ON THE TEMPERATURE MEASUREMENT FROM THE O IV EMISSION LINES

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Abstract. The new calculations of the O IV temperature-sensitive EUV line ratios are presented and compared with previous results.

1. Introduction

The EUV emission lines of the O IV ion have long been recognized as important candidates for the measurement of electron density and temperature of the emitting sources (Flower and Nussbaumer, 1975; Doschek, 1984; Dwivedi and Gupta, 1992). These emission lines have been observed in a variety of astrophysical sources such as novae, planetary nebulae, the solar transition region and quasars, etc. The temperature-sensitive line pair \( \lambda 790/\lambda 554 \) from this ion is proposed for studying the temperature in the solar transition region in a joint CDS-SUMER observation programme (Harrison, 1991; Wilhelm, 1992). Very few temperature-sensitive line pairs are available in the EUV spectral range covered by the Coronal Diagnostic Spectrometer (CDS) and the Solar Ultraviolet Measurements of Emitted Radiation (SUMER) instruments to be flown on board the Solar and Heliospheric Observatory (SOHO) mission. The O IV being a celebrated solar ion for diagnostic studies, we rediscuss it using the new calculations of the line intensity ratios in terms of electron temperature.

2. Temperature Measurement and Atomic Data

We define the line emissivity (per unit volume, per unit time) for an optically thin spectral line as

\[
e(\lambda_{ij}) = N_j A_{ji} \frac{hc}{\lambda_{ij}} \quad (j > i),
\]

where \( A_{ji} \) is the spontaneous radiative transition probability and \( N_j \) the number density of the upper level \( j \), which is parameterized as

\[
N_j = \frac{N_j(X^+p)}{N(X^+p)} \frac{N(X^+p)}{N(X)} \frac{N(X)}{N(H)} \frac{N(H)}{N_e} \cdot \frac{N_e}{N_e}.
\]

Here \( N(X^+p)/N(X) \) is the ionisation ratio of the ion \( X^+p \) relative to the total number density of element \( X \), \( N(X)/N(H) \) is the element abundance, \( N(H)/N_e \) is the hydrogen abundance, \( N_e \) is the electron number density, and \( N_j(X^+p)/N(X^+p) \) is the population of level \( j \) relative to the total number density of the ion \( X^+p \).

In the coronal model, the ion-excited levels are populated by electron collisional excitation from the ground level and depopulated by spontaneous radiative decay to the ground level. Thus

\[
N_i N_e C_{ij} = N_j A_{ji},
\]

where \( C_{ij} \) is the integration of a collisional cross-section over the Maxwellian electron velocity distribution. For allowed transitions, the population of the ion resides almost entirely in the ground level and we can assume \( N_i(X^+p)/N(X^+p) = 1 \). Substituting Equations (2) and (3) into (1), we obtain the line intensity by integrating the line emissivity over the emitting volume:

\[
I(\lambda_{ij}) = \int \varepsilon(\lambda_{ij}) \, dV = \int G(T_e) N_e^2 \, dV,
\]

where

\[
G(T_e) = \frac{h \epsilon \, N(X) \, N(H) \, N_i(X^+p) \, N(X^+p)}{\lambda_{ij} \, N_e \, N(X^+p) \, N(X) \, C_{ij}}.
\]

Thus, in a coronal model, the line intensity ratio of two allowed lines of the same ion becomes a function of temperature, all densities cancelling. For reliable temperature measurements, it is necessary to use good atomic data. However, in order to examine the sensitivity of the ratio to \( T_e \), \( C_{ij} \) can be approximated as the product of a slowly varying term multiplied by \( \exp(-\Delta E_{ij}/kT_e) \), where \( \Delta E_{ij} \) is the excitation energy of the level \( j \). The line intensity ratio then contains a term of the form \( \exp(\Delta E_{ij} - \Delta E_{ii}/kT_e) \), sensitive to \( T_e \) in the range \( kT_e \leq (E_{ij} - E_{ii}) \).

This situation represents an ideal opportunity for a temperature measurement from the line intensity ratios within one ion. It is realized with strong resonance lines having upper levels well separated in energy.

The separations of the first excited configuration of \( \text{O IV}, \, 2s \, 2p^2 \), are such that their relative populations become sensitive to temperature. The observations of the relative intensities of the corresponding emission lines should, therefore, allow the temperature of the emitting region to be determined. Previous atomic calculations have been reported, including Flower and Nussbaumer (1975) and Hayes (1982, 1983). Hayes' atomic data are presented for the rate coefficients for the excitation of the metastable levels in the \( \text{O IV} \) ion (\( \lambda 1404 \) Å multiplet). Recently Blum and Pradhan (1992) have carried out a more extensive and much more accurate close-coupling calculation for the collision strengths for electron impact excitation of \( \text{C II}, \text{N III}, \) and \( \text{O IV} \). They further note that the \( ^2P^0 - ^2D \) transition in all three