

## OPTICAL SPECTRA OF NARROW EMISSION LINE PALOMAR-GREEN GALAXIES<sup>1</sup>

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### ABSTRACT

Spectra were obtained of 35 of the 36 narrow emission line galaxies isolated in the Palomar-Green (PG) survey of Green, Schmidt, and Liebert. Of these, three are narrow-line Seyfert 1 galaxies, three more are Seyfert 1.5 galaxies, and only one, PG 2259+157 = NGC 7465 = Mrk 313, is a relatively low-ionization active galactic nucleus, a marginal Seyfert 2 with  $[\text{O III}] \lambda 5007/\text{H}\beta \approx 3$ . The rest are H II region galaxies, as is CSO 177, a candidate Seyfert 2 galaxy not previously observed at H $\alpha$ . Redshifts and relative emission-line strengths are given for all these galaxies. These spectra confirm that a survey such as the PG, based on ultraviolet excesses, though good for finding QSOs, is not well suited for finding Seyfert 2 galaxies. However, the PG survey shows that a significant number of Seyfert 1 galaxies are "narrow-line" objects with H I emission-line full widths at half-maximum  $\leq 2000 \text{ km s}^{-1}$ .

*Subject headings:* galaxies: Seyfert

### I. INTRODUCTION

The Palomar-Green (PG) survey was carried out with the primary purpose of finding a homogeneous, statistically complete sample of hot stars and (blue) quasi-stellar objects (Green, Schmidt, and Liebert 1986). The aim was to include all apparently stellar objects with an ultraviolet excess, defined as  $U-B < -0.44$  (Schmidt and Green 1983) or  $< -0.46$  (Green, Schmidt, and Liebert 1986). The Palomar Bright Quasar Survey (BQS) was drawn from the PG survey, and was studied in detail by Schmidt and Green (1983). It included the additional spectroscopic constraint that to be included an object should show broad emission lines with substantial redshift ( $z \gtrsim 0.025$ ). In this way a large sample of "quasars" (quasi-stellar objects) and Seyfert 1 galaxies was isolated. The PG survey, carried out over a large area in the sky (10,714 square degrees) to a fairly bright magnitude limit, was thus very well designed to find high-luminosity blue active galactic nuclei (AGNs).

However, according to Schmidt and Green (1983) the line-width criterion eliminated from the BQS 22 extragalactic PG objects with narrow emission lines, such as those observed in Seyfert 2 and H II region galaxies. As Schmidt and Green (1983) and others, especially Weedman (1976), have emphasized, Seyfert 1 galaxies fit smoothly onto QSOs in the sequence of AGNs, but the best presently available luminosity function shows that Seyfert 2's typically have fainter absolute magnitudes than Seyfert 1's (Meurs and Wilson 1984). There are few if any known QSOs with Seyfert 2 type spectra (Stoche *et al.* 1982). Therefore, we decided to examine the spectra of all the narrow emission line galaxy candidates in the PG survey, to see whether there are indeed any high-luminosity Seyfert 2 galaxies among them.

In addition, we obtain a spectrum of the emission-line galaxy CSO 177 described by Zotov (1985) as a possible Seyfert 2 galaxy at redshift  $z = 0.114$ . If confirmed, it would be a very high-luminosity object of this type.

### II. OBSERVATIONS

In the original BQS paper, Schmidt and Green (1983) named only two of the PG narrow emission line galaxies, PG 1428+285 = Mrk 684 and PG 1102+294 = Mrk 36 = Haro 4. Our spectra showed that the former is a narrow-line Seyfert 1 galaxy (Osterbrock and Pogge 1985), while the latter is an H II region galaxy (Osterbrock 1986). We communicated these early results to Drs. Schmidt and Green, who then very kindly sent us their entire unpublished list of PG narrow emission line candidates.

There are 36 objects in this list. All of them are listed in the PG survey (Green, Schmidt, and Liebert 1986) with the designation "Gal," although Table 6 of that paper states that only 35 are included. Of these 36, a total of 25 are included in the various lists of Markarian galaxies that make up the First Byurakan Survey, as indicated in Table 1. For four of these objects, Lick spectra have previously been published. Mrk 504 is a Seyfert 1 galaxy (Osterbrock 1977), while Mrk 279 and Mrk 817 are Seyfert 1.5 galaxies (Osterbrock and Shuder 1982; Cohen 1983). The presence of these objects with relatively strong, broad H I emission lines among the "narrow-line" candidates represents only a small fraction of the broad-line objects that were correctly classified in the PG survey. Schmidt and Green (1983) had to use short exposure times to obtain data on all 1800 objects, and the classifications of these three were evidently based on spectra too noisy to reveal the broad H I emission lines or components. The other previously published object, Mrk 309, is a narrow emission line galaxy evidently photoionized mostly by OB stars, but with strong Wolf-Rayet features in its spectrum, indicating that an important episode of massive-star formation occurred in it several times  $10^7$  years ago (Osterbrock and Cohen 1982; Kunth and Schild 1986). The redshifts of these four galaxies, based on measurements of the strongest narrow emission lines, taken from image-dissector spectral scans, are repeated from the papers cited in Table 1.

We obtained spectra of 31 of the other 32 PG narrow emission line galaxy candidates. Most of these spectra were taken especially for this investigation, chiefly with the CCD grism

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TABLE 1  
PG NARROW EMISSION LINE GALAXIES:  
ALTERNATIVE NAMES AND REDSHIFTS

PG	Mrk	Other	$z$
0014+167	...	LB 425	0.0988
0018+216	...	...	0.0193
0142+169	361	...	0.0275
0842+163	702	...	0.0537
0926+607	...	LB 555	0.0147
0930+338	...	MCG +06-21-49	0.0044
0947+282	...	MCG +05-23-40	0.0054
1016+336	...	...	0.0245
1046+526	153	...	0.0086
1102+294	36	Haro 4	0.0030
1111+099	732	IC 2637	0.0298
1127+370	424	...	0.0071
1135+124	743	NGC 3773	0.0034
1137+287	1507	Haro 27	0.0067
1222+217	...	...	0.0553
1223+488	209	...	0.0016
1256+351	59	NGC 4861 <sup>a</sup>	0.0032
1322+369	451	...	0.0167
1326+442	259	...	0.0287
1328+315	455	...	0.0346
1351+693	279	...	0.0297
1401+151	802	...	0.0152
1428+285	684	...	0.0462
1428+275	685	...	0.0155
1434+590	817	...	0.0312
1448+358	829	II Zw 70	0.0046
1452+132 W <sup>b</sup>	...	...	0.0334
1452+132 E	...	...	0.0334
1459+169	837	...	0.0324
1544+461	490	...	0.0088
1659+295	504	...	0.0361
2250+245	309	IV Zw 121	0.0427
2259+157	313	NGC 7465	0.0071
2329+287 NW <sup>c</sup>	930	...	0.0189
2329+287 SE	930	...	0.0188
2341+005	...	...	0.0500
2357+260 W <sup>d</sup>	1137	...	0.0254
2357+260 E	1137	...	0.0254
CSO 177	...	...	0.1160

<sup>a</sup> Also cataloged as Arp 266 and I Zw 49.

<sup>b</sup> East component is the brightest.

<sup>c</sup> Northwest component is the brightest.

<sup>d</sup> West component is the brightest.

spectrograph (Lauer *et al.* 1984) at the Cassegrain focus of the Shane 3 m reflecting telescope of Lick Observatory. Three transmission gratings were used, one with 420 lines  $\text{mm}^{-1}$ , for survey purposes, covering approximately the spectral range 4500–8000 Å at a resolution of about 13 Å, a second with 600 lines  $\text{mm}^{-1}$  for higher dispersion, covering the range 5300–7200 Å at a resolution of about 6 Å, and an echelle-prism combination (“echism”) covering the region 6000–7000 Å at a resolution of about 3.5 Å. We obtained spectra of nearly all the objects with the 420 lines  $\text{mm}^{-1}$  grism, but took exposures at one or the other (or in a few cases both) of the other resolutions only if further data appeared necessary or interesting. Exposure times ranged from 15 to 60 minutes; we aimed to obtain spectra with sufficiently good signal-to-noise ratios to be able to recognize and measure emission lines with intensities only a few percent of the strong [O III]  $\lambda 5007$  and H $\alpha$  lines. We also took two spectra of CSO 177 with this CCD spectrograph, using the 420 and 600 lines  $\text{mm}^{-1}$  gratings.

We also obtained spectra of three of the objects, PG 1326+441, PG 1328+315, and PG 2259+156, with the CCD

mounted in a new Schmidt camera (designed by H. W. Epps to specifications by J. S. Miller) at the large Cassegrain spectrograph formerly used with the image-dissector scanner (Miller, Robinson, and Wampler 1976). Gratings of 300 or 600 lines  $\text{mm}^{-1}$  were used, giving resolutions about 12 and 6 Å, respectively. Also, for a few of the galaxies, including PG 1102+296, image-dissector scans that had previously been taken (as described, e.g., by Osterbrock 1981) were used.

One of the objects, PG 0149+137, was much fainter in 1985–1986 when we tried to observe it, and on the Palomar Sky Survey plates (E-1275 and O-1275) taken in 1954, than it was when the PG survey plates were obtained in 1973–1974. Green, Schmidt, and Liebert (1986), no doubt for this same reason, remarked that there was probably a supernova in the galaxy at that time, and we concur. We were not able to get a satisfactory spectrum of this object.

Also, the object identified as PG 1222+217 on the finding chart in Green, Schmidt, and Liebert (1986) is near but not at the position given by them for this object. The object marked on the chart is a faint galaxy, whose position was kindly measured for us by A. R. Klemola on the Lick proper-motion survey plates. Its position in  $\alpha = 12^{\text{h}}22^{\text{m}}25^{\text{s}}.5$ ,  $\delta = 21^{\circ}38'13''$  (1950). We obtained a rather noisy spectrum of this galaxy, which shows emission lines characteristic of an H II region galaxy at a redshift  $z = 0.0553$ , as discussed in subsequent sections. Very close to the *position* given for PG 1222+217 is the quasar 4C 21.35 = PKS 1222+21; its accurate coordinates, also measured for us by Dr. Klemola, are  $12^{\text{h}}22^{\text{m}}23^{\text{s}}.4$ ,  $\delta = 21^{\circ}39'23''$  (1950). Our two spectra of this quasar, resulting in a summed exposure of 1 hr, show broad H $\delta$ , H $\gamma$ , and H $\beta$  emission lines, as well as narrower [O II]  $\lambda 3727$ , [Ne III]  $\lambda 3967$ , and [O III]  $\lambda \lambda 4959, 5007$ , at a redshift  $z = 0.432 \pm 0.001$ , confirming very well the earlier value  $z = 0.433$  measured by Burbidge and Kinman (1966).

### III. REDUCTIONS

The CCD spectral exposures were converted to spectra calibrated in flux units versus wavelength following the methods described by Osterbrock and De Robertis (1985). The few IDS scans we used had previously been calibrated in essentially the same way, as described for instance by Osterbrock (1981). All these spectra were measured for redshift, using only the stronger narrower emission lines, as described in those papers. The results, expressed as heliocentric redshifts, are listed in Table 1. The internal mean errors of these redshifts range from about  $\pm 0.0001$  to  $\pm 0.0004$  (for the noisy spectrum of the faint PG 1222+217), with median  $\pm 0.0001$  and mean  $\pm 0.00015$ . Independently measured redshifts are available for 21 of the Markarian galaxies, from Markarian *et al.* (1987). When their redshifts are converted to heliocentric values for comparison with ours, the mean difference is  $z(\text{this paper}) - z(\text{Markarian } et al. 1987) = +0.00006 \pm 0.0002$ , indicating that the typical errors in each set of values are of order  $\pm 0.0001$  or  $\pm 0.0002$ .

All the spectra were inspected visually for classification. In addition to the four Seyfert 1 and 1.5 galaxies named in § II, there are two additional newly discovered objects of this type among the PG narrow-line candidates. One is PG 1016+336, another narrow-line Seyfert 1 galaxy with relatively strong Fe II emission, whose spectrum is shown in Figure 1. The other is PG 1111+099 = Mrk 732, probably best described as a Seyfert 1.5 galaxy. Its spectrum is shown in Figure 2.

The approximate line widths of the broad components of the

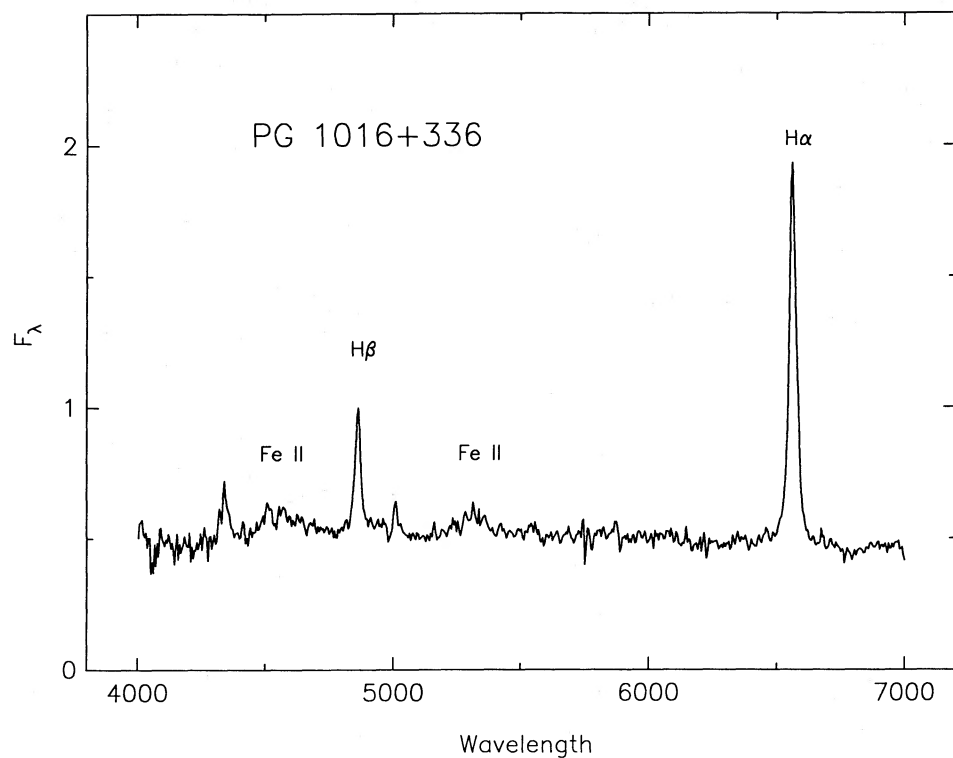


FIG. 1.—Spectrum of PG 1016+336

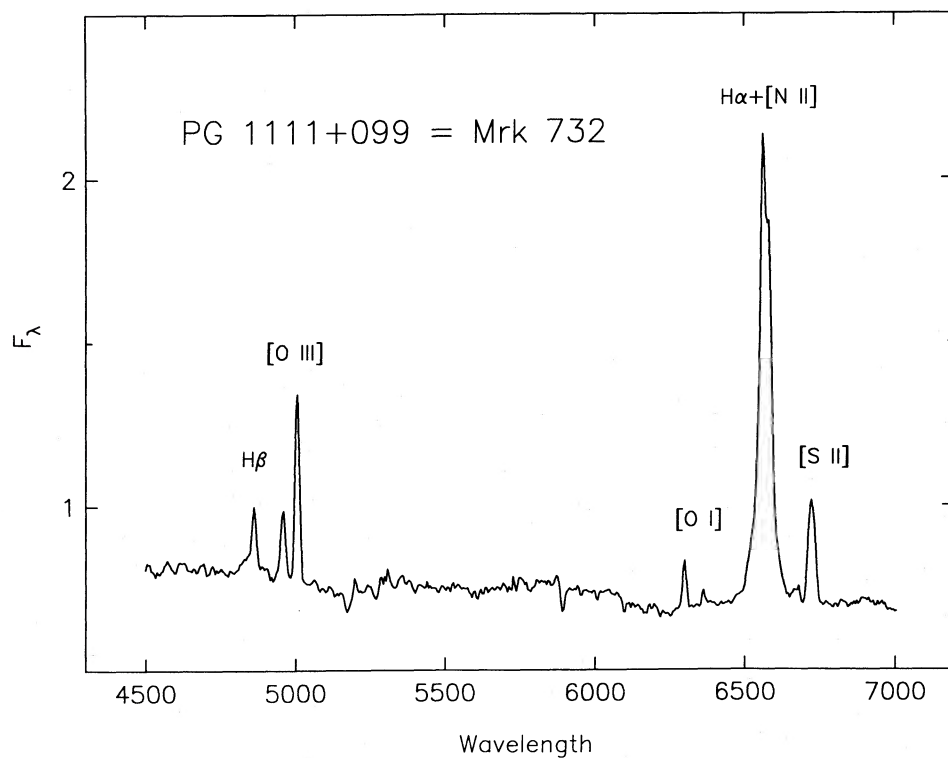


FIG. 2.—Spectrum of PG 1111+099

TABLE 2  
BROAD-COMPONENT WIDTHS OF H I LINES IN SEYFERT 1 AND  
1.5 OBJECTS FROM THE PG NARROW-LINE CANDIDATES

PG	Seyfert	FWHM (km s <sup>-1</sup> )
1016+336 .....	1	1600
1111+099 .....	1.5	3200
1351+695 .....	1.5	6900
1428+285 .....	1	1400
1434+590 .....	1.5	4200
1659+294 .....	1	2000

H I emission lines in all six Seyfert 1 and 1.5 galaxies in the PG narrow-line sample are listed in Table 2. These values were taken from the references cited above for the previously known objects, and estimated from our spectra for the two new ones.

For all the other PG narrow-line candidates, relative strengths of the stronger emission lines were measured. Particular emphasis was placed on the lines used in the diagnostic classification scheme outlined by Veilleux and Osterbrock (1987). The line strengths were measured by essentially the procedures previously described by Osterbrock and Pogge (1985) and Osterbrock and De Robertis (1985). These measured diagnostic line ratios are listed in Table 3 for all the narrow-line objects. Note that in this table [O III] stands for  $\lambda 5007$ , [O I] for  $\lambda 6300$ , and [N II] for  $\lambda 6583$ , but [S II] stands for the sum of the strengths of the two components of the doublet  $\lambda\lambda 6716, 6731$ .

From previous experience with similar spectral data, as well as from the internal consistency of some measurements of multiple spectra for a few of the PG narrow-line candidates, we believe that most of the line ratios in Table 3 are correct to about  $\pm 15\%$  of their values, except for the weak [O I]  $\lambda 6300/H\alpha$  ratios, which typically have larger errors. Some of these galaxies have been measured independently by other authors, for instance, PG 1256+351 = NGC 4861 by French and Miller (1981) and by Dinerstein and Shields (1986). All the diagnostic ratios measured by us in this object agree with those by Dinerstein and Shields to within about 3%, except for the very weak and badly blended [N II]  $\lambda 6583/H\alpha$ , for which the two sets of results differ by about a factor of 2. Likewise, our results for the weaker ratios listed in Table 4 agree nearly perfectly with those of Dinerstein and Shields for PG 1256+351, except for  $\lambda 4363/H\beta$ , for which the results differ by 18%. However, in some of the galaxies the H $\beta$  emission line is superimposed on an only slightly broader H $\beta$  absorption line in the underlying (often early-type) galaxy spectrum. In these cases, defining the H $\beta$  emission line is somewhat subjective and hence difficult, and the expected errors are therefore larger.

These measured line ratios were then corrected for interstellar extinction by the identical method used by Veilleux and Osterbrock (1987), namely, assuming an intrinsic ratio  $H\alpha/H\beta = 2.85$  for the H II region galaxies and 3.10 for the one Seyfert 2, PG 2259+157 (see below), and adopting the Whitford reddening curve as parameterized by Miller and Mathews (1972). For each object in Table 3, the top row gives the measured line ratios, while the bottom row gives the corrected ratios, with  $E_{B-V}$ , the amount of interstellar extinction, listed in place of the corrected  $H\alpha/H\beta$ .

For many of these PG galaxies, it was possible to measure the strengths of additional narrow emission lines, especially He I  $\lambda 5876$ , and in some cases H $\gamma$  and [O III]  $\lambda 4363$ . These

results are listed in Table 4, in the same format as in Table 3. The measurements of  $\lambda 5876$  are subject to significant error because of blending of its red wing with Na I  $\lambda 5893$  absorption, partly interstellar and partly in the integrated stellar galaxy spectrum. In Table 4, as in Table 3, if an entry is blank, we do not have spectra in the range required to measure this ratio, but if ellipses appear, it means the line is too faint to measure on our spectra. Finally, for the galaxies for which we had high-resolution spectra, or for which the spectra taken with the 420 lines mm<sup>-1</sup> had relatively sharp focus in the deep-red region (variation of focus with position on the CCD is a real problem), the [S II] lines could be resolved. The measured  $\lambda 6716/\lambda 6731$  ratios for these objects are listed in Table 5.

The measurements listed in Tables 3, 4, and 5 refer to the nuclei or, in the cases of PG 1452+132 and PG 2329+287, to the two apparent nuclei of these galaxies. For several of the objects our long-slit spectra contain further information on other condensations or extended areas. Among the Seyfert galaxies, in PG 1016+336, faint, narrow H $\alpha$ , [N II] emission can be seen outside the nucleus to approximately 10" east, 6" west on a spectrum taken at P.A. 90°, while in PG 111+099, an extended narrow-line H II region spectrum can be seen to 11" northeast, 13" southwest on a spectrum taken at P.A. 52°.

Visual inspection of the POSS plate images of the 35 PG narrow emission line galaxies studied reveals that six are tidally interacting systems. The long-slit spectra of these galaxies show faint extended emission regions. For three of these galaxies, PG 1452+132, PG 2329+287, and PG 2357+260, the slit includes the nuclei of both galaxies in the interacting pair. Thirteen galaxies are morphologically peculiar or appear tidally disturbed (post/preinteraction?), and their long-slit spectra likewise show extended, faint emission regions. The Seyfert 1.5 galaxy PG 1111+1099 is an example of this type. Eight of the galaxies are compact systems, four of which (including PG 1016+336) show faint, extended emission, and the other four are the faintest galaxies observed (e.g., PG 1222+217). Of the remaining galaxies, seven are essentially normal in appearance, and the last, PG 1256+351 (= NGC 4861) is not a galactic nucleus but rather appears to be a giant H II region complex situated near the southwest end of a Magellanic-type irregular galaxy. This irregular galaxy has no discernible nucleus, and the emission structure along the slit (oriented along P.A. = 45°) is rather complex, showing five distinguishable condensations. The measurements presented are of the central of the five, which accounts for most of the total emission from the complex. In all these galaxies the faint, extended emission regions have H II region spectra.

Finally, we measured approximate FWHMs for all the stronger emission lines for which we had spectra taken with the 600 lines mm<sup>-1</sup> grism. The procedure was similar to that described in earlier papers (e.g., Osterbrock and Pogge 1985; Osterbrock and De Robertis 1985), namely, to measure the FWHM of the galaxy line as observed, and also the FWHMs of comparison lines taken on the same night with the same instrumental settings. The FWHMs were measured by fitting Gaussians to the assumed profiles, or for blended lines, such as H $\alpha$ , [N II]  $\lambda\lambda 6548, 6583$ , and [S II]  $\lambda\lambda 6716, 6731$ , by fitting sums of Gaussians with the peak wavelengths constrained, and with the FWHMs of lines of the same ion constrained to be the same. The comparison lines were assumed to be intrinsically much narrower than the instrumental profile, and thus to define the instrumental FWHM. These instrumental FWHMs were interpolated as a function of wavelength to the position of

TABLE 3  
MEASURED AND CORRECTED EMISSION-LINE STRENGTHS

PG	[O III]/H $\beta$	[O I]/H $\alpha$	[S II]/H $\alpha$	[N II]/H $\alpha$	H $\alpha$ /H $\beta$ ( $E_{B-V}$ )
0014 + 167	3.51	0.03	0.11	0.15	2.78
	3.51	0.03	0.11	0.15	(0.0)
0018 + 216		0.09	0.25	0.46	...
		...	...	...	(...)
0142 + 169	1.48	0.015	0.24	0.28	3.48
	1.45	0.015	0.23	0.28	(0.20)
0842 + 163	3.24	0.019	0.20	0.20	3.65
	3.15	0.020	0.19	0.20	(0.28)
0926 + 607	5.01	0.008	0.10	0.03	2.91
	5.00	0.008	0.10	0.03	(0.02)
0930 + 338	4.14	0.04	0.26	0.06	4.34
	3.95	0.05	0.25	0.06	(0.42)
0947 + 282	4.73	0.04	0.18	0.05	3.69
	4.59	0.05	0.18	0.05	(0.26)
1046 + 526	5.29	0.011	0.09	0.07	3.16
	5.23	0.011	0.09	0.07	(0.10)
1102 + 294	4.53	0.008	0.07	0.02	2.90
	4.52	0.008	0.07	0.02	(0.02)
1127 + 370	4.01	0.04	0.22	0.07	3.78
	3.88	0.04	0.22	0.07	(0.28)
1135 + 124	1.72	<0.007	0.20	0.14	3.78
	1.66	<0.008	0.20	0.14	(0.31)
1137 + 287	1.90	0.05	0.43	0.28	4.88
	1.79	0.05	0.42	0.28	(0.54)
1222 + 217	1.55	<0.09	0.34	0.15	5.20
	1.45	<0.10	0.33	0.15	(0.60)
1223 + 488	5.85	0.01	0.04	0.03	2.72
	5.85	0.01	0.04	0.03	(0.00)
1256 + 351	5.18	0.02	0.07	0.05	2.74
	5.18	0.02	0.07	0.05	(0.00)
1322 + 369	3.53	0.03	0.21	0.11	4.56
	3.35	0.03	0.20	0.11	(0.47)
1326 + 442	4.16	0.02	0.15	0.06	3.31
	4.09	0.02	0.15	0.06	(0.15)
1328 + 315	1.39	0.02	0.19	0.26	3.62
	1.35	0.02	0.18	0.26	(0.24)
1401 + 151	2.77	0.03	0.23	0.19	3.33
	2.72	0.03	0.23	0.18	(0.16)
1428 + 275	3.88	0.05	0.24	0.14	3.34
	3.81	0.05	0.24	0.14	(0.16)
1448 + 358	4.25	0.02	0.13	0.06	3.05
	4.22	0.02	0.13	0.06	(0.07)
1452 + 132 E	2.61	0.05	0.31	0.21	3.24
	2.58	0.05	0.31	0.21	(0.13)
1452 + 132 W	1.83	0.04	0.28	0.24	3.56
	1.79	0.04	0.28	0.24	(0.22)
1459 + 169	3.64	0.03	0.16	0.25	3.98
	3.51	0.03	0.16	0.24	(0.33)
1544 + 461	7.12	0.02	0.06	0.04	2.69
	7.12	0.02	0.06	0.04	(0.00)
2250 + 245	0.40	<0.006	0.09	0.72	5.95
	0.37	<0.006	0.09	0.71	(0.74)
2259 + 157	3.52	0.10	0.50	0.52	5.34
	3.18	0.11	0.47	0.52	(0.90)
2329 + 287 NW	4.98	0.03	0.16	0.05	3.46
	4.88	0.03	0.15	0.05	(0.19)
2329 + 287 SE	4.44	0.03	0.16	0.05	3.84
	4.30	0.03	0.16	0.05	(0.30)
2341 + 005	0.85	0.03	0.30	0.50	6.35
	0.78	0.03	0.29	0.49	(0.80)
2357 + 260 W	1.07	0.03	0.15	0.35	6.96
	0.97	0.04	0.14	0.34	(0.90)
CSO 177	4.56	0.02	0.15	0.09	3.16
	4.51	0.02	0.15	0.09	(0.10)

the galaxy line. Its intrinsic FWHM was then taken to be the square root of the difference of the squares of the observed and instrumental FWHMs. These values, corrected to velocity units in the rest system of the emitting galaxy, are listed in Table 6.

TABLE 4  
ADDITIONAL LINE RATIOS FOR SELECTED GALAXIES

PG	H $\gamma$ /H $\beta$	[O III] $\lambda$ 4363/H $\beta$	He I $\lambda$ 5876/H $\alpha$
0014+167			0.054
			0.054
0018+216 <sup>a</sup>			<0.002
			...
0142+169	0.36	...	0.041
	0.39	...	0.036
0842+163	0.31	...	0.046
	0.35	...	0.039
0926+607			0.038
			0.037
0947+282	<0.15	...	<0.03
	<0.17	...	<0.02
1046+526	0.32	0.12	0.040
	0.34	0.13	0.037
1102+294			0.048
			0.047
1127+370			0.055
			0.046
1135+124			0.049
			0.041
1137+287			0.05:
			0.03:
1223+488	0.50	0.13	0.041
	0.50	0.13	0.041
1256+351	0.46	0.076	0.034
	0.46	0.076	0.034
1322+369	0.15	...	0.030
	0.18	...	0.022
1326+442			0.038
			0.034
1328+315	0.38	...	0.033
	0.43	...	0.028
1401+151	0.36	...	0.043
	0.39	...	0.039
1428+275	0.39	0.084	0.041
	0.41	0.090	0.037
1448+358	0.39	0.084	0.036
	0.40	0.087	0.034
1452+132 E	0.31	...	0.041
	0.33	...	0.038
1452+132 W	0.14	...	0.039
	0.15	...	0.034
1459+169	0.30	0.054	0.040
	0.35	0.062	0.032
1544+461	0.35	0.076	0.034
	0.35	0.076	0.034
2250+245	0.24	...	<0.002
	0.33	...	<0.001
2259+157	...	...	0.074
	...	...	0.069
2329+287 NW	0.41	0.050	0.034
	0.45	0.054	0.030
2329+287 SE	0.43	0.054	0.039
	0.49	0.062	0.032
CSO 177	0.45	0.052	0.13
	0.47	0.054	0.12

<sup>a</sup> H $\beta$  in absorption.

TABLE 5  
LINE RATIOS FOR SELECTED GALAXIES

PG	[Si II] $\lambda$ 6716/ $\lambda$ 6731
0014+167	1.44
0926+607	1.28
1102+294	1.33
1544+461	1.11
2250+245	0.81
2259+157	1.18
2329+287 NW	1.39
2329+287 SE	1.42
2341+005	1.23
2357+260 W	1.15

For CSO 177, the FWHMs of H $\beta$  and of [O III]  $\lambda$ 4959, 5007 were all determined from the 600 line mm<sup>-1</sup> spectrum to be  $\leq 150$  km s<sup>-1</sup>, by the same method. Because of its large redshift, we have no high-dispersion spectrum of this object in the H $\alpha$ , [N II], [S II] region.

#### IV. DISCUSSION

One very interesting result of this survey of the PG narrow emission line galaxy candidates is the fairly large number of Seyfert 1 and 1.5 objects among them, six in all. All of them have  $M_B > -23$  and thus are Seyfert 1's, not QSOs, according to the definition adopted by Schmidt and Green (1983). Three of these six have H I FWHMs  $\leq 2000$  km s<sup>-1</sup> according to Table 2. Adding to these six the 23 Seyfert 1's in the PG sample according to Green, Schmidt, and Liebert (1986) makes a total of 29 Seyfert 1 galaxies in the PG complete sample. The additional Seyfert 1 galaxies thus only change the discussion of the low-luminosity quasar and Seyfert 1 nuclei luminosity function by Schmidt and Green (1983) at the 20% level. However, in addition to the three narrow-line objects in Table 2, at least one more of the 23 Seyfert 1's, PG 0005+124 = I Zw 1, has H I emission lines with FWHM  $\leq 2000$  km s<sup>-1</sup>. Thus, in this sample, 14% and possibly more of the known Seyfert 1's are "narrow-line" objects in this sense. They represent a by no means insignificant fraction of the distribution of Seyfert 1 galaxy H I line widths, as previously stated (Osterbrock and Pogge 1985). Halpern and Oke (1987) have recently identified Mrk 509 as another highly reddened member of this class, which they call narrow-line Seyfert galaxies with permitted Fe II emission.

The narrow-line galaxies from the PG sample that are not Seyfert 1 or Seyfert 1.5 objects are plotted in the three classification diagrams of [O III]  $\lambda$ 5007/H $\beta$  versus [N II]  $\lambda$ 6583/H $\alpha$ ,

TABLE 6  
FWHMS OF EMISSION LINES

PG	FWHM (km s <sup>-1</sup> )		
	H $\alpha$	[N II]	[S II]
0014+167	350	350	400
0926+607	$\leq 150$	$\leq 150$	$\leq 150$
1544+461	$\leq 150$	$\leq 150$	$\leq 150$
2259+157	250	250	200
2329+287 NW	$\leq 150$	$\leq 150$	$\leq 150$
2329+287 SE	$\leq 150$	$\leq 150$	$\leq 150$
2341+005	250	250	250
2357+260 W	$\leq 150$	$\leq 150$	$\leq 150$

[S II] ( $\lambda 6716 + \lambda 6731$ )/ $H\alpha$ , and [O I]  $\lambda 6300/H\alpha$  recommended by Veilleux and Osterbrock (1987) in Figures 3, 4, and 5, respectively. The solid lines in these three diagrams represent the division between H II region galaxies (to the left of the line) and AGNs (to the right of the line) as shown in their paper.

One object is consistently in the AGN region of all three diagrams; it is PG 2259 + 147 = NGC 7465 = Mrk 313, the only Seyfert 2 galaxy found among the narrow emission line PG galaxies. It is quite near, with  $z = 0.0071$ , corresponding (for an assumed  $H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$ ) to a distance  $4.3 \times 10^7 \text{ pc}$ . Its absolute magnitude is only  $M_B = -18.1$ . Its spectrum is shown in Figure 6, where it can be seen to be a low-ionization Seyfert 2. In fact, its intensity ratio [O III]  $\lambda 5007/H\beta = 3.2$  makes it barely a Seyfert 2 (Osterbrock and Shuder 1982), but its [O II]  $\lambda 3727/[O III] \lambda 5007 = 1.4$  would put it in the LINER class (Heckman 1980), though its ratio [O I]  $\lambda 6300/[O III] \lambda 5007 = 0.10$  is too small for that group.

In Figure 3, one other object, PG 1150 + 245, also appears on the AGN side of the boundary; it is the unusual galaxy Mrk 309 with a large population of Wolf-Rayet stars (Osterbrock and Cohen 1982). Its position illustrates that a simple classification into either H II region galaxy or AGN must necessarily break down for peculiar or unusual objects that do not clearly fit into either group.

The line-width data of Table 6 show that PG 2259 + 157 has relatively narrow emission lines for a Seyfert 2 galaxy but that their widths are in the range in which the FWHMs of many other low-luminosity Seyfert 2 galaxies are measured (Phillips, Charles, and Baldwin 1983; Whittle 1985). Most of the H II region galaxies, including CSO 177, have narrower emission lines, but PG 2341 + 005 has FWHMs comparable to those of PG 2259 + 157, while PG 0014 + 167 has significantly broader

emission lines, with  $\text{FWHM} = 350\text{--}400 \text{ km s}^{-1}$ . There are real overlaps in the ranges of line widths of AGNs and H II region galaxies.

The relative strengths of the H II galaxies listed in Tables 3, 4, and 5 are quite similar to those measured in other objects of this type, as listed for instance by French (1980), Balzano (1983), Kunth and Sargent (1983), and Campbell, Terlevich, and Melnick (1986). The temperatures measured from [O III] ( $\lambda 4959 + \lambda 5007$ )/ $\lambda 4363$  are in the range 9000–17,000 K, while the electron densities measured from [S II]  $\lambda 6716/\lambda 6731$  range from approximately 10 to  $10^3 \text{ cm}^{-3}$ , with median about  $10^2 \text{ cm}^{-3}$ . All these values are quite unexceptional for H II region galaxies. Likewise, the  $\text{He}^+/\text{H}^+$  abundance ratios from the measured He I  $\lambda 5876$  relative strengths range from 0.06 to 0.11, again completely normal.

The large number of H II region galaxies found in the PG sample shows that this kind of survey will pick up many objects of this type, photoionized by hot stars, but only a few AGNs.

The very small number of Seyfert 2 objects found in the PG survey confirms that ultraviolet excess is not a good criterion for finding objects of this type, as several authors have previously stated (Phillips, Charles, and Baldwin 1983; Wasilewski 1983). In fact, it is notable that PG 2259 + 157, the only Seyfert 2 found, is not an otherwise normal galaxy. It appears to be tidally interacting with a nearby galaxy (NGC 7463), and our long-slit spectra show faint, extended emission regions with H II region spectra, suggesting that it is a site of relatively active star formation. Its detection in the PG survey may thus be due to a combination of factors, perhaps incidental to its having a Seyfert 2 nucleus. It is interesting that this single Seyfert 2 galaxy found in the PG survey may be used to deter-

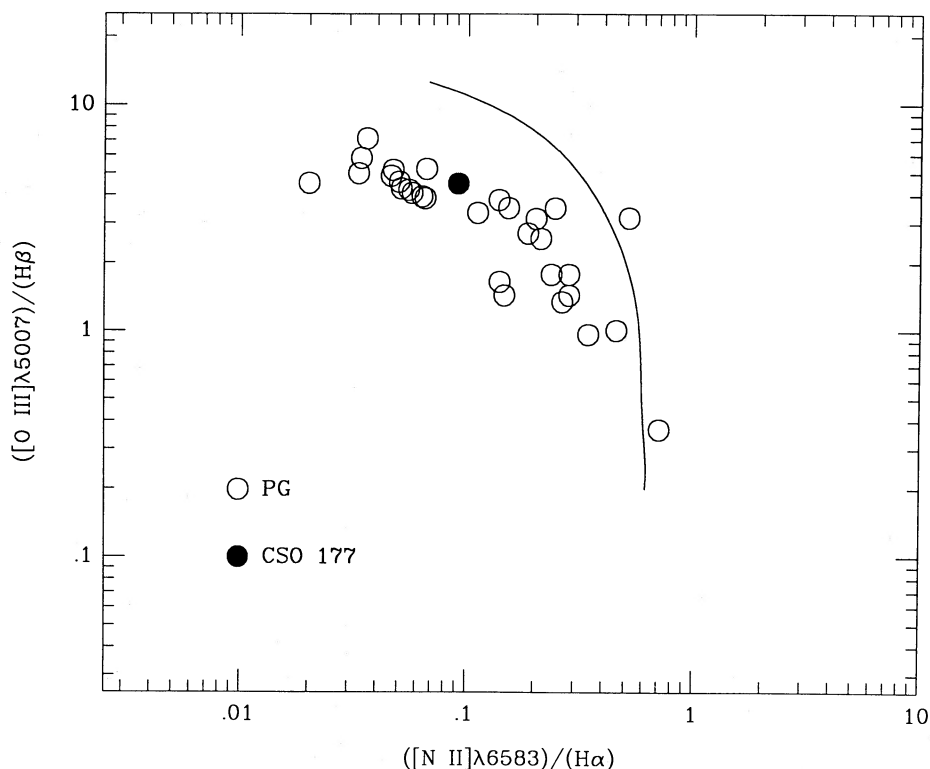


FIG. 3.—[O III]  $\lambda 5007/H\beta$  versus [N II]  $\lambda 6583/H\alpha$  diagnostic diagram

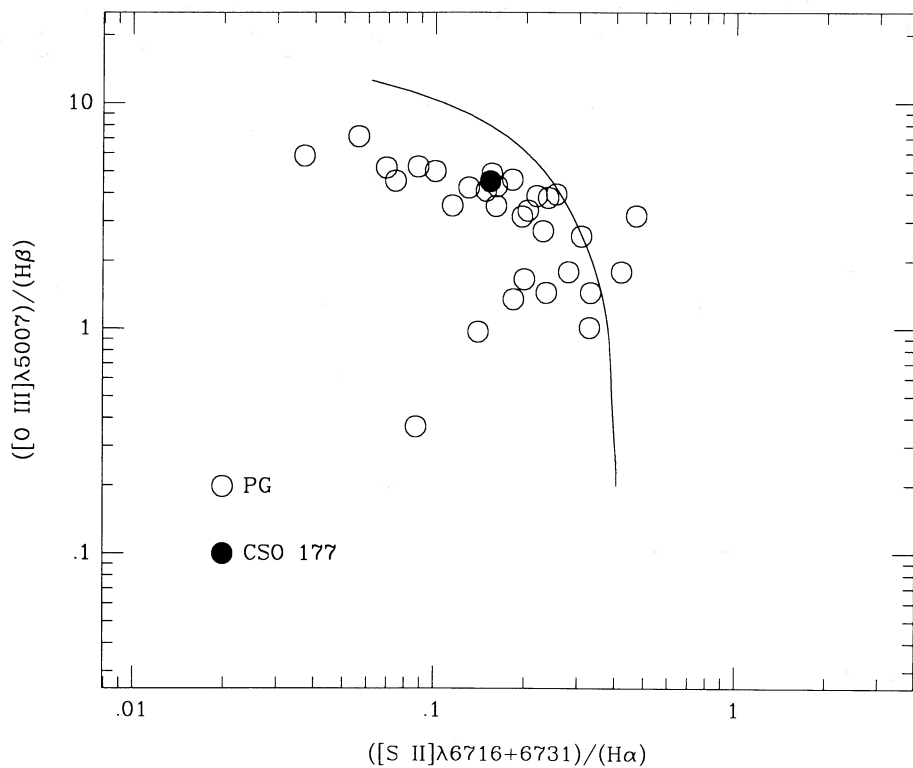


FIG. 4.—[O III]  $\lambda 5007/H\beta$  versus [S II] ( $\lambda 6716 + \lambda 6731$ )/H $\alpha$  diagnostic diagram

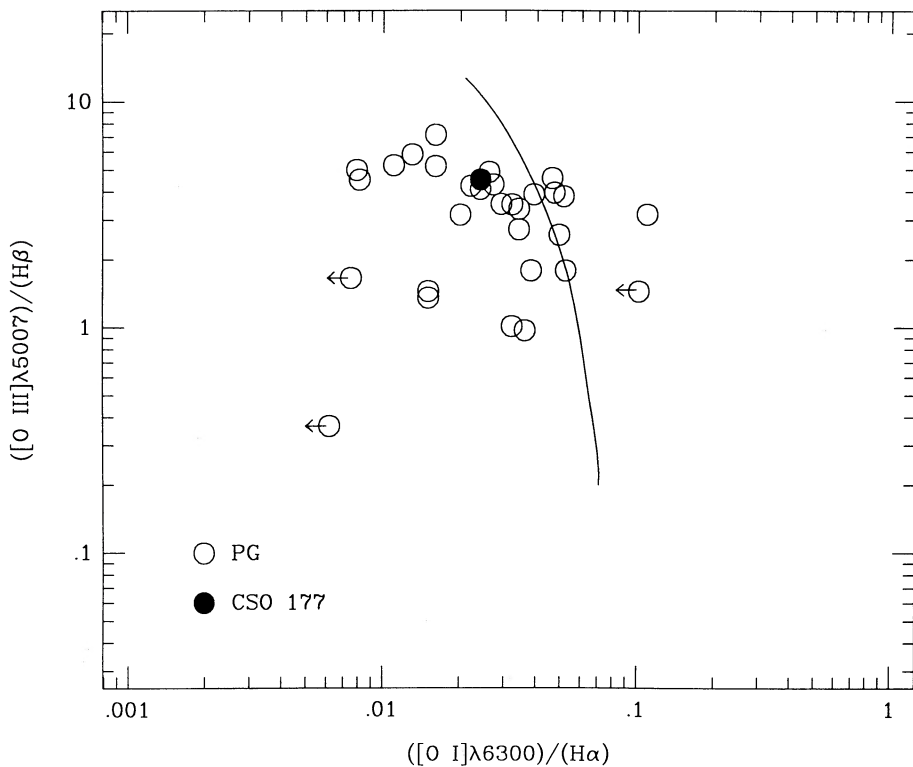


FIG. 5.—[O III]  $\lambda 5007/H\beta$  versus [O I]  $\lambda 6300/H\alpha$  diagnostic diagram

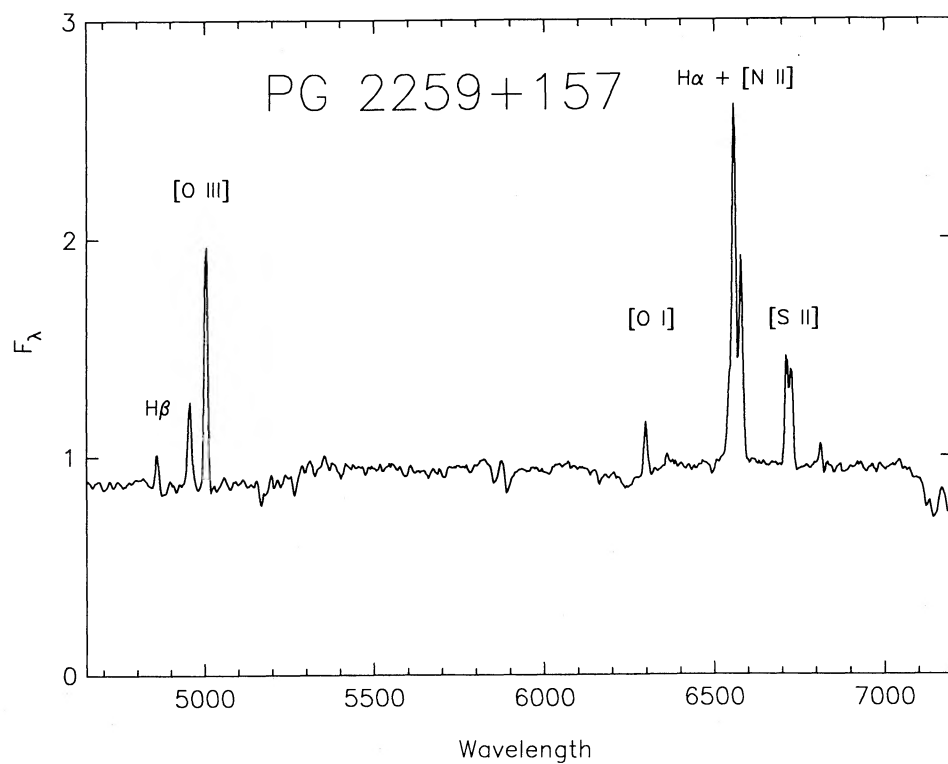
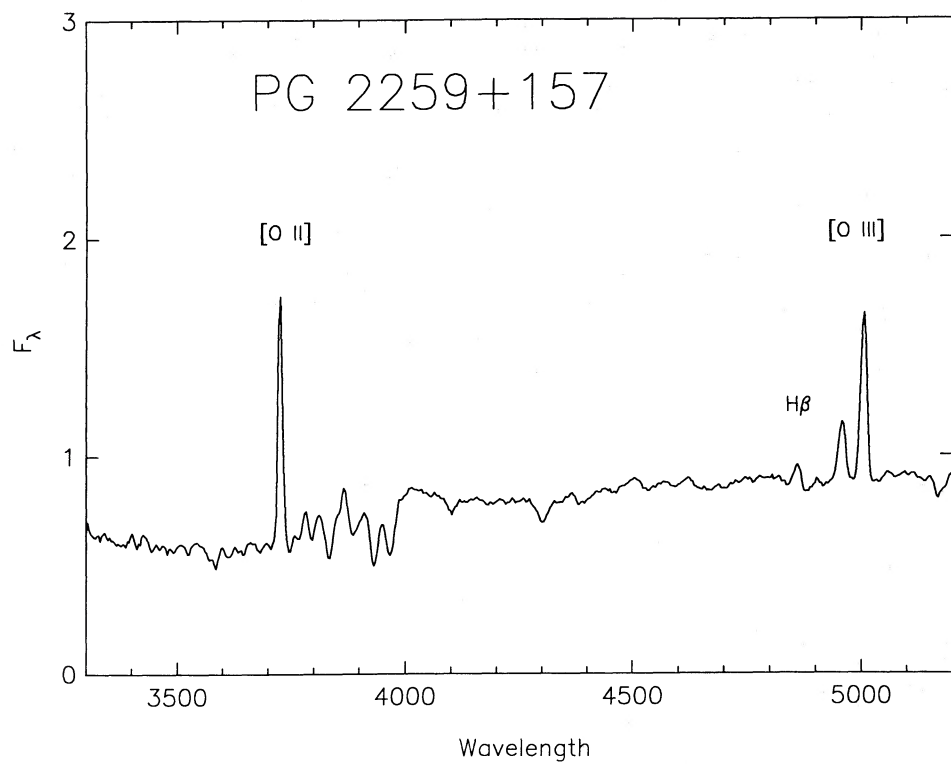


FIG. 6.—Spectrum of PG 2259 + 157 = NGC 7465 = Mrk 313

mine (in order of magnitude only, for the statistical uncertainty of a sample of one object is of the order of the sample itself) a luminosity function for objects of this type. Following the method outlined by Schmidt and Green (1983), which for nearby objects is greatly simplified and is independent of  $q_0$ , and using the plate limit data, tabulated by Green, Schmidt, and Liebert (1986), the number of Seyfert 2's blue enough to be identified in the PG survey and more luminous than  $M_B = -18$  is very roughly  $1/(4.1 \times 10^5) \text{ Mpc}^{-3}$ , or  $2.4 \times 10^{-6} \text{ Mpc}^{-3}$ . This is smaller by about a factor of 4 than the value  $9.2 \times 10^{-6} \text{ Mpc}^{-3}$  (to approximately this same absolute magnitude limit) found by Meurs and Wilson (1984) in the best presently available luminosity function for Seyfert 2 galaxies. Meurs and Wilson's sample was based on the Markarian survey, which has a less well defined cutoff in ultraviolet color

but undoubtedly contains many objects that are less blue than the limit of the PG survey.

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