

On why the iron K-shell absorption in AGN is not a signature of the local warm/hot intergalactic medium

James Reeves,^{1*} Chris Done,² Ken Pounds,³ Yuichi Terashima,⁴ Kiyoshi Hayashida,⁵ Naohisa Anabuki,⁵ Masahiro Uchino⁵ and Martin Turner³

¹*Astrophysics Group, School of Physical and Geographical Sciences, Keele University, Keele, Staffordshire ST5 8EH*

²*Department of Physics, University of Durham, South Road, Durham DH1 3LE*

³*Department of Physics and Astronomy, University of Leicester, University Road, Leicester LE1 7RH*

⁴*Department of Physics, Ehime University, Matsuyama 790-8577, Japan*

⁵*Department of Earth and Space Science, Osaka University, Toyonaka, Osaka 560-0043, Japan*

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ABSTRACT

We present a comparison between the 2001 *XMM-Newton* and 2005 Suzaku observations of the quasar, PG 1211+143, at $z = 0.0809$. Variability is observed in the 7 keV iron K-shell absorption line (at 7.6 keV in the quasar frame), which is significantly weaker in 2005 than during the 2001 *XMM-Newton* observation. From a recombination time-scale of < 4 yr, this implies an absorber density $n > 4 \times 10^3 \text{ cm}^{-3}$, while the absorber column is $5 \times 10^{22} < N_{\text{H}} < 1 \times 10^{24} \text{ cm}^{-2}$. Thus, the size scale of the absorber is too compact (pc scale) and the surface brightness of the dense gas too high (by 9–10 orders of magnitude) to arise from local hot gas, such as the local bubble, group or warm/hot intergalactic medium (WHIM), as suggested by McKernan, Yaqoob & Reynolds. Instead, the iron K-shell absorption must be associated with an active galactic nucleus (AGN) outflow with mildly relativistic velocities. Finally, we show that the association of the absorption in PG 1211+143 with local hot gas is simply a coincidence, and the comparison between the recession and iron K absorber outflow velocities in other AGN does not reveal a one-to-one kinematic correlation.

Key words: accretion, accretion discs – atomic processes – X-rays: galaxies.

1 INTRODUCTION

The cosmological requirement that half the baryons in the Universe are in a warm/hot intergalactic medium (WHIM) has motivated ultraviolet (UV) and X-ray absorption-line studies to detect this otherwise invisible gas, using absorption against a bright active galactic nucleus (AGN) to probe the line of sight material (Bregman 2007). However, most AGN (except blazars) have intrinsic columns of warm absorbing gas in their nuclei, and the fact that this is generally connected to a nuclear outflow (Blustin et al. 2005) complicates separating this intrinsic absorption from extrinsic line-of-sight material using velocity information. None the less, various studies have looked for absorption lines (predominantly O VII/VIII) as signatures of the WHIM, though all current detections are more likely to be associated with material in our Galactic halo or Local Group (Bregman & Lloyd-Davies 2007). These have velocities within a few hundred km s^{-1} of the local standard of rest, and indicate columns of O VII/VIII $> 10^{16} \text{ cm}^{-2}$, equivalent to hydrogen columns of $N_{\text{H}} \sim 10^{19} \text{ cm}^{-2}$.

Much more controversial was the potential association of substantially higher columns of gas to such local material. McKernan et al. (2004, 2005) noted that several AGN with strong He- or H-like Fe-absorption features had these lines at energies which were approximately consistent with the local standard of rest. For any single object, the approximate match between the putative blueshifted outflow velocity and the galaxy redshift could be coincidental, but McKernan et al. (2004, 2005) pointed out three AGN showing this trend, with redshifts spanning ~ 0.008 – 0.15 (MCG -6-30-15, PG1211+143 and PDS 456). However, the derived columns of $N_{\text{H}} \sim 10^{23} \text{ cm}^{-2}$ are high even for an intrinsic AGN outflow (Pounds et al. 2003a, hereafter P03; Reeves, O’Brien & Ward 2003). If these are instead of local origin, then it requires a tremendously significant change to our understanding of the Galactic halo environment (McKernan et al. 2004, 2005).

Here, we use new Suzaku data to show that the highly ionized Fe absorption in PG 1211+143 is variable on a time-scale of years. This conclusively demonstrates that it is intrinsic to the AGN, and not associated with our Galaxy or Local Group. We collate recent results to show that this is also the case for most other AGN with strong Fe K absorption lines, showing that powerful outflows are associated with luminous accretion flows.

*E-mail: jnr@astro.keele.ac.uk

2 THE IONIZED ABSORPTION IN PG 1211+143

Chandra and *XMM-Newton* gratings gave the first high-resolution X-ray spectra of the warm absorbers in AGN (e.g. Blustin et al. 2005; McKernan, Yaqoob & Reynolds 2007). However, only the *Chandra* HETGS can cover the Fe K region, and this has very small effective area. Thus, most of the information on these absorption lines are from the large effective area, moderate-resolution CCDs on *XMM-Newton*. These showed that some powerful AGN have strong absorption lines at 7 keV (observed frame) associated with large columns of highly ionized iron (PG 1211+143: P03; Pounds & Page 2006, hereafter PP06; PDS456: Reeves et al. 2003).

The results on PG 1211+143, at a redshift of $z = 0.0809$, were initially controversial. P03 claimed that the dip in the spectrum at ~ 7 keV was an absorption line, which they initially identified as H-like Fe $K\alpha$ (6.97 keV, lab-frame). Given the source redshift, this requires an outflow velocity of $\sim 24\,000$ km s $^{-1}$ i.e. $0.08c$ assuming an origin in the AGN. Other, weaker but still significant, absorption lines in the CCD spectra at 2.68 and 1.47 keV could also be interpreted as arising from material with the same outflow velocity if these are from H-like S and Mg $K\alpha$, respectively (P03, PP06). The higher resolution Reflection Grating Spectrometer (RGS) instrument also shows lines from lower Z elements at low energies. P03 identified these with transitions which required similarly high velocities as the high-ionization material, while Kaspi & Behar (2006) used different identifications to obtain a lower velocity outflow solution for these lines.

None the less, the origin of the RGS features is not the major issue. Only the CCDs on *XMM-Newton* can show the existence of material which is so highly ionized that heavy elements (S, Mg, Fe) are predominantly He or H like. Surprisingly, Kaspi & Behar (2006) identified the S and Mg K-shell lines with weaker He-like $K\beta$ lines (with little velocity offset), instead of the blueshifted H-like $K\alpha$ transitions, which begs the question as to why the corresponding stronger $K\alpha$ lines are not seen. These authors also model the Fe K absorption in the 2001 *XMM-Newton* data with an edge at 7.27 keV (rest frame) of optical depth $\tau \sim 0.5$, corresponding to a large column ($N_H > 10^{23}$ cm $^{-2}$) of very low ionization state matter (Fe VII/VIII); this should have substantial low energy absorption which is clearly not present in the data. As we show below, accounting for any low ionization absorption (via partial covering) in a self-consistent photoionization model does not remove the requirement for the blueshifted highly ionized iron K absorber.

The only self-consistent option for the features around 7 keV in the *XMM-Newton* data is $K\alpha$ absorption lines from H- or He-like iron. This requires a large blueshift ($0.08c$ or $0.14c$, respectively) if the absorption is intrinsic to the AGN, with the implication being that the kinetic energy associated with this material can dominate the AGN energetics (Pounds & Reeves 2007).

3 DATA REDUCTION

3.1 Suzaku analysis

PG 1211+143 was observed by Suzaku (Mitsuda et al. 2007) between 24 and 27 November 2005. In this Letter, we discuss data taken with the four X-ray Imaging Spectrometer (XIS; Koyama et al. 2007) CCDs. Event files from official version 2.0 of the Suzaku pipeline processing were used. The PG 1211+143 Suzaku event files were screened using identical criteria to those described in Reeves et al. (2007) for the Suzaku observation of MCG -5-23-16.

Subsequently, source spectra from the XIS CCDs were extracted from circular regions of 2 arcmin radius centred on the source, in the off-axis HXD nominal pointing position. Background spectra were extracted from 4 arcmin circles offset from the source region, avoiding the calibration sources on the corners of the CCD chips. XIS response matrix files (RMFs) and ancillary response files (ARFs) were generated using the *XISRMFGEN* and *XISSIMARFGEN* scripts including correction for the hydrocarbon contamination on the optical blocking filter (Ishisaki et al. 2007). A net XIS source exposure of 97.5 ks was obtained for each of the four XIS chips. The three front illuminated XIS chips (XIS 0,2,3) were used in this Letter, as they have the greatest sensitivity at iron K. These chips were found to produce consistent spectra within the statistical errors, so the spectra and responses were combined to maximize signal-to-noise ratio. The net source count rate for the three XIS combined was 0.7984 ± 0.003 counts s $^{-1}$, with background only 3 per cent of the source rate. The XIS source spectrum was binned to a minimum of 100 counts per bin to enable the use of χ^2 minimization. Errors are quoted to 90 per cent confidence for 1 parameter (i.e. $\Delta\chi^2 = 2.7$).

3.2 XMM-Newton analysis

XMM-Newton observed PG 1211+143 twice, on 2001 June 15 for 53 ks and 2004 June 21 for 57 ks, but this second exposure was affected by high particle background, resulting in only 25 ks of usable data. The EPIC-pn spectra used in this Letter are identical to those described in PP06 and Pounds & Reeves (2007), which were processed using the *XMM-Newton* SAS v6.5 software. The EPIC-MOS spectra are consistent with the EPIC-pn, with the same 7 keV absorption feature present in the iron K band, as discussed by PP06.

4 A COMPARISON BETWEEN SUZAKU AND XMM-NEWTON OBSERVATIONS

The 2001–2005 spectra from 0.4 to 10 keV are plotted in Fig. 1, relative to a $\Gamma = 2$ power-law continuum. The CCDs on both *XMM-Newton* and Suzaku have similar responses so the data are directly comparable. A Galactic column of 2.8×10^{20} cm $^{-2}$ is included in all the spectral fits. From the spectra, it is clear that there is little change in the overall spectral shape or normalization. All three observations show a strong soft X-ray excess below 1 keV, though it is marginally more prominent during the 2001 *XMM-Newton* and 2005 Suzaku observations. However, the deep iron K absorption feature observed at 7 keV in 2001 (P03), which is readily apparent even on this broadband spectral plot, is not present at the same strength in either the 2004 or 2005 data. This feature has varied significantly, ruling out a local origin for the absorber.

To quantify this, we use only the 2001 *XMM-Newton* and 2005 Suzaku observations as these have the best signal-to-noise ratio. We fit the data sets simultaneously over the 2–10 keV bandpass to avoid the complexity associated with the soft X-ray excess. A power law with fixed Galactic absorption gives a very similar index between the two data sets as the continua are very similar (see Fig. 1), but the overall fit is poor ($\chi^2/\text{d.o.f.} = 374/154$ and $369/249$ for the *XMM-Newton* and Suzaku data, respectively). Fig. 2 shows the ratio of the data to the model for this fit, where, as well as due to the obvious absorption feature in the *XMM-Newton* data, it is clear that both spectra have iron emission at ~ 6.5 keV. Adding a Gaussian line (with intrinsic width constrained to be equal across the two data sets) gives a line energy and equivalent width consistent between the two data sets, at 6.5 keV and 250 eV, respectively. The intrinsic linewidth is resolved with a FWHM velocity of $25\,000$ km s $^{-1}$, i.e. typical of radii $\lesssim 100R_g$ from the black hole.

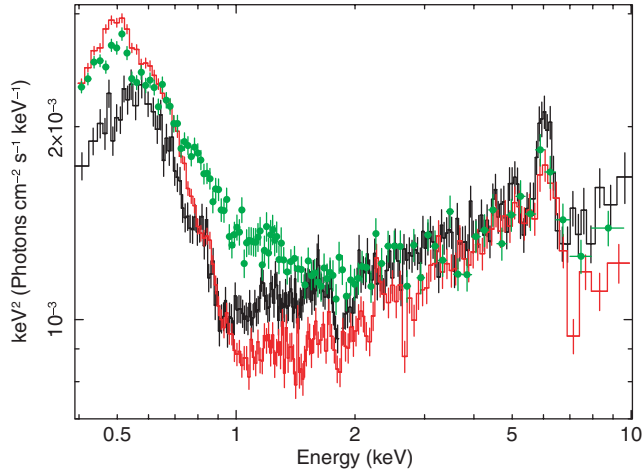


Figure 1. Fluxed spectra from the 2001 *XMM-Newton* (red crosses), 2004 *XMM-Newton* (green circles) and 2005 Suzaku (black crosses) observations of PG 1211+143, compared to a $\Gamma = 2$ continuum. The spectra are plotted in the observed frame (at $z = 0$). The downturn at lower energies is due to the Galactic column of $2.8 \times 10^{20} \text{ cm}^{-2}$. Strong soft X-ray excesses below 1 keV are observed in all three spectra, which are most prominent in the 2001 and 2005 observations. The deep absorption feature at 7 keV is detected in the 2001 *XMM-Newton* observation, but not in the 2004 *XMM-Newton* and 2005 Suzaku observations. The spectra have been re-binned by a factor of $\times 2$ for clarity.

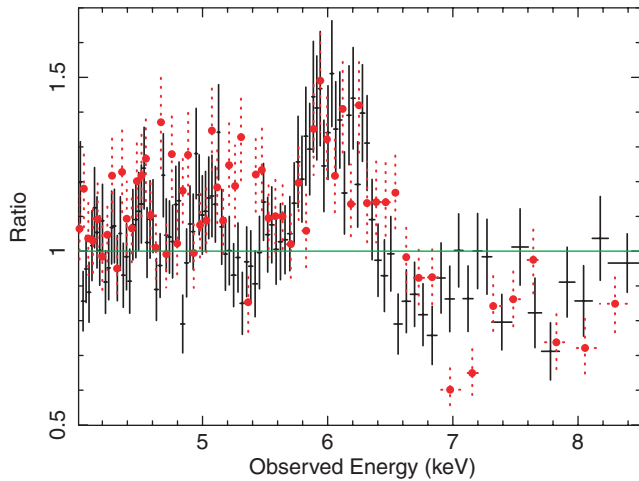


Figure 2. Data/model ratio residuals at iron K to a simple power-law fit to the 2–10 keV spectrum of PG 1211+143. The 2001 *XMM-Newton* observation is in red, and 2005 Suzaku in black. The absorption feature at 7 keV (7.6 keV QSO rest frame) is apparent in the *XMM-Newton* data, but not in the Suzaku observations, showing that the iron K absorption has varied over 4 yr. Broad iron $K\alpha$ emission is present in all observations at 6 keV (6.5 keV rest frame), as well as curvature at 4–6 keV which can be modelled either by a very broad, redshifted line or by continuum complexity.

However, there is still significant curvature in the spectrum, as shown by the poor combined $\chi^2_{\nu} = 582/398$. This can be phenomenologically modelled by an additional Gaussian line, again with intrinsic width tied between the two data sets. This gives an acceptable fit, with $\chi^2 = 441.3/393$, for a very broad line, with an intrinsic width of 1.1 ± 0.2 keV. The line energy is consistent between the two data sets at ~ 4.4 keV but its equivalent width is much larger in the *XMM-Newton* data than in the Suzaku data, at ~ 800 eV compared to ~ 290 eV (see Table 1), showing that there is

more curvature in the *XMM-Newton* data. Since it is also the *XMM-Newton* data which show the line absorption feature, it is possible that this curvature is associated with the absorber, rather than with a broad, redshifted iron line from reflection from the very innermost (i.e. $< 10 R_g$) accretion disc.

We phenomenologically model this by partial covering of the source by partially ionized material (e.g. Miller et al. 2007; Turner et al. 2007), using a grid of XSTAR (v2.11) photoionization models based on the publicly available tabulated ‘grid 25’. This uses the Fe K treatment of Kallman et al. (2004), a turbulent velocity of $\sigma = 200 \text{ km s}^{-1}$ and solar abundances (Grevesse & Sauval 1998), while the illuminating continuum from 1 to 1000 Rydbergs has $\Gamma = 2.2$ rather than $\Gamma = 2$, and spans a wider (but coarser) range of column (0.05 to $500 \times 10^{22} \text{ cm}^{-2}$, 10 points) and $\log \xi$ (-3 to 6 , 12 points). This partially ionized absorption is applied to a fraction f of the assumed continuum, while the remaining $(1 - f)$ is not affected by this material.¹

We fix the redshift of the partial coverer to that of the AGN, and tie the ionization parameter of this material (but not its covering fraction) between the two data sets. This model gives an equally good fit as the broad Gaussian model, with $\chi^2 = 439/393$ for $\log \xi \sim 1.2$. The column of the ionized material is consistent between the two data sets at $\sim 2 \times 10^{23} \text{ cm}^{-2}$, but the covering fraction is much larger in the *XMM-Newton* spectrum (80 per cent compared to 40 per cent), showing that the spectral curvature is more evident in these data. We use these two different models (hereafter termed Gau and Pcfxi, respectively) to assess the robustness of the change in the narrow absorption features to different continuum placement. Note the partial covering model is insensitive to the turbulence assumed, as its effect from 2 to 10 keV is to reproduce the continuum curvature in the spectrum, from bound-free absorption such as the iron K-shell edge.

Fig. 3 shows the χ^2 residuals to the power-law, Gau and Pcfxi models, respectively. The absorption line is still present in the *XMM-Newton* data, even against the Pcfxi model which contains the iron K-shell edge and its associated absorption-line structure (fig. 13, Kallman et al. 2004). We fit an additional inverted Gaussian of fixed width ($\sigma = 0.1$ keV) to the *XMM-Newton* data and find that the fit is significantly improved, to $\chi^2_{\nu} = 418.7/391$ and $417.6/391$ for the Gau and Pcfxi continuum models, respectively. The line energy and equivalent width in both is ~ 7.6 keV (7.05 ± 0.05 keV observed) and 110^{+45}_{-40} eV, respectively. We allow a line with the same energy and width in the Suzaku data, and find a 90 per cent confidence upper limit to its equivalent width of < 25 eV.

5 THE ORIGIN OF THE IRON K-SHELL ABSORPTION

Thus, the absorption line is significantly weaker in the 2005 Suzaku data, so the absorption has changed on a time-scale of < 4 yr. Either the column has physically moved, or its ionization state has changed (or both). The former puts a limit on the size scale of 4 light years, unfeasibly small for any diffuse Galactic halo or intergalactic emission (which should be on kpc scales), while the latter sets a limit on the density through the recombination time-scale, $\tau_r = 1/[\alpha_r(T) n_e]$, where α_r is the recombination rate, which is dependent on the temperature, T . For a WHIM origin, the absorption line must be associated with Fe xxvi in order that its energy matches that of

¹ This model is publicly available as an additional model for XSPEC from <http://heasarc.gsfc.nasa.gov/docs/xanadu/xspec/newmodels.html>.

Table 1. Fit parameters and uncertainties ($\Delta\chi^2 = 2.7$) for the *XMM-Newton* 2001 and Suzaku 2005 spectra from PG 1211+143 for the models shown in Fig. 3.

Model	Γ^a	Norm $\times 10^{-3a}$	Line E (keV) ^b	σ (keV) ^b	EW (eV) ^b	Line E (keV) ^c $N_H \text{ cm}^{-2}$	σ (keV) ^c $\log \xi$	EW (eV) ^c Cov Frac	χ^2_v
po	1.77 ± 0.03	0.88							744/403
	1.76 ± 0.03	0.99							
Gau	1.93 ± 0.05	0.96	6.63 ± 0.09	0.24 ± 0.04	250^{+80}_{-70}	$4.36^{+0.23}_{-0.29}$	$1.07^{+0.24}_{-0.20}$	810^{+210}_{-180}	441.4/393
	1.87 ± 0.04	1.07	$6.52^{+0.04}_{-0.05}$		270 ± 50	$4.39^{+0.38}_{-0.48}$		290 ± 100	
Pcfxi	$2.50^{+0.16}_{-0.17}$	4.07	$6.55^{+0.09}_{-0.07}$	0.20 ± 0.04	235 ± 50	20^{+8}_{-4}	$2.18^{+0.29}_{-1.20}$	$0.78^{+0.08}_{-0.08}$	439.6/393
	$2.10^{+0.12}_{-0.10}$	2.00	$6.53^{+0.05}_{-0.02}$		210 ± 45	16^{+12}_{-6}		$0.42^{+0.09}_{-0.12}$	

^aContinuum photon index and normalization (units photons $\text{cm}^{-2} \text{s}^{-1} \text{keV}^{-1}$ at 1 keV).

^bEnergy (keV), intrinsic width σ (keV) and equivalent width (eV) of the iron line, quoted in the quasar rest frame.

^cEnergy (keV), intrinsic width σ (keV) and equivalent width (eV) of the broad redshifted Gaussian (Gau model), or for the partial covering (Pcfxi) model, column density N_H (units $\times 10^{22} \text{ cm}^{-2}$), ionization parameter ξ (units erg cm s^{-1}) and covering fraction.

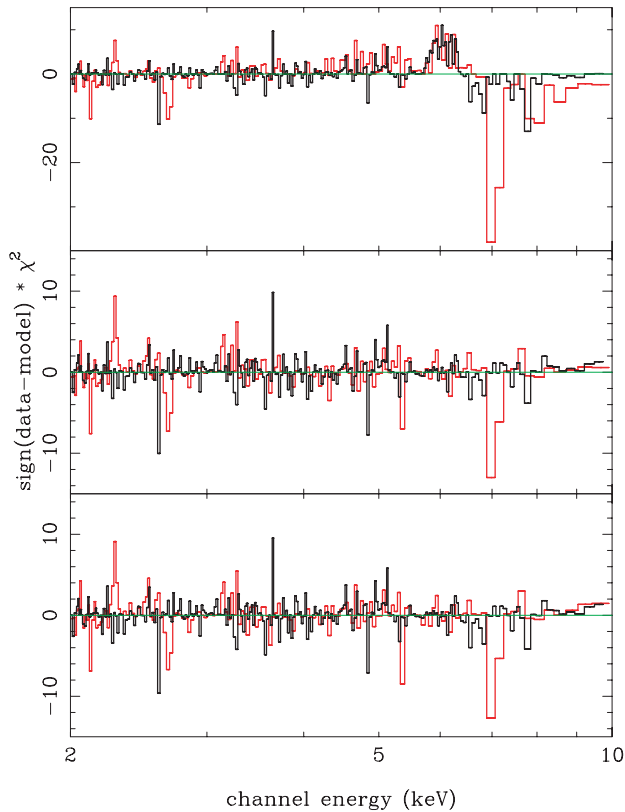


Figure 3. $\Delta\chi^2$ residuals against a power law (top), iron emission line and broad redshifted Gaussian (middle) and iron emission line and partial covering by partially ionized material (bottom) for the *XMM-Newton* 2001 (red) and Suzaku 2005 (black) data, respectively. The absorption feature at ~ 7 keV in the *XMM-Newton* data is significantly stronger than in the Suzaku data irrespective of the phenomenological continuum model.

the observed. Such material should also be collisionally ionized, and requires temperatures $> 10^{7.5}$ K in order to be the dominant ion. This gives a recombination rate of $\alpha_r \sim 2.5 \times 10^{-12} \text{ cm}^3 \text{ s}^{-1}$ (e.g. Arnaud & Rothenflug 1985), so for this to be less than 4 yr requires densities $> 4 \times 10^3 \text{ cm}^{-3}$, which is six orders of magnitude above the typical density even for a local halo component (e.g. Bregman & Lloyd-Davies 2007).

We model the Fe K absorption line using the WARMABS XSTAR photoionization code incorporated into XSPEC, adopting solar abundances. We assume a turbulent velocity of 5000 km s^{-1} , below the

upper limit of $< 8000 \text{ km s}^{-1}$ set by the observed intrinsic width of the line of $\sigma < 0.2$ keV. This gives a column of $8 \pm 3 \times 10^{22} \text{ cm}^{-2}$, with an ionization parameter of $\log \xi = 2.8^{+0.2}_{-0.3}$ at an observed redshift of $z = -0.07 \pm 0.01$, i.e. implying an AGN outflow velocity of $\sim 0.15c$. While the derived column is dependent on the turbulent velocity, the curve of growth is in the linear regime here, so increasing the turbulent velocity does not increase the equivalent width of the line, leading to a robust lower limit of $N_H > 5 \times 10^{22} \text{ cm}^{-2}$.

The lower limit on the density, combined with the column density, can give an upper limit on the size scale ΔR of the absorber as $N_H = n\Delta R$. A huge column of $N_H \geq 10^{25} \text{ cm}^{-2}$ is required in order to produce an iron absorption line with equivalent width of 100 eV if the gas velocity is simply set by its temperature of $10^{7.5}$ K (Kotani et al. 2000, 2006) as expected from any local hot gas. Such a large column is inconsistent with the spectrum, as this produces a strong dip at 8–10 keV (rest frame) due to the Fe K-shell edge structure (Kallman et al. 2004), which is not present in the data. Indeed, from the lack of an iron K edge in PG 1211+143, this sets an upper limit to the column of $< 10^{24} \text{ cm}^{-2}$ and requires that there must be substantial turbulent velocity ($> 1000 \text{ km s}^{-1}$ derived from the curve of growth) in excess of the thermal motions to model the line EW. This itself is inconsistent with a WHIM origin. With this, the upper limit on the absorber size scale is $\Delta R < N_H/n = 10^{24}/4 \times 10^3 < 2.5 \times 10^{20} \text{ cm}$. This is unfeasibly low to be associated with even the smallest local diffuse hot gas, the kpc scale Galactic halo.

Another constraint on the properties of the material comes from the emission measure $EM = n^2 V$, where $V = \pi R^2 \Delta R$ is the volume, assuming that the gas is distributed evenly in a spherical shell at distance R . The total bremsstrahlung luminosity is $L_{\text{brems}} \sim 2 \times 10^{-27} T^{1/2} EM$, so the surface brightness in solid angle $d\Omega$ is $L_{\text{brems}}/(4\pi R^2)$ ($d\Omega/4\pi$). For a solid angle of $1 \text{ arcmin}^2 = 10^{-7} \text{ sr}$, this gives $\sim 1.3 \times 10^{-35} T^{1/2} n N_H > 10^{-5} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ arcmin}^{-2}$, i.e. brighter than the Crab in every square arcmin in X-rays. Indeed, the observed upper limit to the diffuse sky surface brightness in the 3/4 keV band is $\sim 2 \times 10^{-4} \text{ counts s}^{-1} \text{ arcmin}^{-2}$ (Bregman & Lloyd-Davies 2007), corresponding to a flux of $< 2 \times 10^{-15} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ arcmin}^{-2}$, 10 orders of magnitude below the predicted value.

Thus, the variability and column appear to rule out any sort of non-AGN origin for the absorbing material. The best-fitting identification by PP06 of the highly ionized absorption as being dominated by He-like Fe also rules out a local origin as the line is then not close to the rest wavelength of the transition, showing a blueshift with respect to the local frame of -0.07 . This is because the Mg, Si and S K-shell absorption seen in the *XMM-Newton* CCD spectrum can be fit with

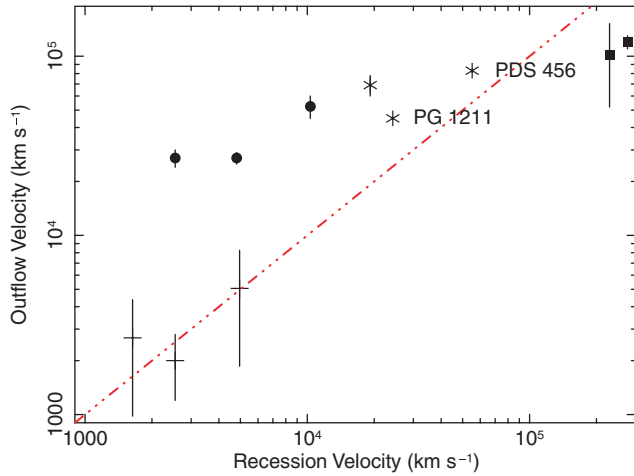


Figure 4. The inferred outflow velocity for the Fe $K\alpha$ absorption lines versus the host galaxy recession velocity. Only the three lowest velocity points (crosses) are kinematically consistent (within uncertainties) with a local rest-frame energy (left- to right-hand side; NGC 1365, Risaliti et al. 2005; MCG -6-30-15, Young et al. 2005; IRAS 13197–1627, Miniutti et al. 2007). The filled circles represent the blueshifted Fe K absorbers in the Seyfert galaxies MCG -5-23-16 (Braitto et al. 2007), IC 4329a (Markowitz et al. 2006) and Markarian 509 (Dadina et al. 2005). Stars represent absorption systems observed in nearby quasars (PG 1211+143, this Letter; PG 0844+349, Pounds et al. 2003b; PDS 456, Reeves et al. 2007). The filled squares correspond to two BAL quasars, PG 1115+080 (Chartas et al. 2003) and APM 08279+5255; Chartas et al. 2002.

the same layer of absorption if the ionization state of iron is lower than H like. This mismatch between the outflow velocity of the absorber and recessional velocity of the AGN is common. There are now many other AGN with blueshifted Fe $K\alpha$ indicating an outflow, and we collate these from the literature in Fig. 4. Aside from the three low-velocity examples in Fig. 4, none of the AGN outflow velocities coincides with the recession velocity. In IC 4329a and MCG -5-23-16, the absorption lines are observed at 7.7 keV (Markowitz, Reeves & Braitto 2006; Braitto et al. 2007) inconsistent with the rest energy of any Fe $K\alpha$ transition line. A further example is from the new 2007 Suzaku data from PDS456 (Reeves et al. 2007), which show iron K absorption lines observed at 7.6 and 8.2 keV, inconsistent with local absorption from iron $K\alpha$. Indeed, the iron K absorption features seen in high-redshift broad absorption line (BAL) QSOs are likewise very far from the iron $K\alpha$ rest energies for local material (Chartas et al. 2002; Chartas, Brandt & Gallagher 2003).

6 CONCLUSIONS

We show that the observed variability in the absorption line in PG 1211+143 between the *XMM-Newton* and Suzaku data taken 4 yr apart conclusively rules out a diffuse gas origin such as the local Galactic halo or WHIM. The gas must be associated with the AGN, as is further evidenced by its large column density in the *XMM-Newton* 2001 data which are far too high for local or intergalactic gas. The conclusive identification with the AGN, and the implausibility of any alternative line transition other than iron $K\alpha$, means that the large outflow velocity of $\sim 0.1c$ is inescapable. Such material

is predicted from the winds which are produced from luminous accretion discs in AGN (Proga & Kallman 2004).

The coincidence of the outflow velocity with the source redshift in these data is not significant. Other powerful AGN which show iron K absorption features clearly show a range of (intrinsic and observed) velocities, removing the apparent trend for the line energy to appear at the rest energy for these transitions. Thus, it is clear that this material is a mildly relativistic outflow from the AGN. Its high velocity means that its kinetic energy can be comparable to the bolometric radiated luminosity of the AGN (King & Pounds 2003; P03; Pounds & Reeves 2007), yet its high ionization means that it is effectively invisible in all other wavebands. While such a major component of AGN energetics could go unnoticed in individual objects, there is increasing evidence that strong AGN feedback controls galaxy formation and evolution. Mildly relativistic winds provide more efficient heating than the jet due to their impact on a larger area, so these highly ionized disc winds may be the key to understanding the growth of structure in the Universe.

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