DARKENING OF CORONAL LINES BY LIMB PROMINENCES
OBSERVED WITH SOHO/SUMER

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ABSTRACT

We report on SOHO/SUMER observations of limb prominences in two coronal EUV emission lines, namely Fe XII 1242 Å and Mg X 625 Å. The importance of this line pair is that while the Mg X line is affected both by absorption and volume blocking, the Fe XII line can be darkened by volume blocking only. Prominence absorption means the hydrogen ground-state photoionisation (Lyman continuum) by the Mg X coronal radiation, while volume blocking accounts for the lack of coronal emission within the volume occupied by the prominence (Heinzel et al. 2003, Anzer and Heinzel 2005).

We use several examples of different prominences and show how these two mechanisms work and how they can be separated by using such a line pair for diagnostics. This work is based on SUMER data also published by Feldman et al. (2003) and Stellmacher et al. (2003) and generalizes previous results of Kucera et al. (1998) on prominence absorption.

1. DEFINITIONS AND EQUATIONS

$I_p$ is the intensity of a coronal line (e.g. Mg X radiance or Fe XII radiance) as measured in a prominence area.

$I_c$ is the total coronal emission in the absence of prominences.

$I_b$ is the line intensity of the corona behind the cool prominence (background radiation).

$I_f$ is the line intensity of the corona in front of the prominence (foreground radiation).

$\tau$ is the optical thickness of the respective photoionisation continuum.

$r_{ab}$ is the contrast $I_p / I_c$ exclusively caused by absorption.

$r_{vb}$ is the blocked radiation due to the lack of coronal emission in a volume occupied by cool plasma.

$r$ is the contrast caused by the combined effects of absorption and volume blocking.

Assuming only absorption and negligible volume blocking leads to

\[ I_p = I_f + I_b e^{-\tau} \]

and

\[ I_c = I_f + I_b \]

The assumption of a symmetrical corona

\[ I_f = \frac{1}{2} \cdot I_c \]

leads to

\[ I_p = \frac{1}{2} \cdot I_c \left( 1 + e^{-\tau} \right) \]

and thus

\[ r_{ab} = \frac{1}{2} \cdot (1 + e^{-\tau}) \]

Taking the volume blocking into account leads to

\[ r_{vb} = (I_c - I_b) / I_c \]

and therefore the combined effect amounts to

\[ r = \frac{1}{2} \cdot (1 + e^{-\tau}) \cdot r_{vb} \]

The limiting cases are $r = r_{vb}$ for negligible $\tau$

(as, e.g., for the Fe XII line) and $r = \frac{1}{2} \cdot r_{vb}$ for large $\tau$.

2. DATA DESCRIPTION AND FIGURE CAPTIONS

Five SUMER prominence studies were selected that use exposures in the interval around 1238\,Å to 1250\,Å, containing lines from the chromosphere, transition region and corona.

The three SUMER scans were performed in August and September 1996 with 60 s exposure time per 1.5" raster step. The prominences are part of the total 720"x300" field of view scanned during 8 hours. A reference "quiet corona" is calculated by averaging those Mg X and Fe XII coronal pixels within the whole scan that are equidistant from the solar limb.

The two SUMER time series were performed in July 2000 with 120 s exposure time and a fixed position targeted on a quiescent prominence. The spectral range used here was exposed 12 times within 4 hours. For a reference "quiet corona", a similar study taken on a location without a prominence was used.

On the following five pages, the scatter plot shows the Fe XII "contrast" vs. the Mg X "contrast" as

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defined above, in order to demonstrate the relative importance of absorption vs. volume blocking in different parts of the prominence. The two straight lines denote the theoretical boundaries of the extreme alternatives, namely the optically thick and optically thin prominence plasmas.

In the three scan images, the lower part (and in the two time-series images, the right part) shows the prominence in four lines, the lower two lines being from transition region and chromosphere and displaying intensities, the upper two lines being coronal and displaying intensity ratios to enhance the contrast. This part is arranged like

<table>
<thead>
<tr>
<th>Fe XII 1242</th>
<th>Mg X 625</th>
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</thead>
<tbody>
<tr>
<td>N V 1238</td>
<td>S II 1250</td>
</tr>
</tbody>
</table>

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**Figure 1: SUMER scan of 13 August 1996** (see page 3)
- Prominence barely visible in Fe XII, contrast close to 1.0
- Mg X contrast between 0.2 and 1.0, corresponding to decreasing opacity
- Opacity is most significant where the prominence is visible in N V and S II
- Volume blocking negligible, spatially narrow structure

**Figure 2: SUMER scan of 20 August 1996** (see page 3)
- Prominence visible as diffuse structure in Fe XII and Mg X, contrast around 0.8 in both lines
- No distinguished dark features in Mg X suggesting opacity
- Cloud of points along the line τ<<1 indicates dominance of the volume blocking
- Extended prominence, but optically thin

**Figure 3: SUMER scan of 05 September 1996** (see page 4)
- Larger cloud along τ<<1, dominance of volume blocking
- Smaller cloud along τ>>1 corresponding to a few dark structures visible in Mg X (cool center as outlined in S II)
- Both clouds indicate significant volume blocking (contrast in Fe XII around 0.7) which is probably due to a line-of-sight projection
- Rather narrow prominence seen edge-on

**Figure 4: SUMER time series of 04 July 2000** (see page 4)
- Two clusters and gradual transition between them
- Lower cluster shows that the most opaque structures are also the most extended
- Upper cluster shows area where prominence slowly vanishes (contrast around 0.9)

TRACE image in H I Ly α 1216 Å (SUMER slit position indicated)

**Figure 5: SUMER time series of 08 July 2000** (see page 4)
- Prominence with significant opacity as well as volume blocking
- Lowest cloud gradually reaches optically-thin limit (volume blocking dominant)
- Probably due to an optically thinner area directly above the limb

TRACE image in H I Ly α 1216 Å (SUMER slit position indicated)

3. PERSPECTIVE AND REFERENCES

The ratios (contrasts) can be used for a quantitative analysis of the prominence opacity and geometrical extension along the line of sight. Detailed results including the intensity cuts (Fe XII and Mg X radiance) along the horizontal or vertical lines will be published elsewhere.

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