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X-RAY OBSERVATIONS WITH THE *EINSTEIN OBSERVATORY* OF EMISSION-LINE GALAXIES

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ABSTRACT

X-ray observations of narrow-emission-line galaxies are presented and discussed. One source, NGC 1365, is found to be extended in the soft X-ray band; three others, NGC 2992, NGC 5506, and NGC 7582, have been observed to vary in intensity. The best fit spectral index and cutoff energy E_a are derived for NGC 2992, NGC 5506, and NGC 7582. The X-ray spectra of these galaxies are similar to those of type 1 Seyfert galaxies. In the case of NGC 5506 and NGC 7582, the absorbing column N_H derived is about one order of magnitude greater than predicted from the reddening of the optical continuum and of the Balmer lines. Possible explanations for the discrepancy are discussed.

Subject headings: galaxies: nuclei — galaxies: Seyfert — X-rays: sources

I. INTRODUCTION

In this paper we present observations made with the *Einstein Observatory* of three emission-line galaxies, NGC 1365, NGC 2992, and NGC 5506, which were previously recognized as strong X-ray emitters (Bahcall *et al.* 1975; Ward *et al.* 1978; Griffiths *et al.* 1979). *Einstein* data on a fourth galaxy of this type, NGC 7582, have already been described by Maccacaro and Perola (1981), and a further observation is presented here.

These four objects belong to a group of X-ray-discovered active galaxies, which were originally classified as narrow-line (or Seyfert 2) galaxies. High-quality spectrophotometry (Veron *et al.* 1980; Shuder 1980; Ward *et al.* 1980) has revealed faint broad wings on the Balmer lines (particularly Hα) in NGC 1365, NGC 2992, and NGC 5506, thus showing the presence in these cases of a nucleus with properties similar to those of the classical type 1 Seyfert galaxies. Furthermore, the nuclear region of NGC 1365 contains several bright spots, as pointed out first by Sersic and Pastoriza (1965).

The four galaxies have the common property of being very dusty, and a fairly large extinction of the light from their nuclei has been inferred from the steepness of both the Balmer decrement and the continuum. This fact has led several authors (Wilson *et al.* 1976; Ward *et al.* 1980; Shuder 1980) to predict, under specific assumptions, values of the hydrogen column density N_H in the line of sight. This would be recognized through a photoelectric cutoff in their X-ray spectra, with the cutoff energy E_a in the range of 0.5–1.5 keV.[4] Evidence of a cutoff at 2 keV was found in NGC 5506 with the Mullard Space Science Laboratory (MSSL) spectrometer on *Ariel 5* (Stark, Bell Burnell, and Culhane 1978), but the uncertainty was very large. The purpose of the observations described here (and in Maccacaro and Perola 1981) was to measure E_a, together with the X-ray spectral index, by means of the Imaging Proportional Counter (IPC, energy window ~0.2–4.0 keV) and the Monitor Proportional Counter (MPC, energy window ~1–20 keV).

In addition to this, we have been able to construct light curves for NGC 2992 and NGC 5506 to position the X-ray sources accurately and to reveal that the X-ray source in NGC 1365 is either extended or multiple. For the distance we have adopted $H_0 = 50$ km s^{-1} Mpc^{-1}.

II. OBSERVATIONS

Table 1 contains information on the dates, instruments, and effective exposure times of the observations. For a description of the instruments, see Giacconi *et al.* (1979), Grindlay *et al.* (1980), and Halpern (1982). The results from the IPC observations are summarized in Table 2A; those from the MPC observations are in Table 2B. In the case of NGC 1365 and NGC 5506, the position of the X-ray source is determined with an accuracy of ±1′ (90% confidence). In the case of NGC 2992, for which an observation with the High Resolution Imager (HRI) was also obtained, the accuracy is ±10″. In all three cases, the X-ray position is coincident, within the experimental errors, with the optical position of the nucleus of the

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[4] E_a is defined by the condition $\sigma(E_a)N_H = 1$. Brown and Gould (1970) cross sections and abundances have been used.

TABLE 1

Einstein Observing Log for Narrow Emission-Line Galaxies

Object	Date	Instrument	Exposure Time (s)	Sequence No.
NGC 1365	1979 Aug 17	IPC	1367	3058
		MPC	819	3058
	1980 Aug 15	IPC	2491	3059
		MPC	3236	3059
NGC 2992	1978 Nov 22–23	HRI	12141	441/1117
	1979 Jun 2	MPC	9902	1493[a]
	1979 Nov 12	IPC	1917	3060
		MPC	1408	3060
	1979 Dec 2	IPC	1875	3061
	1980 Jun 5–9	IPC	8270	6376
		MPC	10337	6376
NGC 5506	1979 Jul 21	IPC	2458	3062
		MPC	1915	3062
	1979 Jul 30	IPC	1715	3063
		MPC	1997	3063
	1979 Aug 9	MPC	12567	1496[a]
NGC 7582	1978 Dec 4	MPC	9180	1494a[a]
	1979 Jun 2	MPC	6904	1494b[a]

[a] These observations were made available to us by courtesy of S. S. Holt and R. Mushotzky.

TABLE 2

A. X-Ray Data: IPC (0.2–3.5 keV)

Object	Z	counts s^{-1}	Flux ($\times 10^{-11}$) (ergs cm^{-2} s^{-1})	Log L_x (ergs s^{-1})	X-Ray Coordinates (1950.0)		Hardness Ratio	Sequence No.
NGC 1365	0.0052	0.054 ± 0.008	0.14 ± 0.02	41.2	$03^h31^m42^s.3$	± 60″	0.73 ± 0.13	3058
		0.051 ± 0.006	0.12 ± 0.01	41.1	−36°18′58″.5			3059
NGC 2992	0.0073	0.292 ± 0.013	0.91 ± 0.04	42.3	$09^h43^m17^s.7$	± 10″	2.17 ± 0.05	3060
		0.302 ± 0.013	0.94 ± 0.04	42.3	−14°05′42″.0			3061
		0.743 ± 0.015	2.32 ± 0.05	42.7	...	...	...	6376a
		0.603 ± 0.012	1.88 ± 0.04	42.6	...	...	...	6376b
NGC 5506	0.0061	0.267 ± 0.011	1.12 ± 0.05	42.2	$14^h10^m40^s.0$	± 60″	4.42 ± 0.35	3062
		0.368 ± 0.015	1.55 ± 0.07	42.4	−2°58′00″.8			3063

B. X-Ray Data: MPC (2–10 keV)

Object	counts s^{-1}[a]	Flux ($\times 10^{-11}$) (ergs cm^{-2} s^{-1})	Log L_x (ergs s^{-1})	α[b]	E_a[b]	N_H ($\times 10^{21}$)[b] (atoms cm^{-2})	Norm	Sequence No.
NGC 1365	<0.3[c]	<0.55	<41.8	...	...	...	...	3058/3059
NGC 2992	1.08 ± 0.11	2.17 ± 0.22	42.7	0.82 ± 0.25	1.5 ± 0.3	$14.3^{+8.0}_{-6.1}$	1.1×10^{-11}	1493
	1.24 ± 0.15	2.66 ± 0.32	42.8	0.97 ± 0.60	1.8 ± 0.6	$22.3^{+22.1}_{-14.1}$	1.9×10^{-11}	3060
	2.77 ± 0.11	6.55 ± 0.26	43.2	0.66 ± 0.07	1.4 ± 0.1	$12.1^{+2.2}_{-2.0}$	2.6×10^{-11}	6376
NGC 5506	2.25 ± 0.15	4.89 ± 0.33	42.9	0.72 ± 0.30	2.4 ± 0.4	$45.3^{+21.3}_{-16.4}$	2.6×10^{-11}	3062
	2.97 ± 0.15	6.25 ± 0.34	42.9	0.93 ± 0.30	2.4 ± 0.3	$45.3^{+15.5}_{-12.7}$	4.6×10^{-11}	3063
	3.16 ± 0.11	6.63 ± 0.23	43.0	0.84 ± 0.05	2.4 ± 0.2	$45.3^{+10.0}_{-8.8}$	4.3×10^{-11}	1496
NGC 7582	2.14 ± 0.10	5.09 ± 0.24	42.7	$0.90^{+0.1}_{-0.3}$	$3.3^{+0.1}_{-0.3}$	$100.0^{+8.0}_{-22.8}$	4.8×10^{-11}	1494a, b

[a] Errors on counts s^{-1} and flux are the combination of photon counting statistics and systematic errors of 0.1 counts s^{-1}.
[b] Errors on the slope and on the cutoff energy E_a are at the 90% confidence level for two interesting parameters.
[c] 3 σ upper limit.

galaxy (Gallouët, Heidmann, and Dampierre 1975; Edmunds and Pagel 1981).

To construct the light curves (Figs. 1 and 3), we used all the MPC data available to us, since they offer the best time coverage. Table 3 shows that variations in the IPC count rate were always consistent with those found in the simultaneous MPC observations.

At present, unfortunately, calibration problems do not allow the derivation of reliable spectral parameters from the IPC pulse-height spectrum. For NGC 2992, NGC 5506, and NGC 7582, however, the energy spectral index α of a power law and the cutoff energy E_a could be derived by fitting the energy distribution of the MPC counts (Table 2B). Only the six channels covering the energy range of 1–10 keV were used, since the two channels at higher energies are often significantly contaminated by the background at these flux levels. In this energy range, the MPC has an energy resolution of $\sim$25%. (0.4 keV at 1.25 keV, and 1.2 keV at 5.9 keV; Giacconi *et al.* 1979). Acceptable χ^2 values were obtained in all cases.

The (0.2–3.5 keV) flux values of NGC 2992 and NGC 5506 in Table 2A were obtained from the IPC count rates using the spectral parameters derived from the MPC data. The errors given are from counting statistics only, but an additional $\sim$20% systematic uncertainty is expected.

These IPC fluxes are consistent with the extrapolation of the spectra fitted through the MPC data. This provides a notable, independent check on the MPC fits. A further check on the consistency, on which we shall comment later, was based on the hardness ratio, HR = counts (1.2–3.0 keV)/counts (0.5–1.2 keV) (cf. Zamorani *et al.* 1981).

a) NGC 1365

This galaxy was observed two times 1 year apart (Table 1). On both occasions NGC 1365 was clearly detected with the IPC, but not with the MPC. Using a method similar to the one discussed by Henry *et al.* (1979), we have tested for extension the surface brightness distribution of the source. We found it to be inconsistent with being pointlike at the $>3\ \sigma$ level. The estimate of its size is 41″ (+12″, −7″). This extension could be due to a truly diffuse emission or to the contribution of compact sources in the bright H II regions surrounding the Seyfert nucleus (Osmer, Smith, and Weedman 1974; Edmunds and Pagel 1981). These possibilities are discussed in § IV*c*.

The two measurements of the X-ray flux are identical within the errors (Table 2A). The hardness ratios from the two observations are consistent with a constant value, and their weighted mean is HR = 0.73 + 0.13. This is a rather low value (cf. Zamorani *et al.* 1981, § III*d*), which implies a soft spectrum and a low value of the intrinsic absorption ($N_H < \sim 5 \times 10^{21}$ cm^{-2}). The flux is computed assuming a power-law spectrum with energy spectral index 1.0, a column density in our Galaxy of 3.0×10^{20} cm^{-2}, appropriate for the galactic latitude of the object ($b^{II} = -54°$), and no intrinsic cutoff.

There is a second, unidentified source present in the 1° × 1° IPC images centered at NGC 1365. Its flux is $\sim$80% that of NGC 1365; its position is R.A. = $03^h31^m18^s.6$; Decl. = −36°30′20″ (±60″; 1950.0 coordinates); its hardness ratio is 1.0 ± 0.3.

The 2–10 keV X-ray flux reported by Ward *et al.* (1978) is 2.7 times greater than the present MPC upper limit. It is doubtful whether this is evidence of variability in NGC 1365, because both *Ariel 5* and the MPC see (different) blends of the two sources reported here because of their small angular separation of $\sim$12′.

b) NGC 2992

Several observations of NGC 2992 were made over a period of 18 months (Table 1), and on all occasions the galaxy was detected. No other source of comparable strength is present in the 1° × 1° region centered on NGC 2992. The HRI data allow us to set an upper limit of $\lesssim 5''$ ($\sim$1 kpc) for its size. NGC 2992 forms the interacting pair, Arp 245 with NGC 2993. We can set a 3 σ upper limit of 8% of the flux of NGC 2992 ($\sim 3 \times 10^{42}$ ergs s^{-1}) on the X-ray flux from NGC 2993 in the HRI band ($\sim$0.2–3.5 keV).

Also, from our data it is evident that NGC 2992 is a variable X-ray source, confirming the finding of Marshall, Warwick, and Pounds (1981). Its light curve is shown in Figure 1. Variability is present in our data on a time scale of several months (almost a factor of 3 increase between 1979 June and 1980 June), as well as on a time scale of a few days ($\sim$30% decrease from 1980 June 6 to June 8).

Although the X-ray flux varies, there is no evidence of variations either in the spectral index or in the low-energy cutoff (see Table 2B). Figure 2 shows the data points and the best fit spectrum of NGC 2992 (1980 June observation). The hardness ratios from the three IPC observations are consistent with a constant value, and their weighted mean is HR = 2.17 + 0.05. This high value is consistent with the presence of the low-energy cutoff at $\sim$1.4 keV, as derived from the MPC data.

c) NGC 5506

Three observations of NGC 5506 were made between 1979 July and August (see Table 1). The IPC image of the source appears unresolved (<40″ diameter for a Gaussian profile, 3 σ limit), and no other source of comparable strength is present in the 1° × 1° field

TABLE 3

COMPARISON BETWEEN IPC AND MPC COUNT RATES

Object	Sequence Nos. (ratios)	IPC	MPC
NGC 2992	3060/6376a	0.39 ± 0.02	0.41 ± 0.04
NGC 2992	6376a/6376b	1.23 ± 0.03	1.25 ± 0.05
NGC 5506	3062/3063	0.73 ± 0.04	0.76 ± 0.04

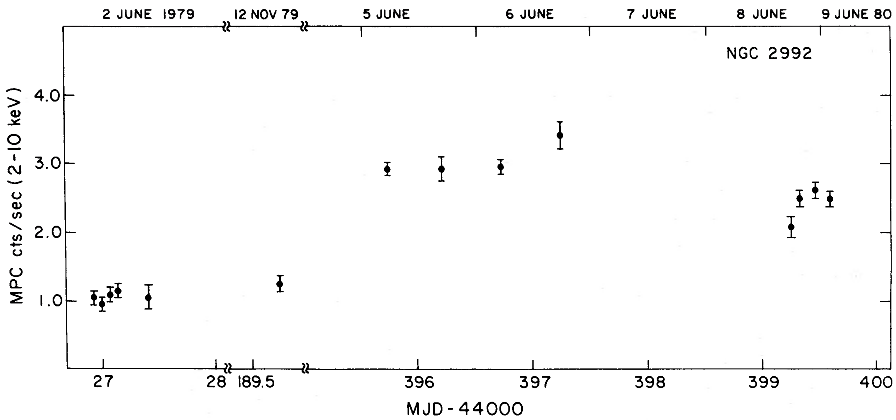

FIG. 1.—X-ray light curve for NGC 2992 from MPC observations

centered on this galaxy. Figure 3 shows the X-ray light curve. The flux is clearly variable on a time scale as short as a few hours (~25% increase), and a longer term variability (~10 days) of the same amplitude can also be seen by comparing the data from the first two observations. A variation of a factor of 3 in the 2–10 keV flux over a time scale of a few days has been previously reported by Marshall and Warwick (1979).

Also, in the case of NGC 5506, the spectral parameters derived from the three MPC observations do not show any significant change, despite the variations in the flux (Table 2B). Figure 4 shows the data points and the best fit spectrum of NGC 5506 (1979 August observation). The hardness ratio from the two IPC observations are consistent with a constant value, and their weighted mean is HR = 4.42 ± 0.35. This rather extreme value implies the almost complete absence of X-ray flux at the very low energies, thus indicating the lack of any low-energy component in the spectrum. By contrast, in the case of NGC 4151, where such a low energy component is present (Holt *et al.* 1980), the hardness ratio was observed to be equal to 1.8 ± 0.2, when the cutoff energy E_a deduced from the simultaneous MPC measurements was similar to that found in NGC 5506 (our data, unpublished).

d) *NGC 7582*

IPC and MPC observations of NGC 7582 and the Grus Quartet have been published already by Maccacaro and Perola (1981). MPC data from a very long exposure have recently become available to us, and we have used them to determine more accurately the spectral parameters of NGC 7582. Figure 5 shows the data points and the best fit spectrum. The values of the spectral index and the cutoff energy (Table 2B) are in agreement with those found by Maccacaro and Perola (1981). It is noteworthy that E_a is larger in NGC 7582 than in NGC 5506,

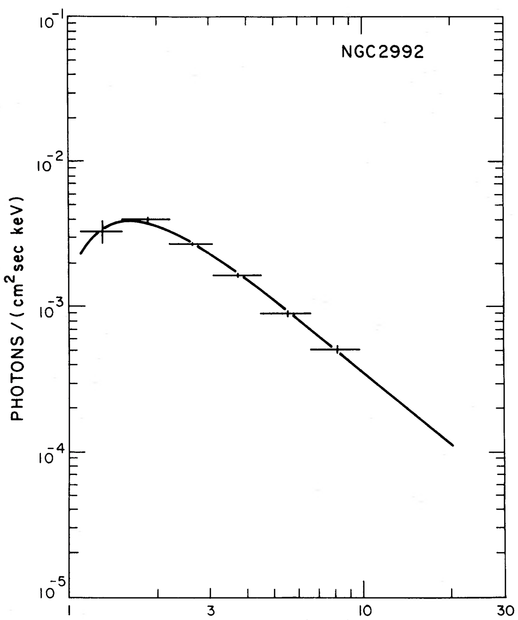

FIG. 2.—The derived incident photon spectrum of NGC 2992; solid line is the best fit to data points.

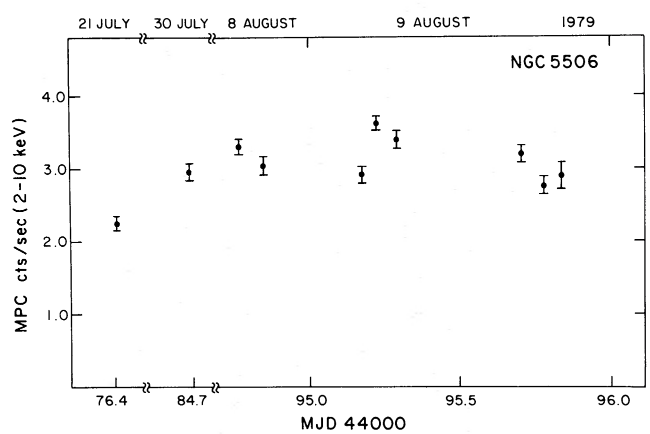

FIG. 3.—X-ray light curve for NGC 5506 from MPC observations

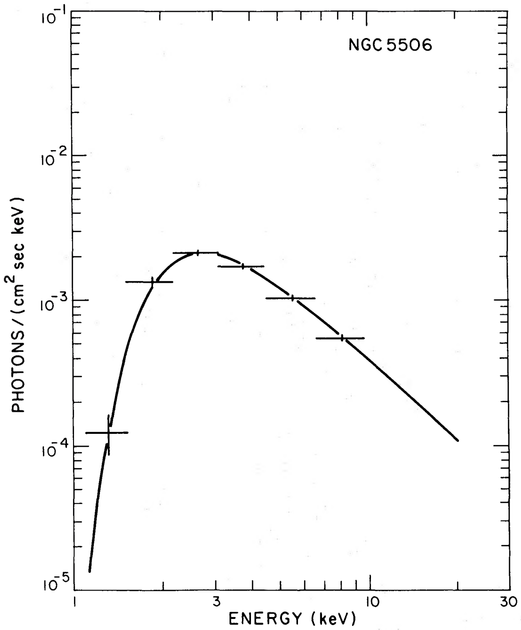

FIG. 4.—The derived incident photon spectrum of NGC 5506; solid line is the best fit to data points.

although the hardness ratio is smaller (HR = 3.03 ± 0.61). According to the remarks made in § II*c*, this fact suggests that a relatively faint, low-energy component might be present in NGC 7582. Finally, we note that the X-ray flux from this galaxy is variable; a decrease by a factor of ~3 over a period of a month was reported in Maccacaro and Perola (1981).

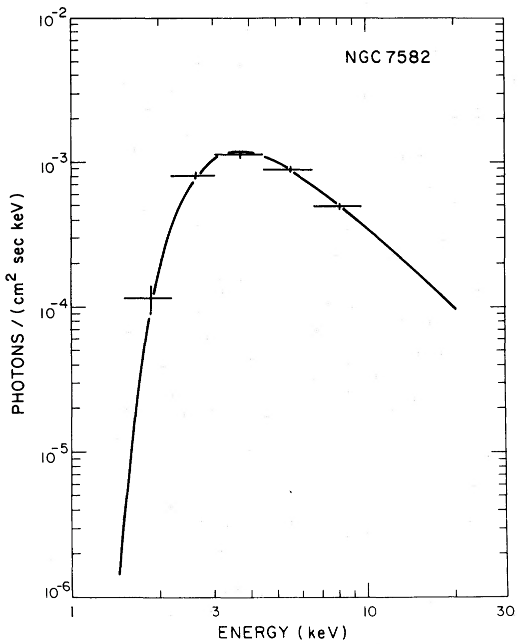

FIG. 5.—The derived incident photon spectrum of NGC 7582; solid line is the best fit to data points. Although the data point at ~1 keV is not plotted, it has been used to best fit the spectral parameters.

III. SLOPES OF IONIZING CONTINUUM AND ABSORBING COLUMN ESTIMATED FROM OPTICAL AND ULTRAVIOLET MEASUREMENTS

All four galaxies have good quality spectrophotometry published: NGC 5506 by Wilson *et al.* (1976); NGC 2992 and 7582 by Ward *et al.* (1980); NGC 1365 by Edmunds and Pagel (1981); and NGC 5506 and 2992 are also in Shuder (1980). In addition, ultraviolet measurements in the range of 1200–3000 Å are available for NGC 5506 (Bergeron, Maccacaro, and Perola 1981) and NGC 7582 (Clavel *et al.* 1980). From these data, estimates of the slope of the photoionizing continuum and of the gas column along the line of sight to the nucleus of these galaxies can be obtained for comparison with the X-ray spectral index and the absorbing column $N_{\rm H}$ corresponding to E_a.

Table 4 lists the slopes of the far-ultraviolet continuum as seen by the gas, assuming photoionization. They are obtained (see, e.g., Penston and Fosbury 1978) from the dereddened ratio He II λ4686/Hβ, taken as a measure of the relative intensity of the continuum at 228 Å and 912 Å. These estimates are relatively unaffected by the uncertainty of the reddening correction which must be applied to the observed line ratio.

Table 5 lists various estimates of the hydrogen absorbing columns obtained with five different methods (references are given in the table). All these methods, except the first, are based on independent estimates of the amount of optical extinction due to dust, which are then connected into $N_{\rm H}$ values according to the relationships $A_v = 3.17 \quad E(B-V) = 4.0 \times 10^{-22} \quad N_{\rm H}$ mag (Jenkins and Savage 1974; Seaton 1979). These reflect the dust properties and the dust-to-gas ratio prevailing in the interstellar medium of our own Galaxy. The five methods and their main underlying assumptions are now briefly described.

a) *Interstellar Absorption Lines*

Interstellar Na I and Ca II absorption lines have been accurately measured in the continuum spectra of two of the objects, and the corresponding absorbing columns have been evaluated. They have been converted into $N_{\rm H}$, assuming that the absorption occurs in H I regions, with relative elemental abundances and ionization states typical of H I clouds in our Galaxy (for the arguments in favor of these assumptions, see Ward *et al.* 1980).

TABLE 4

FAR-UV AND X-RAY ENERGY SPECTRAL INDEXES

Spectral Range	NGC 1365	NGC 2992	NGC 5506	NGC 7582
UV(912–228 Å).	1.6[a]	1.1[b]	1.8[c]	1.4[b]
X-ray (MPC)...	...	0.7[d]	0.8[d]	0.9[d]

[a] Edmunds and Pagel 1981.
[b] Ward *et al.* 1980.
[c] Derived from Wilson *et al.* 1976.
[d] This paper; MPC.

TABLE 5

EQUIVALENT HYDROGEN ABSORBING COLUMNS ($\times 10^{21}$ atom cm^{-2})

Method	NGC 1365	NGC 2992	NGC 5506	NGC 7582
(a) NaD absorption	4[a]	...	...	1.9[b]
(b) Continuum Hβ/He II	3.0[c]	5.3[b]	4.1[d]	3.3[b]
(c) Continuum (2200 Å/absorption)	...	...	< 3[e]	3.4[f]
(d) Narrow-line (Hα/Hβ)	12[a]	11[b], 12[g]	4.8[d], 7.5[g]	9.0[b]
(e) Broad-line (Hα/Hβ)	16[a]	≳12[c]	> 13[h]	...
(f) X-ray cutoff	< 5[i]	12[j]	45[j]	100[j]

[a] Edmunds and Pagel 1981.
[b] Ward *et al.* 1980.
[c] M. J. Ward, private communication.
[d] Wilson *et al.* 1976.
[e] Bergeron, Maccacaro, and Perola 1981.
[f] Clavel *et al.* 1980.
[g] Shuder 1980.
[h] Hayes *et al.* 1981.
[i] This paper; IPC. See Table 2A.
[j] This paper; MPC. See Table 2B.

b) Slope of Nonstellar Optical Continuum

Following Penston and Fosbury (1978), we could assume that the intrinsic slope of the nonstellar optical continuum is the same as the one derived for the ionizing continuum between 228 Å and 912 Å, that the covering factor is unity, and that the extinction follows the wavelength dependence derived by Seaton (1979) for our own Galaxy. Then $E(B-V)$ can be determined from the slope which is actually observed.

c) 2200 Å Absorption Feature

Observation of the absorption feature around 2200 Å allows one to estimate independently $E(B-V)$, again assuming dust properties similar to that found in our Galaxy. There exist two measurements: in NGC 7582 the inferred extinction is in remarkable agreement with the one derived with method (b); in NGC 5506 only an upper limit could be placed in $E(B-V)$, which leads to a $N_{\rm H}$ slightly smaller than estimated with method (b).

d) Narrow-Line Balmer Decrement

In all four galaxies, the Balmer decrement in the narrow lines is steeper than predicted from recombination theory, case B. Assuming that the steepening is merely due to extinction by dust, a value of $E(B-V)$ is derived (the $N_{\rm H}$ values quoted in Table 5 were estimated from the ratio Hα/Hβ). Another possible cause of the steepening is self-absorption, but this is probably not an important effect in the narrow-line region, due to the relatively low densities (10^3–10^4 cm^{-3}) encountered there.

e) Broad-Line Balmer Decrement

In the galaxies where the ratio between the broad components of Hα and Hβ has been measured, it also turns out larger than predicted from the recombination theory. However, in this case self-absorption effects are likely to be important (e.g., Netzer 1975; Kwan and Krolik 1979), hence, the values of $N_{\rm H}$ in Table 5 should be considered as upper limits.

Finally, it must be noted that the estimate of the X-ray absorbing column $N_{\rm H}$ is also based on a specific assumption regarding the abundance relative to hydrogen of the heavy elements which contribute more to the X-ray absorption. We have adopted the σ-E relationship constructed by Brown and Gould (1970).

IV. DISCUSSION

a) Continuum Slopes

The X-ray spectral indices of NGC 2992, NGC 5506, and NGC 7582 (Table 2B) are similar to those found in classical Seyfert 1 galaxies by Mushotzky *et al.* (1980). The mean value of α for the seven galaxies in Mushotzky *et al.* (1980) is 0.7 ± 0.1, which compares very well with our mean slope of 0.8 ± 0.3. This result, together with the similarity in the time variability, shows that there is no fundamental difference in the intrinsic properties of the X-ray sources associated with the nuclei of Seyfert 1 galaxies and of these types of galaxies. To stress this point is particularly important for the case of NGC 7582, where the typical signature of a Seyfert 1 nucleus, namely, the presence of broad permitted lines, has not yet been found.

The slope of the four ultraviolet ionizing continua (Table 4) are typically steeper than those of the medium energy X-rays. Although the former do not come from direct measurements, the differences suggest that the nonstellar continuum cannot be described by a single power law extending from the optical to the X-rays, but that it tends to become flatter toward the X-ray energies.

b) Absorbing Column Densities

Column densities $N_{\rm H}$ in the range 10^{22}–10^{23} cm^{-2} are deduced from the low-energy cutoff in the spectra of NGC 2992, NGC 5506, and NGC 7582. Column densities in the same range have also been found in Seyfert 1 galaxies (Mushotzky *et al.* 1980; Hayes *et al.* 1981); the most outstanding example being NGC 4151, which is also the only case where convincing evidence of variation in N_H between 3.5×10^{22} and 1.8×10^{23} has been discovered (Barr *et al.* 1977).

For an understanding of the location of the X-ray absorbing gas, it is instructive to make a comparison with the values of N_H that can be estimated by the various methods described in § III (see Table 5). The first thing to note is that the columns estimated to be in front of the optical/UV continuum (methods a, b, and c) are typically smaller than those in front of the emission lines (methods d and e). To explain the difference, Ward *et al.* (1980) suggest a model where the emission lines come from dusty clouds, which surround but do not cover (at least not completely) the continuum source; hence, the optical extinction (and the corresponding N_H) is larger for the lines than for the continuum. Since the X-ray source is supposedly coincident with the optical/UV continuum source, the N_H deduced from the X-ray cutoff could be used as a test of this model. However, the N_H values measured by us are not only larger than those estimated for the continuum (with the exception of NGC 1365, a complicated case discussed in § IV*c*), but also, in the case of NGC 5506 and NGC 7582, up to a factor of 10 larger than those estimated for the emission lines.

The following are some possible explanations of this discrepancy:

1. The dust-to-gas ratio could be much smaller or the dust grains could be less efficient in absorbing and scattering the light than in our own Galaxy. This explanation is not very appealing in view of the very dusty appearance of these galaxies and the large infrared luminosity of their nuclei (compared to that of NGC 4151 in Table 6), which is presumably due to reradiation by dust grains, as demonstrated rather convincingly in the case of NGC 4151 by Lebofsky and Rieke (1980). Furthermore, the N_H absorbing columns for the continuum estimated with methods (b) and (c) are in fair agreement with those derived with method (a), which is independent from assumptions on the dust abundance and properties.

2. If the heavy elements abundance relative to hydrogen in the X-ray absorbing gas were much larger than assumed by us, we could have overestimated N_H. No evidence supporting this hypothesis is found, at least in the emission lines from these objects. High-resolution X-ray spectra could determine any such overabundance by measurement of the 7.1 keV iron edge.

3. In NGC 4151 the variability in the X-ray cutoff naturally suggests the identification of absorbing material with the dense gas clouds in the broad-line region, whose size is probably ~ 0.025 pc (Anderson 1974). In this object, too, the column density predicted from the extinction is far less than the one determined from the X-ray cutoff (Mushotzky, Holt, and Serlemitsos 1978; Penston *et al.* 1981). By analogy, Maccacaro and Perola (1981) proposed a similar explanation for the large N_H measured in NGC 7582. They remarked that, in spherical geometry, the absorbing column can be expressed as

$$N_H \approx 7 \times 10^{23} n^{-1} R^{-2} L_b(\mathrm{H}\alpha) , \qquad (1)$$

when n is the density within the clouds, R is the radius of the broad-line region, and $L_b(\mathrm{H}\alpha)$ is the luminosity in the broad Hα component. A lower value of $L_b(\mathrm{H}\alpha)$ can be compensated by a lower value of n to produce the same N_H. In Table 6 we give the total and the broad Hα luminosity (corrected for reddening) of NGC 1365, NGC 2992, NGC 5506, NGC 7582, and of NGC 4151 for comparison. In NGC 2992 $L_b(\mathrm{H}\alpha)$ is similar to that of NGC 4151 and represents about 50% of the total, while in NGC 4151 $L_b(\mathrm{H}\alpha)$ is about 90% of the total. This indicates that a broad Hα component less intense than the narrow component is hard to measure (cf. the case of NGC 5506; Shuder 1980) or even to detect. We cannot, therefore, exclude the presence of broad-line gas, sufficient to produce the observed cutoff, even in NGC 7582. If this explanation were correct, one would predict variations in the cutoff which have not as yet been observed. Furthermore, it leaves the somewhat disturbing fact that the N_H measured in the three galaxies anticorrelates with $L_b(\mathrm{H}\alpha)$.

4. Geometrical effects can also be invoked. If the X-ray absorbing gas were distributed in a flattened configuration seen almost edge-on, and if its thickness were larger than the size of the X-ray source but smaller than the size of the optical/UV source, the former would be more screened than the latter. Such a configuration of the absorbing gas could be identified with an accretion disk. Since the two galaxies with the largest N_H (NGC 5506 and 7582) are seen almost edge-on, the implication would be that the accretion disk is coplanar with the large-scale stellar disk (see also Lawrence and Elvis 1982).

TABLE 6

Hα AND INFRARED LUMINOSITIES

Object	$L(\mathrm{H}\alpha)$[a] (ergs s^{-1}) Total	$L(\mathrm{H}\alpha)$[a] (ergs s^{-1}) Broad	$L(3.5\ \mu\mathrm{m})$ (ergs s^{-1})
NGC 1365	5.2×10^{42}	3.9×10^{42} [b]	7.8×10^{29} [c]
NGC 2992	3.8×10^{42}	2×10^{42} [d]	2.8×10^{29} [e]
NGC 5506	1.3×10^{42}	?[d,f]	4.9×10^{29} [e]
NGC 7582	3.4×10^{42}	...[g]	1.1×10^{29} [e]
NGC 4151	1.1×10^{42}	1.0×10^{42} [h,i]	1.8×10^{29} [e]

[a] Corrected for reddening.
[b] Edmunds and Pagel 1981.
[c] Glass 1973.
[d] Shuder 1980.
[e] Glass 1979.
[f] Wilson *et al.* 1976.
[g] Ward *et al.* 1980.
[h] Anderson 1970.
[i] Boksenberg *et al.* 1975.

c) *The Case of NGC 1365*

NGC 1365 is one order of magnitude less luminous in the X-rays than the other galaxies, and it is the only one for which there is evidence of an extended component. Galaxies rich in H II regions, which are believed to be the sites of recent bursts of star formation, have typical X-ray luminosities in the range 10^{39}–10^{41} ergs s^{-1} (Fabbiano, Feigelson, and Zamorani 1982). Since Osmer, Smith, and Weedman (1974) and Edmunds and Pagel (1981) show that there are many bright H II regions in a region at least 20″ in extent around the nucleus of NGC 1365, it is likely that a component of the X-ray flux is associated with this region. On the other hand, the Seyfert nucleus that Edmunds and Pagel (1981) report is likely to account for a substantial component of the X-ray emission.

We can see whether the X-ray luminosity of NGC 1365 is consistent with that of a Seyfert nucleus by using the relation between L_x and Balmer line luminosity (Kriss, Canizares, and Ricker 1980; Steiner 1981) for active galactic nuclei. Elvis and Van Speybroeck (1982) compiled a histogram of log $(L_x/L_{H\alpha})$ using observed values of L_x taken from the compilation of Steiner (1981). This distribution has a mean of 1.15 and a standard deviation of 0.60 for 55 objects. This ratio would then give log $L_x = 40.7 \pm 0.6$ for NGC 1365 compared with the observed value of 41.2. It must be kept in mind, however, that there are exceptions to the L_x versus Balmer line luminosity relation in the sense of a lack of X-ray emission relative to Balmer emission (Mrk 304 and Mrk 486; Kriss, Canizares, and Ricker 1980). The very large reddening in the Seyfert nucleus of NGC 1365 suggests that this object may also be exceptional.

It is likely that the NGC 1365 X-ray source contains a "compact" in addition to a "diffuse" component. The latter might be responsible for the very soft appearance of the IPC spectrum and, by masking the presence of a cutoff in the former, might explain why this is the only case in our sample where the photoelectric cutoff is lower than predicted.

V. CONCLUSIONS

The main conclusions of this paper are:

1. The X-ray properties of the so-called narrow-emission-line galaxies are similar to those of the low-luminosity Seyfert 1 galaxies.

2. There is direct evidence that their nonstellar continuum becomes harder going from the ultraviolet toward the X-rays.

3. There is no evidence of changes in the slope of the X-ray continuum when the intensity varies.

4. The large absorbing column N_H observed in NGC 5506 and NGC 7582 could be attributed to broad-line gas located very close to the X-ray continuum source, and we have argued that the lack of spectroscopic evidence of such gas in NGC 7582 may be due to the weakness of the broad compared to the narrow components of the Balmer lines. By analogy with NGC 4151, however, one would expect time variations in N_H, which have not been observed so far, thus demanding further monitoring.

An alternative and very suggestive interpretation identifies the X-ray absorbing gas with an accretion disk seen almost edge-on, with the implication for these two galaxies that the accretion and the large-scale stellar disks are essentially coplanar.

5. The case of NGC 1365 requires further study at higher spatial resolution to disentangle the "extended" component from the one suspected to be associated with the Seyfert 1 nucleus. The same purpose might also be achieved through variability studies.

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Note added in proof.—Recently Mushotzky (1982) has arrived at similar conclusions concerning the nature of NELGs. See the paper by R. F. Mushotzky, "The X-Ray Spectrum and Time Variability of Narrow Emission-Line Galaxies," in *Ap. J.*, **256**, 92.

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