LOOP MODELS FROM SOHO OBSERVATIONS

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Abstract. The Coronal Diagnostic Spectrometer (CDS) on SOHO is a grazing/normal incidence spectrograph, aimed to produce stigmatic spectra of selected regions of the solar surface in six spectral windows of the extreme ultraviolet from 150 Å to 785 Å (Harrison *et al.* 1995). In the present work, CDS, EIT, MDI and Yohkoh observations of active region lops have been analyzed. These observations are part of JOP 54. CDS monochromatic images from lines at different temperatures have been co-aligned with EIT and MDI images, and loop structures have been clearly identified using Fe XVI emission lines. Density sensitive lines and lines from adjacent stages of ionization of Fe ions have been used to measure electron density and temperature along the loop length; these measurements have been used to determine the electron pressure along the loop and test the constant pressure assumption commonly used in loop modeling. The observations have been compared with a static, isobaric loop model (Landini and Monsignori Fossi 1975) assuming a temperature-constant heating function in the energy balance equation. Good agreement is found for the temperature distribution along the loop at the coronal level. The model pressure is somewhat higher than obtained from density sensitive line ratios.

Key words: atomic database, synthetic spectra, solar atmosphere, intensity calibration

1. The Observation

The observations were taken on 29 April 1997, between 8:20 and 10:40 AM on an active region on the solar disk centered at around (–100″, –400″). The CDS observations consist of several spectral windows located around selected wavelengths, in order to observe both transition region and coronal lines. The observed lines are formed in the chromosphere (He I), the transition region (O III, O IV, O V, Ne V, Mg VII) and the corona (Mg VIII, Mg IX, Si XI, Si XII, Fe XII, Fe XIII, Fe XIV, Fe XVI). These lines allow density determination (Fe XII, Fe XIII), and they sample the plasma up to temperatures around 2.5×10^6 K. The presence of consecutive stages of ionization for several elements allows the temperature to be diagnosed through intensity ratios of lines of different ions.

The CDS observations have been co-aligned by a cross-correlation technique with EIT and Yohkoh full-disk images. The theoretical intensity ratios for density and temperature diagnostics have been calculated using the CHIANTI database (Landi *et al.* 1999).

2. Results

2.1. Morphology of the Emitting Region

The hottest emitting plasma is confined in a few loop-like regions whose footpoints correspond to photospheric enhancements of magnetic field of opposite polarity.

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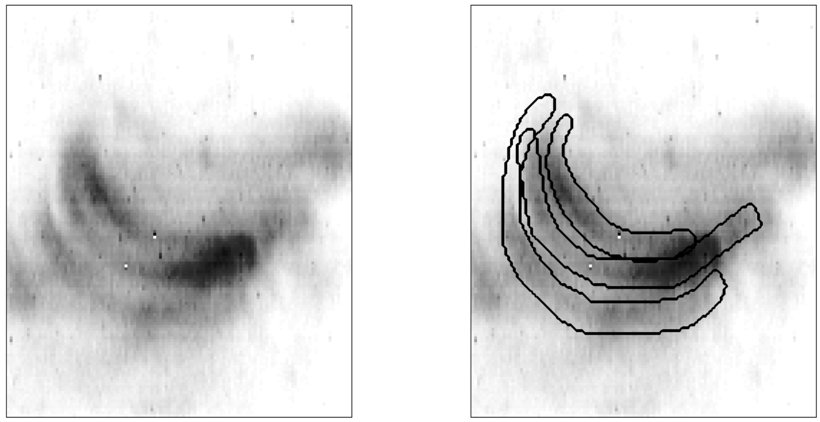

Figure 1. $4' \times 4'$ intensity map of the Fe XVI 335.4 Å line with adopted partition.

Using images in Fe XVI lines (Figure 1), EIT and MDI, the presence of three distinct structures is revealed. The outermost one is studied in the present work; it has been divided into 21 sections, and the relevant line emission has been integrated over each section. Lines from cooler ions (i.e., O V) are restricted to regions around the footpoints of the Fe XVI loops. Emission from transition region ions is confined in small areas, some of which correspond to the footpoints of the loops. Larger and fainter structures are visible from Mg IX emission, appearing completely uncorrelated with the Fe XVI loops.

2.2. Density, Temperature and Pressure Diagnostics

Density measurements for each section are performed by means of the intensity ratio of density sensitive pairs of lines. Lines of Fe XII (364.47 Å and 338.28 Å) and Fe XIII (359.64 Å, 359.84 Å and 348.18 Å) have been used. Background emission from regions adjacent to the loop structures has been subtracted. The density values are scattered within the experimental uncertainties around a constant value (Figure 2). Temperature measurements are performed through the Fe XVI/Fe XIV line ratio; temperatures increase slightly toward the loop center and tend to decrease at the two ends. This is broadly consistent with loop models in the literature. The changes are very small. The constant pressure assumption in loop models appears to be satisfied by the observations.

3. Comparison with the Loop Model

We have compared the observations with the Landini and Monsignori Fossi (1975) loop model. It describes a cylindrical loop with constant pressure P_0; temperature

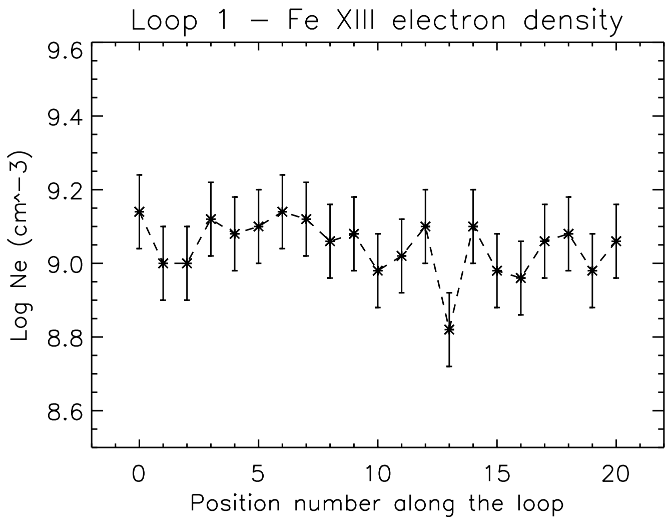

Figure 2. Density diagnostics for the outermost loop in Figure 1.

and density are obtained as a function of position along the loop by the balance of a constant input, radiative losses and divergence of thermal conduction.

The total power emitted by a loop in each optically thin line depends on two parameters: $P_0 S$, where S is the loop cross section, assumed to be constant, and the temperature T_M at which the conductive flux reaches its maximum value and radiative losses balance the input power. Each curve in Figure 3 displays the values of $P_0 S(T_M)$ that fits each observed line emission. The region of the plot where all the curves meet together allows $P_0 S$ to be estimated from the common crossing point Y_{cross} and T_M values, thus determining the loop model that fits all the observations. The following results have been obtained:

1. The loop top temperature T_{top} is evaluated from T_M as log $T_{\text{top}} = 1.79 T_M = 2.2 \times 10^6$ K.
2. The measured values of T_M and the total loop length L (1.1×10^{10} cm) allow P_0 to be evaluated using the scaling law of the loop model: $L = 1.65 \times 10^{-10} (T_M^{3.25}/P_0)$ cm. The resulting pressure is $P_0 = 0.9$ dyne cm^{-2}; this value is to be compared with the pressure P_{ratio} given by the intensity ratio measurements of temperature and density: $P_{\text{ratio}} = 0.3$ dyne cm^{-2}.
3. The crossing point Y_{cross} is given by $Y_{\text{cross}} = 2.1 \times 10^{-8} P_0 S$. Using a measured value of P_0 and Y_{cross}, a cross section $S = 2.6 \times 10^8$ km^2 is obtained, reasonably in agreement with the mean cross section measured on the maps.

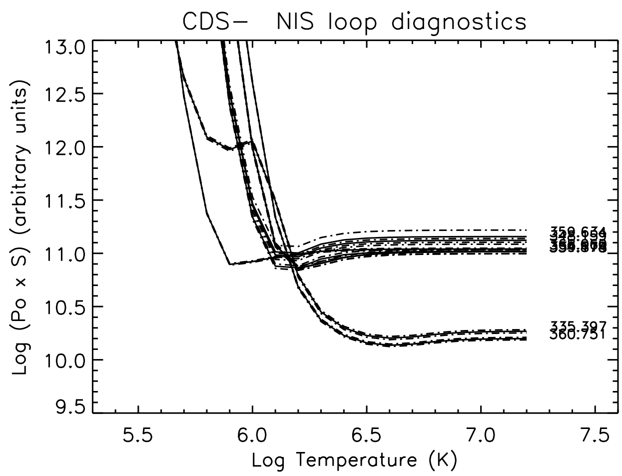

Figure 3. Values of P_0S as a function of temperature T_M for each spectral line.

4. Conclusions

In the present work, CDS, EIT, MDI and Yohkoh observations (JOP 54) of an active region loop are analyzed. The physical properties of the emitting plasma along the loop length have been determined and their values have been compared with the Landini and Monsignori Fossi (1975) loop model. The following results have been found:

1. Lines of different elements show different structures in the active region, and structures of ions formed at different temperature seem to be completely uncorrelated.
2. The maximum loop height is smaller than the scale height, and the loop pressure is expected to be constant along the loop. Measured temperature and density along the loop are in agreement with a constant pressure assumption; different loops show different pressures.
3. There is reasonable agreement between the predictions of the Landini and Monsignori Fossi (1975) loop model and the observations. The predicted loop length and top temperature are in agreement with the values determined from the observations, while the predicted loop pressure is higher than observed.

References

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