THE ASTROPHYSICAL JOURNAL, 285:475–482, 1984 October 15

THE NONSTELLAR CONTINUUM OF THE SEYFERT GALAXY NGC 7213

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Received 1984 January 6; accepted 1984 April 23

ABSTRACT

Optical spectrophotometry of the nearby Seyfert 1 galaxy NGC 7213 reveals that nonstellar radiation accounts for at least 50% of the observed continuum at λ3300. A formal decomposition of the continuum into a power law of index 1.1 (where $f_\nu \propto \nu^{-\alpha}$) and the spectrum of a giant elliptical galaxy suggests that the true nonstellar flux may be substantially larger if reddening is allowed. The derived visual extinction (A_v) is ~0.61 ± 0.2 mag, of which only ~0.05 mag is likely to be Galactic.

X-ray spectra obtained with the IPC and MPC on the *Einstein Observatory* are approximated by a power law with $\alpha = 0.72 \pm 0.12$ and $N_{\rm H} \lesssim 2.5 \times 10^{20}$ cm^{-2}. The equivalent A_v of $\lesssim$0.12 mag is less than that found from the optical analysis. This discrepancy might be resolved by the emission of substantial bremsstrahlung radiation at temperatures less than 1 keV from a hot medium which confines the forbidden-line clouds.

Published observations at radio, IR, and UV wavelengths are combined with the new data to produce the overall continuum, which is similar to that of other type 1 Seyfert galaxies. A "UV bump" may be present. Since NGC 7213 has one of the highest ratios of X-ray to optical luminosity among active galactic nuclei, it extends a previously established trend to low-luminosity objects. The ionizing continuum of NGC 7213 is of great importance in attempts to explain the optical characteristics of Liners, which it resembles because of the strong low-ionization emission lines and flat-spectrum radio source.

Subject headings: galaxies: individual — galaxies: Seyfert — X-rays: sources — X-rays: spectra

I. INTRODUCTION

Marshall *et al.* (1979) found that the nearby (v = 1769 km s^{-1}) S0 galaxy NGC 7213 lies within the error box of the *HEAO* A-2 X-ray source H2209−471, but the large size of the box (~0°.6 × 2°.8) rendered the association of the two objects uncertain. Subsequent optical spectrophotometry by Phillips (1979) demonstrated the presence of broad Hα emission similar to that found in Seyfert 1 galaxies, making identification with the X-ray source highly probable. On the other hand, Phillips (1979) saw no evidence for a substantial nonstellar continuum at optical wavelengths. The X-ray luminosity of $\sim 3 \times 10^{42}$ ergs s^{-1} ($H_0 = 50$ km s^{-1} Mpc^{-1}) in the 2–10 keV band (Marshall *et al.* 1979) is smaller than that of most type 1 Seyfert galaxies and narrow-line X-ray galaxies (Halpern 1982; Mushotzky 1982), but larger than that of type 2 Seyferts (Kriss 1982). A second *HEAO* A-2 scan obtained 6 months after the first showed that the intensity of the source had increased by ~70% at a confidence level of ~2 σ (Piccinotti *et al.* 1982), providing additional support for the association with a compact Seyfert nucleus. NGC 7213 was detected during pointed observations with the *HEAO 1* scanning modulation collimator (Dower *et al.* 1980), and Kriss (1982) reported a luminosity of 1.1×10^{43} ergs s^{-1} in the 0.5–4.5 keV band with the Imaging Proportional Counter on the *Einstein Observatory*. The Hα luminosity of $\sim 2 \times 10^{41}$ ergs s^{-1}, however, is low for a Seyfert 1 (Phillips 1979).

The optical spectrum exhibits features common not only in type 1 Seyfert galaxies but in Heckman's (1980) "low ionization nuclear emission-line regions" (Liners) as well. Although emission in Liners has often been attributed to heating by shocks, a detailed analysis of the forbidden lines by Filippenko and Halpern (1984, hereafter Paper I) shows how the spectral characteristics of NGC 7213 can be reconciled with photoionization by nonstellar radiation. An important key is the discovery of clouds having densities of order 10^6–10^7 cm^{-3} in the narrow-line region.

In this paper, the optical continuum of NGC 7213 is decomposed into stellar and nonstellar components, and the spectrum at X-ray energies is derived from observations made with the Monitor Proportional Counter (Gaillardetz *et al.* 1978) and Imaging Proportional Counter (Giacconi *et al.* 1979) on the *Einstein Observatory*. Ultraviolet, infrared, and radio observations published elsewhere are then combined with the new data to produce the overall continuum.

II. THE OPTICAL CONTINUUM

a) *Standard Galaxy plus Power Law*

Paper I describes the optical observations in detail. Briefly, spectra having 2.5 Å resolution were obtained with the Intensified Reticon on the 2.5 m du Pont reflector at Las Campanas Observatory. Although relative intensities are accurately calibrated over most of the observed range, the absolute flux is uncertain by ~ ±30% because of the small size of the entrance aperture (2″ × 4″).

Prominent emission of [O I], [O II], [O III], [S II], [Ne III], and H I are visible, and the strong absorption lines in the underlying continuum reveal the dominance of an old stellar population typical of those seen in the bulge of other S0 and Sa galaxies. On the other hand, emission lines produced by such highly ionized species as Ne^{+4} indicate that nonstellar radiation may form a substantial fraction of the optical flux. Furthermore, the continuum is considerably bluer than that of galaxies which exhibit no signs of unusual activity, and the broad Balmer lines resemble those in quasars and type 1 Seyfert galaxies.

The continuum of NGC 7213 was therefore decomposed into a standard galaxy and a power-law spectrum ($f_\nu \propto \nu^{-\alpha}$)

which is presumably of nonthermal origin (e.g., electron synchrotron radiation). A more general analysis (e.g., Malkan and Sargent 1982; Malkan 1983) was not possible because of the very limited wavelength range of the data, but the procedure was similar to that done by Goodrich and Osterbrock (1983), Yee and Oke (1978), and others. The galactic component was represented by the "average" giant elliptical used in a study of radio galaxies by Yee and Oke (1978). Such an object is a fairly good approximation to the bulge of S0 and Sa galaxies; its main drawback is that the continuum is probably somewhat redder than the integrated starlight in the nucleus of NGC 7213. This leads to a slight overestimate of the nonstellar component and/or an underestimate of the reddening. The spectrum of the standard galaxy was transformed from the AB_{69} magnitude scale to the recent AB_{79} scale (Oke and Gunn 1983), since AB_{79} was used to flux-calibrate spectra of NGC 7213.

Regions containing emission lines were ignored, and the resolution was degraded to that of the standard galaxy. Only the index (α) and the ratio of nonstellar flux to total flux at $\lambda 5460$ [$\log \nu$ (Hz) = 14.740] were varied in a least-squares fit to the dereddened spectrum of NGC 7213. It was discovered, however, that the decomposition is not sensitive to α, since nonstellar radiation is not sufficiently dominant and the wavelength range is small. Therefore, α was chosen to be close to 1.1, which is the value found for a sample of QSOs and Seyfert galaxies (Malkan and Sargent 1982; Malkan and Filippenko 1983). In particular, Table 1 lists the results obtained with α set to 0.8, 1.1, 1.4, and 1.7, and Table 2 gives the relative strengths of both components at selected wavelengths for $\alpha = 1.1$.

Figure 1*a* illustrates the best spectral decomposition with $\alpha = 1.1$ when the continuum of NGC 7213 is dereddened by $A_v = 0.05$ mag (where $A_v \sim 3.2E_{B-V}$), the Galactic extinction (Burstein and Heiles 1982; Heiles and Cleary 1979). At $\lambda 5460$ the nonstellar component accounts for only $\sim$11.4% of the flux, while at $\lambda 3250$ it is roughly the strength of the standard galaxy. The overall fit is reasonably good, but the deviations suggest that better agreement could be obtained if the continuum of NGC 7213 were dereddened by a moderate amount.

Additional fits were performed, this time with the reddening of NGC 7213 and the ratio of the nonstellar flux to the total flux at $\lambda 5460$ as free parameters (Table 1). If $\alpha = 1.1$, the best fit is obtained with a continuum reddening corresponding to $A_v \sim 0.61$ mag in NGC 7213. The results are tabulated in Table 2 and plotted in Figure 1*b*. It is apparent that the fit is better than with $A_v = 0.05$ mag, especially at the relatively sharp "break" near $\lambda 3950$. At $\lambda 5460$ the nonstellar component now accounts for $\sim$23.5% of the flux, and its contribution equals that of the standard galaxy at $\sim\lambda 3950$. Over the range $\lambda\lambda 3202$–6272 it accounts for fully 33% of the total flux.

If the observed blue excess were of stellar origin, it would require the presence of 1.3×10^5 B0 or 2.4×10^4 O5 main-sequence stars, but emission lines typical of star burst galaxies (e.g., Weedman *et al.* 1981) would then be expected. Slight errors in the flux calibration, as well as differences between the spectra of giant elliptical galaxies and the bulge of NGC 7213, also cannot account for the enormous nonstellar flux in the blue and near-UV. At $\lambda 3200$, it is a magnitude brighter than the stellar component, whereas the errors are likely to be within ± 0.3 mag. Moreover, no nonstellar component was found when the same procedure was performed on the normal S0 galaxy IC 4889, in agreement with the absence of other signs of activity in this object.

TABLE 1

PARAMETERS OF CONTINUUM DECOMPOSITION

Power Law Slope α[a]	A_v (mag)[b,c]	(Power Law / Total)[d,e] at $\lambda 5460$	(Power Law / Total)[e,f] $\lambda\lambda 3202$–6272
0.8	0.05[a]	0.094	0.15
1.1	0.05[a]	0.114	0.17
1.4	0.05[a]	0.135	0.19
1.7	0.05[a]	0.157	0.21
0.8	0.63	0.202	0.30
1.1	0.61	0.236	0.33
1.4	0.57	0.263	0.35
1.7	0.53	0.300	0.38

[a] Fixed parameter.
[b] Free or fixed parameter.
[c] $E_{B-V} = A_v/3.2$ used to deredden continuum of NGC 7213 prior to decomposition.
[d] Free parameter.
[e] Flux ratio (where total flux = power law + standard galaxy fluxes).
[f] Flux derived from final decomposition.

TABLE 2

RELATIVE FLUXES OF CONTINUA,[a] $\alpha = 1.1$

λ (Å)	(Power Law / Total)[b] $A_v = 0.05$ mag[c]	(Power Law / Total)[b] $A_v = 0.61$ mag[c]
3202	0.536	0.735
3500	0.434	0.648
4000	0.229	0.417
4500	0.152	0.302
5000	0.139	0.280
5460	0.114	0.236
6000	0.102	0.214
6272	0.107	0.223

[a] See Fig. 1.
[b] Flux ratio (where total flux = power law + standard galaxy fluxes).
[c] $E_{B-V} = A_v/3.2$ used to deredden continuum of NGC 7213 prior to decomposition.

b) Reddening

Note that $A_v = 0.61$ mag applies to *all* of the observed continuum; the nonstellar radiation is assumed not to experience any additional extinction as it travels out from the nucleus. Of course, it is also possible that *only* the nonstellar component is substantially reddened (e.g., by dust close to the nucleus). A least-squares decomposition indicates that this is unlikely, however, since acceptable fits (which are nevertheless formally worse than that in Fig. 1*b*) require the power law to experience $A_v \sim 1.8$–1.9 mag. The nonstellar contribution is then nearly equal to that of stars over the range $\lambda\lambda 4000$–6000, which is incompatible with the relatively strong absorption lines observed in NGC 7213. The amount of dilution provided at various wavelengths in the (α, A_v) = (1.1, 0.61) decomposition is roughly consistent with the observed equivalent widths, although there is a range of acceptable dilution due to differences in line strengths among elliptical galaxies and the bulges of spirals. In addition, photographs indicate the presence of dust in the outer portions of NGC 7213 (Phillips 1979), so there might be dust between Earth and the nucleus as well. In reality, somewhat different amounts of reddening may apply to the stellar and nonstellar components, but here it will be assumed that a single value is correct for the entire continuum.

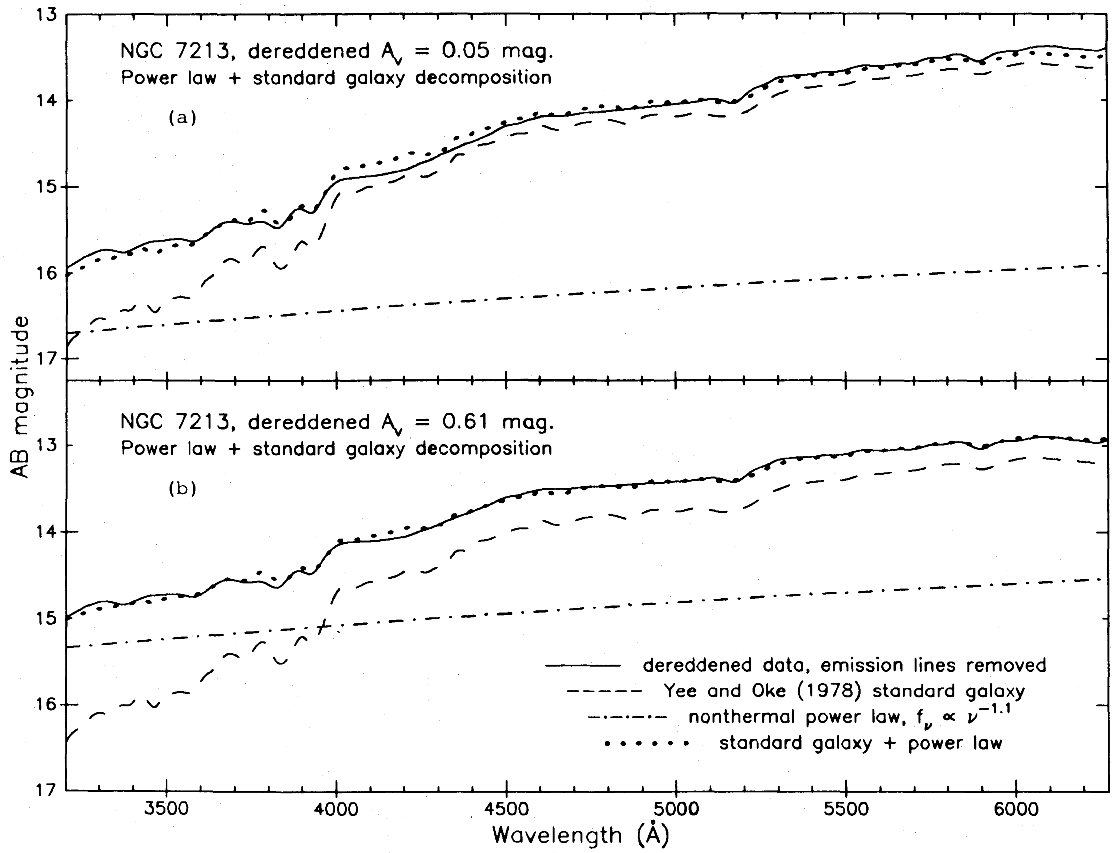

FIG. 1.—The smoothed continuum of NGC 7213 is decomposed into a nonstellar power law plus an old stellar population (represented by a "standard" giant elliptical galaxy). Magnitude AB = $-2.5 \log (f_\nu) - 48.6$, where f_ν is in ergs s^{-1} cm^{-2} Hz^{-1}. In (*a*) the continuum is dereddened under the assumption that Galactic $A_v = 0.05$ mag, where $A_v = 3.2E_{B-V}$. A noticeably more satisfactory fit (*b*) is obtained if an additional extinction $A_v = 0.56$ mag is present in NGC 7213. The absolute calibration is uncertain by $\sim \pm 30\%$ due to the use of a small (2″ × 4″) entrance aperture.

Table 1 shows that the derived extinction $A_v \sim 0.61$ mag ($E_{B-V} \sim 0.19$ mag) depends on the particular choice of spectral index; it can differ by ± 0.1 mag for a plausible range in α. It also changes with the range of wavelengths used in the analysis, and an error of ± 0.1 mag is not inconceivable. Finally, for a given α the fit is satisfactory for values of A_v in a range of roughly ± 0.1 mag. Thus, a reasonable approximation to the error in A_v is ± 0.2 mag.

III. X-RAY OBSERVATIONS

NGC 7213 was observed by *Einstein* on three occasions in 1979 and 1980, with intervals of ~6 months between observations. The dates and integration times are given in Table 3.

a) Monitor Proportional Counter (MPC)

The MPC is mounted on the outside of *Einstein*, and is co-aligned with the imaging telescope. It is an argon-filled, nonimaging detector with an effective area of 667 cm^2 and a 1°.5 (full width at zero-intensity) square collimator. A complete description of the methods used for data reduction, including background subtraction, is given by Halpern (1982, 1984).

Table 3 lists the count rates in the 2–6 keV band and the 2–10 keV fluxes. NGC 7213 was not the primary target of the second observation, but nevertheless was the dominant source in the field of view. The count rate and flux in this case include a multiplicative factor of 1.63 to correct for off-axis transmission of the collimator. Variability by a factor of ~3 is evident,

TABLE 3

Einstein OBSERVATIONS OF NGC 7213

Day	Year	Exposure Time (s)	Counts s^{-1} (2–6 keV)[a]	F_x (2–10 keV) (10^{-11} ergs cm^{-2} s^{-1})	A	α[b]	N_H[c] (10^{21} cm^{-2})	L_x (2–10 keV)[d] (10^{42} ergs s^{-1})	M/I[e]
112......	1979	7493	1.01 ± 0.10	2.20	0.0068	0.85 ± 0.11	<8.0	3.29	M
295......	1979	975	0.81 ± 0.16[f]	1.67	0.0075	1.1 ± 0.6	<20	2.50	M
136......	1980	1516	2.97 ± 0.12	6.80	0.0170	0.72 ± 0.12	<0.25	10.2	M, I

[a] 1 MPC count = 1.05 UFU (*Uhuru* flux unit).
[b] 90% error bars.
[c] Upper limits.
[d] Intrinsic (unabsorbed) luminosity, $H_0 = 50$ km s^{-1} Mpc^{-1}.
[e] Instrument used: M denotes MPC, I denotes IPC.
[f] Includes correction factor of 1.63 for off-axis collimator response.

and the luminosity spans a range which includes the earlier *HEAO* A-2 values.

The pulse height data were fitted with a standard power-law spectrum and absorption due to intervening neutral gas. Specifically,

$$\frac{dN}{dE} = AE^{-(\alpha+1)} \exp\left[-\sigma(E)N_{\rm H}\right] \text{ photons cm}^{-2}\text{ s}^{-1}\text{ keV}^{-1}\,, \tag{1}$$

where $\sigma(E)$ is the Brown and Gould (1970) opacity, $N_{\rm H}$ is the equivalent neutral hydrogen column density, and A is a normalizing factor. The derived spectral parameters and 90% error bars are listed in Table 3. For the 1980 observation, the spectral parameters were derived from MPC and IPC data taken simultaneously (see below). Since there is independent evidence from the IPC that the column density is extremely low ($N_{\rm H} \lesssim 5 \times 10^{20}$ cm^{-2}), absorption in the MPC band is expected to be negligible. Therefore, the spectral index for the first two observations was recomputed under the assumption $N_{\rm H} = 0$, resulting in nearly identical values for the best fit, but slightly smaller formal errors.

b) Imaging Proportional Counter (*IPC*)

The soft X-ray luminosity measured by the IPC on day 136 of 1980 was 1.1×10^{43} ergs s^{-1} in the 0.5–4.5 keV band (Kriss 1982). This is nearly equal to the 2–10 keV luminosity of 1.02×10^{43} ergs s^{-1}, and a simple calculation shows that these values would be equal if a spectral slope $\alpha \sim 0.7$ with no absorption extends throughout both energy bands. The IPC and MPC data can in principle be fitted simultaneously, yielding spectral parameters over the combined energy band, but this is cumbersome due to the significantly different behavior of the two detectors. Temporal and spatial variations exist in the gain of the IPC, and the precise values for this observation have not yet been determined. The gain of the MPC, on the other hand, is quite stable. Since it was necessary to vary the assumed IPC gain about the nominal value, the IPC pulse height data were fitted separately using the same model as in equation (1). The following is a brief description of the procedure.

NGC 7213 appeared in the center of the IPC image, and source counts were determined from a circle of radius 180″ about the X-ray centroid. The background was obtained in an annulus between radii of 320″ and 440″ concentric with the source, and properly scaled by area. It contributes no more than 5% of the count rate in any one channel, and represents only 1.3% of the total. The net (background subtracted) count rate in channels corresponding nominally to 0.12–4.65 keV is 2.69 ± 0.04, and the effective exposure of 1517 seconds includes a 5% correction for dead time. Standard corrections were also applied for counts lost in scattering by the mirrors and in the wings of the IPC point response function.

Grids of model spectra were generated for several assumed values of "BAL," which is a measure of the gain as determined by the mean pulse height channel of the 1.5 keV aluminum line. These values were within ± 1 of the nominal 16.6 for this day of observation. Figure 2 shows the IPC 90% contours superposed on the MPC 90% contour determined from data obtained simultaneously. The dashed line indicates the envelope of acceptable fits when the gain was allowed to vary, and should therefore be taken as an indication of the total uncertainty in the present analysis. Figure 3 displays the theoretical spectra which produced the best fits for the IPC and MPC.

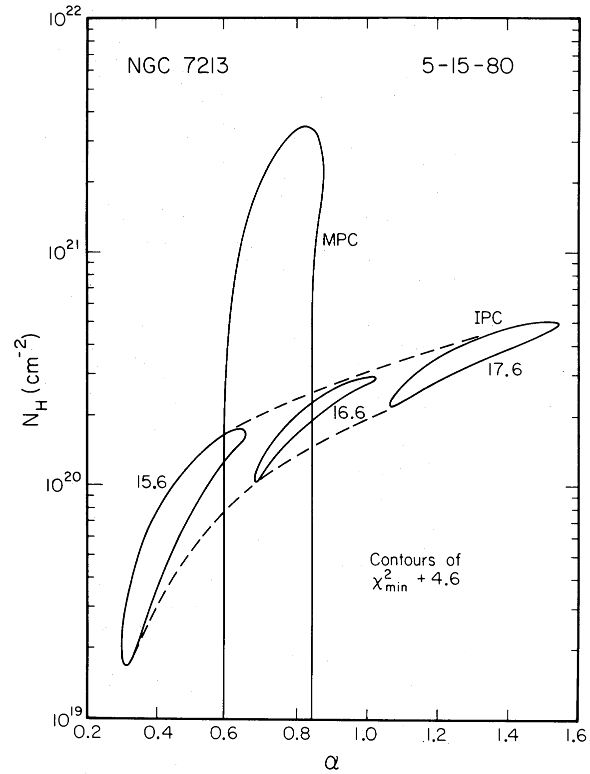

FIG. 2.—Contours of acceptable fits (90% confidence) to the 1980 May 15 *Einstein* MPC and IPC data. The numbers 15.5, 16.6, and 17.6 refer to different assumed gains ("BAL") of the IPC, where 16.6 is the nominal value. The dashed line encompasses the total range of allowed fits to the IPC data.

IV. INTERPRETATION

a) Column Density and Spectral Index

Under the assumption that a single power law applies throughout the observed energy band, the narrow range of overlap in Figure 2 between the IPC and MPC constrains α to 0.72 ± 0.12 and $N_{\rm H}$ to less than 2.5×10^{20} cm^{-2}. It should be emphasized that the existence of a region of overlap is a necessary but not sufficient condition for a constant spectral slope, since the normalizations must also agree. In fact, the best agreement occurs for $\alpha = 0.7$ and $N_{\rm H} = 2 \times 10^{20}$ cm^{-2}, where $A = 0.0170$ photons cm^{-2} s^{-1} keV^{-1} is found for both the MPC and IPC. Most other points within the overlap region also require normalizations that agree to within ± 10%, which is as good as can be expected, given the uncertainties in relative calibration. On the other hand, the true spectrum between 0.25 and 2 keV is probably not much steeper than 0.85 or much flatter than 0.6, even though this seems to be allowed by the IPC contours in Figure 2. Such a curved spectrum would produce discrepant total count rates between the MPC and IPC when forced to fit in the region of overlap.

An independent constraint on the column density comes from the measurements at 21 cm in the Galaxy. Values of $N_{\rm H}$ in the line of sight to extragalactic sources are never observed to be less than $\sim 10^{20}$ cm^{-2}, even near the galactic poles (Dickey, Salpeter, and Terzian 1978). Several observations within 1° of NGC 7213 by Heiles and Cleary (1979) yield $1.6 \times 10^{20} \lesssim N_{\rm H} \lesssim 2.1 \times 10^{20}$ cm^{-2}. This is in agreement with the joint

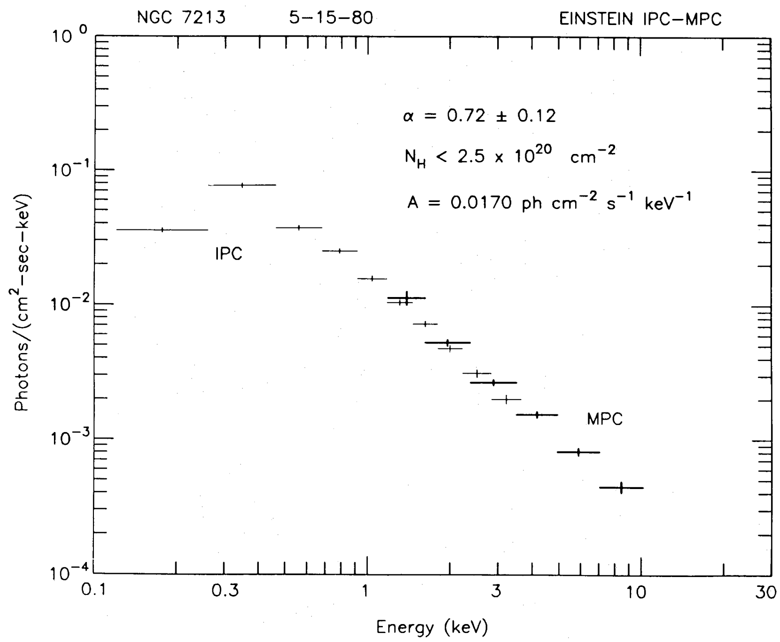

FIG. 3.—Theoretical spectra which represent the best fits to the 1980 May 15 *Einstein* IPC (*light bars*) and MPC (*dark bars*) data are illustrated. Spectral parameters and errors refer to the overlap region of the 90% contours shown in Fig. 2.

X-ray confidence region, and rules out IPC spectra flatter than $\alpha \sim 0.6$ since N_H would be too low. It is also evident from the X-ray spectrum that any column density intrinsic to NGC 7213 must be small. The implications of this last point will be discussed in § IV*b*.

The spectral parameters listed in Table 3 are consistent with the results of Mushotzsky (1982), who found that α generally falls between 0.6 and 0.8 in Seyfert galaxies. Mushotzky (1982) also indicates that $N_H < 5 \times 10^{21}$ cm^{-2} for NGC 7213. Although the first and third MPC observations have comparable statistical uncertainties based on the total source counts, the signal-to-noise ratio was a factor of 3 larger in the latter case because the source was stronger (and the integration time shorter). Hence, the third observation is expected to be least susceptible to systematic errors involving background subtraction, and the simultaneous IPC data can be used to restrict the range of spectral parameters. $N_H \lesssim 2.5 \times 10^{20}$ cm^{-2} and $\alpha = 0.72 \pm 0.12$ are therefore adopted as the best estimates for the spectral parameters in the 0.25–10 keV band, but slight deviations from a power law shape cannot be ruled out.

b) *Covering Fraction and Visual Extinction*

The shape of the X-ray spectrum also demonstrates that the covering fraction of emission-line clouds is small. For the broad-line clouds, expected column densities of several times 10^{22} cm^{-2} (Kwan and Krolik 1981) would cause a low-energy cutoff near 3 keV, as is observed in NGC 4151. Models of narrow-line clouds require $N_H \sim 2.5 \times 10^{21}$ cm^{-2} (Halpern and Steiner 1983) for typical Seyfert galaxies, but there is probably quite a large spread. In particular, column densities 10 times larger than average could explain cases such as NGC 7213 in which the I([O I]λ6300)/I[O II]λ3727) ratio is large (Halpern 1982). All these estimates are much higher than the upper limit $N_H \sim 2.5 \times 10^{20}$ cm^{-2} derived from the X-ray data for NGC 7213, and point to a low covering fraction. Moreover, for interstellar material with normal extinction properties, such a low column density is associated with A_v of at most $\sim$0.12 mag (Gorenstein 1975). This is in direct conflict with the optical analysis presented in § II, which suggests that $A_v = 0.61 \pm 0.2$ mag. It is interesting that the sense of this disagreement is opposite that in most narrow-line X-ray galaxies, in which the X-ray column density is too large compared with other reddening indicators (Maccacaro, Perola, and Elvis 1982; Mushotzky 1982).

The absence of low-energy X-ray absorption, however, applies only to Earth's line of sight, and is not necessarily representative of the global covering fraction as measured by the equivalent widths of emission lines. In addition, the expected functional form of the X-ray absorption given in equation (1) is strictly correct only for a uniform, cold absorber which completely covers the source. If the source were only partially occulted, a spectrum having low resolution might appear only slightly flatter, without a noticeable low-energy turnover. This would be especially true if the absorbing medium were characterized by a broad distribution in N_H.

Nevertheless, the fact that the IPC and MPC data agree with a spectral index of 0.7, both individually and in their relative normalization, is a strong indication that the covering fraction is small. The index is not flatter than average, and there is no evidence for a turnover at low energies except due to material in the Galaxy. Given the estimated uncertainties of $\sim$10% in relative calibration between the IPC and MPC, it appears that any covering fraction due to broad- or narrow-line clouds in the line of sight must be no more than $\sim$30%, and possibly much less.

c) *Thermal Emission*

There is an alternative resolution to the discrepancy between the X-ray and optical extinction. Suppose that the power law at X-ray energies is in fact absorbed by $N_H \sim 1.3 \times 10^{21}$ cm^{-2} (corresponding to $A_v = 0.61$ mag), but that an additional source of thermal emission at temperatures less than 1 keV "fills in" the low-energy absorption. Specifically, Paper I shows that the thermal bremsstrahlung emission may be expected from a hot medium (referred to by the subscript h) which confines the forbidden-line clouds. The radius of the emitting region is

$$r = d\left(\frac{f_0}{chnU}\right)^{1/2} , \quad (2)$$

where d is the distance to NGC 7213, f_0 is the flux density of the ionizing continuum at the Lyman limit, n is the cloud density, and U is the ionization parameter. The integrated emission is (Tucker 1975)

$$\frac{dN}{dE} \approx \frac{1.4 \times 10^{-11}}{Ed^2} \int_{r_{\min}}^{r_{\max}} r^2 n_h{}^2 T_h{}^{-1/2} \exp\left(\frac{-E}{kT_h}\right) dr \quad \text{photons cm}^{-2}\ \text{s}^{-1}\ \text{keV}^{-1} . \quad (3)$$

Since T_h is only approximately known, a constant value of $\sim 10^7$ K is assumed, as expected if the narrow-line clouds are very dense (Paper I). Invoking pressure equilibrium between the two phases, and combining equations (2) and (3), yields

$$\frac{dN}{dE} \approx \frac{1.5 \times 10^{-6}}{E}\left(\frac{10^{-3}}{U}\right)^{3/2}\left(\frac{T}{10^4}\right)^2\left(\frac{10^7}{T_h}\right)^{5/2} \exp\left(\frac{-E}{kT_h}\right) \times \int_{n_{\min}}^{n_{\max}} n^{-1/2} dn \ \text{photons cm}^{-2}\ \text{s}^{-1}\ \text{keV}^{-1} . \quad (4)$$

If the upper limit is taken to be $n \sim 3 \times 10^7$ cm^{-3}, a flux of $\sim 1.3 \times 10^{-3}$ photons cm^{-2} s^{-1} keV^{-1} near the characteristic energy of ~ 0.9 keV is found. This is $\sim 7\%$ of the observed flux (Fig. 3), and would not greatly affect the X-ray spectrum. If T_h were a factor of 3 smaller, however, bremsstrahlung at ~ 0.3 keV would contribute an excess comparable to the observed flux. Unless properly taken into account, this could substantially decrease the derived value of $N_{\rm H}$, and it may resolve the discrepancy between the optical ($A_v = 0.61$) and X-ray ($A_v \lesssim 0.12$) results.

Since the X-ray spectrum of NGC 7213 is typical of type 1 Seyfert galaxies, one might doubt that the above hypothesis actually explains the difference in derived values of A_v. Do any other Seyfert galaxies show evidence of thermal emission, or is NGC 7213 a very special case? Unfortunately, the poor spectral resolution of the *Einstein* data does not permit one to distinguish between power-law and thermal spectra over a large range of assumed parameters. In fact, power-law slopes cannot be unambiguously derived at X-ray energies if thermal emission is a possible contributor. There is a distribution of slopes among Seyfert galaxies, and it may well be that the steeper ones contain contamination from thermal emission. One interpretation of the extended X-ray emission in NGC 4151 discussed by Elvis, Briel, and Henry (1983) was thermal bremsstrahlung from a confining medium in the narrow-line region. Similarly, extended thermal emission superposed on an absorbed power law is a plausible alternative to the "leaky absorber" explanation of the soft X-ray excesses observed (Reichert *et al.* 1983) in a number of Seyfert galaxies. Thus, it is not unlikely that thermal emission from a hot intercloud medium is sufficient to explain much of the discrepancy between the derived values of A_v in NGC 7213, especially in light of the particularly favorable conditions provided by the narrow-line clouds of high density (Paper I).

Note that the total column density of the hot medium in NGC 7213 is $\sim 10^{23}$ cm^{-2}. Elements of medium weight, particularly O, must be almost entirely stripped of electrons in order not to cause significant absorption of the soft X-rays. The Thomson scattering depth is only ~ 0.07, so scattering in the hot medium is negligible.

V. THE OVERALL CONTINUUM

Measurements of NGC 7213 in the infrared bands J, H, K, L, and N were made by Frogel and Elias (as reported by Phillips 1979), Glass (1981), Glass, Moorwood, and Eichendorf (1982), Longmore and Sharples (1982), McAlary *et al.* (1983), and Ward *et al.* (1982). The *International Ultraviolet Explorer* was used by Wu, Boggess, and Gull (1983) to study NGC 7213 at UV wavelengths. Some of these data were combined with the X-ray observations and new optical spectra to produce the overall continuum from X-ray through infrared wavelengths (Fig. 4). NGC 7213 is also a Parkes radio source (PKS 2206−474) with a flux density of 0.23 Jy at 2.7 GHz (Bolton *et al.* 1977). It must be emphasized that the measurements were made at different times and through different apertures, which greatly complicates the interpretation of the spectrum.

The continuum is similar to that seen in type 1 Seyfert galaxies, although a significant stellar component is present at optical and near-infrared wavelengths. Data at 10 μm and possibly 3.5 μm are the only IR points which are not contaminated by stellar light. Glass, Moorwood, and Eichendorf (1982) concluded that $\alpha \sim 1.1$ and $A_v \sim 0.6$ mag in NGC 7213, from an analysis of IR, optical, and UV data. However, these values are based on the assumption that 40% of the dereddened K (2.2 μm) flux in a 9″ aperture is due to the power-law component. This is twice as much nonstellar flux as found in the present study, so the agreement in α and A_v may be fortuitous. Their power law passes through the 10.3 μm point at ~ 250 mJy, but is incompatible with the new optical data since it exceeds the total dereddened flux blueward of 4000 Å. This restriction probably arises because the optical data presented here were taken through a smaller aperture than that used by Phillips (1979). Hence, the nonstellar component is likely to be comparable to the one derived from the least-squares fits in § II (and shown again in Figure 4). The flux at 10 μm may therefore contain a significant contribution from thermally-emitting dust at temperatures of several 100 K, as expected if $A_v \sim 0.6$ mag.

There is also a discrepancy among the IR measurements themselves. The J and H fluxes taken through a 9″.1 aperture are more than a factor of 2 larger than the corresponding fluxes in a 7″ aperture. This is difficult to understand in terms of any reasonable distribution of stellar light, and may require a substantial variation in the nonstellar flux. On the other hand, variability seems to be excluded by the agreement of all the measurements at L. A reconciliation of the various IR measurements would obviously be desirable.

One representation of the overall continuum shape is given by the spectral index β_{ox} between 4000 Å and 2 keV (Grindlay *et al.* 1980), which is 1.06 ± 0.08 in NGC 7213. With the (α, A_v) = (1.1, 0.61) decomposition derived in § II, it is found that β_{ox} of the *nonthermal component alone* is 1.04 ± 0.08, not significantly different from the "raw" number given above. These values (whose error bars are due almost entirely to the observed range of X-ray variability) are near the low end of the distribution for type 1 Seyfert galaxies and X-ray selected extragalactic objects (Kriss 1982), and NGC 7213 therefore has one of the highest ratios of X-ray to optical luminosity among active galactic nuclei. It has been shown (Zamorani *et al.* 1981; Reichert *et al.* 1982; Avni and Tananbaum 1982) that the ratio of X-ray to optical luminosity is inversely related to total luminosity for X-ray or optically selected QSOs. This correla-

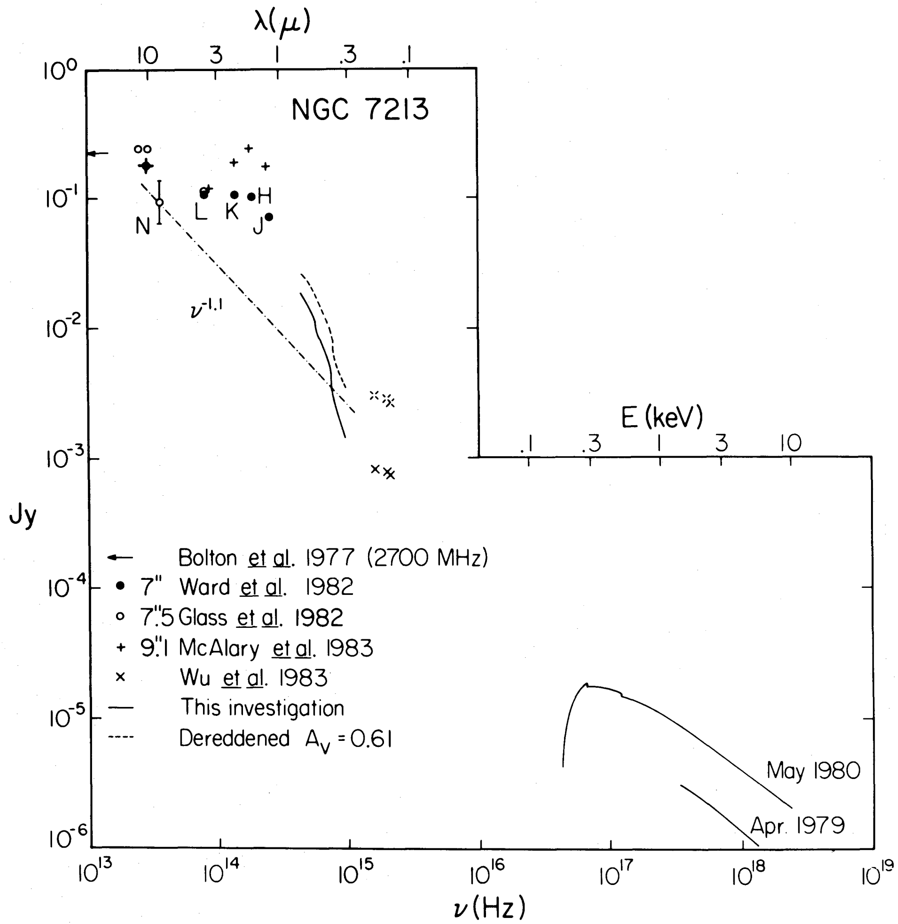

FIG. 4.—Data covering the overall continuum of NGC 7213. Note that the radio, IR, optical, UV, and X-ray measurements were taken through different effective apertures and at different epochs. Frogel and Elias obtained the 10 μm point at 0.19 Jy (*filled circle with tick marks*), as reported by Phillips (1979), and N refers collectively to all four observations near 10 μm. The point at 8.3 μm has much larger error bars than other measurements. Solid lines represent the new optical and X-ray spectra reported in this paper. Open crosses and the dashed line show the optical and UV data dereddened by $A_v = 0.61$ mag, but the IR data have not been dereddened. The dash-dot line is the power-law component ($\alpha = 1.1$) derived from a least-squares fit to the optical data only ($A_v = 0.61$), and happens to extrapolate through the observation at 8.3 μm obtained by Glass, Moorwood, and Eichendorf (1982). A possible inconsistency among the IR points is discussed in the text, and an excess typical of Seyfert 1 galaxies is indicated by the UV flux. The flatness of the X-ray slope in comparison with the optical power law requires that there be at least two breaks in the unobserved UV spectrum.

tion extends to Seyfert galaxies (Kriss 1982), and NGC 7213 suggests that it is also true in objects having still lower luminosity.

The UV flux lies substantially above an extrapolation of the optical data. This could simply reflect variability between the epochs of the UV and visual observations (which would be interesting in itself), but alternatively it may indicate the presence of the "UV bump" often seen in quasars and Seyfert 1 galaxies (Malkan and Sargent 1982; Oke, Shields, and Korycansky 1984). Excess emission in the far-UV decreases the derived deficit of ionizing photons (based on the strength of the Balmer lines) which exists if the power-law component alone is used (Paper I). The X-ray spectrum follows the common pattern in which the slope is flatter than the optical power law, and there must be at least two changes in slope if the spectra are to join continuously in the far UV.

Sadler (1984) recently published new radio observations of a complete sample of southern E and S0 galaxies. The flux density of NGC 7213 is 0.187 ± 0.017 Jy at 2.7 GHz and 0.228 ± 0.010 Jy at 5.0 GHz. The power-law spectrum between 2.7 and 5.0 GHz is therefore *inverted* ($\alpha = -0.3$), whereas a majority of galaxies have steep ($\alpha \gtrsim 0.5$) spectra. Heckman (1980) found that many of the Liners in his sample have compact nuclear radio sources, so NGC 7213 is more like a Liner than a Seyfert galaxy in this respect.

VI. SUMMARY

Phillips (1979) first identified broad Hα emission in NGC 7213, supporting the claim that this galaxy is associated with the *HEAO* A-2 source H2209−471. X-ray observations presented here show that the spectral index is typical of Seyfert galaxies. Moreover, the overall continuum resembles those in classical active extragalactic objects, as evidenced by the possible UV bump, the flat radio spectrum, and the optical nonstellar continuum. There can be little doubt that gas near the nucleus is photoionized by a nonstellar continuum.

This is an important conclusion since NGC 7213 also exhibits some of the optical characteristics of Liners (Heckman 1980), whose emission lines have often been attributed to heating by shocks. If the "shock" features of NGC 7213 can be reconciled with photoionization models, it is possible that the entire class of Liners consists of objects in which the basic physical processes are similar to those in QSOs and type 1 Seyfert galaxies. An extensive analysis of the optical emission lines is presented in Paper I, where it is shown that shocks are indeed not necessary to explain the observed features.

The small X-ray column density disagrees with the reddening of $A_v = 0.61$ mag determined from the optical spectrum. However, there may be thermal emission at temperatures of $\sim 5 \times 10^6$ K which is sufficient to fill in the soft X-ray turnover and create an approximation to a single power law. Thermal emission from a hot medium which confines the narrow-line clouds may also make a substantial contribution to the soft X-ray flux of other Seyfert galaxies. X-ray spectra having higher resolution are needed to look for line emission or continuum features which may be indicative of a spectrum containing both thermal and power-law components.

The able assistance of the electronics technicians and telescope operators at Las Campanas Observatory is greatly appreciated. Permission to make use of the MIT IPC observation of NGC 7213 was kindly granted by G. Kriss. An anonymous referee made several helpful remarks concerning the analysis and presentation of the data. This research was supported in part by NASA grant NGL 05-002-134 to J. B. Oke, by NSF grant AST 82-16544 to W. L. W. Sargent, and by the Fannie and John Hertz Foundation in the form of a graduate fellowship to A. V. F.

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