DEM analysis to study the plasma properties of an EUV wave

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Introduction

Extreme UltraViolet (EUV) waves are globally propagating disturbances in the solar corona which are associated with Coronal Mass Ejections (CMEs). They propagate in 3 dimensions and possibly trigger other eruptions/oscillations far away from the CME site (Liu & Ofman 2014). The high cadence and resolution of Atmospheric Imaging Assembly (AIA) has helped in improving the knowledge of kinematics and fine structure at the wave front. However, studies related to the plasma properties of the EUV wave have been limited by the low chance of encountering such transient phenomena in the limited field-of-view of spectrometers. Dedicated observing campaigns (ex. Veronig et al. 2011) have managed to capture particular events with good signal. Thus, we rely on Differential Emission Measure (DEM) inversion codes that can be applied to imaging data. By combining the multi-channel EUV images from AIA with the DEM technique developed by Hannah & Kontar (2012) we have obtained the plasma parameters of a wave front as well as studied the response of the surrounding corona to the passage of an EUV wave.

Data:15 Feb 2011 - X2.2 flare

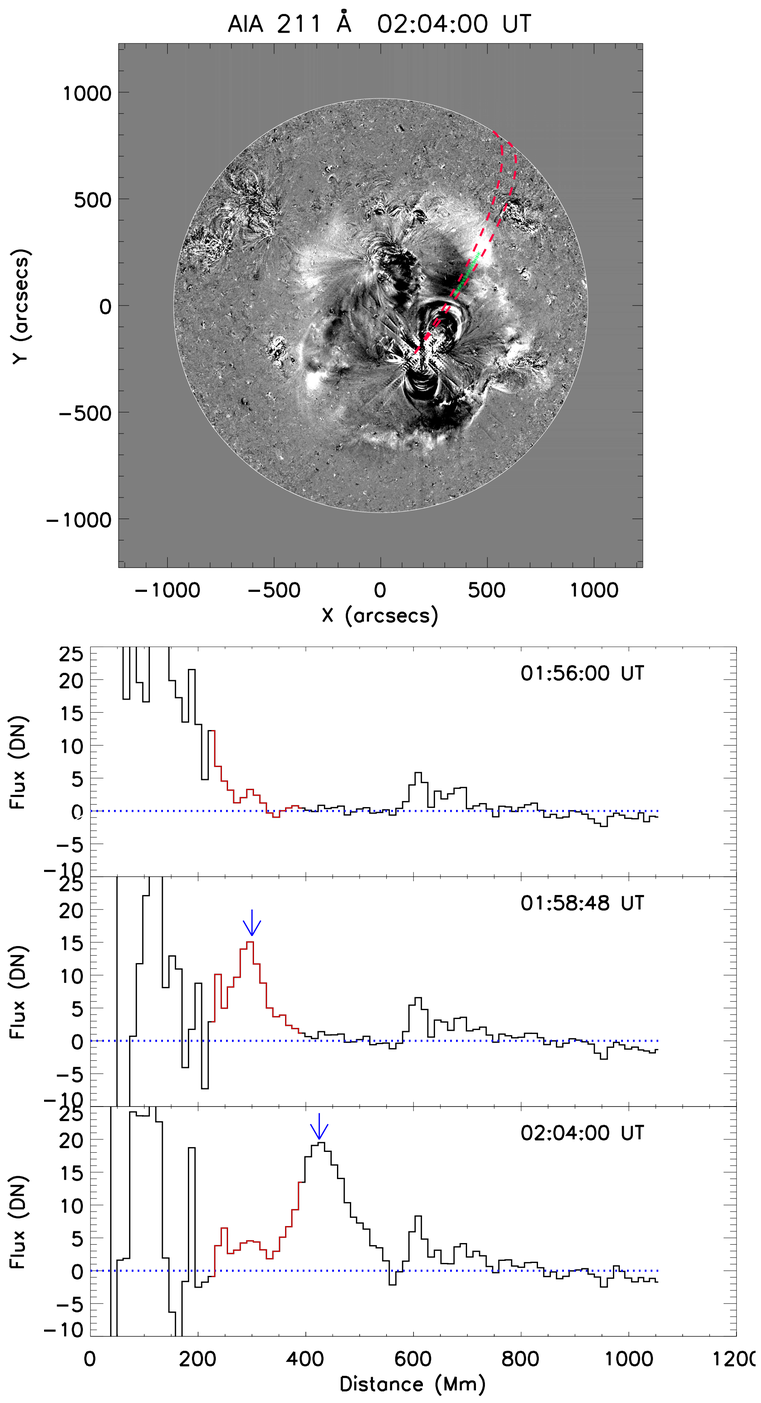
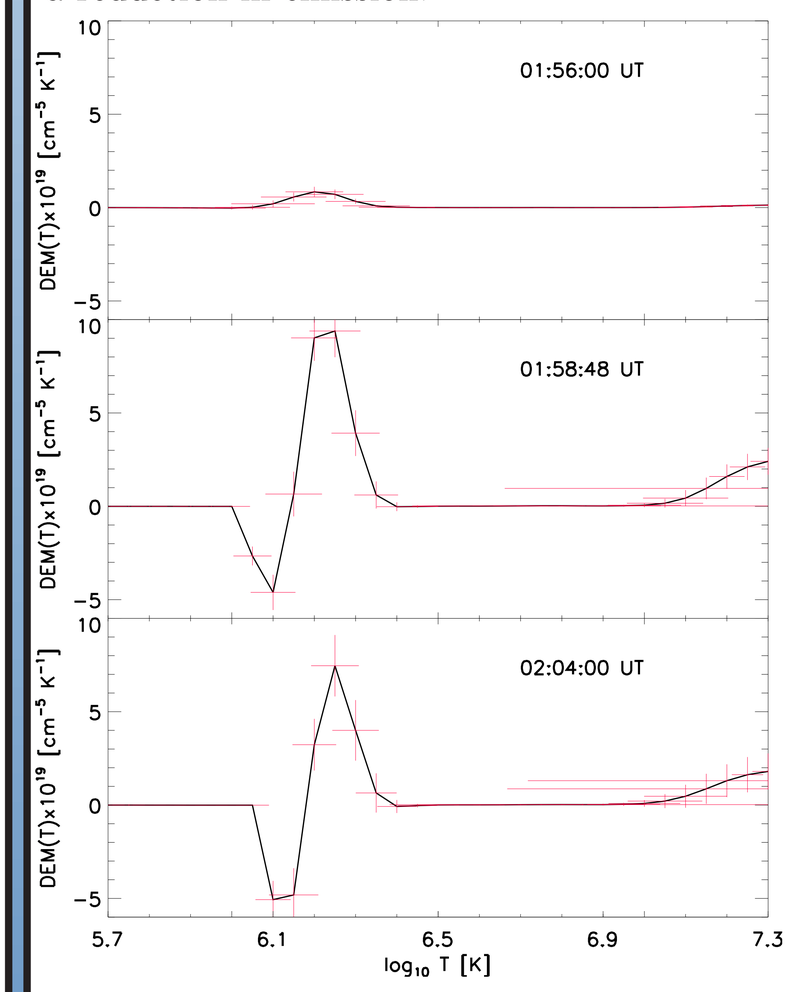


Figure 1: Top: Base difference image showing the sector (red dashed lines) along which the evolution of the EUV wave was studied. **Bottom:** Perturbation profiles derived from AIA 211 Å base difference images to identify and track the propagating wave front (indicated by the blue arrow). The intensities calculated from such profiles in the 6 different AIA coronal channels are used as input for the DEM analysis.

DEM Analysis

Figure 2: Examples of DEM curves constructed from the intensities taken from the region marked by green asterisks in Figure 1 (top) for 3 different time steps. The corresponding intensity profiles are shown by the red curves in Figure 1 (bottom). At 01:56:00 UT the EUV wave has not yet reached this position. The DEM curve at this time represents mostly only the background emission. At 01:58:48 UT the DEM for the whole EUV wave is obtained and at 02:04:00 UT most the EUV wave has moved out of this region. The negative DEM implies a reduction in emission.



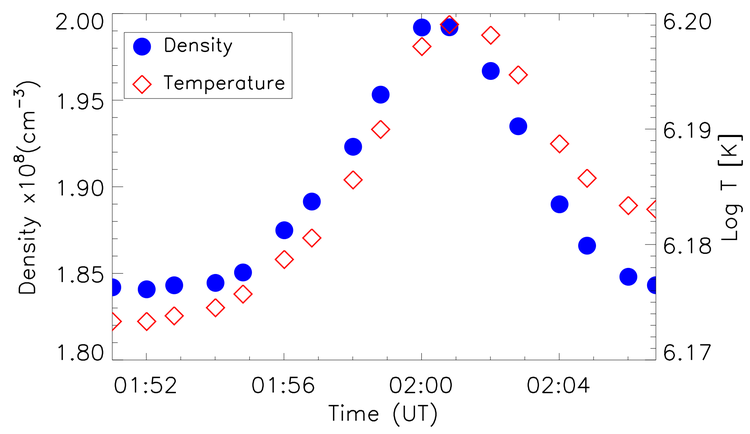
DEM weighted plasma density (n) and average temperature ($\bar{T}$) are derived using the formulas

$$n = \sqrt{\frac{\int DEM(T)\mathrm{d}T}{h}}, \bar{T} = \frac{\int DEM(T) \times T\mathrm{d}T}{\int DEM(T)\mathrm{d}T}$$

where h is the distance along the line of sight.

Plasma Diagnostics

Figure 3: Time evolution of density and temperature within the fixed region marked by green asterisks in Figure 1 (top).



There is a 8 % increase in density as the EUV wave passes over the selected region (blue filled circles). Kozarev et al. (2011) estimated 12–18 % increase for an off-limb event. Temperature shows 6 % increase (red open diamonds with axis on the right) and follows a similar pattern as density which is consistent with adiabatic heating due to compression at the wave front. The increase in density and temperature agrees with the values derived by Schrijver et al. (2011) for passage of an EUV wave over the quiet Sun.

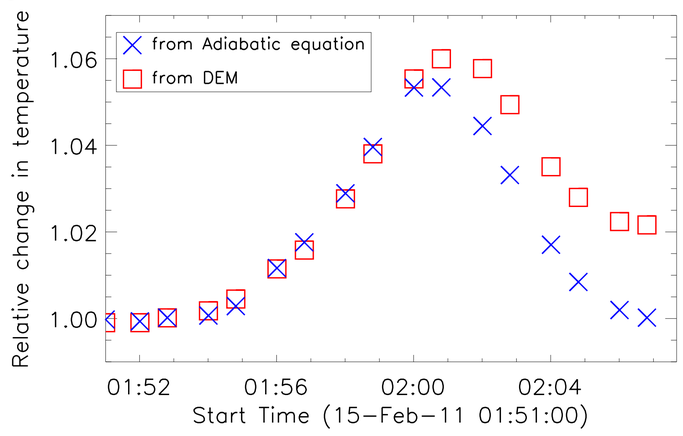


Figure 4: The expected change in temperature for an adiabatic process (blue crosses) is compared with the temperature changes obtained from the DEM diagnostics (red squares).

$$\left(\frac{\rho}{\rho_0}\right)^{\gamma-1} = \frac{T}{T_0}, \qquad \text{taking } \gamma = 5/3$$

The above relation for an adiabatic process is used to calculate the temperature changes from the measured densities. During the heating phase, the DEM estimated and adiabatic values are in good agreement suggesting that the energy exchange is purely due to adiabatic compression of the plasma below the passing wave. However, to account for the cooling phase other mechanisms have to be included.

Summary and Conclusion

- We have generated perturbation profiles from base difference images along a direction that is free from other coronal structures to study the evolution of an EUV wave.
- DEM curves were successfully constructed from the intensity profiles to study the coronal response to the passage of the EUV wave.
- Density and temperature parameters of the plasma were derived from the DEM curves.
- The adiabatic compression arising from 8 % density increase due to the wave resulted in local increase of up to 6 % in plasma temperature, whereas the relaxation of the corona cannot be completely accounted for by an adiabatic process.

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