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SOHO 15 : Coronal Heating

Determining the temperature profile along a plasma loop III: spectrometers versus imagers

R.W. Walsh[1], I.Ugarte-Urra[2], J.G. Doyle[2] and J. B. Noglik[1]

1 Centre for Astrophysics, University of Central Lancashire, Preston, PR1 2HE, UK
2 Armagh Observatory, College Hill, Armagh, BT61 9DG, UK

1. Introduction

Recently interest has heightened in determining the fundamental plasma properties within loops - namely their temperature (*T(s)*) and density ($\rho(s)$) profiles along the structure (*s*) coupled with any plasma flows or driven periodicities. In particular, two avenues of investigation have been to

(i) calculate loop thermal profiles from observations and then match this with a *T(s)* from a 1D hydrostatic model that will yield a unique localized heating profile (*H(s)*), or

(ii) fold your model calculations through some instrument response function (such as the TRACE EUV filters) and compare the results with observations.

The results from this approach have been mixed with the cases of uniformly distributed (Priest et al, 2000), apex dominant (Reale, 2002) and base dominant (Aschwanden et al, 2001) all being reported.

Currently, we have at our disposal both UV/EUV spectrometers (SOHO CDS and SUMER) and imagers (SOHO/EIT and TRACE) to try and diagnose the solar atmosphere.

In the following, we outline **two different methods** to determine basic magnetic loop plasma parameters; one using the **EUV spectrometer SOHO/CDS** while the other involves the **EUV imager SOHO/EIT**.

2. Determining a loop density profile using SOHO/CDS

2.1 Observations

SOHO/CDS observed a coronal loop situated at a latitude of ~ 48 degrees above the North-East limb. It is clearly visible in the hottest lines of the dataset, i.e. Fe XVI (log T = 6.4 K) and Si XII and Fe XIV (log T = 6.3 K). For cooler lines (log T = 6.2 K), like Fe XIII, Fe XII or Si X, the apex becomes fainter, being visible in only the foot-points of the loop legs. The coolest lines of the sample (i.e. He I, Ne VI and O V) showed only a brightening at the foot-points location.

It is well known that the electron density, N_e , can be determined spectroscopically from the intensity ratio of lines of the same ion.

In the present work, we determine N_e along the loop using the **electron density sensitive line ratio of Fe XIV 353.83/334.17** and the CHIANTI (Dere et al, 1997; Young et al, 2003) atomic database using

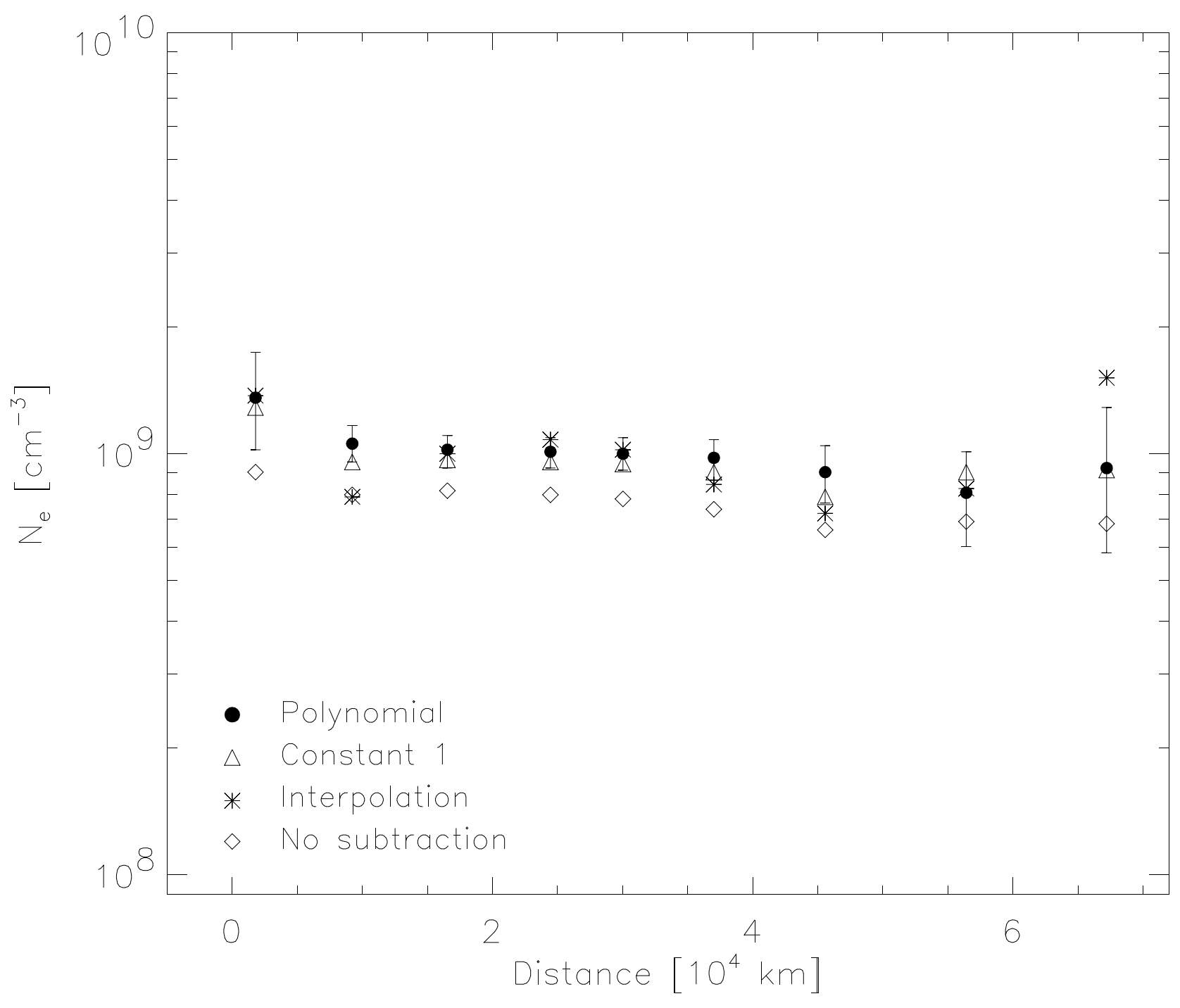

Figure 2 : The derived electron density along one leg. The origin in distance corresponds to the footpoint location.

We divided the loop (of half-length = 7.2 x 10^4 km) in nine sections of ten arc-seconds each and summed the emission in order to improve the signal-to-noise ratio.

Various background subtraction techniques were tested and the loop geometry was investigated (see Ugarte-Urra et al, 2004 for details). The resulting density profile along the unobscured part of the loop is shown in Fig. 2.

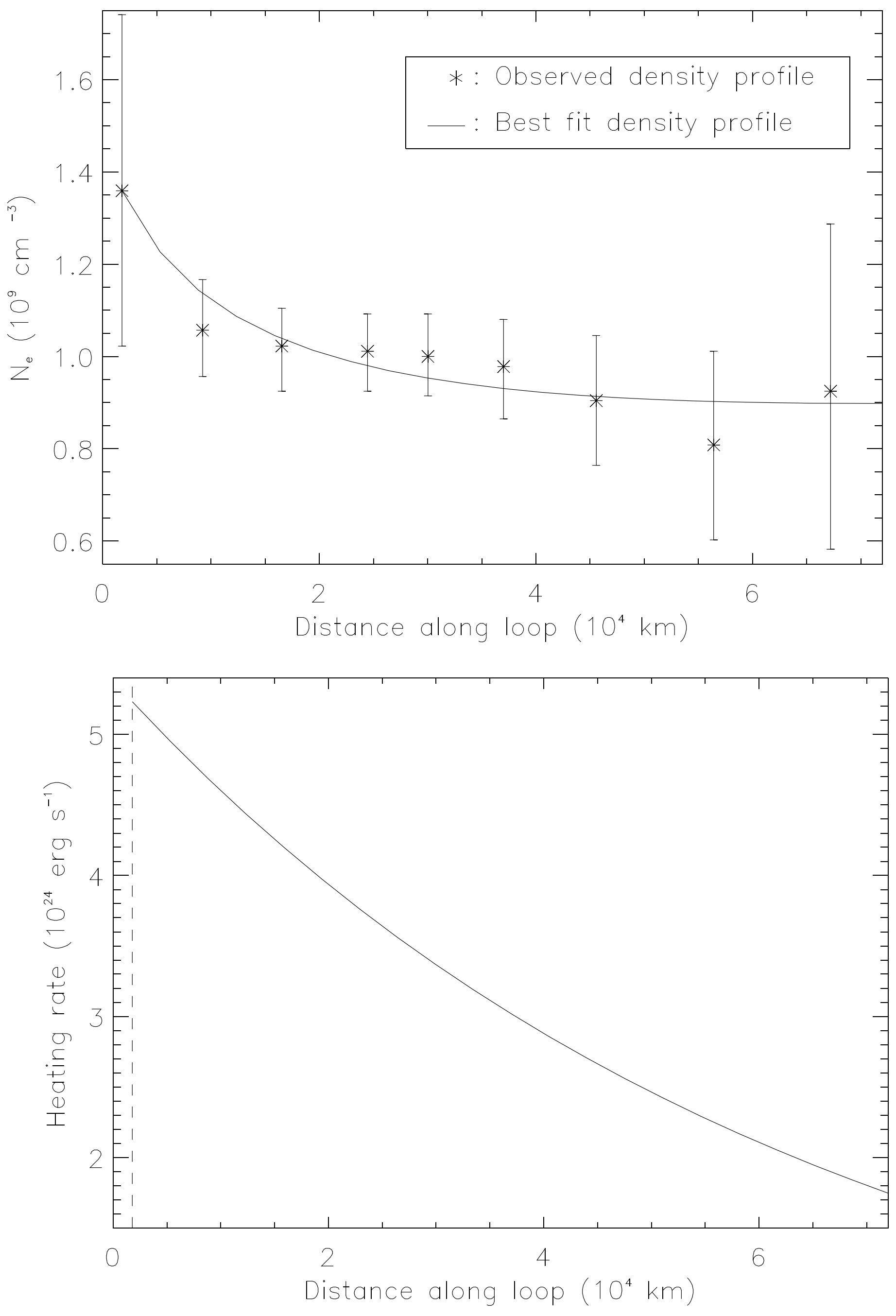

Figure 3 : Top panel: the overall best fit for the theoretically derived density profile compared to the observed data; bottom panel: the corresponding *H(s)*.

2.2 Loop model

It is assumed that the corona is a low β plasma such that any subsequent plasma motions are along the field. The dynamical system reduces to one dimension along a given fieldline. Secondly, although it is possible the observed loop consists of a bundle of unresolved strands, for the purposes of this analysis the assumption is made that each strand is acting identically.

Thus a **one-dimensional hydrodynamic model for a single strand**, with gravity neglected, was employed **to generate loop density profiles** to match with the observed structure.

A spatially varying heating term *H(s)* is employed of the form,

$$H(s)=H^{*}\exp(\lambda s),$$

where λ and H^* are determined for each specific numerical experiment. In order to quantify the comparison between the observed temperature at the location given and the theoretical predictions, a minimum Chi-squared analysis was employed (Priest *et al*, 2000).

Having generated and compared over thirty thousand individual solutions, the best fit result is displayed in Fig. 3.

In the top panel the density profile relative to the observed density values along with the error bars for each observed point is shown; in the bottom panel, the spatially varying energy input is displayed for this best fit. The best solution appears as a **footpoint** or **base dominant heat deposition**.

3. EUV imager Colour-colour method: a multi-thermal atmosphere

The colour-colour method suggested by Chae *et al* (2002) is outlined in detail in Posters I and II in this series.

In Poster I, this method was applied to SOHO/EIT data of flare loops at the solar limb (Fig. 4). The resulting cluster of the data points (see Fig. 5) on the c-c diagram are well away from the c-c curve hence making a proper determination of temperature very difficult. Can this clustering of points in this specific area of the graph be due to the fact that we are **observing through a multi-thermal atmosphere**?

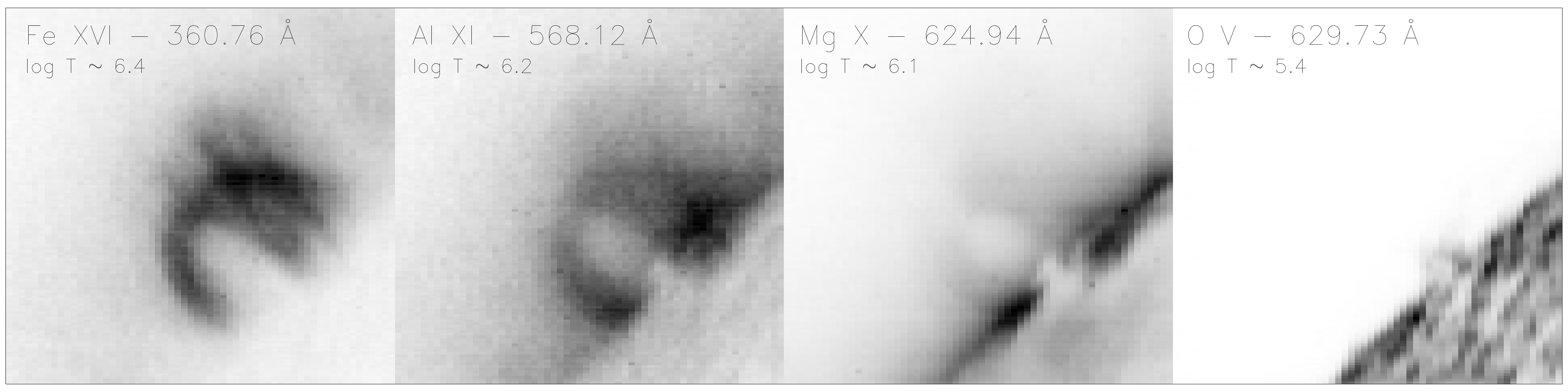

Figure 1: The coronal loop observed by CDS on April 1998 at 20:00 in Fe XVI, Al XI, Mg X and its footpoints seen in OV.

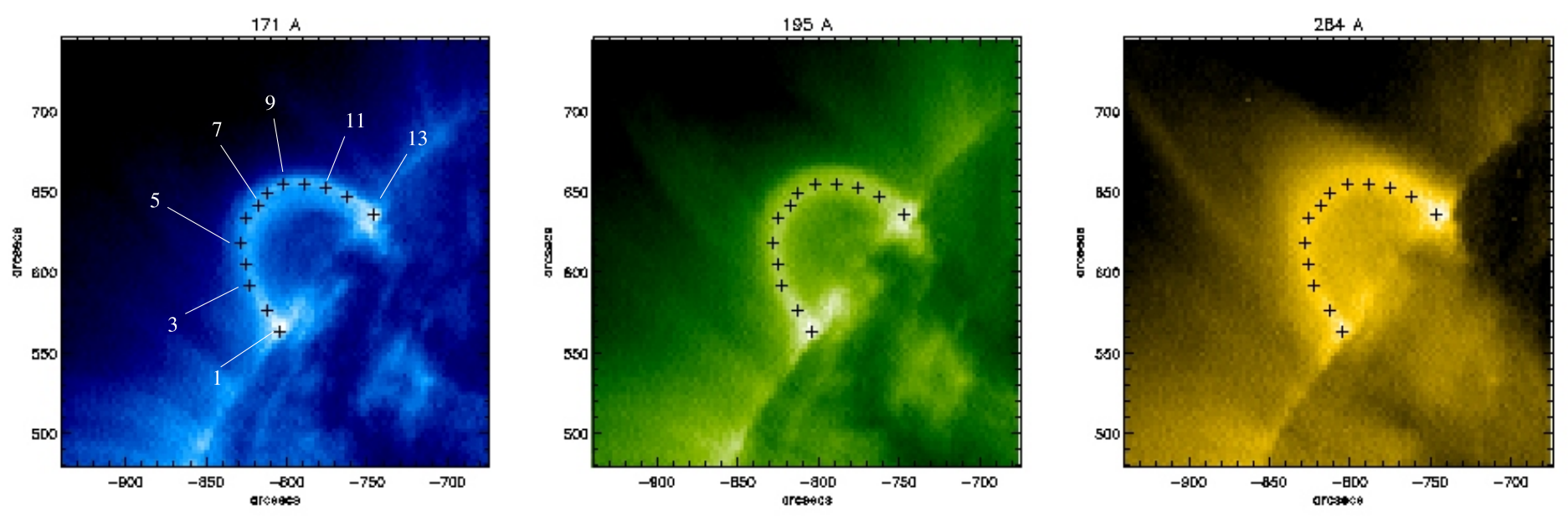

Figure 4: Diagram showing the loop structure taken by SOHO/EIT in 171, 195 and 284 Angstroms. The crosses marked on the three images indicate the points used for the temperature analysis profile.

As a first approximation, consider the case when there are only two distinct temperature plasmas T_1 and T_2 along your line of sight. Also, we assume that the two plasma regimes are at the same density.

Thus, we have,

$$C_1(s) = \frac{E_{284}(T_1) + E_{284}(T_2)}{E_{195}(T_1) + E_{195}(T_2)} ,$$

with a similar expression for $C_2(s)$ using 195 and 171 Angstroms. We know from our observations in Poster I where on the c-c diagram the values for (C_1 , C_2) should lie.

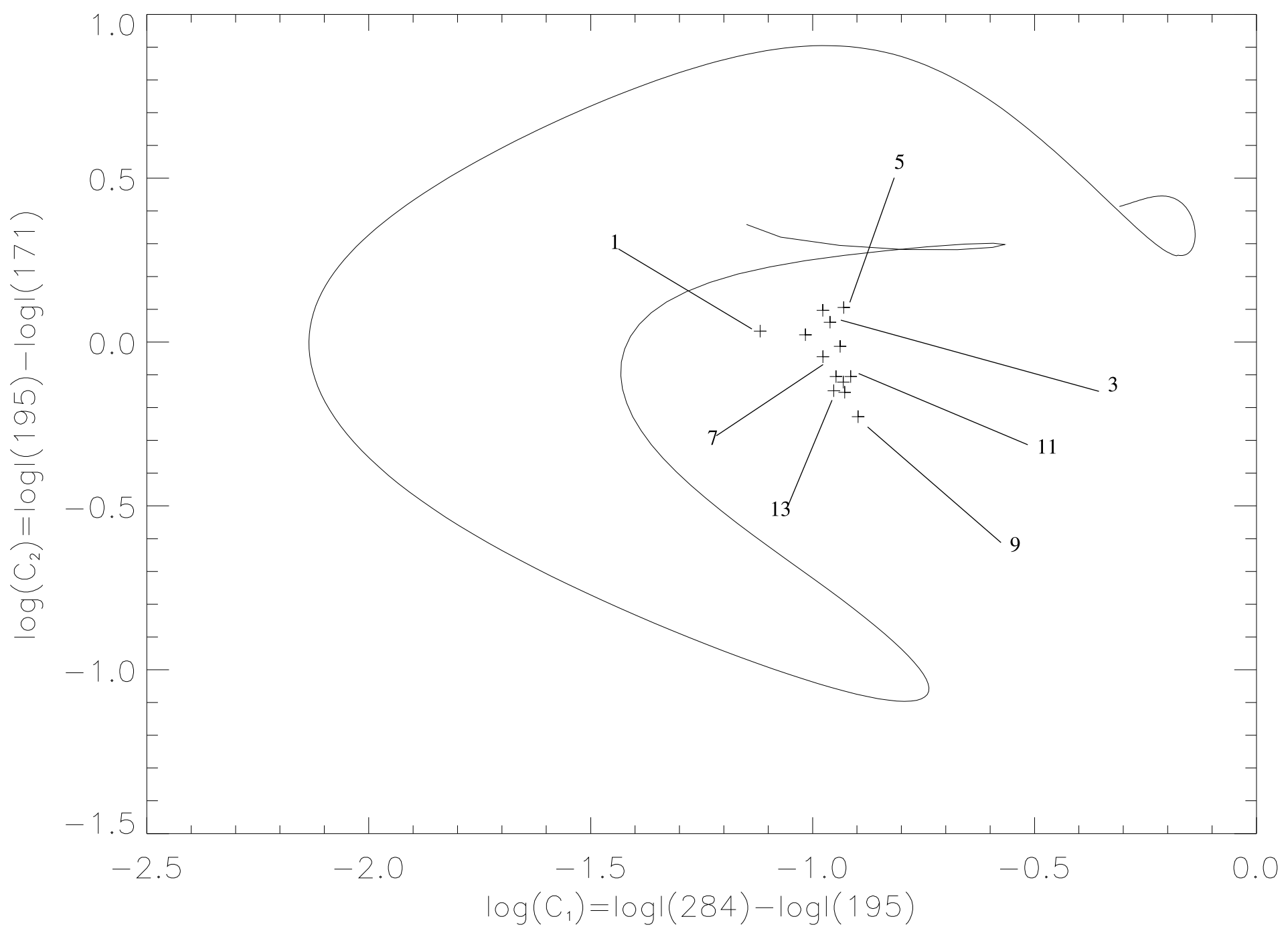

Figure 5: . SOHO/EIT colour-colour diagram, the crosses depict where the calculated ratios from the data lie.

Fig.6 displays the same c-c curve with a box added to indicate the region of c-c space that overlaps with the observed data-points.

Also marked are three temperature pairings for T_1 and T_2 which place within (C_1 , C_2) the "observational box". These are listed in Table 1.

Each temperature in the pairings is quite distinct from its partner. The widest temperature range is for a 5 MK and 0.48 MK plasma. This overlaps well with Testa et al (2002) paper who used TRACE single filter ratio temperature calculations and obtained both very hot (>5 MK) and cool (~ 10^5 K) loops

Hence, it is possible with a multi-thermal atmosphere to reproduce the observed c-c result.

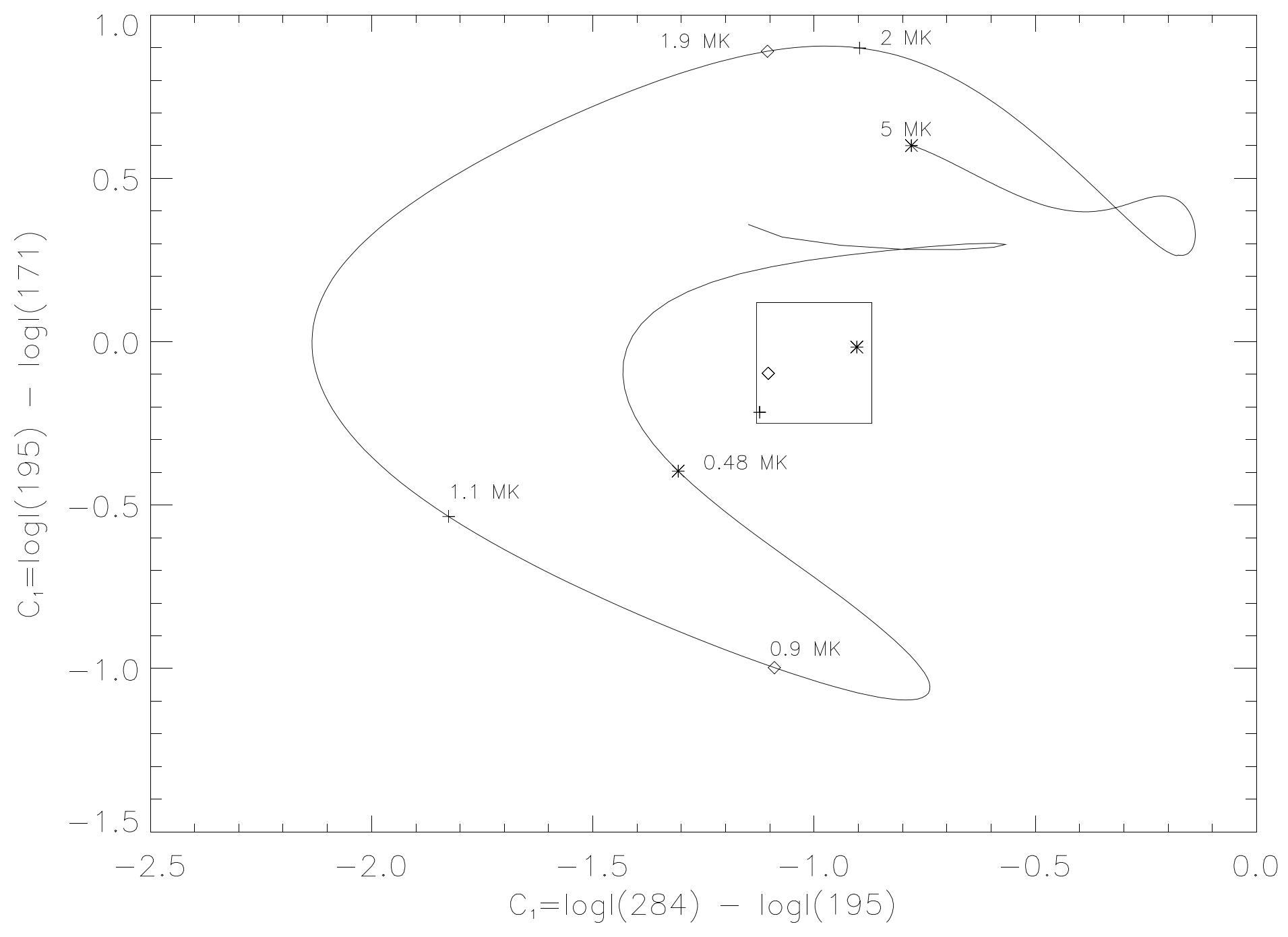

Figure 6: SOHO/EIT colour-colour diagram. The boxed region indicates the area of c-c space that overlaps with the observations. The crosses (2 MK and 1.1 MK), diamonds (1.9Mk, 0.9MK) and stars (5 MK, 0.48 MK) indicate distinct temperature pairings that result in c-c values lying in the region of interest.

T1 (MK)	T2 (MK)	Mark on c-c
2.0	1.1	cross
1.9	0.9	diamond
5.0	0.48	Star

Table 1: Temperature pairings used in multi-thermal atmosphere analysis.

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