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SLIT SPECTRA OF SECOND BYURAKAN SURVEY GALAXIES[1]

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ABSTRACT

Slit spectra have been obtained at Lick Observatory of 18 Seyfert galaxy candidates from the Second Byurakan Spectral Sky Survey (SBS). The great majority of them turned out to be Seyfert galaxies. The classifications and redshifts of all the galaxies are reported. Measurements of the intensity ratios of the emission lines used in classifying the galaxies are tabulated and plotted on diagnostic diagrams. The spectra of seven of the galaxies are described in detail. In general, our classification and redshift measurements are in very good accord with those of Lipovetsky, Stepanian, and their collaborators at the Special Astrophysical Observatory, showing that their results can be used in conjunction with the Lick results with little if any systematic differences between the two data sets. The importance of the SBS as a source of new Seyferts bridging the gap between low-redshift Seyfert galaxies and higher luminosity QSOs is also emphasized.

1. INTRODUCTION

The Second Byurakan Spectral Sky Survey (SBS) (Markarian & Stepanian 1983; Markarian *et al.* 1987; Stepanian *et al.* 1990a) is an objective-prism survey which has been carried out at the 1 m Schmidt telescope of the Byurakan Astrophysical Observatory (but only published in part to date) and is presently being complemented with slit spectroscopic observations at the 6 m telescope of the Special Astrophysical Observatory (Markarian *et al.* 1983; Stepanian *et al.* 1991). It was initiated in the late seventies by B. E. Markarian and his associates upon completion of the First Byurakan Spectral Sky Survey (FBS) (Lipovetsky *et al.* 1987). Although both surveys were made with the same Schmidt camera, the SBS extends down to a limiting magnitude $m_B=19$, which is about 2 mag fainter than the FBS. However, the SBS covers a smaller region of the northern sky ($\alpha=8^h-17^h$, $\delta=49°-61°$).

The FBS and SBS constitute a rich source of new AGNs, in particular Seyfert galaxies. In fact, a large fraction of the presently known Seyfert galaxies are Markarian galaxies which were discovered in the FBS and have been well studied by many workers. To isolate Seyfert galaxy candidates, the FBS relied almost exclusively on the ultraviolet excess in the continuum of galactic nuclei. The SBS, on the other hand, attempts to use the emission lines as well as the ultraviolet continuum. Because of their fainter magnitudes and higher redshifts, the Seyfert galaxies of the SBS bridge the gap between the low-redshift Seyferts and QSOs and can provide new insights into the structure and evolution of AGNs.

Markarian *et al.* (1989) have published a catalogue of all the Markarian galaxies discovered in the FBS, giving among other data their coordinates, redshifts, magnitudes, spectral types (Seyfert or otherwise), *UBV* colors, and *IRAS* fluxes. Mazzarella & Balzano (1986) have also tabulated exhaustive data on the FBS galaxies including radio and infrared flux densities.

To gain an understanding of the similarities and differences between the Mrk (FBS) and SBS galaxies, we have begun an experimental study of the SBS Seyfert galaxies over the Hβ to Hα wavelength interval in order to study their continua and emission lines, improve their classification, and provide accurate measurements of their redshifts and abundances.

In the present paper, we report on the SBS Seyfert galaxy candidates which we have observed to date: 13 Seyfert galaxies, 1 LINER, and 3 starbursts. We are unable to classify one other object because no identifiable spectral line is present in the wavelength region covered by our spectrum. In the following, we present and discuss the results of this investigation.

2. OBSERVATIONS AND REDUCTIONS

All the spectra were acquired at the Cassegrain focus of the Shane 3 m reflector at Lick Observatory on five nights. A journal of the observations is provided in Table 1. In the first column, the objects are named in the same fashion as in the discovery papers. To clearly differentiate the two galaxies of the SBS 1538+574 system, we have renamed the galaxy identified by Markarian *et al.* (1986) as SBS 1538+574A and its companion to the north as SBS 1538+574B.

Four different instrumental configurations were utilized, as noted in the fourth column of Table 1. On the first night of 1984 January, a TI 500×500 CCD detector and a 420 g/mm grism were used with a lens camera. This combination produced spectra with a wavelength dispersion of 5.2 Å/px (350 Å/mm) and a resolution of 11 Å (FWHM) over the wavelength interval λλ4700–7325 (Setup II). The Hα complex of

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TABLE 1. Journal of observations.

Object	UT Date	Exposure (minutes)	Instrument*
SBS 0807+581	1987 Apr 5	40	I
SBS 0808+587	1987 Apr 5	30	I
SBS 0936+562	1984 Jan 4	25	II
SBS 1038+580	1984 Jan 4	20	II
SBS 1125+581	1984 Jan 4	20	II
....	1984 Jan 5	45	IV
SBS 1133+572	1984 Jan 4	20	II
SBS 1136+594	1984 Jan 4	20	II
SBS 1200+608	1993 May 15	50	III
SBS 1213+549 A	1993 May 14	35	III
SBS 1220+544	1993 May 15	40	III
SBS 1318+605	1993 May 14	35	III
SBS 1518+593	1993 May 14	30	III
SBS 1521+598	1993 May 15	60	III
SBS 1524+604	1993 May 14	30	III
SBS 1528+589	1993 May 15	60	III
SBS 1538+574 A	1993 May 14	35	III
SBS 1538+574 B	1993 May 14	35	III
SBS 1543+593	1993 May 14	35	III

* : I : 300 g/mm grating, λλ4300 – 7460.

II : 420 g/mm grism, λλ4700 – 7325.

III : 600 g/mm grating, λλ5055 – 7850.

IV : 150 g/mm echism, λλ6300 – 7185.

SBS 1125+581 was observed on the following night with a 150 g/mm echelle-grism ("echism") in the fifth order (isolated by a combination red glass-interference filter), giving a dispersion of 1.5 Å/px and a resolution of 3 Å over λλ6300–7185 (Setup IV). In 1987 April, the spectra were collected with a Schmidt camera, a TI 800×800 CCD detector, and a 300 g/mm grating at a wavelength dispersion of 4.0 Å/px and a resolution of 10 Å in the spectral range λλ4300–7460 (Setup I). The spectrograph used in these earlier years has been described by Miller *et al.* (1988). On the two nights in 1993 May, a Reticon 1200×400 CCD detector mounted on the new Kast spectrograph (Miller & Stone 1993) with a 600 g/mm grating produced spectra with a scale of 2.35 Å/px at a resolution of 6 Å in the spectral region λλ5055–7850 (Setup III).

The objects that we observed in 1984 and 1987 are among the brightest ($15.5<m_B<16.5$) of the SBS galaxies and their redshifts were listed in published papers. The 1993 objects, on the other hand, are fainter ($16.0<m_B<18.5$), and the redshifts of six of them were unknown to us at the time of observation. Since both the Hβ and Hα emission lines are crucial in the classification of Seyfert galaxies and in reddening corrections, we chose a wavelength interval (λλ5055–7850) that includes these two lines in a single spectrum for a range in redshift of 0.04 to 0.20, based on the average redshift of the other SBS Seyferts. This proved to be a suitable choice since only one object (SBS 1521+598) turned out to have a redshift greater than 0.2, so that only its Hβ line was detected.

Optical positions accurate to 1$''$.5–2$''$ were found for nine of our objects in Kojoian *et al.* (1985), Nelson *et al.* (1988), Seal *et al.* (1990), and Simpson (1990). For the remaining objects we simply corrected the positions listed in the discovery papers by measuring offsets in right ascension and declination on the POSS plates.

We also observed SBS 1534+588 in 1993 May. Its spectrum is that of a local star ($z=-0.0006\pm0.0002$) with strong Hα and weak Na D in absorption, and a smooth continuum which rises rapidly to the blue. Markarian *et al.* (1986) originally listed it as a BSO, possibly a Seyfert galaxy, but from a slit spectrum Stepanian *et al.* (1990b) later concluded that it is a DA white dwarf.

When observing SBS 1200+608, we included in the slit the object to the southwest of it which appears to be a nearby companion to the galaxy. Its spectrum exhibits moderately strong absorption lines of Hα, Na D, Fe I λλ5270, 5328, and strong Mg I b, with a redshift $z=-0.0002\pm0.0002$. Evidently this object is also a local star lying along the line of sight to SBS 1200+608.

All the images were reduced with the image-processing package VISTA (Terndrup *et al.* 1984). Each image was bias-corrected and divided by a normalized flat field to remove the pixel-to-pixel variations. Cosmic ray hits and hot pixels were eliminated interactively with a median-filtering procedure. The sky lines were removed from the object spectrum by appropriately scaling and subtracting adjacent sky regions on the image. The wavelength calibration was accomplished with He, Ne, Ar, Hg, and Cd lines from standard comparison lamps observed at the beginning and end of each night. A third-order polynomial was typically fitted to a dozen comparison lines. Each spectrum was then converted to a linear wavelength scale with a four-point Lagrangian interpolation method and corrected for atmospheric extinc-

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TABLE 2. Type, redshift, and magnitudes of the SBS objects.

Object	Type	Type†	z^*	$z^†$	m_B†	M_B‡
SBS 0807+581	Sey 2	Sey 2	0.0279	0.0279	16.5	−18.7
SBS 0808+587	Sey 2	Sey 2	0.0272	0.0268	16.0	−19.2
SBS 0936+562	Sey 1	Sey 1	0.1167	0.1172	16.5	−21.8
SBS 1038+580	Sey 2	Sey 1.5	0.0676	0.0671	16.0	−21.2
SBS 1125+581	Sey 2	Sey 2	0.0510	0.0514	15.5	−21.0
SBS 1133+572	Sey 2	Sey 2	0.0507	0.0514	16.0	−20.5
SBS 1136+594	Sey 1.5	Sey 1.5	0.0601	0.0604	16.0	−20.9
SBS 1200+608	LINER	Sey	0.0655	—	17.0	−20.1
SBS 1213+549 A	NL Sey 1	Sey 1	0.1503	0.1505	16.5	−22.4
SBS 1220+544	Sey 1.5	Sey	0.1564	0.1564	16.5	−22.5
SBS 1318+605	Sey 1.5	Sey 1.5	0.1000	0.0993	16.5	−21.5
SBS 1518+593	Sey 1	Sey 1	0.0781	0.0793	16.0	−21.5
SBS 1521+598	Sey 1	Sey 1	0.2862	—	18.0	−22.3
SBS 1524+604	Sey 2	Sey	0.0789	—	16.0	−21.5
SBS 1528+589	Starburst	Sey	0.0609	—	18.5	−18.4
SBS 1538+574 A	Starburst	Sey	0.0809	—	17.5	−20.0
SBS 1538+574 B	Starburst	—	0.0805	—	—	—
SBS 1543+593	—	Sey	—	—	17.5	—

* : measured heliocentric redshifts.

† : from the Markarian and associates' papers.

‡ : calculated with $H_0 = 75$ km s^{-1} Mpc^{-1}.

tion by using the appropriate mean atmospheric coefficients for Mount Hamilton. In order to measure accurate redshifts, the zero-point of the wavelength scale of each spectrum was adjusted with the most prominent night-sky lines. All the spectra were flux-calibrated with standard stars observed throughout each night.

The two atmospheric bands of O_2 (the λ6990 B and the λ7620 A band) and the λλ7100–7450 H_2O band were removed by the method described in Osterbrock *et al.* (1990). This was accomplished for every spectrum except those of 1984 January, which were not corrected for the H_2O band. Thus the [S II] λλ6716, 6731 doublets of SBS 1038+580 and SBS 1136+594 slightly overlap the H_2O band, and their measured fluxes are lower limits to the true values. The Hα and [N II] λλ6548, 6583 lines are not affected.

3. RESULTS

In Table 2, we have tabulated the types and heliocentric redshifts of the galaxies in our sample as measured by us in the second and fourth columns and as published by Markarian and his collaborators in the third and fifth columns. All the apparent magnitudes listed in the sixth column come from the Markarian papers and the absolute magnitudes of the seventh column were calculated with $H_0=75$ km s^{-1} Mpc^{-1}, without any correction for interstellar extinction.

All our spectra were classified in the well known Seyfert-galaxy system, as outlined very briefly in the summarizing article by Osterbrock (1993), or at greater length in Osterbrock (1989). Very briefly, Seyfert 1 galaxies have strong, broad, permitted emission lines and narrower forbidden lines, while Seyfert 2 galaxies and LINERs have strong narrower, permitted and forbidden emission lines. Both have forbidden lines covering a wider range of ionization than starburst or H II region galaxies. The intermediate types are Seyfert 1.5, with strong, broad and narrow components of their permitted emission lines; Seyfert 1.8, with strong, narrow and weak, broad components of permitted Hα and Hβ; and Seyfert 1.9, with still weaker broad components of Hα, and the broad component of Hβ too weak to be easily visible. These types Seyfert 1 through 1.9 were classified by visual inspection of our spectral scans. Among the narrow line objects, the three diagnostic diagrams recommended by Veilleux & Osterbrock (1987) were used to separate Seyfert 2 galaxies and LINERs from starburst galaxies. The Seyfert 2 galaxies are those with reddening corrected intensity ratio [O III] λ5007/Hβ>3.0; LINERs are those with [O III] λ5007/Hβ<3.0.

According to this classification scheme, there are six Seyfert 2s, three Seyfert 1s, one narrow line Seyfert 1, three Seyfert 1.5s, one LINER, and three starburst galaxies in our sample. The low S/N in the continuum of our spectra prevented us from detecting weak, broad wings in Hβ and/or Hα in the Seyfert 2 spectra. Thus, we cannot be positive that some of the Seyfert 2 galaxies are not actually Seyfert 1.8 or 1.9. We could not classify SBS 1543+593 nor measure its redshift because its spectrum displays no identifiable emission line in the spectral range λλ5055–7850. Veilleux & Osterbrock (1987) and Osterbrock (1987) classified seven of our Seyfert galaxies based on the same spectra, and except for SBS 1038+580, which Osterbrock designated as a Seyfert 1.9, our types agree with those earlier papers. Our revised classification should be used. However, for the spectra taken on 1984 Jan 4 the focus in the red region was a trifle soft. Hence we cannot be certain of the absence of weak, broad Hα emission components in SBS 1038+580, SBS 1125+581, or SBS 1133+572.

Our redshifts were measured by locating the centroids of the strongest unblended lines (usually [O III] λ5007) at approximately 90% of the peak. On average, the difference between our redshifts and those of Markarian and his associates is $z(\text{MO})-z(\text{Markarian})=-0.0002\pm0.0002$. In their papers these authors listed absolute magnitudes for the eleven galaxies in Table 2 for which they had measured redshifts. They had calculated these absolute magnitudes with $H_0=75$ km s^{-1} Mpc^{-1} also, but in addition corrected them for an average interstellar extinction $\Delta m=0.25 \csc b$. For this reason their tabulated absolute magnitudes are approxi-

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mately 0.34 ± 0.02 mag brighter than ours, which are listed in Table 2.

The line fluxes were measured by first de-redshifting the spectra, and then fitting Gaussian profiles to the emission lines by a nonlinear least-squares method. Because of the poor S/N in the continuum of the Seyfert 2 spectra, we were unable to subtract successfully the absorption continuum with a template galaxy spectrum. For any particular strong blend, such as Hα+[N II], the [S II] doublet, and in some cases Hβ+[O III], the emission lines were fitted simultaneously. Forbidden lines produced from transitions from the same upper level in one ion were constrained to have the same FWHMs and a fixed ratio of fluxes, in particular [O III] λ5007/[O III] λ4959=2.88, [O I] λ6300/[O I] λ6364=3.04, and [N II] λ6583/[N II] λ6548=2.94, as calculated from their wavelengths and transition probabilities. The FWHMs of [S II] λ6716 and [S II] λ6731 were also taken to be equal but no condition was imposed on the ratio of their fluxes. The [N II] λ6583/Hα ratio of SBS 1125+581 was measured on its high dispersion spectrum of 1984 Jan 5, and was then used to deblend the low-dispersion spectrum of 1984 Jan 4. The broad Hβ and Hα components of the Seyfert 1.5 galaxies were approximated independently by single Gaussians.

The normalized ratios of the strongest narrow emission lines for all the galaxies except the Seyfert 1s are listed in Table 3. For each galaxy, the first row lists the measured ratios, while the second row gives that same ratio corrected for interstellar extinction using the Whitford reddening curve as parametrized by Miller & Mathews (1972). We adopted an intrinsic flux ratio of $I(\mathrm{H}\alpha)/I(\mathrm{H}\beta)=3.1$ for the Seyfert 2 galaxies and the LINER, and $I(\mathrm{H}\alpha)/I(\mathrm{H}\beta)=2.85$ for the starburst galaxies. The [S II] $\lambda\lambda$6716, 6731 doublet is simply referred to as [S II] λ6724 (Column 7). The quantity r=[S II] λ6716/[S II] λ6731, which measures the mean electron density N_e and the extinction coefficient c are given in the last column. The latter, as explained for instance in Osterbrock (1989), is a measure of the amount of extinction, normalized so that $c=1.00$ corresponds to $E_{B-V}=0.77$ (see also Veilleux & Osterbrock 1987). The accuracies of r and c depend on the data for the individual objects, but a good overall average based on measurements of many previous objects, is ± 0.05 to ± 0.10 for both these quantities. It was not possible to separate accurately the narrow components from the broad in the Seyfert 1 spectra, and for this reason the narrow line ratios could not be measured in these objects.

The line ratios of the weaker, narrow emission lines of some of the galaxies are given in Table 4, while measurements of the narrow and broad Balmer lines of some of the Seyfert 1 and 1.5 galaxies are tabulated in Table 5. The Balmer decrement derived from the narrow Hβ and Hα lines was used to correct schematically the broad components for reddening in the narrow line region. The errors on the line ratios of Tables 3–5 are typically 10%–20% for the strongest lines and can be as large as 50% for the weakest.

Diagnostic diagrams of the most-easily measured narrow emission lines are plotted in Figs. 1–3. All the ratios are corrected for reddening. The solid curves that separate the AGNs from the H II region galaxies were adopted from

TABLE 3. Logarithms of measured and corrected narrow emission line ratios.*

Object	Hβn	[O III] λ5007	[O I] λ6300	Hαn	[N II] λ6583	[S II] λ6724	$r^{\dagger}$ / $c^{\ddagger}$
SBS 0807+581	0.00	0.88	0.06	1.02	1.03	0.66	—
	0.00	0.83	−0.40	0.49	0.50	0.09	1.58
SBS 0808+587	0.00	0.97	0.15	0.75	0.90	0.85	—
	0.00	0.94	−0.07	0.49	0.64	0.58	0.77
SBS 1038+580	—	0.08	−0.61	0.00	0.13	−0.75	—
	—	—	—	—	—	—	—
SBS 1125+581	0.00	0.84	−0.58	0.89	0.76	0.44	—
	0.00	0.80	−0.92	0.49	0.36	0.02	1.18
SBS 1133+572	0.00	1.00	−0.38	0.75	0.86	0.34	—
	0.00	0.98	−0.61	0.49	0.60	0.06	0.77
SBS 1136+594	0.00	1.09	−0.13	0.81	0.21	−0.07	—
	0.00	1.05	−0.42	0.49	−0.11	−0.42	0.96
SBS 1200+608	—	—	—	0.00	0.36	0.32	1.35
	—	—	—	—	—	—	—
SBS 1220+544	0.00	0.89	−0.30	0.70	0.28	0.30	1.16
	0.00	0.87	−0.48	0.49	0.07	0.08	0.62
SBS 1318+605	0.00	0.95	−0.55	0.62	0.54	0.04	1.21
	0.00	0.94	−0.66	0.49	0.41	−0.10	0.38
SBS 1524+604	0.00	0.85	−0.14	0.84	0.79	0.61	1.23
	0.00	0.81	−0.44	0.49	0.44	0.23	1.05
SBS 1528+589	0.00	0.40	—	0.65	−0.07	0.33	1.08
	0.00	0.38	—	0.45	−0.26	0.13	0.58
SBS 1538+574 A	0.00	0.03	−1.16	0.62	0.13	−0.14	1.25
	0.00	0.01	−1.31	0.45	−0.03	−0.31	0.50
SBS 1538+574 B	—	—	—	0.00	−0.27	−0.38	—
	—	—	—	—	—	—	—

* normalized with respect to Hβn except for SBS 1038+580, SBS 1200+608, and SBS 1538+574 B which are normalized with respect to Hαn. For each object, the upper row gives measured values and the lower row gives computed values, corrected for interstellar extinction.

† : Intensity ratio [S II] λ6716/[S II] λ6731.

‡ : Measure of interstellar extinction : E_{B-V} = 1.00 for c = 0.77 and standard interstellar extinction curve.

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TABLE 4. Logarithms of measured and corrected narrow emission line ratios.

Object	He II λ4686	[Fe VII] λ5721	[Fe VII] λ6087	[Fe X] λ6375	[Ar III] λ7136
SBS 1136+594	0.28	—	—	—	—
	0.32	—	—	—	—
SBS 1220+544	−0.56	—	—	—	—
	−0.53	—	—	-	—
SBS 1318+605	−0.55	−0.53	−0.33	−0.91	—
	−0.54	−0.60	−0.43	−1.02	—
SBS 1538+574 A	—	—	—	—	−1.07
	—	—	—	—	−1.27

* : normalized with respect to Hβn.

Veilleux & Osterbrock (1987) and Osterbrock & Martel (1993).

4. DISCUSSION

4.1 Individual Galaxies

In this section, we briefly describe the spectra of seven galaxies of this sample, either to clarify points noted above or to indicate features worthy of special attention.

TABLE 5. Measured and corrected emission line ratios for Seyfert 1 and 1.5 galaxies.

Object	Hβb*	Hβn*	Hαb*	Hαn*	Hαb/Hβb	Hαb/Hαn
SBS 1136+594	14.9	1.00	39.5	6.49	2.6	6.1
	14.9	1.00	18.8	3.10	1.3	6.1
SBS 1213+549 A	2.66	—	13.5	—	5.1	—
	—	—	—	—	—	—
SBS 1220+544	5.44	1.00	22.9	4.98	4.2	4.6
	5.44	1.00	14.2	3.10	2.6	4.6
SBS 1318+605	10.0	1.00	50.1	4.16	5.0	12.0
	10.0	1.00	37.3	3.10	3.7	12.0
SBS 1518+593	2.63	1.00	3.88	2.36	1.5	1.6
	—	—	—	—	—	—

* : normalized with respect to Hβn, except for SBS 1213+549 A.

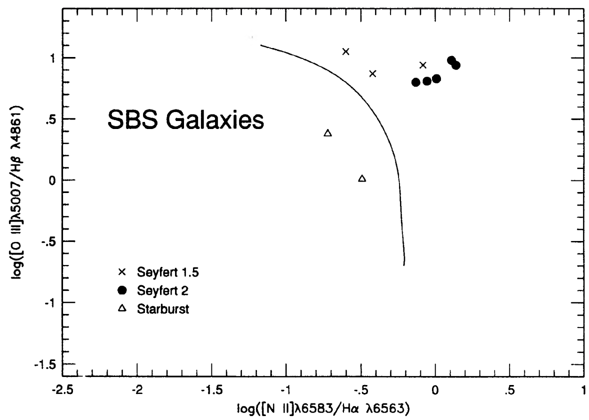

FIG. 1. Reddening-corrected [O III] λ5007/Hβ vs [N II] λ6583/Hα intensity ratios for galaxies from the SBS. Solid curve divides AGNs from H II regionlike objects (Veilleux & Osterbrock 1987; Osterbrock & Martel 1993).

SBS 0936+562

This galaxy was classified as a Seyfert 1 by Markarian *et al.* (1983), in accord with our classification. Our spectrum of SBS 0936+562 is quite noisy and only part of the Hα +[N II] complex is included in our observed spectral range because of the large redshift of the object. Hence measurement of the fluxes of those lines is impossible on this spectrum. However, the Fe II blends λλ4570, 5190, 5320 are definitely present. (This spectrum is shown in Fig. 4.)

SBS 1038+580

Markarian *et al.* (1983) classified this galaxy as a Seyfert 1.5, based on a spectrum of the Hα region only. Our scan shows no measurable Hβ in emission, and a narrow Hα emission line, strongly blended with the [N II] doublet. The absence of any broad Hβ emission component, and apparently Hα as well, lead us to classify it as a Seyfert 2 although it is conceivable it is a Seyfert 1.9. It may have varied between 1.5 and 1.9 between the times the two spectra were taken.

SBS 1213+549A

This galaxy is a narrow-line Seyfert 1, in which the per-

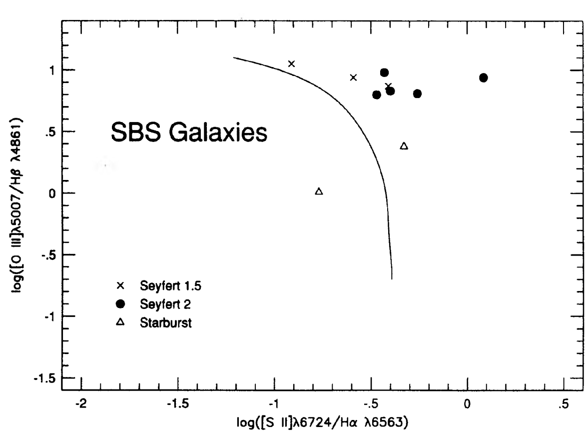

FIG. 2. Reddening-corrected [O III] λ5007/Hβ vs [S II] λ6724/Hα intensity ratios for galaxies from the SBS. Solid curve as in Fig. 1.

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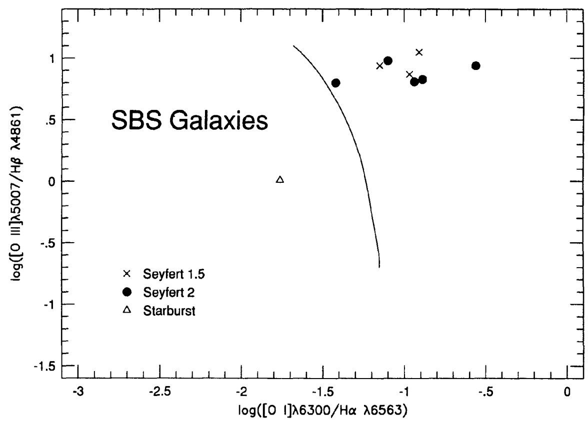

FIG. 3. Reddening-corrected [O III] λ5007/Hβ vs [O I] λ6300/Hα intensity ratios for galaxies from the SBS. Solid curve as in Fig. 1.

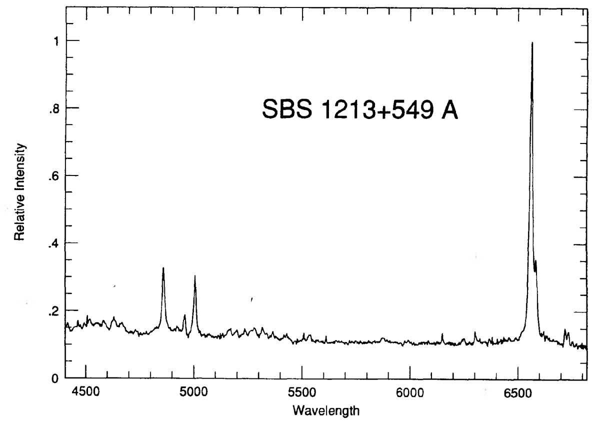

FIG. 5. Reduced spectral scan of SBS 1213+549 *A* in relative flux units per unit wavelength interval vs rest wavelength. This is a typical narrow-line Seyfert 1 galaxy, with Hβ slightly broader than [O III] λ5007, and the Fe II blends λλ4570, 5190, 5320 easily apparent.

mitted H I and Fe II lines are broader than the forbidden lines, but not greatly so. It was classified as a Seyfert 1 by Stepanian *et al.* (1991). Its spectrum resembles closely those of other narrow line Seyfert 1 galaxies such as Mrk 42 and Mrk 493 (Osterbrock & Pogge 1985). The strong Fe II complexes λ4570 and λλ5190, 5320 are present. The [O III] λ4959 line is comparatively narrow. There are no visible absorption lines. (This spectrum is shown in Fig. 5.)

SBS 1518+593

This is a typical Seyfert 1, with strong, broad Hα and Hβ, broad He I λ5876, and weak, broad Fe II λλ5190, 5320 in the observed spectral region. Fairly strong, narrow [Fe VII] λλ5721, 6087 and weaker [Fe X] λ6375 are detectable, in addition to the typical lower ionization narrow lines. (This spectrum is shown in Fig. 6.)

SBS 1521+598

This is the highest redshift galaxy of our sample (z $=0.2862$). Based on its Hβ complex, we have classified it as a Seyfert 1, in accord with Stepanian *et al.* (1990b). A very prominent nonthermal continuum underlies the broad and strong Hδ, Hγ, Hβ, and Fe II lines and the weak, narrow [O III] λ5007 line. The FWHM of Hβ is approximately 63 Å (~3900 km/s). (This spectrum is shown in Fig. 7.)

SBS 1524+604

This is a Seyfert 2 galaxy with [O III] λ5007/Hβ barely stronger than in a LINER. Markarian *et al.* (1986) state that it possesses weak Seyfert characteristics. Its [O III] λλ4959, 5007 lines are asymmetric to the blue and are clearly broader (FWHM=11 Å) than Hβ and Hα (FWHM=7 Å), and [N II] and [S II] (FWHM=9 Å). The peak intensities of [O III] λ5007 and Hβ are in the ratio 3 : 1, but because of the larger width of [O III] λ5007, the ratio of the integrated fluxes is significantly larger. [O I] λ6300 is fairly strong. On the diag-

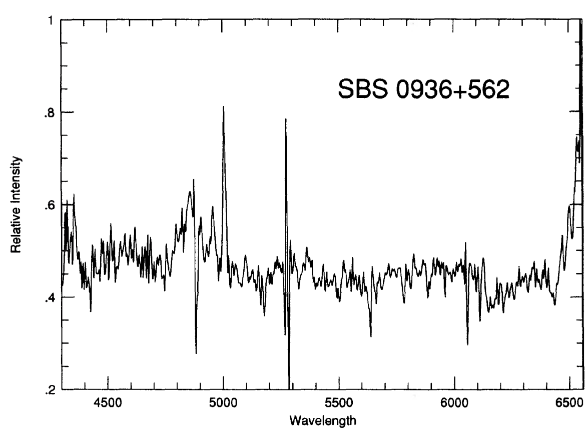

FIG. 4. Reduced spectral scan of SBS 0936+562 in relative flux units per unit wavelength interval vs rest wavelength. The narrow noise spikes result from incomplete cancellation of strong night-sky emission lines. Broad Hβ λ4861 emission and the shortest wavelength part of broad Hα λ6563 can be seen, as well as the clumps of blended Fe II emission multiplets centered near λ4570 and λλ5190, 5320.

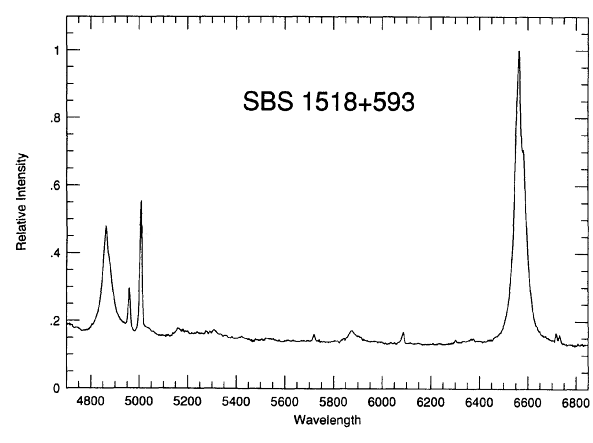

FIG. 6. Reduced spectral scan of SBS 1518+593 in relative flux units per unit wavelength interval vs rest wavelength. This is a typical Seyfert 1, with strong, broad Hα and Hβ, broad He I λ5876, and weak broad Fe II λλ5190, 5320 in the observed spectral region. Note that fairly strong, narrow [Fe VII] λλ5721, 6087 and weaker [Fe X] λ6375 (blended with [O I] λ6364) are detectable.

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nostic diagrams, SBS 1524+604 falls in the region of the Seyfert 2 galaxies.

SBS 1543+593

This galaxy was classified simply as a Seyfert by Markarian *et al.* (1986). They give no redshift for it. In the region λλ5055–7850, its spectrum exhibits a strong, smooth nonthermal continuum with no emission lines except possibly at λ5055, the blue edge of the spectrum, and at λ5350, where a "bump" is present. Further observations in a different spectral region are necessary to determine the true nature of this object.

4.2 Diagnostic Diagrams

The diagnostic diagrams of the Seyfert and starburst galaxies for which the ratios [O III] λ5007/Hβ, [O I] λ6300/Hα, [N II] λ6583/Hα, and [S II] λ6724/Hα could be measured are plotted in Figs. 1, 2, and 3. Some general trends are apparent. All the Seyfert 1.5 and 2 galaxies have a line ratio [O III] λ5007/Hβ>3 and occupy the AGN portion of the plots (upper right) where photoionization by a power-law continuum is the dominant ionization mechanism. An [O III] λ5007/Hβ ratio >3 is often indicative of Seyfert activity among narrow line galaxies, though some starburst objects are known to have ratios exceeding this value.

4.3 High-Redshift Seyferts and QSOs

An important aspect of the SBS is that it covers a range in redshift and magnitude intermediate between those of the most commonly studied low-redshift Seyfert galaxies and the QSOs. For example, the Seyfert galaxies in the complete CfA sample of Huchra & Burg (1992) possess an average redshift of $z=0.02$, and are all brighter than $m_B=14.5$. The SBS galaxies of the present study, on the other hand, span a range in redshift of $z\approx0.03$–0.3 and apparent magnitudes of $m_B=15.5$–18.5 (see Table 2). As a comparison, the redshift and magnitude of the well known QSO 3C 273 are $z=0.158$ and $m_B=13.1$, respectively.

To distinguish between Seyfert 1s and QSOs, Schmidt & Green (1983) define objects with $M_B<-23$ as QSOs, and those with $M_B>-23$ as Seyfert 1s, using a Hubble constant of $H_0=50$ km s^{-1} Mpc^{-1}. According to this definition, three of our objects, SBS 1213+549A, a narrow line Seyfert 1, SBS 1220+544, a Seyfert 1.5, and SBS 1521+598, a Seyfert 1, are barely luminous enough to be classified as QSOs. On the POSS plates, all three objects appear stellar with some very slight extensions. For $H_0=75$ km s^{-1} Mpc^{-1}, none of these objects would have calculated M_B more luminous than -23; they are all quite close to the "boundary" between Seyfert 1 and QSO with $H_0=50$ km s^{-1} Mpc^{-1}.

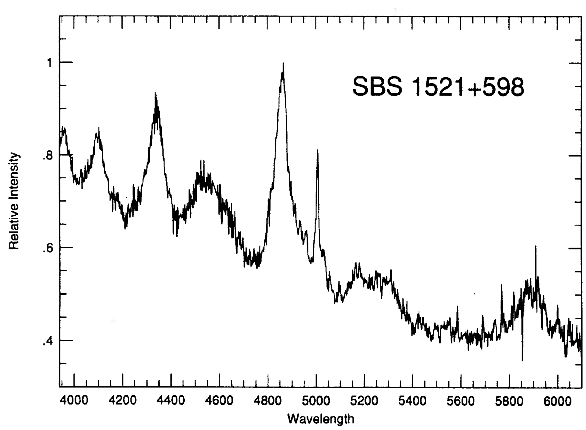

FIG. 7. Reduced spectral scan of SBS 1521+598 in relative flux units per unit wavelength interval vs rest wavelength. This is a Seyfert 1 galaxy with a redshift so large that Hα does not appear in the observed range, but strong, broad Hδ, Hγ, Hβ, He I λ5876, and Fe II emission features are apparent, as well as narrow [O III] λ5007 (blended with an Fe II feature).

5. CONCLUSION

We have reported the results of slit-spectroscopic observations of eighteen SBS galaxies, all of them described as Seyfert galaxies or Seyfert galaxy candidates in the original SBS papers. Thirteen of them (over 70%) turned out to be Seyferts, approximately half of them Seyfert 2s. In addition one is a LINER. Only three are starburst galaxies and one is unknown. One more SBS Seyfert galaxy candidate turned out to be a star, not a galaxy. Thus the Seyfert galaxy candidates from the SBS have a very high probability of being actual Seyfert galaxies.

Furthermore, in all the cases in which Markarian, Lipovetsky, Stepanian, and their associates obtained slit spectrograms (at the Special Astrophysical Observatory), their Seyfert galaxy classifications and measured redshifts are in extremely good accord with ours. Thus their results can be used in conjunction with the Lick data, and intercompared with them with little if any systematic differences between the two data sets.

The SBS goes to a considerably fainter level than the FBS, and on the average the SBS galaxies have noticeably larger redshifts than the Mrk galaxies. However, considerably more spectroscopic observations of individual SBS candidates will be necessary to test the completeness of Seyfert galaxy samples drawn from this survey.

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