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Multi-temperature maps of the solar corona using SDO/AIA data

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Introduction

There have been many previous studies of the temperature of the corona. Most of these studies have found three predominant temperatures corresponding to three types of coronal plasma: log(T) ≈ 5.9 in coronal holes, log(T) ≈ 6.1 in quiet sun regions and log(T) ≈ 6.5 in active regions (see Feldman & Landi 2008 for a review of previous studies). However, many of these studies do not make a rigorous examination of multiple temperature regimes along the line of sight. The long-term goal of this work is to use the multiple channels of AIA/SDO data to identify and constrain the possible multiple temperature regimes along the line of sight by the development of a tomographical method. This initial study is a prerequisite for the full tomographical treatment. We show here 1) the height variation of the coronal temperature by observing the atmosphere above the solar limb, and 2) temperature maps showing good agreement with previous studies.

Observations and methods

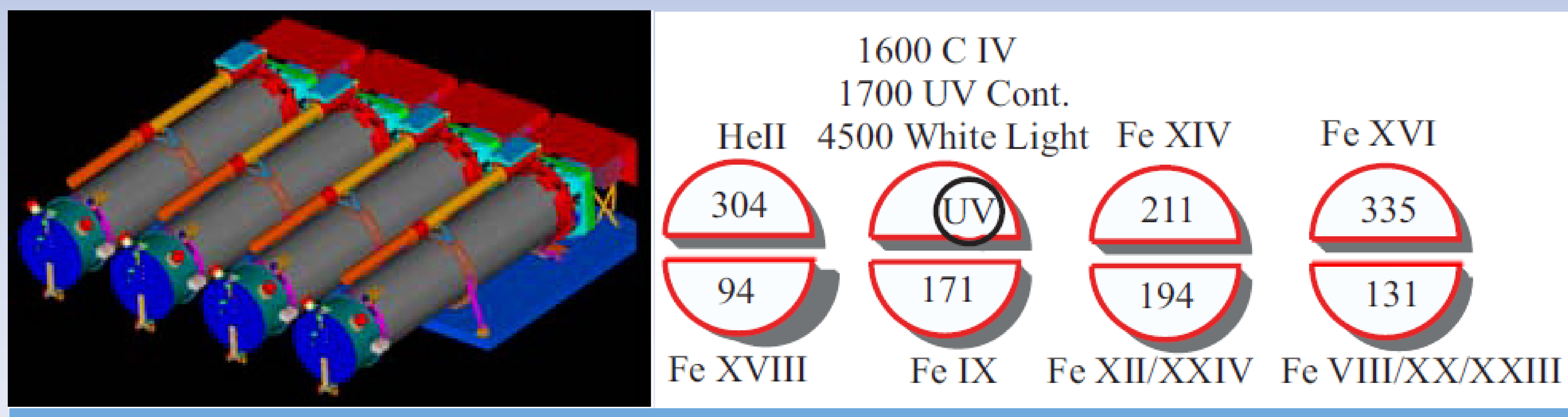

Fig. 1: Model of the AIA instrument (left) and arrangement of the wavelength channels (right). Image from Weber et al 2004.

Data were obtained from the Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory satellite (SDO). AIA provides images of the sun and corona in very high spatial and temporal resolution, and in ten different wavelengths. Each channel is dominated by an emission line of an ion formed at a particular range of temperatures. Each wavelength channel therefore has a temperature response function with a characteristic peak temperature.

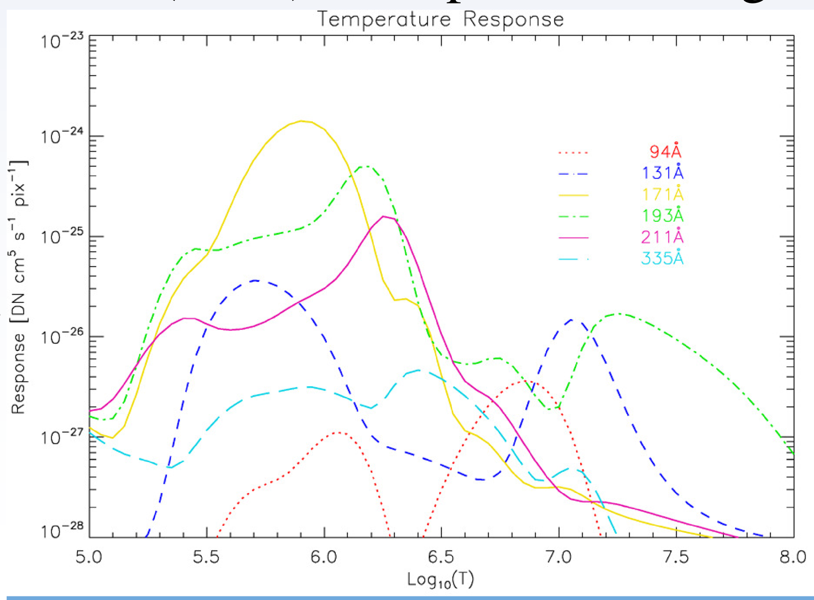

Fig. 2: Temperature response of the six EUV channels used for this method. Image from Boerner et al 2012.

Using the temperature response functions of the six Extreme Ultra-Violet (EUV) wavelength channels dominated by emission from Fe ions (94Å, 131Å, 171Å, 193Å, 211Å and 335Å), a theoretical pixel value was calculated for each wavelength at a range of temperatures between log(T)=5.0 and log(T)=7.0. These theoretical values were compared to the actual measured data, giving a goodness-of-fit profile for each pixel of an image.

For each pixel, the minimum of the goodness-of-fit profile indicates the temperature at which the model most closely fits the observed data. The temperature of the closest fit for each pixel was therefore used as the temperature in that pixel and used to compile the temperature map.

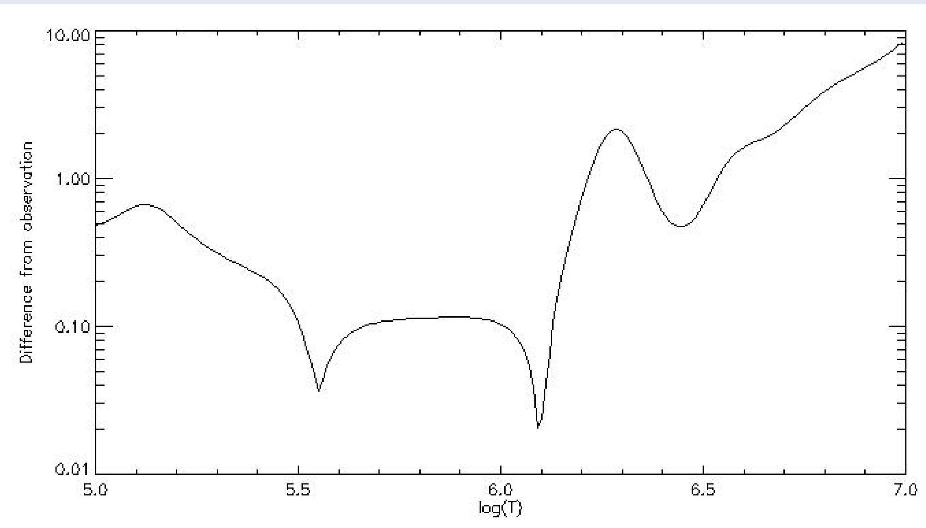

Fig. 3: Typical goodness-of-fit profile for one pixel.

The method was first applied to a region of the solar disk in order to check how accurately it could reproduce the temperature values found in previous studies. It was then used to produce temperature maps of a large off-limb region of the corona spanning approximately 90° of the solar limb. This region was transformed into polar coordinates for ease of viewing.

Results

The method was able to produce temperature maps showing the expected temperatures. Figure 4 shows the region of the solar disk used

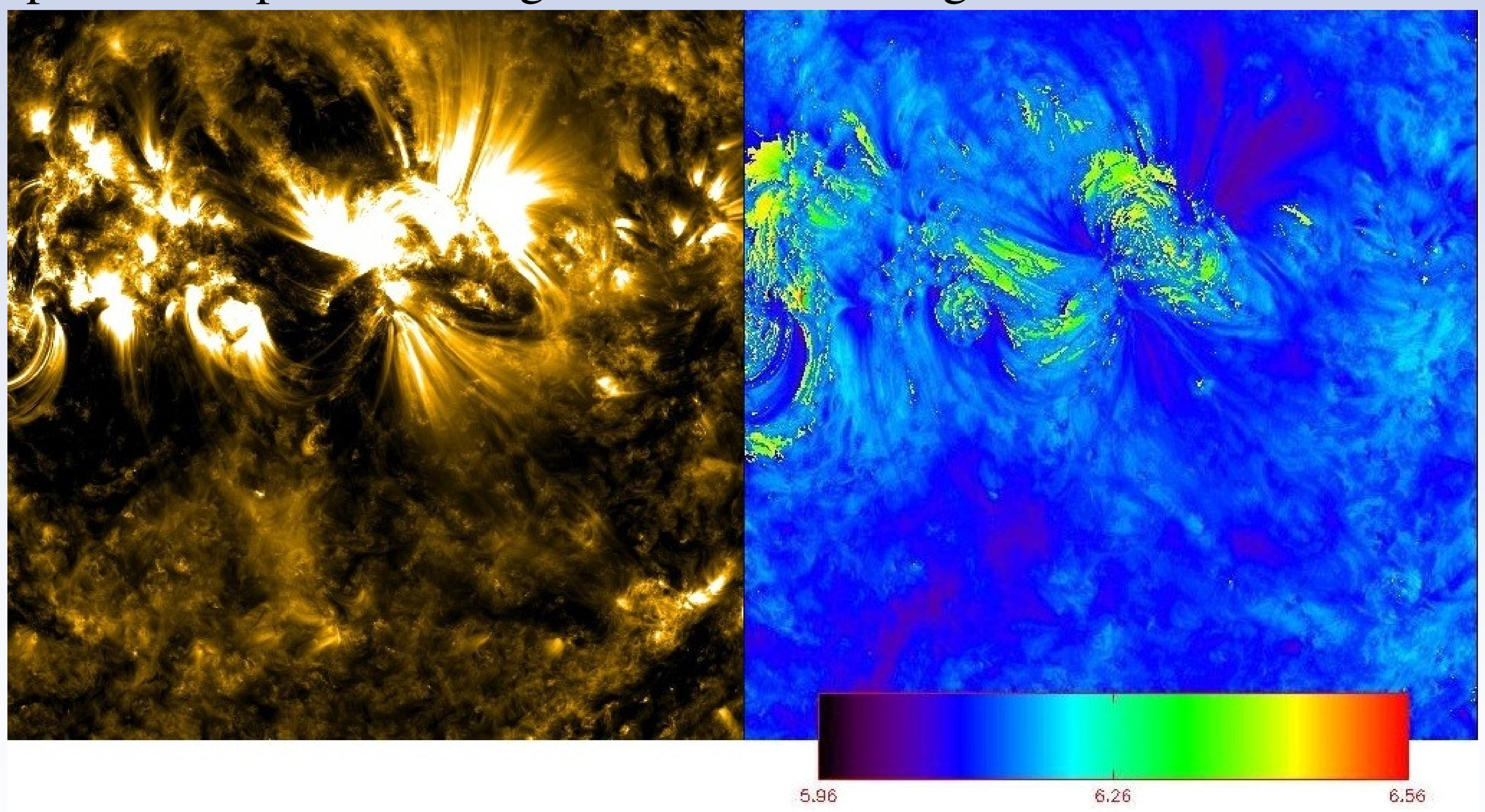

Fig. 4: 171 Å image of a portion of the corona (left) and temperature map for that region showing log(T) (right).

for the initial test of the method and the temperature map produced. The active region in figure 4 shows higher temperatures of log(T)≈6.4 aligned with the brightest loops. Quiet sun regions are more uniform in temperature, with a typical most probable temperature of log(T)≈6.1.

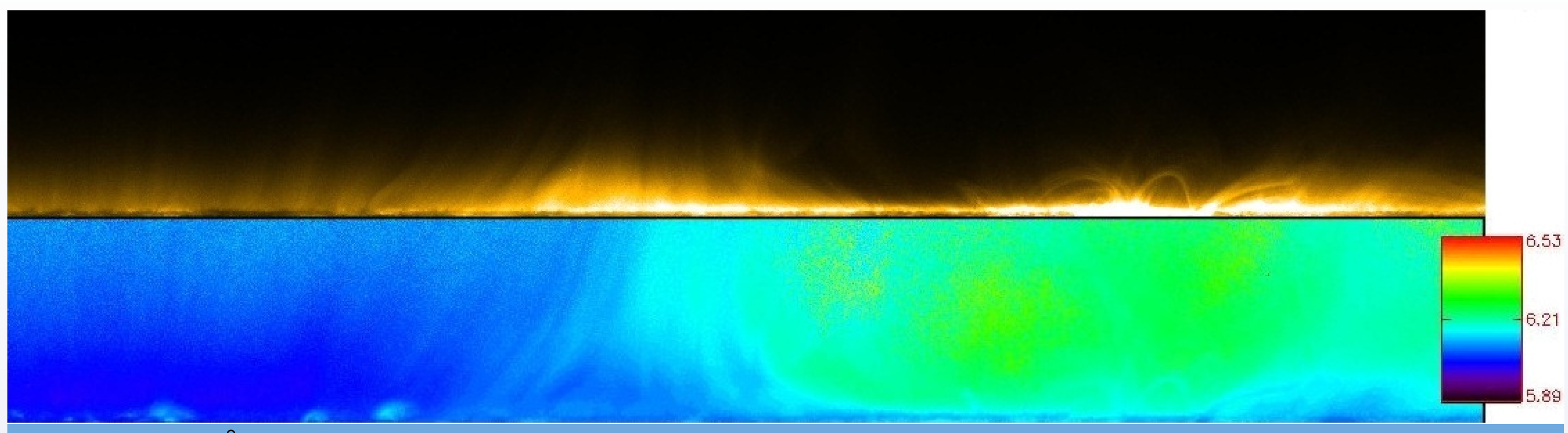

Fig. 5: 171 Å image of a region of off-limb corona (top) and temperature map of plasma in that region (bottom).

An interesting channel of cooler material cuts across the map from south-east to north-west. Figure 5 shows the map produced for the off-limb region. Temperatures were found to be log(T)≈6.0 in the coronal hole at the left of the image and log(T)≈6.3 above the active region.

Discussion

The method was able to identify the expected coronal temperatures: log (T) ≈ 5.9, log(T) ≈ 6.1 and log(T) ≈ 6.5. Temperature values for active regions were slightly lower than expected, particularly in the limb temperature map. This may be due to limited instrument sensitivity in the correct temperature range for active region loops. Alternatively, it could be that loops appear hotter when looking down at the disk because there is hot material above them along the line of sight (as can be seen in figure 5).

Future work

It is hoped that this work can be improved to identify multiple temperature regimes along the line of sight. This will form the basis of a tomographic approach with the aim of reconstructing the three-dimensional temperature structure of the corona.

References

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