Comments On The Intrinsic X-ray/UV Absorbers In AGN

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**Abstract.**

This talk discusses the unified X-ray/UV absorption models in AGN. I will first review the models and discuss how they offer an unique opportunity to probe the near nuclear environment of AGNs. Recently, however, the validity of these models has been questioned by a number of authors. I will discuss these papers and argue that the data/models presented in them do NOT contradict the unified X-ray/UV picture. I will conclude by presenting our new HST spectrum of a X-ray warm absorber.

1. **Introduction**

About 10% of AGN show ‘associated absorption’ in their UV spectra. While this absorbing material must be associated with the active nucleus, it does not appear to be due to any known component of an AGN and there is no accepted model for it (Foltz *et al.* 1988).

Similarly, many AGNs, mainly Seyfert galaxies, exhibit strong low energy X-ray cut-offs due to neutral (“cold”) material in their nuclei, also with no accepted identification. Recent observations of X-ray ionized (“warm”) absorbers showed the existence of high column density, highly ionized material in the near nuclear region. Due to their apparently different physical properties, the possibility of linking any of these three types of absorbers has not seemed promising. Only a limited understanding of the physical conditions in the absorbing material is obtained through UV or X-ray studies alone since the ionization structure of the absorber is not known.

| Absorption Systems in Quasar Spectra |
|--------------------------------------|
| UV | X-ray (Cold) | X-ray (Warm) |
| Low $N_H$ ($<10^{20}$) | High $N_H$ ($>10^{24}$) | High $N_H$ ($>10^{24}$) |
| Neutral | Ionized | High $U$ ($>1$) |
| Low $U$ ($10^{-3}$) | Neutral | Ionized |


This situation changed with quasi-simultaneous observations of the quasar 3C351 with ROSAT and HST. The X-ray spectrum revealed the presence of a warm absorber showing K-edge due to OVII or OVIII (Fiore et al. 1993). The UV spectrum showed strong, associated, high ionization absorption lines including OVI λλ1031, 1037 (Bahcall et al. 1993). Through detailed modeling we found an excellent match between the X-ray and UV absorber properties (Mathur et al. 1994). The combination of both X-ray and UV datasets allows strong constraints to be placed upon the physical conditions of the absorber. In 3C351 we find that the absorber has well determined properties which describe a component of nuclear material not previously recognized: highly ionized, outflowing, low density, high column density material situated outside the broad emission line region.

Since the discovery of a unified X-ray/UV absorber in an X-ray quiet quasar 3C351, we have found that the X-ray and UV absorber are also one and the same in other, quite different, AGN: a ‘red’ quasar 3C212 (Mathur 1994) and a variable Seyfert galaxy NGC5548 (Mathur et al. 1995). We developed a model for an evolving X-ray/UV absorber in NGC3516 which explains the previous presence and present disappearance of its broad absorption lines (Mathur et al. 1997). It makes definite predictions about the evolution of its X-ray warm absorber which can be tested with future X-ray missions. A unified X-ray/UV absorber is also found in NGC 3783 (Shields, J. these proceedings). M. Crenshaw and collaborators (these proceedings) have also found the common occurrence of UV and X-ray absorption in Seyfert 1 galaxies with high signal-to-noise HST spectra. These results open up the possibility that this unified picture is quite general. It suggests that a wide range of associated absorbers may in fact be related through a continuum of properties like the column density, ionization parameter, distance from the continuum source, and the outflow velocity. These results may be extended to the broad absorption line quasars (BALQSOs). The prototype BALQSO PHL5200, the only BALQSO with a X-ray spectrum, shows strong X-ray absorption (Mathur, Elvis & Singh 1995). (See Paul Green’s article in these proceedings for X-ray properties of BALQSOs).

Understanding of the physical properties of the absorber allowed us to pose astrophysical questions about the geometry and kinematics of the absorbing outflow. We found that the outflow is likely to be edge-on with the kinetic energy a large fraction of the bolometric luminosity of the AGN (Mathur et al 1995). This is similar to the large out-flow energy discussed by J. Miller yesterday.

2. The Debate

Clearly, the unified picture of X-ray/UV absorbers offers an unique opportunity to probe the nuclear environment of AGNs. It was greeted by the AGN community with both enthusiasm and skepticism. Enthusiasm for obvious reasons, that it offered something new, interesting and useful. Skepticism because the X-ray and UV absorbers don’t have to be one and the same: (1) A small N_H, small U solution still exists for UV absorbers, so they need not be the same as X-ray absorbers; (2) there are theoretical models of X-ray absorbers (Krolik & Kriss (K&K) 1995 ) with much larger N_H and larger U which do not produce UV absorption lines.
The K&K models for X-ray warm absorbers can be easily distinguished from our X/UV models by their Fe-K edge. The K&K models predict the presence of an Fe-K edge in addition to the OVII/OVIII edges while the X/UV models do not. I would like to point out that an Fe-K edge was not detected in ASCA observations of NGC5548 and NGC3516. It was detected in NGC3783, however the warm absorber model fit to the OVII/OVIII edges could not simultaneously fit the Fe-K edge (George et al. 1995). This implies a different origin for the gas producing Fe-K edge from that producing the OVII/OVIII warm absorber. This might also be the case in other AGNs showing Fe-K edges in their Ginga spectra.

2.1. Further Debate

The uniqueness of the combined X-ray-UV absorber has been questioned recently. I will discuss the relevant papers in turn.

1. A detailed paper by Netzer (1996) discusses X-ray lines in AGN & photoionized gas. The models presented in this paper span a range of parameter space in density, column density and ionization parameter. The author claims that the X-ray warm absorber model for NGC 5548 cannot reproduce the strengths of the observed UV absorption lines whereas Mathur et al. (1995) present a detailed analysis demonstrating their consistency. The reason for this apparent contradiction is the different input continuum shape. The input continuum assumed by Netzer leads to N(CIV) < N(NV) and the resulting disagreement with the observations. We, on the other hand, used the observed continuum for NGC5548 which contains an additional strong soft excess characterized by a black-body spectrum of temperature 150,000K. For this continuum N(CIV) > N(NV) as observed. This illustrates not only the danger of comparing results using differing assumptions but also the importance of using the observed data. It may also offer a way of determining the unobservable EUV continuum.

2. NGC3516: The Seyfert galaxy NGC3516 contains the strongest UV associated absorption line system. It has both broad and narrow lines of both high and low ionization. It also contains a X-ray warm absorber. Clearly, it has a complex, multicomponent absorption system. Kriss et al. (1996a,b) present simultaneous HUT and ASCA observations of NGC 3516. They conclude that a unified X-ray/UV absorber model is not applicable for NGC 3516.

We note, however, that the X/UV model generally associates broad UV absorption with X-ray absorption. In NGC3516, the broad lines disappeared since ~1992 (Koratkar et al. 1996). Kriss et al. compared the narrow UV lines with the X-ray warm absorber and found the two to be incompatible, which is not surprising. Based on ROSAT data, we found that the properties of the warm absorber are in fact consistent with the present non-detection of the broad high ionization lines (Mathur, Wilkes & Aldcroft 1997). We developed an evolving model in which the ionization parameter of the absorber increases due to a decrease in density as it expands while out-flowing. This scenario is consistent with the presence of broad lines in the past and their subsequent disappearance. This X-ray/UV absorber model makes definite predictions about the future (e.g. the OVIll edge would get stronger than the OVII edge) which can be tested with
missions like AXAF and XMM.

3. Other Cases: Hamann (1997) has found some cases in which the overall level of ionization is not consistent with single zone models of the UV line and X-ray warm absorbers. In the $z_{a} \approx z_{e}$ systems discussed in this paper low as well as high ionization lines are present. Clearly, a range of ionizations is required to produce these lines. The X-ray warm absorber typically has a high ionization parameter defined by its OVII/OVIII ratio. It cannot contribute to the low ionization lines. This is entirely as expected from the X/UV models in which the X-ray warm absorber produces the high ionization absorption lines in the UV. Note also that none of the $z_{a} \approx z_{e}$ systems in Hamann (1997) has a known X-ray warm absorber. A direct comparison of the X-ray and UV absorbers thus cannot be made.

3. PG1114+445: New HST Spectra

The ROSAT spectrum of PG1114+445 shows that it contains a X-ray warm absorber (Laor et al. 1994). Based on the unified X-ray/UV absorber picture, we expected it to show high ionization UV absorption lines. To test this prediction we observed PG1114+445 with HST FOS. The UV spectrum clearly shows the absorption lines of CIV, NV and Ly$\alpha$ at 1770Å, 1418Å and 1389Å respectively (Figure 1). The low ionization MgII absorption line was not detected, as expected (spectrum not shown here).

Can this be just a chance coincidence? About 10% of Seyfert galaxies have associated absorption lines in their UV spectra (Ulrich 1988). So, there is a 10% chance of finding them in any randomly selected Seyfert galaxy. Strong associated absorption also appears to arise predominantly in steep spectrum, radio-loud objects (Foltz et al. 1988) rather than in radio-quiet quasars. In fact, there has been some evidence of dichotomy between the occurrence of associated absorption in radio-loud quasars and broad absorption lines in radio-quiet quasars (BALQSOs) (Foltz et al. 1988). It is thus highly unlikely that the existence of associated absorption lines in radio-quiet PG1114+445 is a chance coincidence. This observation suggests that the X-ray and UV absorbers are physically related. A few more such tests could be conclusive.

4. Conclusions

Present evidence argues strongly in favor of the unified picture of the X/UV absorbers with the X-ray and UV absorbers physically related, if not identical. The X-ray warm absorbers, with their large column densities, would typically contribute strongly to the broad, high ionization absorption lines seen in the UV. As discussed in §2, the UV line systems may not require continuum absorption in X-rays, but the X-ray absorbers must produce the high ionization absorption lines.

Even though the unified model of X-ray and UV absorbers is a good description of the observations, it may not be adequate to explain complex systems in its present single-zone, photoionization equilibrium form. Multi-zone, multi-parameter models will be required when the absorption systems show multiple
Figure 1. The HST FOS Spectrum Of PG1114+445
components (e.g NGC3516, objects in Hamann 1997). In some highly variable objects (e.g. NGC 4051), non-equilibrium models might be necessary (Nicastro et al. 1997). The X/UV models should evolve as better quality of data becomes available. These models, however, provide an unique opportunity and a good starting point for understanding the associated absorption systems and so probe the near nuclear environment of AGN.

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**References**

Bahcall, J. N. et al. 1993, ApJS, 87, 1
Fiore, F., Elvis, M., Mathur, S., Wilkes, B., & McDowell, J. 1993, ApJ, 415, 129
Foltz, C. B., Chaffee, F. H., Weymann, R. J., & Anderson, S. F. 1988, in *QSO Absorption Lines* Ed.: J. C. Blades, D. Turnshek, C. Norman. [CUP]
George, I., Turner, J., & Netzer, H. 1995, ApJL, 438, L67
Hamann, F. 1997, ApJS, 109, 279
Koratkar, A. et al. 1996, ApJ, 470, 378
Kriss, G. et al. 1996, ApJ, 467, 629
Kriss, G., Espey, B.R., Krolik, J.H., Tsvetanov, Z., Zheng, W. and Davidsen, A.F. 1996, ApJ, 467, 622
Krolik, J. & Kriss, G. 1995, ApJ, 447, 512
Laor, A., Fiore, F., Elvis, M., Wilkes, B., & McDowell, J. 1994, ApJ, 435, 611
Mathur, S. 1994 ApJL, 431, L75
Mathur, S., Wilkes, B. J., Elvis, M. S., & Fiore, F. 1994 ApJ, 434, 493
Mathur, S., Elvis, M. S. & Wilkes, B. J. 1995, ApJ, 452, 230
Mathur, S., Elvis, M. & Singh, K. P. 1995, ApJL, 455, 9
Mathur, S., Wilkes, B. J., & Aldcroft, T. 1997, ApJ, 478, 182
Netzer, H. 1996 ApJ, 473, 781
Nicastro, F. et al. 1997, in preparation.
Ulrich, M. H., 1988, MNRAS, 230, 121