Abstract. The Extreme-ultraviolet Imaging Spectrometer (EIS) on board Hinode provides an excellent opportunity to study the physical plasma parameters in spatially resolved coronal features. In this paper we present the density structure in an active region at many different temperatures. The active region was rastered on May 01, 2007 with the $2''$ slit. We find that the electron density is highest in the core of the active region where it exceeds $\log_{10} N_e = 10.5$.

1. Introduction

Active regions are the brightest features seen on the Sun’s surface when observing in ultra-violet and X-rays. They are the structures with the most complex magnetic topology. Most of the high energy explosions such as flares and coronal mass ejections (CMEs), which have lethal consequences for space weather and geo-space climate, originate from active regions (e.g., Tripathi et al. 2004). Moreover, studying active region evolution is very important in order to understand the problem of coronal heating. There have been numerous models to explain coronal heating (see Klimchuk 2006 for a review). However, the solution remains elusive.

From the observational point of view, studying the problem of coronal heating requires precise and simultaneous measurements of the plasma parameters, such as electron density, temperature and plasma flows at different temperatures. Various attempts have been made using previous instruments such as the Coronal Diagnostic Spectrometer (CDS; Harrison et al. 2005) on board the Solar and Heliospheric Observatory (SoHO) amongst others. For an active region observed by the CDS, Mason et al. (1999), using the line ratio technique for plasma diagnostics, found that the core of the active region was denser and hotter in comparison to the outer region. See also Milligan et al. (2005) and Tripathi et al. (2006). However, due to a limited temperature coverage and a limited number of density and temperature sensitive spectral lines, a comparison of electron densities at different temperatures was not possible.

The Extreme-ultraviolet Imaging Spectrometer (EIS, Culhane et al. 2007) on board Hinode, having unprecedented spatial and spectral resolution with broad temperature coverage, provides an excellent opportunity to study the physical plasma parameters in active regions in the greatest possible detail. In
this paper we study the density structure of an on-disk active region observed on May 01, 2007 using Hinode/EIS.

2. Observations, Data Preparation and Analysis

The EIS on-board Hinode is an off-axis paraboloid design with focal length of 1.9 metre and mirror diameter 15 cm. It consists of multi-toroidal gratings which disperse the spectrum on two different detectors covering 40 Å each. The first detector covers the wavelength range 170–210 Å and second covers 250–290 Å.
providing observation in a broad range of temperature (5.8 to 6.7 MK). The EIS has four slit/slot options available (1'' , 2'', 40'', and 266''). The EIS provides monochromatic images of the transition region and corona at high cadence using a slot, while high spectral resolution images can be obtained by rastering with a slit (1'' or 2''). The spatial resolution of images obtained using EIS is about 2''/pixel.

In this paper we have used the EIS study 'cam_arth_cds_a' which comprises 22 spectral lines covering a broad range of temperatures. This study uses the 2'' slit with an exposure time of 10 seconds and was run on an on-disk active region on May 01, 2007. It covered a field of view (FOV) of 200'' × 200'' in 20 minutes. This FOV covers almost a complete active region. This study includes many different density sensitive lines, providing an opportunity to simultaneously measure electron densities at different temperatures. We have applied standard processing routine, namely 'eis_prep.pro', and have fitted the spectrum for each pixel using the routine 'eis_auto_fit.pro', both available in the “solar software tree”. Table 1 shows only those pairs of identified lines (1st column) which were used to derive the electron density with their sensitivity range (third column) and peak formation temperatures (fourth column). The electron density values were obtained using the theoretical line intensity ratios calculated using CHIANTI (Dere et al. 1997; Landi et al. 2006) with the Mazzotta et al. 1998 ionization balance.

3. Results

Figure 1 displays intensity images and density maps obtained by fitting selected spectral lines. In Figure 1: the top row shows the intensity images of the region in Mg VII (λ280, left; λ278, middle; density, right), second row for Fe XII (λ186, left; λ195, middle; density, right), third row for Fe XIII (λ202, left; λ203, middle; density, right) and bottom row for Fe XIV (λ264, left; λ274, middle; density, right). The Mg VII λ278 line is blended with a Si VII line, the Fe XIII λ203 is blended with another Fe XII line and Fe XIV λ274 line is blended with a Si VII line. These blends were taken into account while fitting the line. The Fe XII blend from Fe XIII λ203 was removed by fitting double Gaussian. However, we have used another Si VII λ275, which is quite a strong line, to remove blends from Mg VII λ278 and Fe XIV λ274 lines. The Fe XII λ186 has a self blend and care has to be taken when deriving the densities using Fe XII λ186 and λ195 lines.

From Fig. 1 it is evident that the core of the active region appears to be denser than the outer regions. This density in the core can be as high as 10^{10.5} cm^{-3}. The density maps obtained from using the Fe XIII (203/202) ratio appear to be saturated in the very core of the active region where the density is higher than 10^{10} cm^{-3}. This is likely to be due to a problem at very high densities with the atomic data for Fe XIII in CHIANTI. The Fe XII (186/195) ratio gives the best density diagnostic due to its broad range of sensitivity. Using this line ratio, the density inside the active region, as well in the outer region, can be derived simultaneously.
4. Summary and conclusions

The EIS on broad Hinode provides a unique opportunity to study the physical parameters in spatially resolved coronal structures at many different temperatures simultaneously. In this paper we have studied density structure in an active region using a range of line ratios. For all temperatures, the core of the active region is denser than the outer regions. The density in the core can be as large as \(10^{10.5}\) cm\(^{-3}\). The Fe XII (186/195) is the best ratio for deriving electron densities in the corona due to its broad range of sensitivity.

<table>
<thead>
<tr>
<th>Line ID</th>
<th>λ (Å)</th>
<th>log(N_e)</th>
<th>(T_e) (log(T))</th>
<th>Transition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg VII</td>
<td>278.39</td>
<td>8–11</td>
<td>5.8</td>
<td>(2s^2.2p^2 ^3P_2 - 2s.2p^3 ^3S_1)</td>
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<tr>
<td>Mg VII</td>
<td>280.75</td>
<td>8–11</td>
<td>5.8</td>
<td>(2s^2.2p^2 ^1D_2 - 2s.2p^3 ^1P_1)</td>
</tr>
<tr>
<td>Fe XII</td>
<td>186.88</td>
<td>7–12</td>
<td>6.1</td>
<td>(3s^2 3p^3 ^2D_{5/2} - 3s^2 3p^2(^3P)3d ^2F_{5/2})</td>
</tr>
<tr>
<td>Fe XII</td>
<td>186.85</td>
<td>7–12</td>
<td>6.1</td>
<td>(3s2 3p3 ^2D_{5/2} - 3s2 3p2 (^3P)3d ^2F_{7/2})</td>
</tr>
<tr>
<td>Fe XII</td>
<td>195.12</td>
<td>7–12</td>
<td>6.1</td>
<td>(3s^2 3p3 ^4S_{3/2} - 3s^2 3p^2(^3P) 3d ^4P_{5/2})</td>
</tr>
<tr>
<td>Fe XIII</td>
<td>202.02</td>
<td>8–10.5</td>
<td>6.2</td>
<td>(3s^2.3p^2 ^3P_0 - 3s^2.3p3d ^3P_1)</td>
</tr>
<tr>
<td>Fe XIII</td>
<td>203.83</td>
<td>8–10.5</td>
<td>6.2</td>
<td>(3s^2.3p^2 ^3P_2 - 3s^2.3p3d ^3P_3)</td>
</tr>
<tr>
<td>Fe XIV</td>
<td>264.78</td>
<td>8–11</td>
<td>6.3</td>
<td>(3s^2.3p ^2P_{3/2} - 3s.3p^2 ^2P_{3/2})</td>
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<tr>
<td>Fe XIV</td>
<td>274.20</td>
<td>8–11</td>
<td>6.3</td>
<td>(3s^2.3p ^2P_{1/2} - 3s.3p^2 ^2S_{1/2})</td>
</tr>
</tbody>
</table>

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