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AGN winds as probes of cosmic feedback: the case of Mrk 509

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Abstract

Outflowing gas in active galactic nuclei (AGN), seen as blue-shifted absorption lines in UV and X-ray spectra, is recognized as an important structural feature. The high frequency of occurence of UV and X-ray absorption suggests that the absorbing gas has a high covering fraction, and that is present in all AGN. The AGN wind both heats and removes the interstellar medium (ISM) of the host galaxy, effectively stopping further star formation, and removing the fuel for further black hole growth as well as influencing the surrounding intergalactic medium. If the kinetic luminosity injected in the medium is high enough, then the impact on the host galaxy is sufficient to regulate galaxy growth (cosmic feedback).

Despite the obvious importance of understanding the structure and energetics of such outflows, we are only beginning to learn about the acceleration mechanism, the location of the gas in the context of the unification scheme of AGN, and its geometry. Here we present the results of a successful multi-wavelength campaign on the Seyfert 1 galaxy Mrk 509. The source was observed in the X-ray domain by Chandra and XMM-Newton, and simultaneously in the UV domain with the Cosmic Origins Spectrometer onboard the Hubble Space Telescope. We thus obtained one of the best characterization of an outflow in an AGN, and set limits on its location and possible launching mechanisms. We found that the outflowing absorbing gas is located at pc-scale distances, likely associated with thermally-driven winds originated in the putative dusty torus that surrounds the AGN engine.

1 Introduction

Active galactic nuclei (AGN) are powered by accretion of matter onto the supermassive black hole (SMBH) that is believed to reside in their centre. The large bolometric output of AGN is powerful enough to drive ionized winds into the medium of the host galaxy in the form of mass outflows. Indeed, more than 50% of nearby Seyfert 1 galaxies show evidence of photoionised gas, the so-called warm absorber (WA), in their UV and soft X-ray spectra, blueshifted with respect to the systemic velocity of the source by hundreds of km s^{-1}. These outflows may

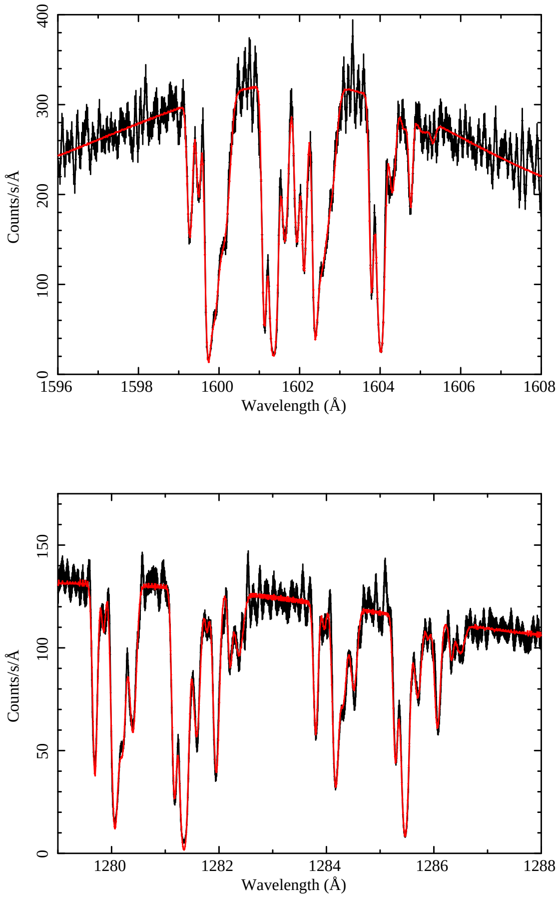

Figure 1: HST/COS spectrum of Mrk 509 in the C IV (upper panel) and N V (lower panel) doublet regions. The solid line represents the best fit to the data.

affect the evolution of the SMBH and the host galaxy as they inject mass and energy into the surrounding interstellar medium (ISM), thus playing a role in cosmic feedback processes [4].

In spite of their importance, the structure, origin, and launching mechanism of the X-ray WA, as well as their relation with the UV absorbers, are not yet fully understood. The proposed origins for AGN outflows include winds emanating from the accretion disk, which are expected to lie within several hundreds $r_{\rm g}$ [3], and thermally-driven winds lying at pc-scale distances, at or beyond the location of the obscuring torus [9]. An accurate determination of the distance is therefore essential to estimate the actual mass outflow rate and assess the importance of AGN WA as feedback sources.

Photoionised gas is characterized by its ionization parameter $\xi = L/nr^2$, where L is the ionizing luminosity in the $1 - 1000$ Ryd range, n is the hydrogen density, and r is the distance of the gas to the ionizing source. While L and ξ can be determined from the analysis if the spectrum of the source, the product nr^2 is degenerate. The only way to determine n is by measuring changes in the ionisation state of the gas in response to changes in the ionizing continuum, as n scales inversely with the recombination time.

The multiwavelength campaign on Mrk 509 aims to address a number of key questions such as the location and physics of the WA outflows, the nature of the continuum emission, the geometry and physical state of the BLR, the Fe-K complex, the metal abundances, and the ISM of our own Galaxy along our line of sight. For that purpose data from 5 satellites (XMM, Chandra, Integral, Swift, and HST) and 2 ground-based facilities (WHT and Pairitel) were collected. An overview of the campaign can be found in [5], and references therein.

2 Campaign observations

As part of the multi-wavelength campaign on Mrk 509, the source was extensively observed in UV and X-rays. In order to study the physics of the outflow we analyzed the following spectra:

- *XMM-Newton RGS:* This observation conforms the backcbone of the campaign. It consisted of ten pointings of 60 ks each, taken 4 days apart, for a total exposure of 600 ks. The analysis of the stacked spectrum [6] revealed a complex outflow structure with 5 distinct ionization components in two kinematic regimes [1].
- *Chandra LETGS:* Mrk 509 was observed by *Chandra* for ~180 ks. The LETGS spectrum revelead the presence of three ionization components in three different velocity regimes. Two of these components are outflowing at velocitiess of hundreds of km s^{-1}, while the lowest ionization component is slightly redshifted with respect to the systemic velocity of Mrk 509 and is not probably part of the outflow [2].
- *HST/COS:* Mrk 509 was also observed in the UV domain with the COS instrument onboard HST. This observation was simultaneous with *Chandra* and revealed the presence of a complex UV absorber with 13 different kinematic components [8].

3 Structure of the outflow

Although a one-to-one comparison between the UV and X-ray components is not feasible due to the lower resolution of the X-ray gratings, at least 3 UV components can be kinematically associated to the X-ray WA components within the error bars. This could indicate a possible co-location of both absorbing gases. Since the degree of ionization of the UV-absorbing gas is too low to generate any significant absorption in the X-rays, it could be possible that both gases co-exist in the form of dense low-ionization clouds embedded in a more diffuse highly ionized X-ray wind [2, 8].

However, the UV and X-ray components are not in pressure equilibrium with each other and therefore it is unlikely that they may form long-lived structures. Furthermore, a fit to the UV data using photo-ionization models (see Fig. 1) predicts inconsistent ionic column densities with respect to those measured in X-rays. The X-ray and UV absorbers are probably originated at pc-scale distances from the central ionizing source. Their launching mechanisms (probably thermal winds from the torus) and how they are related will be discussed in a forthcoming paper (Ebrero et al., in preparation).

Acknowledgments

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