Warm absorber (WA) is an ionised gas present in the line of sight to the AGN central engine. The effect of the absorber is imprinted in the absorption lines observed in X-ray spectra of AGN. In this work, we model the WA in Seyfert 1 galaxy Mrk 509 using its recently published shape of broad band spectral energy distribution (SED) as a continuum illuminating the absorber. Using the photoionization code Titan, recently we have shown that the absorption measure distribution (AMD) found for this object can be successfully modelled as a single slab of gas in total pressure (radiation+gas) equilibrium, contrary to the usual models of constant density multiple slabs. We discuss the transmitted spectrum that would be recorded by an observer after the radiation from the nucleus passes through the WA.

1 Introduction

The first ever evidence of X-ray absorption has been discussed by Halpern (1984) who analysed the EINSTEIN data of QSO MR 2251-178. Since then, significant progress has been made in the study of X-ray absorption by an ionized absorber present in the line of sight to the centers of active galaxies. This was possible as a result of the advancement in the X-ray instrumentation which enabled the acquisition of high resolution X-ray data clearly showing numerous X-ray absorption lines in the spectra of ∼ 50% of Seyfert 1 galaxies. These observations facilitated the exploration of the physical properties as well as the ionization and thermal structure of the absorbing gas for many AGNs (Kaastra et al., 2002; Rozańska et al., 2004; Holczer et al., 2007; Behar, 2009; Detmers et al., 2011; Stern et al., 2014, and many others).

Absorption lines observed in the high resolution X-ray data together with the photoionisation modelling can be used to quantify the strength of absorption which is parametrized as absorption measure distribution (AMD) (Holczer et al., 2007); i.e., the distribution of gas column density $N_H$ in ionization parameter $\xi$. There is no general consensus whether these absorbers exist under pressure equilibrium or the number density is constant inside them. Recently, Adhikari et al. (2015, hereafter AD15) have shown that the warm absorber in Mrk 509 can be modelled with a single plane parallel slab of gas in total (gas+radiation) pressure equilibrium. Using the photoionization modelling with the constant pressure assumption, they were successful in reproducing the observed AMD derived by Detmers et al. (2011) from the 600 ks RGS spectrum of XMM-Newton.

In this paper, we focus on the transmitted spectrum that an observer would see if the WA is modelled as in AD15. We also discuss the future prospects of fitting the modelled spectra to the high resolution data that will be available from the advanced spectrometers in future X-ray missions; e.g. Astro-H and ATHENA. This will allow
us to constrain the physical parameters of the absorbing cloud by fitting the observed absorption lines with relevant models. We discuss the potential effect of the warm absorption on the relativistic Fe line around 6.4 keV following the idea presented in Różańska et al. (2006).

2 Model parameters

We performed numerical simulations of the transmitted spectra with photoionization code TITAN [Dumont et al., 2000] using the shape of the SED of Mrk 509 constrained by Kaastra et al. [2011] as the broad band continuum illuminating the WA. TITAN solves the full radiative transfer equation and determines the physical state of the gas at each depth assuming the local balance between ionization and recombination of ions, excitations and de-excitations, local energy balance and finally total energy balance. For the detail features of the TITAN code and its implementation in the study of WA, we refer the reader to the relevant papers (Collin et al., 2004; Gonçalves et al., 2006; Różańska et al., 2006). In this study, we assumed the accretion radiation is normally incident on plane parallel slab of absorbing gas. Constant total pressure assumption self-consistently allows the gas to be stratified in density when it is illuminated by the incident accretion radiation. The photoionization modelling requires the following parameters: SED, number density of the gas, ionization degree (all defined at the illuminated side of the WA) and the chemical composition. We refer to the paper AD15 for the definitions, equations, and values of the relevant parameters used in our calculations.

3 Results and Discussion

The observed AMD found by Detmers et al. (2011) can be successfully modelled by the cloud compressed by radiation pressure as presented in AD15 (see Fig.8). Absorption measure distribution in Mrk 509 exhibits two dippers which are reproduced by our photoionization model. In this work, we discuss the continuum transmitted through the absorber described by the best fit parameters as given in AD15. Fig. 2 (panel a)
shows the transmitted spectrum from the best fitting WA model in Mrk 509. Numerous absorption lines are expected in the spectrum when the radiation is absorbed by the ionized gas. The absorption lines produced due to ions of lower ionization degree are seen in the transmitted spectra (panels (b) and (c) of Fig. 2) together with lines from higher ionization level from the one absorption component of the gas under constant pressure (panel d). Expanded view of the spectra in the Fe line region around 6.4 keV is shown in panel (d). Around 6.4 keV, we see a number of absorption lines due to highly ionized Fe ions with significant equivalent widths. This result clearly shows that the WA has a potential to significantly affect the Fe line emission that may be present in the illuminating spectrum due to the reflection of the hard X-ray continuum on the disk surface. However, a quantitative conclusion can be drawn only after the confirmation of this result in the spectra observed with high resolution instruments in the future X-ray missions, such as Asto-H and ATHENA.
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