Detection of a second high velocity component in the highly ionized wind from PG 1211+143

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ABSTRACT

An extended XMM-Newton observation of the luminous narrow line Seyfert galaxy PG1211+143 in 2014 has revealed a more complex highly ionized, high velocity outflow. The detection of previously unresolved spectral structure in Fe K absorption finds a second outflow velocity component of the highly ionized wind, with an outflow velocity of \( v \approx 0.066 \pm 0.003 \times c \), in addition to a still higher velocity outflow of \( v \approx 0.129 \pm 0.002 \times c \) consistent with that first seen in 2001. We note that chaotic accretion, consisting of many prograde and retrograde events, offers an intriguing explanation of the dual velocity wind. In that context the persisting outflow velocities could relate to physically distinct orientations of the inner accretion flow, with prograde accretion yielding a higher launch velocity than retrograde accretion in a ratio close to that observed.

Key words: galaxies: active – galaxies: Seyfert: quasars: general – galaxies: individual: PG1211+143 – X-ray: galaxies

1 INTRODUCTION

X-ray spectra from an XMM-Newton observation of the luminous Seyfert galaxy PG1211+143 in 2001 provided the first detection in a non-BAL AGN of strongly blue-shifted absorption lines of highly ionized gas, corresponding to a sub-relativistic outflow velocity of \( \sim 0.09 \times c \) (Pounds et al. 2003). That velocity was based primarily on the identification of a strong absorption line at \( \sim 7 \) keV with the resonance Lyman-\( \alpha \) transition in Fe XXVI. The subsequent inclusion of additional absorption lines, of Ne, Mg, Si and S, led to the re-identification of the \( \sim 7 \) keV absorption line with the resonance 1s-2p transition in Fe XXV, and a revised outflow velocity of \( 0.14 \pm 0.01 \times c \) (Pounds and Page 2006). Further observations of PG1211+143 over several years with XMM-Newton, Chandra and Suzaku found the high velocity outflow to be persistent but of variable strength (Reeves et al. 2008). Evidence that the mean outflow in PG1211+143 was both massive and energetic - with potential importance for galaxy feedback - was obtained from the detection of PCygni and other broad emission features by combining the 2001, 2004 and 2007 XMM-Newton EPIC spectra (Pounds and Reeves 2009).

Examination of archival data from XMM-Newton and Suzaku subsequently showed ultra-fast, highly-ionized outflows (UFOs) to be relatively common in nearby, luminous AGN (Tombesi et al. 2010; Gofford 2013). The frequency of these detections appeared to confirm a substantial covering factor, with a persistent wind having sufficient mechanical energy to disrupt the bulge gas in the host galaxy (Pounds 2014a). An indication how much of that energy could be lost before reaching a still-active star forming region came with evidence of a UFO shocking against the ISM or slower-moving ejecta in the low mass Seyfert galaxy NGC4051 (Pounds and Vaughan 2011, Pounds and King 2013).

Determination of the correct wind velocity, \( v \), is critically important in estimating the mass and energy rates of AGN winds, with the latter being dependent on \( v^3 \) in a radial outflow. However, significant uncertainty remains when the deduced velocity depends on the identification of a single blue-shifted absorption line, typically of Fe K, as in many early UFO detections (e.g. Tombesi et al. 2010). Spectral modelling over a wider energy band reduces ambiguities in line identification, as first demonstrated in Pounds and Page (2006), while also providing additional outflow parameters, including the mean ionization parameter and column density. Such broad-band spectral modelling was used in the second paper on the XMM-Newton archival data (Tombesi et al. 2011) and by Gofford (2013) in their similar analysis of Suzaku data.

In the present paper we make a further addition, in simultaneously modelling the outflow of PG1211+143 with both photoionized absorption and emission grids. To quantify absorption and emission structure we employ photoionized grids of pre-computed spectra based on the xstar code (Kallman et al. 1996), with the publicly available grid 25
(turbulence velocity 200 km s$^{-1}$) being found to provide a satisfactory match to the highly-ionized absorption, and velocity-broadened emission adequately modelled by grid 22 (turbulence velocity 3000 km s$^{-1}$).

Initially employing that procedure in re-modelling the 2001 outflow we re-affirm a column density $N_H$ of $\sim 10^{23}$ cm$^{-2}$, ionization parameter $\log \xi \sim 2.9$ erg cm s$^{-1}$ and outflow velocity $v \sim 0.14 \pm 0.01c$. By comparison with the typical properties of UFOs (Tombesi et al. 2011) and with the new observations reported here, it appears the unusually low outflow ionization - and correspondingly high opacity - in the 2001 observation was a primary reason for it being amongst the most highly visible UFOs yet seen.

2 A NEW XMM-NEWTON OBSERVATION OF PG1211+143 IN 2014

In order to further explore the ionized wind in PG1211+143 an extended XMM-NEWTON observation was carried out during 7 spacecraft orbits over the period 2014 June 2 to 2014 July 9. The present paper describes the analysis of high energy spectral data, with subsequent papers reporting the detection of a low ionization outflow in the soft x-ray spectrum, and evidence for short-term variability. We use data from the European Photon Imaging Cameras (EPIC) pn CCD (Strueder et al. 2001), operated in large window mode.

On-target exposures for individual orbits were typically $\sim 100$ ks, apart from the fifth observation (rev2664) of $\sim 55$ ks, giving a total on-target exposure of $\sim 630$ ks. Full details of the XMM-NEWTON observing log and data extraction procedures, and of accompanying Swift observations, are given in Lobban et al.(2015), reporting the results of a detailed timing analysis.

Raw data were processed using version 14.0 of the XMM-NEWTON Scientific Analysis Software * package, following standard procedures. Source events were extracted from 20 arcsec circular regions centred on the AGN, while background events were taken from much larger regions away from the target source and from other nearby background sources. For our EPIC-pn analysis, we utilized single and double good pixel events (PATTERN $\leq 4$). The exclusion of short intervals of background flaring resulted in a final $\sim 570$ ks of high quality pn data. The total residual background count rate was $< 1$ per cent of the source rate for all three EPIC cameras in each observation (Figure 2).

We assume an AGN redshift of $z = 0.0809$ (Marziani et al. 1996). Spectral modelling is based on the XSPEC package (Arnaud 1996) and includes absorption due to the line-of-sight Galactic column of $N_H = 2.85 \times 10^{20}$ cm$^{-2}$ (Murphy et al. 1996). 90 % confidence intervals on model parameters are based on $\Delta \chi^2 = 2.706$. Published estimates for the black hole mass in PG1211+143 range from $3 \times 10^7$ $M_\odot$ (Kaspi et al. 2000) to $1.5 \times 10^7$ $M_\odot$ (Bentz et al. 2009), with the lower value making the mean luminosity close to the Eddington limit. All derived velocities are corrected for the relativistic Doppler effect.

* http://xmm.esac.esa.int/sas/

3 CONFIRMATION OF A HIGH VELOCITY WIND IN PG1211+143

While examination of pn spectra from the 7 individual orbits in 2014 showed strong variability in the soft x-ray band, the harder continuum changes relatively little above $\sim 2$ keV. To obtain a baseline hard x-ray spectrum of PG1211+143 with maximum statistical quality we therefore summed low background pn data from all 7 orbits for an initial spectral analysis. The resulting low background source exposure is a factor $\sim 10$ greater than for any of the previous XMM-NEWTON observations in 2001, 2004 and 2007.

Figure 1 compares the stacked pn spectrum from 2014 with that from 2001, both data sets being plotted as a ratio to a double power-law continuum. While the most prominent absorption line near 7 keV is weaker than in 2001, the much longer 2014 exposure allows the overall spectrum to be better defined. In particular, the Fe K emission profile is resolved into high and low ionization components and additional absorption structure is indicated at higher energies.
prominent absorption line at ∼7 keV is again seen in the 2014 data, albeit being less deep than in 2001. Other differences in the 2014 spectrum include weaker absorption in the lower mass ions, but a clear indication of additional absorption structure in the Fe K band between 6–10 keV. Those differences suggest the fast wind in 2014 was more highly ionized than in 2001, a suggestion we now confirm by modelling the broad band spectrum from 2014 with the same photoionized grids used to parameterise the 2001 outflow.

Figure 3 (top panel) shows a section of the stacked pn spectrum covering the Fe K region. The data have been grouped with a minimum of 25 counts (for $\chi^2$ compatibility) and with a maximum of 3 data points per pn camera resolution (FWHM) to optimise the visibility of spectral structure. The emission near 6 keV is resolved into components with rest energies close to the neutral Fe–K fluorescent emission line and the 1s–2p resonance emission lines of He-like and H-like Fe, respectively. The absorption line at ∼7 keV is a factor ∼3 weaker than the corresponding line in 2001, with an equivalent width of 37±5 eV. In contrast, the deep 2014 exposure reveals additional structure at ∼6–10 keV, with apparent absorption lines at ∼6.9, ∼7.3, ∼7.5, ∼7.8, ∼8.2 and ∼8.6 keV. †

Gaussian fitting of those spectral features is detailed in Section 4.1, and while the significance of individual lines is limited, we emphasise that finding a common velocity for a line series can be highly significant, again underlining the importance of taking proper account of multiple absorption lines in the study of x-ray outflows. Analysis and interpretation of the Fe K absorption line structure, providing further detail on the highly ionized wind in PG1211+143, is the main purpose of this paper.

Before testing for ionized absorption it is especially important to correctly model the underlying continuum for such high quality data. In particular, scattering from optically thick matter (or so-called ‘reflection’ found to be common in AGN spectra (Nandra and Pounds 1994)) may impose a step change near the Fe K absorption edge (∼6.5 keV in observer space), and an indication of such an effect can be seen in Figure 3 (top panel). To quantify that ‘reflection’ we added a XILLVER component (Garcia et al. 2013) to the power law continuum model in XSPEC, simultaneously matching the fluorescent Fe K emission line and continuum reflection from optically thick ionized matter. When previously modelled with a Gaussian, the Fe K line energy of ∼5.96 keV (∼6.44 keV at the AGN redshift), and EW of 73 eV yielded a 2–10 keV spectral fit statistic of (χ^2 of 1513/1364). Re-fitting the Gaussian with XILLVER provided a corresponding adjustment to the continuum from reflection, with a further improvement in χ^2 of 1495/1359. The reflection component had an ionization parameter of logξ∼2.1, with inclination fixed at 45° and a small outflow velocity of 1500±1200 km s^{-1} in the AGN rest-frame. Critically, although reduced in depth, the absorption features at ∼7–9 keV in Fig.3 (top) remained clearly visible.

Having modelled the underlying continuum, a photoionized absorber was then added to match that absorption structure, obtaining a significant improvement to the spectral fit (χ^2 of 1470/1361), for a column density $N_H$ of 7.2±5.0 $×$ 10^{22} cm$^{-2}$, ionization parameter logξ=3.3±0.1 erg cm s$^{-1}$ and outflow velocity of 0.119±0.003c. The addition of a photoionized emission spectrum, with tied ionization parameter, reproduced the ionized emission lines at ∼6.2 and ∼6.45 keV, and further improved the fit (χ^2 of 1445/1359), with the column density of the absorber decreasing to $N_H$ of 5.8±3.2 $×$ 10^{22} cm$^{-2}$. The tied ionization parameter (logξ=3.42±0.05 erg cm s$^{-1}$) and absorber velocity were unchanged in this second fit, while untying the ionization parameters of the emission and absorption spectra made little difference to χ^2. The ionized emission spectrum was found to have a blueshift (relative to the AGN), corresponding to an outflow velocity of 4200±1200 km s$^{-1}$, which we take to represent a mean value averaged over an extended ionized outflow.

Figure 3 (lower panel) illustrates the key 4–9 keV section of the single velocity outflow model, with absorption lines seen in the data at ∼7 and ∼7.3 keV identified with the 1s–2p resonance lines of FeXXV and XXVI, and absorption lines at ∼8.2 and ∼8.6 keV with He–β and a blend of Lyman–β and He–γ of the same ions. Finding a match to four absorption features with the same outflow velocity adds confidence in the robustness of the spectral fit.

The photoionized emission spectrum in Figure 3 correspondingly matches the two high energy components in the ratio plot, being identified with the He– and H-like resonance lines, in a ratio set by the linked ionization parameter. Encouragingly, the He–β emission line can also be seen at ∼7.7 keV in both data and model, with a similar blueshift.

† The absorption lines at ∼8.2 and ∼8.6 keV lie close to fluorescent x-ray emission lines of Cu and Zn arising from energetic particle impacts on the pn camera electronics board (Struder et al. 2001). Fortunately, the low particle background throughout most of the 2014 XMM-Newton observations (Figure 2) ensured such background features have a negligible effect on the source spectrum, an outcome confirmed by obtaining a very similar ratio plot to that in Figure 3 when no background data is subtracted.
improvement to the fit (fitting the 2–10 keV spectrum showed a further substantial
portion parameter, column density and velocity again free. Re-
the fit a second absorber was therefore added, with ioniza-
and data is incomplete. To seek a further improvement in
XXVI in the photoionized outflow, the comparison of model
resonance and higher order transitions in Fe XXV and Fe
XXVI. The model includes continuum reflection and linked Fe K
fluorescence line emission (black) and is completed with a softer,
absorption imprinted on the hard power law continuum (red). A
∼ lines observed at
∼ lines, again of Fe XXV and
∼ lines identified as
the He-like absorption line in the lower velocity outflow, pre-
viously partly hidden by the emission line at
∼ keV. A consequence of that line blend is to increase the
relative strength of the higher velocity Lyman-α line and hence - substantially - both the ionization parameter and
column density of that flow component. The higher outflow
velocity is also increased slightly in the dual velocity fit, to
0.129±0.002c.
An important consequence of simultaneously modelling
the absorption and (re-)emission spectra is demonstrated by
the He-α absorption line in the lower velocity outflow, previous-
ly partly hidden by the emission line at
∼ keV. In turn, the partial absorption of the Fe Lyman-α emission line
explains the relative weakness of that emission component
in the data ratio plot. Comparing Figures 3 and 4, and the
fit residuals, confirms that a significant contribution to the
improved dual absorber fit lies in better matching the ob-
served opacity at
∼ keV, while the lower velocity He-like absorption line models the sharp drop in the data at
∼ 6.6 keV as it cuts into the blue wing of the H-like emission line.
From the dual velocity outflow spectral fit we find a
mean 2–10 keV source luminosity of
∼ 6×10^{43} \text{ erg s}^{-1}. The total extracted (absorbed) and added (emission) luminosi-
ties are
∼ 2.2×10^{42} \text{ erg s}^{-1} and
∼ 7×10^{41} \text{ erg s}^{-1}, respectively, with the lower velocity, lower ionization absorber contributing ∼80% of the 2–10 keV opacity. Table 1 sum-
marises the main parameters of the photoionized absorption
and emission spectra describing the highly ionized outflow
in PG1211+143 in 2014.
To summarise, in XSPEC terms the final model is:
TBabs(\text{pl}_{\text{soft}} + (\text{pl}_{\text{hard}})(mtable)(mtable)) + \text{XILLVER} + \text{atable}, where \text{pl}_{\text{hard}} is the dominant continuum component (Γ∼1.6), subject to ionized absorption from the two outflow
components. XILLVER represents the reflection continuum and associated Fe K fluorescence line, as described in the
text. \text{pl}_{\text{soft}} is a soft continuum component (Γ∼2.9) found from inter-orbit difference spectra where the subtraction of low flux spectra from high flux spectra show the residual spectrum is well described by a simple power law. While this variable, soft continuum component has little impact on the
present analysis, it is included for consistency with the soft x-ray analysis of XMM-Newton grating spectra (Pounds et al. 2015).

Figure 4 (lower panel) compares the stacked 2014 pn
data with the dual velocity outflow model (plotted immedi-
ately above), while Figure 5 shows the spectral model plot

### Table 1. Final parameters of the highly ionized outflow obtained from a 2–10 keV spectral fit to the 2014 pn data, with two photoionized absorbers, defined by ionization parameter $\xi$ (erg cm s$^{-1}$), column density $N_H$ (cm$^{-2}$) and outflow velocity ($v/c$), together with a photoionized emission spectrum modelled by an ionization parameter and outflow velocity. Extracted or added luminosities (erg s$^{-1}$) over the fitted spectral band 2–10 keV and the improvement in $\chi^2$ are also given for each photoionized model component.

| comp | log$\xi$ | $N_H$ (10^{23}) | $v/c$ | $L_{abs/em}$ | $\Delta\chi^2$ |
|------|---------|----------------|-------|--------------|--------------|
| abs  | 4.0±0.2 | 3.7±2.9        | 0.129±0.002 | 5×10^{41}   | 15/3         |
| abs  | 3.4±0.1 | 2.0±1.0        | 0.066±0.003  | 1.8×10^{42} | 27/3         |
| emi  | 3.5±0.1 | 1 (f)          | 0.011±0.003  | 7×10^{41}   | 34/3         |

### 3.1 A second velocity component in the highly ionized wind of PG1211+143.

Examination of Figure 3 shows that while the absorption
lines seen at
∼ 7.3, ∼ 8.2 and ∼ 8.6 keV are matched by
resonance and higher order transitions in Fe XXV and Fe
XXVI in the photoionized outflow, the comparison of model and
data is incomplete. To seek a further improvement in
the fit a second absorber was therefore added, with ioniza-
tion parameter, column density and velocity again free. Re-
fitting the 2–10 keV spectrum showed a further substantial
improvement to the fit ($\chi^2$ of 1415/1356), with the second
absorption component having a significantly lower outflow
velocity of 0.066±0.003c.

Figure 4 (top) illustrates the dual velocity absorber model, with the Lyman-α line of the lower velocity flow now
blending with He-α from the high velocity wind to provide
a better match to the broad absorption feature observed at
∼ 6.9 keV. A consequence of that line blend is to increase the
relative strength of the higher velocity Lyman-α line and hence - substantially - both the ionization parameter and
column density of that flow component. The higher outflow
velocity is also increased slightly in the dual velocity fit, to
0.129±0.002c.
over the full 2–10 keV energy range to better illustrate continuum and line emission components.

From the lower panel of Figure 5 we note the absence of a hard excess in the data-to-model ratio confirms that continuum reflection is adequately modelled by Xillver, at least up to 10 keV in our spectral fit, and does not indicate the strong reflection reported in Zoghbi et al.(2015). Although discussed further at this point we note the strongest residual in the lower part of Figure 5 is excess emission near 9 keV, which - if confirmed - could represent blue-shifted FeXXVI RRC, perhaps indicative of a cooling flow.

4 SUPPORTING EVIDENCE FOR DUAL OUTFLOW VELOCITIES

4.1 Gaussian line fitting to the observed spectral structure

Gaussian fitting to the emission and absorption line structure seen in the stacked pn data provides a model-independent check on the robustness of the above spectral analysis. The 4–10 keV ratio plot shown in Figure 6, obtained by removing the photoionized absorption and emission spectra from the best fit model of Section 3, was scanned sequentially with positive and negative Gaussians, having a minimum (1σ) line width of 50 eV comparable to the pn detector resolution. All features giving $\Delta \chi^2 \geq 6$ were recorded and the sweep was then repeated with two broader absorption features at $\sim$7 keV and $\sim$8.2 keV re-fitted as narrow line pairs, making 9 absorption lines in all. The emission and absorption blend at $\sim$6.5–6.6 keV was resolved by fixing the emission line width at 100 eV. The resulting fit is shown in Figure 6, with the measured line energies, equivalent width and proposed identifications listed in Table 2.

Of the 9 narrow absorption lines in Table 2, those at $\sim$6.62, $\sim$6.87, $\sim$7.82 and $\sim$8.17 keV have observed line energies consistent with an outflow velocity in the range 0.065–0.069c when identified with the $\alpha$ and $\beta$ lines of FeXXV and FeXXVI. Taken as a line set, the weighted mean velocity is $\Delta \chi^2 = 51/8$), providing strong model-independent support for the lower velocity absorber in Table 1. Four (of 5) remaining Gaussians, at $\sim$7.04, $\sim$7.31, $\sim$8.34 and $\sim$8.70 keV, are consistent with the higher outflow velocity found in spectral modelling, with individual values - based on identification with the same set of resonance absorption lines - ranging from 0.125–0.134c, and a mean value $v$ $\sim$0.128±0.002c. For this higher velocity line-set the statistical improvement of Gaussian line fitting is also highly significant ($\Delta \chi^2 = 57/8$).

Absorption line 5 does not fit the dual outflow velocity pattern, but is interesting in that the possible association with...
though not resolved in the Fe K spectrum in 2001, there is an observation in 2001 is again detected in 2014. 

Key factors in identifying the lower velocity flow in 2014 were the high quality of the stacked 2014 spectral data, allowing spectral features to be identified near the limit of CCD energy resolution, and the simultaneous modelling of highly ionized Fe, consistent with two distinct outflow velocities. The faster wind component has a velocity of \( v \simeq 0.19c \) which gave a marginal improvement to the dual velocity spectral modelling described in Section 3.2.

5 DISCUSSION

The extended observation of PG1211+143 in 2014 has provided high quality hard x-ray spectra revealing previously unseen spectral structure of a UFO in the ~6-10 keV energy band. Spectral modelling has identified the observed absorption structure with resonance and higher order lines of highly ionized Fe, consistent with two distinct outflow velocities. The faster wind component has a velocity of \( v \simeq 0.13c \), similar to that first seen in 2001, but with a higher column density and ionization parameter. The second outflow component, not resolved in the EPIC data in 2001, has a similar column density but a lower velocity \( v \sim 0.066c \).

Key factors in identifying the lower velocity flow in 2014 were the high quality of the stacked 2014 spectral data, allowing spectral features to be identified near the limit of CCD energy resolution, and the simultaneous modelling of highly ionized emission, which allowed - in particular - the lower velocity Fe XXV He-α absorption line to be detected. The photoionized emission spectrum also successfully reproduces the higher energy features observed in the stacked 2014 pn data, identified with resonance emission from He and H-like Fe ions in a similar ratio to that seen in absorption. Comparison of absorbed and (re-) emission luminosities indicates a substantial covering factor of the highly ionized wind.

An important outcome of the present analysis is in finding that the ultra-fast outflow discovered in an XMM-Newton observation in 2001 is again detected in 2014. Although not resolved in the Fe K spectrum in 2001, there is independent evidence for the co-existence of the lower velocity outflow in that earlier observation, from a re-analysis of the soft x-ray spectrum (Pounds 2014b) and in an earlier partial-covering spectral fit which required an absorber moving at \( \sim 0.07c \) to explain continuum curvature (Pounds and Reeves 2009).

The properties of powerful AGN winds are reviewed in King and Pounds (2015), where a highly ionized wind is envisaged being launched at the local escape velocity by continuum photons from a SMBH accreting at modest Eddington ratios \( \dot{m} = M/\dot{M}_{\text{Edd}} \sim 1 \), finding - for accretion from a disc - the excess accreting matter is expelled in a quasi-spherical wind, with a launch velocity \( v \sim \frac{2\dot{m}}{\dot{m}+1} \sim 0.1c \). Observational support for that picture is provided by recent archival searches (Tombesi et al. 2010, 2011; Gofford et al. 2013) which find a substantial fraction of luminous AGN having a highly ionized wind with a velocity in the range \( \sim 0.03-0.3c \).

The new observations indicate a more complex picture, with two distinct outflow velocities, co-existing in observations 13 years apart. Chaotic accretion (King and Pringle 2006), consisting of many prograde and retrograde events, offers an intriguing explanation of such a dual velocity wind, the persistence of two distinct outflow velocities perhaps relating to physically distinct orientations of the inner accretion flow, both close to Eddington, and with differing values of the accretion efficiency \( \eta \) and hence of velocity. That possibility is discussed in more detail by King and Nixon (2016).

Higher resolution hard x-ray spectra from the forthcoming Astro-H observatory should show how common are such complex highly ionized AGN winds as reported here for PG1211+143.

6 CONCLUSION

An extended XMM-Newton observation of the luminous narrow line Seyfert galaxy PG1211+143 in 2014 has revealed previously unseen spectral structure in Fe K absorption, finding a second high velocity component of the highly ionized wind. In identifying that additional complexity within the limits of CCD energy resolution, the 2014 observation benefited critically from the high statistical significance of the EPIC data resulting from the unusually long observation. The outcome promises further revelations of the dynamical structure of AGN winds in a new era of high resolution hard x-ray spectroscopy, heralded with the near-future launch of Astro-H.

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### Table 2.
Sequential Gaussian fits to the positive and negative features in the pn 2014 data shown in Figure 6. Absorption lines (abs 1-9) have a fixed width comparable to the pn detector resolution, with the fitted line energy, proposed identification and corresponding outflow velocity listed in each case. Improvement in $\Delta \chi^2$ is after re-fitting the data at 4–10 keV following each added line. All line identifications are with transitions in Fe XXV or Fe XXVI. The equivalent width of each line has been estimated separately in XSPEC.

| component | obs energy (keV) | EW (eV) | rest energy (keV) | line id | energy (keV) | v/c | $\Delta \chi^2$ |
|-----------|-----------------|---------|------------------|---------|--------------|-----|----------------|
| Fe K-α    | 5.98±0.01       | 80±7    | 6.46±0.01        | Fe K-α  | 6.40         | 0.009±0.002 | 139/3|
| Fe 25     | 6.26±0.02       | 19±7    | 6.77±0.02        | He-α    | 6.70         | 0.010±0.003 | 8/2  |
| Fe 26     | 6.49±0.07       | 73±15   | 7.02±0.07        | Ly-α    | 6.96         | 0.01±0.01   | 34/2 |
| abs 1     | 6.62±0.02       | -31±11  | 7.16±0.02        | He-α    | 6.70         | 0.066±0.003 | 12/2 |
| abs 2     | 6.87±0.01       | -22±6   | 7.43±0.01        | Ly-α    | 6.96         | 0.065±0.002 | 16/2 |
| abs 3     | 7.04±0.02       | -11±7   | 7.61±0.02        | He-α    | 6.70         | 0.127±0.003 | 7/2  |
| abs 4     | 7.31±0.02       | -22±8   | 7.90±0.02        | Ly-α    | 6.96         | 0.126±0.003 | 25/2 |
| abs 5     | 7.49±0.03       | -9±7    | 8.10±0.03        | He-α    | 6.70         | 0.188±0.004 | 7/2  |
| abs 6     | 7.82±0.03       | -16±9   | 8.45±0.03        | He-β    | 7.88         | 0.069±0.003 | 10/2 |
| abs 7     | 8.17±0.02       | -20±8   | 8.83±0.02        | Ly-β    | 8.25         | 0.068±0.002 | 13/2 |
| abs 8     | 8.34±0.04       | -16±9   | 9.02±0.04        | He-β    | 7.88         | 0.134±0.005 | 6/2  |
| abs 9     | 8.70±0.02       | -41±11  | 9.40±0.02        | Ly-β    | 8.25         | 0.129±0.003 | 19/2 |
| abs 9     | 8.70±0.02       | -41±11  | 9.40±0.02        | He-γ    | 8.29         | 0.125±0.003 | 19/2 |

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