LOOKING FOR SIGNATURE OF CORONAL HEATING IN THE RADIATIVE EMISSION OF A CORONAL LOOP

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ABSTRACT

Using a reduced MHD model we built the energy input for a multi-stand loop hydrodynamic model. This energy has a distribution that follows a power law with index $-1.6$. Here we investigate if and under which conditions this specific property can be transmitted to the plasma response. Our results show that only the high temperature emission conserves a power law distribution with index close to that of the input energy.

Key words: Sun - EUV spectra.

1. INTRODUCTION

In this work we investigate the statistical properties of a cooling coronal loop subject to a turbulent heating along the lines of Cargill (1994) work. We are interested to see if the statistical properties of the injected energy are conserved by the radiation produced during the cooling phase. The potentiality of this kind of study is in the direct connection between the theory adopted for the coronal heating and the real data available from the observations. We model a coronal loop as composed by $N$ unresolved identical threads. Each elemental thread has a half length $L$, a section area $A$ and at each time $t$ is described by one temperature $T_e$ and one density $N_e$. We simulate the heating-cooling cycle of each thread and calculate its radiative losses. We use this quantity to build synthetic spectra that we will compare with observations from instruments such as SOHO and Solar B. Here we summarize the work which is extensively presented in Parenti et al., 2006.

2. THE MODEL

We use the Buchlin et al (2003) model to simulate the injection of energy in the loop system in the corona. This energy originates from turbulent fluctuations in the photosphere and propagates in the corona through Alfvén waves. The dissipation is done through instantaneous nanoflare events ($\langle Q \rangle = 1.2 \times 10^{24}$ergs). The Probability Distribution Function (PDF) of this energy ($Q$) is a power law function with index $\alpha = -1.6$. Individual events with energy $Q$ are randomly distributed in space.

The elemental strand that is instantaneously heated, cools through conduction and radiation (Cargill 94). These processes are governed by their characteristic time scales $\tau_T$ and $\tau_R$. The histories of the plasma parameters $T_e$, $N_e$ during the time of the simulations are then used for statistical studies. Some general properties of the radiative emission of a loop subject to a power law heating function have been anticipated in Cargill & Klimchuk 2004.

3. RESULTS

3.1. The filling factor

![Figure 1. Total intensity of Fe XV 284 \AA as function of time.](image)

Figure 1 shows the loop system total intensity emitted by the Fe XV 284 \AA (logT = 6.3) line as function of time. The intensity shown in Figure 1 is calculated by considering the total variation of the $N_e$ and $T_e$ parameters in the loop system during the simulation, and using the
CHIANTI (Young et al. 2003) atomic database. The signature of the impulsive heating is still recognised by the rapid variation of the intensity. These fluctuations can be studied statistically.

![Figure 2. PDF for the Fe XV shown in Figure 1.](image)

The filling factor is the parameter which gives us information on the feasibility of the loop system at high temperature. Figure 2 shows the PDF for the intensities of Figure 1. For this simulation we have a loop system with a low filling factor (0.06). In this case the PDF follows a power law similar to the heating function. This means that part of the information on the heating is still present. However, the index $\alpha$ of the power law has changed. The intensity of the same line calculated in a loop system with a high filling factor (0.5) has the PDF which has lost the power law shape. Both low and high filling factor loops systems give a PDF for the Fe XII 195 Å (1.4 MK) that never reproduces the distribution of the heating function.

Figure 3 shows the PDF for the Fe XIX 1118 Å (T = 8MK) for same conditions as Figure 2. In this case the index $\alpha$ is very close to the index of the distribution of the heating function, and similarly to the Fe XV, the PDF for a high filling factor case does not follow a power law.

3.2. The temperature

We have seen that low filling factor and high temperature best conserve the information on the heating properties. The spectral line used to investigate the heating is then fundamental to obtain the right information from the observations. Figures 4 show the PDFs for the Fe XIX line obtained assuming two different ranges of flare energies: $E_1 < E_2$. Only in the top case we find the right index $\alpha$. The reasons for this can be understood using Figure 5. In this figure, the solid and dashed curves are the distributions in temperature of $N_e^2$ in the loop system for the two cases of Figure 4. This quantity is representative of the Differential Emission Measure. At the maximum of the $N_e^2$ distribution the conduction and radiation phases coexist. The lines Fe XII (1.4 MK) - XV (2 MK) always form while the strand are cooling by radiation (left side of the $N_e^2$ distribution). For $E = E_1$ (top PDF in Figure 4) the Fe XIX line is, instead, formed during the cooling by conduction; for $E = E_2$ (bottom PDF in Figure 4) the line is formed in a mixed situation of strands that are cooling both by conduction or radiation (the plateau of the $N_e^2$ distribution). Only the conduction phase seems to conserve the properties of the heating function.

![Figure 4. PDF for the Fe XIX line for two different energy losses ($E_1$, $E_2$).](image)
Figure 5. The Differential Emission Measures for the loop assuming $E = E_1$ (solid curve) and $E = E_2$ (dashed curve).

4. CONCLUSIONS

The results of this work show that the properties of the PDF of the energy given as input for our loop model are only partially conserved in the radiated emission. This depends on the fine unresolved structure of the loop system. However, the observed emission can reproduce the right properties of the heating under certain conditions:

- Low filling factor loops. This is the situation when the nanoflares are isolated events inside the strands, that is, a very thin fine structure.

- The line observed is formed during the conduction phase of the cooling. This is the phase that follows the heat injection in corona. The closer we get to detect this moment, the more precise information on the heating can be obtained. This results from the averaging effect of the fine structure which is reduced in the presence of only a few strands being just heated.

- Similar results to the above two points were found in analysing the PDF of the thermal energy of the loop system.

- To isolate the emission during the cooling dominated by the conduction, we need to look at spectral lines formed at very high temperatures. Temperatures of the background corona of 1-2 MK are not sufficient. At these temperatures we observe the superposition effects of a large number of strands which are already cooled down.

Our work points to the attention one must pay to very hot lines. The SolarB/EIS instrument, with its high resolution and large wavelength bands, which include high temperature lines, will be an important source of information for studying the nanoflare case.

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