THE EFFECT OF CHANGES IN THE *ASCA* CALIBRATION ON THE Fe-K LINES IN ACTIVE GALAXIES

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ABSTRACT

The *ASCA* calibration has evolved considerably since launch and indeed, is still evolving. There have been concerns in the literature that changes in the *ASCA* calibration have resulted in the Fe-K lines in active galaxies (AGN) now being *systematically* narrower than was originally thought. If this were true, a large body of *ASCA* results would be impacted. In particular, it has been claimed that the broad red wing (when present) of the Fe-K line has been considerably weakened by changes in the *ASCA* calibration. We demonstrate explicitly that changes in the *ASCA* calibration over a period of about eight years have a negligible effect on the width, strength, or shape of the Fe-K lines. The reduction in both width and equivalent width is only $\sim 8\%$ or less. We confirm this with simulations and individual sources, as well as sample average profiles. The average profile for type 1 AGN is still very broad, with the red wing extending down to ~ 4 keV. The reason for the claimed, apparently large, discrepancies is that in some sources the Fe-K line is complex, and a single-Gaussian model, being an inadequate description of the line profile, picks up different portions of the profile with different calibration. However, one cannot make inferences about calibration or astrophysics of the sources using models which do not describe the data. Better modeling of the Fe-K in such cases gives completely consistent results with both old and current calibration. Thus, inadequate modeling of the Fe-K line in these sources can seriously underestimate the line width and equivalent width, and therefore lead to incorrect deductions about the astrophysical implications.

Subject headings: galaxies: active – galaxies: emission lines – galaxies: individual: MCG–6–30–15 – X-rays: galaxies

1. INTRODUCTION

The *Advanced Satellite for Cosmology and Astrophysics* (*ASCA* – Tanaka, Inoue, & Holt 1994) found that the Fe-K fluorescent emission line in Seyfert 1 galaxies is often very broad, and this is generally interpreted as the result of an origin in matter in an accretion disk rotating around a central black hole (see Fabian *et al.* 2000 and references therein). The line profile is thought to be sculpted by characteristic gravitational and Doppler energy shifts. Currently, study of the Fe-K emission line is the only way to probe matter within a few to tens of gravitational radii of a black hole. Indeed, the broad Fe-K lines provide some of the strongest evidence to date for the existence of black holes.

It has been known since the early days of *ASCA* that the Fe-K line in AGN is not always tremendously broad (e.g. Ptak 1994) and that the profile comes in a variety of shapes (e.g. Yaqoob & Weaver 1996; Nandra *et al.* 1997, hereafter N97). It has also been known that Seyfert type 1.9–2.0 galaxies have a predominantly narrow Fe-K line, with FWHM less than $\sim 10,000$ km/s, probably originating in cold matter far from the black hole (e.g. NGC 2992; Weaver *et al.* 1996). It was apparent that many Seyfert 1.5–1.9 galaxies likely have composite narrow and broad Fe-K line components (e.g. Weaver *et al.* 1993, Yaqoob *et al.* 1995, Weaver *et al.* 1997, Weaver & Reynolds, 1998). *Chandra* and *XMM* have now shown that composite narrow and broad Fe-K lines are common even in Seyfert 1 galaxies and quasars (Yaqoob *et al.* 2001a, Kaspi *et al.* 2001, Reeves *et al.* 2000, Pounds *et al.* 2001).

Recently Lubiński and Zdziarski (2001; hereafter LZ01) have claimed that the Fe-K lines in AGN are *systematically* narrower and weaker (smaller equivalent width, or EW) than had previously been thought. They speculated that this result can be attributed to changes in the calibration of the *ASCA* instruments. However they did not attempt to demonstrate this by isolating calibration effects. The purpose of the present paper is to explicitly demonstrate that changes in the *ASCA* calibration have *not* resulted in any significant changes in the width, equivalent width, or shape of the Fe-K lines in AGN. This issue is important to resolve because speculation about the *ASCA* calibration has brought into question a significant body of *ASCA* results and has rendered the astronomical community rather confused. We will also give the real explanation of the results of LZ01, which turns out to be a very subtle data analysis issue.

2. PRINCIPAL CALIBRATION CHANGES

We shall compare the results of fitting various data sets with two sets of calibration. The first, which we shall call 'OLD', is the same, or essentially the same, as that used by N97. The second, which we shall call 'CURRENT' is the same as that used by LZ01. The CURRENT calibration files are from the TARTARUS AGN database[5], except where noted. All of the observations considered by LZ01 were made before radiation damage made a significant impact on the CCDs. Therefore the principal differences between the OLD and CURRENT calibration for these early data are, (1) improvements in the SIS response matrix, (2) multiplicative, energy-dependent corrections for the effective area (the so-called 'arf filter'), and (3) changes in the X-ray Telescope (XRT) ray-tracing (see Yaqoob *et al.* 2001b for further details on calibration history). The latter is the *only* change that can make the OLD and CURRENT calibration have different effects on different observations since the first two are independent of position on the detector and independent of time of the observation (as long as that time is early enough in the mission). Even so, the XRT response is a smooth function of source off-axis angle, and its variation is small from observation to observation, given the limited range of off-axis angles in observations.

[5]http://tartarus.gsfc.nasa.gov/

We performed simulations of SIS0+SIS1 spectra in order to isolate calibration effects from data processing differences and statistical effects (the latter by using a very large exposure time of 10^{10} s). We used the original (OLD) calibration files used by Tanaka *et al.* (1995) in their analysis of *ASCA* AO2 data for MCG−6−30−15. First, we used one of the best-fitting relativistic Schwarzschild disk-line models of Tanaka *et al.* (1995), namely, the model with the Fe-K rest energy fixed at 6.4 keV, continuum power-law index of 1.96, and the radial line-emissivity power-law index, q, fixed at -3. We then investigated the effect of using CURRENT calibration (from TARTARUS) with the spectra that were simulated using the OLD calibration. The line profiles, in the form of ratios of data to power-law models fitted over the 3–4 keV and 8–10 keV bands for each calibration, are compared in Figure 1 (a). Indeed, it can be seen that the CURRENT calibration reduces the red wing of the line. However, spectral fitting of the simulated data with the CURRENT calibration shows that the *EW is reduced by only 8%.* Note that residuals from the latter fit are never more than 3%. We repeated this excercise with a Gaussian line profile, using parameters which are typical of Seyfert type 1 galaxies with some of the broadest lines. Using the same continuum as above, we simulated a Gaussian with $\sigma = 0.6$ keV, EW = 300 eV, centered at 6.4 keV. The line profiles for the OLD and CURRENT calibration are compared in Figure 1 (b). The red side is slightly diminished and the blue side slightly enhanced for the CURRENT calibration relative to OLD. However, spectral fitting reveals that the *width (σ) is reduced only by 8%, and the EW only by 3.6%.* There is an apparent slight shift in the centroid energy but this is only by 2% and will also depend on the actual width of the line. *It is important to note that this apparent shift in the centroid energy is NOT due to changes in the instrumental energy scale, which have been measured to be much less than this.* Rather, the apparent shift is due to different weights given to the red and blue sides of the broad Gaussian by the changes in effective area.

These results are of course confirmed for the real data from the *ASCA* AO2 observation of MCG−6−30−15. Figure 1 (c) shows the Fe-K line profiles (produced in the same way as for the simulated data) for the OLD and CURRENT calibration. Now statistical effects make it very hard to see any difference in the profiles. We fitted the real 3–10 keV SIS0+SIS1 data with a power-law plus relativistic Schwarzschild disk-line model. The only parameters that were fixed were $q = -3$, and the rest energy of the line (6.4 keV). We obtained the following (Tanaka *et al.* 1995 values in parentheses): a disk inclination angle of $31.6^{+2.1}_{-2.2}$ ($29.7^{+2.9}_{-3.9}$) degrees, an inner disk radius of $7.5^{+2.5}_{-1.1}$ ($7.4^{+3.6}_{-1.4}$) r_g, an outer disk radius of $20.9^{+28.5}_{-6.3}$ ($20.0^{+25.0}_{-6.4}$) r_g, and an EW of 344^{+79}_{-74} (380^{+100}_{-110}) eV. Yaqoob etal (2001b) also show that a double-Gaussian model for the Fe-K line again gives completely consistent results for the Tanaka *et al.* (1995) and TARTARUS data and calibration.

3. THE N97 SAMPLE

In the previous section we explained why changes in *ASCA* calibration should not have a significant impact on the Fe-K line parameters for any of the observations considered by LZ01. Nevertheless, we attempted to discover the origin of the results of LZ01. For this we concentrated on the N97 sub-sample, since these AGN have some of the broadest lines. N97 could not constrain the line width for all observations in their sample and, excluding these, as well as NGC 4151 and NGC 6814 (LZ01 omitted these latter two), we have used fourteen observations of twelve sources to directly compare with N97. These AGN are F9 (AO1), 3C 120 (AO1), NGC 3227 (AO1), NGC 3516 (AO1), Mkn 766 (AO1), IC 4329A (PV), NGC 5548 (PV), Mkn 841 (PV, sequence 70009000), Mkn 509 (AO1), NGC 7469 (AO1, sequence 71028030), MCG −6−30−15 (PV), NGC 3783 (AO1). The latter two sources have two observations each in this sample and we use the same notation, (1) and (2), as in N97 to distinguish them. Note that 'PV' refers to the 'Performance Verification' phase of *ASCA*.

We then repeated the N97 3–10 keV power-law plus Gaussian spectral fits using the CURRENT calibration by using the actual spectral and calibration files used by LZ01 (i.e. from TARTARUS), except for two sources (F9, and NGC 3227) which were not available in the TARTARUS database at the time. For these, we reduced the data following the methods described in Yaqoob *et al.* (1998). As will become clear, our conclusions do not depend on these details of data reduction. For convenience we shall take the liberty of referring to all fourteen of these datasets as TARTARUS spectra and calibration. We used four instruments (SIS,GIS) fitted simultaneously, as did N97 and LZ01. The best-fitting line widths and their mean statistical errors obtained using the CURRENT calibration are plotted against the corresponding N97 values (which are based on the OLD calibration) in Figures 2a and 2b respectively. The corresponding equivalent widths (EW) and mean statistical errors are shown in Figures 2c and 2d. The statistical error shown here is the straight mean of the positive and negative error on each measurement, for a $\Delta\chi^2$ criterion of 4.7 (this exact value was used by N97 and corresponds to 68% confidence for three parameters).

Figure 2 shows that all the results from TARTARUS and N97 are consistent except for three observations. These are NGC 3783(1), Mkn841, and NGC 3516, for which the TARTARUS spectral fits indicate significantly narrower Fe-K lines than N97. In order to investigate how such apparently huge differences in the best-fitting parameters could come about, for these sources we emulated OLD calibration for the TARTARUS spectra in order to isolate calibration effects and separate them from data reduction and statistical effects. To do this we used old SIS response matrices, as in N97, (`s0c1g0234p40e1_512v0_8i.rmf`, and `s1c3g0234p40e1_512v0_8i.rmf`), disabling the multiplicative effective area factors in `ascaarf`, and using v1.1 of the XRT response (see Yaqoob *et al.* 2001b for details on all these files and procedures). First, we compared the SIS Fe-K line profiles with this OLD and CURRENT calibration by fitting a power-law continuum to the 3-4 keV and 8-10 keV band only and computing the ratios of the data to this continuum model. Note that OLD and CURRENT calibration fits were performed separately, since that is how they would be compared in the literature. Figure 1 (d)–(f) shows the results, namely that the *line profiles for all three sources are very broad and the difference between OLD and CURRENT calibration is negligible.* Yet the formal best-fits from spectral fitting yield disparate results: according to LZ01, these three very broad lines are some of the narrowest. Table 1 shows the single-Gaussian results for each source and each calibration. We are able to reproduce the results of N97 with the OLD calibration and the results of LZ01 with the CURRENT calibration. How can the broad line profiles in Figure 1 (d)–(f) yield such narrow line widths from fits with the CURRENT calibration? One gets a clue by noticing that, in each source, single-Gaussian models of the line have two minima which are very close in χ^2 space (see Figure 3). In fact, if one correctly accounts for the double minima in χ^2 space, the differences in the widths from the single-Gaussian fits are not statistically significant (see Table 1). Also, it is clear from Figure 1 (d)–(f) that the narrow-line solutions are only modeling the core of a very broad profile. Clearly, *regardless of the calibration*, a single Gaussian is inadequate to model these line profiles, which are complex. However, since the continuum slope is slightly different for the OLD and CURRENT calibration, the formal best-fit can be nudged from modeling only the broad part or only the narrow core of the line. If we fit these complex lines with a double-Gaussian model we get completely consistent results between the OLD and CURRENT calibration (see Table 1). Moreover, the addition of the second Gaussian is highly statistically significant for each source and each calibration ($\Delta\chi^2$ ranges between 13.7–36.5, for the addition of two free parameters). An important lesson here is that *it is erroneous to make statements about instrument calibration, and indeed to make astrophysical inferences, based on a model which does not describe the data.* Single-Gaussian spectral fits which only model the narrow core of the line seriously underestimate the line width and equivalent width. Moreover, attempts to relate measurements of the narrow core to relativistic disk models of the line are erroneous since the core of the line very likely does not come from the disk, and the part that does, is not measured with the single-Gaussian, narrow-line fits using the CURRENT calibration. The results of N97, which modeled the broad component in the case of complex lines, are actually a fairer respresentation of the overall width and total equivalent width of the Fe-K lines.

4. COMPOSITE LINE PROFILES

We have also constructed and compared the SIS0+SIS1 composite data/model ratios for two samples, both drawn from N97. The first sample excludes only the observations of NGC 6814, MCG −6−30−15, and NGC 4151 from N97 (leaving seventeen observations). The second sample is comprised of the same fourteen observations which were used in the spectral analysis described above and shown in Figure 2. In all the following, Fe-K profiles were constructed by computing ratios of data to power-law models fitted to individual observations over the 3–4 keV and 8-10 keV bands. Figure 4(a) shows the composite profile for sample 1, using the original data files and calibration from N97 (crosses), with the corresponding composite using TARTARUS data files and calibration (filled circles). Figure 4(b) shows the composite profile for sample 2, this time *using only the* TARTARUS *spectral files* but first fitted with emulated OLD calibration (crosses), and then compared to fitting with the TARTARUS (CURRENT) calibration. The OLD calibration was emulated as described above in §2 and 3. Three things are abundantly clear from Figure 4. (1) Calibration differences (and for that matter, data extraction differences) do not have a discernable effect on the composite profiles; (2) all the composites are very broad, with some asymmetry in the red wing, which extends down to $\sim$ 4 keV; (3) inclusion of MCG −6−30−15 in the composite does not bias the composite profiles.

LZ01 found an apparently large difference in the comparison of composite line profiles from N97 and TARTARUS (see their Figure 2). This difference was exaggerated due to at least two factors. First, they compared a scaled version of the fit to the N97 composite line profile with their own composite data/model ratio. The line profile and data/model ratio are not equivalent, with the former being the latter multipled by the continuum slope. As this is steep, the effect is to de-emphasize the strength of the red wing (and enhance the blue) in the appearance of the ratio. LZ01 used this to support their scientific conclusion, when it is in fact a difference in presentation of the data. Moreover, LZ01 used a slightly different method for calculating the average ratio compared to N97. Before averaging data/model ratios from different sources they must first be rebinned so that they all have the same binning. In this binning process, LZ01 attempted to account for the fact that some input bins overlap more than one output bin since the input bin widths could be larger than the output bin widths. However, they distribute the value in an input bin over the output bins by an amount proportional to the ratio of the width of the output bin to the input bin width. In the case that an input bin boundary falls inside an output bin, it is the fraction of the output bin width that overlaps the input bin that is used. LZ01 explicitly used this method to conserve numbers of photons during the rebinning. However, this method is incorrect since we are dealing with a *ratio*. Only the error in the ratio should be weighted by the method described above, not the ratio itself. This error in LZ01 causes them to systematically underestimate the data/model ratio in all bins because the output bins will have, most of the time, less than the true data/model ratio, and never more. Also, since the input bin-width distribution could be very different for the different data sets that the average is comprised of, it is even possible that the average ratio is distorted. These errors in LZ01 are the cause of the discrepancies with N97. The ratios shown in our Figure 4 were computed by correct rebinning of the input data/model ratios but we note that this causes only very small differences in the ratio compared to the method of N97 (in which fractional bin overlaps were not treated rigorously).

We reiterate here something that has already been stated in N97. That is, mean line profiles serve only an illustrative purpose and it can be highly misleading to try and model them since they are obtained by adding sources with different continuum spectra, line shapes, and fluxes. For example, suppose we have a sample in which 50% of the line profiles have a strong red wing and the other 50% have a strong blue wing. From the composite spectrum one would conclude that the average source has a symmetric line profile, when in fact not a single source may possess such a profile. Clearly, analyses which model average profiles presuppose that the individual profiles and continuua are similar, but this need not be true at all.

5. CONCLUSIONS

We find that the width, equivalent width, and shape of the Fe-K lines in AGN have not been significantly affected by changes in the *ASCA* calibration over a period of more than eight years. In particular, the width and equivalent width change by only $\sim 8\%$ or less. The red wing, in the case of a higly skew Fe-K line profile as in MCG $-6-30-15$ is reduced by a similar magnitude. In most cases the statistical errors are larger, so the changes in *ASCA* calibration are inconsequential for almost all *ASCA* observations. We also compared the sample composite Fe-K line profiles using OLD and CURRENT calibration and find that the differences are still not statistically significant. In some individual cases the Fe-K lines are complex so single-Gaussian models are inadequate for describing the profile and consequently only model a portion of the line. Then, the line width and equivalent width may be seriously understimated, leading to erroneous conclusions about the astrophysics of the line and about instrument calibration. When adequately modeled, we again find no significant difference in the Fe-K line parameters with respect to changes in calibration.

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Table 1. Single and Double-Gaussian Models for NGC 3783, Mkn 841, and NGC 3516

	E_N (keV)	σ_N (keV)	EW_N (eV)	E_B (keV)	σ_B (keV)	EW_B (eV)	χ^2(d.o.f)	$\Delta\chi^2$ †
NGC3783(1)								
S (OLD)				$6.13^{+0.16}_{-0.19}$	$0.69^{+0.36}_{-0.27}$	527^{+346}_{-219}	804.5(784)	
S (CURRENT)	$6.41^{+0.16}_{-0.50}$	$0.0^{+1.09}_{-0.00}$	169^{+45}_{-40}				806.7(784)	
D (OLD)	$6.41^{+0.05}_{-0.06}$	0.001(f)	114^{+44}_{-59}	$5.88^{+0.32}_{-0.41}$	$0.91^{+0.91}_{-0.44}$	469^{+761}_{-253}	777.5(782)	27.0
D (CURRENT)	$6.41^{+0.54}_{-0.55}$	0.001(f)	129^{+54}_{-54}	$5.88^{+0.36}_{-0.44}$	$1.35^{+0.71}_{-0.30}$	700^{+474}_{-314}	777.3(782)	29.4
Mkn 841								
S (OLD)				$6.11^{+0.41}_{-0.26}$	$0.70^{+0.35}_{-0.66}$	738^{+575}_{-355}	422.6(398)	
S (CURRENT)	$6.48^{+0.09}_{-0.08}$	$0.09^{+0.79}_{-0.09}$	257^{+116}_{-101}				419.8(398)	
D (OLD)	$6.51^{+0.10}_{-0.12}$	0.001(f)	154^{+128}_{-102}	$5.87^{+0.37}_{-0.49}$	$0.72^{+0.56}_{-0.48}$	556^{+672}_{-288}	407.2(396)	15.4
D (CURRENT)	$6.51^{+0.11}_{-0.09}$	0.001(f)	250^{+96}_{-178}	$5.64^{+0.67}_{-0.42}$	$0.59^{+1.09}_{-0.30}$	324^{+885}_{-231}	406.1(396)	13.7
NGC3516								
S (OLD)				$6.09^{+0.12}_{-0.14}$	$0.65^{+0.22}_{-0.19}$	360^{+143}_{-106}	873.4(770)	
S (CURRENT)	$6.33^{+0.07}_{-0.22}$	$0.23^{+0.60}_{-0.10}$	171^{+245}_{-45}				884.3(770)	
D (OLD)	$6.41^{+0.04}_{-0.05}$	0.001(f)	75^{+22}_{-40}	$5.86^{+0.36}_{-0.22}$	$0.77^{+0.38}_{-0.11}$	294^{+233}_{-84}	840.6(768)	32.8
D (CURRENT)	$6.41^{+0.08}_{-0.04}$	0.001(f)	79^{+30}_{-34}	$5.91^{+0.37}_{-0.33}$	$1.00^{+0.93}_{-0.24}$	318^{+581}_{-115}	847.8(768)	36.5

Note. — Comparison of the OLD and CURRENT calibration for single (S) and double-Gaussian (D) models of the Fe-K line. Subscripts N and B denote the parameters (center energy, E, intrinsic width, σ, and equivalent width, EW) for the narrow and broad Fe-K line components respectively. Statistical errors are 68% confidence for four ($\Delta\chi^2 = 4.70$) and six ($\Delta\chi^2 = 7.00$) interesting parameters, for the single and double-Gaussian models respectively. (†) $\Delta\chi^2$ is the difference in χ^2 between single and double-Gaussian fits.

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Figure Captions

Figure 1

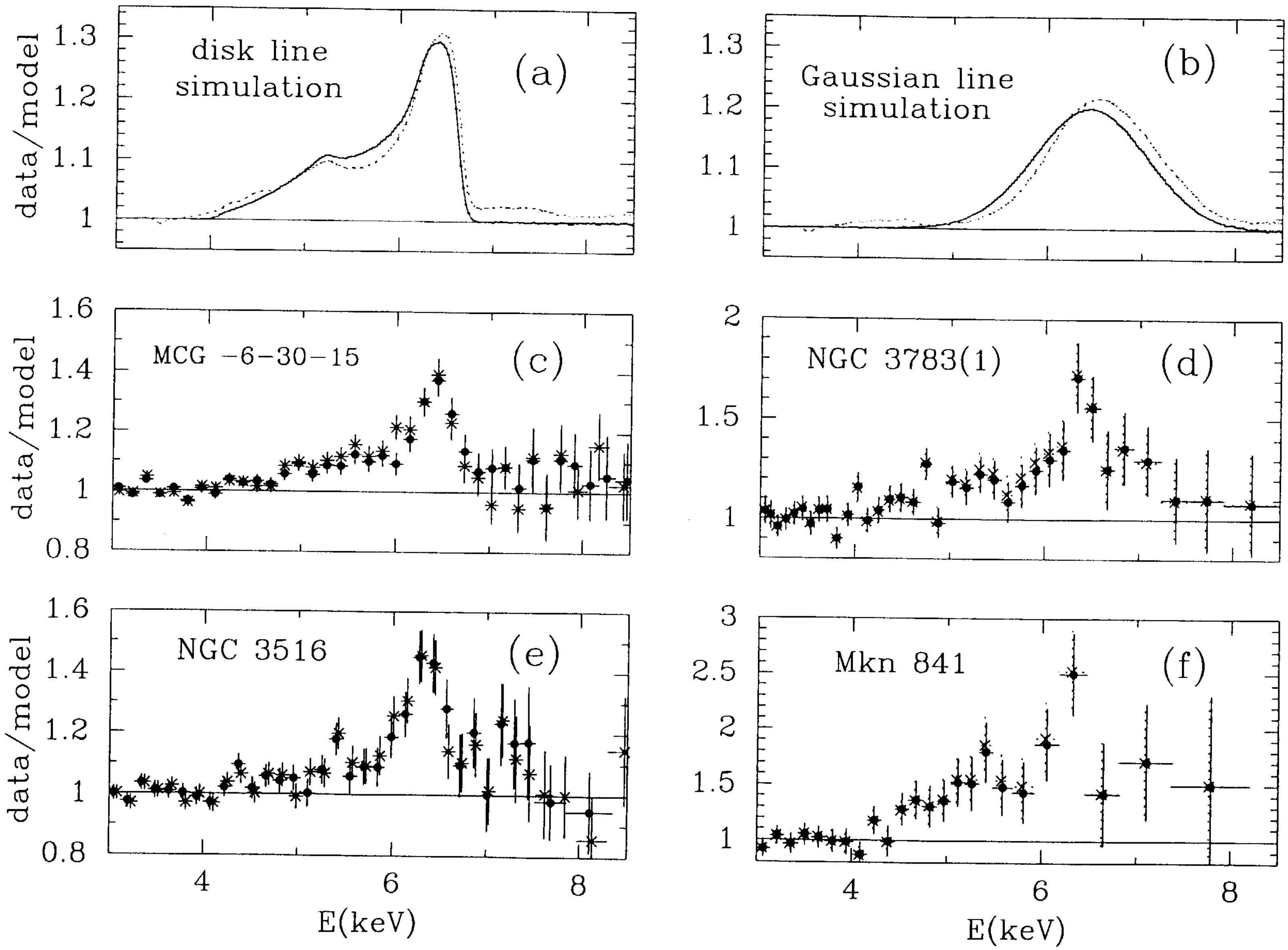
(a) Isolation, from other effects, of differences between OLD and CURRENT *ASCA* calibration and their effect on a typical Fe-K relativistic disk line profile. Shown is a simulation of co-added SIS0 plus SIS1 data for the relativistic disk line model for MCG −6−30−15 of Tanaka *et al.* (1995) described in the text, using OLD calibration (solid line). An extremely large exposure time was used (10^{10} s) to eliminate statistical effects. The dotted line shows the line profile one would deduce if the simulated data were then fitted in the same way as real data, using the CURRENT calibration instead. (b) As (a) but for a typical broad Gaussian line profile with parameters as described in the text. (c) Effect of changes in the *ASCA* calibration on the Fe-K line profile using the actual data for MCG −6−30−15 (*ASCA* AO2). SIS0 and SIS1 are data co-added. See text for details. Crosses correspond to the original Tanaka *et al.* (1995) data and calibration, and filled circles correspond to TARTARUS data and calibration. (d), (e), (f) The SIS0+SIS1 Fe-K line profiles for the three data sets which show the largest discrepancies in spectral fitting results between the OLD and CURRENT calibration. Yet the line profiles using the OLD and CURRENT calibration (crosses and filled circles respectively) are virtually identical. All three are *very broad* and have large equivalent widths (see Table 1). The line profiles are complex and cannot be adequately modeled with a single Gaussian. Thus, a single Gaussian only models the core of the line if the CURRENT calibration is used. Consistent results are obtained between OLD and CURRENT calibration when a double-Gauissian model is used (see Table 1).

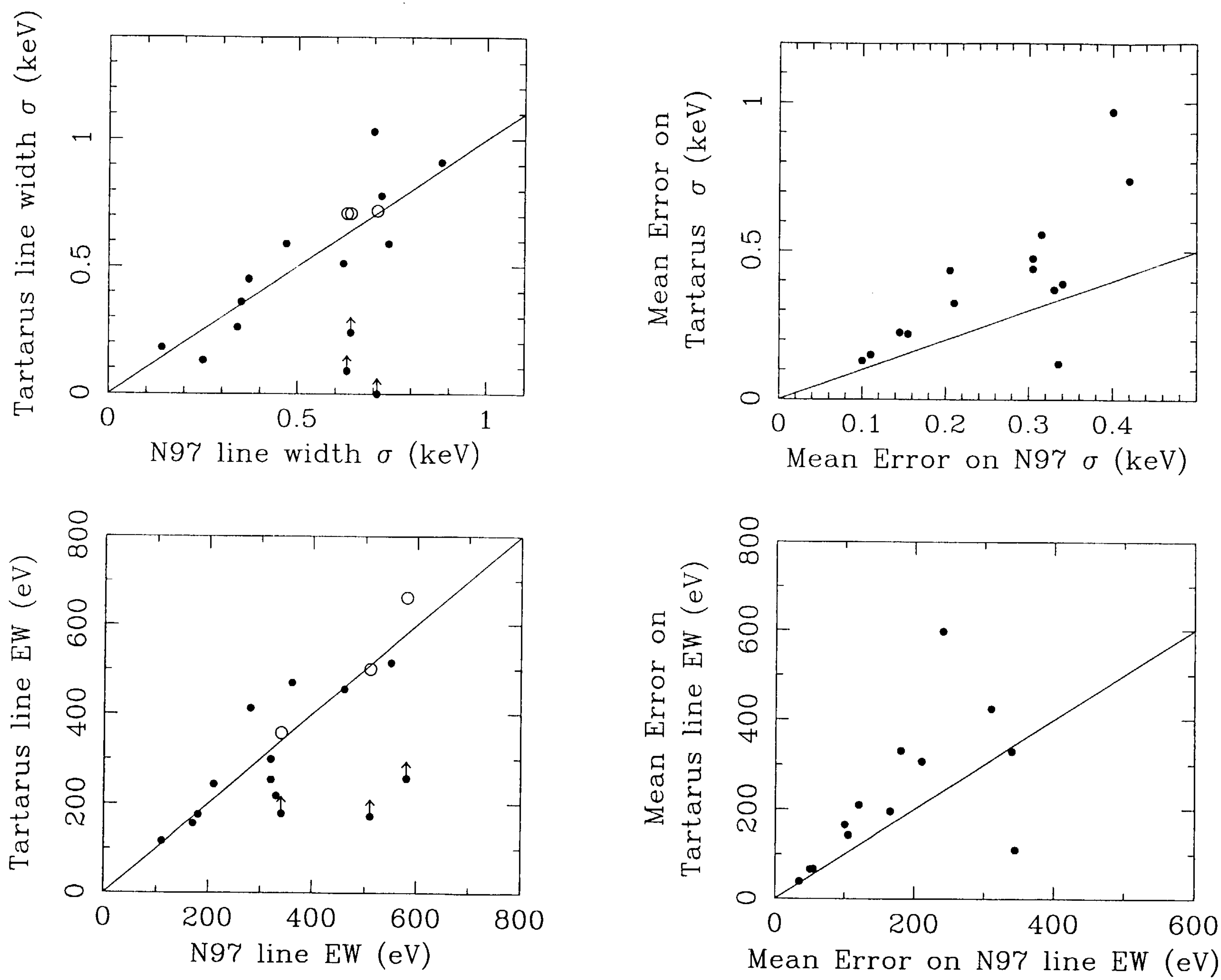
Figure 2

Comparison of the N97 and TARTARUS results for the deduced width and equivalent width of the Fe-K lines for 14 observations of 12 AGN, when modeled only with a single Gaussian (top panels). Also shown are the corresponding mean statistical errors of the measurements (bottom panels). The observations are from a sub-sample which is common to both the samples of N97 and LZ01 (see text). The solid lines correspond to the case if the N97 data (OLD calibration) and TARTARUS data (CURRENT calibration) were to give identical results. The statistical errors are the straight means of the positive and negative errors deduced from a $\Delta\chi^2 = 4.7$ criterion, identical to that used by N97, and corresponds to 68% confidence for three interesting parameters. Filled circles are the direct comparisons for single-Gaussian fits. Open circles, for NGC 3783(1), NGC 3516, Mkn 841, correspond to the second minimum from the single-Gaussian fits with TARTARUS data (also see Figure 3). Table 1 shows that the broad-line widths and equivalent widths using double-Gaussian models are completely consistent for the OLD and CURRENT calibration and correspond to these second minima. The single-Gaussian narrow-line solutions (indicated by arrows) obviously underestimate the true width and equivalent width of the lines much more than the broad-line solutions. The actual line profiles for these three cases are shown in Figure 1 and are *very broad.*

Figure 3 The change in χ^2 as the line width in the single-Gaussian model is varied away from the best-fit with the CURRENT calibration for NGC 3783(1). It can be seen that there are two minima, which correspond to the solutions of LZ01, N97. This indicates that the line is complex and that a single Gaussian is inadequate to model the line, which is very broad (see Figure 1).

Figure 4 Average SIS0+SIS1 Fe-K line profiles in the form ratios of data to power-law models fitted independently to individual observations. (a) Seventeen observations from the N97 sample (excluded are observations of MCG −6−30−15, NGC 4151 and NGC 6814). Crosses are the original N97 data and calibration. Filled circles are the TARTARUS data and calibration. (b) Isolation of calibration effects for the N97 sub-sample of fourteen observations discussed in this paper. Crosses correspond to emulated OLD calibration, and filled circles correspond to the TARTARUS (CURRENT) calibration. In both cases the TARTARUS spectra were used, thus eliminating effects of data extraction and processing.


data/model
disk line
simulation
(a)
Gaussian line
simulation
(b)
MCG -6-30-15
(c)
NGC 3783(1)
(d)
NGC 3516
(e)
Mkn 841
(f)
E(keV)
E(keV)


Tartarus line width σ (keV)
N97 line width σ (keV)
Mean Error on Tartarus σ (keV)
Mean Error on N97 σ (keV)
Tartarus line EW (eV)
N97 line EW (eV)
Mean Error on Tartarus line EW (eV)
Mean Error on N97 line EW (eV)

$\Delta\chi^2$ relative to single-Gaussian best-fit (CURRENT calibration)