Emission features from X-ray irradiated atmospheres

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ABSTRACT

Some applications of detailed calculations on optically thick model spectra of compact X-ray sources are shown. Accreting systems in general are potentially bright X-ray sources. This applies to stellar sources like cataclysmic variables (accretion onto a white dwarf) and X-ray binaries (accretion onto a neutron star or black hole). Our optically thick model spectra offer the possibility to analyze the X-ray observations of compact objects made by XMM. The emitted spectra from such atmospheres show up in the (soft) X-ray regime. The model spectra include edge and line opacities. The presence of strong edges has proven to be a valuable diagnostic in the interpretation of X-ray spectra. Spectral lines show up in absorption in 'isolated' atmospheres, but under certain circumstances they appear in emission when the atmosphere is irradiated. Such X-ray emission characteristics can be investigated in detail by XMM with its good energy resolution and simultaneous high sensitivity, thus revealing the internal geometry of binary systems.

1. Introduction

The atmospheric soft X-ray emission from accreting compact objects like cataclysmic variables is studied. Model parameters like the surface gravity and effective temperature are chosen such that they apply to hot, high-gravity atmospheres such as found on white dwarfs and may be an approximation to inner accretion discs. The emitted spectra from these atmospheres show up in the (soft) X-ray regime.

The mass flow onto the white dwarf can take place through both disk (Verbunt 1996) and column accretion (polars, Beuermann et al. 1996). In both cases the hot, shocked plasma emits relatively hard X-ray radiation which can irradiate and heat up the atmosphere of the white dwarf.

The reprocessed radiation from an irradiated atmosphere shows characteristic emission features like emission lines and edges. By simulating XMM spectra of irradiated atmospheres it is demonstrated that these features will show up in the XMM RGS spectra and may provide substantial information about the accretion processes close to and atmospheric conditions of the white dwarf.

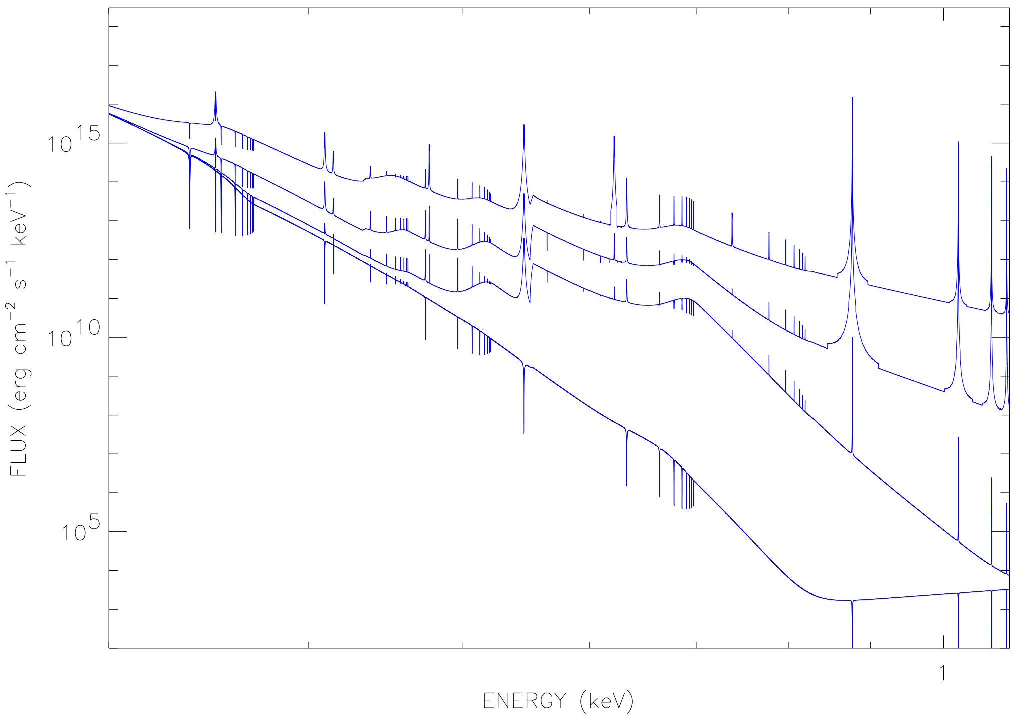

Fig. 1.— Unirradiated (bottom) and irradiated atmosphere spectra. Lyman line series turn to emission even at low irradiation flux levels. Strong emission lines of high ionic species (O VII, O VIII and Ne IX) appear

2. X-ray irradiation

2.1. Model calculations

A series of model atmospheres and their corresponding spectra applicable to hot, massive white dwarfs are calculated (Hartmann & Heise 1997; Hubený 1988). The bottom spectrum in Fig. 1 shows such a spectrum in case of no irradiation. The flux declines many orders of magnitude with increasing energy.

In the next three spectra, from bottom to top, the atmosphere is irradiated with a 1 keV bremsstrahlung spectrum at $10^{-4}, 10^{-3}$ and 10^{-2} times the total flux. The effect of irradiation is to heat the outer atmosphere and shift the ionization balance towards a high degree of ionization. Therefore, not only the 'reflected' bremsstrahlung continuum becomes visible, but also emission lines of high degree of ionic species. Emission features indicating an unexpectedly high degree of ionization are characteristic for irradiated atmospheres.

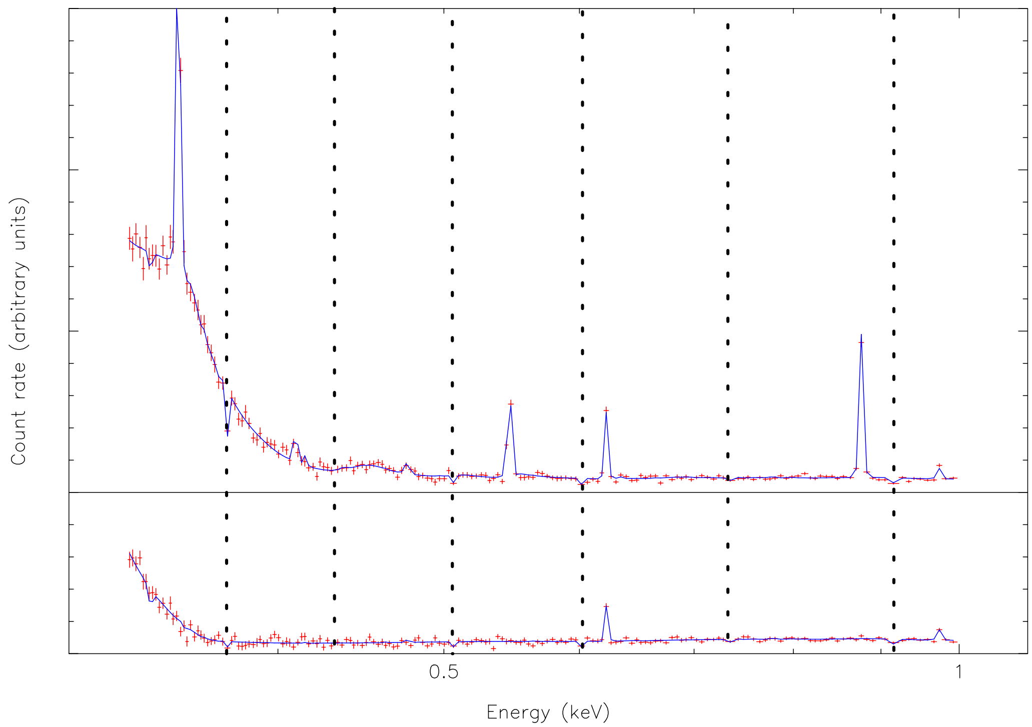

Fig. 2.— Top spectrum: 'Observational' signature of an irradiated atmosphere. Emission lines of highly ionized metals appear. Dashed lines indicate the band gaps in the response matrix used (XMM user manual 1998)

2.2. Spectral simulations

Fig. 2 shows two simulated XMM RGS observations of compact atmospheres using the X-ray spectral analysis package SPEX (Kaastra et al. 1996). Both the unirradiated and an irradiated model spectrum are folded with with the combined two XMM RGS response matrices. The number of response elements has been rebinned such that a S/N ratio of at least 3 is obtained. In the unirradiated case (bottom spectrum) only the almost featureless continuum (with the exception of a single line from an additional 10 keV plasma) is visible. This changes dramatically when the atmosphere is irradiated (top spectrum). The broad emission lines in Fig. 1 having a relatively large equivalent width show up strongly in the simulated XMM RGS spectrum.

Table 1: Input parameters and fit results for two XMM RGS spectral simulations. The irradiation fractions for simulation 1 and simulation 2 of 1.8 and 2.2 correspond to 6.3×10^{-4} and 1.6×10^{-3} times the total flux respectively

	Atmosph. norm.	Irrad. fraction	Metal abund.	Plasma norm.	Plasma T (keV)	Reduced χ^2
Input simulation 1	1.0	1.8	1.4	1.0	10.0	
Fit 1	0.8–3.4	1.2–2.0	1.1–2.0	0.98–1.03	9.5–11.6	1.1
Input simulation 2	1.0	2.2	0.8	1.0	10.0	
Fit 2	0.9–1.3	2.14–2.26	0.73–0.90	0.95–0.99	8.6–10.2	0.97

3. Conclusion

XMM RGS will be able to observe the spectral signatures of accretion processes close to or at the atmosphere of the white dwarf in a cataclysmic variable. This offers the possibility to study the irradiation of compact atmospheres.

In order to demonstrate that it enables us to unambiguously constrain spectral parameters with XMM RGS, two of the simulated observations are used as input for a spectral fit. Table 1 shows that the original model fit parameters are recovered from arbitrary input values within the errors quoted. Thus it is possible to distinguish emission lines due to irradiation from emission lines due to metal overabundances.

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