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Plasma Diagnostics and Magnetic Complexity of a Post-Flare Active Region with Hinode/XRT: Spatial and Temporal Evolution

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Abstract. Flares are localized phenomena in active regions, but the magnetic and plasma responses may propagate to a larger area. In this work we investigate the temporal evolution of a flare in an active region with particular attention to the morphological details, and to the temperature and emission measure diagnostics allowed by Hinode/XRT.

1. The Data

We consider Hinode/XRT data of a C1.1 flare observed on the 12th November 2006 (Fig. 1). The flare, localized in region *X* on the figure, peaked at 10:46UT; a second smaller brightening was observed at 11:28UT. We analyze the time sequence of the XRT emission maps, to investigate the rapid changes in the morphomogy of the flaring loops. XRT Combined Improved Filter Ratio (CIFR, Reale et al. 2007) is used to derive temperature and emission measure maps and evolution in the loops marked as *X*, *H* and *L*.

2. Results

Figure 2 reports a selection of *Al_poly* images of region *X* showing the evolution of the magnetic topology. The loops show no or small tangling before and just after the flares (10:36UT, 11:01UT). More loop tangling and bridges formation are seen just before the flares (10:41 UT, 11:21 UT).

Figure 3 shows a selection in time of the temperature maps of the subregion including loops *X*, *H* and *L*, obtained by applying the CIFR method. The gray scale is $6.3 < \log T < 6.8$, with the darker colors being the hotter. The saturated pixels in region X are marked in white. Before the flare the region has a homogeneous temperature. Later on we see the hot plasma propagating from the flare core to the region *H* and then *L*. At the end of the sequence, while the region *X* has already cooled down, the longer loops are still hot. This time variation is quantified in Fig. 4.

Figure 4 shows the temperature variation (left) and EM (right) in selected regions (boxes in Figure 1) of *X* (solid line), *H* (dashed line), *L* (dot-dashed line). In region *X* the flare determines a temperature peak of 9 MK, which is to be interpreted as a

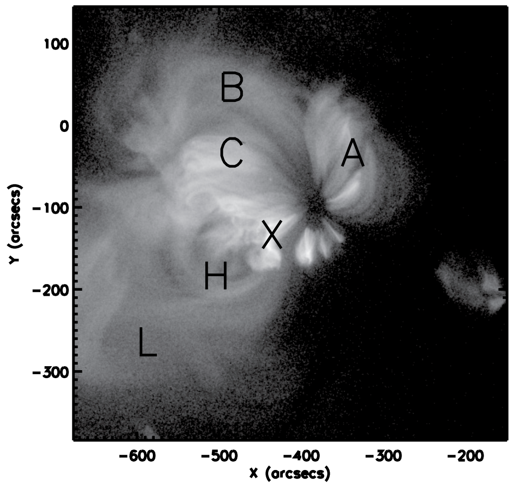

Figure 1. XRT/Al_poly map of active region 10923 on the 12 November 2006 at 10:36UT. Labeled are the loop systems analyzed in this work and the boxes for the thermal analysis. The flare happened in region *X*.

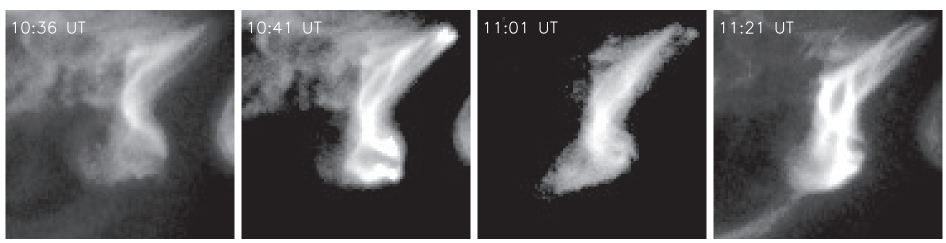

Figure 2. XRT/Al_poly maps of region *X*.

weighted average of a non-uniform EM distribution along the line of sight and as an effect of excluding the hottest but saturated core. The temperature of loop *H* also clearly increases and shows a peak a few minutes later than region *X*. Loop *L* shows a more gradual temperature increase which is still going on at the end of the time sequence. After 11:16UT all selected regions settle to a similar temperature level of 5 MK. The variation of the EM in *X* follows the flare evolution, as signature of dynamic heating, while no significant variations are seen for *L*. This plot indicates that between the beginning and the end of the flare there has been an increase of pressure. While significant chromospheric evaporation is present in the *X* area and, probably, some in loop *H*, this is not the case for loop *L*.

3. Conclusions

The results highlight rapid morphology changes with high spatial resolution on XRT data of the shorter loop system (region *X*) directly involved in the flare. The changes consisted in systematic cycles of tangled followed by relaxed configurations, with the maximum of tangling being just before a flare. The increase of tangling before flares, if confirmed to be systematic, could be used to forecast flares. The data show progressive

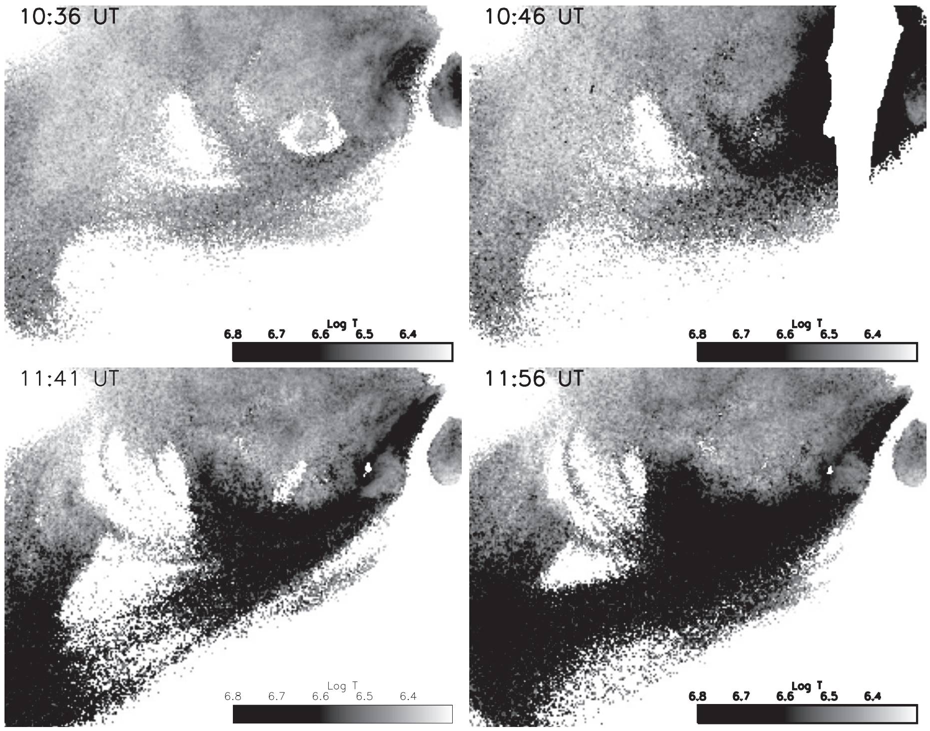

Figure 3. Temperature maps of loops X, H, L for selected times.

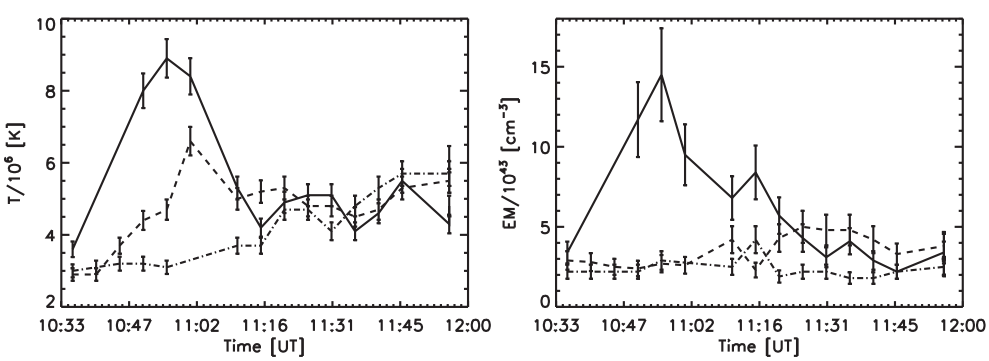

Figure 4. Evolution of the average temperature (from CIFR) and total emission measure for the top of loops L (dashed-dotted) and H (dashed), and the box in region X (solid).

extension of the heated region, from the flare core to intermediate (H) and then larger loops (L). Figure 5 suggests that both loops are heated asymmetrically starting from their western footpoint and that there is a clear correlation between the flare and the ignition of the other two loops.

Our estimate for the flare budget indicates that loop H needs about 1/4 of the flare energy to reach its maximum of temperature, while for loop L just a small fraction. Loops L and H represent therefore a minor component of the energy release in this event. We have shown that XRT data allow for diagnostics of temperature, EM and dynamic analysis of a flare over fine spatial scales and relatively short time scales. For more details of this analysis see Parenti et al. 2010.

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