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OPTICAL SPECTROPHOTOMETRY OF THE SUSPECTED X-RAY GALAXIES NGC 6221 AND NGC 7213

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ABSTRACT

Optical spectrophotometry of two suspected X-ray galaxies, NGC 6221 and NGC 7213, is presented. The spectrum of the nucleus of NGC 6221 shows emission lines of moderately low ionization, and differs significantly from the spectra of previously discovered narrow-line X-ray galaxies. Identification of NGC 6221 with the *HEAO* A-2 source H1649−595 should therefore be considered uncertain.

The nuclear spectrum of NGC 7213 shows broad Hα emission characteristic of a Seyfert 1 galaxy, thus making identification with the *HEAO* A-2 source H2209−471 likely. Interestingly, the optical spectrum bears a close resemblance to the spectra of certain broad-line radio galaxies. Direct plates reveal NGC 7213 to be probably of morphological class S0. This observation further extends the range of morphological types over which the Seyfert 1 phenomenon is known to occur.

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

I. INTRODUCTION

Recent observations made with the *HEAO* A-2 have led to the identifications of the southern galaxies NGC 6221 and NGC 7213 as possible sources of X-ray emission (Marshall *et al.* 1978). NGC 6221 is a barred spiral galaxy, classified by de Vaucouleurs (1963) as an SBc. Martin (1976) has measured the radial velocity to be 1320 km s^{-1}, and describes the nucleus as starlike, with a low-excitation emission-line spectrum. According to de Vaucouleurs (1975), NGC 6221 and two other nearby spirals, NGC 6215 and NGC 6300, may be the brightest members of a loose group of approximately eight galaxies.

NGC 7213 has been variously cataloged as an elliptical galaxy and an early-type spiral. Evans (1952) published a short-exposure plate, and classified the galaxy as an Sa. On the other hand, Sérsic (1968) has classified NGC 7213 from a longer-exposure plate as an E1 galaxy, with a faint absorption band north of the nucleus. De Vaucouleurs (1975) lists NGC 7213 as the brightest member of a group of five galaxies. The radial velocity of the galaxy is given by de Vaucouleurs, de Vaucouleurs, and Corwin (1976) as 1769 km s^{-1}.

Both NGC 6221 and NGC 7213 lie within the 90% confidence error boxes (on the assumption of no variability of the source during the observations) of the *HEAO* A-2 sources H1649−595 and H2209−471, respectively. However, since the error boxes are large (approximately 0°.6 × 2°.8), identification of the sources with these galaxies is not assured. Therefore, to further investigate the likelihood of association with the X-ray emission, optical spectra of the nuclei of NGC 6221 and NGC 7213 were obtained at Cerro Tololo Inter-American Observatory. In this *Letter*, the results of these observations are reported.

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II. OBSERVATIONS AND RESULTS

The data were obtained with the SIT–vidicon spectrometer (Osmer and Smith 1976; Atwood *et al.* 1979) at the Cassegrain foci of the 4.0 and 1.5 m reflectors. For NGC 6221, all of the observations were made with the 4.0 m telescope on the nights of 1978 August 8, 9, and 10 (UT). Low-resolution (~25 Å) spectra were obtained with a 6″ slit in the wavelength ranges λλ3300–6200 and λλ4500–7200. In addition, higher-resolution (~5 Å) data were taken with a 4″ slit, covering a 750 Å wavelength region centered near Hα.

A high-resolution spectrum of NGC 7213 at Hα was obtained on the 4.0 m telescope the night of 1978 August 10 (UT). Low-resolution observations in the red with a 4″ slit were also made with the 4.0 m the same night, and a low-resolution spectrum in the blue was subsequently obtained with a 7″ slit on the 1.5 m telescope on 1978 August 27. Direct plates of NGC 7213 were also taken with the 61 cm Curtis Schmidt telescope at CTIO the night of 1978 August 12.

The results for both galaxies are summarized below.

a) NGC 6221

The low-resolution SIT–vidicon spectra of this galaxy show moderately strong emission lines superposed on a galaxian continuum. Most prominent in emission are the Balmer lines, with Hα, Hβ, Hγ, and Hδ all clearly present. In the blue spectral region, [O II] λ3727 and [O III] λλ4959, 5007 are observed, with λ3727 and λ5007 both approximately one-half the strength of Hβ. In the red, [N II] λλ6548, 6583 emission is present with an intensity ratio of λ6583/Hα ≈ 0.5.

The [S II] λλ6716, 6731 lines are also observed, with each about one-eighth the strength of Hα. The underlying continuum is apparently dominated by the radiation of late-type stars, with absorption features of Ca II H and K, G band, Mg I *b*, and Na I D all visible in the low-resolution data.

These observations essentially confirm Martin's description of the nuclear spectrum of NGC 6221. In particular, the gas does not appear to be highly ionized. A careful search was made of the low-resolution spectra for evidence of He II λ4686 and [Ne V] λ3426 emission, but with no success. If these lines are present they must be weaker than 0.05 $F(H\beta)$. Emission in [O I] λ6300, which arises in regions of very low ionization, is likewise very weak. Measurement of the high-resolution data yields an upper limit for the strength of this line of less than 0.03 $F(H\alpha)$. The absence of emission lines covering a wide range in ionization precludes classification of NGC 6221 as a Seyfert 2 galaxy. The high-resolution spectra also show the Hα, [N II], and [S II] line profiles to be only slightly resolved, indicating full widths at half-intensity of less than 200 km s^{-1}, which is smaller than in most Seyfert 2 galaxies (Koski 1978). However, this in itself should probably not be considered evidence against classification as a Seyfert galaxy, since the lower limit to the distribution of line widths for Seyfert 2 galaxies is not really known.

b) NGC 7213

The sum of the low-resolution SIT-vidicon observations of NGC 7213 is plotted in Figure 1 on a linear,

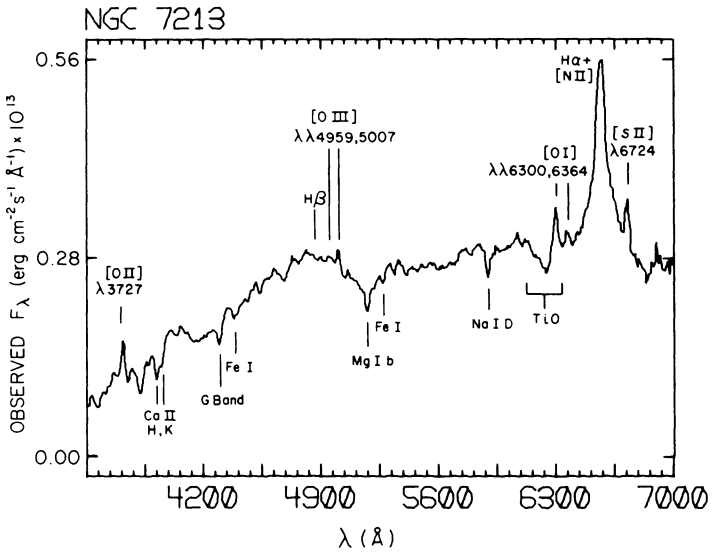


FIG. 1.—The summed data of two low-resolution SIT-vidicon spectra of the nucleus of NGC 7213 are displayed on an observed F_λ scale versus rest system wavelength.

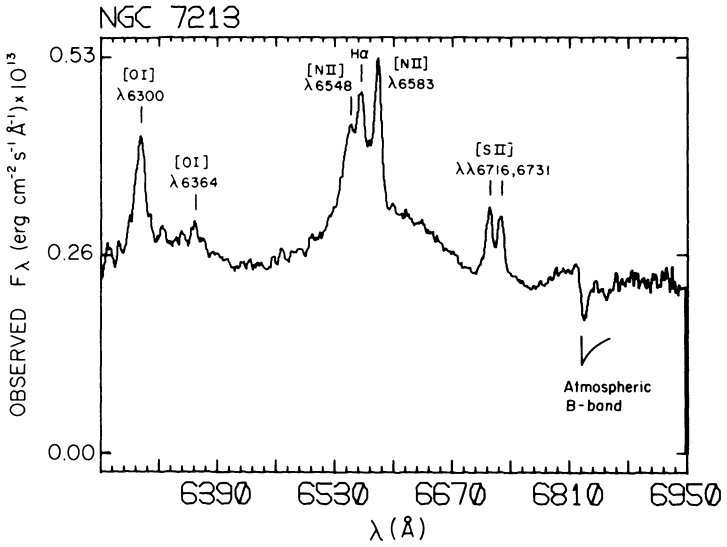


FIG. 2.—A high-resolution spectrum of NGC 7213 at Hα. The data are plotted as in Fig. 1

observed F_λ scale versus rest wavelength. The high-resolution spectrum of Hα is plotted in the same manner in Figure 2. As these data show, the nuclear spectrum of NGC 7213 displays the spectral characteristics of a type 1 Seyfert galaxy. However, the optical spectrum is somewhat peculiar, even for a Seyfert 1 galaxy. In particular, broad 13,000 km s^{-1} emission is clearly visible only at Hα. Broad wings are also probably present at Hβ, but they are very weak. The absolute luminosity in Hα is approximately 2×10^{41} ergs cm^{-2} s^{-1}, assuming a Hubble constant of 50 km s^{-1} Mpc^{-1} and making no correction for galactic extinction. This makes NGC 7213 one of the optically least luminous Seyfert 1 galaxies yet observed.

Narrow emission is observed at [O II] λ3727; [O III] $\lambda\lambda$4959, 5007; [O I] $\lambda\lambda$6300, 6364; [N II] $\lambda\lambda$6548, 6583; and [S II] $\lambda\lambda$6716, 6731. A narrow component of Hα is also present and, as shown in Figure 2, is blueshifted with respect to the centroid of the broad component. The underlying galaxian continuum is very prominent, and superficially resembles the continua observed in the nuclei of giant elliptical galaxies (Schild and Oke 1971; Whitford 1971).

The spectrum of NGC 7213 is remarkably similar to that of the recently discovered Seyfert 1 galaxy NGC 4235 (Abell, Eastmond, and Jenner 1978). The latter galaxy is a nearly edge-on Sb, and the steep Balmer decrement of the broad emission component has been suggested to be due to extinction arising from dust in the plane. However, this situation is not a likely explanation in the case of NGC 7213, which, if it is a disk galaxy, must be nearly pole-on. In several ways, the spectra of both of these galaxies resemble those of certain broad-line radio galaxies (Osterbrock, Koski, and Phillips 1975, 1976; Grandi and Osterbrock 1978), particularly in the steepness of the Balmer decrement, absence of Fe II emission, and prominence of the stellar continuum. Significantly, however, the luminosity of the broad emission in NGC 7213 is considerably less than is typically observed for the latter objects.

Because of the disagreement regarding the morphological classification of NGC 7213, direct plates were taken with the Curtis Schmidt telescope. In Figure 3*a* (Plate L7), an enlargement is shown of a 10 minute IIIa-J plate, baked in dry nitrogen, and taken through a GG385 filter. This plate shows the burned-out nucleus of NGC 7213 to be surrounded by a disk or "lens" structure, with a well-defined edge. The region outside of the lens shows some evidence of annular or ring structure, perhaps caused by dust lanes. Figure 3*b* shows a second baked IIIa-J plate which was exposed for 90 minutes. In this longer exposure, an apparently spheroidal outer envelope is clearly visible. Figure 3*c*, which is a high-contrast print of the same 90 minute plate, shows that there is little or no small-scale structure in the outer part of the galaxy. (The darkening of the plate toward the northwest corner is due to the proximity of the 2d mag star α Gruis.) As pointed out by Sérsic (1968), there is a feature suggestive of an absorption lane approximately 45″ north of the nucleus (best seen in Fig. 3*b*). There is perhaps some slight evidence of condensations or knots, particularly in the northeast quadrant of the outer envelope. A small "companion" galaxy is also visible in Figure 3*c*, approximately 4′ north-northeast of the nucleus.

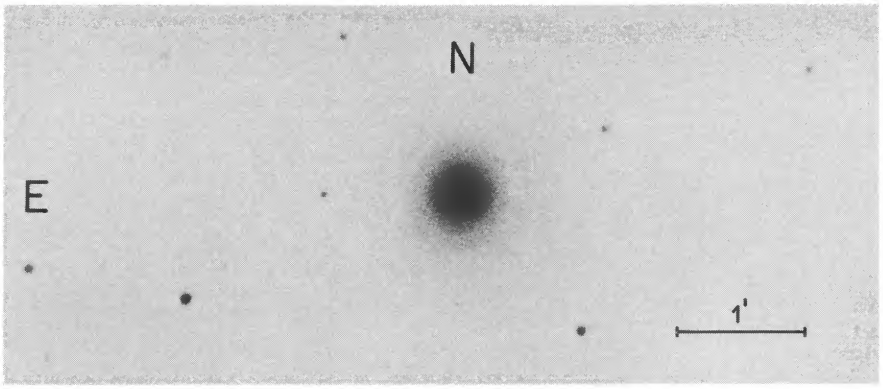
These two plates were not calibrated sensitometrically, and thus no quantitative meaning should be attached to the usage of the terms "disk," "lens," and "spheroid." However, the mere appearance of a lenslike structure argues strongly against classification of NGC 7213 as an elliptical galaxy. The lack of clear spiral structure, on the other hand, does not support classification as an Sa either. Rather, NGC 7213 most resembles a pole-on S0 galaxy such as NGC 524 (see Sandage 1961), or several of the S0 galaxies studied by Kormendy (1977). Thus NGC 7213 represents perhaps the best case of a Seyfert nucleus occurring in an S0 galaxy, and the Seyfert phenomenon now seems well established over a wide range in morphology of spirals and lenticulars, from S0 to Sc, and of barred galaxies as well, from SB0 to SBc (Adams 1977).

III. DISCUSSION

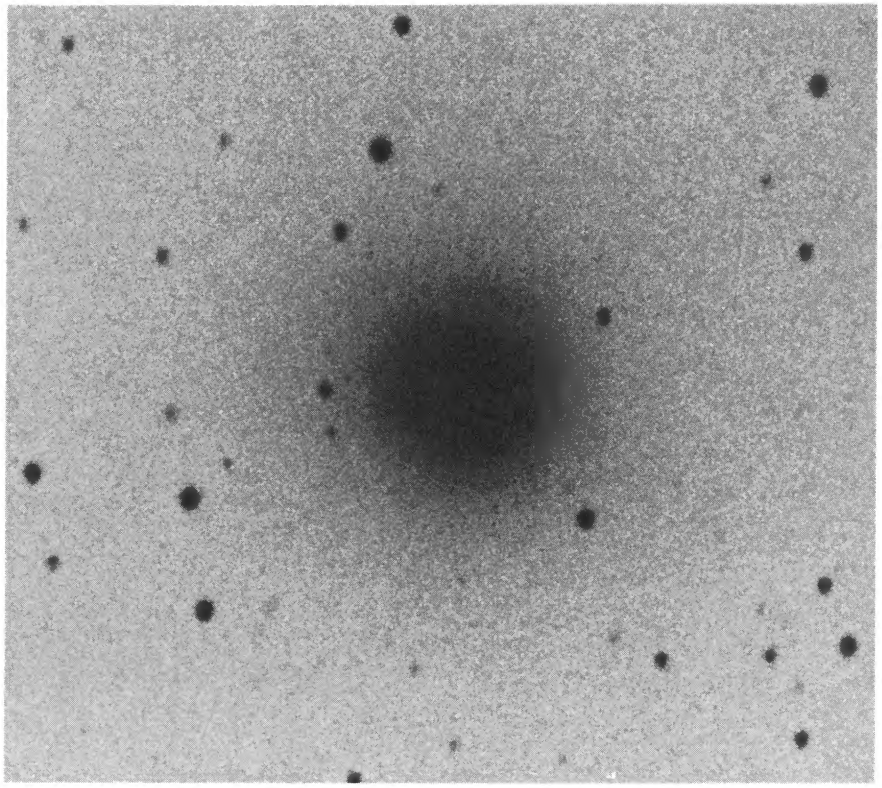
Marshall *et al.* (1978) have suggested NGC 6221 as the optical counterpart of the *HEAO* A-2 X-ray source H1649−595. To date, all narrow-emission-line galaxies which have been discovered to be X-ray sources have also been shown to have nuclear spectra which are similar to those of Seyfert 2 galaxies. For example, the galaxy MCG 5-23-16 was discovered as an X-ray source from observations with *SAS 3* (Pineda and Schnopper 1978), and was described as having a "normal" optical spectrum, with moderate-strength [O III], [N II], and Hα emission lines (Davis *et al.* 1978). However, low-resolution spectrophotometry of this galaxy obtained in 1978 April with the SIT–vidicon on the CTIO 4.0 m telescope shows the [O III] lines to be much stronger than Hβ, and also reveals moderately strong [S II] $\lambda\lambda$6716, 6731 emission. Thus, while this galaxy may not properly be termed a type 2 Seyfert, nevertheless the nuclear spectrum shows evidence of a wide range in ionization. Likewise, Ward *et al.* (1978) have shown that the probable X-ray galaxies NGC 2992 and NGC 7582 have optical spectra which resemble in several ways those of a type 2 Seyfert. The X-ray galaxy NGC 5506 has been studied by Wilson *et al.* (1976) and Rubin (1978), and clearly displays all of the characteristics of a typical Seyfert 2 galaxy (Koski 1978). The same is also true of the recently discovered X-ray galaxy NGC 2110 (Bradt *et al.* 1978).

These observations do not argue for the identification of NGC 6221 with the X-ray source. The emission-line spectrum of this galaxy is most readily understood as arising from gas ionized by hot, young stars, and does not suggest the presence of a nonthermal component of the continuum at ultraviolet and X-ray wavelengths. However, this observation does not *exclude* association with the X-ray emission, and further X-ray observations to better determine the position of the source are needed before any firm conclusions can be reached.

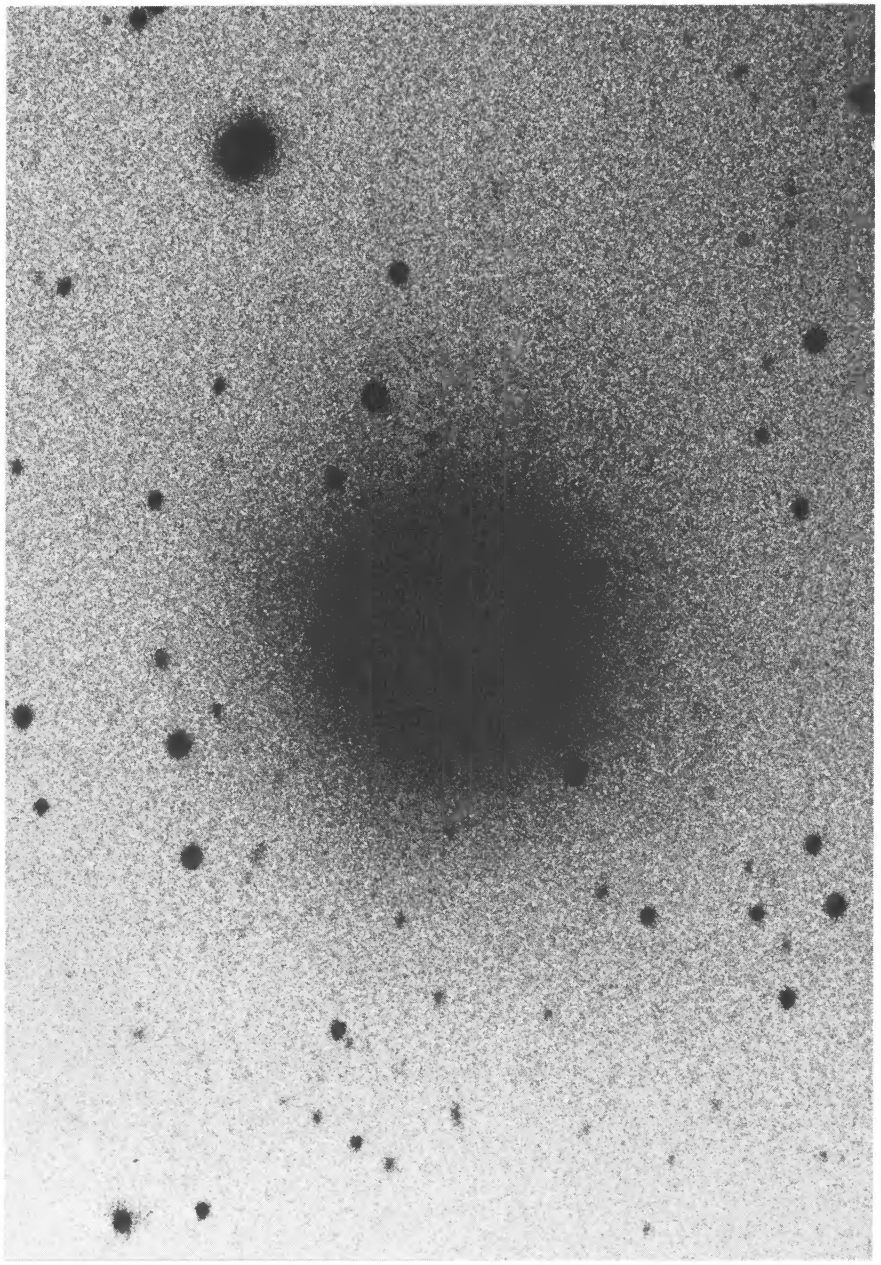
The association of NGC 7213 with the *HEAO* A-2 source H2209−471, on the other hand, is strongly supported by the Seyfert 1 nature of the nuclear spectrum. It has been well established that many Seyfert 1 galaxies are also powerful X-ray sources (e.g., Elvis *et al.* 1978), and the potential for identifying



(a)



(b)



(c)

FIG. 3.—(*a*) A 10 minute exposure of NGC 7213, taken on a baked IIIa-J plate through a GG385 filter, with the CTIO Curtis Schmidt. (*b*) A 90 minute exposure (baked IIIa-J + GG385) of NGC 7213 taken with the Curtis Schmidt. (*c*) The same 90 minute plate of NGC 7213, printed at high contrast. The darkening of the plate to the northwest is due to a nearby 2d mag star. All three prints have the same orientation and scale.

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nearby, previously unknown Seyfert 1 galaxies by their X-ray emission is clearly demonstrated by the case of this galaxy. The absolute X-ray luminosity of NGC 7213 over 2–10 keV is $\sim 3 \times 10^{42}$ ergs s^{-1} (Marshall *et al.* 1978), which is very small for the class. The observations presented in this *Letter* indicate that NGC 7213 is one of the least luminous Seyfert 1 galaxies in the optical as well.

Recently, Frogel and Elias (private communication) have measured a 10 μm flux for the nucleus of NGC 7213 of 190 $\pm$ 20 mJy, with the CTIO 1.5 m telescope. Further observations of this galaxy in the optical, infrared, and radio are desirable, as are large-scale direct plates to verify the morphological type of this peculiar object. Considering the superficial similarity of the optical spectrum of NGC 7213 to that of a broad-line radio galaxy, the detailed study of this relatively nearby galaxy could be particularly interesting.

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