DETECTION OF HIGH VELOCITY OUTFLOWS IN THE SEYFERT 1 GALAXY Mrk 590

A. GUPTA1,2, S. MATHUR2,3, AND Y. KRONGOLD4

1 Department of Biological and Physical Sciences, Columbus State Community College, Columbus, OH 43215, USA; agupta1@cscc.edu
2 Department of Astronomy, The Ohio State University, 140 West 18th Avenue, Columbus, OH 43210, USA
3 Center for Cosmology and Astro-Particle Physics, The Ohio State University, 140 West 18th Avenue, Columbus, OH 43210, USA
4 Instituto de Astronomía, Universidad Nacional Autonoma de Mexico, Mexico City, Mexico

Received 2014 June 10; accepted 2014 October 15; published 2014 December 9

ABSTRACT

We report on the detection of ultra-fast outflows in the Seyfert 1 galaxy Mrk 590. These outflows are identified through highly blueshifted absorption lines of O viii and Ne ix in the medium energy grating spectrum and Si xiv and Mg xii in the high energy grating spectrum on board the Chandra X-ray observatory. Our best-fit photoionization model requires two absorber components at outflow velocities of 0.176c and 0.0738c and a third tentative component at 0.0867c. The components at 0.0738c and 0.0867c have high ionization parameters and high column densities, similar to other ultra-fast outflows detected at low resolution by Tombesi et al. We also found suggestive evidence for super-solar silicon in these components. These outflows carry sufficient mass and energy to provide effective feedback proposed by theoretical models. The component at 0.176c, on the other hand, has a low ionization parameter and low column density, similar to those detected by Gupta et al. in Ark 564. These absorbers occupy a different locus on the velocity versus ionization parameter plane and have opened up a new parameter space of active galactic nucleus (AGN) outflows. The presence of ultra-fast outflows in moderate luminosity AGNs poses a challenge to models of AGN outflows.

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

1. INTRODUCTION

Outflows are ubiquitous in active galactic nuclei (AGNs), manifested by high-ionization absorption lines in X-rays and UV (Mathur et al. 1995, 1997, and references therein). The X-ray absorbers, commonly known as warm absorbers (WAs), have typical outflow velocities of 100–1000 km s⁻¹. The discovery of ultra-fast outflows (UFOs) at velocities of $v \sim 0.1c$ in the hard-X-ray band has added an intriguing aspect to the rich field of AGN outflows. These outflows are exhibited by blueshifted absorption lines, produced mostly by highly ionized iron (Pounds et al. 2003a, 2003b; Tombesi et al. 2010, and references therein). The mass outflow rate of UFOs can be comparable to the accretion rate and their kinetic energy can correspond to a significant fraction of the bolometric luminosity (Tombesi et al. 2013; Pounds et al. 2003a, 2003b; Reeves et al. 2009). Thus, these outflows can provide effective feedback, which is required by theoretical models of galaxy formation (e.g., Hopkins & Elvis 2010; Silk & Rees 1998).

While WAs are detected unambiguously in the high-resolution soft X-ray spectra and their physical properties and kinematics are well determined (e.g., Krongold et al. 2003), the same cannot be said about UFOs. The UFOs in PG 1211+143 and PG 0844+349 (Pounds et al. 2003a, 2003b) were detected in high-resolution grating spectra, but the rest of the UFOs are detected in low-resolution CCD spectra and identified through blueshifted Fe xxv and/or Fe xxvi absorption lines. The restframe energy of Fe xxv and Fe xxvi line transitions are 6.7 keV and 6.97 keV, respectively, and at an outflow velocity of $v \approx 0.1c$ the UFOs are observed at about 7.3 keV. This falls in the region of the spectrum where the effective area and resolution are low. As a result, the significance of the absorption line detection in the hard-X-ray band is often questioned (e.g., Laha et al. 2014; see also Tombesi & Cappi 2014) and with only a few lines observed, accurate parameterization of the photoionized plasma becomes difficult. These difficulties were alleviated with our discovery of relativistic outflows in the soft-X-ray band in high-resolution spectra.

We recently discovered relativistic outflows in Chandra HETG spectra of Seyfert 1 galaxy Ark 564 (Gupta et al. 2013b); these detections are robust, with high statistical significance. We identified highly blueshifted absorption lines of O vi, O vii, and O viii and successfully fitted them with a two-component photo-ionization model. The detection of multiple lines at the same velocity makes the identification of the relativistic outflow robust. This opens up an exciting new opportunity of probing the relativistic disk winds in the soft-X-ray band where we have the best diagnostic power from multiple lines of multiples ionization states of several elements and where the gratings response is the best.

Excited by the discovery of relativistic outflows in Ark 564, we looked for their presence in other AGNs; could it be that they were not found because nobody looked for them? The Chandra HETGS data of Mrk 590 are tantalizing. Mrk 590 is a bright Seyfert 1 galaxy (recently appears to have changed from Type 1 to Type ~1.9–2; Denney et al. 2014) at $z = 0.026$ that has been observed by the Einstein observatory (Kris et al. 1980), the HEAO 1 (Piccinotti et al. 1982), the BATSE (Malizia et al. 1999), and recently by Chandra and XMM-Newton. Gallo et al. (2006) first reported the presence of a strong Fe K emission line revealed in the 2002 ~10 ks XMM-Newton EPIC data. Later, Longinotti et al. (2007) presented its complex spectrum with a reflection component using the ~100 ks observations with Chandra and XMM-Newton and confirmed the presence of the Fe Kα emission line. Here we present a detailed reanalysis of the Chandra HETG observation of Mrk 590.

2. OBSERVATION AND DATA REDUCTION

Mrk 590 was observed by the Chandra High Energy Transmission Grating (HETG) in 2004 for ~100 ks (ObsID: 4924). The HETG is comprised of two gratings: the medium energy...
gratings (MEG) and the high energy gratings (HEG), which disperse spectra into positive and negative spectral orders. We reduced the data for both gratings using the standard Chandra Interactive Analysis of Observations (CIAO) software (v4.3) and Chandra Calibration Database (CALDB, v4.4.2) and followed the standard Chandra data reduction threads. To increase S/N, we coadded the negative and positive first-order spectra and built the effective area files (ARFs) using the fullgarf CIAO script.

3. SPECTRAL ANALYSIS

For the spectral analysis, we binned the MEG and HEG spectra to their resolution element of 0.025 Å and 0.012 Å, respectively, and analyzed them using the CIAO fitting package Sherpa. Throughout this paper, the quoted errors correspond to 1σ significance.

3.1. Continuum Modeling

We fit the intrinsic continuum of the source with an absorbed (Galactic $N_H = 2.7 \times 10^{20} \text{ cm}^{-2}$; Dickey 1990) power law; the fit parameters are reported in the Table 1. In the energy band of 0.3–10 keV, the integrated flux is $9.1 \times 10^{-12} \text{ erg s}^{-1} \text{ cm}^{-2}$, which corresponds to an unabsorbed X-ray luminosity of $1.4 \times 10^{43} \text{ erg s}^{-1}$.

Although an absorbed power law fits the continuum well (MEG: $\chi^2 = 729$, d.o.f. = 679, HEG: $\chi^2 = 1120$, d.o.f. = 1199), there are residual absorption line-like features in the spectral regions of 10–20 Å and 4–9 Å in the MEG and HEG spectra, respectively (Figures 1 and 2). In the subsequent sections, we discuss the identification, statistical significance, and possible origin of these absorption lines.

3.2. Identification of the Absorption Lines

### 3.2.1. Medium Energy Grating Spectrum

In the MEG spectrum of Mrk 590, the most prominent absorption feature (>3σ; Figure 3) is present at 16.03 Å. Addition of a Gaussian absorption feature (at 16.033 ± 0.004) to continuum model improves the fit ($\Delta\chi^2 = 17$ for 2 fewer

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**Figure 1.** Mrk 590 MEG spectrum in the observer frame. The red line shows the best-fit continuum model. In the bottom panel, plotted are the residuals showing absorber features.

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**Table 1**

Continuum Model Parameters for the Mrk 590 Chandra HETG Spectra

| Units             | MEG      | HEG      |
|-------------------|----------|----------|
| Powerlaw          | 1.57 ± 0.03 | 1.56 ± 0.03 |
| Photoindex ($\Gamma$) | 1.56 ± 0.03 | 1.56 ± 0.03 |
| Normalization     | $10^{-4} \text{ ph keV}^{-1} \text{ s}^{-1} \text{ cm}^{-2}$ | $15.84 ± 0.25$ | $13.36 ± 0.37$ |

5 http://cxc.harvard.edu/ciao/threads/index.html
d.o.f.) at the confidence level of 99.97% according to the F-test (Bevington & Robinson 1992). The measured equivalent width (EW) is 46.50 ± 11.04 mÅ. Errors are at a 1σ confidence level and are calculated using the “projection” command in Sherpa. According to the Gaussian probability distribution, the probability of detecting the line by chance is 1.3 × 10⁻⁵. There are 681 wavelength bins in the MEG spectrum, so the probability of finding an absorption line at the observed significance anywhere in the spectrum due to random statistical fluctuations is 0.88%. Thus, it is highly unlikely that this absorption feature is due to random statistical fluctuations.

We tried to identify the absorption feature detected at 16.033 ± 0.004 Å. There is no known instrumental feature near this energy (Chandra Proposers Observatory Guide, or POG). Though this line could be associated with z = 0 O viii Kβ line (λrest = 16.007 Å), we rule out this possibility because there is no corresponding O viii Kα line (λrest = 18.967 Å). Assuming this feature is produced by Fe xvii (λrest = 15.015 Å) ions in an intervening warm–hot intergalactic medium (WHIM; Mathur et al. 2003; Nicastro et al. 2005), the system redshift would be zWHIM = 0.066 which is greater than the zAGN = 0.02638. Thus, this feature could not be from an intervening WHIM system and no other intervening absorption line is likely either. Therefore, we assume that this absorption line is intrinsic to the source.

We identify this line based on a combination of chemical abundance, line strength, and assuming a very broad range of inflow/outflow velocities of ±60,000 km s⁻¹. The likely candidates for the ~16.033 Å feature are Fe xvii (λrest = 15.015 Å; λs = 15.411 Å, wavelength at the source redshift) with an inflow velocity of ~0.04c, or O viii (λrest = 18.96 Å; λs = 19.460 Å) with an outflow velocity of 0.176 ± 0.001c. To distinguish between the two possibilities of inflow and outflow, we search for possible associations of other lines. We do not find any possible association for inflows but found a 2.8σ line at 11.39 ± 0.01 Å (Table 2) corresponding to Ne ix (λrest = 13.447 Å; λs = 13.802 Å; Figure 3) at the similar outflow velocity of 0.175 ± 0.001c.

### 3.2.2. High Energy Grating Spectrum

In the Mrk 590 HEG spectrum, we detected two absorption features at 5.80 Å and 5.88 Å (Figure 4, Table 2) with EWs of 25.0 ± 4.4 mÅ and 21.4 ± 3.2 mÅ, respectively. The HEG and

### Table 2

Absorption Lines Identified with High Velocity Outflows in the HETGS Spectrum of Mrk 590

| Ion          | λobs Å | λrest Å | vout km s⁻¹ | EW mÅ   |
|--------------|--------|---------|-------------|--------|
| Medium Energy Grating |        |         |             |        |
| O viii Kα    | 16.033 ± 0.004 | 18.969 ± 62 | 46.50 ± 11.04 |        |
| Ne ix        | 11.39 ± 0.01   | 13.447 ± 217 | 20.7 ± 7.48   |        |
| High Energy Grating |        |         |             |        |
| Si xiv       | 5.804 ± 0.003  | 6.182 ± 141 | 25.0 ± 4.4    |        |
| Si xiv       | 5.880 ± 0.001  | 6.182 ± 47  | 21.4 ± 3.2    |        |
MEG overlap in this wavelength range, thus, if real, these lines should also be present in the MEG spectrum. We searched for these absorption features in the MEG spectrum and found one at $5.91 \pm 0.04$ Å with EW of $25.3 \pm 12.5$ mÅ; this is consistent with the $5.880 \pm 0.001$ Å HEG line, though the error on the line EW in the MEG spectrum is large. There is no absorption feature in the MEG spectrum corresponding to the $5.80$ Å HEG feature, but again the EW limit in the MEG spectrum is large, $13.13$ mÅ, so the discrepancy is less than $2\sigma$. In the following, we will treat both of these features as real lines, but keeping in mind that our confidence in the $5.80$ Å feature is not as strong as that in the $5.88$ Å feature.

In the HEG spectrum, both lines are present at high significance with a very low probability of finding them by chance ($3 \times 10^{-4}\%$ and $6 \times 10^{-5}\%$) anywhere in the spectrum. The only possible identification we found for them is of Si XIII and Si XIV at outflow velocities of $0.085c$–$0.067c$. We will see later that the photo-ionization model supports the identification of these lines as Si XIV.

4. PHOTO-IONIZATION MODEL: FITTING WITH PHASE

To test the validity of our tentative identifications of absorption features with high-velocity outflows, we fitted them with our photo-ionization model code PHASE (Krongold et al. 2003). The code has four free parameters per absorbing component, namely (1) the ionization parameter $U = (Q(H))/(4\pi r^2 n_H c)$; where $Q(H)$ is the rate of H ionizing photons, $r$ is the distance to the source, $n_H$ is the hydrogen number density, and $c$ is the speed of light; (2) the hydrogen equivalent column density $N_H$; (3) the outflow velocity of the absorbing material $V_{\text{out}}$; and (4) the micro-turbulent velocity $V_{\text{turb}}$ of the material. PHASE has the advantage of producing a self-consistent model for each absorbing component because the code starts without any prior constraint on the column density or ionization fraction of any ion. We have assumed solar elemental abundances (Grevesse et al. 1993) in the following analysis.

The residual features at $16.035 \pm 0.004$ and $11.39 \pm 0.01$ in the MEG spectrum are well fitted with one PHASE component of log $U = -0.10 \pm 0.25$ and log $N_H = 20.2 \pm 0.2$ and outflow velocity of $0.176 \pm 0.001c$ (Figure 5) and the lines are indeed O VIII Ka and Ne IX. The addition of the PHASE component to the continuum model significantly improves the fit ($\Delta \chi^2 = 15$ for 3 fewer d.o.f.). According to F-test, the absorber is present at a confidence level of 99.66%. We call this component as the high-velocity–low-ionization-phase (HV-LIP) absorber. Our best-fit absorber model also predicts absorption from O VII at $18.26$ Å. As shown in Figure 5, the data are consistent with the prediction. However, to securely detect the O VII feature, we require higher signal-to-noise data.

To model the HEG absorption features (at $5.08$ Å and $5.88$ Å) identified as Si XIII or Si XIV, required two PHASE components.

**Figure 3.** Showing the high significance residuals of the data:continuum fit to the MEG spectrum of Mrk 590, in the observer frame.
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Figure 4. Same as Figure 3 for HEG data.

Table 3
Best-fit Photoionization Model Parameters

| Parameter          | MEG  | HEG    | HEG    |
|--------------------|------|--------|--------|
|                    | HV-LIP | HV-HIP-I | HV-HIP-II |
| Log U              | −0.1 ± 0.2 | 2.5 ± 0.2 | 2.5 ± 0.2 |
| Log N$_H$(cm$^{-2}$) | 20.2 ± 0.2 | 23.5 ± 0.3 | 23.5 ± 0.2 |
| V$_{\text{Turb}}$(km s$^{-1}$) | 303 ± 41    | 688 ± 123    | 890 ± 112    |
| V$_{\text{Out}}$(km s$^{-1}$) | 52800 ± 300 | 26010 ± 210    | 22140 ± 120    |
| $\delta \chi^2$     | 11     | 24     | 10     |

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

with log $U = 2.5 \pm 0.3$ and log $N_H = 23.50 \pm 0.03$ at different outflow velocities (Figure 6). The photo-ionization model fitting favors the identification of these features as ionic transitions of Si$^{xvi}$ produced in a highly ionized medium, outflowing with velocities of $0.0867 \pm 0.0007 c$ and $0.0738 \pm 0.0004 c$, respectively. Both the absorbers are required at a high significance of 99.999% ($\Delta \chi^2 = 24$ for 4 fewer d.o.f.) and 99.996% ($\Delta \chi^2 = 28$ for 4 fewer d.o.f.), respectively. The HEG best-fit model with two absorbers also requires Mg$^{xii}$ absorption features at 7.90 and 8.01 Å; these lines are in fact present and are well fitted by the model. The model also predicts Fe$^{xxv}$ and Fe$^{xxvi}$ absorption lines at $\sim7.04$ keV (1.76 Å) and $\sim7.32$ keV (1.69 keV) with EWs of 18.05 mÅ and 13.73 mÅ respectively. However, the HETG response drops significantly above 7 keV, thus the spectrum does not have good enough S/N to confirm the presence of these lines. The best-fit PHASE parameters are reported in Table 3 and the best-fit models are shown in Figure 6. These absorbers fit the high ionization lines, so we will refer to these absorbers as the high-velocity–high-ionization phase I (HV-HIP-I) and high-velocity–high-ionization phase II (HV-HIP-II) components. Successfully modeling the residuals in the MEG and HEG spectra further supports the presence of high-velocity outflows in Mrk 590.

While the HV-HIP-I and HV-HIP-II models fit the Si$^{xvi}$ absorption lines as noted above, they leave some residuals at these lines; as seen in Figure 6, the lines are stronger than the model predictions. Changing the values of ionization parameters or column densities does not resolve the issue as it changes the strengths of other lines as well, which is not observed. This suggests that the silicon abundance is higher than the solar value used in the model. So we left the silicon abundance as a free parameter and refitted the spectrum with PHASE. Indeed, the best fit resulted in super-solar silicon abundance for both the components: $2.0^{+0.0}_{-0.1}$ x solar and $2.3^{+0.7}_{-0.6}$ x solar for HV-HIP-I and HV-HIP-II, respectively. The improvement in the fit is $\Delta \chi^2 = 8$, for 2 fewer d.o.f. This is an over 3$\sigma$ result for both the components, so we argue that the HV-HIP outflows in Mrk 590 have super-solar silicon. Super-solar metal abundances or super-solar metallicities in circum-nuclear region of AGNs have been observed before (e.g., Fields et al. 2005a, 2005b, 2007; Araya-Salvo et al. 2012); HV-HIP outflows in Mrk 590 add to this growing list.

5. MASS AND ENERGY OUTFLOW RATE ESTIMATES

Without knowing the location of the absorber, its mass and energy outflow rates cannot be well constrained. The lower limit on the absorber location can be determined assuming that the observed outflow velocity is the escape velocity at the launch radius $r$, i.e., $r = (2GM_{\text{BH}})/(v_{\text{out}}^2)$. Peterson et al. (2004) determine the central black hole mass of Mrk 590 to be $M_{\text{BH}} = (4.75 \pm 0.74) \times 10^7 M_\odot$. Using the above expression,
we get the minimum distance of Mrk 590 HV-LIP and HV-HIP absorbers of \( \sim 32 r_s \) and \( \sim 133 r_s \), respectively (in units of the Schwarzschild radius; for Mrk 590 \( r_s = 4.6 \times 10^6 \) pc). This is 0.17 and 0.72 light-days from the nuclear black hole, consistent with an accretion disk origin, and inside the broad emission line region.

For a bi-conical wind, the mass outflow rate is \( \dot{M}_{\text{out}} \approx 1.2 \pi m_p N_H v_{\text{out}} r \) (Krongold et al. 2007). Substituting \( r \) with \( r_{\text{min}} \) and using outflow velocities of 52800 km s\(^{-1}\) and 26010 km s\(^{-1}\), we obtain lower limits on mass outflow rates of \( \dot{M}_{\text{out}} \geq 3.8 \times 10^{-5} M_\odot \) s\(^{-1}\) and \( \dot{M}_{\text{out}} \geq 1.5 \times 10^{-4} M_\odot \) s\(^{-1}\), respectively. These correspond to the kinetic luminosities of LIP and HIP high-velocity outflows of \( E_K \geq 1.1 \times 10^{41} \text{ erg s}^{-1} \) and \( E_K \geq 2.2 \times 10^{44} \text{ erg s}^{-1} \), respectively. The X-ray (2–10 keV) luminosity of Mrk 590 is \( 7.0 \times 10^{42} \text{ erg s}^{-1} \); this implies the bolometric luminosity of Mrk 590 is \( 9.0 \times 10^{45} \text{ erg s}^{-1} \), assuming a bolometric correction factor of 10 (Vasudevan & Fabian 2007). Thus, at face value, the kinetic luminosity of the HIP outflow is over three times the radiative luminosity of the source. This suggests that such high velocity outflows are not driven by the radiation pressure (see Section 6 below). Alternatively, it suggests that the formula for the bi-conical outflow used above is not valid; the covering fraction of the outflow could be significantly smaller than assumed. In any case, these outflows have the potential to provide effective feedback to the surroundings.

6. DISCUSSION

The Chandra observation of Mrk 590 has revealed low- and high-ionization high-velocity outflows. The low-ionization and low-column (HV-LIP) component is similar to those recently discovered in another Seyfert-type moderate luminosity AGN Ark 564 (Gupta et al. 2013b). However, the outflows identified as HV-HIP-I and HV-HIP-II have parameters similar to those of UFOs (highly ionized log \( \xi \) = 3–6 erg s\(^{-1}\) and with large column densities \( N_H \approx 10^{22}–10^{24} \text{ cm}^{-2} \)). As noted in Section 1, Mrk 590 has been observed with XMM-Newton for 100 ks. We will analyze the XMM-Newton RGS spectrum and look for consistency with the Chandra result at a later date.

Recently, Tombesi et al. (2013) presented the connection between UFOs and soft X-ray WAs. They strongly suggest that these absorbers represent parts of a single large-scale stratified outflow and that they continuously populate the whole parameter space (ionization, column, velocity), the WAs and the UFOs lying at the two ends of the distribution (Figure 7). The Ark 564 low-velocity WAs (Gupta et al. 2013a) and UFOs (Papadakis et al. 2007) were in agreement with the linear correlation fits from Tombesi et al., but the low-ionization low-column high-velocity outflows in Ark 564 probe a completely different parameter space (\( U, N_H, v_{\text{out}} \)), as shown in Figure 7.
Similarly the Mrk 590 HV-HIP outflows probe the same parameter space as that of UFOs, but HV-LIP outflows probe the parameter space not covered by either low-velocity WAs or high-ionization UFOs.

The presence of different absorption systems with different outflow velocities may suggest that we are looking at the flows in a transverse configuration with respect to the line of sight. This would avoid possible collisions between different components, which would result in shock-heating of the gas and a decrease on the measured opacity. The geometry would have to be conical and the flows must form a large angle with the accretion disk. It is also expected that the orthogonal component of the velocity might have a significant contribution to the total velocity of the flow, but we only observe the component in the line of sight. This would mean that the flows are even faster than detected. In such a steady state configuration, the absorption lines could be expected to remain constant over time, since we would always observe the same section of the wind.

Alternatively, we may be seeing a radial flow, with a nearly spherical geometry and a large velocity gradient in the line of sight. The different velocity components could be explained if they are parts of this single flow, formed by clumps in the flow. In this scenario, strong variability in the observed absorption lines is expected, as the clumps move further out from the central engine, and their velocity and ionization state change. Observations of Mrk 590 over time would allow us to discriminate between these two scenarios.

As discussed in Gupta et al. (2013b), the relativistic outflows cannot be explained by simple models of radiation-pressure-driven winds. Their velocities are too large for their luminosities and magnetohydrodynamics may be involved. Magnetic fields are also important for launching jets; could relativistic outflows be failed jets? To get the in-depth view of AGN outflows, it is important to search for more of these systems, probing the complete parameter space.

We also found suggestive evidence for super-solar silicon in Mrk 590. Several such examples of super-solar abundances and super-solar metallicities have been reported in the literature (Section 4) suggesting that metal enrichment in the centers of galaxies with AGNs might be different than that on large scales.

7. SUMMARY

We have detected high-velocity outflows in the Seyfert 1 galaxy Mrk 590. These absorbers are identified through highly blueshifted absorption lines of O viii and Ne ix in the MEG spectrum and Si xiv and Mg xii in the HEG spectrum. Our best-fit photoionization model requires three absorber components at outflow velocities of 0.176c, 0.0867c, and 0.0738c. The HV-LIP absorber has low ionization and low column density while the two HV-HIP absorbers have high ionization and high column density and super-solar silicon. All the absorbers are required at a high significance of 99.66%, 99.999%, and 99.996%, respectively. The HV-HIPs have sufficient mass and energy
to provide effective feedback proposed by theoretical models. However, the presence of such UFOs in moderate-luminosity AGNs poses a challenge to models of AGN winds.

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Figure 7. log ξ vs. log N_H (top panel), log ξ vs. log v_out (middle panel), and log N_H vs. log v_out (bottom panel) for the low-velocity WAs (green striped region) and UFOs (blue striped region) using data from Tombesi et al. (2013). The solid lines represent the correlation fits to low-velocity WAs and UFOs from Tombesi et al. The data-points represent the Mrk 590 and Ark 564 outflow parameters, (1) Mrk 590: LIP High-velocity outflows (black) and HIP high-velocity outflows (magenta) (2) Ark 564: low-velocity WAs (red; Gupta et al. 2013a), UFO (yellow; Papadakis et al. 2007), and high-velocity outflows (blue; Gupta et al. 2013b). As we see, the high-velocity low-ionization absorbers in Ark 564 and Mrk 590 occupy an unexplored region of the parameter space.