DISCOVERY OF RELATIVISTIC OUTFLOW IN THE SEYFERT GALAXY Ark 564

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ABSTRACT

We present Chandra High Energy Transmission Grating Spectra of the narrow-line Seyfert-1 galaxy Ark 564. The spectrum shows numerous absorption lines which are well modeled with low-velocity outflow components usually observed in Seyfert galaxies. There are, however, some residual absorption lines which are not accounted for by low-velocity outflows. Here, we present identifications of the strongest lines as Kα transitions of O vii (two lines) and O vi at outflow velocities of $\sim$0.1c. These lines are detected at 6.9σ, 6.2σ, and 4.7σ, respectively, and cannot be due to chance statistical fluctuations. Photoionization models with ultra-high velocity components improve the spectral fit significantly, providing further support for the presence of relativistic outflow in this source. Without knowing the location of the absorber, its mass and energy outflow rates cannot be well constrained; we find $\dot{E}$(outflow)/$L_{bol}$ lower limit of $\geq$0.006% assuming a bi-conical wind geometry. This is the first time that absorption lines with ultra-high velocities are unambiguously detected in the soft X-ray band. The presence of outflows with relativistic velocities in active galactic nuclei (AGNs) with Seyfert-type luminosities is hard to understand and provides valuable constraints to models of AGN outflows. Radiation pressure is unlikely to be the driving mechanism for such outflows and magnetohydrodynamic may be involved.

Key words: black hole physics – galaxies: Seyfert – quasars: absorption lines – X-rays: galaxies

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1. INTRODUCTION

There have been reports of ultra-high-velocity outflows in the X-ray spectra of radio-quiet active galactic nuclei (AGNs) and quasars. These outflows are identified through blueshifted Fe xxv and/or Fe xxvi absorption lines (at rest-frame energies of 7–10 keV) from highly ionized gas ($\log \xi^{\mathrm{Fe}} = 3$–$6 \mathrm{erg \ s^{-1} \ cm}$), with column densities as large as $N_{\mathrm{H}} = 10^{22}$–$10^{24} \mathrm{cm^{-2}}$, and with relativistic velocities of 0.1c–0.3c (Pounds et al. 2003a, 2003b; Tombesi et al. 2010 and references therein). The mass outflow rate of these high-velocity outflows was comparable to the accretion rate and their kinetic energy was a significant fraction of the bolometric luminosity (Tombesi et al. 2012). These outflows can provide effective feedback that is required by theoretical models of galaxy formation to solve a number of astrophysical problems ranging from cluster cooling flows to structures of galaxies.

Although high-velocity outflows are detected in a large number of sources, in all the cases, identification is based on Fe K-shell transitions which fall in a region of the spectrum where instrumental resolution is much lower than in the soft X-ray band. The significance of the absorption line detections is often questioned and with only a few lines observed accurate parameterization of the photoionized plasma becomes difficult. While the observed transitions are from highly ionized gas ($\log \xi = 3$–$6 \mathrm{erg \ s^{-1} \ cm}$), photoionization models predict that in such a plasma, in addition to highly ionized iron, lighter elements should also be present, the strongest of which are S, Si, and O (e.g., Sim et al. 2010; Krongold et al. 2003). Absorption lines from these highly ionized elements lie in the soft X-ray band, so warm absorber (WA) signatures of relativistic outflows at soft X-rays should be present, but were never unambiguously observed until now (see Section 5.3 for existing evidence). For a complete understanding of the properties of high-velocity outflows, it is necessary to detect transitions of other ions such as O, Ne, Si, and S as predicted by models.

In this paper, we report the serendipitous discovery of high-velocity outflows in the soft X-ray band in Ark 564, identified during our detailed analysis of the Chandra archival data of this source (Gupta et al. 2013, hereafter Paper I). Primary goal of Paper I was to self-consistently analyze and model the grating spectra of typical ($V_{\text{out}} = 100$–1000 km s$^{-1}$) WAs in Ark 564. Here, we present the discovery of WAs with ultra-high velocities.

2. DATA AND SPECTRAL ANALYSIS

Ark 564 is a bright, nearby ($z = 0.024684$), narrow-line Seyfert 1 (NLS1) galaxy, with luminosity of $L_{2–10 \mathrm{keV}} = (2.4–2.8) \times 10^{43} \mathrm{erg \ s^{-1}}$ (Turner et al. 2001; Matsumoto et al. 2004; Paper I). In Paper I, we discussed the Chandra observation and data reduction of this source which we briefly summarize here. Ark 564 was observed with the Chandra High Energy Transmission Grating Spectrometer (HETGS) in 2008 in three separate exposures totaling 250 ks. We followed the standard procedure to extract spectra. We used the software package CIAO (Version 4.3) and calibration database CALDB (Version 4.4.2) developed by the Chandra X-Ray Center. We co-added the negative and positive first-order spectra and built the effective area files (ARFs) for each observation using the fullgarf CIAO script. The HETG–MEG spectra were analyzed using the CIAO fitting package Sherpa.

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6 The ionization parameter $\xi = L_{\mathrm{ion}}/nr^2$, where $L_{\mathrm{ion}}$ is the ionizing luminosity between 1 Ryd and 1000 Ryd (1 Ryd = 13.6 eV), $n$ is the number density of the material, and $r$ is the distance of the gas from the central source.
We co-added the spectra obtained with HETG–MEG and averaged the associated ARFs. We fitted the continuum with absorbed power law plus blackbody component and modeled all the statistically significant local absorption ($z = 0$) features with Gaussian components. Further, we used the photoionization model fitting code PHotoionized Absorption Spectral Engine (PHASE; Krongold et al. 2003), to fit the typical WA features. The best-fit model of intrinsic absorption requires two WAs with two different ionization states ($\log U^7 = 0.38 \pm 0.02$ and $\log U = -1.3 \pm 0.13$), both with moderate outflow velocities ($\sim 100$ km s$^{-1}$) and relatively low line-of-sight column densities ($\sim N_H = 10^{20}$ cm$^{-2}$). For detailed spectral analysis and best-fit parameters, we refer readers to Paper I.

Though most of the intrinsic absorption features in the source spectrum are well fitted with two WAs, there are residual absorption line-like features in the spectral regions of 19.0–21.0 Å, 17.0–17.5 Å, and 13.5–13.8 Å each with individual significance of $1.7\sigma$–$6.9\sigma$ (Figure 1). To check for the consistency of these residuals and to confirm that these are not the artifacts of co-adding spectra, we inspect individual Ark 564 HETGS–MEG spectra from the 2008 observations. After fitting the data with continuum, Galactic, and two-phase WAs model (Model A) as noted above, the same residuals are found in the same spectral region in all the three observations (Figure 2). In the following sections, we discuss the identifications, statistical significance, and possible origin of these absorption lines.

3. DISCOVERY OF HIGH-VELOCITY OUTFLOWS

3.1. Identification of the Absorption Lines

The strongest residual features in the co-added spectrum are present at 19.805 ± 0.005 Å, 19.845 ± 0.001 Å, and 20.250 ± 0.011 Å (observed frame; Figure 1). Errors refer to 1σ confidence level throughout the paper unless noted otherwise. First, we try to identify the features at 19.805 ± 0.005 Å and 19.845 ± 0.001 Å. There is no known instrumental feature near these energies (Chandra Proposers’ Observatory Guide, or POG). The $z = 0$ lines are already included in the model; there are no permitted lines with oscillator strength >0.001 at wavelength of either 19.805, 19.845, or 20.250 Å. At the observed energies, there would be no intervening system with $z_{\text{WHIM}} < z_{\text{Ark564}}$ from the warm–hot intergalactic medium (WHIM; Mathur et al. 2003; Nicastro et al. 2005). Therefore, we assume that these absorption lines are intrinsic to the source. We identify these lines based on a combination of chemical abundance and line strength (the oscillator strength $f > 0.1$). Given the detected wavelength and assuming a very broad range of inflow/outflow velocities $-60,000$ to $60,000$ km s$^{-1}$ the likely candidates are O vii Kβ at $\lambda_{\text{rest}} = 18.62$ Å, O viii Kα at $\lambda_{\text{rest}} = 18.96$ Å, Ca xvii Kβ at $\lambda_{\text{rest}} = 19.56$ Å, Ca xvi Kβ at $\lambda_{\text{rest}} = 20.617$ Å, Ar xv Kβ at $\lambda_{\text{rest}} = 21.15$ Å, Ca xv Kα at $\lambda_{\text{rest}} = 21.45$ Å, and O vii Kα at $\lambda_{\text{rest}} = 21.602$ Å. Considering that argon and calcium are orders of magnitude less abundant than oxygen, and because O vii Kα and O viii Kα are by far the strongest possible lines, the most likely candidates are O viii Kα with inflow velocities of 0.019c and 0.021c, or O vii Kα with outflow velocities of 0.105c and 0.103c.

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Figure 1. Residuals of data: Model A fit to the co-added spectrum of Ark 564, in the observer frame (Model A: two-component WA model plus continuum, emission lines, and local absorption from Paper I). The possible transitions due to high-velocity WAs are indicated with red labels. (A color version of this figure is available in the online journal.)
To distinguish between the two possibilities of inflow and outflow, we search for possible associations of other lines such as O viii kβ, O vii kβ, O vi, and/or O v. We do not find any possible association for inflows. The absorption feature at 20.25 ± 0.01 Å corresponds to O vi kα (λ_{rest} = 22.037 Å) at the outflow velocity of 0.103c. We also found an absorption feature at 17.085 ± 0.011 Å with 1.7σ significance, corresponding to O vii kβ line at the outflow velocity of 0.105c. The detection of O vi kα and O vii Kβ lines at the same velocity favors the outflow scenario.

3.2. Statistical Significance of Absorption Lines

To investigate whether the apparent absorption lines could be due to statistical fluctuations, we calculate the probability of detecting individual lines due to random statistical fluctuation. First, we fit the lines with negative Gaussians of fixed width 0.001 Å, folding through the detector response and leaving other parameters (centroid and amplitude) free to vary. The addition of three Gaussian lines at 19.805 ± 0.006 Å, 19.845 ± 0.005 Å, and 20.250 ± 0.005 Å to our previous model (Model A) improves the fit statistic by Δχ^2 = 120, Δdof = 6, an improvement at more than 99.99% confidence by the F-test (Bevington & Robinson 1992). We measured the equivalent width (EW) of lines at 19.805 Å, 19.845 Å, and 20.250 Å of 15.6 ± 2.5 mÅ, 16.5 ± 2.4 mÅ, and 16.1 ± 3.4 mÅ, respectively. Errors are at 1σ confidence level and are calculated using the “projection” command in Sherpa. Thus, the three absorption lines are detected with 6.2σ, 6.9σ, and 4.7σ significance, respectively. Further, using the Gaussian probability distribution, we looked for the probability of detecting these lines by chance. For the lines detected with 6.2σ, 6.9σ, and 4.7σ significance, the probability of false detection is 2.8 × 10^{-10}, 2.6 × 10^{-12}, and 1.3 × 10^{-6}, respectively. There are, however, 4801 wavelength bins in our spectrum (these are all the wavelength bins in the wavelength range of 1–25 Å, beyond which data are of poor quality. The rest of the HETG spectrum was never used in any of the analysis, even in Paper I). Therefore, the probability of finding absorption lines at the observed significance anywhere in the spectrum due to random statistical fluctuations is 0.0001%, 0.000001%, and 0.6%, respectively.

For the outflow system with a velocity of 0.105c, we also detected the O vii Kβ line with chance probability of 0.04. Thus, the combined chance detection probability of detecting both O vii Kα and O vii Kβ lines is 4 × 10^{-6}. Similarly, for the other system (at 0.103c) the combined chance detection probability of detecting both O vii Kα and O vi Kα is 4 × 10^{-8}. Thus, we conclude that the detected absorption lines are not due to random statistical fluctuations, but are signatures of outflows.

3.3. Other Absorption Lines at a Blueshift of ≈0.1c

After confirming the high detection significance of O vii and O vi absorption lines identified with high-velocity outflows, we searched the entire spectrum for other ionic transitions at similar blueshifts. We detected two other absorption features at 17.351 ± 0.009 and 13.625 ± 0.011 Å with EWs of 11.8 ± 2.7 and 5.0 ± 1.7 mÅ (Figure 3 and Table 1). The feature at 13.63 Å is also detected in the High-Energy Grating spectrum. The tentative identification of these features is O vii Kα and Fe xvii.
and to the above-reported systems of high-velocity outflow. The outflow velocities of these systems are close to each other.

The equivalent hydrogen column density parameters of the code are (1) the ionization parameter \( U \), (2) absorb of the material, its column density, and its internal turbulent motion. The abundances have been set at the solar values (Grevesse et al. 1993). Usually, the micro-turbulent velocity is not left free to vary, because different transitions due to ionized gas are heavily blended, or because different velocity components are also blended and cannot be resolved (e.g., Krongold et al. 2003, 2005 for NGC 3783). In the case of Ark 564, with the HETGS resolution, it is possible to distinguish two velocity components (see below). Thus, despite the fact that the individual absorption lines cannot be resolved, we have left the micro-turbulent velocity free to vary. We used the Ark 564 spectral energy distribution from Romano et al. (2004) to calculate the ionization balance of the absorbing gas in the PHASE, same as in Paper I.

A PHASE component (which we call system 1) with an ionization parameter of \( \log U = -0.60 \pm 0.38 \) and column of \( \log N_\text{H} = 19.8 \pm 0.2 \text{ cm}^{-2} \) successfully reproduced the O vi K\( \alpha \) and K\( \beta \) lines at \( 19.805 \) and \( 17.085 \) km s\(^{-1} \), at a blueshift of \( 32365 \pm 38 \) km s\(^{-1} \) with respect to the source (Figure 4). The addition of the PHASE component “system 1” to Model A significantly improves the fit (\( \Delta \chi^2 = 15 \), \( \Delta \text{dof} = 4 \)). According to F-test, the absorber is present at a confidence level of 99.87%. A second low ionization parameter component (we call this system 2) with log \( U = -1.2 \pm 0.21 \) and column of \( \log N_\text{H} = 20.0 \pm 0.3 \text{ cm}^{-2} \) is also required to fit other high-velocity outflow absorption features such as of O vi and O vii, with outflow velocity of \( 31735 \pm 59 \) km s\(^{-1} \) (Figure 4). Including this component improves the fit (\( \Delta \chi^2 = 31, \Delta \text{dof} = 4 \)) over the previous model at a confidence level of more than 99.999%, according to F-test. The best-fit PHASE parameters are reported in Table 2 and the best-fit model is shown in Figure 5. Successfully modeling the residuals with two PHASE components robustly confirms the presence of high-velocity outflows in Ark 564.

### Table 1
Absorption Lines Identified with Relativistic Outflows in the HETGS Spectrum of Ark 564

| Ion | \( \lambda_{\text{obs}} \) (\( \AA \)) | \( \lambda_{\text{rest}} \) (\( \AA \)) | \( v_{\text{out}} \) (km s\(^{-1} \)) | EW (mA) |
|-----|-----------------|-----------------|-----------------|--------|
| O vi | 20.250 ± 0.005 | 22.026 | 30834 ± 67 | 16.1 ± 3.4 |
| O vii K\( \alpha \) | 19.845 ± 0.005 | 21.602 | 31039 ± 68 | 16.5 ± 2.4 |
| O vii K\( \alpha \) | 19.805 ± 0.006 | 21.602 | 31581 ± 81 | 15.6 ± 2.5 |
| O vii | 17.351 ± 0.009 | 18.969 | 32199 ± 139 | 11.8 ± 2.7 |
| O vi K\( \beta \) | 17.085 ± 0.011 | 18.627 | 31463 ± 175 | 4.0 ± 2.4 |
| Fe xvii | 13.625 ± 0.011 | 15.015 | 34330 ± 215 | 5.0 ± 1.7 |

K\( \alpha \) at outflow velocities \( \sim -0.110c \) and \( \sim -0.114c \), respectively. The outflow velocities of these systems are close to each other and to the above-reported systems of high-velocity outflow.

### 4. PHOTOIONIZATION MODELING OF HIGH-VELOCITY OUTFLOWS

To determine the physical properties of the absorber responsible for producing highly blueshifted absorption features and to check for the physical consistency of line identifications, we modeled the negative Gaussian lines in the above fits with a photoionization model based on the code PHASE (Krongold et al. 2003). The PHASE code models self-consistently more than 3000 X-ray bound–bound and bound–free transitions imprinted by photoionized absorbers, given the ionization state of the absorber, its column density, and its internal turbulent motion. The parameters of the code are (1) the ionization parameter \( U \), (2) equivalent hydrogen column density \( N_\text{H} \), (3) outflow velocity of the absorbing material \( v_{\text{out}} \), and (4) micro-turbulent velocity \( v_{\text{turb}} \) of the material. (A color version of this figure is available in the online journal.)
Figure 4. High-velocity outflow absorption features fitted with two PHASE components of outflow velocity of 0.103c (red) and 0.105c (blue). The ionic transitions are labeled in black. The spectrum is presented in the observer frame.

(A color version of this figure is available in the online journal.)

Table 2

| Parameter               | System 1          | System 2          |
|-------------------------|-------------------|-------------------|
| $\log U$                | $-0.60 \pm 0.38$  | $-1.2 \pm 0.21$   |
| $\log N_H$ (cm$^{-2}$)  | $19.8 \pm 0.2$    | $20.0 \pm 0.3$    |
| $V_{\text{Turb}}$ (km s$^{-1}$) | $85 \pm 14$        | $92 \pm 12$        |
| $V_{\text{Out}}$ (km s$^{-1}$) | $32365 \pm 38$      | $31735 \pm 59$     |
| $\Delta \chi^2_a$      | 15                | 31                |
| $\log (\xi \text{ erg s}^{-1} \text{ cm})$ | $1.25 \pm 0.38$ | $0.65 \pm 0.21$ |

Note. * Improvement in $\chi^2$ to fit after adding model component.

5. DISCUSSION

5.1. Comparison with Theoretical Models

Several models suggest radiation pressure as the driving mechanism to produce the typical low-velocity outflows observed in Seyfert galaxies (Proga & Kallman 2002, 2004; Krolik & Kriss 1995; Dorodnitsyn et al. 2008). But in radiation-driven disk-wind models outflow velocities depend on AGN luminosity and these models cannot account for relativistic velocities in AGNs with Seyfert-type luminosities (Barai et al. 2011). Relativistic outflows in the UV have been detected only in most luminous broad absorption line quasars. Indeed, Laor & Brandt (2002) and Ganguly & Brotherton (2008) have shown that the maximum outflow velocity is proportional to $L^{0.6}$, close to what is expected from radiation-pressure-driven winds. Observations of relativistic outflows in X-rays in moderate luminosity AGNs therefore pose intriguing puzzles; as shown in Figure 6, the relativistic outflows (from Tombesi et al. 2011) lie above the Ganguly & Brotherton line of maximum velocity. The relativistic outflow we find in Ark 564, shown as an * in Figure 6, also lies above the line. Thus, these high-velocity outflows appear not to be driven by the radiation line pressure mechanism.

The King (2010) shock-wind models produce winds with velocities $v \sim 0.1c$, but in quasars accreting at Eddington limits.
velocity outflow in Ark 564, we estimate the mass and energy outflow rates in several different ways.

It is often assumed that the observed outflow velocity is the escape velocity at the launch radius \( r \); i.e., \( v = (2GM_{\text{BH}}/r_{\text{out}}) \).

There is no justification for this assumption, as shown by Mathur & Stoll (2009). Nonetheless, making this assumption provides us with a lower limit on the absorber location. Romano et al. (2004) determine the central black hole mass of Ark 564 to be \( M_{\text{BH}} \lesssim 8 \times 10^6 M_\odot \). This leads to the minimum distance of system 1 and system 2 absorbers of \( r_{\text{min}} = 84 r_s \) and \( r_{\text{min}} = 88 r_s \), respectively (in units of the Schwarzschild radius; for Ark 564 \( r_s = 7.8 \times 10^{-7} \) pc). The estimate of maximum distance from the central source can be derived assuming that the depth \( \Delta r \) of the absorber is much smaller than the radial distance of the absorber (\( \Delta r \ll r \)) and using the definition of the ionization parameter (\( U = (Q(H)/4\pi r^3 n_{\text{HIC}}) \)), i.e., \( r \lesssim r_{\text{max}} \approx (Q(H)/4\pi U n_{\text{HIC}}) \).

Using the best-fit values of the ionization parameter and column density, we estimated the upper limits on system 1 and system 2 absorber locations of \( r_{\text{max}} = 5.4 \) kpc and \( r_{\text{max}} = 13.6 \) kpc, respectively, which are not very interesting limits.

For a bi-conical wind, the mass outflow rate is \( \dot{M}_{\text{out}} \approx 1.2\pi m_p N_{\text{HIC}} v_{\text{out}}^2 \) (Krongold et al. 2007). Substituting \( r \) with \( r_{\text{min}} \) and using outflow velocities of 32,365 km s\(^{-1}\) and 31,735 km s\(^{-1}\), we obtain lower limit on mass outflow rates of \( M_{\text{out}} \gtrsim 4.1 \times 10^{26} \) g s\(^{-1}\) and \( M_{\text{out}} \gtrsim 4.2 \times 10^{26} \) g s\(^{-1}\) for system 1 and system 2 absorbers, respectively. Similarly, we obtained the constraints on kinetic luminosity of the outflows of \( E_K \gtrsim 7.2 \times 10^{59} \) erg s\(^{-1}\) and \( E_K \gtrsim 7.1 \times 10^{59} \) erg s\(^{-1}\) for system 1 and system 2 absorbers, respectively. In comparison to the Ark 564 bolometric luminosity of \( 2.4 \times 10^{44} \) erg s\(^{-1}\), the total kinetic luminosity of these high-velocity outflows is \( E_K/L_{\text{bol}} \gtrsim 0.006\% \). This lower limit is much smaller than the ratio of \( E_K/L_{\text{bol}} \sim 0.5\%–5\% \) expected if the outflow is to be important for feedback (Hopkins & Elvis 2010; Silk & Rees 1998; Scannapieco & Oh 2004; di Matteo et al. 2005). However, with very large uncertainties between \( r_{\text{min}} \) and \( r_{\text{max}} \), the ratio between the mechanical power of these outflows and the bolometric luminosity cannot be well constrained.

5.3. Comparison with Other High-Velocity Outflows

Before this work, the high-velocity outflows were detected mostly with Fe xxv and/or Fe xxvi absorption lines in hard X-ray band (Section 1). In a handful of quasar such as PG1121+143 (Pounds et al. 2003b), PG0844+349 (Pounds et al. 2003a), and MR 2251–178 (Gibson et al. 2005) high-velocity outflows were detected at soft X-ray energies, but these detections were either based on absorption lines of low statistical significance or have strong contamination from absorption lines from the halo of our Galaxy.

Here, we present the detection of high-velocity outflows in Ark 564; this is the first time such outflows are found in the soft X-ray band in a Seyfert galaxy. We firmly establish the presence of high-velocity WAs first through identifying number of ionic transitions at similar velocity and further successfully modeling these features with photoionization models. Papadakis et al. (2007) also detected an absorption line at 8.1 keV in the low-resolution CCD spectra of Ark 564 and assuming that this line corresponds to Fe xxvi, they suggested the presence of highly ionized, absorbing material of \( \log N_{\text{H}} > 23 \) cm\(^{-2}\) outflowing with relativistic velocity of 0.17c. If the presence of a feature and its identification are correct, then this is suggestive of a velocity gradient with higher charge states such as Fe xxvi at higher velocity. Interestingly, the two “other” lines we identified

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**Figure 6.** Outflow velocity plotted as a function of AGN luminosity. The solid line represents the upper envelope relation from Ganguly & Brotherton (2008) modified to plot the bolometric luminosity instead of the 3000 Å luminosity. The points are for the relativistic outflows in Tombesi et al. (2011). Ark 564 ultra-fast outflow is shown by a star (this work). It is clear that these ultra-fast outflows are not confined within the Ganguly & Brotherton envelope.
in Ark 564 (Section 3.3) also have somewhat higher velocity than system 1 and system 2 and have higher charge states. This is exactly as expected from the models of King (2010) and Fukumura et al. (2010a, 2010b).

Recently, Tombesi et al. (2013) presented the connection between ultra-fast outflows (UFOs) and soft X-ray WAs. They strongly suggest that these absorbers represent parts of a single large-scale stratified outflow and they continuously populate the whole parameter space (ionization, column, velocity), with the WAs and the UFOs lying always at the two ends of the distribution (Figure 7). The Ark 564 low-velocity WAs (Paper I) and UFOs (Papadakis et al.) are in well agreement with linear correlation fits from Tombesi et al. (2013). However, our low-ionization low-column high-velocity outflows in the Ark 564 probe a completely different parameter space. Figure 7 clearly shows that Ark 564 high-velocity outflows have the ionization parameter and column density as of typical WAs, but much higher velocity, probing a distinct region in velocity versus ionization/column parameter space.

6. CONCLUSION

We report on the discovery of high-velocity outflows in the NLS1 Galaxy Ark 564. These absorbers are identified through multiple absorption lines of O vi, O vii Kα, O vii Kβ, O viii, and Fe xvii at blueshifts of ~0.1c (with respect to the source) detected in the Chandra HETG–MEG spectra. The two observed velocity components are well fitted with two photoionization model components. Both absorbers have a low ionization parameter of \( \log U = -0.60 \pm 0.38 \) and \(-1.2 \pm 0.21 \) and low-column densities of \( \log N_H = 19.8 \pm 0.2 \) and \(20.0 \pm 0.3 \) cm\(^{-2}\) and are required at high significance of 99.87\% and > 99.99\%, respectively.

Without knowing the location of the absorber, its mass and energy outflow rates cannot be well constrained; we find \( \dot{E}/L_{\text{bol}} \) lower limit of \( >0.006\% \) assuming a bi-conical wind geometry. Determining the absorber location is therefore very important for providing meaningful constraints. This can be achieved through studying the response of absorption lines to continuum variations. This is the first time that absorption lines with ultra-high velocities are unambiguously detected in the soft X-ray band. The presence of outflows with relativistic velocities in AGNs with Seyfert-type luminosities is hard to understand and provides valuable constraints to models of AGN outflows. Radiation pressure is unlikely to be the driving mechanism for such outflows and magnetohydrodynamic may be involved. Finding such relativistic outflows in several other AGNs and measuring their mass/energy outflow rates is therefore important.

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