Warm absorbers in Narrow-Line Seyfert 1 galaxies

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Abstract

We present a study of the X-ray properties of several NLS1 galaxies, focusing on their warm absorbers. In the first part, we discuss properties of dusty and dust-free warm absorbers in NLS1s, and study their potential contribution to high-ionization optical iron lines. In the second part, we summarize our work on the exceptional spectral variability of the NLS1 galaxy RX J0134.3−4258 (from \( \Gamma \simeq -4.4 \) in the ROSAT all-sky survey observation, to \( \simeq -2.2 \) in our subsequent pointed observation).

Key words: AGN, warm absorbers, emission lines, individual objects: IRAS 13349+2438, IRAS 17020+4544, NGC 4051, RXJ0134−4258

1 Dusty warm absorbers in NLS1 galaxies

Warm absorbers (WAs) are an important new probe of the physical conditions within the central regions of active galaxies. They have been observed in \( \sim 50\% \) of the well-studied Seyfert galaxies and have also been detected in quite a number of Narrow-line Seyfert 1 galaxies (see Komossa 2000 for a review, and references therein). The photoionization calculations presented below were carried out with Ferland’s (1993) code Cloudy.

Dusty WAs were suggested to be present in several NLS1 galaxies. Model calculations of dusty WAs were first applied to NGC 4051 (Komossa & Fink 1997a, KF97 hereafter). The bulk of its WA turned out to be dust-free. Other NLS1s were then successfully fit with this model. Tab. 1 lists the results, including also types of AGN other than NLS1s.
Table 1
Summary of the candidates for dusty warm absorbers, successfully modeled as such, listed in the chronological order that they were suggested, and results from spectral fits. Values of the ionization parameter $U$ given here and elsewhere in the text refer to a continuum spectrum with $\alpha_{\text{EUV}} = -1.4$ (between Lyman-limit and 0.1 keV), if not noted otherwise, and photon index $\Gamma_x$ as listed.

| object                  | type         | warm absorber fit | references |
|-------------------------|--------------|-------------------|------------|
| 3C 212                  | ‘red’ quasar | $\Gamma_{\text{intr}}$ = -2.9, log $U$ = -0.4, log $N_w$ = 21.2$^1$ | [1]        |
| IRAS 13349+2438         | NL quasar    | -1.9, log $U$ = -0.3, log $N_w$ = 21.8 | [2],[8]    |
| NGC 3227                | Sy 1.5       | -1.9, log $U$ = -0.8, log $N_w$ = 21.7 | [3]        |
| NGC 3786                | Sy 1.8       | -2.2, log $U$ = 21.7 | [4]        |
| MCG –6-30-15            | Sy 1         | -2.8, log $U$ = 0.7, log $N_w$ = 21.6$^1$ | [6],[9]    |
| IRAS 17020+4544         | NLS 1        | -2.2, log $U$ = -0.1, log $N_w$ = 21.6 | [7]        |
| 4C +74.26               | radio quasar | -2.2, log $U$ = -0.1, log $N_w$ = 21.6 | [7]        |

(1) fixed to the value $N_{\text{opt}}$ determined from optical reddening. (2) Comments: 3C 212: model of dusty WA not yet fit. (3) References: [1] Mathur 1994, [2] Brandt et al. 1996, [3] Komossa & Fink 1997b, [4] Komossa & Fink 1997c, [5] Reynolds et al. 1997, [6] Leighly et al. 1997, [7] Komossa & Meerschweinchen 2000, [8] Komossa & Greiner 1999, [9] Komossa & Bade 1998; for a more complete list of references on the individual objects, see Komossa 2000.

2 The warm absorber of NGC 4051 and the (missing) relation between WA and CLR.

Dust-free warm absorbers, like the one in NGC 4051, might contribute significantly to the emission in optical/UV iron coronal lines. In the following we shall examine in detail the warm absorber in the NLS1 galaxy NGC 4051 with respect to the question of whether this ionized material can account for the optical coronal lines observed in this galaxy. This is an update of our earlier work on this subject (KF97). The X-ray analysis (KF97) yielded the following parameters for the WA: log $U = 0.4$, log $N_w = 22.7$, and a density $n_H \lesssim 3 \times 10^7 \text{cm}^{-3}$, using as input continuum the observed multi-$\lambda$ SED. Intensity ratios of coronal lines were taken from the literature (e.g., Nagao et al. 2000).

We then checked, for this best-fit warm absorber model, the strengths of the optical/UV lines originating from the ionized material; in particular, the Fe lines [FeVII] $\lambda 6087$, [FeX] $\lambda 6374$, [FeXI] $\lambda 7892$, and [FeXIV] $\lambda 5303$ (see Tab. 2 of Komossa 2000). We find that all of them are much weaker than observed. Next, we varied those parameters that do not strongly influence the X-ray absorption structure, but could have an effect on the predicted Fe line strengths; namely: the metal abundances, the gas density, the EUV continuum shape,
and the IR continuum strength. We find that in all cases, the lines [Fe VII]–[Fe XI] remain much weaker than observed by several orders of magnitude (see Tab. 2 in Komossa 2000 for a detailed list of predicted line ratios). The reason for this is that the warm absorber is always too highly ionized, with a totally negligible amount of Fe9+ and Fe10+ ions in the gas. Therefore, changes in collisional strengths for the relevant Fe transitions, which are still poorly known, are not expected to alter this result. We conclude that for the case of NGC 4051 the warm absorber and the coronal line region are not one and the same component, but are of different origins. This is consistent with the recent findings of Nagao et al. (2000) that the [Fe XI] emission of NGC 4051 is not confined to the nucleus, but widely extended (out to at least ~150 pc).

Recently Porquet et al. (1999; P99 hereafter) presented a parameter space study of the strengths of Fe coronal lines that originate from warm absorbers. They conclude that Fe lines in low-density absorbers (they studied the density range log nH = 8–12) are over-predicted for part of the parameter space. Comparing our earlier results on NGC 4051 (KF97) with their results, we find they are consistent: for warm absorbers dominated by O VIII absorption and high ionization parameters, no overprediction in line emission occurs (their Tab. 1). The question remains whether the ‘OVII absorbers’ of P99 do indeed overpredict the Fe lines and thus are in conflict with observations. We propose that most of the strong OVII absorbers likely contain dust (which was not included in the models of P99), as suggested by the study of Reynolds (1997). The strong depletion of Fe into dust grains then results in weaker gas phase emission in the Fe coronal lines; see Komossa 2000 for further discussion.

3 The X-ray transient NLS1 RXJ0134–4258

The Narrow-line Seyfert 1 galaxy RXJ0134–4258 is one of the rare sources that showed dramatic spectral variability. Its spectrum changed from ultrasoft (Γx = −4.4) in the ROSAT all-sky survey (RASS) to flat (Γx = −2.2) in our pointed PSPC observation made two years later, while its count rate remained nearly constant (Komossa & Meerschweinchen 2000, and references therein). One possible explanation for this kind of spectral variability is the presence of a warm absorber.

We find that a warmly-absorbed, intrinsically flat power law fits the RASS observation well, with log Nw ∼ 10^{23} cm^{-2} (χ^2_{red} = 0.6). To account then for the much flatter spectrum during the later PSPC observation requires a change in ionization state of the warm absorber. Since the intrinsic luminosity of the source is not significantly different between the two observations, it is then required that the ionization state of the warm absorber reflects the (un-observed) history of the variability in the intrinsic luminosity (see KM2000
Fig. 1. **Left**: Residuals after fitting a *warm absorber* to the RASS spectrum (= ‘steep-state’ spectrum) of RXJ0134–4258. **Right**: Residuals after fitting a *power law* to the pointed PSPC data (= ‘flat-state’ spectrum) of RXJ0134–4258.

After allowing for non-equilibrium effects in the absorber and/or a range in densities, such a warm absorber is consistent with the long- and short-timescale variability behavior of RXJ0134–4258. We did not favor this explanation, because it introduces a new level of complexity (more free parameters) as compared to the simpler case of an absorber in equilibrium. Alternatively, a cloud of ionized material may have passed through our line of sight during the RASS observation, and may have (nearly) disappeared during the later PSPC observation. Finally, it is interesting to note that the presence of high-ionization UV absorption lines in this object was reported by Goodrich at this meeting. Indeed, recent studies suggest a nearly one-to-one match of the presence of UV and X-ray warm absorbers. For a more detailed discussion of RXJ0134–4258, including alternative model descriptions, we refer to Komossa & Meerschweinchen 2000 (and references therein).

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[http://www.xray.mpe.mpg.de/~skomossa/](http://www.xray.mpe.mpg.de/~skomossa/)

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