ANALYSIS OF THE HIGH RESOLUTION Mg xi X-RAY SPECTRA

III. Non-Thermal Interpretation of Some Spectra

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Abstract. In part III of the paper containing the analysis of the INTERCOSMOS 16 ADP spectra, it is shown that by assuming the existence of a small admixture (1%) of non-thermal electrons in the active-region plasma it is possible to improve the agreement between measured and calculated fluxes for some spectra. The analysis follows the suggestion contained in the paper by Karev et al. (1980).

1. Introduction

In Paper II (Siarkowski et al., 1982) we have extensively discussed the analysis of the high-resolution Mg xi ‘triplet’ spectra in terms of thermal models. We have shown that many spectra of the active region McMath 14352 could be explained assuming that the emitting plasma is multi- or one-temperature. But for a number of spectra (for instance spectrum No. 5; see Table III in Paper II) the thermal interpretation is not satisfactory.

In order to get a better agreement between calculated and measured fluxes in the six spectral bands A, B, C, D, E, and F defined in Paper II, we have considered in this part two non-thermal plasma models M1 and M2. In model M1 we assume, following the paper by Karev et al. (1980), that the emitting plasma consists of two components: a low-temperature \( T_1 = 1.5 - 2.0 \times 10^6 \) K main thermal component, and a so called non-thermal component, which is a small admixture (less than 1%) of monoenergetic \( E_e \sim 1.5 - 2.0 \) keV electrons interacting with thermal plasma within the same volume. In model M2, we consider a two-temperature plasma model with ‘hot’ and ‘cool’ regions. A ‘transition’ region exists, between the two, which acts as a filter continuously transmitting the part of the high-energy electrons from the hot region, creating there the non-thermal conditions.

In both models, the small marginal admixture of the non-thermal electrons leads to a considerable increase of the collisional excitation processes. This is followed by an
increase of the fluxes in the resonance, intercombination, and forbidden lines, and also in the innershell excitation satellite lines (for instance, lines $q$ and $r$).

The fluxes in the purely dielectronic recombination satellite lines do not increase until the energy of the non-thermal electrons coincides exactly with the energy of the excitation of doubly excited levels (resonance process). In our considerations, the dielectronic recombination satellite line intensities are not affected.

The non-thermal electrons could also disturb the ionization state of the thermal plasma as it was pointed out by Roussel (1980a, b). In the case of our models M1 and M2, the total amount of the non-thermal electrons is only $0.1-1 \%$ of the number of thermal electrons and, as we have carefully checked, this small amount does not introduce significant (greater than $1 \%$) perturbations of the equilibrium ionization state of the thermal component.

2. Calculations of the Line Fluxes in Model M1

Let us assume that within the volume $V$ confining the thermal plasma at temperature $T_1$ ($1.5-2.0 \times 10^6$ K) and emission measure $e_1$ there exists a small admixture of monoenergetic, non-thermal electrons of energy $E_e$ ($1.5 \times 2.0$ keV) and emission measure $e_e \sim 0.001 e_1$. The increase of the fluxes (in the lines produced by collisional excitation) due to the presence of non-thermal electrons, could be written as:

$$F_{\epsilon_i \rightarrow j} = 5.99 \times 10^{-36} \frac{A_{El}}{\lambda} S_{ij} \frac{n_z}{n_{El}} e_e \text{ erg cm}^{-3} \text{ s}^{-1}$$

where $A_{El}$ is the abundance of the element relative to hydrogen (assumed $3 \times 10^{-5}$ for Mg), $\lambda$ is the wavelength of the line, $n_z/n_{El}$ is the fraction of the element being in the ionization state $z$ (from which the excitation process take place), the source distance $L$ is 1 AU, $n_e = 1.8 n_H$. $S_{ij}$ is the rate coefficient for the direct excitation or innershell transitions. In the case of monoenergetic electrons with energy $E_e$

$$S_{ij} = 1.129 \times 10^{-9} \frac{\lambda E_e^{-1/2} BRC_1 g(U)f}{\text{cm}^3 \text{s}^{-1}}$$

where $\lambda$ is in Å, $E_e$ in eV, $f$ is the absorption oscillator strength, $C_1$ is the correction factor for cascades, and $BR$ is the appropriate branching ratio factor (cf. Mewe and Gronenschild, 1981); the gaunt factor $g(U)$ could be approximated by

$$g(U) = A + BU^{-1} + CU^{-2} + 2DU^{-3} + E \ln U,$$

where $U = E_e/E_{ij}$ and $E_{ij}$ is the excitation energy for a given transition.

In the calculations we have adopted the values of the parameters given by Mewe and Gronenschild (1981) and Vainshtein and Safranova (1978). In Figure 1 we present the