“Warm absorbers” and “-mirrors”: one and the same gas?

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**Abstract.** We review the main properties of “warm mirrors” in obscured AGN, and discuss whether the scattering gas could be also responsible for “warm absorbers” commonly observed in unobscured AGN.

“X-ray obscured” (generally type 2) AGN are not totally X-ray silent at energies below their soft X-ray photoelectric cut-off. The advent of broadband moderate resolution X-ray spectroscopy led to the discovery of soft X-ray emission, in excess above the extrapolation of the obscured nuclear continuum (Turner et al. 1997). This spectral feature is present almost ubiquitously in samples of nearby Seyfert 2 galaxies (Guainazzi et al. 2005). The dramatic improvement in the spatial and spectral resolution provided by the scientific payload on-board Chandra and XMM-Newton has allowed us to understand, almost unambiguously, the nature of this spectral component. Obscured AGN soft X-ray spectra are dominated by emission lines from He- and H-like transitions of elements from Carbon to Neon, as well as by L-shell transitions from Fe\(^{xvii}\) to Fe\(^{xxi}\) (Guainazzi & Bianchi 2006). “Narrow” (intrinsic width, \(\sigma \lesssim 10\) eV) Radiative Recombination Continuum features from C\(^v\), O\(^vii\) and O\(^viii\) are unambiguous signatures of photoionization. The comparatively large intensity of higher order transitions - when compared to their K\(_{\alpha}\) - indicates that resonant scattering also plays an important role in the ionization balance (Kinkhabwala et al. 2002). This prevents standard spectral diagnostics (Gabriel & Jordan 1969; Porquet & Dubau 2000) from being usable. Nonetheless, spectra of obscured AGN and of starburst galaxies are systematically different, once diagnostic parameters unaffected by resonant scattering are considered (Guainazzi & Bianchi 2006). This does not impede that in a few type 2 sources (Levenson et al. 2005) - often low-luminosity AGN (Jiménez-Bailón et al. 2003) - the X-ray Spectral Energy Distribution is dominated by stellar processes.

Furthermore, the morphology of the soft X-ray emitting gas exhibit a striking coincidence with high-resolution O[III] images on scales as large as \(\sim 0.1–1\) kpc (Young et al. 2001; Bianchi et al. 2006). Simple mono-phase photoionization models reproduce well the observed X-ray to optical luminosity ratio (Bianchi et al. 2006). Successful models yield an almost constant ionization parameter across the whole extension of the gas, hence a radial dependence of the electronic density \(n_e \propto r^{-\beta}\), with \(\beta \simeq 1.8–2.0\). The latter results are in good agreement with those derived from spatial-resolved optical spectroscopy of the Narrow Line Regions (NLRs) (Kraemer et al. 2000; Bradley et al. 2004; Collins et al. 2005). The possibility that the soft X-ray extended emission is...
mainly powered by “local” photoionization, due to gas heated by mechanical
shocks in the interaction between a jet and the interstellar medium, cannot in
principle be ruled out. However, the discovery of this close connection between
soft X-ray emitting gas and NLRs again points to AGN-photoionization as the
main physical mechanism responsible for the ionization balance.

The physical properties of these X-ray “warm mirrors” are relatively
poorly constrained. Detail photoionization models applied to the best quality
spectra indicate:

- column densities in the range $10^{21} - 10^{22}$ cm$^{-2}$ (Sako et al. 2000; Sambruna et al. 2001; Bianchi & Matt 2002; Kinkhabwala et al. 2002).
- a wide range of ionization parameters ($\xi = L/n_e r^2$, where $L$ is the ion-
izing luminosity): $\log(\xi) = 0 - 3$. The soft X-ray spectra we measure
are probably due to a mixture of contributions from different gas phases
(Sambruna et al. 2001; Bianchi & Matt 2002). The detection of fluores-
cent emission lines from highly ionized iron (Bianchi et al. 2005) confirms
this hypothesis
- turbulent velocities of the order of a few hundreds km s$^{-1}$, in the very few
cases where these measurements are possible (Kinkhabwala et al. 2002;
Guainazzi & Bianchi 2006)

The existence of an electron-dominated scattering plasma filling the torus
axial region is one of the basic ingredient of standard Seyfert unification sce-
narios, invoked to explain wavelength-independent polarization of optical broad
lines in polarimetric measurements of some type 2 AGN (Antonucci & Miller 1985;
Tran 1995).

In a large fraction - probably as high as 50% - of “X-ray unobscured” (gener-
ally type 1) AGN the high-energy nuclear radiation is transmitted through pho-
toionized gas, the so called “warm absorber”. Since their discovery (Halpern 1984)
and early characterization (Reynolds 1997; George et al. 1998), warm absorbers
represent a fundamental ingredient of any AGN structure model. An Occam’s
razor argument may suggest that “warm absorbers” and “warm mirrors” are
actually one and the same gaseous system. Again, our understanding of the
physical and dynamical properties of the absorbing gas has dramatically im-
proved with the advent of X-ray high-resolution spectrometers. After a recent
study by Blustin et al. (2005) on a sample of 23 nearby AGN, one can summarize
the properties of the warm absorbing gas as follows: i) average ionization pa-
rameter covering a wide range ($\log(\xi) = 0 - 3$); ii) total column densities in the
range $10^{21} - 10^{22}$ cm$^{-2}$; iii) typical outflowing velocities of a few hundreds km s$^{-1}$,

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1It should be born in mind that X-ray spectroscopic slits typically encompasses a few kilo-parsecs
around the nucleus even in the closest AGN

2Actually, the range of ionization parameters is even wider than that, if one include in-/outflows
traced by absorption from He- and H-like iron (Pounds et al. 2003; Dudina et al. 2005), as well
as spectral signatures of low-ionization gas such as the Unresolved Transition Arrays of M-shell
iron (Behar et al. 2001)
except for “iron” outflows, whose velocities can be up to one order of magnitude larger. The basic gas physical parameters are therefore largely coincident between “warm absorbers” and “warm mirrors”.

The exact geometry of the warm absorber is unknown, although dynamical constraints are consistent with it originating as a radiation-driven high-velocity outflow in accretion disk instabilities (Krongold et al. 2005; Nicastro, this volume), and propagating up to typical NLR distances (Kraemer et al. 2006). These uncertainties prevent firm statements on the identity between warm absorbers and warm mirrors from being drawn. Interestingly enough, however, there is at least one known source, exhibiting a transition from an absorber-into a mirror-dominated soft X-ray spectrum. NGC 4051 is one of the most dramatically X-ray variable AGN in the local Universe. It is a $L_X \sim 10^{42}$ erg s$^{-1}$ Narrow Line Seyfert 1 Galaxy, which occasionally exhibits extreme low flux states. During one of these states, XMM-Newton observed a spectrum practically indistinguishable from an highly obscured AGN (Pounds et al. 2004), at odds with the standard “warm absorbed” spectrum observed during normal flux states (see Fig. 1).

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Figure 1. XMM-Newton RGS spectra of the Narrow Line Seyfert 1 Galaxy NGC 4051 during a normal flux state (May 2001; top panel) and a low flux state (bottom panel). The former exhibits typical features of a “warm absorber”; the latter, taken 18 months later, is almost indistinguishable from the “warm mirror”-dominated soft X-ray spectrum of an obscured AGN. The deep feature at $\lambda \approx 20.80\,\text{Å}$ is instrumental. The main transitions observed typically in warm absorbers and warm mirrors are labeled for reference. See also Pounds et al. 2004.