of B3 0141+398, even though the optical and radio coordinates differ by only ~ 2–3 arc sec). Some representative spectra are shown in Figure 1. Table 1 lists the information on measured lines and redshifts. In addition to the features listed there, other absorption (e.g., the 4000 Å break) or emission (e.g., the [S II] λλ6716+6731 doublet) were often seen

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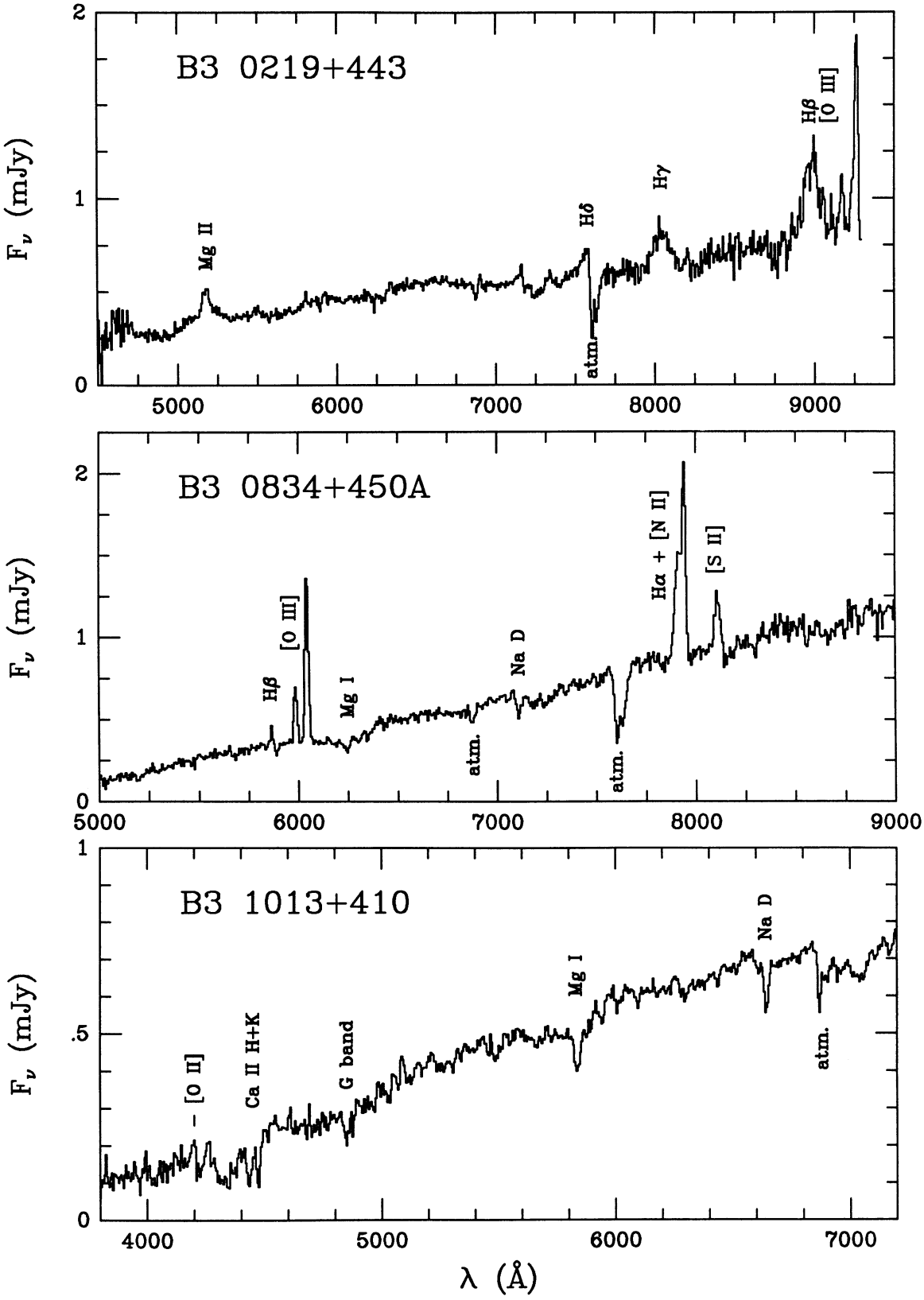

FIG. 1–Spectra of three representative sources: a quasar (B3 0219+443), and AGN (B3 0834+450A), and a galaxy with little or no line emission (B3 1013+410). Some line features are identified. The flux calibration zero point is uncertain by as much as 0.5 mag and is different for different objects.

TABLE 1

Observed Lines and Redshifts

Source	Line	rest	obs	z	Type, average z
B3 0141+398	several	...	...	0	Foregr. star
B3 0219+443	Mg II	2799	5177	0.8496	QSO
	H gamma	4340	8041	0.8526	
	H beta	4861	8987	0.8487	<z> = 0.850 +- 0.001
	[O III]	4959	9174	0.8500	
	[O III]	5007	9261	0.8497	
B3 0729+391	Mg II	2799	4651	0.6616	QSO
	H beta	4861	8093	0.6648	
	[O III]	5007	8328	0.6633	<z> = 0.663 +- 0.001
B3 0812+382	Mg I blend	5170	6077	0.1754	Galaxy
	Na D	5890	6915	0.1740	<z> = 0.1747 +- 0.0007
B3 0834+450A	H beta	4861	5864	0.2064	Seyfert 2
	[O III]	4959	5986	0.2071	
	[O III]	5007	6043	0.2070	<z> = 0.2075 +- 0.001
	H alpha	6563	7940	0.2099	
B3 0836+402	[O II]	3727	4575	0.2275	Galaxy
	Mg I blend	5170	6370	0.2321	<z> = 0.230 +- 0.002
B3 0906+421	Mg I blend	5170	5895	0.1402	Galaxy
	Na D	5890	6715	0.1401	<z> = 0.1401 +- 0.0002
B3 0918+444	[O II]	3727	4647	0.2468	Seyfert 2
	H beta	4861	6112	0.2574	
	[O III]	4959	6177	0.2456	<z> = 0.248 +- 0.002
	[O III]	5007	6242	0.2468	
B3 1013+410	[O II]	3727	4194	0.1253	Galaxy
	Mg I blend	5170	5835	0.1286	
	Na D	5890	6642	0.1277	<z> = 0.127 +- 0.0015
B3 1141+374 (N)	Mg I blend	5170	5775	0.1170	Interacting Double
	Na D	5890	6575	0.1163	
	H alpha	6563	7144	0.0886	<z> = 0.1165 +- 0.0005
B3 1141+374 (S)	[O II]	3727	4150	0.1135	Interacting Double
	[O III]	4959	5525	0.1142	Seyfert 2 ?
	[O III]	5007	5583	0.1151	
	Mg I blend	5170	5765	0.1151	<z> = 0.1145 +- 0.0005
	Na D	5890	6565	0.1146	
B3 1309+412A	[O III]	4959	5507	0.1105	Seyfert 2
	[O III]	5007	5559	0.1102	
	Mg I blend	5170	5740	0.1103	<z> = 0.1103 +- 0.0002
	Na D	5890	6540	0.1104	
	H alpha	6563	7284	0.1099	
	[N II]	6583	7307	0.1099	

but were unusable for the redshift measurements due to blending and ill-defined central wavelengths. In some cases (e.g., B3 1309+412A) the Hα and [N II] lines gave somewhat discrepant redshifts from the remaining lines; this is probably an artifact of line blending and/or poor wavelength calibration near the CCD edges.

B3 0219+443 is a *steep* radio spectrum quasar ($\alpha = -1.17$), and as such is worthy of further attention. B3

1141+374 is identified with a close double, both components of which show some line emission. The VLA map published by Vigotti *et al.* (1989) shows distorted and diffuse radio emission. The line emission is stronger in the southern component, and the Hβ/[O III] ratio is characteristic of a high-ionization object, e.g., Seyfert 2 nucleus. It is possible that the interaction of two galaxies is the cause for the nuclear activity in one of them.

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