TEMPERATURE ANALYSIS OF THE POST–FLARE LOOPS OF JUNE 25 – 26, 1992

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Abstract

We have performed an analysis of temperatures and emission measures of thermal plasma on a post–flare loop system following an X3.9 flare of June 25, 1992, at 20:14 UT in NOAA active region 7205 near the west limb (N09, W67). The filter ratio method was applied to the data sets taken using the Al 0.1 μm (thin Al) and Al 12 μm (thick Al) filters of the Yohkoh Soft X-ray Telescope (SXT). We found that the plasma temperature of the top of loops was in the range $5 - 8 \times 10^6$ K and log emission measure between 44.6 and 46.7 cm^{-3} for data sets taken from 22:56:57 UT of June 25 to 09:00 UT of June 26. Furthermore, the occurrence of a C1–class flare at the top of the flare loops increased the plasma temperature from 5.5×10^6 K to 6.6×10^6 K at 06:57:11 UT. The loops top was much brighter than the legs and footpoints, with $\triangle$T was about 0.1×10^6 K.

Key words: Flare loops – Thermal X–ray plasma

1. Introduction

Post–flare loops are probably the most spectacular features associated with the large Hα two–ribbon flares where the footpoints of the flare loops are rooted. Our understanding on the physical state and evolution of the post–flare loops has been much improved by studies using data from ground–based observatories, such as Hα filtergrams and spectrograms, as well as from space observatories (*Skylab*, SMM, *Hinotori*) which provide EUV spectra, X-ray spectra and images (see *e.g.* Moore *et al.*, 1980; Hanaoka *et al.*, 1986; Schmieder *et al.*, 1988; Poletto and Švestka, 1990; Heinzel *et al.*, 1992; Poletto and Švestka, 1992)

It is widely accepted that the post–flare loops are formed via successively magnetic reconnection as an open magnetic field configuration evolves to a closed configuration (Kopp and Pneuman, 1976). The loops system does not appear to consist of single loops rising upward but, rather, of newly formed or activated stationary loops appearing at successively higher levels (Moore *et al.*, 1980). The new loops are seen in X–ray as *hot loops* with temperature of about 10^7 K which then cooled to form Hα *cool loops* during the decay phase.

In this paper we present a preliminary results of an analysis on temperatures and emission measures of the thermal X–ray plasma of the flare loops using data from the *Yohkoh* Soft X-ray Telescope (SXT).

2. Observation

The *Yohkoh* SXT (Tsuneta *et al.*, 1991) observed a post–flare loops on June 25–26, 1992, which occurred close to the west limb (N09, W67) following an X3.9 flare (20:14 UT) in NOAA 7205. This event can be seen for more than 16 hours after the flare maximum. It was also observed by the Nobeyama Radioheliograph in 17 GHz (Hanaoka 1993, private communication) as well as by the Domeless Solar Telescope of Hida Observatories in Hα (Funakoshi and Kitai 1992, private communication). According to GOES X-ray time profiles, two flares (M– and C–class flares) were occurred during this interval at 04:15 UT and 06:57 UT of June 26, respectively. The C–class flare at the top of loops was observed during a real time contact between the *Yohkoh* and Kagoshima Space Center, while the M–class flare could not be observed since *Yohkoh* entered the night side. Prior to the C–class flare, there was a sequential brightening of small loop system beneath the flare loops which may triggered the flare at the top of loops (Anwar *et al.*, 1993). Other X–class flare (X1.8) was also occurred in the same region on June 28 at 05:14 UT, when NOAA 7205 was located just behind the west limb.

SXT provides X-ray images of multi–wavelengths of an active region, based upon an observation mode selected (Tsuneta *et al.*, 1991). During the Hα two–ribbon flare of June 25, 1992, which accompanied a beautiful post–flare loops, for example, SXT has took X-ray images using Al 0.1 μm (thin Al) and Al 12 μm (thick Al) filters during the decay phase. Unfortunately, SXT lost the important data during the impulsive phase and the next three hours data of the decay phase caused by a failure in the software onboard *Yohkoh* and *Yohkoh's* night time. Therefore, we could only present an analysis using the X–ray images taken during the decay phase from 22:56:57 UT of June 25 to 09:00 UT of June 26. The data are consist of *Full* resolution (1 × 1 pixels summation, 1 pixel = 2.46 arc sec) images taken during *Flare* and *Quite* modes with 64 × 64 and 128 × 128 pixels field of view, respectively. It should be noted that some data could not be obtained as the spacecraft entered the night side. A rather detail description on morphological evolution of the loop system was given by Anwar *et al.* (1993).

3. Temperature and emission measure

Using the above data sets, we calculated the temperatures and emission measures of the flare loops based on the filter ratio method (Vaiana *et al.*, 1973; Gerassimenko and Nolte, 1978). This method has been used for determining temperatures and emission measures of an active region (Hara *et al.*, 1992) and a limb flare (Tsuneta *et al.*, 1992) using *Yohkoh* SXT images.

Fig. 1 shows locations at the flare loops where the temperatures (T) and emission measures (EM) were calculated, which are marked with boxes and numbers. We sequentially measured an average of T and EM in boxes from the smallest number to the largest one. By this method, we obtained a general characteristics of T and EM, as well as we could identify the source of new energy generation as an input to the flare loops. Some examples are presented in Fig. 2 for box No. 3 (loops top) during *Quite* mode.

In general, the temperature profiles of the loops top showed a decay pattern with time, from 8.0 × 10^6 K to 5.3 × 10^6 K within 10 hours after 22:56:57 UT of June 25, while the log emission measures decreased from 46.7 to 44.6 cm^{-3}. The difference of temperature and log emission measure of the loops top and the legs were about 0.1 × 10^6 K and 0.5 cm^{-3}, respectively. Meanwhile, the occurrence of a C–class flare at the top of loops (06:57:11 UT) has increased significantly the temperature from 5.5×10^6 K to 6.6×10^6 K within 2 min. The temperature was almost constant during the next 10 min (*Flare* mode), but returned to 5.5×10^6 K 7 min later.

The *Flare* mode data have also been obtained about 3 hours after the maximum intensity, from 22:56:57 UT to 23:06:20 UT. The temperature showed a decreasing pattern, in general, but there was an increasing temperature at loops top approximately within box No. 12 in Fig. 1. This increasing temperature seems to be a clear evident of magnetic reconnection process proposed by Kopp and Pneuman (1976).

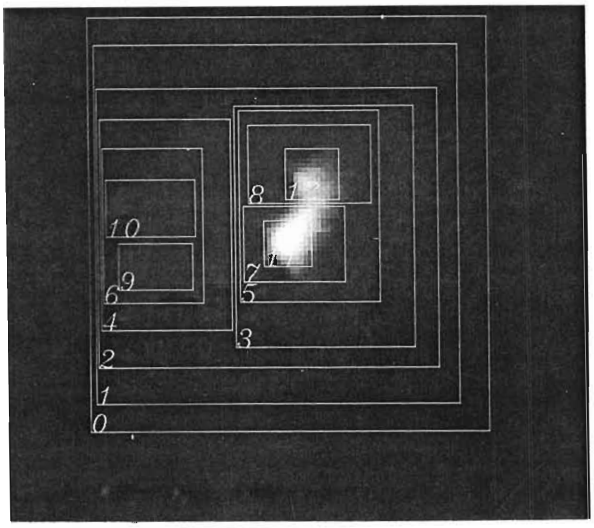

Fig. 1. Locations of boxes at the flare loops for temperatures and emission measures calculation.

4. Conclusion

We have performed an analysis of temperatures and emission measures of the flare loops of June 25–25, 1992. In general, the time profiles of the temperatures and emission measures were in agreement with the previous studies. Although the C–class flare at the top of loops gave a rise in temperature of about 1.1×10^6 K for 17 min, we ruled out a possibility that it is the main mechanism of heating responsible for maintaining the long–live flare loops.

A continuing activities in the lower atmosphere – *e.g.* sequentially brightening of small loop system beneath the flare loops – and their interaction with the footpoints and the legs of the flare loops, after the impulsive phase, may produce an additional energy for the flare loops. A slow magnetic reconnection in the loop system may also contribute to the heating process within the flare loops. Further study in this direction is needed to find a clue in the energy balance problem by comparing the *Yohkoh* SXT data, Nobeyama Radioheliograph and Hida Hα data, as well as performing a MHD simulation.

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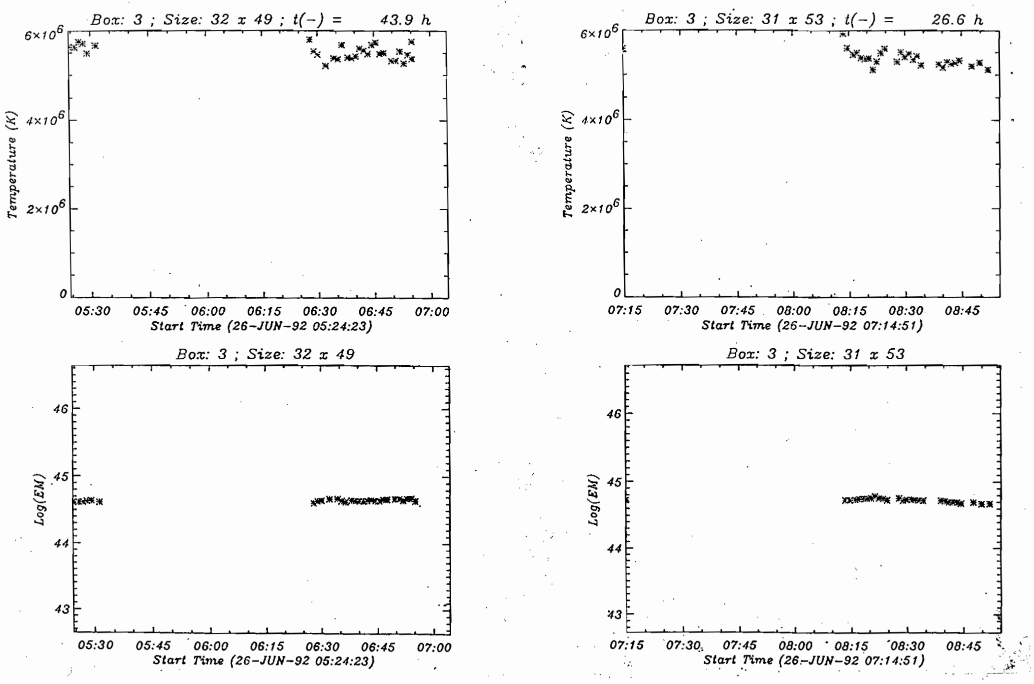

Fig. 2. The time profiles of temperatures and emission measures of the top of loops during *Quite* mode observation. The box size is in pixel unit and t(-) is the decay time in hours estimated from the data sets used in each figure.

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