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THERMAL INSTABILITIES IN THE WIND OF NGC 3783

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Abstract. Outflows in Active Galactic Nuclei play an important role for galaxy evolution and the enrichment of the intergalactic medium. In the X-ray range they appear as warm absorbers (WA). Thanks to the recently introduced Absorption Measure Distribution (AMD) method, the column densities of individual ionic species of the wind can be derived from observed X-ray spectra, which gives a new handle on constraining the physics of the WA. We report first results on the theoretical interpretation of an AMD analysis for the Seyfert galaxy NGC 3783. The AMD results based on the known 900-ksec Chandra observation suggest that the WA is in pressure equilibrium as was indicated before by spectral analysis. Conducting radiative transfer simulations for such a case we reproduce the measured ionic column-densities by adjusting several crucial parameters of the medium: the ionization parameter, the total column density, and the amount of micro-turbulence. We use the code TITAN that is particularly adequate to the radiative transfer in X-ray photoionized gases at constant total pressure. It turns out that the WA plasma is probably a clumpy, two-phase medium where cold, dense clumps are embedded in a hotter, diffuse gas.

1 Thermal instabilities in photoionized gases

A photoionized gas in thermal equilibrium such as in the warm absorber (WA) of active galactic nuclei can display thermal instabilities. The phenomenon can be illustrated when plotting the temperature versus the ratio of radiation to gas pressure (Krolik et al. 1981). The S-shape of the plot indicates the possible co-existence of several gas temperature phases at the same pressure ratio. At a given pressure, the gas can be in three (or more) thermal equilibrium states, which depend on the ionizing spectral energy distribution and other physical parameters related to the heating and cooling function of the gas. Some of these equilibrium states are thermally unstable, others are not.

The TITAN code for radiative transfer in X-ray irradiated plasma gas (Dumont et al. 2000, 2003) allows to choose between the hot and the cold stable solutions; it also provides an intermediate solution which can be understood as a mixture of the WA cold and hot phases (Gonçalves et al. 2007). In the work presented in this note we explore the intermediate solution of a WA gas in total pressure equilibrium.

2 Model comparison to the measured ionic column densities in the warm absorber of NGC 3783

Using a long Chandra observation, Holczer et al. (2007) apply the so-called AMD method to constrain the elemental abundances and the column densities $N_{\rm i}$ of various ionic species in the WA gas of the Seyfert galaxy NGC 3783. Gonçalves et al. (2006) have shown that the absorption spectrum of this object can be explained

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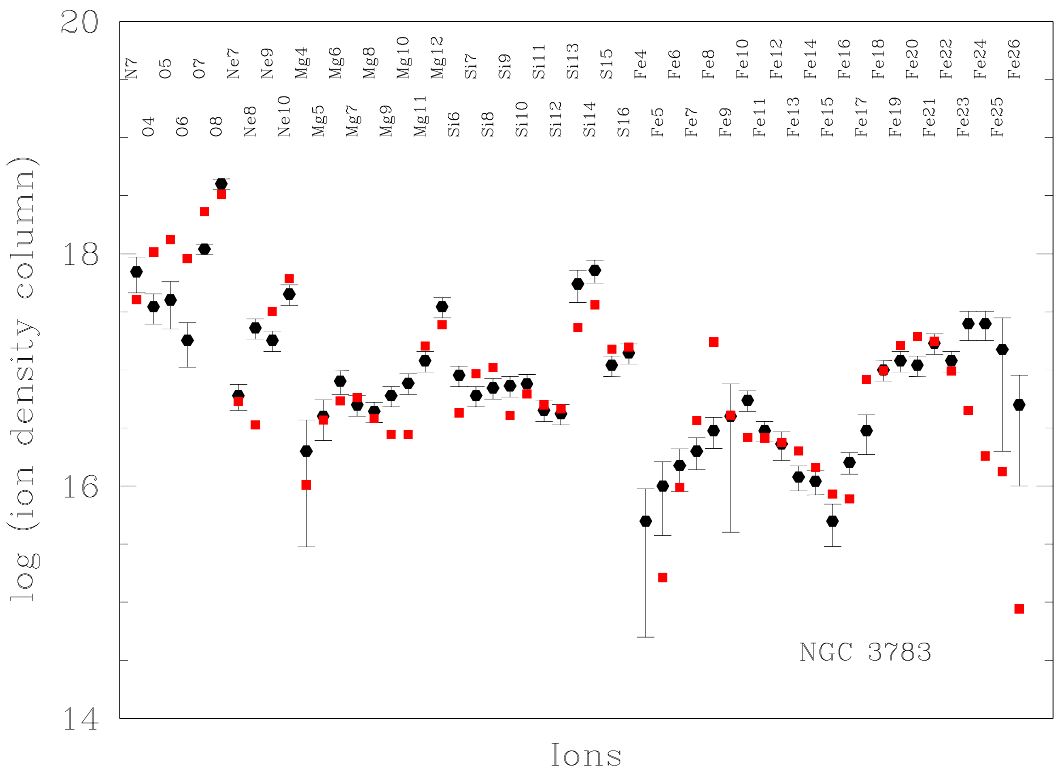

Fig. 1. Ionic column densities derived from the observed data by the AMD method (black circles with error bars; Holczer et al. 2007) and from the best TITAN model (red squares).

by a photoionized gas in constant total (i.e. gas + radiation) pressure. Here, we attempt to reproduce also the measured distribution of $N_{\rm i}$ computing various TITAN models. We vary the ionization parameter ξ, the total column density $N_{\rm H}$ of the gas, and its turbulent velocity $v_{\rm turb}$. The result for the best fitting model is shown in Fig. 1. The data is taken from the analysis by Holczer et al. (2007) and the model corresponds to the parameters $\xi = 2500$ cm ergs/s, $N_{\rm H} = 4 \times 10^{22}$ cm^{-2} and $v_{\rm turb} = 150$ km/s. There are striking similarities between the observed ionic column densities and the results from modeling the warm absorber in total pressure equilibrium. A discrepancy remains for the highest ionization species of iron where the model underestimates the observed column densities. This difference may be explained by the current limits on the measurements and/or theoretical computations of dielectronic recombination coefficients for highly ionized iron.

In addition to the best model shown in Fig. 1, other couples $(\xi, N_{\rm H})$ in the adjacent parameter region also provide a reasonable estimate of both the observed spectrum and the measured individual ionic column densities. We have examined the temperature and ionization profiles of our different models and compared them to the results of the AMD method. It turns out the model can reproduce the characteristic temperature gap revealed by the AMD analysis. This “forbidden” temperature zone seems to point out the existence of the thermal instability in the warm absorber gas. More details of this analysis will be published elsewhere.

References

Dumont et al. 2000, A&A 357, 223

Dumont et al. 2003, A&A 407, 13

Gonçalves et al. 2006, A&A 451, L23

Gonçalves et al. 2007, A&A 465, 9

Holczer et al. 2007, ApJ 663, 799

Krolik et al. 1981, ApJ 249, 422