THE BROADENING CAUSE OF THE CaXIX RESONANCE LINE IN SOLAR FLARES

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ABSTRACT

We distinguish different broadening mechanisms of the CaXIX resonance line by studying the influence of the loop orientation, based on the data observed with SXT and BCS on Yohkoh. The results seem to support that the broadening of the CaXIX resonance line is caused by the nonthermal turbulence, rather than by the velocity dispersion.

INTRODUCTION

The broadening of the soft X-ray line during the impulsive phase of solar flares is one of the two basic characteristics revealed from the early observations like SMM, P78-1, and Hinotori. (e.g., Antonucci, 1989). Since the data from Yohkoh were available, the studies on the line broadening have been greatly refined. At present, however, it is still not clear which case is true, velocity dispersion or nonthermal turbulence. The most unfavorable evidence against the explanation of the velocity dispersion was thought to be the non-correlation between the line width and the distance from the Sun center (Mariska et al., 1993). It seems to have been understood for a long time that the evaporation model should predict the line width decreasing from the disk center to the limb. As a matter of fact, however, it is not true at all! The line broadening predicted by the evaporation model depends not only on the distance from the Sun center, but also on the loop orientation. Li et al. (1989) showed that only when the loop is at the solar limb and the plane of the loop is vertical to the line of sight, is there no line broadening resulted from evaporation; otherwise, if the plane of the loop is not vertical to the line of sight, even if the flare is at the limb, we may expect the line broadening. It is therefore a meaningful work to check the relationship between the line broadening and the loop orientation.

RESULTS

We selected 20 limb events among the samples studied by Gan & Watanabe (1997), which show a rather ideal single loop and can be rather definitely derived the loop orientation. About the definition of the loop
orientation, we use the formula given by Li et al. (1989)

\[ V_{ls} = V_l (\cos \theta \cos \alpha_i \pm \sin \theta \sin \alpha_i \cos \Omega) \]  

(1)

where \( V_l \) is the velocity along the loop, \( V_{ls} \) the velocity along the line of sight, \( \alpha_i \) the elevation angle of the segment (see Li et al., 1989), \( \theta \) the angular distance of the loop from disk center, and \( \Omega \) the orientation of the toroidal axis of the loop to the radius vector between the disk center and the midpoint of the loop. When the flare lies at the limb of the Sun, \( \theta = 90^\circ \), \( V_{ls} \) depends only on \( \Omega \). If \( \Omega = 90^\circ \), \( V_{ls} = 0 \), no line broadening will appear; if \( \Omega = 0^\circ \), the broadening will be at its maximum. While the \( \Omega \) can be derived from the SXT images. Therefore, the line broadening variation with the angle \( \Omega \) for the limb events can provide an information on the broadening mechanism of a solar flare.

Fig. 1. The line broadening versus the orientation of the loop for the 20 limb flares with a single loop.

We measured the maximum FWHM \( W_m \) and the FWHM \( W_p \) at the peak time from the CaXIX resonance line observed with BCS for each sample flare. We use a relative ratio \( W_m/W_p \) to reflect the line broadening. Figure 1 shows the \( W_m/W_p \) versus \( \Omega \), for the 20 limb flares observed with SXT and BCS. There are two implications from Figure 1. First, the values of \( \Omega \) for most samples are close to 90°. As we know from equation (1) that if \( \Omega = 90^\circ \), the velocity dispersion will not result in any line broadening, that is, the line width for the limb events with \( \Omega = 90^\circ \) should be smaller if the velocity dispersion is the cause of the line broadening. But in comparison with figure 6 of Gan & Watanabe (1997) which shows the number distribution of the line widths for the whole flares (not limited to limb events), we have not found any difference in the width values. This provides an evidence that the velocity dispersion may play an unimportant role in the line broadening. Second, from Figure 1 we see that there is not any tendency of the line broadening variation with the \( \Omega \). This result conflicts with the prediction by the velocity dispersion which requires a width decreasing distribution related to the \( \Omega \). Therefore, both the implications seem to support that the line broadening is due to the nonthermal turbulence, although more samples are much necessary to draw a further reliable statistical conclusions.

REFERENCES


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