COORDINATED OPTICAL AND YOHKOH OBSERVATIONS
OF 26 JUNE 1992 FLARE LOOPS

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Abstract. Optical spectra of large flare loops were detected by the Ondřejov Multichannel Flare Spectrograph (MFS) during coordinated observations with MSDP at Pic du Midi (Hα) and the soft X-ray telescope (SXT) on Yohkoh. The CCD video images taken by the MFS slit-jaw camera document the time-development of the flare loops as seen through the Hα filter. Preliminary analysis of the MSDP images shows the intensity structure of the cool flare loops and their velocity fields. From the spectra we can clearly see the intensity variations along the cool loops. SXT images show the structure of hot X-ray loops similar to that of cool loops. Special attention is devoted to the bright tops, simultaneously observed in X-rays, Hα and other optical lines. Based on a preliminary analysis of the optical spectra, we speculate about possible mechanisms leading to an observed bright emission at the tops of cool loops. We suggest that direct soft X-ray irradiation of cool loops at their tops could be, at least partly, responsible for such a strong brightening.

Key words: Flare loops – Heating mechanisms

1. Coordinated observations

A huge system of W-limb (post) flare loops was observed simultaneously by the Ondřejov Multichannel Flare Spectrograph (MFS), Multichannel Subtractive Double Pass Spectrograph (MSDP) at Pic du Midi and the soft X-ray telescope (SXT) on board Yohkoh on 26 June 1992. These coordinated observations span the time period from about 07:00 UT till 09:40 UT with overlaps between MFS, MSDP and SXT.

MSDP observations

Hα images of cool loops have been digitized on the MAMA microdensitometer at the Observatory of Paris and processed using the technique described by Mein (1977). Fig. 1a shows the Hα intensity structure at about 07:08 UT, while Fig. 1b displays the velocity field derived from MSDP data. Highly structured cool loops with rather bright tops clearly exhibit the downward motions along both legs (see light pattern - the blue shift and dark one - the
Fig. 1. Flare loops observed with the MSDP. a) left - intensity in the Hα line center, and b) right - velocity in Hα ± 0.3 Å (see text).

Fig. 2. Flare loops observed: a) in X-rays from SXT/Yohkoh (left) and b) by the MFS Hα slit-jaw camera (right). Note different scales in both pictures.

red shift in Fig. 1b). The Hα line profiles reconstructed from MSDP pixels show a complex behaviour which is to be compared with MFS spectra.

SXT images
The system of hot loops was observed by Yohkoh SXT almost continuously from 01:49:03 till 10:35:29 UT. Almost all of SXT images (e.g. Fig. 2a) exhibit bright tops of the loops. The temperatures of the hot loops were derived from the SXT images, each being observed with a different filter. They are of the order of $6 \times 10^6$ K (Anwar et al., 1993).
Fig. 3. Hα profiles of various knots observed at tops (left) and at middle heights (right) of the loops. Intensities are in % of the disk-center continuum.

**MFS data**

In Fig. 2b we show the Hα CCD slit-jaw picture with the indicated position of the spectrograph slit. Around 07:40 UT we obtained several sets of MFS spectra of the loop system at various heights above the limb, including the bright tops. The spectra have been taken in the hydrogen, helium and CaII lines with exposure times 5 or 9 sec and the dispersion 1 Å/mm. They were digitized by the Ondřejov Universal Microphotometer (Kotrč and Zicha, 1993). The intensities are generally higher at the tops as compared to loop legs (Fig. 3), which is consistent with Hα slit-jaw pictures (Fig. 2b). An important feature is the velocity pattern. In the legs we detect substantial Doppler shifts to the blue and to the red, depending on which leg actually intersects the spectrograph slit. At the top of the loops velocities of the same order are also present, but some plasma knots move rather slowly.

2. Heating of the loops

It is usually assumed that the enhanced brightness at the tops of both hot (X-ray) and cool (Hα) loops is due to the heating processes taking place at the reconnection site (Forbes and Malherbe, 1986, Démoulin - private communication). Here we propose an idea that the tops of cool loops are, at least partly, heated by a strong soft X-ray irradiation from close hot loops (such heating mechanism in the case of the chromosphere was studied by Hénoux and Nakagawa, 1977). Moreover, this X-ray irradiation will modify the hydrogen ionization thus leading to a change of the Hα brightness.
Using the non-LTE technique described in Heinzel et al. (1992), we have performed some test computations in order to see whether \( \text{H} \alpha \) can be enhanced at the loop tops due to strong soft X-ray irradiation, consistent with SXT images.

Two models have been considered:

- \( T=10000 \text{ K, } P=0.5 \text{ dyn cm}^{-2}, D=1000 \text{ km} \)
- \( T=10000 \text{ K, } P=5.0 \text{ dyn cm}^{-2}, D=1000 \text{ km} \),

where \( T \) is the temperature, \( P \) is the gas pressure and \( D \) represents the thickness of the cool loop.

Lower-pressure model leads to lower \( \text{H} \alpha \) emission when X-ray irradiation is taken into account. However, the higher pressure one gives almost a factor of two brighter \( \text{H} \alpha \) than the same model without incident soft X-ray radiation.

3. Conclusions

Our simultaneous optical and SXT observations provide us with a unique opportunity to discriminate between various heating mechanisms in cool flare loops. A possibility of soft X-ray heating at the tops of cool loops was suggested, in analogy to studies of the chromospheric heating (Hénoux and Nakagawa, 1977, Hawley and Fisher, 1993). To check the proposed idea, we plan to proceed further in the following directions:

- the reduction of MFS spectra and MSDP images
- specification of soft X-ray fluxes from hot loops, using SXT data
- detailed non-LTE modeling of cool loops, irradiated by soft X-rays
- evaluation of synthetic hydrogen, helium and CaII line profiles.

One important output from our modeling is the predicted range of UV-line emissivities which can be compared to SOHO-SUMER observations.

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References


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