Spectroscopic Study of a Dark Lane and a Cool Loop in a Solar Limb Active Region by Hinode/EIS

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Abstract

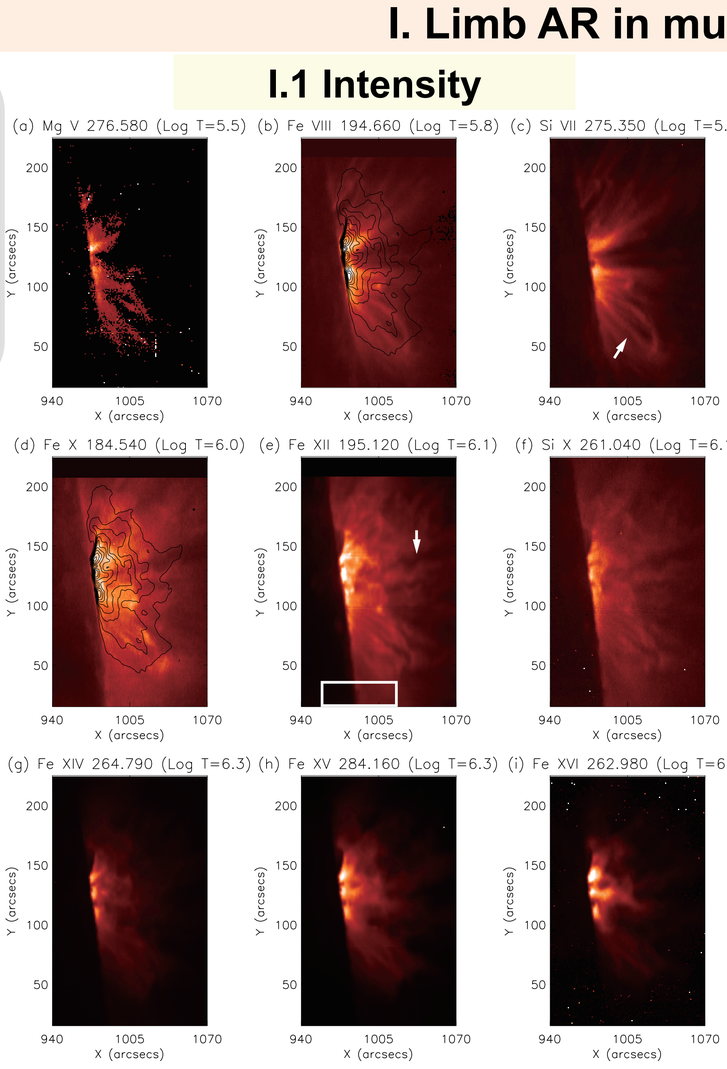
We investigate a cool loop and a dark lane over a limb active region on 2007 March 14 by the Hinode/EUV Imaging Spectrometer (EIS). The cool loop is clearly seen in the EIS spectral lines formed at the transition region temperature (log T = 5.8). The dark lane is characterized by an elongated faint structure in coronal spectral lines (log T = 5.8 – 6.1) and rooted on a bright point. We examine their electron densities, Doppler velocities, and non-thermal velocities as a function of distance from the limb using the spectral lines formed at different temperatures (log T = 5.4 – 6.4). The electron densities of the cool loop and the dark lane are derived from the density sensitive line pairs of Mg VII, Fe XII, and Fe XIV spectra. Under the hydrostatic equilibrium and isothermal assumption, we determine their temperatures from the density scale height. Comparing the scale height temperatures to the peak formation temperatures of the spectral lines, we note that the scale height temperature of the cool loop is consistent with a peak formation temperature of the Mg VII (log T = 5.8) and the scale height temperature of the dark lane is close to a peak formation temperature of the Fe XIII (log T = 6.2). It is interesting to note that the structures of the cool loop and the dark lane are most visible in their scale height temperatures. While the non-thermal velocity in the cool loop slightly decreases (less than 7 km s-1) along the loop, which in the dark lane sharply falls off with height. Such a decrease in the non-thermal velocity may be explained by wave damping near the solar surface or turbulence due to magnetic reconnection near the bright point.

I. Limb AR in multi-wavelengths observed by Hinode/EIS

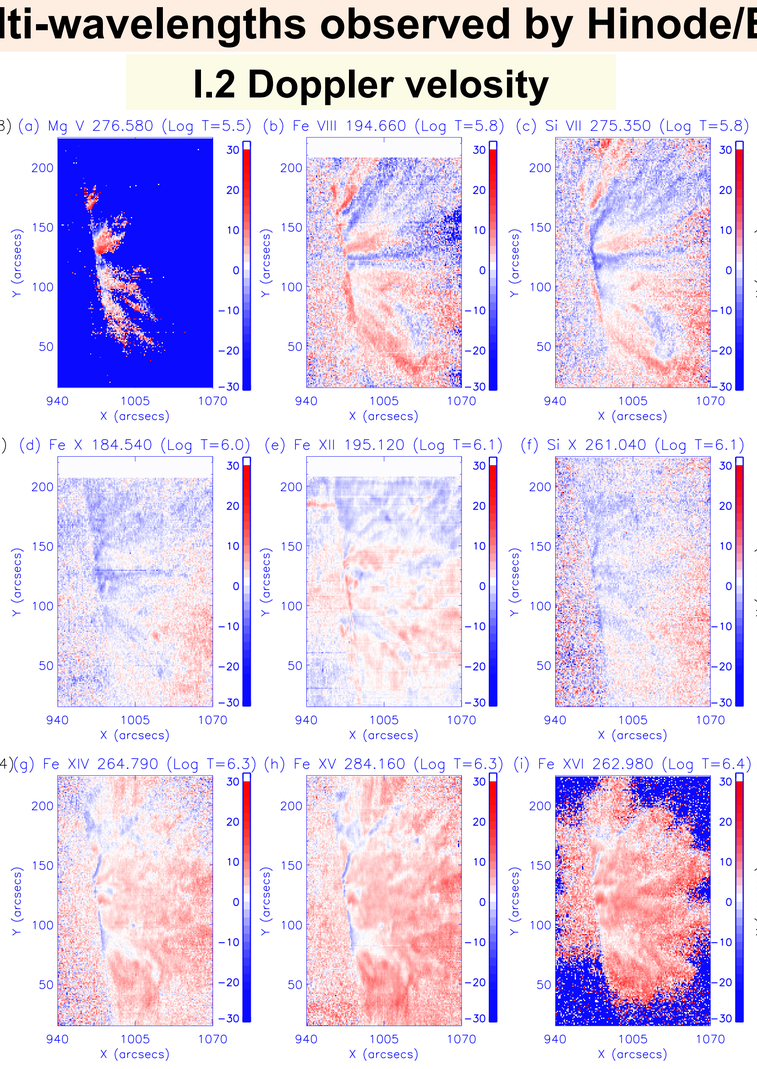
List of Spectral Lines Used in the Present Study
* indicates the spectra for the density diagnostics

Line ID (Å)	$\log T_{max}$ (K)
Mg V 276.58	5.5
Fe VIII 194.66	5.8
Mg VII 278.39 *	5.8
Mg VII 280.75 *	5.8
Si VII 275.35	5.8
Fe X 184.54	6.0
Si X 258.37 *	6.1
Si X 261.04 *	6.1
Fe XII 186.88 *	6.1
Fe XII 195.12 *	6.1
Fe XII 196.64 *	6.1
Fe XIII 196.54 *	6.2
Fe XIII 202.04 *	6.2
Fe XIII 203.83 *	6.2
Fe XIV 264.79 *	6.3
Fe XIV 274.20 b *	6.3
Fe XV 284.16	6.3
Fe XVI 262.98	6.4

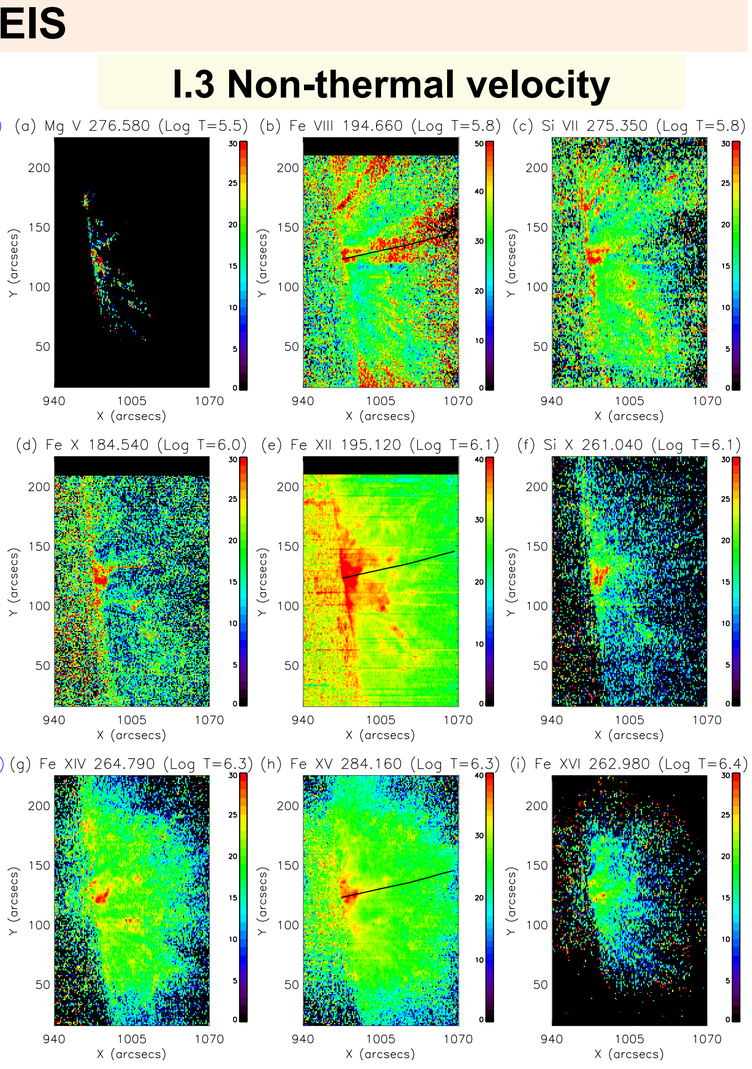
I.1 Intensity



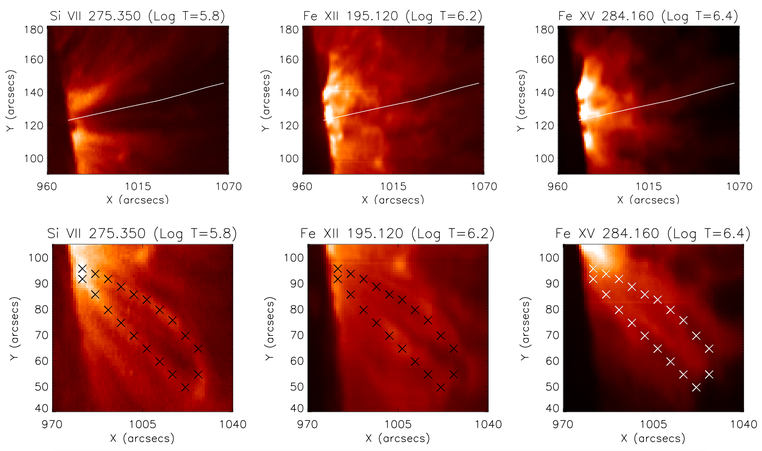
I.2 Doppler velosity



I.3 Non-thermal velocity

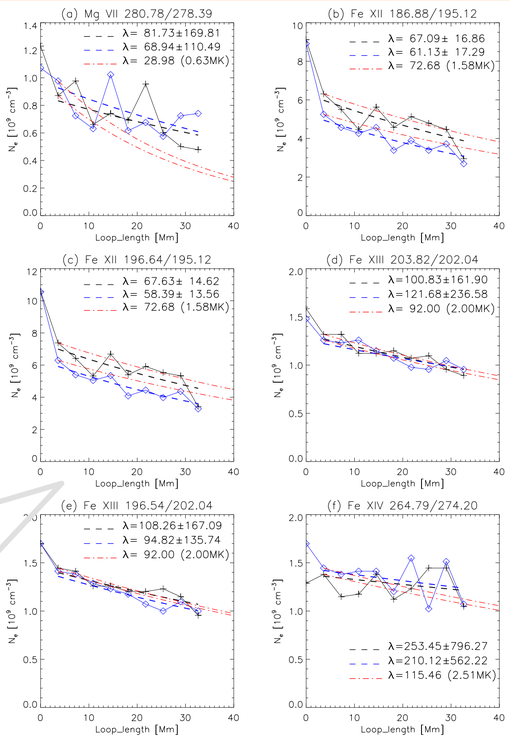


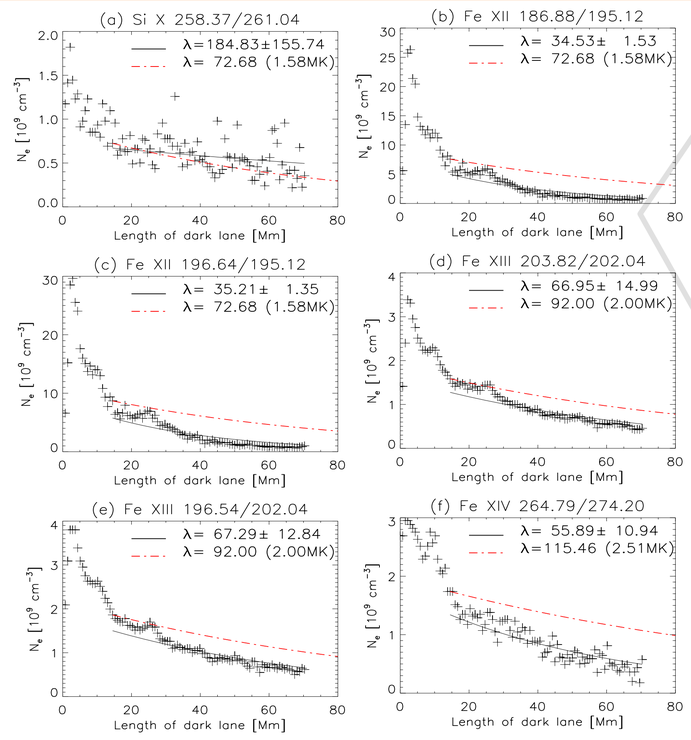
II. Dark lane and cool loop



Electron density of the cool loop (left) and the dark lane (right) as a function of height with an exponential fit for estimating the density scale height. Red dot-dashed lines represent the density profile using the peak formation temperature of the lines.

III. Density with height – Hydrostatic or Hydrodynamic





Density profile with height

$$n_e(h) = n_{e0}\exp[\frac{-h}{\lambda}]$$

Under the hydrostatic equilibrium and isothermal assumption, the scale height

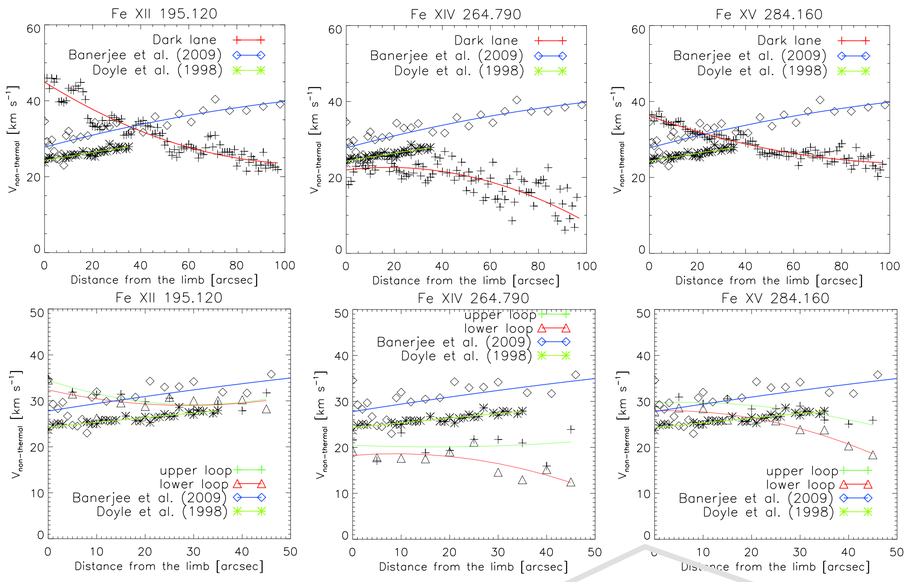
$$\lambda(T_e) = \frac{k_B T_e}{\mu m_H g} \sim 46(\frac{T_e}{1MK})[Mm]$$

Cool loop: close to hydrostatic equilibrium at coronal temperature lines except for the Mg VII

Dark lane: under dense

They are not possibly in hydrostatic equilibrium.

IV.1 Non-thermal velocity with height



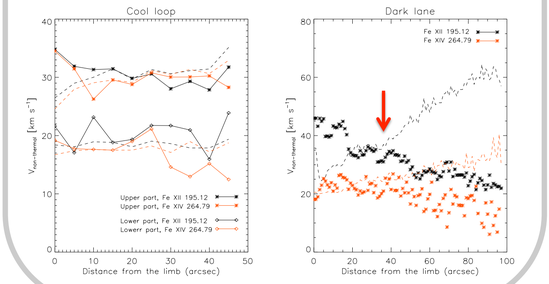
Variation in **non-thermal velocity** with height - **Decrease**
Top: cool loop (cross : upper loop, triangle: lower loop)
Bottom: dark lane (cross)
The blue and light green lines: non-thermal velocity results from the Banerjee et al. (2009) and Doyle et al. (1998)

IV.2 Decrease of the non-thermal velocity with height

Wave damping near the solar surface

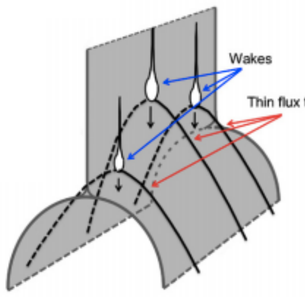
Edge of bright region in AR shows the weak intensity and largest line width (Doschek et al. 2007; Imada et al. 2007, 2009)

Dissipation of the energy from the wave damping (Bemporad & Abbo 2012) at ~ 0.04 $R_\odot$ from the limb.



Turbulence from the Magnetic reconnection

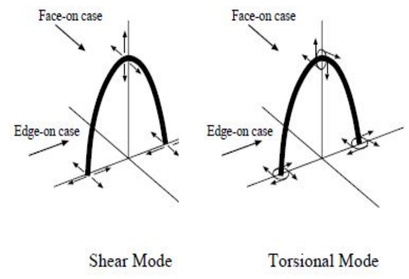
Off-limb magnetic reconnection - The dark lane rooted on the bright point in the limb AR.
Oserved dark voids with off-limb reconnection (Flare obs.) - SADs (Supra Arcade Downflows)



Savage, Mckenzie, & Reeves (2012)

Projection effect of loop structures

Alfven waves in coronal loops (Hara & Ichimoto 1999) observed differently depending on the orientation of the loop with the line-of-sight



Hara & Ichimoto (1999)