BROAD BAND X-RAY OBSERVATIONS OF THE NARROW LINE X-RAY GALAXY NGC 5506

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ABSTRACT

We present a detailed analysis of broad band X-ray data of the Seyfert 2 galaxy NGC5506, obtained with the ASCA and ROSAT, to address the nature of Fe Kα line profile and the soft X-ray excess in this AGN. Variations up to 60% in the 2-10 keV band are detected during a 1-day ASCA observation performed in January 1997, while no significant change in the 2-10 keV continuum shape is found. The ASCA spectrum consists of an absorbed power-law, a 'soft excess' below 2 keV, and an Fe Kα emission line at 6.4 keV. The 'soft excess' can be well described by either thermal emission from very low abundance material at a temperature kT ≃ 0.8 keV, or scattered/leaking flux from the primary power-law plus a small amount of thermal emission. The luminosity of the thermal emission in the former case is 1.2×10^{40} erg s⁻¹ over the 0.5-2 keV band, while the excess is ∼ 1% of the intrinsic hard X-ray continuum in the latter case. Analysis of ROSAT HRI data reveals that the soft X-ray emission is extended on kpc scales in this object, and the extended component may account for most of the soft X-ray excess observed by the ASCA. The result suggests that in this type 2 AGN, the 'soft excess' at least partly comes from an extended region, imposing serious problem for the model in which the source is partially covered. We argue that the generally low abundances are a drawback for the thermal model, favoring a scattering dominated model. The scatterer is likely to be relatively cold (kT ≪ 1 keV) in this object.

Fe Kα profile is complex and can not be satisfactorily modeled by a single gaussian. Models of either double gaussians, or a narrow gaussian plus a line from a relativistic accretion disk viewed at an inclination of about 40°±10° provide good fits to the data. However, the inclination of the disk can be substantially larger if there is a small amount of excessive Fe K edge absorption. The intermediate inclinations for NLXGs are consistent with the ideas that the inner accretion disk is aligned with the outer obscuring torus.

Subject headings: galaxies: individual: NGC5506 – galaxies: Seyfert – X-ray: galaxies

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1. INTRODUCTION

The discovery of weak, broad lines in the polarized light in some Seyfert 2 galaxies lead to the general picture, the so called Seyfert unification scheme, that the central engine of Seyfert 1 and Seyfert 2 are essentially the same, and the viewing angle is the only parameter of importance in determining the appearance of all Seyfert galaxies (Antonucci 1993). In Seyfert 2 galaxies, the nuclear light is blocked by a thick, dusty torus from being directly observed and fine particles, located above the torus, scatter a small fraction of light into our line of sight, resulting the observed polarized broad emission lines (Antonucci & Miller 1985). In Seyfert 1 galaxies, the nuclear light is not significantly attenuated by this obscuring material owing to our preferential direction. However, the conjecture that both types of AGN have the same type of engine cannot be proved by polarized light itself, and must be explored by other means.

X-ray observations provide a unique tool to probe the nature of Seyfert 2 galaxies in this respect. X-rays can penetrate material up to a column density of $\sim 10^{24} \text{ cm}^{-2}$, which allows us to directly view the very center of nuclei in at least some Seyfert 2 galaxies and, therefore, to make a straight test of the assumption behind the unification scheme. The rapid variability, Seyfert 1-type X-ray spectral characteristics, and in particular, the disk-type FeK$\alpha$ line emission, should be revealed by X-ray observations of Seyfert 2 galaxies. Furthermore, the amount of material along our line sight to the nucleus, which is an important parameter in the unification model, can be directly measured from the X-ray spectra. The distribution of column densities provides an important clue to the structure of obscuring torus. Finally, the fraction of scattered light in the unification model, which can hardly be directly measured in other band, can be determined technically from X-ray observations.

To date, X-ray observations are qualitatively in agreement with the unification models. Type 2 AGN are absorbed in the X-ray band by column densities $10^{22} - 10^{24} \text{ cm}^{-2}$ (Awaki 1997), sufficiently high to suppress the optical broad lines if they are located outside the BLR. Rapid variations in X-ray flux were detected in a number of Seyfert 2 galaxies (Turner et al. 1997a). Below $\sim 2$ keV, emission in excess of the extrapolation of a single power-law fit is usually observed, which is also consistent with a few percent of scattered light predicted by the unification model (Mulchaey et al. 1993, Turner et al. 1997b). The detection of strong Fe K$\alpha$ emission in Seyfert 2 galaxies is also in line with the unification scheme (Awaki 1997).

However, it is not clear how these observations reconcile with the unification model in detail. Fe K$\alpha$ profiles with reasonable quality data have been obtained only for a few Seyfert 2 galaxies. Turner et al. (1998) examined the profiles of a sample Seyfert 2s from the ASCA archive, and claimed that the line profiles are similar to those of Seyfert 1’s, indicating reprocessing by face-on disks and contradicting the expectation of the unification scheme. **Contrary to this, Weaver & Reynolds (1998) found intermediate inclination angle of accretion disk when a narrow emission line from torus is considered.** The results of Turner et al. (1998) can also be due to improper continuum modeling. Among three NLXGs for which Turner et al. (1998) claimed with high confidence evidence of face-on disks, two have unusually flat X-ray spectra and the third possesses
a reflection component. In view of models proposed to explain the flatness of the X-ray spectrum, the absorption might also be complex.

Although scattering by the ionized electron-scattering “mirror” is an attractive simple model for the soft X-ray excess, current observations showed that the situation is more complicated. In a number of cases, the spatially extended emission on kpc or even 10 kpc scales is observed (Morse et al. 1995, Weaver et al. 1995, Komossa et al. 1998), and emission line features in the soft X-ray band are detected in a number cases (Netzer 1998). These characteristics can be explained by thermal emission from the extended region, perhaps powered by starburst activity or an AGN-driven outflow (Marshall et al. 1993). In some other cases the soft X-ray emission is compact. Light from the nucleus that “leaks” through material partially covering the source is also a viable explanation.

NGC 5506 is a relatively nearby bright Seyfert 2 galaxy viewed nearly edge-on. Broad wings on the Balmer lines and broad infrared hydrogen lines are claimed to have been detected (Veron 1981). Both the narrow and broad emission lines in this galaxy are heavily reddened with $A_v = 8.1$ and 60 mag respectively (Veilleux et al. 1997). Minor-axis outflows from the nucleus are seen in extended optical and radio emission (Colbert et al. 1996a, Colbert et al. 1996b). Rapid X-ray variability down to time scales of a few 1000s was detected by EXOSAT (Konig & Timmer 1997), a soft X-ray excess, fluorescent Fe K$\alpha$ line and evidence for either an absorption edge or a reflection bump was found in the Ginga data (Bond et al. 1993). Furthermore, extended soft X-ray emission aligned with the minor axis outflows is observed (Colbert et al. 1998). These authors interpreted the extent as thermal X-ray emission from the outflow plasma. These properties, together with its brightness in the X-ray band, make NGC 5506 an ideal target for tackling all these questions. In this paper, we present a detailed analysis of the X-ray spectrum and image from ASCA and ROSAT HRI observations of this object.

2. OBSERVATIONS AND THE DATA REDUCTION

NGC 5506 was observed by the ASCA on 1997 January 30. The observation was carried out in the 1CCD faint acquisition mode for the two SIS detectors and in the PH mode for the two GIS detectors. The faint mode data were converted into bright2 mode data, which corrects then for the dark frame error and echo effects. After the data were cleaned using standard screening criteria, the remaining usable time was 43.3 ks for the GIS and 39.2 ks for the SIS. Hot and flickering pixels were removed from the GIS data and rise-time rejection was applied to exclude particle events for the GIS data. SIS photon event grades 0, 2, 3, 4 were selected for the analysis. The source counts were extracted from circular regions of radius $\sim3.5^\prime$ and $\sim7^\prime$ for the SIS and GIS, respectively. The background counts for the GIS were extracted from a region near the source. For the SIS, the background spectra were estimated from a source free region at the same chip of the CCD.

After correcting for the background, which accounts for 2% to 4% of the total counts, the source count rates are $0.941 \pm 0.005$, $0.727 \pm 0.004$, $0.800 \pm 0.005$, $0.880 \pm 0.005$ cts/sec in the 0.5-10
keV range for SIS0 and SIS1, and in the 0.7-10keV range for GIS2 and GIS3, respectively. The
data preparation and spectral analysis were performed using version 1.4 of the XSELECT package
and version 10.01 of XSPEC.

In addition to the ASCA observation, NASA/GSFC archival ROSAT HRI data were used
for the image analysis. The HRI observation was performed in 1994, 3 years ahead of the ASCA
observation.

3. RESULTS

3.1. Time variability

Figure 1 shows the 2.0-10.0 keV source+background light curves binned at intervals of 256 s
for the GIS and SIS. The background is negligible and, therefore has not been subtracted. The
lightcurve consists of two major events. At about \( \sim 2 \times 10^4 \) s after the start of the observation,
the source brightens by \( \simeq 30\% \) higher and then decreases to its begining level in \( 10^4 \) s. The source
increases by about 20\% in \( 2 \times 10^4 \) s, and then decreases during again. The ratio of the maximum
to minimum count rate is 1.7, or a maximum variability amplitude of 70\%. Variations up to 10\%
are visible down to the time scale as short as 1000 sec. The rms fraction variation is estimated to
be 0.13±0.01 and 0.11±0.01 for the 256 s binned SIS and GIS light curves, respectively.

Soft (0.5-1.0 keV) and hard (2.0-10.0 keV) band light curves for SIS data have been examined
in order to see if the fluxes in both bands vary differently. The curves were binned at intervals
of 5760s in order to increase S/N ratio of each bin in the soft band. A background light-curve,
which has been extracted from a source free region and binned at the same intervals, is subtracted
from the source light curves. The count rates in the soft band are consistent with no variations
(\( \chi^2_\nu = 0.7, \) for 16 degrees of freedom). However, a model in which the count rates at the soft
and the hard band are proportional also gives an acceptable fit (\( \chi^2_\nu = 1.08 \) for 16 degrees of freedom),
although the \( \chi^2 \) is worse by 6. Therefore this analysis is inconclusive due to low statistics.

Spectra from the high and low states (marked in Fig. 1) have been accumulated from the
data. Fitting a power-law plus a broad gaussian Fe K\( \alpha \) model (see below) to both spectra yields
similar spectral indices \( (\Gamma_l=1.78^{+0.06}_{-0.04} \) and \( \Gamma_h=1.80^{+0.06}_{-0.05} \) for the low and high state, respectively),
line energy \( (E_l=6.44\pm0.07 \) and \( E_h=6.34\pm0.10 \) keV), equivalent width \( (\text{EW}_l=190^{+60}_{-40} \) eV and
\( \text{EW}_h=220^{+80}_{-70} \) eV), and line flux \( (f_l = 1.57^{+0.53}_{-0.35} \times 10^{-4} \) and \( f_h = 1.82^{+0.66}_{-0.46} \times 10^{-4} \) photon cm\(^{-2} \) s\(^{-1} \)).

3.2. Spectral Properties

The 2-SIS spectra and the 2-GIS spectra are combined together to improve statistics, while
fits to GIS and SIS spectra are preformed separately. The spectra have been regrouped to have a
minimum of 25 counts per energy bin. In the following, all errors are quoted at \( \Delta \chi^2 = 2.71, \) or
90\% confidence level for single free parameter. Energies are referred to the observer’s frame unless
specified. A column density of $4.2 \times 10^{20}$ cm$^{-2}$ is adopted for the Galactic absorption (Elvis et al. 1989).

The broad band (0.5-10.0 keV) spectrum is complex, showing a soft X-ray excess and an Fe Kα emission line with respect to a single absorbed power-law fit. In the subsequent sections, we will present detailed modeling for the Fe Kα line and the soft excess.

### 3.2.1. The Fe Kα Line Profile

Before describing the detailed modeling, we show the Fe Kα line profile in Figure 2. A strong narrow core and complicated broad wings are clearly indicated in the plot. Since Figure 2 shows the ratio of data to the model and the continuum is weaker at higher energy, the actual profile should peak at somewhat lower energy.

To examine the Fe K region, only the data above 2.0 keV were fitted. This avoids complications of modeling the soft excess. The continuum is modeled as a single power-law absorbed by a fully covered material with the cosmic abundance. As a consistent check, including the soft excess component does not significantly affect the Fe Kα fit. The results are presented in Table 1 and Table 2.

The line profile is sensitive to the exact placement of continuum, and so a careful modeling of continuum is required. Although a reflection component was suggested by the Ginga data (Bond et al. 1993), adding it to the models described below does not improve the fit, and the covering factor always converges to a value close to zero. Therefore we only describe the power-law continuum model. And further, SIS and GIS fits yield consistent results, therefore we fit the SIS and GIS data simultaneously in order to better constrain the parameters, allowing the normalizations of the power-law component to vary independently. The Results are listed in Tables 1 and 2.

Initially, the line is modeled with a narrow gaussian ($\sigma$ is fixed at 0.02 keV). The fit yields a line energy $E=6.30\pm0.06$ keV and equivalent width of the line $134\pm37$ eV. Although the fit is statistically acceptable ($\chi^2/\nu=1.041/1105$, see Table 1), the systematic deviations of the data from the model suggest that the fit is poor. Excesses to the blue and red sides of the line are visible in the residuals (Figure 3). The fit is improved at $>99\%$ confidence level, with a $\Delta \chi^2 = 18$, when the line width is allowed to vary. The best fitting line width is $0.20\pm0.21$ keV. The broad line fit yields significantly more line flux, with an EW of $203^{+94}_{-74}$ eV, because the broad line fit picks up the flux in the line wings.

Structure is visible in the residuals and so we try a complicated model. A model with a broad plus a narrow gaussian is fitted to the data, and the residuals is shown in Fig. 3b. The fit is improved at a confidence of $>95\%$ level, with $\Delta \chi^2 \simeq 9$ for 2 more degrees of freedom, relative to the broad gaussian fit. The broad line is found at energy of $6.3^{+0.2}_{-0.3}$ keV, slightly redshifted relative to the narrow one, with a width of $\sigma=0.6^{+0.5}_{-0.3}$ keV (Table 2). The line fluxes in the narrow and broad components are similar. In comparison with the line profile of the Seyfert 1 galaxy MCG
6-30-15 (Iwasawa et al. 1996), the broad line in NGC5506 is less redshifted ($E_b=5.9±0.1$ keV for MCG 6-30-15), has a similar width ($\sigma=0.6$ keV) and is weaker (EW$_b\simeq 200-400$ eV).

Next, we model the line assuming emission from an accretion disk around a Schwarzschild (Fabian et al. 1989, hereafter Fabian; Fig. 3c) or extreme Kerr black hole (Laor 1991, Laor; Fig. 3d). The parameters are the inner and outer accretion disk radii, the index of disk emissivity law $q (F \propto r^{-q})$, line intensity, and the inclination of the system. Since the line has a strong narrow core, the outer radius of the disk must be large. It should be mentioned that the Loar91 model in the current XSPEC does not calculate the disk emission beyond 400 $r_g$. In all fits presented below, the outer radius is allowed to vary freely with upper limit of 400 $r_g$ for Laor model and $10^6$ $r_g$ for Fabian model, while the inner radius is fixed at 1.235 and 6 $r_g$ for Loar91 and Fabian models respectively. The best fits yield to a $q=2.2±0.1$ and $1.8^{+0.4}_{-0.8}$, and inclinations $16^{+10}_{-16}$ and $41±10^\circ$ for the Laor and Fabian models, respectively. The different results can be simply due to the fact that the outer radius of Laor model does not go beyond 400 $r_g$. We have noticed that for given outer and inner radii, the the inclination is mainly determined by the blue peak energy, which moves to a low value when the outer radius increases except for extremely face-on disk and at very small radius (Fig. 1 of Laor 1991). So taking the emission line from outside 400 $r_g$ falsely as emission within it will result in an apparently low inclination. This is exactly the case we did here with Laor model. The best fitting outer radius is $10^5$ $r_g$ for Fabian model and reached the upper boundary for Laor model.

Keeping in mind that the absorbing material also emits Fe Kα, we add a narrow gaussian to the disk models (Fig. 3e and Fig. 3f). The line energy and outer radius of the disk are fixed at 6.4 keV and 400 $r_g$. The fit is improved at the 90% confidence level for the Laor model ($\Delta \chi^2=3.4$ for 1 more constraint), while no significant improvement occurs for the Fabian case. This time, however, the line parameters for the two models are similar, with an inclination for the disk of $40±10^\circ$ for both models. The EW of narrow line is 30-80 eV for the Fabian model and 50-110 eV for the Laor model. The disk line has an equivalent width of approximately 200 eV.

Inspecting the residuals, we find an excesses between 7.7-8.3 keV (Fig. 3e,f). This might be part of the blue wing, if there is an absorption edge at around 7 keV. An absorption edge might be expected if the Fe is over-abundant in the absorbing material or the absorption is complex. To explore this possibility, we added an Fe K edge to the model, The fit is moderately improved for the Loar91 model, with a $\Delta \chi^2=4.4$ for 2 more free parameters. For this case, the best fit converges to $i=69^{+20}_{-9}^\circ$ and $\tau=0.10±0.07$. For the Fabian model, the improvement is not significant.

### 3.2.2. The Soft X-ray Excess

Next we try to model the soft X-ray band. As shown in the last section, the detailed spectral slope and the absorbing column density are not sensitive to the modeling of Fe Kα. Here the Fe Kα line is modeled with double gaussian (see above) and the line energies and the widths are fixed at their best fitting values (Table 1). The primary continuum is described as an absorbed single
power-law, with neither reflection nor absorption edge included.

The soft excess is modeled as either partially absorbed optically thin plasma emission (Raymond-Smith model; Fig. 4a) or a power-law (Fig. 4b). In the latter case, the spectral index is fixed at the value for the primary one; this corresponds to the case of partially covered absorption or scattering of the primary continuum (referred to as scattering model below). The results are summarized in Table 3. An excess is still visible between 0.8-1.0 keV (Fig. 4 (a) and (b)) for both models, although the thermal model produces a better fit than the scattering model. The total luminosity in thermal component in the 0.5-2 keV band is $1.2 \times 10^{40}$ erg s$^{-1}$ (assuming $H_0=50$), the abundances are extremely low with $Z = 0.03^{+0.04}_{-0.01}Z_{\odot}$, and the best fit plasma temperature is $\simeq 0.8$ keV. For the scattering model, the normalization is $\simeq 1.3\%$ of the primary unabsorbed component, which corresponds to a partial covering factor $\simeq 98.7\%$ in the case of partially covered absorption.

For the scattering model, the excess between 0.8-1.0 keV could be a thermal emission component. If the scatter is the hot plasma, it must physically produce thermal emission as well. When a Raymond-Smith component (abundance fixed at solar value) is added to the scattering model, the fit is dramatically improved with a $\Delta \chi^2=17$ for 2 more degrees of freedom (Fig 4 (c)), but the amount of thermal emission is uncertain (Table 3). This fit has the same number of parameters as the free abundance Raymond-Smith model, and produces a slightly better fit with $\Delta \chi^2 = 6.5$.

### 3.3. Spatial Extent at HRI Image

The ROSAT HRI image has been analyzed by Colbert et al. (1998), who estimate the X-ray emission to be extended on the kpc scale. We re-analyze the HRI data to determine if the soft X-ray excess seen with ASCA can be explained by the extended emission. The best fitting soft excess model (RS+PL in Table 4) for the soft X-rays convolved with the ROSAT HRI response predicts a count rate 0.024 cts s$^{-1}$; 0.008 cts s$^{-1}$ for the RS component and 0.016 cts s$^{-1}$ for the scattered component.

The HRI image is extracted from the events file obtained from the ROSAT archive at GSFC. Using XIMAGE, we estimate source count rate of 0.049$\pm$0.002 cts s$^{-1}$, which is in good agreement with that obtained by Colbert et al. (1998). Background accounts for $\sim 10\%$ in a 1′ circle. The radial profile of counts per unit area and the in-flight PSF, binned at intervals of 0′.05, are plotted in Figure 5. Excess emission beyond 0′.1 is obvious with weak emission extending up to 0′.4. The count rate from the extended emission can be estimated by subtracting the normalized PSF from the radial profile of NGC5506 and integrating between 0′.1 to 0′.4. This yields a net count rate from the extended component (beyond 0′.1), $\sim 0.015\pm0.002$ cts/s, or 25 to 35% of the total HRI counts. This count rate is slightly lower, but approximately consistent with that derived from the soft X-ray excess model from the ASCA band. However, we are cautious about this result, since an uncertainty in the aspect solution occasionally produces an apparent source extent in the HRI.
observed sources (David et al. 1992, Briel et al. 1994) which was found to be of the order 1″ in FWHM (Morse 1994).

Colbert et al.’s conservative estimation of 0.0040±0.0008 cts s⁻¹ for the count rate between 10″ and 25″, is about 8% of total HRI count rate, and only accounts 1/6 of the ASCA soft excess derived from the ASCA spectral fitting. And this number is also a factor of 2 lower than the contribution from RS component in the RS+PL model (Table 4).

4. DISCUSSION

We have shown that the soft-X-ray excess in NGC 5506 is spatially extended on kpc scales and can be fitted by thermal plasma emission with very low abundances having temperature kT ≃ 0.8 keV, or by a scattered primary power-law component plus a small amount of thermal emission with cosmic abundances.

Although the luminosity, ≃ 10⁴⁰ erg s⁻¹, and the temperature derived from the optically thin thermal plasma model is well within the range found for normal galaxies (Matsumoto et al. 1996), the extremely low abundances however are a drawback. The thermal emission from late type galaxies usually has abundances of only a few times lower than the solar value, but we find a factor of 50 times lower. This is unexpected because the optical narrow line spectrum of NGC5506 is similar to the other Seyfert galaxies; and the ratio of metal lines to the Balmer lines are of typical value (Malkan 1986). Very low abundances have been found in some other type 2 AGN when a single component thermal model was fitted: 0.07⁺0.11₋0.05 Z_⊙ for NGC2110 (Hayashi et al. 1996), 0.05 Z_⊙ for NGC4388 (Iwasawa et al. 1997). The low abundances imply that the emission lines are weak in comparison with the continuum emission. This can be due to the extra emission in the continuum, e.g., from plasma with temperature much higher (e.g. >2 keV) than the one produce the line features in the 0.7-1.0 band. High ionized plasma is insufficient line emitter. In order to account for so low abundances, the high temperature gas should be a factor 10 more than the low temperature, but it still emit only small amount of total flux in 2-10 keV band. Another possible solution is that the gas is much higher ionized than indicated by its excitation level (temperature), this is a characteristic of photonized gas. Simulations is needed in order to see if these can indeed explain the low abundance.

If the soft excess is scattered continuum flux, the scattered light accounts for ~1% of unabsorbed primary power-law. The scattered fraction is typical for type 2 AGN observed by ASCA (Turner et al. 1998). However, the actual fraction is hard to estimate since the scattering region is likely to be spatially extended on kpc scales and the AGN is variable.

If the emission between 6″-10″ is real, then the size of the scattering region is of order of R ~1 kpc. An order of magnitude estimate would suggest that the scatterer is relatively cold (kT<<1keV), and that the extra thermal emission is only from a small amount of gas, perhaps
hot phase gas. For an optical depth of $\tau_{sc} \sim 0.01$, we derive a Raymond-Smith normalization of,

$$A_{RS} = \left(10^{-14}/4\pi D^2\right) \int n_e n_h dV \simeq 10^{-14}/3D^2 \left(\frac{\tau_{es}}{\sigma_T}\right)^2 R^{-1} \simeq 0.6$$

for a homogeneous medium, and it would be larger for other cases. However, our spectral fitting results suggests a value of only $10^{-4}$ for the RS component, 4 orders of magnitude lower than expected. A simple simulation shows that the temperature of this plasma should be lower than 0.1 keV in order not to produce too much excess emission at low energies. Since $A_{RS}$ is inversely proportional to $R$, this conclusion is even valid for $R$ as small as 10 pc.

Extranuclear scattered light on the kpc scale had not been detected in the X-ray, however, it was observed in the optical band in recent years. Shields & Filippenko (1996) reported the first case of extended ($10''$) broad line emission in NGC 4388, which was interpreted as scattered light coming from an obscured Seyfert 1 nucleus. Ogle et al. (1997) found broad polarized emission in Cygnus A, and they resolved the polarized light into three extended regions, concluding that the broad emission lines arise from the scattered light of a quasar of modest luminosity hidden in the nucleus of the galaxy. More recently, Mediavilla et al. (1998) find a broad emission line region of 8 kpc scale in the Seyfert 1 galaxy Mrk509. Thus it is no surprise that we detect scattered light in the X-ray band on kpc scale. Future spatially resolved spectroscopy in the X-ray, optical bands should verify kpc scale emission.

The fluorescent iron line provides a diagnostic tool with which to probe the region immediately around the putative black hole. The line profiles from Seyfert 1 galaxies show a broad red wing extending to the energy 4-5 keV (Nandra et al. 1997), which can be naturally interpreted as emission from a face-on relativistic accretion disk around a black hole (Tanaka et al. 1995), although an alternative model may also explain the characteristics of the Fe K line (Misra & Kembhavi 1998). In Seyfert 2s, the situation is somewhat complicated. For many of them, the obscuring material is so optically thick that only the scattered light is seen, such as for NGC1068, and their spectrum is dominated by a compton-thick reflection component with a very large EW of Fe K emission. A line component similar to Seyfert 1s has also been identified in some cases (Turner et al. 1998). For a particular subclass of type 2 galaxies, called NLXG, the absorbing column is less than $10^{23}$ cm$^{-2}$ and is transparent to the X-rays at energies $>$3keV. These sources possess Fe K$\alpha$ profiles similar to those seen in Seyfert 1s.

For a sample of six NLXGs, Turner et al. (1998) compared the observed line profiles to disk-lin model predictions and claimed that the Fe K$\alpha$ profiles are indicative of reprocessing from face-on disks. The inclinations were well constrained to less than 30° for 3 objects (NGC2110, NGC526A, MCG 5-23-16) among 6. However, Weaver et al. (1997) found an intermediate inclination solution for MCG 5-23-16 when a reflection component and narrow Fe K line was included in the model. The existence of a reflection has subsequently been confirmed by data from RXTE (Weaver et al. 1998). The remaining two objects, NGC2110 and NGC526A, show flat spectra in the ASCA band. It has been proposed that the absorption in these AGN is complicated (e.g. Hayashi et al. 1996, Cappi 1998). When a complex absorption model, which consists of a partially covered high column and a fully covered low column densities material, is applied to the data, we find the
disk inclinations: $65^{+7}_{-22}^\circ$ and $52\pm15^\circ$ for NGC2110 and NGC526A, respectively. The different inclinations is due to the fact that either reflection component or complex absorptions contain an edge around 7.1 keV, which make the apparent blue wing of the Fe K\(\alpha\) weaker, resulting a low inclination disk. When the edge is corrected, the disk inclination become higher. Using a 2-component (Gaussian plus disk line) model for Fe K\(\alpha\), Weaver and Reynolds (1998) also find large inclinations. An intermediate inclination (40-50\(^\circ\)) disk is also found for the type 2 AGN IRAS 18325-5926. For NGC5506, the best fit inclination is $40\pm10^\circ$, which is intermediate. Based on carefully calculated numbers of Seyfert 1, Seyfert 2 and intermediate Seyfert galaxies, it was proposed that partially obscured type 2 AGN, such as NLXG, are viewed at an angle between 35-55\(^\circ\) with respective to the axis of torus (Osterbrock & Shaw 1988, Osterbrock & Martel 1993, Maiolino & Rieke 1995). The intermediate inclinations derived for these objects are consistent with ideas that the inner disk and outer torus are aligned, contrary to Turner et al..

The narrow Fe K line in our two component fit has an EW of $\sim70$ eV, which is comparable to the same component in 4 NLXGs (Weaver et al. 1998). The line EW is still somewhat larger than predicted 30 eV from absorbing material with the observed column density uniformly covering the source at cosmic abundances. However, if we view through the low column density part of the obscuring torus, and the majority of the torus is much thicker, as proposed for partially obscured type 2 AGN (Veilleux et al. 1997), the torus may well explain the narrow line component. Alternatively, a large EW may also result from an over-abundance in Fe.

5. CONCLUSION

We have analyzed the broad band X-ray data of NGC5506 collected from the ASCA and ROSAT mission. The main results can be summarized as follows:

1. Up to 60\% variations in the 2-10 keV count rate are observed during a 1-day ASCA observation. The ASCA spectrum consists of an absorbed power-law, a 'soft excess' below 2 keV, and an Fe K\(\alpha\) emission line at 6.4 keV.

2. The soft excess can be well described by either thermal emission from extremely low abundance material at a temperature kT\(\simeq0.8\) keV or a scattered/leakage of a primary power-law plus a small amount thermal emission. For pure thermal, we find $L_x \simeq 1.2 \times 10^{40}$ erg s\(^{-1}\) in the 0.5-2 keV band, while if we assume the soft X-rays are scattered, the excess is $\sim1\%$ of the directly viewed hard X-ray continuum.

3. ROSAT HRI data reveal that the soft X-ray emission is extended on a kpc scale in this object. The extended component may account for most of the soft X-ray excess observed by the ASCA.

4. The Fe K\(\alpha\) profile is complex, and can not be satisfactorily modeled by a single gaussian. Models of either double gaussians, or a narrow gaussian plus a line from a relativistic
accretion disk viewed at an inclination angles about 40±10° provide good fits to the data. The inclination could be larger if there is small amount of excess FeK edge.

We conclude that the soft X-ray excess is most likely dominated by nuclear X-rays scattered from relatively cold material, plus a small amount of thermal emission from extended thermal matter. The later can be identified with the large scale outflow gas by (Colbert et al. 1998). Future spatially resolved spectroscopy in X-rays and optical can verify or dismiss this explanation. The intermediate disk inclinations found for this and other NLXGs are consistent with the idea that the inner accretion disk and outer obscurer are aligned.

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REFERENCES

Briel U., Aschenbach B., Hasinger G. et al. 1994, ROSAT user’s handbook

This preprint was prepared with the AAS LATEX macros v4.0.
Fig. 1.— ASCA SIS and GIS light curves in the 2-10 keV band. The count rate have been binned to 256 seconds, and 2 SIS (GIS) data are combined together. The background count rate, which accounts for 2-5% of the total, has not been subtracted. The time is from MJD 128848448.9678306 sec.

Fig. 2.— Ratio of the data to an absorbed power-law model fitted from 2 to 4.5 keV and from 7.5 to 10 keV bands to illustrate the Fe K line profile for the SIS (a) and the GIS (b). The data from 2 detectors were combined in each case.

Fig. 3.— Plot of data to model ratios for the simultaneous fits to the SIS and GIS data over 2-10 keV. The corresponding model for Fe Kα is labeled in each panel (see also Table 1 and 2).

Fig. 4.— Simultaneous fit over broad band ASCA spectrum of the SIS and GIS. The Fe Kα has been modeled with double gaussians and the soft X-ray excesses are fitted with Raymond-Smith emission in panel (b), scattered power-law in panel (c) and a scattered power law plus Raymond-Smith emission with cosmic abundances in panel (d). We have also show the fit without modeling soft excess in panel (a).

Fig. 5.— The spatial profile of X-ray image around NGC5506 from the ROSAT HRI data. The count rate, together with its error bar, at each radius is shown. The on-orbit HRI PSF is overplotted as a solid line. At the distance of NGC 5506, the scale 0:1 corresponds to a physical size of 0.7 kpc.
**Table 1. Gaussian fits for the Iron Line (2-10 keV)**

| fit   | \( N_H \) \(10^{22}\,\text{cm}^{-2} \) | \( \Gamma \) | \( A^a \) | \( E_n \) \( \text{keV} \) | \( \text{EW}_n \) \( \text{eV} \) | \( E_b \) \( \text{keV} \) | \( \sigma_b \) \( \text{keV} \) | \( \text{EW}_b \) \( \text{eV} \) | \( \chi^2/\nu \) |
|-------|--------------------------------------|-------------|---------|----------------|----------------|----------------|---------------|----------------|----------------|----------------|
| NL    | 3.01\( \pm \)0.20                    | 1.75\( \pm \)0.05 | 2.4\( \pm \)0.2 | 6.30\( \pm \)0.06 | 134\( ^{+37}_{-37} \) | | | | | 1.041/1105 |
| BL    | 3.07\( \pm \)0.25                    | 1.78\( \pm \)0.09 | 2.5\( \pm \)0.2 | 6.39\( ^{+0.09}_{-0.08} \) | 0.20\( ^{+0.21}_{-0.11} \) | 203\( ^{+94}_{-74} \) | | | | 1.025/1104 |
| NL+BL | 3.21\( \pm \)0.14                    | 1.82\( \pm \)0.04 | 2.7\( \pm \)0.2 | 6.41\( ^{+0.03}_{-0.05} \) | 101\( ^{+19}_{-27} \) | 6.25\( ^{+0.21}_{-0.25} \) | 0.63\( ^{+0.45}_{-0.28} \) | 126\( ^{+88}_{-50} \) | | 1.018/1102 |

\( ^a \)SIS normalization at 1 keV in unit of photon cm\(^{-2} \) s\(^{-1} \) keV\(^{-1} \).

fits: NL – narrow gaussian, BL – broad gaussian, NL+BL – narrow plus broad gaussians.

**Table 2. Disk Line model Fitting to the Fe K\( \alpha \) line**

<table>
<thead>
<tr>
<th>fit</th>
<th>( N_H ) (10^{22},\text{cm}^{-2} )</th>
<th>( \Gamma )</th>
<th>( A^a )</th>
<th>( E_n ) ( \text{keV} )</th>
<th>( \text{EW}_n ) ( \text{eV} )</th>
<th>( E_d ) ( \text{keV} )</th>
<th>( q )</th>
<th>( i )</th>
<th>( \text{EW}_d ) ( \text{eV} )</th>
<th>( \chi^2/\nu )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabian</td>
<td>3.18( \pm )0.13</td>
<td>1.81( \pm )0.04</td>
<td>2.6( \pm )0.2</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
<td>6.38( ^{+0.04}_{-0.05} )</td>
<td>2.2( ^{+0.1}_{-0.1} )</td>
<td>41( \pm )9</td>
<td>225( ^{+34}_{-39} )</td>
<td>1.011</td>
</tr>
<tr>
<td>Laor</td>
<td>3.16( \pm )0.13</td>
<td>1.80( \pm )0.04</td>
<td>2.6( \pm )0.2</td>
<td>( \cdots )</td>
<td>( \cdots )</td>
<td>6.5( \pm )0.1</td>
<td>1.8( ^{+0.4}_{-0.8} )</td>
<td>16( \pm )10</td>
<td>208( ^{+81}_{-48} )</td>
<td>1.015</td>
</tr>
<tr>
<td>NL+Fabian</td>
<td>3.18( \pm )0.14</td>
<td>1.81( \pm )0.04</td>
<td>2.6( \pm )0.2</td>
<td>6.37( ^{+0.05}_{-0.06} )</td>
<td>66( ^{+46}_{-32} )</td>
<td>6.4( \text{fixed} )</td>
<td>2.6( ^{+0.7}_{-0.9} )</td>
<td>39( \pm )7</td>
<td>156( ^{+49}_{-47} )</td>
<td>1.011</td>
</tr>
<tr>
<td>NL+Laor</td>
<td>3.16( \pm )0.14</td>
<td>1.81( \pm )0.04</td>
<td>2.6( \pm )0.2</td>
<td>6.38( ^{+0.04}_{-0.05} )</td>
<td>84( ^{+30}_{-30} )</td>
<td>6.4( \text{fixed} )</td>
<td>2.4( ^{+0.7}_{-0.7} )</td>
<td>40( \pm )7</td>
<td>163( ^{+84}_{-66} )</td>
<td>1.011</td>
</tr>
</tbody>
</table>

fits: Fabian – Disk line model from Fabian et al. (1989); Laor – Disk line model from Laor (1991); NL+Fabian – narrow gaussian plus Fabian model; NL+Laor – narrow gaussian plus Laor model.

\( ^a \)SIS normalization at 1 keV in unit of 0.01 photon cm\(^{-2} \) s\(^{-1} \) keV\(^{-1} \)
<table>
<thead>
<tr>
<th>fits</th>
<th>$N_H^{(1)}$ ($10^{22}$ cm$^{-2}$)</th>
<th>$\Gamma$</th>
<th>$N_H^{(2)}$ ($10^{22}$ cm$^{-2}$)</th>
<th>kT  (keV)</th>
<th>abundance</th>
<th>$A_{RS}^{(a)}$</th>
<th>$A_{pl}^{(b)}$</th>
<th>$\chi^2/\nu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>RS</td>
<td>3.15±0.08</td>
<td>1.82±0.03</td>
<td>0.22$^{+0.62}_{-0.13}$</td>
<td>0.77$^{+0.12}_{-0.15}$</td>
<td>0.031$^{+0.038}_{-0.014}$</td>
<td>26$^{+19}_{-10}$</td>
<td>26$^{+19}_{-10}$</td>
<td>1.029/1297</td>
</tr>
<tr>
<td>PL</td>
<td>3.25±0.07</td>
<td>1.84±0.03</td>
<td>0.06$^{+0.07}_{-0.02}$</td>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
<td>3.4$^{+0.8}_{-0.6}$</td>
</tr>
<tr>
<td>RS+PL</td>
<td>3.22±0.10</td>
<td>1.82±0.03</td>
<td>0.19$^{+0.26}_{-0.19}$</td>
<td>0.67$^{+0.17}_{-0.41}$</td>
<td>1.0(fixed)</td>
<td>1.0$^{+1.5}_{-0.5}$</td>
<td>3.5$^{+1.4}_{-1.4}$</td>
<td>1.024/1297</td>
</tr>
</tbody>
</table>

$^a$Raymond-Smith normalization, $A_{RS} = (10^{-14}/(4\pi D^2)) \int n_ee_nHdV$, where $D$ is the distance to the source in cm, $n_e$ and $n_h$ are the electron and H densities in cm$^{-3}$.

$^b$the second power-law normalization, in 0.01 photon cm$^{-2}$ s$^{-2}$ keV$^{-1}$.