Modelling of the X-ray broad absorption features in Narrow Line Seyfert 1s

Delphine Porquet

Service d’Astrophysique, CEA, Saclay, France

Martine Mouchet, Anne-Marie Dumont

DAEC, Observatoire de Paris, section de Meudon, France

Abstract

We investigate the origin of the broad absorption features detected near 1-1.4 keV in several Narrow Line Seyfert 1 galaxies, by modelling the absorbing medium with various physical parameters, using the ionisation code PEGAS. The observed properties of the X-ray absorption features can be reproduced by taking into account the peculiar soft X-ray excess which is well fitted by a blackbody plus an underlying power law. We equally stress that the emission coming from the absorbing medium (related to the covering factor) has a strong influence on the resulting X-ray spectrum, in particular on the apparent position and depth of the absorption features. A non-solar iron abundance may be required to explain the observed deep absorption. We also investigate the influence of an additional collisional ionization process (“hybrid case”) on the predicted absorption features.

Key words: galaxies: active–galaxies: Seyfert–X-rays: galaxies–atomic processes

1 Introduction

A systematic analysis of the X-ray spectral properties of a sample of 22 so-called Narrow Line Seyfert 1s (NLS1s) based on ASCA observations has shown evidence for a broad absorption feature centred in the energy range 1.1-1.4 keV, in 6 of the 22 objects [1]. The absorption feature strength is typically about 100 eV with an intrinsic width ranging from 0.1 to 0.3 keV. Until now, this type of absorption has never been detected in Broad Line Seyfert 1s (BLS1s) spectra. Only 3 NLS1s exhibit absorption edges in the 0.7-0.9 keV range consistent with that seen in at least 50% of the BLS1s. Several explanations of the 1.1-1.4 keV absorption features have been proposed: a blueshift of O VII–O VIII...
edges or lines (outflow: $z \sim 0.2-0.6c$) [2,3]; resonance absorption lines from Mg, Si, S and Fe L [4,5]; an enhancement of Fe or Ne [2,3].

2 The models and results

The calculations are made with the photoionization code PEGAS adapted for optically thin media [6]. A photoionized plasma is characterized by its ionization parameter: $\xi = \frac{L}{n_H R^2}$, where $L$ is the bolometric incident luminosity (erg s$^{-1}$), $n_H$ (cm$^{-3}$) is the hydrogen density and $R$ (cm) is the distance of the inner layer of the cloud from the ionizing incident source.

- Influence of the incident continuum shape
  NLS1s tend to be stronger soft X-ray emitters with respect to BLS1, and often have steeper photon indices: $\Gamma(2-10\text{ keV}) = 1.6-2.5$ [1]. Their soft excesses can be modelled as blackbody (BB) emission superposed on an underlying power law (PL). We consider a “typical incident NLS1 continuum” as the sum of a BB at $T=130$ eV and a PL with $\alpha = 1$ ($F(E) = E^{-\alpha}$) and with $L_{BB}/L_{PL}(2-10\text{ keV}) = 3$. For a given $\xi$ and $N_H$ (column density in cm$^{-2}$) the “typical incident NLS1 continuum” gives less absorption and higher ionization states than a single PL with the same slope. This could explain why the absorption features in NLS1s are located at higher energies.

- Influence of iron overabundance
  Figure 1 shows the transmitted spectrum obtained for an iron overabundance of a factor 10, as well as the spectrum for a solar iron abundance. An iron over-abundance could be responsible for a strong absorption above 1 keV (Fe xvii + some Ne ix) and a weak oxygen absorption.

- Influence of emission (covering factor)
  The emission ($\varepsilon$) depends on the covering factor ($f_c$) of the medium responsible for the absorption ($\varepsilon \propto f_c$). Figure 2 illustrates the great importance of the emission lines on the observed spectrum.

- Influence of collisional processes
  The Warm Absorber in BLS1s could be purely photoionized, but an additional ionization process such as collision or a non pure radiative equilibrium are not ruled out [7–9]. This could be also the case in NLS1s. As shown in Figure 2, a pure photoionized case and a hybrid case ($T = 3.6 \times 10^6$K) have different line ratios and different profiles of absorption (for the same incident continuum and $\xi$). In the hybrid case, higher ionisation states occur (i.e. Fe xvii, Ne X).
and for a non negligible covering factor ($f > 0.5$), the spectrum exhibits an absorption above 1 keV but no oxygen edges, which could explain the lack of detection of oxygen edges in the spectra of the 6 objects with broad absorption above 1 keV.

3 Conclusion and perspectives

Several properties of NLS1s eg. UV-X-ray energy distribution, iron overabundance, hybrid plasma with high covering factor, could account for the peculiarities observed in some soft X-ray spectra of these objects. The spectral resolution attainable by ASCA was insufficient to disentangle between these different possibilities. The new X-ray satellites (Chandra, XMM-Newton) offer the prospect of detailed spectra that will certainly allow us to determine the nature of the 1 keV feature (emission or absorption). Moreover X-ray spectroscopic diagnostics such as those based on the ratios of He-like ion lines will enable us to determine the ionizing process (either pure photoionization, or photoionization plus an additional ionization process), as well as the gas density [10,11]. The determination of the physical parameters for the Warm Absorber media in NLS1s and in BLS1s will provide constraints on unified schemes.
Fig. 2. Spectra normalized to the incident continuum, for a pure photoionized medium (left) and for a hybrid case with T fixed at 3.6 $10^6$ K (right). Bottom: a covering factor $f=0.1$; top: $f=1.0$. Model parameters are $\xi=50$, $N_H=10^{22}\text{cm}^{-2}$, and $E/\Delta E=30$.

References

[1] Vaughan S., Reeves J., Warwick R., Edelson R. 1999, MNRAS, 309, 113
[2] Leighly K. M., Mushotzky R. F., Nandra K., Forster K. 1997 , ApJ, 489, L25
[3] Ulrich M. -H., Comastri A., Komossa S., Crane P. 1999, A&A , 350, 816
[4] Nicastro F., Fiore F., Matt G. 1999, ApJ, 517, 108
[5] Turner T. J., George I. M., Netzer H. 1999, ApJ, 526, 52
[6] Dumont A.-M., Porquet D., 1998, ASP Conf. Ser., Vol. 175,p. 19
[7] Porquet D., Dumont A.-M., 1998, ASP Conf. Ser., Vol. 175, p.359
[8] Porquet D., Dumont A.-M., Collin S., Mouchet M. 1999, A&A, 341, 58
[9] Nicastro F., Fiore F., Perola G. C., Elvis M. 1999, ApJ, 512, 184
[10] Porquet D., Dubau J. 2000, A&AS, in press [astro-ph/0002319]
[11] Kaastra J. S., Mewe R., Liedahl D. A., Komossa S., Brinkman A. C. 2000, A&A, 354, L83