X-RAY PROPERTIES OF LINERs AND LOW-LUMINOSITY SEYFERT GALAXIES OBSERVED WITH ASCA. I. OBSERVATIONS AND RESULTS

Yuichi Terashima,1,2 Naoko Iyomoto,1 Luis C. Ho,3 and Andrew F. Ptak4,5

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ABSTRACT

This paper presents a comprehensive study of the X-ray properties of low-ionization nuclear emission-line regions (LINERs) and low-luminosity Seyfert galaxies based on observations obtained with the ASCA satellite. We analyzed data of 53 observations of 21 LINERs and 17 low-luminosity Seyferts. X-ray emission has been detected in all but one object. The X-ray luminosities in the 2–10 keV band range from \(4 \times 10^{39}\) to \(5 \times 10^{41}\) ergs s\(^{-1}\), which are 1–3 orders of magnitude smaller than in classical Seyfert galaxies. The X-ray spectra of most objects are well described by a canonical model which consists of (1) a soft component from a thermal plasma with \(kT < 1\) keV and (2) a hard component represented by a power law with a photon index of \(\Gamma \approx 1.8\) or thermal bremsstrahlung emission with \(kT \approx 10\) keV. Several objects do not require the soft thermal component, and their continua are well fitted by a single power-law model. Some objects show heavy absorption with column densities in excess of \(10^{23}\) cm\(^{-2}\). We detect in several objects Fe K line emission with equivalent widths ranging from 50 eV to 2 keV.

Variability on timescales less than a day is uncommon in our sample. By comparing multiple observations made with ASCA or with published 2–10 keV observations from other satellites, we show that at least eight objects are variable on timescales of a week to several years. We find that the morphologies of many objects, both in the soft and hard bands, are consistent with being pointlike relative to the telescope point-spread function; a few are clearly extended in either or both energy bands.

The second paper of this series will discuss the physical interpretation of the X-ray emission and its implications for low-luminosity active galactic nuclei.

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

1. INTRODUCTION

It is widely accepted that many bright galaxies possess low-level nuclear activity. The Palomar optical spectroscopic survey of nearby galaxies by Ho, Filippenko, & Sargent (1995, 1997a, 1997b) showed that more than 40% of the 486 galaxies with \(B_T \leq 12.5\) mag and \(\delta > 0^\circ\) have optical spectra classified as Seyfert nuclei, low-ionization nuclear emission-line regions (LINERs; Heckman 1980), or transition objects (spectra intermediate between LINERs and H \(\Pi\) nuclei). It is not clear, however, what fraction of these objects are genuine active galactic nuclei (AGNs), which we take to be objects powered by nonstellar processes. Extensive observations have been made in various wavelengths to clarify the nature of these classes of objects (for reviews see Ho 1999, 2002). X-ray observations play a key role in this regard. This paper presents the first systematic analysis of a large sample of LINERs and low-luminosity Seyfert galaxies observed with the ASCA satellite.

The gross spectroscopic characteristics of LINERs can be explained by a variety of ionization mechanisms, including traditional photoionization by a low-luminosity AGN (LLAGN), photoionization by a population of unusually hot stars, and mechanical heating by shock waves. Recent reviews on this topic have been given by Filippenko (1996) and Barth (2002). If LINERs are low-luminosity versions of AGNs, which are powered by accretion onto massive black holes, we expect them to emit nonthermal, hard X-rays. On the other hand, X-rays from thermal plasmas are expected from shock-heated gas. Hot stars also have soft thermal spectra in the X-ray band. Thus, X-ray observations can help discriminate between the various models for LINERs. We note, however, that hard X-rays (hereafter defined as \(E > 2\) keV) are not a signature unique to AGNs: potential contributors to the hard-energy band include X-ray binaries, supernovae, and hot (\(kT \approx 10\) keV) gas produced by starburst activity. An unambiguous search for AGNs using X-ray data thus requires careful consideration of the spectral, structural, and variability properties of the sources.

Many Seyfert galaxies have been identified in the Palomar survey. The median H\(\alpha\) luminosity of these sources is \(L_{H\alpha} \approx 2 \times 10^{39}\) ergs s\(^{-1}\), which is more than 2–3 orders of magnitude lower than in classical Seyfert galaxies (e.g., Dahari & De Robertis 1988; Whittle 1992). X-ray observations of such low-luminosity Seyferts (hereafter LLSeyferts) are necessary to determine whether they are genuine AGNs and whether they are similar to luminous AGNs.

In addition to studying the origin of activity in LINERs and LLSeyferts, the X-ray properties of these sources themselves hold great interest. By defining an LLAGN sample using strong AGN candidates based on detailed study of individual objects, we can investigate the nature of LLAGNs as a class, compare them with more luminous...
AGNs, and potentially constrain models for accretion flows. For example, the spectral properties (continuum shape, absorption column, Fe K line strength, presence or absence of ionized absorbers) and variability characteristics can be used to probe the structure of the central engine, in a region of parameter space that is likely to be quite unique because of the extreme conditions involved. In the regime of low mass accretion rate, it has been suggested that advection-dominated accretion flows may be present (Narayan & Yi 1994; see reviews by Kato, Fukue, & Mineshige 1998 and Quataert 2001). Comparisons between observations and theoretical predictions are critical for testing these and other ideas.

X-ray observations of LINERs and LLSeyferts, in both the soft and hard energy bands, have been published by a number of authors. However, most, if not all, previous studies have been limited either by sample size or restricted energy bandwidth. In the soft X-ray band, data based on observations with Einstein and ROSAT have been presented by Halpern & Steiner (1983), Koratkar et al. (1995), Komossa, Böhringer, & Huchra (1999), Roberts & Warwick (2000), Lira, Lawrence, & Johnson (2000), and Halderson et al. (2001). The primary disadvantages of observations in the soft X-ray band are contamination by emission from hot gas, often observed in galaxies, and decreased sensitivity to absorbed AGNs. The number of hard X-ray observations of LINERs and LLSeyferts prior to ASCA is very limited. Because of sensitivity limitations, only a few of the brightest objects have been observed (e.g., M81 and NGC 3998). The significantly improved sensitivity and imaging capability in the broad energy band (0.5–10 keV) of ASCA provide an unprecedented opportunity to study systematically objects with low-level activity.

This paper presents a comprehensive analysis of ASCA observations of LINERs and LLSeyferts. In a subsequent paper (Terashima et al. 2002, in preparation, hereafter Paper II), we discuss the origin of the X-ray emission using the X-ray properties derived here, along with comparisons with data from other wavelengths, and the broader implications for LLAGNs. Previous ASCA results based on smaller samples can be found in Serlemitsos, Ptak, & Yaqoob (1996), Terashima (1998, 1999a, 1999b), Awaki (1999), and Ptak et al. (1999). The references for ASCA results on individual objects are given in Terashima, Ho, & Ptak (2000a) and § 9 in this paper. This paper is organized as follows. We define the sample in § 2. Section 3 briefly presents the observations and data reduction. The results of a spectral analysis, a summary of the best-fit spectral parameters, and a tabulation of the derived fluxes and luminosities are presented in §§ 4, 5, and 6, respectively. Sections 7 and 8 are devoted to timing and imaging analyses, respectively. Notes on individual objects are given in § 9. Section 10 summarizes the main results.

2. THE SAMPLE

The galaxies in this study were chosen from the Palomar survey of nearby galaxies. We selected objects classified by Ho et al. (1997a) as LINERs and Seyfert galaxies which were either in the ASCA data archives as of 1999 December or belonged to our own proprietary observing programs. We decided to analyze Seyferts with \( L_{H\alpha} < 10^{41} \) ergs s\(^{-1}\), roughly the luminosity of NGC 4051, the lowest luminosity “classical” Seyfert galaxy. Luminous Seyferts which have been extensively studied were excluded. The list of galaxies we analyzed is shown in Table 1, where we list the Hubble types, distances, heliocentric velocities, and optical spectroscopic classifications. We use the distances adopted by Ho et al. (1997a), which are taken from Tully (1988) and are based on a Hubble constant of \( H_0 = 75 \) km s\(^{-1}\) Mpc\(^{-1}\). The velocities are taken from the NASA/IPAC Extragalactic Database (NED).

We omitted a few objects with ambiguous spectral classification. The LINER 2 NGC 4486 (M87) was also excluded because of the complexity of its X-ray emission (Matsumoto et al. 1996; Reynolds et al. 1996; Allen, Di Matteo, & Fabian 2000). The X-ray spectrum of M87 consists of multiple components, namely emission from an AGN and hot gas from the host galaxy and the Virgo cluster. Properly measuring the spectral parameters of the AGN component requires detailed image analysis and a sophisticated modeling of the thermal emission, including the effects of multiple temperatures, metal abundances, and temperature and metallicity gradients. This is beyond the scope of this paper.

The two transition objects NGC 4569 and NGC 4192, which were analyzed by Terashima et al. (2000b), were included. Several objects in the southern hemisphere (NGC 1097, 1365, 1386, and 4941), which have good ASCA data, were also used. The optical classifications for these objects were taken from Phillips et al. (1984), Storchi-Bergmann, Baldwin, & Wilson (1993), Véron-Cetty & Véron (1986), and Storchi-Bergmann & Pastrizza (1989).

The final sample consists of nine LINER 1s, 12 LINER 2s, eight Seyfert 1s, and nine Seyfert 2s. Some of these objects were observed at least twice with ASCA. Whenever possible we analyzed the multiple observations to achieve better photon statistics and to search for variability. In total there are 53 observations, as summarized in Table 2. Section 9 gives comments on the observations which were not used.

3. OBSERVATIONS AND DATA REDUCTION

A log of the ASCA observations is shown in Table 2. It gives the start date of the observations, observation modes, count rates obtained for the SIS and GIS detectors, and net exposure times after data screening. The GIS detectors (Ohashi et al. 1996; Makishima et al. 1996) were operated in the PH mode with the nominal bit assignment for all the observations. The spread discriminator was not turned on in the observations of NGC 3079, 4258, and 5194. The clocking and telemetry modes of the SIS detectors (Burke et al. 1994; Yamashita et al. 1999) are also summarized in Table 2. In the SIS observations, in which both the faint and bright modes were used, the two data sets were combined after the faint-mode data were converted to the format of the bright-mode data; the only exception was the 1995 observation of NGC 4579 (see Terashima et al. 1998a).

The data were screened using the following set of criteria: (1) elevation angle above the Earth’s limb greater than 5°, (2) cutoff rigidity greater than 6 GeV c\(^{-1}\), (3) avoidance of South Atlantic Anomaly, and (4) elevation angle above the day Earth’s limb greater than 25° (SIS only). X-ray spectra and light curves were extracted from a circular region with a typical radius of 3°–4° for SIS and 6° for GIS. A smaller extraction radius was used in some cases to avoid a bright nearby source. Background spectra were accumulated from a source-free region in the same field.
We fitted the SIS and GIS spectra simultaneously using the XSPEC spectral-fitting package (version 10). The spectra of the two SIS detectors were combined, as were those from the two GIS detectors. The quoted errors are at the 90% confidence level for one interesting parameter ($\Delta \chi^2 = 2.7$). The Galactic absorption column densities are derived from HI measurements by Murphy et al. (1996), when available, or else from those by Dickey & Lockman (1990). The results of the spectral fits are presented in Figures 1–12. In each figure, the left column displays the SIS spectra, the right column the GIS spectra. Within each plot, the upper panel shows the data and the best-fit model, and the lower panel shows the residuals of the fit. For multicomponent models, we plot each component with a different line type in the upper panel.

### Simple Models

We fitted the spectra with a simple power-law model modified by photoelectric absorption along the line of sight. We added a Gaussian component to those objects which showed an indication of a linelike emission feature around 6 keV. The results of the fits are shown in Table 3. Errors are not shown for the fits with poor reduced $\chi^2$ because the error estimations using the $\Delta \chi^2 = 2.7$ criterion are not valid. Acceptable fits were obtained for only several objects: NGC 3031, 3147, 3507, 3998, 4203, 4579 (1998 observation), 4639, and 5033. The other objects show significant residuals in the soft-energy band and/or a more complicated continuum shape. In many objects emission lines are seen in the region 0.6–2 keV, indicative of the presence of a sub-keV thermal plasma. In the next subsection we evaluate

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**TABLE 1**

**The Sample**

| Name          | Other Name | Hubble Type | Distance (Mpc) | $cz$ (km s$^{-1}$) | Spectral Class$^a$ |
|---------------|------------|-------------|----------------|-------------------|-------------------|
| NGC 315       |            | E + :       | 65.8           | 4942              | L1.9              |
| NGC 404       |            | S0–         | 2.4            | 43                | L2                |
| NGC 1052      |            | E4          | 17.8           | 1470              | L1.9              |
| NGC 1097      |            | SB53        | 14.5           | 1275              | S1.5/L2           |
| NGC 1365      |            | SBb         | 16.9           | 1636              | S1.8              |
| NGC 1366      |            | SB0 +       | 16.9           | 868               | S2                |
| NGC 2273      |            | SBa          | 28.4           | 1871              | S2                |
| NGC 2639      |            | Sa2         | 42.6           | 3336              | S1.9              |
| NGC 2655      |            | SB0/a       | 24.4           | 1404              | S2                |
| NGC 3031      |            | Sab         | 1.4            | 34                | S1.5              |
| NGC 3079      |            | Sbc         | 20.4           | 1125              | S2                |
| NGC 3147      |            | Sbc         | 40.9           | 2820              | S2                |
| NGC 3507      |            | SBb         | 19.8           | 979               | L2                |
| NGC 3607      |            | S0:         | 19.9           | 935               | L2                |
| NGC 3998      |            | S0?         | 21.6           | 1040              | L1.9              |
| NGC 4111      |            | S0 + spin   | 17.0           | 807               | L2                |
| NGC 4192      |            | M98         | 16.8           | –142              | T2                |
| NGC 4203      |            | SAB0–:      | 9.7            | 1086              | L1.9              |
| NGC 4258      |            | M106        | 6.8            | 448               | S1.9              |
| NGC 4261      |            | E2 +        | 35.1           | 2238              | L2                |
| NGC 4374      |            | M84         | 16.8           | 1060              | L2                |
| NGC 4438      |            | S0/a:       | 16.8           | 71                | L1.9              |
| NGC 4450      |            | Sab         | 16.8           | 1954              | L1.9              |
| NGC 4457      |            | SB0/a       | 17.4           | 882               | L2                |
| NGC 4501      |            | Sb          | 16.8           | 2281              | S2                |
| NGC 4565      |            | Sb? spin    | 9.7            | 1282              | S1.9              |
| NGC 4569      |            | M90         | 16.8           | –235              | T2                |
| NGC 4579      |            | M58         | 16.8           | 1519              | S1.9/L1.9         |
| NGC 4594      |            | M104        | 20.0           | 1024              | L2                |
| NGC 4636      |            | E0 +        | 17.0           | 938               | L1.9              |
| NGC 4639      |            | SB0c        | 16.8           | 1010              | S1.0              |
| NGC 4736      |            | M94         | 4.3            | 308               | L2                |
| NGC 4941      |            | SAB0        | 6.4            | 1108              | S2                |
| NGC 5005      |            | SAB0c       | 21.3           | 946               | L1.9              |
| NGC 5033      |            | Sc          | 18.7           | 875               | S1.5              |
| NGC 5194      |            | Sbc pec     | 7.7            | 463               | S2                |
| NGC 7217      |            | Sab         | 16.0           | 952               | L2                |
| NGC 7743      |            | SB0 +       | 24.4           | 1710              | S2                |

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$^a$ Spectral class of the nucleus taken from Ho et al. 1997a except for NGC 1097 (Phillips et al. 1984; Storchi-Bergmann et al. 1993), NGC 1365, NGC 1386 (Véron-Cetty & Véron 1986), and NGC 4914 (Storchi-Bergmann & Pastriz 1989), where L = LINER, S = Seyfert, T = “ transition object” (LINER/H II), 1 = type 1, 2 = type 2, and a fractional number between 1 and 2 denotes various intermediate types.
a model consisting of a hard component and a soft thermal plasma component.

Several objects show both a heavily absorbed hard component and a less absorbed soft component. In order to fit such a spectral shape, we tried a partially covered power-law model. This model is equivalent to one consisting of a combination of an absorbed power law plus and a scattered power law, as is often observed in Seyfert 2 galaxies (e.g.,

| NAME      | DATEa  | SIS MODE | SIS       | GIS       |
|-----------|--------|----------|-----------|-----------|
| NGC 315    | 1996 Aug 05 | 1CCD Faint | 0.031 | 0.018 |
| NGC 404    | 1997 Jul 21 | 1CCD Faint | ... | ... |
| NGC 1052   | 1998 Feb 06 | 1CCD Faint | 0.046 | 0.041 |
| NGC 1097   | 1994 Jan 12 | 2CCD Faint | 0.079 | 0.055 |
| NGC 1365   | 1994 Aug 12 | 1CCD Faint | 0.019 | 0.024 |
| NGC 1386   | 1995 Jan 26 | 4CCD Faint/Bright LD* 0.48 keV | 0.017 | 0.034 |
| NGC 2273   | 1996 Oct 20 | 1CCD Faint LD^ 0.48 keV | 0.004 | 0.013 |
| NGC 2639   | 1997 Apr 16 | 1CCD Faint | 0.008 | 0.005 |
| NGC 2655   | 1998 Oct 29 | 2CCD Faint/Bright LD^ 0.55 keV | 0.012 | 0.009 |
| NGC 3031   | 1995 Oct 21 | 1CCD Faint | 0.35  | 0.19  |
| NGC 3079   | 1993 May 09 | 1CCD Faint | 0.022 | 0.008 |
| NGC 3147   | 1993 Sep 29 | 4CCD Faint/Bright | 0.048 | 0.045 |
| NGC 3507   | 1998 Nov 30 | 1CCD Faint | 0.006 | 0.003 |
| NGC 3607   | 1996 May 26 | 2CCD Faint/Bright | 0.011 | 0.007 |
| NGC 3998   | 1994 May 10 | 2CCD/1CCD Faint | 0.29  | 0.18  |
| NGC 4111   | 1997 Dec 07 | 1CCD Faint LD^ 0.48 keV | 0.008 | 0.004 |
| NGC 4192   | 1997 Dec 17 | 2CCD Faint/Bright | 0.075 | 0.088 |
| NGC 4203   | 1993 Dec 17 | 2CCD Faint | 0.035 | 0.041 |
| NGC 4258   | 1993 May 15 | 4CCD Faint/Bright | 0.16  | 0.12  |
| NGC 4438   | 1995 Dec 24 | 2CCD/1CCD Faint | 0.017 | 0.013 |
| NGC 4636   | 1995 May 25 | 1CCD Faint LD^ 0.41 keV | 0.056 | 0.065 |
| NGC 4659   | 1997 Jun 05 | 1CCD Faint | 0.17  | 0.13  |
| NGC 4736   | 1995 May 25 | 1CCD Faint LD^ 0.41 keV | 0.073 | 0.042 |
| NGC 4941   | 1997 Jun 08 | 1CCD Faint | 0.008 | 0.009 |
| NGC 5005   | 1995 Dec 13 | 1CCD Faint | 0.024 | 0.012 |
| NGC 5033   | 1995 Dec 14 | 1CCD Faint | 0.16  | 0.11  |
| NGC 5194   | 1993 May 11 | 4CCD Faint/Bright | 0.044 | 0.020 |
| NGC 7217   | 1995 Nov 19 | 2CCD Faint/Bright LD^ 0.48 keV | 0.008 | 0.004 |
| NGC 7743   | 1998 Dec 09 | 1CCD Faint | 0.36  | 0.37  |

a Observation start date.
b Count rate includes a nearby source.
c Level discriminator is enabled.
Fig. 1.—ASCa SIS (left) and GIS (right) spectra. In each plot, the upper panel shows the data and the model, and the lower panel shows the residuals of the fit. NGC 315 (top), NGC 1052 (middle), NGC 1097 (bottom).
Fig. 2.—Same as Fig. 1: NGC 1365 (top), NGC 1386 (middle), NGC 2273 (bottom)
Fig. 3.—Same as Fig. 1: NGC 2639 (top), NGC 2655 (middle), NGC 3031 (bottom)
Fig. 4.—Same as Fig. 1: NGC 3079 (top), NGC 3147 (middle), NGC 3507 (bottom)
Fig. 5.—Same as Fig. 1: NGC 3607 (top), NGC 3998 (middle), NGC 4111 (bottom)
Fig. 6.—Same as Fig. 1: NGC 4203 (top), NGC 4258 (1993) (middle), NGC 4258 (1996) (bottom)
Fig. 7.—Same as Fig. 1: NGC 4261 (top), NGC 4374 (middle), NGC 4438 (bottom)
Fig. 8.—Same as Fig. 1: NGC 4450 (top), NGC 4457 (middle), NGC 4501 (bottom)
Fig. 9.—Same as Fig. 1: NGC 4565 (top), NGC 4569 (middle), NGC 4579 (1995) (bottom)
Fig. 10.—Same as Fig. 1: NGC 4579 (1998) (top), NGC 4594 (middle), NGC 4636 (bottom)
Fig. 11.—Same as Fig. 1: NGC 4736 (top), NGC 4941 (middle), NGC 5005 (bottom)
Fig. 12.—Same as Fig. 1: NGC 5033 (top), NGC 5194 (middle), NGC 7217 (bottom)
NGC 1052, 2273, 2639, 2655, and 4565 seem to have a softer component accompanied by emission lines from a thermal plasma. In the next subsection, we examine a multicomponent model which consists of a partially covered power law and a soft thermal plasma.

We also tried a thermal bremsstrahlung model instead of a power-law model. Again, we added a Gaussian line when a line-like feature was seen around 6 keV. We did not attempt the thermal bremsstrahlung model for those objects

| Name          | $N^1_{\text{H}}$ (10$^{22}$ cm$^{-2}$) | $N^2_{\text{H}}$ (10$^{22}$ cm$^{-2}$) | Covering Fraction | $\chi^2$/dof |
|---------------|--------------------------------------|----------------------------------------|------------------|---------------|
| NGC 1052...   | 0.0 (<0.034)                         | 9.5 ± 1.6                              | 0.77 ± 0.07      | 1.11 ± 0.24   | 128.6/107    |
| NGC 2273...   | 0.0 (<0.070)                         | 108 ± 10                               | 0.983 ± 0.003    | 1.54 ± 0.12   | 69.1/57      |
| NGC 2639...   | 0.08 (<0.32)                         | 33 ± 12                                | 0.89 ± 0.06      | 2.8 ± 1.6     | 45.8/49      |
| NGC 2655...   | 0.0 (<0.046)                         | 44 ± 12                                | 0.87 ± 0.00    | 2.6 ± 0.4     | 74.5/58      |
| NGC 4565...   | 0.3 ± 0.07                            | 2.9 ± 0.8                              | 0.65 ± 0.10      | 2.60 ± 0.32   | 140.6/110    |
| NGC 4941...   | 0.16 ± 0.14                           | 99 ± 12                               | 0.966 ± 0.006    | 1.48 ± 0.14   | 45.5/51      |
Table 5: Results of Thermal Bremsstrahlung Fits

| Name            | $N_H$ (10^{22} cm^{-2}) | $kT$ (keV) | $\chi^2$/dof |
|-----------------|--------------------------|------------|--------------|
| NGC 315         | 0.0                      | 6.2        | 179.9/71     |
| NGC 1097        | 0.0                      | 5.3        | 418.5/147    |
| NGC 1365        | 0.0                      | 3.7        | 330.2/180    |
| NGC 2655        | 0.0                      | 200        | 193.5/60     |
| NGC 3031        | 0.0(<0.0007)             | 5.16^{+0.15}_{-0.14} | 757.5/515    |
| NGC 3079        | 0.0                      | 2.1        | 182.7/90     |
| NGC 3147        | (0(<0.019)               | 6.5^{+0.5}_{-0.2}    | 256.0/243    |
| NGC 3507        | (0(<0.054)               | 6.3^{+0.2}_{-0.2}    | 28.7/25      |
| NGC 3607        | 0.0                      | 2.0        | 240.4/64     |
| NGC 3998        | 0.03(<0.010)             | 5.5 ± 0.3   | 373.8/279    |
| NGC 4111        | 0.0                      | 0.65       | 74.3/24      |
| NGC 4203        | 0.0(<0.005)              | 6.1^{+0.9}_{-0.7}    | 76.5/71      |
| NGC 4261        | 0.0                      | 2.0        | 261.9/183    |
| NGC 4374        | 0.0                      | 0.75       | 220.1/81     |
| NGC 4450        | 0.0(<0.009)              | 3.7^{+0.8}_{-0.6}    | 93.0/70      |
| NGC 4457        | 0.0                      | 3.1        | 70.7/27      |
| NGC 4501        | 0.0                      | 4.2        | 132.6/76     |
| NGC 4552        | 0.0                      | 2.1        | 204.8/82     |
| NGC 4565        | 0.14 ± 0.03              | 6.4^{+1.1}_{-0.8}    | 148.2/112    |
| NGC 4636        | 0.33                     | 0.25       | 13008/541    |
| NGC 4639        | 0.005(<0.037)            | 9.3^{+1.8}_{-2.1}    | 149.0/123    |
| NGC 4659        | 0.0                      | 3.5        | 119.8/36     |
| NGC 4759 (1995) | 0.00(<0.004)             | 5.9^{+0.2}_{-0.2}    | 260.3/203    |
| NGC 4759 (1998) | 0.00(<0.005)             | 5.9 ± 0.4   | 232.5/226    |
| NGC 4954        | 0.0(<0.023)              | 10.2^{+2.0}_{-1.8}   | 133.7/88     |
| NGC 4636        | 0.26                     | 0.32       | 13038/541    |
| NGC 4639        | 0.005(<0.039)            | 9.3^{+2.4}_{-2.1}    | 149.4/123    |
| NGC 4736        | 0.0                      | 3.1        | 450.4/151    |
| NGC 5005        | 0.0                      | 2.8        | 188.2/60     |
| NGC 5033        | 0.018 ± 0.013            | 7.9^{+0.8}_{-0.7}    | 197.8/186    |
| NGC 5194        | 0.0                      | 0.8        | 748.0/156    |
| NGC 7217        | 0.0                      | 5.2        | 92.6/58      |

with a heavily absorbed continuum shape, since the temperature cannot be well determined and a heavily absorbed continuum is likely to indicate the presence of an obscured AGN. The result of these fits are given in Table 5. Again errors are not shown for the fits with poor reduced $\chi^2$. This thermal model resulted in significantly worse fits for those objects which were well fitted with a power-law (plus Gaussian) model, except for the relatively faint objects NGC 3507 and NGC 4639, for which $\chi^2$-values similar to those of the power-law fits were obtained. Note that these two galaxies are fainter than the rest of objects which are well fitted with a simple power-law model.

4.2. Two-Component Models

Only a few objects were represented successfully by a simple power-law model; the majority indicated the presence of emission from a soft thermal plasma in addition to the hard component. Therefore, we investigated multiple-component models. We first adopted a model consisting of an absorbed power law plus a Raymond-Smith (RS; Raymond & Smith 1977) thermal plasma modified by Galactic absorption. The abundance was allowed to vary only if a meaningful constraint could be obtained. In many cases the abundance was not well constrained and was fixed at 0.1 solar or 0.5 solar, values typically observed for thermal plasmas in normal and starburst galaxies. A Gaussian line was also added if a linelike feature was seen around 6 keV. When the continuum shape suggests the presence of both a heavily absorbed and a lightly absorbed component, we used a partially covered power-law model instead of a simple power law; this applied to NGC 1052, 2655, and 4565. Both models were tried for NGC 2639. The results of the fits are summarized in Table 6. The fits were successful for all the objects except NGC 4258 (1993 observation) and NGC 4636, which show very complicated spectra.

Thus, a model consisting of an RS plasma plus a hard power-law component can be applied to nearly all objects, with a few objects not requiring the soft component. This "canonical" model successfully represents the spectra of the LINERs and LSBeyerts discussed here. Ptak et al. (1999) found that this model was also applicable to starburst galaxies.

In objects whose continuum was not heavily absorbed, we also evaluated the possibility that in the two-component model the power law could be substituted by a thermal bremsstrahlung model. In all the cases, we obtained $\chi^2$-values (Table 7) similar to those for the RS plasma plus power-law model.

Some objects show apparently weak Fe L emission compared to other emission lines such as the K lines from O, Ne, Mg, and Si. For these objects, we fitted the abundances of Fe and the $\alpha$-processed elements separately. We fixed the abundances of the $\alpha$-processed elements at 0.5 solar because the photon statistics are too limited to allow these abundances to be constrained individually. The abundance of Fe was allowed to vary. We assumed a power-law shape for the hard component in these fits. Only objects with a relatively good signal-to-noise ratio for the soft component were fitted with this model. The results are tabulated in Table 8. The $\chi^2$-values show improvement for NGC 1097, 3079, 4636, and 5194, compared to the case of a RS plasma with solar abundance ratios.

4.3. Complex Models

The spectra of only two objects, NGC 4258 (1993 observation) and NGC 4636, cannot be fitted with the models described above. As discussed in § 9, we applied more complex models to these objects.

4.4. Fe K Lines

Tables 9 and 10 summarize the parameters of the Fe K emission line. Adding a Gaussian component to the best-fit continuum model improved the $\chi^2$-values ($\Delta \chi^2 > 3$) for the 16 objects shown in Table 9. The additional parameters in the fit are the center energy, line width, and line intensity. In cases where the photon statistics are limited, we assumed the line to be narrow. For NGC 2639, the line center energy was fixed at 6.4 keV in the source rest frame. Table 10 gives upper limits for the rest of the objects in which the Fe K emission line is not clearly seen.

5. SUMMARY OF THE SPECTRAL RESULTS

We summarize the best-fit models and parameters for all the spectral classes. Tables 11 and 12 present results for the soft and hard components, respectively. These tables show that the spectra of most of the objects analyzed here are well
| Name          | $N_{H}$ (10$^{22}$ cm$^{-2}$) | $kT$ (keV) | Abundances (solar units) | $N_{H}$ (10$^{22}$ cm$^{-2}$) | Γ | $\chi^2$/dof |
|--------------|-------------------------------|------------|--------------------------|-------------------------------|---|--------------|
| NGC 315      | 0.059(f)                       | 0.77±0.05  | 0.5(f) (0.12)            | 0.49±0.41                     | 1.73±0.28 | 89.5/69     |
| NGC 1052     | 0.030(f)                       | 1.0±2.2    | 0.04<10.12               | 20.0±7.0                     | 1.67±0.57 | 104/104     |
| NGC 1097     | 0.019(f)                       | 0.75±0.06  | 0.077(0.040)             | 0.12±0.21                     | 1.66±0.13 | 175/3/14    |
| NGC 1365     | 0.015(f)                       | 0.85±0.05  | 0.14<0.071               | 0.54<2.0                      | 1.12±0.45 | 186/7/176   |
| NGC 1386     | 0.014(f)                       | 1.09±0.30  | 0.136±0.396 0.128        | 45±13.2                      | 1.7(f)    | 62/1/38     |
| NGC 2639     | 0.027(f)                       | 0.81±0.35  | 0.1(f)                   | 0.0<3.1                       | 1.64±1.18 | 45/3/49     |
| NGC 2655     | 0.021(f)                       | 0.65(f)    | 0.1(f)                   | 40±12.12                      | 1.2±0.7   | 58/0/58     |
| NGC 2655     | 0.042(f)                       | 0.86(f)    | 0.1(f)                   | 0.0<0.053                     | 1.76±0.027 | 437/4/114   |
| NGC 3031     | 0.024(f)                       | 0.86(f)    | 0.5(f)                   | 0.0<0.036                     | 1.80±0.027 | 437/5/114   |
| NGC 3079     | 0.008(f)                       | 0.33±0.11  | 0.1(f)                   | 0.0<0.09                      | 1.87±0.18  | 105/1/8     |
| NGC 3507     | 0.016(f)                       | 0.65(f)    | 0.1(f)                   | 1.1±1.0 9                     | 2.3±1.0    | 23/9/24     |
| NGC 3607     | 0.015(f)                       | 0.73±0.06  | 0.1(f)                   | 1.6±1.12 9                    | 2.1±1.1    | 25/3/24     |
| NGC 4111     | 0.014(f)                       | 0.65±0.14  | 0.5(f)                   | 0.0<3.0                       | 0.92±1.03  | 42/8/61     |
| NGC 4111     | 0.014(f)                       | 0.66±0.10  | 0.5(f)                   | 0.0<0.47                      | 1.36±0.46  | 16/1/22     |
| NGC 4258 (1993) | 0.012(f)                       | 0.27±0.04  | 0.77±0.05               | 0.26±0.03 12.7±1.1            | 1.65±1.06  | 197/3/164   |
| NGC 4258 (1996) | 0.012(f)                       | 0.69±0.02  | 0.5(f)                   | 0.0<0.62                      | 1.81±0.16  | 64/2/68     |
| NGC 4261     | 0.016(f)                       | 0.82±0.03  | 0.17±0.03               | 0.17±0.39                     | 1.30±0.07  | 201/7/178   |
| NGC 4374     | 0.026(f)                       | 0.78±0.05  | 0.12±0.31               | 0.0<2.2                      | 0.29±0.11  | 69/1/78     |
| NGC 4438     | 0.021(f)                       | 0.79±0.15  | 0.1(f)                   | 1.4±0.53                      | 2.0±1.5    | 35/0/40     |
| NGC 4450     | 0.024(f)                       | 0.64±0.21  | 0.1(f)                   | 0.0<0.082                     | 1.75±0.18  | 63/9/68     |
| NGC 4457     | 0.024(f)                       | 0.63±0.22  | 0.5(f)                   | 0.0<0.062                     | 1.81±0.16  | 64/2/68     |
| NGC 4501     | 0.011(f)                       | 0.68±0.16  | 0.1(f)                   | 1.1<3.8                       | 1.7±1.08   | 18/0/25     |
| NGC 4501     | 0.018(f)                       | 0.66±0.10  | 0.5(f)                   | 0.15<1.2                      | 1.5±0.7    | 18/2/25     |
| NGC 4505     | 0.011(f)                       | 0.79±0.16  | 0.1(f)                   | 0.66<2.3                      | 1.49±0.74  | 93/6/74     |
| NGC 4565     | 0.038(f)                       | 1.23±0.30  | 0.1(f)                   | 0.0<0.90                      | 1.48±0.30  | 93/8/74     |
| NGC 4569     | 0.038(f)                       | 1.36±1.36  | 0.5(f)                   | 0.24±0.09                     | 2.48±0.29  | 136/0/108   |
| NGC 4579 (1995) | 0.029(f)                       | 0.66±0.09  | 0.1(f)                   | 1.5±1.08                      | 2.18±0.71  | 54/9/32     |
| NGC 4594     | 0.031(f)                       | 0.67±0.09  | 0.5(f)                   | 0.11±0.88                     | 2.17±0.62  | 55/1/32     |
| NGC 4594     | 0.031(f)                       | 0.90±0.05  | 0.5(f)                   | 0.04±0.03                     | 1.72±0.05  | 192/4/201   |
| NGC 5194     | 0.038(f)                       | 0.90±0.04  | 0.5(f)                   | 0.04<0.13                     | 1.81±0.06  | 200/5/225   |
| NGC 5194     | 0.038(f)                       | 0.64±0.15  | 0.05±0.07               | 0.73±0.33                     | 1.89±0.17  | 104/8/95    |
| NGC 5194     | 0.018(f)                       | 0.77±0.15  | 0.31                   | 0.15                          | 1.32       | 1398/5/38   |
| NGC 5172     | 0.011(f)                       | 0.61±0.10  | 0.08±0.06               | 0.0<1.3                       | 1.56±0.12  | 165/3/146   |
| NGC 5005     | 0.011(f)                       | 0.76±0.06  | 0.06±0.02               | 0.10<0.86                     | 0.97±0.37  | 71/3/57     |
| NGC 5194     | 0.013(f)                       | 0.64±0.04  | 0.040±0.012             | 2.1±1.2                       | 1.60±0.40  | 186/4/151   |

**Note.**—Entries followed by "(f)" indicate that the parameter is fixed.

- The power-law component is assumed to be covered partially.
- Two-temperature Raymond-Smith model is assumed for the soft component.
- Fitting results of the nucleus + the off-center source.
TABLE 7
RESULTS OF THERMAL BREMSSTRAHLUNG + RAYMOND-SMITH MODEL FITS

| Name            | $N_H$ (galactic) (10$^{22}$ cm$^{-2}$) | $kT$ (keV) | Abundances (solar units) | $N_H$ (10$^{22}$ cm$^{-2}$) | $kT$ (keV) | $\chi^2$/dof |
|-----------------|---------------------------------------|------------|--------------------------|-----------------------------|------------|---------------|
| NGC 315         | 0.059 (f)                             | 0.77±0.05  | 0.5 (f) >0.11             | 0.29±0.30                   | 10.4±2.6   | 90.9±66       |
| NGC 1097        | 0.019 (f)                             | 0.78±0.05  | 0.065±0.045              | 0.15±0.16                   | 12.2±1.3   | 181.3±143     |
| NGC 1365        | 0.015 (f)                             | 0.85±0.03  | 0.14±0.02                | 0.72±0.33                   | >14        | 186.9±176     |
| NGC 3031        | 0.042 (f)                             | 0.86±0.05  | 0.1 (f)                   | 0.00±0.009                  | 7.53±0.46  | 564.7±514     |
| NGC 3079        | 0.008 (f)                             | 0.33±0.08  | 0.05 (f)                 | 0.00±0.006                  | 5.0±1.7    | 109.5±88      |
| NGC 3507        | 0.016 (f)                             | 0.65±0.14  | 0.1 (f)                   | 0.71±1.4                    | 4.1±1.2    | 25.0±24       |
| NGC 3607        | 0.015 (f)                             | 0.73±0.08  | 0.05 (f)                 | 0.00±0.006                  | 9.5±1.7    | 25.9±24       |
| NGC 4111        | 0.014 (f)                             | 0.65±0.09  | 0.05 (f)                 | 0.00±0.004                  | 9.5±1.7    | 25.9±24       |
| NGC 4261        | 0.016 (f)                             | 0.82±0.02  | 0.17±0.02                | 0.13±0.35                   | >44        | 203.1±178     |
| NGC 4374        | 0.026 (f)                             | 0.78±0.04  | 0.12±0.03                | 0.00±0.019                  | >7.3       | 69.3±78       |
| NGC 4438        | 0.020 (f)                             | 0.79±0.07  | 0.1 (f)                   | 0.98±4.2                    | 6.2±2.0    | 35.1±40       |
| NGC 4450        | 0.024 (f)                             | 0.67±0.20  | 0.1 (f)                   | 0.00±0.047                  | 7.2±1.2    | 68.6±68       |
| NGC 4457        | 0.024 (f)                             | 0.64±0.18  | 0.1 (f)                   | 0.00±0.026                  | 5.6±1.7    | 72.2±68       |
| NGC 4501        | 0.011 (f)                             | 0.68±0.16  | 0.1 (f)                   | 0.84±3.1                    | 11.8±2.8   | 17.9±25       |
| NGC 4569        | 0.018 (f)                             | 0.66±0.14  | 0.1 (f)                   | 0.07±0.83                   | 19±4.3     | 18.1±25       |
| NGC 4579 (1995) | 0.011 (f)                             | 0.75±0.12  | 0.1 (f)                   | 0.37±1.7                    | 34±5.2     | 94.0±74       |
| NGC 4579 (1998) | 0.011 (f)                             | 0.78±0.13  | 0.1 (f)                   | 0.00±0.53                   | 19±6.7     | 94.2±74       |
| NGC 5194        | 0.029 (f)                             | 0.66±0.12  | 0.1 (f)                   | 1.1±0.8                     | 5.7±1.2    | 56.2±32       |
| NGC 7217        | 0.031 (f)                             | 0.89±0.12  | 0.5 (f)                   | 0.0±0.0010                  | 7.9±11.2   | 200.3±201     |
| NGC 5194        | 0.031 (f)                             | 0.89 (f)   | 0.5 (f)                   | 0.0±0.002                   | 6.8±1.0    | 213.6±225     |
| NGC 4636        | 0.018 (f)                             | 0.77       | 0.31                     | 0.0                      | 10 (f)     | 1418.1±539    |
| NGC 4736        | 0.011 (f)                             | 0.61±0.09  | 0.048±0.027              | 0.01±1.0                    | 16±1.2     | 161.4±146     |
| NGC 5005        | 0.011 (f)                             | 0.74±0.08  | 0.072±0.036              | 0.12±0.10                   | >31        | 72.6±57       |
| NGC 5194        | 0.031 (f)                             | 0.64±0.04  | 0.041±0.001              | 28±8.1                     | 187.4±151  |
| NGC 7217        | 0.011 (f)                             | 0.74±0.14  | 0.1 (f)                   | 1.0±1.2                     | 4.0±1.5    | 70.1±57       |
| NGC 7217        | 0.011 (f)                             | 0.70±0.12  | 0.5 (f)                   | 0.46±0.35                   | 4.5±1.0    | 69.6±57       |

Note.—Entries followed by “(f)” indicate that the parameter is fixed.

represented by the canonical model and that a small fraction of LINER 1s, Seyfert 1s, and Seyfert 2s do not require the soft RS component. Thus, this canonical spectrum appears to be widely applicable to LINERs and LLSeyferts.

Figure 13 shows histograms of the spectral parameters (photon index, absorption column, and temperature for the RS component) for each spectral class. Since the errors of the spectral parameters for many objects are large, we present weighted histograms, where the same area of a rectangle is assigned to each data set and the width of the rectangle is the error range in the spectral fits. In generating the histograms of photon indices and absorption column densities, we excluded objects with very low signal-to-noise ratios or cases where the photon index was not well constrained (NGC 404, 1386, 4192, and 7743). The histogram of the temperature of the RS component is created using objects which clearly show the presence of the soft thermal component. The objects for which the temperature was not well constrained were excluded.

The distribution of photon indices for the four spectral classes is similar to each other, although LINER 2s and Seyfert 2s have somewhat broader distribution than LINER 1s and Seyfert 1s. This difference is possibly due to the larger errors in the type 2 objects.

The distributions of the absorption column densities appear different from each other. Very large column densities—in excess of 10$^{22}$ cm$^{-2}$—are observed in several Seyfert 2s, one LINER 1 (NGC 1052), and one Seyfert 1 (NGC 4258, 1993 observation). No LINER 2s in the present sample are obscured by $N_H > 10^{23}$ cm$^{-2}$. We note that in objects with very high columns ($N_H > 10^{24}$ cm$^{-2}$), only scattered emission would be seen, and the apparent (observed) column densities would be much lower than the true column densities. Such is the situation in NGC 1365 and NGC 5194.
### TABLE 8
Results of Power-Law + Variable Abundance Raymond-Smith Model Fits

| Name               | $N_H$ (10^22 cm⁻²) | $kT$ (keV) | Abundance (O, Ne, Mg, Si) | Abundance (Fe) | $N_H$ (10^22 cm⁻²) | $\Gamma$ | $\chi^2$/dof |
|--------------------|---------------------|------------|---------------------------|---------------|---------------------|---------|-------------|
| NGC 315           | 0.059(f)            | 3.57       | 0.5(f)                    | 0.32 (>0.17)  | 0.61 ± 0.09         | 1.70 ± 0.29 | 88.9/68    |
| NGC 1052          | 0.030(f)            | 3.29       | 0.1(f)                    | 0.051 (<0.12) | 1.9 ± 1.6           | 5.5 ± 0.49 | 104.8/104  |
| NGC 1097          | 0.019(f)            | 0.65 ± 0.08| 0.5(f)                    | 0.11 ± 0.07   | 0.13 ± 0.10         | 1.67 ± 0.10 | 167.6/143  |
| NGC 1365          | 0.015(f)            | 0.84 ± 0.04| 0.5(f)                    | 0.31 ± 0.14   | 0.06 (<1.0)         | 1.08 ± 0.28 | 186.7/176  |
| NGC 3079          | 0.008(f)            | 0.62 ± 0.09| 0.5(f)                    | 0.048 ± 0.026 | 0.019 ± 0.12        | 1.7 ± 1.3  | 196.2/74    |
| NGC 4261          | 0.016(f)            | 0.81 ± 0.03| 0.5(f)                    | 0.35 ± 0.04   | 0.044 (<0.18)       | 1.37 ± 0.07 | 205.7/178  |
| NGC 4374          | 0.026(f)            | 0.77 ± 0.06| 0.5(f)                    | 0.20 ± 0.06   | 0.00 (<2.6)         | 1.34 ± 0.61 | 67.4/78    |
| NGC 4450          | 0.024(f)            | 0.65 ± 0.30| 0.5(f)                    | 0.09 (<0.3)   | 0.00 (<0.32)        | 1.64 ± 0.39 | 62.8/68    |
| NGC 4301          | 0.011(f)            | 0.77 ± 0.11| 0.5(f)                    | 0.16 (<0.035) | 0.59 (<3.5)         | 1.43 ± 0.55 | 93.3/73    |
| NGC 4565          | 0.038(f)            | 0.80 ± 0.10| 0.5(f)                    | 0.034 (<0.092) | 3.4 ± 1.3 | 2.71 ± 0.43 | 133.2/107  |
| NGC 4579 (1995)   | 0.031(f)            | 0.89 ± 0.12| 0.5(f)                    | 0.4 ± 0.12    | 0.04 ± 0.03         | 1.72 ± 0.05 | 192.6/201  |
| NGC 4594          | 0.035(f)            | 0.62 ± 0.11| 0.5(f)                    | 0.11 ± 0.08   | 0.73 ± 0.29         | 1.89 ± 0.16 | 100.2/85   |
| NGC 4636          | 0.018(f)            | 0.76       | 1(f)                      | 0.60          | 0.046               | 1.60      | 1315.9/538 |
| NGC 4736          | 0.011(f)            | 0.61 ± 0.05| 0.5(f)                    | 0.26 ± 0.04   | 0.00 (<0.31)        | 1.62 ± 0.10 | 166.6/146  |
| NGC 5005          | 0.011(f)            | 0.72 ± 0.09| 0.5(f)                    | 0.14 ± 0.22   | 0.00 (<0.27)        | 1.06 ± 0.24 | 73.8/57    |
| NGC 5194          | 0.013(f)            | 0.60 ± 0.05| 0.15 ± 0.06               | 0.046 ± 0.016 | 2.2 ± 1.3 | 1.63 ± 0.42 | 177.4/150  |

Note.—Entries followed by "(f)" indicate that the parameter is fixed.

* The power-law component is assumed to be partially covered.

### TABLE 9
Summary of Fe K Emission-Line Parameters

| Name               | Center Energya (keV) | Line Width (keV) | Equivalent Width (eV) | $\Delta \chi^2$ | Notesb |
|--------------------|----------------------|-----------------|-----------------------|----------------|--------|
| NGC 1052          | 6.35 ± 0.08          | 0(f)            | 180 ± 30               | 12.1           | 5      |
| NGC 1365          | 6.59 ± 0.04          | 0.002 (<0.12)   | 1900 ± 1000           | 36.4           | 2      |
| NGC 1386          | 6.59 ± 0.04          | 0(f)            | 910 ± 200              | 5.7            | 2      |
| NGC 2273          | 6.33 ± 0.03          | 0(f)            | 1040 ± 400             | 20.1           | 4      |
| NGC 2639          | 6.4(f)               | 0(f)            | 1490 ± 1110            | 3.3            | 4      |
| NGC 3031          | 6.59 ± 0.22          | 0(f)            | 106 ± 66               | 11.0           | 2      |
| NGC 3147          | 6.49 ± 0.09          | 0(f)            | 490 ± 220             | 12.9           | 1      |
| NGC 3998          | 6.41 ± 0.12          | 0(f)            | 85 ± 41                | 3.7            | 1      |
| NGC 4258 (1993)   | 6.66 ± 0.20          | 0(f)            | 108 ± 73               | 7.4            | 2d     |
| NGC 4258 (1996)   | 6.31 ± 0.09          | 0(f)            | 54 ± 25                | 10.6           | 2      |
| NGC 4261          | 6.85 ± 0.08          | 0(f)            | 550 ± 300              | 8.5            | 2      |
| NGC 4579 (1995)   | 6.73 ± 0.12          | 0.17 ± 0.11     | 490 ± 190              | 20.0           | 2      |
| NGC 4579 (1998)   | 6.39 ± 0.09          | 0.01 (<0.16)    | 250 ± 105             | 17.8           | 2      |
| NGC 4639          | 6.67 ± 0.23          | 0(f)            | 520 ± 320              | 7.7            | 1      |
| NGC 4736          | 6.51 ± 0.42          | 0(f)            | 334 ± 233             | 5.1            | 2      |
| NGC 4941          | 6.35 ± 0.04          | 0(f)            | 568 ± 222             | 14.9           | 4      |
| NGC 5033          | 6.43 ± 0.13          | 0.08 (<0.23)    | 306 ± 116             | 22.5           | 1      |
| NGC 5194          | 6.34 ± 0.04          | 0(f)            | 910 ± 350             | 17.8           | 2      |

Note.—Entries followed by "(f)" indicate that the parameter is fixed.

a Line center energy is corrected for redshift.

b Improvement of $\chi^2$ by adding a Gaussian component.

c Models applied: (1) PL model, (2) PL + RS model, (3) PL + variable RS model, (4) partial covering PL model, (5) partial covering PL + RS model.

d See text for details.
The temperature of the RS component is confined to the range 0.5–0.8 keV. This distribution is similar to that presented by Ptak et al. (1999) for a smaller, more heterogeneous sample of LINERs, Seyferts, and starburst galaxies. Apart from the absorption column densities, which exhibit greater diversity, the spectral parameters of the LINERs and Seyferts in our sample are rather homogeneous. The canonical model we have adopted, however, can also be applied to starburst galaxies and normal galaxies (e.g., Ptak et al. 1999). The apparent similarity of the spectra, therefore, does not in itself imply that the different classes of objects share the same X-ray production mechanism, nor

| Name         | $\text{Fe K 6.4 keV EW (eV)}$ | $\text{Fe K 6.7 keV EW (eV)}$ | $\Delta \chi^2 (6.4 \text{ keV})^a$ | $\Delta \chi^2 (6.7 \text{ keV})^a$ | Notes$^b$ |
|--------------|-------------------------------|-------------------------------|-----------------------------------|-----------------------------------|-----------|
| NGC 315      | <380                          | 325(<1030)                    | 0.0                               | 0.7                               | 2         |
| NGC 404      | ...                           | ...                           | ...                               | ...                               | ...       |
| NGC 1097     | <160                          | <210                          | 0.0                               | 0.1                               | 3         |
| NGC 2655     | <270                          | 125(<420)                     | 0.0                               | 0.6                               | 5         |
| NGC 3079     | 930(<1960)                    | 1320(<2670)                   | 2.4                               | 2.5                               | 2         |
| NGC 3507     | 193(<2830)                    | 70(<3580)                     | 0.0                               | 0.0                               | 2         |
| NGC 3607     | 590(<1260)                    | 334(<1220)                    | 2.1                               | 0.4                               | 2         |
| NGC 4111     | <1860                         | <2800                         | 0.0                               | 0.0                               | 2         |
| NGC 4192     | ...                           | ...                           | ...                               | ...                               | ...       |
| NGC 4203     | <310                          | <270                          | 0.0                               | 0.0                               | 1         |
| NGC 4374     | <720                          | 610(<1780)                    | 0.0                               | 0.9                               | 2         |
| NGC 4438     | <1300                         | <3900                         | 0.0                               | 1.0                               | 2         |
| NGC 4450     | 550(<1200)                    | 610(<1400)                    | 2.5                               | 1.7                               | 2         |
| NGC 4457     | ...                           | ...                           | ...                               | ...                               | ...       |
| NGC 4501     | 1200$^{±1100}_{±1000}$        | 910$^{±900}_{±870}$           | 2.9                               | 2.6                               | 2         |
| NGC 4565     | 240(<620)                     | <350                          | 1.7                               | 0.1                               | 5         |
| NGC 4569     | <1800                         | <4800                         | 0.0                               | 0.0                               | 2         |
| NGC 4594     | <150                          | <260                          | 0.0                               | 0.0                               | 3         |
| NGC 4636     | 250(<540)                     | <120                          | 2.7                               | 0.0                               | 3         |
| NGC 5005     | 200(<810)                     | <510                          | 0.9                               | 0.0                               | 2         |
| NGC 7217     | <460                          | <1100                         | 0.0                               | 0.0                               | 2         |
| NGC 7743     | ...                           | ...                           | ...                               | ...                               | ...       |

$^a$ Improvement of $\chi^2$ by adding a Gaussian component.

$^b$ Models applied: (1) PL model, (2) PL + RS model, (3) PL + variable RS model, (4) partial covering PL model, (5) partial covering PL + RS model.

$^c$ Low signal-to-noise ratio.

The temperature of the RS component is confined to the range 0.5–0.8 keV. This distribution is similar to that presented by Ptak et al. (1999) for a smaller, more heterogeneous sample of LINERs, Seyferts, and starburst galaxies. Apart from the absorption column densities, which exhibit greater diversity, the spectral parameters of the LINERs and Seyferts in our sample are rather homogeneous. The canonical model we have adopted, however, can also be applied to starburst galaxies and normal galaxies (e.g., Ptak et al. 1999). The apparent similarity of the spectra, therefore, does not in itself imply that the different classes of objects share the same X-ray production mechanism, nor

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**Fig. 13.** Weighted histograms of the best-fit parameters for the whole sample. (a) Photon index, (b) absorption column density, (c) temperature of RS plasma.
## TABLE 11

### Summary of the Spectral Parameters for the Soft Component

| Name            | Spectral Class | $kT$ (keV) | Abundances (solar units) | Fe Abundance (solar units) | Model$^{a}$   |
|-----------------|----------------|------------|--------------------------|----------------------------|---------------|
| NGC 315         | L1.9           | 0.79$^{+0.05}_{+0.07}$ | ...                      | ...                        | PL + RS       |
| NGC 1052        | L1.9           | 1.0$^{+0.2}_{-0.3}$     | 0.04$^{<0.10}$           | ...                        | PC + RS + GA   |
| NGC 3998        | L1.9           | ...                   | ...                      | ...                        | PL + GA       |
| NGC 4203        | L1.9           | ...                   | ...                      | ...                        | PL + RS       |
| NGC 4438        | L1.9           | 0.79$^{+0.07}_{-0.15}$ | 0.1(t)                   | ...                        | PL + RS       |
| NGC 4450        | L1.9           | 0.76$^{+0.08}_{-0.13}$ | 0.5(t)                   | ...                        | PL + RS       |
| NGC 4579 (1995) | S1.9/L1.9      | 0.90$^{+0.10}_{-0.05}$ | 0.5(t)                   | ...                        | PL + RS + GA   |
| NGC 4579 (1998) | S1.9/L1.9      | 0.90(t)               | 0.5(t)                   | ...                        | PL + RS + GA   |
| NGC 4636        | L1.9           | 0.76                   | 1(t)                     | 0.60                       | PL + RS       |
| NGC 5005        | L1.9           | 0.76$^{+0.07}_{-0.08}$ | 0.06$^{+0.09}_{-0.02}$   | ...                        | PL + RS       |
| NGC 404         | L2             | ...                   | ...                      | ...                        | ...           |
| NGC 3507        | L2             | 0.65(t)               | 0.1(t)                   | ...                        | PL + RS       |
| NGC 3607        | L2             | 0.73$^{+0.06}_{-0.07}$ | 0.1(t)                   | ...                        | PL + RS       |
| NGC 4111        | L2             | 0.66$^{+0.12}_{-0.14}$ | 0.1(t)                   | ...                        | PL + RS       |
| NGC 4912        | T2             | ...                   | ...                      | ...                        | ...           |
| NGC 4261        | L2             | 0.89$^{+0.02}_{-0.03}$ | 0.17$^{+0.03}_{-0.02}$   | ...                        | PL + RS + GA   |
| NGC 4374        | L2             | 0.76$^{+0.03}_{-0.05}$ | 0.12$^{+0.31}_{-0.06}$   | ...                        | PL + RS       |
| NGC 4457        | L2             | 0.66$^{+0.12}_{-0.16}$ | 0.1(t)                   | ...                        | PL + RS       |
| NGC 4569        | T2             | 0.66$^{+0.09}_{-0.09}$ | 0.1(t)                   | ...                        | PL + RS       |
| NGC 4594        | L2             | 0.67$^{+0.08}_{-0.11}$ | 0.5(t)                   | 0.11$^{+0.08}_{-0.03}$    | PL + vRS      |
| NGC 4736        | L2             | 0.66$^{+0.05}_{-0.10}$ | 0.06$^{+0.05}_{-0.06}$   | ...                        | PL + RS + GA   |
| NGC 7217        | L2             | 0.76$^{+0.10}_{-0.13}$ | 0.1(t)                   | ...                        | PL + RS       |
| NGC 1097        | S1.5/L2        | 0.65$^{+0.08}_{-0.07}$ | 0.5(t)                   | 0.11$^{+0.07}_{-0.04}$    | PL + vRS      |
| NGC 1365        | S1.8           | 0.85$^{+0.05}_{-0.07}$ | 0.14 (>0.071)            | ...                        | RS + PL + GA   |
| NGC 2639        | S1.9           | 0.81$^{+0.27}_{-0.35}$ | 0.1(t)                   | ...                        | RS + PL + GA   |
| NGC 3031        | S1.5           | 0.86(t)               | 0.1(t)                   | ...                        | RS + PL + GA   |
| NGC 4258 (1993) | S1.9           | 0.79$^{+0.02}_{-0.04}$ | 0.26$^{+0.03}_{-0.05}$   | ...                        | PL + RS + RS + BRE + GA |
| NGC 4258 (1996) | S1.9           | 0.69$^{+0.02}_{-0.06}$ | 0.042$^{+0.007}_{-0.006}$ | ...                        | PL + RS + GA   |
| NGC 4639        | S1.5           | 1.25$^{+0.30}_{-0.37}$ | 0.1(t)                   | ...                        | PC + RS       |
| NGC 5033        | S1.5           | ...                   | ...                      | ...                        | PL + GA       |
| NGC 1386        | S2             | 1.09$^{+0.30}_{-0.22}$ | 0.136$^{+0.036}_{-0.128}$ | ...                        | PL + RS + GA   |
| NGC 2273        | S2             | ...                   | ...                      | ...                        | PC + GA       |
| NGC 2655        | S2             | 0.65(t)               | 0.1(t)                   | ...                        | PC + RS       |
| NGC 3079        | S2             | 0.69$^{+0.09}_{-0.12}$ | 0.5(t)                   | 0.048$^{+0.026}_{-0.019}$ | PL + vRS      |
| NGC 3147        | S2             | ...                   | ...                      | ...                        | PL + GA       |
| NGC 4501        | S2             | 0.79$^{+0.10}_{-0.16}$ | 0.1(t)                   | ...                        | PL + RS       |
does it necessarily mean that they are physically related. Recall that, with very few exceptions, the hard component of the spectral fit could just as well be represented by a power law or a thermal bremsstrahlung model. Therefore, we need to analyze carefully all the available information—morphology, variability, and multiwavelength information—before we can draw firm conclusions regarding the nature of these sources. This is the subject of Paper II.

6. FLUXES AND LUMINOSITIES

The total X-ray fluxes and luminosities, and the respective quantities for the hard and soft components separately, are listed in Tables 13 and 14. The best-fit model was assumed to calculate them. As for the hard component, we assumed a power law rather than a thermal bremsstrahlung model for all the cases, since the power-law model gave better or similar results compared to a thermal bremsstrahlung model. The total (soft plus hard components) fluxes and luminosities in the 0.5–2 keV and 2–10 keV bands are shown in columns (2) and (3). The observed and absorption-corrected fluxes and luminosities for the power-law component are given in columns (4) and (5) for the 2–10 keV band, and in columns (6) and (7) for the 0.5–4 keV band. Since the estimated fluxes and luminosities of the soft component depend on the assumed abundance, we show two cases (abundance = 0.1 solar and 0.5 solar) if the abundance was assumed in the fits. The fluxes and luminosities of the hard component depend only weakly on the assumed abundance of the soft component.

7. VARIABILITY

X-ray variability is one of the most important characteristics of AGNs. We searched for X-ray variability by inspecting light curves constructed by binning the data to a bin size of 5760 s, one orbital period of ASCA. When observations were performed more than twice, we searched for long-term variability between multiple observations, usually separated by intervals of a week to a few years. The variability was seen in other objects. See Table 2 for count rates in individual observations.

7.2. Long-Term Variability

We searched for long-term variability by comparing X-ray fluxes in multiple ASCA observations. Eleven objects (NGC 404, 1365, 3031, 4111, 4192, 4258, 4438, 4569, 4579, 4639, and 4941) were observed with ASCA more than twice. NGC 3031 (see Ishisaki et al. 1996; Iyomoto & Makishima 2001), NGC 4258 (Reynolds, Nowak, & Maloney 2000), and NGC 4579 (Terashima et al. 2000c) show significant variability on timescales of a week to 3 years. No significant variability was seen in other objects. See Table 2 for count rates in individual observations.

We compared the fluxes obtained here with ASCA and those measured with other satellites. Although there are flux measurements in the soft-energy band, it is difficult to compare them with the fluxes in the harder band because of the presence of thermal emission in the soft X-ray band and because of possible calibration uncertainties. Therefore, we used the energy band of 2–10 keV for the comparison. To minimize contamination from extranuclear sources, we used mainly data from imaging detectors, the exceptions being NGC 3998, 5033, and 5194. The 2–10 keV fluxes of NGC 3998 and NGC 5194 were obtained with Ginga. NGC 5033 was observed with EXOSAT. NGC 1052, 1365, 1386, 2273, 3079, 3998, 4258, 4565, 4941, 5005, and 5194 were observed with BeppoSAX. Table 15 provides a summary of these fluxes.

Seven out of these 12 galaxies (NGC 1365, 3031, 3998, 4258, 4941, 5005, 5194) clearly show long-term variability on a timescale of a month to several years. The variability in other objects is not clear, given the uncertainties in calibration and spectral modeling.

8. IMAGE ANALYSIS

Next, we examine whether the X-ray images are consistent with the point-spread function (PSF) of ASCA. Only SIS images were used since the combination of SIS, and the X-ray telescope (XRT; Serlemitsos et al. 1995) has better spatial resolution than GIS + XRT. In order to compare the observed SIS images with the PSF, we constructed radial
| Name               | Spectral Class | $N_H$ (10$^{22}$ cm$^{-2}$) | Photon Index | Model$^a$          |
|--------------------|----------------|----------------------------|--------------|-------------------|
| NGC 315           | L1.9           | 0.49$^{+0.41}_{-0.33}$     | 1.73$^{+0.28}_{-0.25}$ | PL + RS           |
| NGC 1052          | L1.9           | 2.5$^{+1.2}_{-1.4}$        | 1.5$^{+0.7}_{-0.40}$  | PC + RS + GA      |
| NGC 3998          | L1.9           | 0.082$^{+0.012}_{-0.012}$  | 1.90$^{+0.03}_{-0.04}$ | PL + GA           |
| NGC 4203          | L1.9           | 0.022$^{+0.053}_{-0.053}$  | 1.78$^{+0.07}_{-0.08}$ | PL                |
| NGC 4450          | L1.9           | 0$^{<0.062}_{<0.062}$      | 1.81$^{+0.16}_{-0.13}$ | PL + RS (0.5)     |
| NGC 4579 (1995)   | S1.9/L1.9      | 0.04$^{+0.003}_{-0.003}$   | 1.72$^{+0.05}_{-0.05}$ | PL + RS + GA      |
| NGC 4579 (1998)   | S1.9/L1.9      | 0.04$^{+0.013}_{-0.013}$   | 1.81$^{+0.06}_{-0.06}$ | PL + RS + GA      |
| NGC 4636          | L1.9           | 0.018$^{+0.018}_{-0.018}$  | 1.67$^{+0.04}_{-0.04}$ | PL$^b$            |
| NGC 5005          | L1.9           | 0.10$^{<0.86}_{<0.86}$     | 0.97$^{+0.37}_{-0.37}$ | PL + RS           |
| NGC 404           | L2             | ...                        | ...          | ...$^c$           |
| NGC 3507          | L2             | 1.1$^{+1.0}_{-0.9}$        | 2.3$^{+1.0}_{-0.7}$   | PL + RS (0.1)     |
| NGC 3607          | L2             | 1.6$^{+1.6}_{-1.2}$        | 1.63$^{+0.72}_{-0.42}$ | PL + RS (0.1)     |
| NGC 4111          | L2             | 0$^{<3.0}_{<3.0}$          | 0.92$^{+1.03}_{-0.62}$ | PL + RS (0.1)     |
| NGC 4192          | T2             | 0.027$^{+0.027}_{-0.027}$  | 1.79$^{+0.09}_{-0.16}$ | PL$^e$            |
| NGC 4261          | L2             | 0.17$^{<0.39}_{<0.39}$     | 1.30$^{+0.06}_{-0.06}$ | PL + RS + GA      |
| NGC 4374          | L2             | 0$^{<2.2}_{<2.2}$          | 1.29$^{+0.81}_{-0.77}$ | PL + RS           |
| NGC 4569          | T2             | 1.5$^{+1.5}_{-0.8}$        | 2.16$^{+0.71}_{-0.66}$ | PL + RS (0.1)     |
| NGC 4594          | L2             | 0.73$^{+0.29}_{-0.29}$     | 1.89$^{+0.16}_{-0.16}$ | PL + vRS          |
| NGC 4736          | L2             | 0$^{<1.3}_{<1.3}$          | 1.56$^{+0.12}_{-0.15}$ | PL + RS + GA      |
| NGC 7217          | L2             | 1.6$^{+1.6}_{-1.8}$        | 2.40$^{+0.79}_{-0.71}$ | PL + RS (0.1)     |
| NGC 1097          | S1.5/L2        | 0.13$^{+0.10}_{-0.07}$     | 1.67$^{+0.09}_{-0.10}$ | PL + vRS          |
| NGC 1365          | S1.8           | 0.54$^{+0.23}_{<2.0}$      | 1.15$^{+0.43}_{-0.37}$ | PL + RS + GA      |
| NGC 2639          | S1.9           | 0$^{<3.1}_{3.1}$           | 1.64$^{+0.91}_{-1.18}$ | PL + RS + GA (0.1)|
| NGC 3031          | S1.5           | 0$^{<0.036}_{<0.036}$      | 1.79$^{+0.027}_{-0.027}$ | PL + RS + GA (0.1)|
| NGC 4258 (1993)   | S1.9           | 12.7$^{+9.9}_{-11.1}$      | 1.64$^{+0.10}_{-0.16}$ | PL + RS + RS + BRE + GA |
| NGC 4258 (1996)   | S1.9           | 6.6$^{+0.3}_{+0.2}$        | 1.55$^{+0.06}_{-0.07}$ | PL + RS + GA      |
| NGC 4565          | S1.5           | 0.37$^{+0.15}_{-0.15}$     | 2.51$^{+0.35}_{-0.33}$ | PC + RS (0.1)     |
| NGC 4639          | S1.0           | 0.069$^{+0.041}_{-0.038}$  | 1.66$^{+0.10}_{-0.10}$ | PL + GA           |
| NGC 5033          | S1.5           | 0.087$^{+0.017}_{-0.017}$  | 1.72$^{+0.04}_{-0.04}$ | PL + GA           |
| NGC 1386          | S2             | 45$^{+15}_{-22}$           | 1.74$^{+0.07}_{-0.07}$ | PL + RS + GA      |
| NGC 2273          | S2             | 0$^{<0.070}_{<0.070}$      | 1.54$^{+0.12}_{-0.11}$ | PC + GA           |
| NGC 3507          | S2             | 1.7$^{+1.9}_{-1.2}$        | 1.94$^{+0.74}_{-0.71}$ | PL + vRS          |
| NGC 3147          | S2             | 0.062$^{+0.024}_{-0.024}$  | 1.83$^{+0.10}_{-0.09}$ | PL + GA           |
| NGC 4501          | S2             | 0.66$^{+2.3}_{<2.3}$       | 1.49$^{+0.74}_{-0.51}$ | PL + RS (0.1)     |

$^a$ Photons per steradian, $^b$ Upper limit, $^c$ Lower limit, $^d$ Photon Index Model

### TABLE 12

Summary of the Spectral Parameters for the Hard Component
profiles of the surface brightness when there is no nearby bright source. Then we fitted the radial profile with a model PSF plus a constant background using a χ² minimization technique. The free parameters in this fit are the normalization of the PSF and the background level. We also tried to apply a model two-dimensional Gaussian convolved with the PSF plus a constant background to constrain the source extent (technique described in Ptak 1998). The free parameters in this fit are the normalization of the Gaussian, the width of the Gaussian (σ), and the background level. Examples of fits can be found in Ptak (1998) and Terashima et al. (2000b).

In some cases there is a nearby source of non-negligible brightness compared to the main target. We constructed a one-dimensional projection along the two sources. The one-dimensional profile of the surface brightness was fitted with a model consisting of two PSFs plus a constant background. The peak positions for the two sources were fixed, and the free parameters are the two normalizations of the PSF and the background level. If the main target was clearly extended, we utilized instead a two-dimensional Gaussian convolved with the PSF. The resulting two-dimensional model is then projected into one dimension using the same procedure as applied to the actual data. Figure 14 gives examples of fits to the one-dimensional projections for NGC 2273 and NGC 4438 in the two energy bands 0.5–2 keV and 2–10 keV. The source 2′ south of NGC 2273 (Figs. 14a and 14b, left peak) coincides with the radio source 064542.0+605210 within positional accuracy, but the source near NGC 4438 located at (12h27m57s, 13°21′8″) (J2000) (Figs. 14c and 14d, left peak) has no counterpart in NED. The soft-band image of NGC 4438 is extended compared to the PSF, while the hard-band image is consistent with a point source. NGC 2273 is pointlike in both energy bands. The nucleus of NGC 2273 is brighter in the hard band than the adjacent radio source, whose spectrum can be well fitted by a power law with a photon index of 1.9. This fact indicates that the spectrum of NGC 2273 is very hard and in agreement with the results of the spectral fits.

The objects which clearly show extended emission in the hard-energy band are NGC 3607, 4111, 4374, 4569, 4636, 5194, and probably 7217. Some of the objects whose images are consistent with the PSF are faint. We comment on the constraints on the source extent from Gaussian fits in the next section for such objects. Some information from ROSAT HRI images and recent Chandra observations are given in § 9.

9. NOTES ON INDIVIDUAL OBJECTS

This section presents some notes on individual objects, based mainly on data from the hard X-ray band. The optical spectroscopic classification is given in parentheses after the object name.

NGC 315 (L1.9).—An analysis of the ASCA data is presented in Matsumoto et al. (2001). A ROSAT HRI image shows a compact core and probably an extended component. The contribution of the point source to the HRI flux depends on modeling details (Canosa et al. 1999; Worrall & Birkinshaw 2000). Extended emission is seen in the ROSAT PSPC image (Worrall & Birkinshaw 2000). The ASCA images in the soft and hard bands are consistent with being pointlike.

NGC 404 (L2).—An analysis of the ASCA data is presented in Terashima et al. (2000c). No clear X-ray emission was detected in our ASCA observations. Komossa et al. (1999) and Roberts & Warwick (2000) reported a ROSAT HRI detection with an X-ray luminosity of 5×10³⁷ erg s⁻¹ in the 0.1–2.4 keV band. Lira et al. (2000) also reported a similar result. This luminosity is slightly higher than our upper limit which is obtained assuming a power-law spectrum with Γ = 2. The ROSAT detection and luminosity suggest that this source has a softer X-ray spectrum than that we assumed, since ROSAT is more sensitive in the softer energy band than ASCA. Alternatively, the source could have faded since the ROSAT observation. No spectral information was obtained from the ROSAT observation.

We analyzed a recent 24 ks Chandra observation and found a compact nucleus with a very soft spectrum which is well represented by a thermal plasma model with kT ≈ 0.8 keV. A hint of a hard component is also seen. If the hard component is modeled by a power law with a photon index of 2.0, the observed flux in the 2–10 keV band becomes ~3×10⁻¹³ ergs s⁻¹ cm⁻², which corresponds to a luminosity of 2×10³⁷ ergs s⁻¹.

NGC 1052 (L1.9).—ASCA results are presented in Guainazzi & Antonelli (1999) and Weaver et al. (1999). Detection of hard X-rays up to ~200 keV with BeppoSAX is reported in Guainazzi et al. (2000).

A heavily absorbed continuum, which indicates the presence of an obscured AGN, is clearly seen in the ASCA spectrum. Systematic undulations in the residuals were seen in the fits using a partially covered power-law model or a RS plus absorbed power-law model. The best-fit model we obtained is a RS plus partially absorbed power-law model.
| Name          | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---------------|-----|-----|-----|-----|-----|-----|-----|
| NGC 315       | 0.450 | 0.908 | 0.892 | 0.935 | 0.271 | 0.325 |
| NGC 404       | <0.011 | <0.066 | ... | ... | ... | ... |
| NGC 1052      | 0.349 | 4.78 | 4.72 | 9.94 | 0.316 | 0.344 |
| NGC 1097      | 1.27 | 2.08 | 2.04 | 2.07 | 0.551 | 0.587 |
| NGC 1365      | 0.506 | 1.16 | 1.12 | 1.16 | 0.458 | 0.479 |
| NGC 1386      | 0.258 | 0.388 | 1.27 | 1.27 | 0.159 | 0.165 |
| NGC 2273      | 0.0684 | 1.25 | 1.25 | 8.71 | ... | ... |
| NGC 2639      | 0.167 | 0.323 | 0.323 | 2.14 | ... | ... |
| NGC 2655      | 0.210 | 1.04 | 1.03 | 3.03 | 1.46 | 1.57 |
| NGC 3031      | 10.1 | 18.3 | 18.3 | 18.4 | 0.271 | 0.306 |
| NGC 3079      | 0.463 | 0.457 | 0.431 | 0.504 | 0.441 | 0.454 |
| NGC 3147      | 0.792 | 1.64 | 1.64 | 1.67 | ... | ... |
| NGC 3507      | 0.090 | 0.161 | 0.158 | 0.178 | 0.055 | 0.058 |
| NGC 3607      | 0.276 | 0.298 | 0.281 | 0.318 | 0.269 | 0.286 |
| NGC 3998      | 2.06 | 0.260 | 0.252 | 0.252 | 0.173 | 0.181 |
| NGC 4111      | 0.157 | 0.190 | 0.182 | 0.182 | 0.089 | 0.097 |
| NGC 4192      | 0.057 | 0.112 | ... | ... | ... | ... |
| NGC 4203      | 1.19 | 2.05 | 2.05 | 2.06 | ... | ... |
| NGC 4258(1993)| 2.06 | 7.13 | 6.55 | 12.3 | 2.38 | 2.48 |
| NGC 4258(1996)| 1.83 | 14.4 | 14.3 | 29.9 | 1.90 | 1.98 |
| NGC 4261      | 0.837 | 1.04 | 0.988 | 1.00 | 0.711 | 0.745 |
| NGC 4374      | 1.46 | 0.760 | 0.650 | 0.651 | 1.46 | 1.58 |
| NGC 4438      | 0.402 | 0.278 | 0.243 | 0.276 | 0.400 | 0.426 |
| NGC 4450      | 0.444 | 0.658 | 0.654 | 0.655 | 0.0857 | 0.0932 |
| NGC 4457      | 0.175 | 0.251 | 0.242 | 0.265 | 0.153 | 0.163 |
| NGC 4501      | 0.166 | 0.260 | 0.257 | 0.261 | 0.100 | 0.106 |
| NGC 4501      | 0.343 | 0.575 | 0.552 | 0.576 | 0.280 | 0.290 |
| NGC 4565      | 0.715 | 1.64 | 1.60 | 2.20 | 0.286 | 0.320 |
| NGC 4569      | 0.264 | 0.301 | 0.288 | 0.338 | 0.235 | 0.256 |
| NGC 4579(1995)| 2.18 | 4.27 | 4.24 | 4.27 | 0.319 | 0.347 |
| NGC 4579(1998)| 3.01 | 5.86 | 5.84 | 5.86 | 0.174 | 0.189 |
| NGC 4594      | 1.22 | 2.78 | 2.74 | 2.94 | 0.689 | 0.776 |
| NGC 4636      | 5.43 | 0.768 | 0.479 | 0.482 | 5.51 | 5.82 |
| NGC 4639      | 0.436 | 1.07 | 1.07 | 1.07 | ... | ... |
| NGC 4736      | 1.32 | 1.93 | 1.91 | 1.91 | 0.54 | 0.57 |
| NGC 4941      | 0.089 | 1.31 | 1.31 | 9.88 | ... | ... |
| NGC 5005      | 0.426 | 0.730 | 0.701 | 0.706 | 0.353 | 0.366 |
| NGC 5194      | 1.26 | 0.919 | 0.854 | 0.999 | 1.28 | 1.34 |
| NGC 5033      | 2.40 | 5.49 | 5.49 | 5.53 | ... | ... |
| NGC 7217      | 0.127 | 0.212 | 0.202 | 0.244 | 0.104 | 0.144 |
| NGC 7743      | 0.046 | 0.073 | ... | ... | ... | ... |

* In units of $10^{-12}$ ergs cm$^{-2}$ s$^{-1}$.

* Partial covering model without a Gaussian component.

* The values in parentheses denote the assumed abundance of the RS component.
### TABLE 14
Summary of X-Ray Luminosities

| Name           | (Observed) 0.5–2 keV | (Observed) 2–10 keV | (Intrinsic) 2–10 keV | (Observed) 0.5–4 keV | (Intrinsic) 0.5–4 keV |
|----------------|----------------------|---------------------|----------------------|----------------------|----------------------|
| NGC 315........ | 23.4                 | 47.2                |                      | 14.1                 | 16.9                 |
| NGC 404........ | <0.00076             | <0.0046             |                      |                      |                      |
| NGC 1052........| 1.33                 | 18.2                | 17.9                 | 37.8                 | 1.20                 | 1.31                 |
| NGC 1097........| 3.20                 | 5.24                | 5.16                 | 5.22                 | 1.39                 | 1.48                 |
| NGC 1365........| 1.73                 | 3.98                | 3.84                 | 3.98                 | 1.57                 | 1.64                 |
| NGC 1386........| 0.884                | 1.33                | 4.35                 | 4.35                 | 0.544                | 0.565                |
| NGC 2273........| 0.662                | 12.1                | 12.1                 | 84.3                 |                      |                      |
| NGC 2639........| 3.64                 | 7.03                | 7.03                 | 46.6                 |                      |                      |
| NGC 2655........| 1.50                 | 7.43                | 7.36                 | 21.6                 | 1.04                 | 1.12 (0.1)           |
| NGC 3031........| 0.238                | 0.430               | 0.430                | 0.433                | 0.0637               | 0.0720 (0.1)         |
| NGC 3079........| 2.31                 | 2.28                | 2.15                 | 2.52                 | 2.29                 | 2.27                 |
| NGC 3147........| 1.59                 | 32.9                | 32.9                 | 33.5                 |                      |                      |
| NGC 3507........| 0.423                | 0.757               | 0.743                | 8.37                 | 0.259                | 2.73 (0.1)           |
| NGC 3607........| 1.31                 | 1.42                | 1.34                 | 1.51                 | 1.28                 | 1.36 (0.1)           |
| NGC 3998........| 25.5                 | 45.1                | 45.1                 | 45.5                 |                      |                      |
| NGC 4111........| 0.714                | 0.902               | 0.874                | 0.874                | 0.600                | 0.628 (0.1)          |
| NGC 4192........| 0.19                 | 0.38                |                      |                      |                      |                      |
| NGC 4203........| 1.34                 | 2.32                | 2.32                 | 2.32                 |                      |                      |
| NGC 4258(1995) | 1.14                 | 3.96                | 3.63                 | 6.82                 | 1.32                 | 1.38                 |
| NGC 4258(1996) | 1.02                 | 8.03                | 7.95                 | 16.6                 | 1.05                 | 1.10                 |
| NGC 4261........| 12.3                 | 15.5                | 14.6                 | 14.8                 | 10.5                 | 11.0                 |
| NGC 4374........| 4.93                 | 2.57                | 2.20                 | 2.20                 | 4.68                 | 5.08                 |
| NGC 4438........| 1.36                 | 0.940               | 0.823                | 0.934                | 1.35                 | 1.44 (0.1)           |
| NGC 4450........| 1.50                 | 2.23                | 2.21                 | 2.22                 | 0.290                | 0.315 (0.1)          |
| NGC 4457........| 1.50                 | 2.19                | 2.18                 | 2.19                 | 0.191                | 0.208 (0.5)          |
| NGC 4501........| 0.636                | 0.912               | 0.879                | 0.963                | 0.556                | 0.592 (0.1)          |
| NGC 4566........| 1.16                 | 1.94                | 1.87                 | 1.95                 | 0.948                | 0.982 (0.1)          |
| NGC 4569........| 0.894                | 1.02                | 0.975                | 1.14                 | 0.796                | 0.867                |
| NGC 4579(1995) | 0.847                | 1.02                | 1.00                 | 1.12                 | 0.671                | 0.738                |
| NGC 4579(1998) | 7.40                 | 14.4                | 14.4                 | 14.4                 | 1.08                 | 1.17 (0.5)           |
| NGC 4594........| 5.86                 | 13.3                | 13.2                 | 14.1                 | 3.31                 | 3.72                 |
| NGC 4636........| 18.8                 | 2.66                | 1.66                 | 1.67                 | 19.1                 | 20.2                 |
| NGC 4639........| 1.48                 | 3.62                | 3.62                 | 3.62                 |                      |                      |
| NGC 4736........| 0.293                | 0.428               | 0.424                | 0.424                | 0.120                | 0.126                |
| NGC 4941........| 0.044                | 0.644               | 0.644                | 0.644                |                      |                      |
| NGC 5055........| 2.32                 | 3.97                | 3.82                 | 3.84                 | 1.92                 | 1.99                 |
| NGC 5033........| 10.1                 | 23.0                | 23.0                 | 23.2                 |                      |                      |
| NGC 5194........| 0.896                | 0.654               | 0.608                | 0.711                | 0.911                | 0.953                |
| NGC 7217........| 0.390                | 0.651               | 0.620                | 0.749                | 0.319                | 0.442 (0.1)          |
| NGC 7743........| 0.33                 | 0.52                |                      |                      | 0.227                | 0.313 (0.5)          |

* In units of 10^{40} ergs s^{-1}.
* Partial covering model without a Gaussian component.
* The values in parentheses denote the assumed abundance of the RS component.
The resulting photon index of $1.67^{+0.57}_{-0.40}$ is similar to those found in luminous AGNs and in other objects presented in this paper. Since the photon index depends on the assumed spectral model (see tables in this paper and Weaver et al. 1999), the very flat spectral slope obtained by Guainazzi & Antonelli (1999) and Guainazzi et al. (2000) ($\Gamma \approx 1.4$) should be taken with caution. The thermal plasma component in the best-fit model plausibly can be attributed to a hot gaseous halo associated with the elliptical host of NGC 1052.

**NGC 1097 (L2/Sl.5).**—An analysis of the *ASCA* data is presented in Iyomoto et al. (1996). The ROSAT HRI image shows a distinct nucleus and weak extended emission due to a circumnuclear star-forming ring (Pérez-Olea & Colina 1996). A recent *Chandra* observation shows that the hard X-ray emission is dominated by the nucleus (Y. Terashima & A. S. Wilson 2001, private communication).

**NGC 1365 (Sl.8).**—The results of the *ASCA* observations, performed in 1994 August and 1995 January, are presented in Iyomoto et al. (1997). A serendipitous source is detected at 1.5 SW of the nucleus in the second observation, but the separation is too close to allow the two sources to be separated with GIS, which has a broader PSF than SIS.

Iyomoto et al. (1997) generated five spectra: (1) SIS spectrum of the nucleus in 1994, (2) SIS spectrum of the nucleus in 1995, (3) SIS spectrum of the serendipitous source in 1995, (4) GIS spectrum of the nucleus in 1994, and (5) GIS spectrum of the nucleus plus the serendipitous source in 1995, fitted simultaneously. The spectral models they used were (a) a sum of a power law, Gaussian, and RS plasma for (1), (2), and (4) (nuclear component), (b) a power law for (3) (serendipitous source), and (c) a sum of the nuclear component and the serendipitous source model for (5). The spectral parameters for SIS and GIS were assumed to be same. No spectral variability was assumed between the 1994 and 1995 observations.

We applied a similar technique to fit both the nucleus and the serendipitous source. We fitted the three spectra (SIS spectrum of the nucleus [(1) + (2)], SIS spectrum of the serendipitous source (3), and GIS spectrum of the nucleus plus the serendipitous source [(4) + (5)]) simultaneously. The radii used to extract the spectra are the same as those in Iyomoto et al. (1997). A serendipitous source is presented in Iyomoto et al. (1996). The very flat spectral slope obtained by Guainazzi & Antonelli (1999) and Guainazzi et al. (2000) ($\Gamma \approx 1.4$) should be taken with caution. The thermal plasma component in the best-fit model plausibly can be attributed to a hot gaseous halo associated with the elliptical host of NGC 1052.

**REFERENCES.**—(1) Guainazzi et al. 2000; (2) Risaliti et al. 2000; (3) Maiolino et al. 1998; (4) Iyomoto & Makishima 2001; (5) Pellegrini et al. 2000a; (6) Iyomoto et al. 2001; (7) Awaki et al. 1991; (8) Pellegrini et al. 2000b; (9) Fiore et al. 2001; (10) Reynolds et al. 2000; (11) Risaliti et al. 2000; (12) Turner & Pounds 1989; (13) Makishima et al. 1990; (14) Fukazawa et al. 2001.

### TABLE 15

| Name         | Dates                | Flux       | Instruments | References |
|--------------|----------------------|------------|-------------|------------|
| NGC 1052     | 1996 Aug 11          | 4.78       | *ASCA*      |            |
|              | 2000 Jan             | 4.0        | *BeppoSAX*  | 1          |
| NGC 1365     | 1994 Aug 12, 1995 Jan | 1.16       | *ASCA*      | 2          |
|              | 1997 Aug             | 6.6        | *BeppoSAX*  | 3          |
| NGC 1386     | 1995 Jan 26          | 0.39       | *ASCA*      | 4          |
|              | 1996 Dec 10          | 0.24       | *BeppoSAX*  |            |
| NGC 2273     | 1996 Oct 20          | 1.25       | *ASCA*      | 5          |
|              | 1997 Feb 22          | 0.99e      | *BeppoSAX*  | 6          |
| NGC 3031     | 1993 Apr 30–1998 Oct 20 | 12–40 | *ASCA*      | 7          |
|              | 1998 Jun 04          | 38         | *BeppoSAX*  |            |
| NGC 3079     | 1993 May 15          | 7.13       | *ASCA*      | 8          |
|              | 1996 May 23–1996 Dec 18 | 14.4     | *ASCA*      |            |
| NGC 3998     | 1996 Dec 19–22       | 8.0        | *BeppoSAX*  |            |
|              | 1999 May 15          | 5.8        | *ASCA*      | 9          |
| NGC 4258     | 1993 May 15          | 7.13       | *ASCA*      |            |
|              | 1999 Jun 29          | 12.0       | *BeppoSAX*  | 10         |
| NGC 4565     | 1994 May 28          | 1.64f      | *ASCA*      | 11         |
|              | 1996 Jul 19, 1997 Jan | 1.31       | *ASCA*      |            |
| NGC 4941     | 1997 Jan 22          | 0.66       | *BeppoSAX*  | 12         |
| NGC 5005     | 1995 Dec 13          | 0.73       | *ASCA*      |            |
|              | 1999 May 03          | 0.3        | *BeppoSAX*  | 13         |
| NGC 5194     | 1998 Dec 14          | 5.5        | *ASCA*      |            |
|              | 1999 May 11          | 0.919      | *ASCA*      |            |
|              | 2000 Jan 18–20       | 0.34       | *BeppoSAX*  | 14         |

* Observed flux in the 2–10 keV band (not corrected for absorption), in units of $10^{-12}$ ergs s$^{-1}$ cm$^{-2}$.
* The two observations were combined.
* No description of a nearby source in the reference.
* Sixteen observations during this period.
* Three observations during this period.
* Includes the flux from a nearby source.

The resulting photon index of $1.67^{+0.57}_{-0.40}$ is similar to those found in luminous AGNs and in other objects presented in this paper.
moto et al. (1997). In the present analysis, the background spectra were extracted from a source-free region in the same field of view. Various models were examined for the AGN component, as in the other galaxies. The best-fit model consists of a power law, a Gaussian, and a RS component. We confirmed the presence of a strong Fe line (EW = 1.9$^{+0.8}_{-0.6}$ keV) at a center energy higher than 6.4 keV (6.59$^{+0.04}_{-0.03}$ keV).

The X-ray flux obtained in a later BeppoSAX observation (Risaliti et al. 2000) is higher by a factor of 6 compared to ASCA, and an absorbed ($N_H = 4 \times 10^{23}$ cm$^{-2}$) direct continuum from the nucleus appeared. The Fe line center energy in the BeppoSAX observation is slightly lower than 6.4 keV.

A soft-band image obtained with the ROSAT HRI may be extended compared to the PSF (Stevens, Forbes, & Norris 1999; but see also Komossa & Schultz 1998). Plausible origins of the soft component are soft thermal gas due to starburst activity or scattered emission from the AGN.

NGC 1386 (S2).—Detailed results are discussed in Iyomoto et al. (1997). In the NGC 1386 field, nonuniform diffuse emission due to the Fornax cluster is seen. In the present paper, we measured the temperature and brightness of the cluster component using a region which is located the same distance from the cluster center as is NGC 1386, and then added it to the spectral model instead of subtracting it from the data in order to improve the photon statistics.

A power law absorbed with $N_H = 4.5 \times 10^{23}$ cm$^{-2}$ is seen in our ASCA spectrum. Maiolino et al. (1998), on the other hand, modeled the BeppoSAX spectrum of this source using a cold reflection model. The difference in spectral models, however, does not necessarily imply true spectral variability, because the photon statistics of the BeppoSAX spectrum are very limited.

NGC 2273 (S2).—There is a serendipitous source 2$^\prime$ south of NGC 2273 in both the SIS and GIS images. The position of this source coincides with the radio source 0645+6052. We extracted SIS spectra of NGC 2273 and this radio source using circular regions with a radius of 1$^\prime$.5 and 1$^\prime$.0, respectively. We made one GIS spectrum using an extraction radius of 4$^\prime$ which contains both sources since the separation is too small to be resolved with the GIS. These three spectra were fitted simultaneously. The models applied are (a) a partially covered power-law model with two Gaussians (Fe K$\alpha$ and Fe K$\beta$) modified by absorption along the line of sight for the SIS spectrum of NGC 2273, (b) an absorbed power-law for the SIS spectrum of the radio source, and (c) a combination of (a) and (b) for the GIS spectrum. The normalizations for the SIS model and GIS model were fitted separately, while the other spectral parameters were tied. The ratio of the normalizations of the two sources for GIS was assumed to be same as those of SIS. The results of the fits are shown in Table 4. The best-fit spec-

Fig. 14.—Examples of fits to the one-dimensional projection of the surface brightness. The model consists of two PSFs plus a constant background. (a) NGC 2273 in 0.5–2 keV, (b) NGC 2273 in 2–10 keV, (c) NGC 4438 in 0.5–2 keV, (d) NGC 4438 in 2–10 keV.
teral parameters for the radio source are $\Gamma = 1.85^{+0.30}_{-0.24}$, $N_H = 0(7.0 \times 10^{20})$ cm$^{-2}$, and $f(2-10$ keV) = $1.2 \times 10^{-23}$ ergs s$^{-1}$ cm$^{-2}$. In Figure 2, the steeper power law corresponds to the spectrum of the radio source.

The spectrum of NGC 2273 shows a heavily absorbed continuum ($N_H = 1.1 \times 10^{24}$ cm$^{-2}$) and a strong fluorescent Fe K line with EW = 1.0 keV. The large EW of the Fe line indicates that the hard X-ray emission is dominated by reflection from cold material. Our modeling of the continuum shows that transmitted emission through a column density of $10^{24}$ cm$^{-2}$ is also present. We tried a pure reflection component instead of a heavily absorbed power law, but this gave a worse fit ($\Delta \chi^2 = +16$). Maiolino et al. (1998) detected a strong (EW = 3.8 ± 1.1 keV) fluorescent Fe K line using BeppoSAX, and they suggested that the source contains a significant cold reflection component. Pappa et al. (2001) recently analyzed the same ASCA data set. Their preferred model is consistent with ours, although our spectrum has a better signal-to-noise ratio because we used a larger extraction radius for the GIS data.

NGC 2639 (S1.9).—ASCA observations of this Seyfert 1.9 galaxy were published by Wilson et al. (1998). We used SIS0 + SIS1 and GIS2 + GIS3 spectra, while Wilson et al. fitted only GIS3 and SIS1 because of a large offset angle from the optical axis for GIS2 and SIS0 data. Inclusion of data from all the detectors improved the photon statistics, particularly in the low-energy band which strongly affects the power-law slope. The best fit was achieved with a partially covered power-law model. The derived photon index is somewhat steeper than normal for Seyferts, perhaps an indication of the presence of an additional soft component. Therefore, we tried a model consisting of a power law plus a reflection component. The abundance of the RS component was assumed to be 0.1 or 0.5 solar, and a Gaussian line was added. This model also successfully reproduced the observed spectrum. In this case, however, a heavily absorbed component is not necessary. On the other hand, the large EW (> 1.1 keV) of the Fe emission line suggests that the nucleus is highly obscured. The observed hard emission thus can be interpreted as scattered emission. If this is the case, the intrinsic luminosity should be 1 or 2 orders of magnitude higher than the observed luminosity.

NGC 2655 (S2).—The ASCA spectrum of this Seyfert 2 galaxy clearly shows the presence of a heavily absorbed component and an additional soft component. A RS + power-law model fit gave a negative photon index. Although such a very flat spectral slope is expected from a cold reflection, the lack of a strong Fe K fluorescent line rules out this possibility. Therefore, we tried three alternative models: a partially covered power-law model, a double power-law model, and a RS + partially covered power-law model. The best-fit photon index in the partially covering model ($\Gamma = 2.6$) is steeper than the canonical slope of Seyfert galaxies. This slope is primarily determined by the soft-energy band, which has better photon statistics, and suggests that there exists a softer component in addition to a hard power law from the AGN. If we adopt a double power-law model, the photon index of the soft component becomes $\Gamma = 2.4$, where we fixed the photon index of the hard component at $\Gamma = 2.0$. In this model, the absorption column density for the hard component is $N_H = 4.0 \times 10^{23}$ cm$^{-2}$. Finally, we tried to add a RS component to a partially covering model. We assumed a temperature of $kT = 0.65$ keV and an abundance of 0.1 solar since these parameters were not well constrained. The absorption column densities for the RS component and the less absorbed power law were assumed to be equal to the Galactic value. The model improved by $\Delta \chi^2 = -16.3$ for one additional parameter (normalization of the RS component) compared to the partial covering model. The best-fit photon index and absorption column are $\Gamma = 1.26^{+0.57}_{-0.69}$ and $N_H = 4.5^{+2.0}_{-1.4} \times 10^{23}$ cm$^{-2}$.

NGC 3031 (S1.5).—ASCA observed this galaxy many times; see Iyomoto & Makishima (2001), who analyzed 16 data sets, for the observation log and a timing analysis. Ishisaki et al. (1996) presented detailed results of the observations between 1993 May 1 to 1995 April 1, while Serlemitsos et al. (1996) describe three observations done on 1993 April 16, April 25, and May 1.

We present a combined spectrum of the three observations performed on 1994 October 21, 1995 April 1, and 1995 October 24 (observations 9, 10, and 11 in Iyomoto & Makishima 2001). More recent observations were made using unusual observation modes (lower spectral and spatial resolution but higher timing resolution for GIS). In the earlier observations, the nearby source SN 1993J was bright, and we therefore omitted these in the present analysis.

In our spectral fits, we discarded the energy range below 1 keV for the GIS data since the spectra of the SIS and GIS deviate in this energy range, most likely because of a calibration problem of the GIS in the soft-energy band. This problem is visible only in bright objects such as NGC 3031, and possibly NGC 4579 and NGC 5033.

A soft thermal component is not clearly seen in our spectra presumably due to the brighter hard component in our spectrum, and we assumed the temperature obtained by Ishisaki et al. (1996). The width of the Gaussian component for the Fe line was assumed to be narrow since the line width was not well constrained. The broad ($\sigma \approx 0.2$ keV) or possibly multiple-component Fe line previously reported by Ishisaki et al. (1996) and Serlemitsos et al. (1996) is not clearly seen in our spectra, presumably due to the limited photon statistics. The BeppoSAX observation of Pellegrini et al. (2000b) gave upper limits of 0.3 keV for the width of an Fe line. The line centroid energy and EW we obtained are consistent with the ASCA results by Ishisaki et al. (1996) and Serlemitsos et al. (1996) and the BeppoSAX results of Pellegrini et al. (2000b). Pellegrini et al. (2000b) obtained an upper limit of 42 eV for the EW of an Fe line at 6.4 keV.

NGC 3079 (S2).—ASCA results are presented in Ptak et al. (1999) and Dahlem, Weaver, & Heckman (1998). Although hard X-ray emission is detected, we found no clear evidence for the presence of an AGN from the present data. The small $L_X/L_{\text{H}\alpha}$ ratio (Terasimsha et al. 2000a) indicates that the AGN component, if any, is not the dominant ionizing source of the optical emission lines, should be heavily obscured in the energy band below 10 keV. The upper limit on the EW of a Fe K emission line is large ($\sim$2 keV), not inconsistent with a highly obscured nucleus. A recent BeppoSAX observation detected a strong Fe K emission line and highly absorbed hard X-ray emission (Iyomoto et al. 2001). Such a spectral shape gives clear evidence for the presence of a heavily obscured AGN.

The low-energy portion of the ASCA spectrum shows strong emission lines arising from $\alpha$-processed elements, which are most likely associated with hot gas arising from a powerful starburst activity. A variable abundance model gives a significantly better fit than the solar case ($\Delta \chi^2 = -16.3$).
The absorption column for the hard component depends on the model adopted for the soft component. Our best-fit value is \( N_H = 1.7^{+3.9}_{-1.2} \times 10^{22} \text{ cm}^{-2} \). Dahlem et al. (1998) used a two-temperature MEKAL plasma plus a partially covered power law and obtained \( N_H = 6 \times 10^{22} \text{ cm}^{-2} \). Ptak et al. (1999), assuming a RS + power-law model, derived a very small column, with a typical upper limit of \( N_H \approx \text{few} \times 10^{22} \text{ cm}^{-2} \). Since the hard component seen by ASCA is probably a combination of scattered emission from the AGN and contributions from the starburst region (X-ray binaries, supernovae, and hot gas), the amount of absorption to be attributed to the AGN is highly ambiguous.

NGC 3147 (S2).—A detailed analysis of the ASCA data is given in Ptak et al. (1996). We confirmed their detection of a strong Fe K emission line. Although this object is optically classified as a Seyfert 2 galaxy, no strong absorption is given in Ptak et al. (1996). We confirmed their detection of a source located 2\( \text{s} \) from the AGN in Iyomoto et al. (1998). There exists a serendipitous source located 2\( \prime \) SE of the nucleus of NGC 4203. In the present analysis, we extracted the SIS and GIS spectra using a circular aperture with a radius of 1\( \prime \)2 and 1\( \prime \)5, respectively. ROSAT PSPC and HRI images show a nucleus as well as some extended emission (Halderson et al. 2001). The Chandra image published by Ho et al. (2001) is dominated by the nucleus.

NGC 4258 (S1.9).—We analyzed four ASCA observations obtained in 1993 and 1996. Makishima et al. (1994) reported the discovery of an obscured X-ray nucleus using the 1993 observation; Ptak et al. (1999) also discussed the same data set. We reanalyzed this data set in greater detail, as well as three others taken in 1996. Reynolds, Nowak, & Maloney (2000) performed a deep (~200 ks) observation in 1999.

The ASCA spectrum from 1993 is very complex. In the following fits, we assume the Galactic absorption column density for the soft thermal components. We examined the canonical model which consists of a soft thermal plasma and a hard component. This simple model failed to explain many of the emission lines seen in the region 0.5–3 keV as well as the broadband continuum shape. A single-temperature fit to the soft X-ray spectrum resulted in \( kT \approx 0.65 \) keV, but residuals remained near the locations of the H-like O K, He-like and H-like Mg K, and Fe L emission lines in the 0.7–1.4 keV region. This suggests that the plasma has multiple components, with temperatures cooler and hotter than 0.65 keV, or that a temperature gradient is present. Therefore, we tried a model composed of a two-temperature RS plasma plus a hard component. This model gave a better fit to the soft thermal emission. However, systematic convex-shaped residuals remained in the 3–10 keV region, which can be attributed to a deficit in the model around 2–3 keV and to an \( N_H \)-value too small and a photon index (for the hard component) too steep at the \( \chi^2 \) minimum. A satisfactory fit can be achieved with a model consisting of a two-temperature RS plasma, a thermal bremsstrahlung component, and an absorbed power law. The abundances of the two RS components were assumed to be identical. The temperature of the thermal bremsstrahlung component was fixed at 4 keV. An Fe line is seen at 6.66+0.07 eV, but residuals remained near the locations of the H-like O K, He-like and H-like Mg K, and Fe L emission lines in the 0.7–1.4 keV region. This suggests that the plasma has multiple components, with temperatures cooler and hotter than 0.65 keV, or that a temperature gradient is present.

NGC 3147 (S2).—A detailed analysis of the ASCA data is given in Ptak et al. (1996). We confirmed their detection of a strong Fe K emission line. Although this object is optically classified as a Seyfert 2 galaxy, no strong absorption is seen in the X-ray spectrum. The relatively strong Fe K emission line (\( EW = 490^{+220}_{-230} \) eV) could be an indication that the observed X-rays are scattered emission and that the nucleus is obscured below 10 keV. However, the \( L_X/L_{4000} \) ratio (32) falls in the range of unobscured AGNs. The ratio of X-ray to [O iii] \( \lambda5007 \) luminosity is also typical of those observed in Seyfert 1 nuclei (Bassani et al. 1999). Some LLAGNs with low absorption in our sample also show similarly large EWs for the Fe line (\(<300 \) eV). For example, the X-rays from NGC 4579 (\( EW = 490 \) eV) and NGC 5033 (\( EW = 306 \) eV) must be dominated by direct emission because the sources are variable. This suggests that NGC 3147, too, could be largely unobscured. Future observations to search for variability or emission lines due to a scattering medium are crucial to distinguish between these two competing possibilities.

NGC 3507 (L2).—This object is very faint, and a power-law model describes the spectrum well. By adding a RS component, the fit improved by \( \Delta \chi^2 = -3.2 \) for one additional parameter (normalization of the RS component); we assumed a temperature of \( kT = 0.65 \) keV and an abundance of 0.1 solar because the photon statistics are inadequate to constrain these parameters. The image in the 2–10 keV band is consistent with the PSF, although the constraint is not tight. A Gaussian fit to the observed image yielded \( \sigma = 0.5^{+0.8}_{-0.6} \).
The flux of the hard component is about twice that observed in 1993, and the energy band above 2 keV is now dominated by the AGN emission. This variability provides additional evidence for the presence of an LLAGN. The medium-hard component introduced to fit the 1993 spectrum was not required for the 1996 data. The soft component can be represented by a single-temperature RS model, in contrast to the 1993 result. This is probably attributable to (1) the degraded energy resolution of the SIS, (2) the limited energy band used in the spectral fits, and (3) the brighter hard component in 1996. The absorption column for the AGN component decreased from \( N_H = 1.3 \times 10^{23} \text{ cm}^{-2} \) in 1993 to \( 7 \times 10^{22} \text{ cm}^{-2} \) in 1996. An Fe emission line is detected at 6.31–0.10 keV (source rest frame) with EW = 54\(^{+25}_{-25} \) eV. The line centroid energy decreased from 6.66 keV to 6.31 keV in the interval of 3 years, while the continuum luminosity increased during the same period. A similar behavior of Fe line variability has been reported for NGC 4579 (Terashima et al. 2000c). The Fe line energy and EW measured by BeppoSAX are 6.57 ± 0.20 keV and 85 ± 65 eV, respectively, but it is unclear whether these values are different compared to those measured with ASCA.

**NGC 4261 (L2).**—An ASCA spectrum is presented in Sambruna, Eracleous, & Mushotzky (1999) and Matsumoto et al. (2001). This FR I radio galaxy has a pointlike hard X-ray source with a relatively high X-ray luminosity. The \( L_X/L_{\text{H}\alpha} \) ratio of this type 2 LINER suggests that it is predominantly ionized by an LLAGN (see Paper II). Sambruna et al. (1999) claimed that they marginally detected an Fe K line. They assumed a rest energy of 6.4 keV in their spectral fits. On the other hand, Matsumoto et al. (2001) obtained only an upper limit of EW = 400 eV. We fitted the Fe line in our ASCA spectrum with a free line centroid energy. The line energy we obtained, \( E = 6.85^{+0.08}_{-0.15} \) keV, is higher than observed in luminous AGNs (typically \( E \approx 6.4 \) keV).

The soft-band image is extended to \( r > 20' \) and is most likely sampling emission associated with the elliptical host and the galaxy group of which NGC 4261 is a member. In the spectral fits, we made a background spectrum using an annular region around the nucleus in which diffuse emission is clearly present. The soft X-ray flux presented here, therefore, should be regarded as a lower limit to the true flux from the diffuse component. The radial surface brightness profile of the soft-band image is not well fitted by a model consisting of a Gaussian plus a constant background. This is probably due to the presence of bright soft X-ray emission from the elliptical host galaxy and the surrounding group. The \( \chi^2 \)-value for the fit of the 2–10 keV image is also poor, probably for the same reason. The 4–10 keV image, by contrast, is consistent with the PSF. Inspection of archival Chandra data shows that the hard-band image indeed is dominated by the nucleus and that the soft-band image is extended.

**NGC 4374 (L2).**—The X-ray images in the soft and hard bands are clearly extended. The contribution of the AGN to the hard emission should be small; this is confirmed by the Chandra of Ho et al. (2001). The most likely origin of the extended hard emission is X-ray binaries in the host galaxy, as discussed in Matsushita et al. (1994). The hot gas component in this elliptical galaxy has been analyzed by Matsumoto et al. (1997), Buote & Fabian (1998), and Matsushita et al. (2000).

**NGC 4438 (L1.9).**—The LINER 1.9 nucleus of this galaxy is a very weak X-ray source. The image in the 2–10 keV band is consistent with the PSF, while the 0.5–2 keV image is clearly extended. The ROSAT HRI image is also extended (Halderson et al. 2001). The \( L_X/L_{\text{H}\alpha} \) ratio (0.8) is too low to account for the optical line emission, unless the nucleus is heavily obscured at energies above 2 keV.

**NGC 4501 (L2).**—The ROSAT PSPC image is dominated by a pointlike nucleus (Halderson et al. 2001). The serendipitous source seen in the PSPC image (~3′ NE of the nucleus, Komossa et al. 1999) is not clearly present in the ASCA data.

**NGC 4565 (S1.9).**—Mizuno et al. (1999) presented ASCA results for NGC 4565. The nucleus and an off-nuclear source 0′8 away, previously detected with ROSAT (PSPC: Vogler, Pietsch, & Kahabka 1996; HRI: Mizuno et al. 1999, Halderson et al. 2001), are seen in the ASCA SIS images, but they are not resolved in the GIS images. The source coincident with the nucleus appears pointlike in a ROSAT HRI image (Halderson et al. 2001). The off-nuclear source is ~2 times brighter than the nucleus. As the spatial resolution of ASCA is insufficient to resolve the two sources, we extracted a single spectrum for both sources. Among the models we examined, the most successful fit was obtained with a partially covered power law plus a RS plasma. A partial covering model without the RS component yielded a slightly worse result (\( \Delta \chi^2 = 4.6 \)). A simple power-law model seems inappropriate in view of the systematic, wavy residuals it generated. We also attempted a multicolor disk blackbody model (Mitsuda et al. 1984), which was examined by Mizuno et al. (1999), and obtained results consistent with theirs. The best-fit parameters for this model are \( kT_{\text{in}} = 1.49 \pm 0.08 \) keV and \( N_H = 1.22^{+1.23}_{-1.21} \times 10^{20} \) cm\(^{-2} \); \( \chi^2 = 151.4 \) for 112 dof.

Inspection of the one-dimensional projected profiles in the hard and soft-energy bands shows that the two sources have similar spectral hardness. Thus, the nucleus and the off-nuclear source each contributes about one-third and two-thirds, respectively, to the total luminosity (1.8 \times 10^{40} \text{ ergs s}^{-1} ). The intrinsic luminosity depends on the assumed model. Tables 13 and 14 show the intrinsic flux and luminosity for the case of a partially covered power law plus RS model.

Mizuno et al. (1999) interpreted that both sources are luminous accreting black hole binaries (see also Makishima et al. 2000). They suggest that the derived absorption col-
umn density ($N_H < 2 \times 10^{21} \text{ cm}^{-2}$) is too low for the nucleus of an edge-on galaxy. We argue that an LLAGN is a likely origin for the nuclear source. First, the nucleus shows an optical spectrum classified as a type 1.9 Seyfert (Ho et al. 1997a). The detection of broad Hα emission provides strong support for the presence of an AGN. Second, the $L_X/L_{H\alpha}$ ratio (20) is in good agreement with those of LLAGNs and luminous AGNs (Terashima et al. 2000a). Third, the internal reddening determined from the Balmer decrement, $E(B-V)^{\text{int}} = 0.47$ mag (Ho et al. 1997a), corresponds to $N_H = 2.7 \times 10^{21}$ cm$^{-2}$ for the conversion $E(B-V) = N_H/(5.8 \times 10^{21})$ cm$^{-2}$ mag (Bohlin, Savage, & Drake 1978). This value of $N_H$ is consistent with the mild absorption observed in the X-ray spectrum. Finally, the radio properties further support the AGN interpretation: the nucleus contains a compact radio core which has a flat spectrum (Nagar et al. 2000; Falcke et al. 2000) and is variable (Falcke et al. 2001; Ho & Ulvestad 2001). Further X-ray observations with higher spatial resolution would be extremely useful.

**NGC 4569 (T2).—** Detailed analysis of an ASCA observation is presented in Terashima et al. (2000c). The ASCA image in the hard band (2–7 keV) is clearly extended compared to the PSF. This implies that the luminosity of the nucleus (before correction for absorption) is much lower than the observed luminosity. The recent Chandra observation of Ho et al. (2001) shows that the nucleus is surrounded by other sources of comparable brightness; for a power-law spectrum with $\Gamma = 1.8$ and $N_H = 2 \times 10^{20}$ cm$^{-2}$, the X-ray luminosity of the nucleus is $2.6 \times 10^{39}$ ergs s$^{-1}$ in the 2–10 keV band. This luminosity is about a factor of 4 smaller than the ASCA luminosity in the same energy band.

**NGC 4579 (S1.9/L1.9).—** Detailed analyses of three ASCA observations are presented in Terashima et al. (1998a, 2000c). A Chandra image in the hard band is dominated by the nucleus (Ho et al. 2001).

**NGC 4594 (L2).—** ASCA results are briefly discussed in Nicholson et al. (1998). These authors reported that adding an RS component to the power-law model did not affect the fit appreciably. By contrast, we find that adding an RS component significantly improves the fit ($\chi^2 = -33.8$ for three additional parameters). Our result agrees well with the independent analyses of the same data set by Serlemitsos et al. (1996), Ptak et al. (1999), and Roberts, Schurch, & Warwick (2001). Fabianno & Juda (1997) and Roberts et al. (2001) detected a nuclear point source which dominates the soft X-ray luminosity in the ROSAT HRI image. A Chandra image in the hard band is dominated also by the nucleus (Ho et al. 2001).

**NGC 4636 (L1.9).—** NGC 4636 was observed with ASCA in 1993 and 1995–1996. We analyzed only the newer data set because the second observation is much deeper than the first. In the spectral fits, all four spectra from SIS and GIS were fitted simultaneously since the photon statistics are very good. This elliptical galaxy has a very bright extended X-ray halo with a temperature of $\sim 0.8$ keV. The canonical model consisting of soft thermal emission and a hard component was not acceptable because the single-temperature RS model poorly fits the low-energy portion of the spectrum. This is probably due to several complications, including the possible presence of temperature and abundance gradients, nonsolar abundance ratios, and uncertainties in the model, in particular the treatment of the Fe L emission lines. The thermal emission of this galaxy has been extensively discussed by Matsushita et al. (1997) and Matsushita et al. (2000), and we will not address it here.

We fitted a simple power-law model to the region 4–10 keV, the latter chosen to minimize contamination from thermal emission; the best fit gives $\Gamma = 1.67^{+0.64}_{-0.60}$ and $\chi^2 = 103.7$ for 92 dof. The upper limit on the Fe K line shown in Table 10 was estimated from the same model. We tried to fit the spectrum with a thermal bremsstrahlung model instead of a power law and obtained $kT = 13.5(>5.7)$ keV ($\chi^2 = 103.9$, 92 dof). These results are in good agreement with the composite spectrum of elliptical galaxies given by Matsumoto et al. (1997): thermal bremsstrahlung with $kT = 12.0^{+5.5}_{-2.9}$ keV or a power law with $\Gamma = 1.8 \pm 0.4$.

The hard-band image above 4 keV is clearly extended compared to the PSF. Therefore, the contribution of an AGN to the hard component in this galaxy is small, if any. The $L_X/L_{H\alpha}$ ratio calculated using the integrated X-ray luminosity (89) is in the range of unobscured AGNs. But the hard X-ray emission is dominated by sources other than an AGN, and the $L_X/L_{H\alpha}$ ratio for the nucleus alone should be much smaller. The X-ray output of the nucleus is probably insufficient to drive the optical line emission. The powering source of the optical emission lines and the origin of the broad Hα line are thus still puzzling.

The most likely origin of the majority of the hard emission is X-ray binaries distributed over the host galaxy (see Matsushita et al. 1994). This idea has been confirmed by recent Chandra observations. The high-resolution image reveals an extensive population of discrete point sources, while the nucleus is not clearly detected (Loewenstein et al. 2001).

**NGC 4639 (S1.0).—** A detailed analysis of the ASCA data is presented in Ho et al. (1999). The reanalysis of the same data set in this paper shows a hint of an Fe K line. The ROSAT HRI image shows a pointlike nucleus (Koratkar et al. 1995). A Chandra image in the hard band is dominated by the nucleus.

**NGC 4736 (L2).—** ASCA and ROSAT results are given by Roberts, Warwick, & Ohashi (1999) and Roberts et al. (2001). They reported a marginal detection of an ionized Fe K emission line. We found a possible hint of Fe K emission in the ASCA spectrum, although the equivalent width in our fit is lower than previously obtained. The line center energy is consistent with a He-like ionization state for Fe, but neutral Fe cannot be ruled out. Very extended emission is seen in the ROSAT HRI image (Cui, Feldkühn, & Braun 1997; Halderson et al. 2001). There are several bright X-ray sources in an archival Chandra image of the nuclear region. The ASCA flux is the superposition of these sources and is not dominated by the nucleus.

**NGC 4941 (S2).—** The observed luminosity of this Seyfert 2 galaxy before correction of absorption is only $6.4 \times 10^{39}$ ergs s$^{-1}$, which is among the weakest Seyfert 2s observed thus far in the X-rays. Comparing with the results obtained with BeppoSAX (Maiolino et al. 1998) suggests variability of the absorption column.

**NGC 5005 (L1.9).—** The ASCA data show the presence of a pointlike hard X-ray nucleus with an X-ray luminosity consistent with that expected from the Hα luminosity (Terashima et al. 2000a). Furthermore, comparison between the ASCA and BeppoSAX data (Table 15) indicates that the 2–10 keV flux has varied by a factor of 2.4 between the two observations. These characteristics strongly suggest that the nuclear source is an LLAGN. A soft X-ray image taken
with the ROSAT HRI shows an extended component (~13% of the total flux; Rush & Malkan 1996) and is presumably associated with the soft thermal plasma emission seen in our ASCA spectrum.

NGC 5033 (S1.5).—A detailed analysis of the ASCA data is presented in Terashima et al. (1999). The ROSAT HRI image is pointlike (Koratkar et al. 1995), as is the Chandra image (Ho et al. 2001).

NGC 5194 (S2).—Results of the first ASCA observation are presented in Terashima et al. (1998b). The second ASCA observation performed in 1994 is discussed in Ptak et al. (1999) and Fukazawa et al. (2001). In this paper, we concentrate on the first observation in 1993 because the SIS data in 1994 suffered from serious telemetry saturation. The hard-band image is extended and indicates that the AGN does not dominate the hard X-ray flux. The detection of a strong fluorescent Fe K line gives strong evidence for the presence of a heavily obscured AGN. Long-term variability in the hard X-ray band also supports the presence of an AGN (Table 15; see also Fukazawa et al. 2001). A recent Chandra spectrum that spatially isolates the nucleus confirms the presence of a strong Fe K fluorescent line (Terashima & Wilson 2001). The Compton-thick nature of the nucleus is further suggested by the BeppoSAX detection of an absorbed ($N_H = 5.6_{-1.6}^{+0.4} \times 10^{24}$ cm$^{-2}$) power-law continuum above 10 keV (Fukazawa et al. 2001).

NGC 7217 (L2).—The image in the 2–10 keV band is probably extended. A Gaussian fit to the radial surface brightness profile yielded $\sigma = 0.80 \pm 0.40$. The flux from an AGN, even if present, thus should be lower than the observed flux. With $L_X/L_{Ho} = 1.2$, the observed X-ray power is insufficient to drive the optical line emission. The possibility of a Compton-thick AGN may be ruled out by the relatively low upper limit of on the EW of a fluorescent Fe K line (<460 eV). The soft-band (0.5–2 keV) image is consistent with being pointlike ($\sigma = 0.20\pm0.16$), but the ROSAT HRI image shows extended emission (Roberts et al. 2001).

NGC 7743 (S2).—This object is very faint, and we calculated the X-ray fluxes in the 0.5–2 keV and 2–10 keV band by fitting the one-dimensional projection of the SIS images along the axis connecting the nucleus with a serendipitous source located at $(23^h44^m49^s, 0\deg95'35''$) (J2000) on the same CCD chip. We used a width of 3$''$ to make the projected profile. This is the same technique as applied to NGC 4192 by Terashima et al. (2000c). We estimated the spectral shape of the nucleus by using the hardness ratio (2–10 keV)/(0.5–2 keV). Assuming the Galactic absorption ($N_H = 5.3 \times 10^{20}$ cm$^{-2}$) and a power-law spectrum, we obtained a photon index of 1.89$^{+0.16}_{-0.13}$ (errors are at 1 $\sigma$). Although this value is consistent with the canonical spectrum of Seyfert galaxies, the spectral shape might be more complicated, as is the case for the other galaxies in our sample, and we cannot constrain the intrinsic absorption column density of the AGN. Using the Galactic absorption and $\Gamma = 1.9$, we derive X-ray fluxes of $4.6 \times 10^{-14}$ erg s$^{-1}$ cm$^{-2}$ in the 0.5–2 keV band and $7.3 \times 10^{-14}$ ergs s$^{-1}$ cm$^{-2}$ in the 2–10 keV band, which correspond to X-ray luminosities of $3.3 \times 10^{39}$ ergs s$^{-1}$ and $5.2 \times 10^{39}$ ergs s$^{-1}$, respectively.

NGC 7743 is the only object in our low-luminosity Seyfert sample which does not show any signature of an AGN (see Paper II). We need future observations to see whether this object is a Compton-thick AGN or truly a Seyfert 2 nucleus without an accretion-powered source.

10. SUMMARY

We have systematically analyzed archival ASCA data for a large sample of LINERs and low-luminosity Seyfert galaxies in order to derive a homogeneous database of X-ray properties suitable for investigating the physical nature of low-level activity in the centers of nearby galaxies. This paper defines the sample, discusses the observations and reductions, and presents the basic quantitative measurements of the spectral, spatial, and variability properties. The next paper of this series discusses the implications of these results for a variety of issues concerning the nature of low-luminosity AGNs.

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