The warm absorber in a high luminosity AGN: QSO MR 2251-178

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ABSTRACT

The study of complex low energy X-ray absorption features due to highly ionized gas – the warm absorber – is a unique probe of the physical state in the inner regions of AGN. The BeppoSAX satellite has an excellent capability to study the warm absorber in AGN, thanks in particular to the good effective are and low energy resolution down to 0.1 keV of its Low Energy Concentrator Spectrometer (LECS). Here we present recent BeppoSAX observations of the radio quiet and X-ray bright QSO MR 2251-178 which suggest that the warm absorber material is in simple photoionization equilibrium with the ionizing X-ray continuum source.

1. Introduction

MR 2251-17.8 is a nearby (z = 0.064) radio quiet and X-ray bright QSO ($L_X \sim 10^{45}$ erg s^{-1}). Early X-ray observations of this source with the Einstein Observatory revealed both a soft excess and variable intrinsic absorption, giving the first evidence for warm absorbers in AGN (Halpern 1984). The source was later monitored by EXOSAT between 1983 and 1984 (Pan et al. 1990, Mineo & Stewart 1993). During this period the 2–10 keV flux varied by a factor ∼1.8 with timescales as short as ∼10 d. The spectral behavior can be well described using a self-consistent warm absorber model showing that the ionization parameter of the gas is clearly correlated with the continuum flux. ASCA observations in 1993 (Reeves et al. 1997) reveal an Fe line feature at ∼ 6.6 keV due to partially ionized iron.

2. What BeppoSAX observed

MR 2251-17.8 was observed by BeppoSAX from 14–17 June 1998, with a total effective exposure time in the MECS instrument of 6.1 10^4 sec. We describe here a preliminary analysis of the LECS and MECS 0.1–10 keV data. Weak variability was expected from previous observations. Indeed, only marginal variations occured during the 2.3 days of elapsed time in the 0.1–2 keV band (Fig. 1), whereas no significant variability was detected in the 2–10 keV band. A fit of the light curves with a constant value yields $\chi^2_\nu = 1.36$ and 1.12 for the 0.1–2 and 2–10 keV bands, respectively and for 21 degrees of freedom. The 2–10 flux was 4 $\times 10^{-11}$ erg s^{-1} cm^{-2}, a medium level, higher by a factor 1.2–2 than those observed with EXOSAT but slightly lower than the

Table 1: Combined spectral fit LECS: 0.1–3 keV, MECS: 1.8–10 keV. The model is composed of a power-law, neutral galactic absorption N_{HGal}, an absorption edge due to ionized oxygen, a gaussian Fe Kα emission line and a LECS/MECS normalization constant. χ^2= 350.0, dof = 401)

N_{HGal} 10^{-20} cm^{-2}	Γ	E_{edge} keV	τ	$E_{FeK\alpha}$ keV	EW eV
3.2 ± 0.3	$1.65 \pm ^{0.02}_{0.03}$	0.80 ± 0.03	$0.67 \pm ^{0.15}_{0.13}$	$6.51 \pm ^{0.23}_{0.57}$	$172 \pm ^{212}_{100}$

ASCA flux in 1993. Figure 2 shows the LECS/MECS spectrum and the residuals to a simple absorbed power-law fit. Absorption due to OVII and OVIII is apparent near 1 keV. Table 1 shows the results of spectral fitting with an absorbed power-law including a single absorption edge. The power-law index is comparable to that measured with ASCA ($\Gamma_{ASCA} = 1.60 \pm 0.02$, Reeves et al. 1997) The LECS does not resolve the OVII and OVIII absorption edges and no significant improvement to the quality of fit is obtained when two edges are fit with their energies frozen to the redshifted values for OVII and OVIII. The optical depths τ_{OVII} and τ_{OVIII} are then 0.38 ± 0.19 and 0.33 ± 0.17, respectively (all uncertainties are quoted here as 90% confidence levels), and comparable to ASCA values ($\tau_{OVII} = 0.32 \pm 0.10$, $\tau_{OVIII} = 0.15 \pm 0.08$, Reynolds, 1997). The presence of a Fe Kα line is significant at a confidence level >99% and its EW and flux are compatible with those measured with ASCA (Reeves et al. 1997). However the line width is not resolved by BeppoSAX.

3. Photoionization models

Fits of the warm absorber were also performed using models obtained with the photoionization code CLOUDY (Ferland 1993), assuming photoionization equilibrium and a "standard AGN" ionizing continuum which includes an "X-ray" power-law ($\Gamma_X = 1.6$) and a "Blue Bump". The best fit parameters are U= $0.53\pm^{0.34}_{0.20}$ and $N_W = (1.41\pm^{0.33}_{0.26})10^{21}$ cm^{-2}, where U is the ionization parameter and N_W is the total hydrogen column density of the warm absorber and with $\chi^2_\nu = 0.91$ (for 355 dof). This value of U is comparable to those measured by Mineo and Stewart (1993) from Ginga and EXOSAT data when the source was in a significantly lower flux state (F(2–10)$\leq$ 2.2 $\times 10^{-11}$ erg s^{-1} cm^{-2}). This somewhat contradicts their results which show a clear trend between ionization parameter and continuum flux. However, our warm absorber results agree well with the smooth correlation between flux and ionization parameter ξ obtained by Otani et al. 1998 with ASCA data (assuming ξ/U $\sim$ 20, from the spectral shape of the ionizing continuum and the conversion relation given by George, 1998). A value of $N_W = 1.5\,10^{21}$ cm^{-2} gave the best fit results for the data set analyzed by Mineo and Stewart (1993) and agrees well with our value, confirming that the column density does not vary much on time scales of several years.

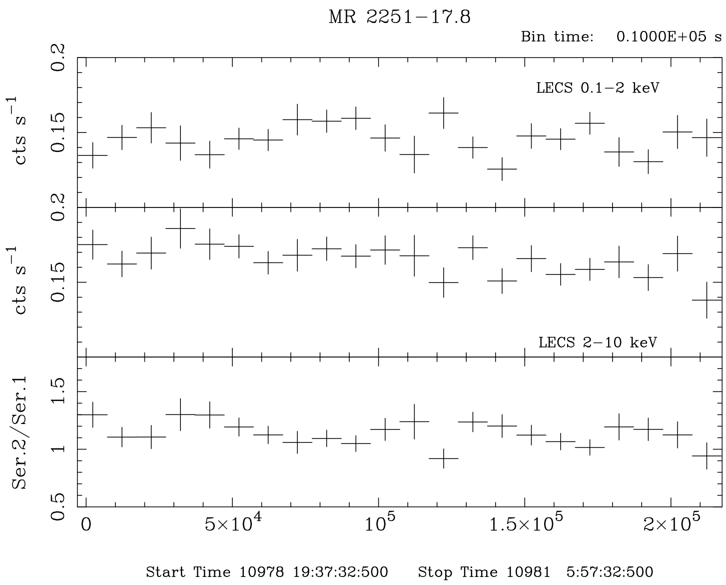

Fig. 1.— LECS 0.1–2 and 2–10 keV light curves and (2–10 keV / 0.1–2 keV) hardness ratio

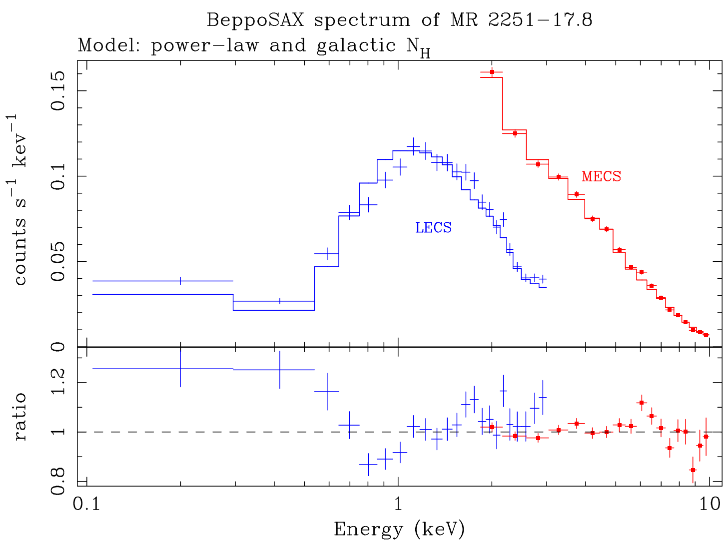

Fig. 2.— LECS and MECS 0.1–10 keV spectrum of MR 2251-17.8 fit with a power-law and neutral galactic absorption. Significant residuals are due to OVII and OVIII absorption near 1 keV and Fe Kα emission at $\sim$ 6 keV

4. Conclusions

These preliminary BeppoSAX results confirm that the X-ray bright, radio quiet quasar MR 2251-17.8 does not show short time scale (few days) variations of its X-ray spectrum nor of its warm absorber properties and that any long ($\geq$months) time scale variations are of low amplitude. Such a pattern is in strong contrast with that observed in low luminosity Seyfert 1 AGN such as MCG-6-30-15 ($L_X \sim 10^{43}$ erg s^{-1}, Orr et al. 1997). Although photoionization equilibrium is favoured in such "quiet" conditions, the preliminary analysis of the BeppoSAX data for MR 2251-178 does not yet allow to exclude a more complex situation.

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