Mg II lines in chromospheric flares : IRIS observations and synthetic spectra

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Abstract

The IRIS mission is capable of detecting the Mg II resonance lines *h* and *k*, together with other nearby positioned in Mg subordinate lines. These lines have been known to be in strong emission during flares, which was also confirmed by new IRIS observations of various flares. In this study we investigate the role of non-thermal excitations and ionizations of Mg II and synthesize the spectra of Mg II lines using detailed NLTE modeling.

IRIS Flare Spectra

During one year of operation, IRIS has observed several flares of various sizes. Here we analyzed the NUV spectra of Mg II lines detected during the X1 flare on March 29, 2014 (SOL2014-03-29:T17:48). Fig. 1 shows the time evolution of the spectrum from pre-flare conditions up to the flare maximum in HXR (RHESSI). Strong Mg II emission in the *h* and *k* lines, as well as in subordinate lines, is detected.

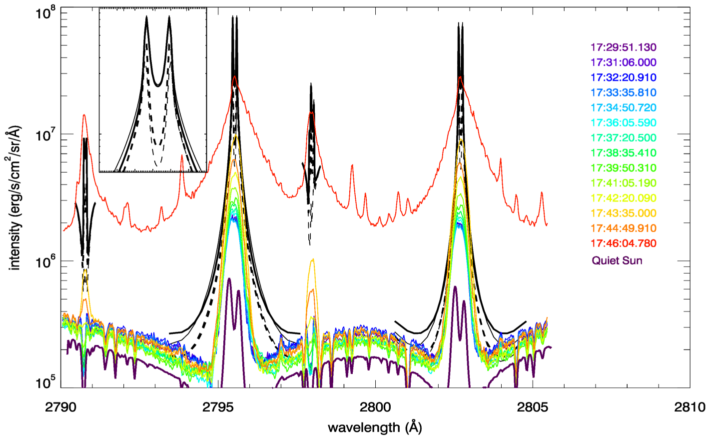

Figure 1
IRIS NUV spectrum taken during the X1 flare on March 29, 2014. Time evolution is marked in color. We also show the quiet-Sun spectrum for reference. Black lines correspond to synthetic Mg II line profiles emergent from a flare snapshot. Full lines: flux 4.5 10^{10} erg/cm^2/s, dashed lines : 0.75 10^{10} erg/cm^2/s (spectral index is equal to 3). Thick-line profiles have been computed with non-thermal collisional rates in Mg II, thin ones correspond only to thermal collisions. The line-core intensities are in rough agreement with spectra at the maximum, but the observed profiles are much broader which may indicate a high level of turbulence. Zoomed image shows details of the *k*-line core which is reversed, contrary to observations. We reproduce a strong emission of subordinate lines.

Synthetic Spectra of Mg II Lines

For one selected snapshot of our RHD simulations (Kašparová et al. 2009) we solved the NLTE problem for a five-level plus continuum Mg II model atom, using a modified version of the MALI code (Heinzel et al. 2014). The VAL-C model atmosphere was used as the initial atmosphere for time-dependent simulations. In all cases we assumed complete frequency redistribution for simplicity. The main focus is on the role of non-thermal excitations and ionizations of Mg II due to electron beams, which is studied for the first time. The atomic cross-sections have been compiled from several sources and the velocity-averaged collisional rates (over the Maxwellian distribution) have been found to be consistent with the rates of Sigut and Pradhan (1995). In presence of non-thermal (beam) electrons the electron distribution is non-Maxwellian. The distribution of non-thermal electrons is calculated using a test-particle code which is part of the RHD code. We therefore take a snapshot of the non-thermal electron distribution from the test-particle simulations and perform the averaging of the relevant cross-sections in order to obtain the non-thermal collisional rates. These rates are then simply added to thermal ones in the MALI code.

The snapshot was taken at a time when the electron-beam flux is constant and at its maximum level. We clearly see a strong enhancement of all Mg II lines as compared to the pre-flare situation. This is qualitatively consistent with the IRIS spectra, but details of the line profiles differ which deserves further systematic studies. Our simulations indicate that the non-thermal collisional rates are more important for lower electron-beam fluxes, while for higher fluxes the emission is saturated by thermal excitations. For lower fluxes, also the three subordinate lines seem to be affected by the non-thermal collisional excitations to their respective lower levels, which are the upper states of the Mg II *h* and *k* resonance lines.

We conclude that the Mg II lines are good indicators of the impulsive flare heating, but for strong beam fluxes they show only marginal sensitivity to non-thermal collisional processes. A significant broadening of the Mg II lines during the impulsive phase is an issue for the present model. IRIS observations also indicate a strong red asymmetry of these lines at later times of the flare evolution.

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