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HARD X-RAY EMISSION FROM A NARROW-LINE RADIO GALAXY IC 5063 AND OBSCURED ACTIVE NUCLEUS

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ABSTRACT

We report the first detection of hard X-rays (above 2 keV), from the narrow-line radio galaxy (NLRG) IC 5063. The hard X-ray spectrum is described by a power-law photon index of 1.5 with a large absorption corresponding to the $N_{\rm H}$ value of 2×10^{23} H cm^{-2}. The X-ray luminosity (2–20 keV band) after the correction of the absorption is 2.5×10^{43} ergs s^{-1}. Since the X-ray luminosity and spectral index are in the range found for Seyfert 1's and broad-line radio galaxies (BLRG), we conclude that IC 5063 has an intrinsic BLRG type nucleus hidden behind a high gas column. There is a hint of X-ray flux variations with time scales between 10^3 s and 10 hr which, if confirmed, would further support that the hard X-rays are the direct beam from a compact nucleus penetrating the high gas column.

Subject headings: galaxies: individual (IC 5063) — galaxies: nuclei — galaxies: Seyfert — radio continuum: galaxies — X-rays: galaxies

1. INTRODUCTION

The recent discovery that a number of Seyfert 2 nuclei harbor broad emission-line regions (BLR), that are obscured from direct view at optical wavelengths, led to the development of the socalled unified model of AGNs (Antonucci & Miller 1985). In this scheme the viewing angle determines whether the BLR is seen directly, or only via reflection above and below, or transmission through, a torus of molecular material and dust grains. X-ray spectra of Seyfert 2's provide strong support for the obscuration hypothesis because many show low-energy cutoffs corresponding to high columns of gas. In these cases the hard X-ray luminosities are similar to those of Seyfert 1's. However, in the case of NGC 1068 the obscuring material is so thick that even at high energies only electron scattered X-rays are seen (Elvis & Lawrence 1988; Koyama et al. 1989).

There is considerable interest in whether the unified AGN model can be applied to the radio analogs of Seyferts, i.e., the narrow-line radio galaxies (NLRGs) and the broad-line radio galaxies (BLRGs). In this letter we report the first X-ray evidence for the presence of a hidden BLRG type nucleus in an AGN classified optically as a NLRG.

One of the most basic, but least understood, distinctions within the classification of active galactic nuclei is the dichotomy between radio-loud and radio quiet nuclei. Although in terms of their optical emission-line spectra there are close similarities between Seyfert 2's and narrow-line radio galaxies (NLRG), and Seyfert 1's and broad-line radio galaxies (BLRG), there are some clear differences in other respects. The host galaxies of radio-loud active galactic nuclei (AGNs) appear to be elliptical galaxies, whilst the host galaxies of radio-quiet Seyferts are spirals or in a few cases S0's.

IC 5063 is the radio galaxy PKS 2048−57, and is associated to a giant elliptical or S0 host galaxy at $z = 0.0110$, with a pronounced dust lane across the nucleus (Colina, Sparks, & Macchetto 1991). The radio flux of 5×10^{29} ergs s^{-1} Hz^{-1} sr^{-1} at 1415 MHz does not correspond to a very powerful radio source like Cyg A for example, but nevertheless it is still an order of magnitude higher than found for most Seyfert galaxies. Hence IC 5063 may be classified as a NLRG (Caldwell & Phillips 1981).

2. OBSERVATIONS AND RESULTS

IC 5063 was observed by the Japanese X-ray satellite *Ginga* LAC (Large Area Proportional Counter; Turner et al. 1989) on 1990 October 2. We have made pointing observation with the LAC center position at $(\alpha, \delta)_{1950} = (311.9, -57.4)$. Although the LAC consists of eight identical proportional counters, we used only six of them because the other two became slightly noisy during the observation. Therefore the maximum effective area was 3000 cm^2 in the energy range of 1–37 keV. The X-ray data were accumulated into 48 pulse-height channels (MPC-1 mode) with low bit rate which provided a time resolution of 16 s. Since the X-ray flux of IC 5063 was expected to be faint, the data qualification was made carefully. The data accumulated in the ground-contact orbits were excluded because of higher background due to the South Atlantic Anomaly. The data from the regions of low geomagnetic cutoff rigidty (<9 GeV c^{-1}) and unusual high background events caused by a sudden increase in the charged particle flux were also excluded (Hayashida et al. 1989; Awaki et al. 1991a). Then the effective accumulation time of useful data for the pointed mode was 1×10^4 s.

The background subtractions were made for the top- and mid-layer of LAC separately using the method described by Awaki et al. (1991a). The X-ray efficiency of the mid-layer below the 6 keV band is less than a few percent and the excess

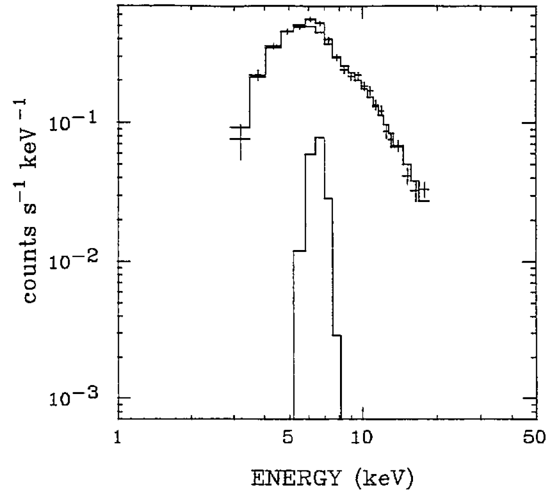

FIG. 1.—Pulse height spectrum of IC 5063. The histogram is the best-fit continuum emission and iron line as described in the text.

count rate in this energy range after the background subtraction was found to be only 0.1 counts s^{-1}. Therefore we conclude that the background has been well subtracted. In fact, we have used only the top-layer data, because most of the X-ray flux below about 10 keV is absorbed by the top-layer, and inclusion of the mid-layer data degrades the overall S/N ratio in the relevant energy band.

The X-ray spectrum is shown in Figure 1. We fitted the observed data with a model consisting of a power-law and iron emission line feature, and absorption due to a column of gas. This is the same procedure as used to model the X-ray spectra of Seyfert 2's. In order to determine the abundance and ionization of iron in the intervening gas, we allowed the iron abundance and K-edge energy to be free parameters. The best-fit model parameters for the X-ray spectrum are given in Table 1, and the model function, convolved with the detector response is shown in Figure 1 together with the iron line. Using this model we have determined the intrinsic X-ray luminosity (2–20 keV band) to be 2.5 × 10^{43} ergs s^{-1} (for $H_0 = 50$ km s^{-1} Mpc^{-1}).

The X-ray light curve after the background subtraction is given in Figure 2, where the accumulation time for each data bin is about 10^3 s. The X-ray flux shows gradual increase from 3.2 counts s^{-1} at the beginning to 3.7 counts s^{-1} at the end of the observation. In fact, a constant flux assumption was excluded with the χ^2 value 24 for 13 degrees of freedom.

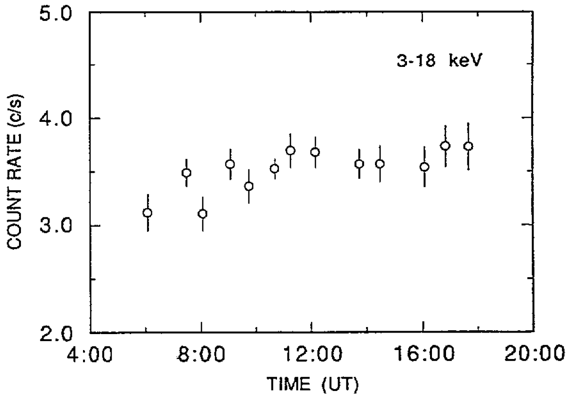

FIG. 2.—X-ray light curve in the 3–18 keV energy band. Error are at 1 σ level and typical accumulation time of data bin is 10^3 s.

3. DISCUSSION

The parameters derived from the X-ray spectrum of IC 5063 are similar to those found for the obscured nuclei in the Seyfert 2's, Mkn 3, NGC 4507 and Mkn 348 (Awaki et al. 1990; Awaki et al. 1991b; Warwick et al. 1989). The X-ray column density is intermediate between them, and all four nuclei have similar intrinsic (2–10 keV) luminosities. The X-ray luminosity of about 3 × 10^{43} ergs s^{-1} is similar to those of Seyfert 1 galaxies and is far higher than that observed from the most luminous early-type galaxies (Canizares, Fabbiano, & Trinchieri 1987). Furthermore the photon index of the X-ray spectrum is about 1.5, which is similar to those measured for Seyfert 1's and BLRGs. These facts imply that the hard X-ray flux from IC 5063 is the transmitted component from the broad-line type AGN. The low-energy X-ray are absorbed by a very high gas column density of 2 × 10^{23} H cm^{-2}. Such a high column is sufficient to obscure the true nucleus at all frequencies except at hard X-rays and gamma rays. Since IC 5063 is not an edge-on spiral, this high column gas would not be due to the host galaxy but would be from the region near the X-ray source.

Recently, Fabbiano, Kim, & Trinchieri (1992) reported a soft X-ray flux (0.2–3.5 keV) of IC 5063 to be 4 × 10^{-13} ergs s^{-1} cm^{-2}. If we simply extrapolate the best-fit *Ginga* spectrum to the low energies, we obtain the X-ray flux in the 0.2–3.5 keV band to be about 10^{-11} ergs s^{-1} cm^{-2}, which is nearly two orders of magnitude larger than that observed with the *Einstein* observatory. However if we adopt the absorption due to N_H of 2 × 10^{23} H cm^{-2} to the best-fit *Ginga* spectrum, then we obtain the X-ray flux in the 0.2–3.5 keV band to be 2 × 10^{-13}

TABLE 1

RESULTS OF SPECTRAL FIT

CONTINUUM EMISSION			IRON LINE		IRON EDGE		
Flux[a] 2–20 keV (ergs^{-1} cm^{-2})	Photon Index α	Column Density log [N_H(cm^{-2})]	Line Energy[b] (keV)	Equivalent Width (keV)	Edge Energy[b] (keV)	Column Density[c] log [N_{HFe}(cm^{-2})]	χ^2/d.o.f.
4.9 × 10^{-11}	1.48 ± 0.14	23.37 ± 0.06	6.42 ± 0.37	0.23 ± 0.10	7.14 ± 0.14	23.46 ± 0.17	19/16

NOTE.—Errors are at the 90% confidence level.

[a] Unabsorbed flux.

[b] Corrected for a redshift.

[c] $N_{HFe} = 10^{4.48} N_{Fe}$ (cosmic abundance).

ergs s^{-1} cm^{-2}. Therefore the high absorption derived from the *Ginga* spectrum can provide an explanation of the low flux measured by the *Einstein* observatory. The other possibility is that the soft X-rays from the nucleus are completely absorbed, and the soft X-rays we see are scattered flux. The less probable possibility of flux variability of two orders of magnitude between the dates of the *Ginga* and *Einstein* observations cannot of course be excluded.

The iron column density ($N_{\rm Fe}$) determined from the depth of the iron K-edge is about (6–14) × 10^{18} Fe cm^{-2}. The ratio of $N_{\rm Fe}$ and $N_{\rm H}$ implies the iron abundance of the absorbing gas in the range of 1–2 times the cosmic value. The iron K-line emission in the spectrum of IC 5063 is detected with an equivalent width of about 230 eV. Since the origin of the iron feature is believed to be fluorescence in the gas surrounding the compact nucleus, the equivalent width can provide a measure of the solid angle of the fluorescent gas from the nucleus. If the X-ray emission from the central engine, and the gas distribution around it are uniform and the solid angle of the covering gas is 4π sr, then we would expect the iron equivalent width to be about of Ab × 200 eV for a hydrogen column density of 2×10^{23} H cm^{-2} (Inoue 1985), where Ab is the iron abundance in units of the cosmic value. Since we find that Ab is 1–2, we conclude that the solid angle from the nucleus to the fluorescent gas is larger than 2π sr. The best-fit iron line energy is 6.42 ± 0.37 keV, which is consistent with the energy of neutral iron. A stronger constraint on the ionization state of the iron comes from the iron edge energy of 7.14 ± 0.14 keV. From this value, we estimate that the ionization state of the iron is between neutral and Argon-like (Inoue 1985). So we conclude that IC 5063 has an optically thick cold gas column along our line of sight, with the $N_{\rm H}$ of 2×10^{23} H cm^{-2}, and the covering factor of this gas is larger than 0.5. This picture is very similar to the accretion torus model proposed for Seyfert 2 nuclei.

Additional evidence for the status of IC 5063 as a radio-loud example of the Seyfert 2 phenomenon, comes from optical imaging by Colina et al. (1991), which shows a high excitation cone of ionized gas, similar to that seen in several Seyfert 2's. Also spectropolarimetry by Inglis et al. (1992), shows a broad polarized component in the Hα profile, which presumably results from the same processes as in NGC 1068 (Antonucci & Miller 1985).

More generally there is some evidence for the presence of obscured AGNs in the famous radio galaxies Cyg A and Cen A. The indirect evidence for a quasar at the core of Cyg A is given in Ward et al. (1991). The X-rays from Cyg A are contaminated by the thermal emission from the cluster, and hence it is difficult to define the X-ray spectrum of the AGN alone. However, a deconvolution analysis is consistent with a high luminosity source with a heavy cutoff spectrum in the nucleus of Cyg A (Ueno et al. 1993). The X-ray spectrum of Cen A clearly shows low energy absorption with a value of $N_{\rm H}$ of about 10^{23} H cm^{-2} (Wang et al. 1986). Cen A exhibits rapid hard X-ray variability which confirms the presence of a compact AGN, although its luminosity is at the low end of the range for Seyfert 1's. The X-ray luminosity of IC 5063 is more than a factor of 10 higher than Cen A, and is more typical of Seyfert 1's. Our results thus strengthen the angle dependent obscuration hypothesis.

Finally, we find some hint of short term variability in the X-ray light curve spanning about 12 hr. However further X-ray monitoring is required to confirm that the hard X-rays do indeed arise from a compact variable nucleus.

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REFERENCES

Antonucci, R. R. J., & Miller, J. S. 1985, ApJ, 297, 621
Awaki, H., Koyama, K., Kunieda, H., & Tawara, Y. 1990, Nature, 346, 544
Awaki, H., et al. 1991a, ApJ, 366, 88
Awaki, H., Kunieda, H., Tawara, Y., & Koyama, K. 1991b, PASJ, 43, L37
Caldwell, H., & Phillips, M. M. 1981, ApJ, 244, 477
Canizares, C. R., Fabbiano, G., & Trinchieri, G. 1987, ApJ, 312, 503
Colina, L., Sparks, W. B., & Macchetto, F. 1991, ApJ, 370, 102
Elvis, M., & Lawrence, A. 1988, ApJ, 331, 161
Fabbiano, G., Kim, D.-W., & Trinchieri, G. 1992, ApJS, 80, 531
Hayashida, K., et al. 1989, PASJ, 41, 373
Inglis, M., et al. 1992, preprint
Inoue, H. 1985, Space Sci. Rev., 40, 317
Koyama, K., et al. 1989, PASJ, 41, 731
Makino, F., & the ASTRO-C team 1987, Astrophys. Lett., 25, 223
Miller, J. S., & Goodrich, R. W. 1986, ApJ, 355, 456
Turner, M. L. J., et al. 1989, PASJ, 41, 345
Ueno, S., et al. 1993, in preparation
Wang, B., Inoue, H., Koyama, K., & Tanaka, Y. 1986, PASJ, 38, 685
Ward, M. J., Blanco, P. R., Wilson, A. S., & Nishida, M. 1991, ApJ, 382, 115
Warwick, R. S., et al. 1989, PASJ, 41, 739