Characterizing the Background Corona with SDO/AIA

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Abstract

Characterizing the nature of the solar coronal background would enable scientists to more accurately determine plasma parameters, and may lead to a better understanding of the coronal heating problem. Because scientists study the 3D structure of the Sun in 2D, any line-of-sight includes both foreground and background material, and thus, the issue of background subtraction arises. By investigating the intensity values in and around an active region, using multiple wavelengths collected from the Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory (SDO) over an eight-hour period, this project aims to characterize the background as smooth or structured. Different methods were employed to measure the true coronal background and create minimum intensity images. These were then investigated for the presence of structure. The background images created were found to contain long-lived structures, including coronal loops, that were still present in all of the wavelengths, 131, 171, 193, 211, and 335 Å. The intensity profiles across the active region indicate that the background is much more structured than previously thought.

Introduction

The corona is the outermost layer of the Sun's atmosphere, extending over a million kilometers from the surface. Its higher than expected temperature, approximately one to two million degrees Kelvin, is the subject of the coronal heating problem as the solar surface is only 6000 K. In addition, the corona is optically thin, which leads to every line-of-sight being composed of both foreground and background material. In order to accurately determine plasma parameters such as density and temperature, it is important to appropriately account for the coronal background. It is uncertain whether the background corona is smooth or structured.

AIA, one of three instruments on board SDO, collects high-resolution full-disk images of the corona in seven extreme ultraviolet band passes, each centered on distinct spectral lines. One of the advantages of these narrow-band filters is the ability to simultaneously supply temperature measurements for large areas of the corona. Each telescope mirror has a multilayer coating that enables the isolation of different spectral lines (Lemen *et al.*, 2011). However, the coatings still image a range wider than a single spectral line, resulting in the response functions being wide and/or double peaked (see Figure 1). This makes the analysis more difficult.

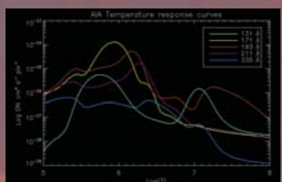

Figure 1: Temperature response function for the five EUV channels

Wavelength	Primary Ion(s)	Characteristic Temperature
131 Å	Fe VIII, Fe XXI	10 million K
171 Å	Fe IX/X	1 million K
193 Å	Fe XII	1.25 million K
211 Å	Fe XIV	5 million K
335 Å	Fe XVI	2.8 million K

Table 1: Details of the five SDO/AIA EUV filters used in this study. The main ions in each pass-band are listed along with the characteristic temperature that these ions represent. More information can be found in O'Dwyer et al. (2010).

Active regions on the Sun occur where the magnetic field is especially strong. They appear bright in ultraviolet and x-ray images. It is common to have solar activity in the form of coronal mass ejections and solar flares associated with active regions.

Method

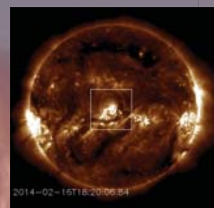
Figure 2: Full-disk AIA 193 Å image showing location of active region. The timestamp indicates the first image in an eight-hour data set

Eight hours of AIA data at a two-minute cadence was downloaded from the Virtual Solar Observatory in five wavelength channels, 131, 171, 193, 211, and 335 Å beginning on February 16, 2014 at 18:20:00 UT and ending on February 17, 2014 at 02:20:00 UT. The active region (AR11977) was selected at disk center in order to reduce both projection and background effects. Choosing an active region at disk center also reduced the ambiguity of the geometry of the loops. Likewise, the line of sight was shortest, and therefore, there was less foreground material to contaminate the intensity measurements.

SSWIDL (SolarSoft Interactive Data Language) was used to process and analyze the data. The data was processed using the aia_prep routine to change the data from Level 1 to Level 1.5. This included making roll, alignment, and plate-scale adjustments as well as removing bad pixels. Additionally, the instrument jitter was removed using cross-correlation techniques and the data was corrected for the effects of solar rotation. The eight hours of data in the five channels was used to construct images of the background corona by creating 'minimum' images. These minimum images were created using several methods, including spatial and temporal ones, in order to find the most robust method. The preferred method created the minimum image using the fifth lowest intensity value for each pixel from the eight-hour time period. The fifth lowest was used as opposed to the lowest in order to remove the possibility of sudden drops in the intensity values. The intensities through the active region in the minimum images were plotted in order to investigate if there was any structure present.

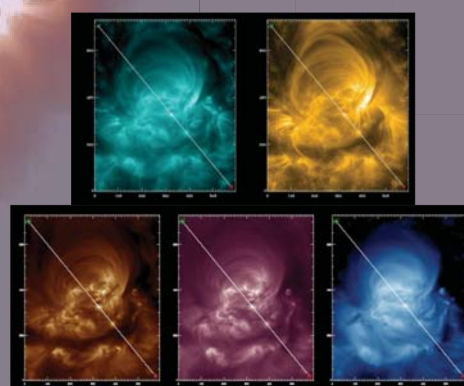
Figure 3: Minimum images of the five wavelengths: 131 Å, 171 Å (top), 193 Å, 211 Å, 335 Å (bottom).

Results

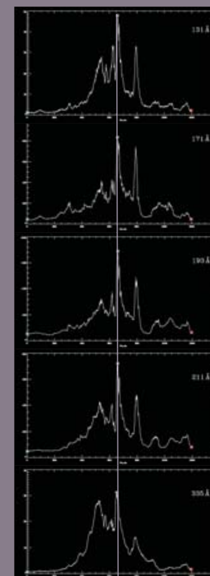
Figure 4: Intensity profiles of cuts along active region from Fig 3.

Contrary to expectations, the loops were still present in the minimum images. Usually, such features appear and disappear within a few hours. However, the coronal loops were still present in all five wavelengths after eight hours. When the intensity values were plotted through the active region (Figure 4) structured, not smoothly varying intensity profiles can be seen. Figure 5 shows results from the Differential Emission Measure (DEM) method plotted along the same diagonal cut showing the temperature of the plasma in this region. This method uses information from the intensity along this cut in different AIA channels in conjunction with the instrument response function to make the best guess of the temperature of the plasma.

It is very important to accurately determine the coronal background in order to correctly determine plasma parameters such as temperature and density. Accurately knowing these parameters may lead scientists to a better understanding of the coronal heating problem.

Future work will examine these long-lasting background loops in more detail to see if there is something special about them that could explain their longer lifetimes e.g. if they have a different temperature profile to other loops, if they are rooted in a particular type of region, if the magnetic field at the footpoints is doing something different to the rest of the region i.e. cancelling or emerging flux is observed. Figure 6 shows some new work being done to examine the multi-wavelength nature of this AR. Scan the QR code below for a link to the movie.

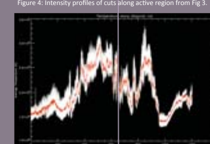
Figure 5: Temperature profile along same diagonal slice made using the DEM method. The solid red line shows the best guess of the temperature and the white area gives an indication of the uncertainty.


Figure 6: Three color image of the AR using 171, 193 and 211 A data that has been enhanced to show the loops.

Acknowledgments

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