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# MgII statistics in GRB and QSO absorptions

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**Abstract.** MgII absorption systems in the spectra of GRB optical afterglows show an excess with respect to QSOs incidence. Among other hypotheses, absorptions occurring in clumps inside the host interstellar medium has been recently discussed. We discuss briefly whether this scenario is consistent with the kinetics of recombinations of magnesium in the conditions expected in such absorbing clumps.

*Keywords* : gamma-ray bursts: absorption lines – ionization states

## 1. Introduction

MgII absorptions in the quasar spectra have been recognized as tracers of cosmic history of field galaxies (Bergeron & Boissé 1991). They are found to be widely and homogeneously spread in intervening space, with no obvious signs of cosmological evolution and dependence on the nature of the background source. Therefore, it is quite natural to use the most bright emitters in the Universe – GRB optical afterglows, for studying MgII absorptions. The very first spectroscopic observations of MgII absorptions in optical afterglows (Prochter et al. 2006) however delivered surprises: while nearly every GRB line-of-sight with $\langle z\rangle \sim 1$ shows at least one strong rest-frame MgII system ($W_\lambda^{2796} > 1$ Å), quasars show around four times smaller incidence of MgII absorbers: $(dN/dz)_{\rm GRB} \sim 4(dN/dz)_{\rm QSO}$. This finding was confirmed later with high-resolution spectra (Sudilovsky et al. 2007; Tejos et al. 2007; Vergani et al. 2009). Four possible explanations of such a discrepancy have been discussed in the literature (Prochter et al. 2006; Sudilovsky et al. 2007): (i) enhanced MgII absorption

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statistics in GRB afterglows could be due to strong absorptions intrinsic to hosts; (ii) obscuration of background QSOs by dust; (iii) gravitational lensing of GRB by the absorbers; (iv) the GRB beam size is smaller than the beam size of intervening MgII clumps (Frank et al. 2007; Hao et al. 2007). It has recently been clear that dust obscuration, gravitational lensing and effects of the beam size cannot change the statistics of MgII absorptions both in blazar and GRB spectra (see discussion in Bergeron et al. 2011). In this brief communication, we therefore concentrate on the first possibility, which implies that MgII absorptions in GRB afterglows occur partly in fast moving MgII clumps inside the host ISM.

## 2. Ionization state of shocked gas

Bergeron et al. (2011) have argued that the incidence of MgII absorbers may depend on the background light-source: they show, in particular, that lines-of-sight toward blazars show an excessive incidence of MgII similar to what has been seen in GRB spectra. They found the excess of incidents of MgII absorbers both in blazars and GRBs with respect to QSOs to be

$$Ex_{\rm Bl,\ GRB} = \left(\frac{dN}{dz}\right)_{\rm Bl,\ GRB} \Bigg/ \left(\frac{dN}{dz}\right)_{\rm QSO} \simeq 2. \qquad (1)$$

For blazars, such an excess can be naturally connected with strong jet outflows where MgII absorption could arise in the relaxed gas far behind the shock wave (Elvis 2000). Bergeron et al. (2011) have shown that in this case, typical column densities of the swept up gas are very close to those observed in blazar absorption spectra.

When the absorptions are attributed to motions in the interstellar medium within GRB host, their typical expansion velocities are assumed to be rather high in order to produce the observed difference in redshifts of the afterglows and the absorbing systems: $\Delta v \sim 10^4$ km s$^{-1}$ (see, Bergeron et al. (2011)). In such conditions it is natural to expect formation of strong shock waves compressing and heating the gas to high temperatures

$$T_s = \frac{3}{16}\frac{m_p \Delta v^2}{k} \sim 10^9 \text{ K}. \qquad (2)$$

At such temperatures, the characteristic ionization time is quite short, $t_i \sim 10^7 n^{-1}$ s, and for the conditions expected in the clumps surrounding a GRB, $n \sim 10^3$ cm$^{-3}$ could be as short as a few hours. One therefore assumes magnesium to be highly ionized behind the shock front. Below we calculate the evolution of the ionization state of magnesium behind such shock waves. To be more conservative, we assume the initial (immediately behind the front) ionization state of Magnesium to correspond to collisional equilibrium at gas temperatures of $T = 10^8$ and $T = 3 \times 10^5$ K. We, then allowed the gas to recombine freely neglecting the possible ionization from external sources and from the shocked gas itself, which therefore yields upper limits for the fraction of MgII.

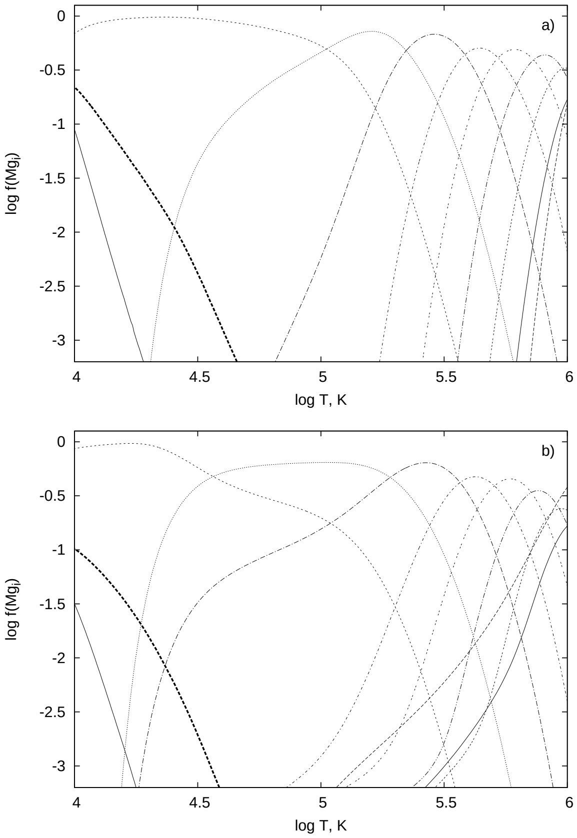

**Figure 1.** Evolution of the ionization state of magnesium in gas heated by a shock wave with the velocity $v_s = 10^4$ km s$^{-1}$: *a)* for solar metallicity, *b)* for the metallicity $[Z] = -3$; from left to right evolutionary tracks – abundances of MgI, MgII, MgIII,... versus temperature in gas cooling immediately behind the shock front – are shown. The MgII track is depicted by thick line.

Figs 1 and 2 show evolutionary tracks – dependence of the fraction of different ion species $X$(Mg i) on temperature in a cooling gas behind the shock front $T(t)$ for the initial temperatures behind the front $T = 3\times10^5$ K, and $T = 10^8$ K, respectively. It is readily seen that in both cases relevant (and observationally consistent) abundances of MgII ion are reached only at temperature $T \lesssim 3\times10^4$ K, and at higher temperatures Magnesium is dominantly in highly ionized (unobserved) ionization states. However, for the gas to cool down from $T \sim 10^5$ to $10^8$ K it takes around $t_c \sim 30/n$ Myr Vasiliev et al. (2012), too long for GRB afterglow events, and therefore the internal absorptions in the ISM of host galaxies does not seem to explain the excess MgII absorptions. One can note that the MgII abundance below $T \lesssim 3\times10^4$ K is almost the same for both initial temperature values considered here. A significant difference in a

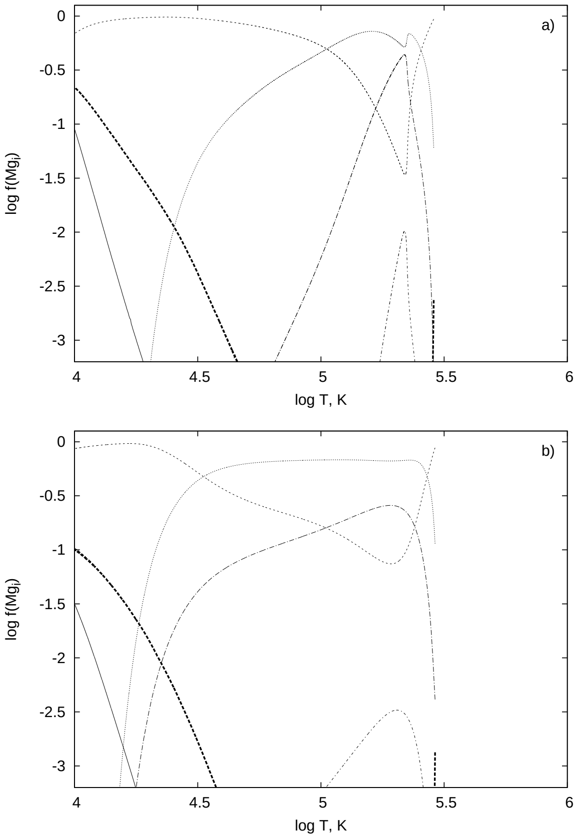

**Figure 2.** The same as in Fig. 1, but for a shock wave with the velocity $v_s = 10^2$ km s$^{-1}$.

collisionally ionized gas can be found only for initial temperature below $T \sim 10^5$ K. Also a very rapid decrease of the MgII abundance can be seen in Figure 2 (a small tail at $T \sim 3 \times 10^5$ K). The rapid decrease appears as the initial ionization composition of a gas (before a shock wave) was taken equal to that at $T \sim 2 \times 10^4$ K, so that the gas behind a shock is ionized faster.

## 3. Summary

In this brief communication, we showed that the high velocity ($v \sim 10^4$ km s$^{-1}$) inside the host galaxies result in formation of hot and highly ionized gas. Subsequent cooling and recombination requires millions of years, and thus such motions that are connected with the jet flows associated with GRBs, apparently cannot be responsible for an excessive incidence of MgII absorption systems in GRB optical afterglow spectra in comparison to those in QSOs spectra.

Detailed consideration of the issues briefly discussed here are given in a forthcoming paper Vasiliev et al. (2012).

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