A Suzaku observation of the ULIRG IRAS19254-7245: disclosing the AGN component.

V. Braito\textsuperscript{1,2}, J.N. Reeves\textsuperscript{2,3}, R. Della Ceca\textsuperscript{4}, A. Ptak\textsuperscript{2,5}, G. Risaliti\textsuperscript{6,7}, and T. Yaqoob\textsuperscript{2,5}

\textsuperscript{1} X-Ray Astronomy Group, Department of Physics and Astronomy, Leicester University, Leicester LE1 7RH, UK e-mail: bv67@star.le.ac.uk
\textsuperscript{2} Department of Physics and Astronomy, Johns Hopkins University, Baltimore, MD 21218.
\textsuperscript{3} Astrophysics Group, School of Physical and Geographical Sciences, Keele University, Keele, Staffordshire ST5 5BG
\textsuperscript{4} INAF-Osservatorio Astronomico di Brera, via Brera 28, I-20121 Milan, Italy.
\textsuperscript{5} Astrophysics Science Division, Code 662, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, USA
\textsuperscript{6} INAF-Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125 Florence, Italy.
\textsuperscript{7} Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138.

Preprint online version: May 7, 2009

ABSTRACT

We discuss here a long Suzaku observation of IRAS 19254-7245 (also known as the Superantennae), one of the brightest and well studied Ultra Luminous Infrared Galaxies in the local universe. This long observation provided the first detection of IRAS 19254-7245 above 10 keV, and measured a 15–30 keV flux of $\sim 5 \times 10^{37}$ erg cm$^{-2}$ s$^{-1}$. The detection above 10 keV has allowed us to unveil, for the first time, the intrinsic luminosity of the AGN hosted in IRAS 19254-7245, which is strongly absorbed ($N_H \sim 3 \times 10^{24}$ cm$^{-2}$) and has an intrinsic luminosity in the QSO regime ($L(2-10$ keV) $\sim 3 \times 10^{44}$ erg s$^{-1}$).

The 2–10 keV spectrum of IRAS 19254-7245 is remarkably hard ($\Gamma \sim 1.2$), and presents a strong iron line (EW $\sim 0.7$ keV), clearly suggesting that below 10 keV we are seeing only reprocessed radiation. Since the energy of the Fe K emission is found to be at $\sim 1$ keV, consistent with He-like Fe, and its EW is too high to be explained in a starburst dominated scenario, we suggest that the 2–10 keV emission of IRAS 19254-7245 is dominated by reflection/scattering from highly ionized matter. Indeed, within this latter scenario we found that the photon index of the illuminating source is $\Gamma = 1.87^{+0.11}_{-0.21}$, in excellent agreement with the mean value found for radio quiet obscured AGN.

Key words. galaxies: active – galaxies: individual (IRAS 19254-7245) – galaxies: Seyfert – X-rays: galaxies

1. Introduction

Ultra Luminous Infrared Galaxies (hereafter ULIRGs) are an enigmatic class of sources which emit most of their energy in the far-infrared (FIR, 8–1000\,$\mu$m) domain (Sanders & Mirabel, 1996), with luminosities above $\sim 10^{12}$ L$_\odot$, i.e., comparable to QSO luminosities. The importance of understanding the physical processes at work in ULIRGs is strengthened by the observational evidence that they are generally advanced mergers of gas-rich galaxies; these events are now considered to be at the origin of some of the massive elliptical and S0 galaxies (Hopkins et al., 2005, 2006; Springel et al., 2005) and the QSO stage could be a phase during the evolution of these systems. However, understanding their physical nature is complicated by the large amount of obscuration from dust present in these sources, which makes it difficult to directly observe the nuclear source.

X-ray observations of ULIRGs performed with XMM-Newton (Franceschini et al., 2003, Braito et al., 2003) and Chandra (Ptak et al., 2003; Teng et al., 2005) and recently Suzaku (Teng et al., 2009) have proved to be a fundamental tool to disentangle the contribution of starburst and AGN activity and to investigate the presence of hidden AGNs in these sources. These observations have shown that ULIRGs are intrinsically faint X-ray sources, their observed X-ray luminosities being typically $L(2-10$ keV) $\lesssim 10^{42} - 10^{43}$ erg s$^{-1}$. The X-ray spectra of ULIRGs are complex and present the signatures of both the starburst and the AGN activity, confirming the composite nature of ULIRGs. These studies have also shown that more than half of the local brightest AGN-ULIRGs (5/8) host an obscured AGN, with three being Compton Thick ($N_H > 10^{24}$ cm$^{-2}$; NGC6240, Vignati et al. 1999, Mrk 231, Braito et al. 2004 and UGC5101, Imanishi et al. 2003). Observations above 10 keV are thus fundamental for measuring the intrinsic X-ray luminosity of obscured AGN hosted in ULIRGs and its contribution to their high observed FIR emission.

IRAS 19254-7245 (also known as the SuperAntennae) belongs to a flux limited sample at 60\,$\mu$m composed of the 15 brightest nearby ULIRGs (Genzel et al., 1998). Located at $z = 0.062$, IRAS 19254-7245 has an infrared luminosity of $L_{6-1000\mu m} = 1.1 \times 10^{12}L_\odot$ corresponding to a bolometric luminosity of $L_{bol} \sim 4 \times 10^{45}$ erg s$^{-1}$. Like most of the ULIRGs, IRAS 19254-7245 is a merger system of two gas-rich spiral galaxies.

The southern nucleus, optically classified as a Seyfert 2, is both a powerful starburst and an obscured AGN, while there is no evidence of AGN activity in the northern nucleus.

A previous X-ray observation of IRAS 19254-7245 performed with XMM-Newton suggested that this ULIRG harbors a heavily obscured and high-luminosity AGN. Indeed the hard
power-law continuum above 2 keV (photon index $\Gamma = 1.3$) and the detection of a strong Fe-Kα emission line at 6.5 ± 0.1 keV ($EW \sim 1.4$ keV) were highly indicative of a Compton-thick source (Braito et al., 2003). As the two nuclei are located ∼ 9 arcsec apart from each other, XMM-Newton could not resolve them; however the centroid of the hard X-ray emission was spatially coincident with the southern nucleus. Chandra observation which would settle or solve this issue has not been performed yet.

The best fit model obtained for the 0.5–10 keV X-ray emission detected with XMM-Newton was composed by a strong soft thermal component, associated with the starburst emission and a hard X-ray component associated with the AGN activity.

This AGN component was parametrized with a Compton thick AGN model and was composed of a pure Compton-reflected continuum (with $\Gamma \sim 1.8$), a scattered power law component and a strong Fe emission line. The observed 2–10 keV luminosity of the AGN was found to be $\sim 4 \times 10^{45}$ erg s$^{-1}$. Due to the limited energy bandpass of XMM-Newton, this observation did not allow us to directly see the intrinsic continuum, thus to measure the absorbing column density and the intrinsic X-ray luminosity of IRAS 19254-7245.

Here we present the analysis of a deep Suzaku observation (∼ 150 ksec) of this system, which allowed us for the first time to constrain the intrinsic power of the AGN hosted in IRAS 19254-7245, as well as to investigate in detail the properties of the Fe line complex. In Sec. 2 we present the Suzaku data analysis and results, while in Sec. 3 we discuss the overall scenario for X-ray emission of IRAS 19254-7245. Throughout this paper, the current popular cosmology is assumed with $H_0 = 73$ km s$^{-1}$ Mpc$^{-1}$; $\Omega_M = 0.27$ and $\Omega_{\Lambda} = 0.73$.

2. Observations and data reduction

Suzaku (Mitsuda et al., 2007) is the fifth Japanese X-ray satellite, which carries on board four sets of X-ray mirrors, with a X-ray CCD (XIS; three front illuminated, FI, and one back illuminated, Bl) (Koyama et al., 2007) at their focal plane, and a non imaging hard X-ray detector (HXD, Takahashi et al., 2007). The latter is composed by 2 main instruments: the Si PIN photodiodes and the GSO scintillator counter. Altogether the XIS and the HXD-PIN cover the 0.5–10 keV and 12–70 keV bands respectively.

Suzaku observed IRAS 19254-7245 for a total exposure time of about 150 ksec; the observation was performed at the beginning of November 2005, when all the 4 XIS were still working. Cleaned event files from the version 2 of the Suzaku pipeline processing were used with the standard screening. The net exposure times are 97.5 ksec for each of the XIS and 142.1 ksec for the HXD-PIN. The XIS source spectra were extracted from a circular region of 2.9′ radius (which correspond to an energy encircled fraction of 90%) centered on the source. Background spectra were extracted from two circular regions of 2.4′ radius offset from the source and the calibration sources. The XIS response (rmfs) and ancillary response (arfs) files were produced, using the latest calibration files available, with the tools xisrmfs and xissimarfgen respectively. The net 0.5–10 keV count rates are: $(1.67 \pm 0.07) \times 10^{-2}$ cts/s, $(1.57 \pm 0.06) \times 10^{-2}$ cts/s, $(1.55 \pm 0.06) \times 10^{-2}$ cts/s and $(1.84 \pm 0.09) \times 10^{-2}$ cts/s for the XIS0, XIS2, XIS3 and XIS1 respectively. The source spectra from the three FI CCDs were then combined, while the Bl (the XIS1) spectrum was kept separate and fitted simultaneously. The net XIS source spectra were then binned in order to have a minimum S/N of 4 in each energy bin and $\chi^2$ statistics have been used.

2.1. HXD-PIN data reduction

For the HXD-PIN data reduction and analysis we followed the latest Suzaku data reduction guide (the ABC guide Version 2). For the analysis we used the rev2 data, which include all 4 cluster units, and the best background available (Fukazawa et al., 2009), which account for the instrumental background (NXB; Takahashi et al., 2007; Kokubun et al., 2007). We then simulated a spectrum for the cosmic X-ray background counts (Boldt, 1987; Gruber et al., 1999) and added it to the instrumental one.

At the time of the writing two different instrumental background files have been released (background A or “quick” background and the background D or “tuned” background; Mizuno et al. 2008; Fukazawa et al. 2009). We tested both the instrumental backgrounds and we included a ±10% uncertainty in the level of the CXB. The inspection of the IRAS 19254-7245 net spectrum shows that the source is detected in the 15–30 keV with both the two background files. The net count rate in the 15–30 keV using background A and D are respectively $1.59 \pm 0.14 \times 10^{-2}$ cts s$^{-1}$ and $1.48 \pm 0.14 \times 10^{-2}$ cts s$^{-1}$ and the corresponding background count rates are 0.25 ± 0.004 cts s$^{-1}$ and 0.26 ± 0.003 cts s$^{-1}$.

We then decided to use the latest release (background D), which is affected by lower systematic uncertainties (of about 1.3% at 1σ), which correspond to about half of the first release of the N XB. Using this background IRAS 19254-7245 is detected in the 15–30 keV band at ∼ 5.5% above the background (a total of ∼ 2000 net counts have been collected), corresponding to a signal-to-noise ratio $S/N = 10.8$. The dominant component in the background is the instrumental one with a count rate of 0.24 ± 0.001cts s$^{-1}$, while the CXB count rate ranges from 1.4 × 10$^{-2}$ to 1.6 × 10$^{-2}$ when we include the ±10% uncertainty on its level. If we then assume a 10% higher CXB level the source is still detected at 5.0% above the background (mean count rate in the 15–30 keV is $1.35 \pm 0.14 \times 10^{-2}$ cts s$^{-1}$) with $S/N = 9.7$, thus the detection of IRAS 19254-7245 is not dependent on the CXB absolute level. As a further check for the level of the CXB we analyzed the Suzaku observation of the Lockman Hole performed in May 2007. We performed an identical analysis of the CXB HXD-PIN observation as we did for IRAS 19254-7245. The flux of the CXB measured with the Lockman Hole observation is $F(15–50$ keV)$= 1.1 \pm 0.2 \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$ (corresponding to a flux

1 Later that month Suzaku XIS2 failed. No charge injection (see: http://suzaku.gsfc.nasa.gov/docs/suzaku/analysis/sci.html) was applied at the time of the observation so the nominal energy resolution of the XIS at 6 keV was degraded with respect to the prelaunch one.

2 The screening filter all events within the South Atlantic Anomaly (SAA) as well as with an Earth elevation angle (ELEV) < 5° and Earth day-time elevation angles (DYE_ELV) less than 20°. Furthermore also data within 256 s of the SAA were excluded from the XIS and within 500s of the SAA for the HXD. Cut-off rigidity (COR) criteria of > 8 GV for the HXD data and > 6 GV for the XIS were used.

3 see http://legacy.gsfc.nasa.gov/suzaku/doc/xrt/suzakumemo-2008-04.pdf

4 http://heasarc.gsfc.nasa.gov/docs/suzaku/analysis/abc/

5 http://www.astro.isas.jaxa.jp/suzaku/doc/suzakumemo/suzakumemo-2008-03.pdf
density of $3 \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$ deg$^{-2}$, in agreement with the flux of the simulated CXB ($F(15-50$ keV$)= 1.0 \pm 0.2 \times 10^{-11}$ erg cm$^{-2}$ s$^{-1}$) and with the flux measured with BeppoSAX (Frontera et al. 2007) and the recent measurement obtained with Swift (Moretti et al. 2009).

Since the HXD-PIN is a non imaging detector, and taking into account the large field of view of the instrument ($0.56$ deg $\times 0.56$ deg), we first checked that the detection is not due to another X-ray source. In particular, we searched the NED data base for known AGN in the HXD field of view and we inspected the available XMM-Newton observation. Indeed, two X-ray sources with a 2–10 keV flux comparable to IRAS 19254-7245’s emission are detected with XMM-Newton. The two sources are both AGNs, belonging to the XMM Bright Survey sample (XBS J193138.9-725115 and XBS J193248.8-723355; Della Ceca et al. 2004; Caccianiga et al. 2008). XBS J193138.9-725115 is a type 1 AGN ($z=0.701$) and its XMM-Newton spectrum is well modeled with single unabsorbed power law component ($\Gamma \sim 2$) with no evidence of absorption. XBS J193248.8-723355 is a Seyfert 2 at $z=0.287$; the X-ray emission of this source is in agreement with the classification as a Compton-Thin Seyfert; indeed, a low energy cut-off is present in the XMM-Newton spectrum corresponding to $N_H \sim 10^{22}$ cm$^{-2}$ and there there is no evidence that this source could be Compton thick. The predicted 15–30 keV emission from these sources (derived from the analysis of the XMM-Newton and Suzaku data) is less than $\sim 10^{-13}$ erg cm$^{-2}$ s$^{-1}$, which is below the HXD-PIN sensitivity and a factor of $\sim 50$ below the measured 15–30 keV flux.

For the spectral analysis we re-binned the HXD-PIN spectrum of IRAS 19254-7245 to have a signal-to-noise ratio of 5 in each energy bin. In order to have a first estimate of the 15–30 keV flux and luminosity of IRAS 19254-7245 we fitted the HXD-PIN spectrum assuming a power law model with $\Gamma = 1.9$ (i.e a standard AGN value; Reeves & Turner 2000; Page et al. 2004; Caccianiga et al. 2004). Taking into account the systematic uncertainties of the NXB model, with this simple model we obtained $F(15-30$ keV$)\sim 5.2 \pm 1.1 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$, and $L(15-30$ keV$)\sim 4.7 \times 10^{43}$ erg s$^{-1}$. The extrapolation of this model down to 2 keV predicts an intrinsic luminosity (which does not include a correction for Compton scattering) of the AGN in IRAS 19254-7245 of $L(2-10$ keV$)\sim 9.5 \times 10^{44}$ erg s$^{-1}$.

2.2. The broad band spectrum

Overall the Suzaku observation confirms the XMM-Newton results. A good fit for the 0.5–10 keV Suzaku data is obtained with a model composed by: a thermal emission component ($kT = 0.64 \pm 0.10$ keV and abundance $Z = Z_\odot$, likely associated with the starburst activity), a strong hard power law component ($\Gamma = 1.2 \pm 0.1$, likely associated with the AGN emission), and a strong iron K emission line ($EW = 710 \pm 190$ eV, with respect to the observed continuum). The flux and observed luminosity, $F(2-10$ keV$)\sim 2.9 \times 10^{-13}$ erg cm$^{-2}$ s$^{-1}$, and $L(2-10$ keV$)\sim 2.5 \times 10^{42}$ erg s$^{-1}$, are found to be consistent with the values measured with XMM-Newton. The de-absorbed luminosity of the starburst component is $L(0.5-2$ keV$)\sim 4 \times 10^{42}$ erg s$^{-1}$ also in agreement with luminosity measured with XMM-Newton.

We then tested the best fit model obtained for the XMM-Newton spectrum. In this model the soft X-ray emission is still modeled with a thermal component, while the hard ($\Gamma \sim 1.2$) power law component is replaced with a pure Compton reflected continuum (the pexrav model in Xspec; Magdziarz & Zdziarski, 1995, with an intrinsic $\Gamma = 1.8$) combined with a moderately absorbed ($N_H \sim 5 \times 10^{21}$ cm$^{-2}$) power law component with the same $\Gamma$, representing the possible scattered emission. The parameters of the reflection component are: an inclination angle $i = 45^\circ$, abundance $Z = Z_\odot$ (using the abundances of Wilms et al. 2000) and a reflection fraction (defined by the subtending solid angle of the reflector $R = \Omega/2\pi$) R fixed to 1. The normalization of this component was allowed to vary. This model is a good fit to the XIS data alone ($\chi^2$/dof = 159/144, see Fig. 1) and the fluxes and observed luminosity of the AGN components are consistent with the values measured with the XMM-Newton observation. However, this model clearly under predicts the counts detected above 10 keV (see Fig. 1 green data points). Indeed, when we include in the fit the HXD-PIN data, fixing the cross-normalization between the XIS and the PIN to 1.16 (Manabu et al. 2007; Maeda et al. 2008) the model is statistically unacceptable ($\chi^2$/dof = 231/147) and even allowing for a harder photon index ($\Gamma \sim 1.3$) it is not a good representation of the 0.5–30 keV emission ($\chi^2$/dof = 220/146).

In order to account for the excess detected above 10 keV, we added to the model a second heavily absorbed power law component. Since the HXD/PIN residuals suggest the presence of a high column density absorber, we used for this component the model by Yaqoob (1997) (pexabs in Xspec), which correctly takes into account Compton down-scattering. Indeed, for high column densities the observed X-ray continuum may also be suppressed by Compton down-scattering, and the intrinsic absorption

Fig. 1. 0.5-30 keV Suzaku XIS-FI (black data points), XIS-BI (red) and HXD-PIN (green) data and ratio with the 0.5-10 keV best fit model. The model is composed by: a thermal emission component dominating the 0.5-2 keV emission, a Compton reflected continuum ($R=1$, $\Gamma = 1.8$) and a strong Fe emission line at 6.7 keV (EW $\sim$ 700 eV). A clear excess is present above 10 keV, which we attribute to the intrinsic X-ray emission of IRAS 19254-7245 transmitted through the high column density absorber.

---

http://www.astro.isas.jaxa.jp/suzaku/doc/suzakumemo/suzakumemo-2007-11.pdf; http://www.astro.isas.jaxa.jp/suzaku/doc/suzakumemo/suzakumemo-2008-06.pdf
luminosity must be corrected by a factor $e^\tau$, where $\tau = N_H \sigma_T$ and $\sigma_T = 6.65 \times 10^{-25} \text{cm}^2$ is the Thomson cross-section.

This model provides now a good fit for the 0.5–30 keV spectrum ($\chi^2$/dof = 164/145; see Fig. 2 upper panel and Table 1 model A). However, we found a low value of the reflection fraction with respect to this primary absorbed power law component ($R < 0.1$). This suggests that the line and the hard 2–10 keV spectrum are unlikely to be produced by reflection off cold material. Indeed, the broad band continuum could be also reproduced by a model without the reflected component (see Table 1 model B). Statistically this model gives a slightly worse fit ($\chi^2$/dof = 181/146) than the previous one, but it is not able to account for the hardness of the 2–10 keV emission. In particular clear residuals are present in the 5–10 keV band where the reflected component dominates (see Fig. 2 top panel). Finally, if we allow the photon index to vary, we found that although the fit improves we again need an unusually hard photon index of the power law component ($\Gamma = 1.20^{+0.17}_{-0.04}$, $N_H = 4 \pm 1 \times 10^{24} \text{cm}^{-2}$; see Table 1 model C).

One of the main results of this observation is that, although we can confirm the presence of a strong Fe line as detected with XMM-Newton, the centroid of this line is now at 6.67 ± 0.05 keV in the rest frame ($EW \sim 0.7$ keV; for the model without the reflected component), consistent with He-like Fe. Furthermore, the line appears to be marginally broad ($\sigma = 0.12 \pm 0.06$ keV). The inclusion of the line in the model improves the fit by $\Delta \chi^2 = 51$ for 3 degree of freedom. However, if we constrain the line to be unresolved the fit is worse only by $\Delta \chi^2 = 5$. In order to check the energy and the intrinsic width of the Fe line detected in the XIS, we examined the spectra of the 55Fe calibration source lines, which are located on two corners of each XIS. The calibration source produces lines from Mn Kα1 at 5.899 keV and Mn Kα2 at 5.899 keV. From the spectrum of the calibration source we found that the line energy is shifted red-wards by about 25 eV, while the residual width is $\sigma \sim 50$ eV which confirms that the broadening of the line is intrinsic to the source and not instrumental. After the subtraction in quadrature of this residual width we get $\sigma_{\text{int}} = 110 \pm 60$ eV. However, taking into account the present count statistics of the data, this broadening could be due to the presence of other line components, which are not resolved. In particular, the line profile can be explained with three unresolved Gaussian lines (at 6.4 keV, 6.7 keV and 6.96 keV; see Fig. 3). Statistically this model gives a similar good fit than models with a single broad line ($\chi^2$/dof = 161/145) with the strongest line being the 6.7 keV line ($EW \sim 400$ eV). Though the other two lines are not statistically required a weak ($EW < 200$ eV) emission line could be present at the energy of the neutral Fe Kα, while the 90% upper limit on the 6.96 keV line is 150 eV.

Since the energy centroid of the line detected with Suzaku appears to be in disagreement with the XMM-Newton results and the EW appears to be lower we went back to the XMM-Newton data and compared them with the Suzaku results. The exposure of the XMM-Newton observation was only 20 ksec and when we take into account the errors on the flux and line continuum we found that the two lines are consistent within each others. Furthermore, the energy centroids are consistent within the errors ($E_{\text{XMM}} = 6.5 \pm 0.1$ keV; $E_{\text{Suzaku}} = 6.66 \pm 0.05$ keV). Finally, a possible blending of 3 lines was also present in the XMM-Newton data, but again the low exposure time of this observation does not allow a more detailed analysis of the Fe line profile.

From a statistical point of view all these models are a good representation of the 0.5–30 keV emission, but they are unable to account for the hardness of the continuum. Furthermore the line energy of the strongest emission line is at odds with a scenario where the 2–10 keV emission is dominated by reflection/scattering off cold material as assumed with the

\footnote{for the scenario with the reflected component the fit improves by $\Delta \chi^2 = 40$}

\footnote{This residual width is due to the degradation of the XIS after the launch and prior to the correction with the charge injection}

\footnote{The intrinsic width of the Fe line in the spectrum of IRAS 19254-7245 can be $\sigma_{\text{int}} = \sigma_{\text{mean}} - \sigma_{\text{lamp}}$ (where $\sigma_{\text{mean}}$ is the measured width and $\sigma_{\text{lamp}}$ is the width of the calibration lines)}
Fig. 3. Residuals of the data/model of IRAS 19254-7245 XIS data at the Fe band, when no iron line is included in the model. The three vertical lines highlights the energy centroids of the three possible components of the Fe line complex (6.4 keV, 6.7 keV and 6.97 keV). The energy scale is in the rest frame.

continuum model tested above. One possibility is that the 6.7 keV line is due to reflection from highly ionized matter; we thus replaced the cold reflected (pEXRAV) power law component with an ionized reflected component, as is described by the Ross & Fabian (2005) table (otherwise known as the reflion model). This model allows different values for the ionization parameter of the reflecting material and it also includes the Fe K emission line, as well as emission lines from other elements in addition to the reflected continuum. We fixed the Fe abundance to solar and we included a lower column density in front of the reflected component. The photon index of the illuminating source is now \( \Gamma = 1.87^{+0.11}_{-0.08} \), where the value of the ionization is determined mainly by the strength and energy of the Fe line; at this ionization level, Fe K emission is almost entirely due to Fe xxv. The reflected component is modified by a lower column density absorber with \( N_{\text{H}} \sim 10^{23} \text{ cm}^{-2} \), which is probably on a larger scale than the inner high column density absorber. We stress that a second SNe are at the higher end of the expected range of X-ray luminosity (\( L_x = 10^{40} - 10^{41} \text{ erg s}^{-1} \)), we need a factor 10 times more SNe than the predicted rate to maintain the observed hard X-ray emission. Furthermore, X-ray observations of SB galaxies showed that the major contributor to the 2–10 keV emission has a luminosity similar to the contribution from the SNe. In summary, although the starburst model can well reproduce the line intensity and the overall shape of the 2–10 keV continuum, the luminosity of this thermal component (L(2–10 keV)\( \sim 2 \times 10^{42} \text{ erg s}^{-1} \)) is likely to be too high for a pure starburst scenario.

Finally, we would like to note that if we assume that the emission detected above 2 keV is dominated by the emission of unresolved HMXB we still cannot explain the 6.7 keV emission line. Indeed, we would expect a lower EW of the Fe line (EW~ 0.3 keV; White et al. 1983; Persic & Rephaeli 2002), which is not consistent with the high value observed in IRAS 19254-7245. One possibility is that only a fraction of the Fe line at 6.7 keV originates in a high temperature plasma. We thus added to our best fit model a second high temperature emission fixing the abundance to the solar value. This high temperature thermal emission can account for \( \sim 30\% \) of the flux of the line at 6.7 keV. Though the inclusion of this emission can account for a fraction of the Fe line at 6.7 keV, we still need a strong ionized reflection component to account for the same time for the continuum shape and the line.

On the other hand if we attribute the hard X-ray emission to the presence of the AGN the flatness of its observed continuum together with strong Fe emission lines are usually considered.  

3. Discussion and Conclusions

The detection of the Fe K emission line at 6.7 keV instead of the 6.4 keV emission line expected from neutral iron may suggest that this line is associated with strong starburst activity and that the emission below 10 keV is not due to the AGN, but rather to a hot thermal plasma as expected in a starburst dominated scenario. Indeed, from a statistical point of view we can obtain a good fit (\( \chi^2/\text{dof} = 147/144 \)) replacing the AGN reflected emission with a thermal component. This model gives a best fit temperature of \( kT = 8.1_{-1.3}^{+1.2} \text{ keV} \), \( N_{\text{H}} \sim 6 \times 10^{22} \text{ cm}^{-2} \), twice solar abundances (\( Z \sim 2.1Z_\odot \)) and a luminosity of \( L(2–10 \text{ keV}) \sim 2 \times 10^{42} \text{ erg s}^{-1} \).
evidence of a Compton-Thick source, where no direct emission is seen below 10 keV and the shape is produced by reflection off cold matter. However, contrary to what is seen in other Compton thick sources, the Fe K emission is unaffected.

These models do not include a cold reflected component, and the luminosities of the order of $10^{44}$ cm$^{-2}$.

The inferred column density of the Compton-thick reprocessor is $\tau_{\text{C}}$ = 5 km/s, and the X-ray luminosity is $L(2-10 \text{ keV}) = 1.5 \times 10^{45}$ erg s$^{-1}$.

For example, for a column density of $10^{25}$ cm$^{-2}$, a scattering fraction of $f > 0.01$ will reduce the EW of the Fe K line by more than an order of magnitude, so that an EW of 1 keV would be reduced to less than $\sim 100$ eV, and it could render the line undetectable.

The intrinsic EW (i.e., prior to the dilution effect) of Fe K lines depends on several factors, including the column density of the absorber, but also the geometry of the absorber (e.g., the half opening angle of the putative torus; see Ghisellini et al. 1994). For example, for an half opening angle of $30^\circ$ and our estimate of the column density of the absorber, the intrinsic EW of the 6.4 keV Fe K line can span the range from 1 to 4 keV.

The inferred column density of the Compton-thick reprocessor implies that a scattering fraction of only $\sim 0.1\%$ in the optically-thin zone is required to begin to dilute the 6.4 keV Fe K line and a scattering fraction of a few percent is sufficient to reduce the EW of the line well below 100 eV, consistent with the upper limit of the EW and the $\sim 2\%$ scattering fraction (measured with respect to the de-absorbed primary power law component) as measured with the Suzaku data.

A second possible geometry is that we have a direct view of the inner surface of the Compton-thick reprocessor, but the outer part of this reprocessor is ionized. In this case, if the remaining part of the reprocessor is Compton-thin, the EW of the 6.4 keV Fe K line will be reduced and the emission detected below 10 keV is the reflected emission from this inner ionized surface of the torus which will also produce a strong 6.7 keV line.

Thus, we see that the lack of a large EW neutral Fe K in IRAS 19254–7245 is not unexpected. The spectrum below 10 keV is then dominated by this optically-thin scattered continuum and the dominance of the emission line from ionized Fe is consistent with this picture.

It is worth noting that this is not a unique case of a detection of a strong 6.7 keV line in a luminous infrared galaxy. Other examples are Arp 220 (Iwasawa et al. 2005, Iwasawa et al., 2005), Arp 220, and Arp 220, the X-ray luminosity is not indicative of AGN activity, their X-ray emission and the 6.7 keV line can be explained with the presence of an AGN and an ionized reflector as in the case of IRAS 19254–7245. However, while in the case of Arp 220, the X-ray luminosity is not indicative of AGN, the bolometric luminosity is a high-luminosity AGN, in the case of IRAS 00182-7112 the X-ray luminosity is too large to be accounted for by the strong starforming activity (L(2–10) > $10^{44}$ erg s$^{-1}$) as for IRAS 19254-7245. For all these sources, the presence of a strong ionized Fe line, with little or no

**Table 1. Results of the Spectral Fit**

| Model | $N_{\text{Ht}}$ | $E_{\text{e}}$ | $E_{\text{L}}$ | $\sigma_{\text{amp}}$ | EW$_{\text{L}}$ | $L(2-10 \text{ keV})$ | $L(10-30 \text{ keV})$ | $\chi^2/\text{dof}$ |
|-------|----------------|---------------|---------------|---------------------|--------------|----------------------|----------------------|------------------|
| A     | $1.8^{+0.2}_{-0.1}$ | $2.7^{+0.4}_{-0.3}$ | $6.9^{+0.8}_{-0.5}$ | $0.11^{+0.06}_{-0.06}$ | $0.60^{+0.12}_{-0.22}$ | 4.0 | 3.6 | 164/145 |
| B$^c$ | $1.8^{+0.1}_{-0.0}$ | $3.1^{+0.3}_{-0.2}$ | $6.6^{+0.4}_{-0.3}$ | $0.14^{+0.07}_{-0.06}$ | $0.86^{+0.25}_{-0.18}$ | 2.1 | 1.9 | 181/146 |
| C$^d$ | $1.20^{+0.11}_{-0.09}$ | $3.2^{+0.3}_{-0.2}$ | $6.6^{+0.3}_{-0.2}$ | $0.15^{+0.06}_{-0.05}$ | $0.67^{+0.16}_{-0.15}$ | 1.7 | 3.9 | 154/145 |
| D$^d$ | $1.87^{+0.11}_{-0.09}$ | $3.3^{+0.3}_{-0.2}$ | $1000^{+400}_{-300}$ | $10^{24}$ | $L(10-30 \text{ keV})$ | $10^{44}$ | $L(10-30 \text{ keV})$ | $10^{44}$ | $\chi^2/\text{dof}$ |

*The values of $\sigma$ are the measured ones, which are not corrected for width of the calibration lines, $\sigma_{\text{amp}}$.

*b* The EW is measured against the total observed continuum.

*c* The luminosities are derived from the XIS front illuminated CCDs.

*d* These models do not include a cold reflected component.
The total X-ray luminosity estimated from the intrinsic component at $E > 10 \text{ keV}$ can be converted into a bolometric luminosity and compared with the total infrared emission. We adopted the $\alpha_{\text{OX}}$-luminosity correlation of [Steffen et al. 2006] in order to estimate the 2500 Å luminosity, and the [Elvis et al. 1994] quasar spectral energy distribution to estimate the bolometric luminosity of the AGN component. Assuming $L_{2-10} \sim 10^{44} \text{ erg s}^{-1}$, we obtain $L_{\text{bol}}(\text{AGN}) \sim 2 \times 10^{44} \text{ erg s}^{-1}$, i.e. about 50% of the infrared luminosity. A different way to estimate the AGN luminosity is through its emission in the mid-infrared, the only other band where the continuum emission of the AGN is not completely suppressed. [Nardini et al. 2008], from an analysis of the Spitzer-IRS spectrum estimated an AGN contribution to the bolometric luminosity of IRAS 19254-7245 of $\sim 25\%$. Considering the uncertainties in the bolometric corrections in both the X-ray and the mid-infrared bands, the two estimates can be considered in rough agreement. If the difference is assumed to be real, this could be an indication of the non-complete covering factor of the AGN circumnuclear absorber: indeed, the estimate form the mid-infrared spectrum is done assuming a complete reprocessing of the intrinsic AGN emission in the infrared. However, the optical classification of IRAS 19254-7245 as a Seyfert 2 suggests that the obscuration of the nuclear source is not complete. The estimates from the X-ray and infrared spectra would be then perfectly reconciled assuming a covering factor of the obscuring material of about 50%.

In conclusion, this deep Suzaku observation allowed us to measure for the first time the hard X-ray emission of IRAS 19254-7245 and infer that its intrinsic 2–10 keV luminosity is of about few times $10^{44} \text{ erg s}^{-1}$. We have found evidence that the AGN hosted in IRAS 19254-7245 is highly obscured, with a measured column density of the neutral absorber of $N_{\text{H}1} \sim 3 \times 10^{24} \text{ cm}^{-2}$. We confirm the presence of a strong iron K emission line with $E_{\text{W}} \sim 0.7 \text{ keV}$. The energy of iron K emission line is found to be consistent with Fe xxv. We propose that the X-ray emission detected below 10 keV can be ascribed to scattered/reflected emission from highly ionized matter, which could be identified with the warm Compton-thin gas which fills the space between the neutral Compton-Thick reprocessor.

Acknowledgements. VB acknowledge support from the UK STFC research council. RDC acknowledge financial support from the ASI (Agenzia Spaziale Italiana) grant I/088/06/0. Support for this work was provided by the National Aeronautics and Space Administration through the NASA grant NNG04GB78A. We thank the anonymous referee for his/her useful comments, which have improved this paper.

References

Ballo, L., Braito, V., Della Ceca, R., Maraschi, L., Tavecchio, F., & Dadina, M. 2004, ApJ, 600, 634
Bianchi, S., & Matt, G. 2002, A&A, 387, 76
Boldt, E. 1987, Phys. Rep., 146, 215
Braito, V., et al. 2003, A&A, 398, 107
Braito, V., et al. 2004, A&A, 420, 79
Caccianiga, A., et al. 2008, A&A, 477, 735
Caccianiga, A., et al. 2004, A&A, 416, 901
Della Ceca, R., et al. 2004, A&A, 428, 383
Elvis, M., et al. 1994, ApJS, 95, 1
Franceschini, A., et al. 2003, MNRAS, 343, 1181
Frontera, F., et al. 2007, ApJ, 666, 861
Fukazawa, Y., et al. 2009, PASJ, 61, 17
Genzel, R., et al. 1998, ApJ, 498, 579
Ghisellini, G., Haardt, F., & Matt, G. 1994, MNRAS, 267, 743
Grimm, H.-J., Gilfanov, M., & Sunyaev, R. 2003, MNRAS, 339, 793
Gruber, D. E., Matteson, J. L., Peterson, L. E., & Jung, G. V. 1999, ApJ, 520, 1224
Kokubun, M., et al. 2007, PASJ, 59, 53
Hopkins, P. F., Hernquist, L., Cox, T. J., Di Matteo, T., Martini, P., Robertson, B., & Springel, V. 2005, ApJ, 630, 705
Hopkins, P. F., Hernquist, L., Cox, T. J., Di Matteo, T., Robertson, B., & Springel, V. 2006, ApJS, 163, 1
Ikeda, S., Awaki, H., & Terashima, Y. 2009, ApJ, 692, 608
Imanishi, M., Terashima, Y., Anabuki, N., & Nakagawa, T. 2003, ApJ, 596, L167
Iwasawa, K., Sanders, D. B., Evans, A. S., Trenthnam, N., Miniutti, G., & Spoon, H. W. 2005, MNRAS, 357, 565
Koyama, K., et al. 2007, PASJ, 59, 23
Magdziarz, P., & Zdziarski, A. A. 1995, MNRAS, 273, 837
Mannucci, F., et al. 2003, A&A, 401, 519
Matt, G., Brandt, W. N., & Fabian, A. C. 1996, MNRAS, 280, 823
Mitsudu, K., et al. 2007, PASJ, 59, 1
Moretti, A., et al. 2009, A&A, 493, 501
Nandra, K., & Iwasawa, K. 2007, MNRAS, 382, L1
Nardini, E., Risaliti, G., Salvati, M., Sani, E., Imanishi, M., Marconi, A., & Maiolino, R. 2008, MNRAS, 385, L130
Page, K. L., Reeves, J. N., O’Brien, P. T., Turner, M. J. L., & Worrall, D. M. 2004, MNRAS, 353, 133
Persic, M., & Rephaeli, Y. 2002, A&A, 382, 843
Persic, M., Rephaeli, Y., Braito, V., Cappi, M., Della Ceca, R., Franceschini, A., & Gruber, D. E. 2004, A&A, 419, 849
Ptak, A., Heckman, T., Levenson, N. A., Weaver, K., & Strickland, D. 2003, ApJ, 592, 782
Ranalli, P., Comastri, A., & Setti, G. 2003, A&A, 399, 39
Reeves, J. N., & Turner, M. J. L. 2000, MNRAS, 316, 234
Risaliti, G., et al. 2003, ApJ, 595, L17
Ross, R. R., & Fabian, A. C. 2005, MNRAS, 358, 211
Sanders, D. B., & Mirabel, I. F. 1996, ARA&A, 34, 749
Springel, V., Di Matteo, T., & Hernquist, L. 2005, MNRAS, 361, 776
Steffen, A. T., Stratteva, I., Brandt, W. N., Alexander, D. M., Koekemoer, A. M., Lehmer, B. D., Schneider, D. P., & Vignali, C. 2006, AJ, 131, 2826
Takahashi, T., et al. 2007, PASJ, 59, 35
Teng, S. H., Wilson, A. S., Veilleux, S., Young, A. J., Sanders, D. B., & Nagar, N. M. 2005, ApJ, 633, 664
Teng, S. H., et al. 2009, ApJ, 691, 261
Vignati, P., et al. 1999, A&A, 349, L57
Weedman, D. W., & Houck, J. R. 2008, ApJ, 686, 127
White, N. E., Swank, J. H., & Holt, S. S. 1983, ApJ, 270, 711
Wilms, J., Allen, A., & McCray, R. 2000, ApJ, 542, 914
Yaqoob, T. 1997, ApJ, 479, 184