Mass and energy supply of a cool coronal loop near its apex

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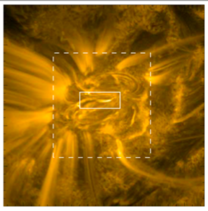
Abstract

Different models for the heating of solar corona assume or predict different locations of the energy input: concentrated at the footpoints, at the apex, or uniformly distributed. The brightening of a loop could be due to the increase in electron density n_e, the temperature T , or a mixture of both.

We investigate possible reasons for the brightening of a cool loop at transition region temperatures through imaging and spectral observation. The loop first appears at transition region temperatures and later also at coronal temperatures, indicating a heating of the plasma in the loop. The appearance of hot plasma in the loop coincides with a possible accelerating upflow seen in Si IV, with the Doppler velocity shifting continuously from ~−70 km/s to ~−265 km/s. The corresponding photospheric magnetic flux shows significant decrease and the extrapolated 3D magnetic field lines indicates possible signature of magnetic reconnection. These observations suggest that the loop is probably heated by the interaction between the loop and the upflows, which are accelerated by the magnetic reconnection between small-scale magnetic flux tubes at lower altitudes. Before and after the possible heating phase, the intensity changes in the optically thin (Si IV) and optical thick line (C II) are mainly contributed by the density variation without significant heating.

Context of the active region

Fig. 1. Context of the active region as seen in AIA 193 Å, showing plasma around 1.5 MK. The FOV is 249.6″ × 249.6″ centered at solar X = 50″ and solar Y = −225″.



White dashed rectangles: the full FOV of IRIS

The white solid rectangles: the subregion shown in Fig.2

Temporal evolution of the loop

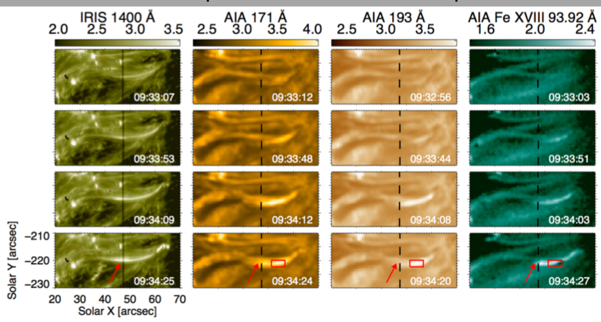


Fig. 2. The columns show the images obtained through the IRIS slit-jaw-images in 1400 Å (0.1 MK), the AIA channels at 171 Å (1 MK) and 193 Å (1.5 MK), and the Fe XVIII (93.92 Å; 7 MK) emission extracted from the AIA channel at 94 Å. The black dashed vertical lines indicate the slit position of the IRIS spectrometer.

Temporal evolution of the spectral profile of the loop

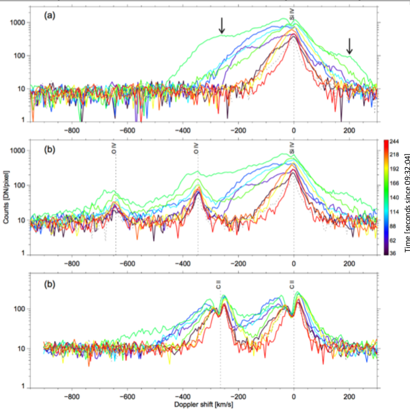


Fig. 3. The three rows show spectral windows centered around Si IV 1394 Å (panel a), Si IV 1403 Å including the nearby O IV lines (panel b), and C II 1335 Å and 1336 Å (panel c). Each panel shows the evolution of the line profiles over 3.5 min starting at 09:32:40 UT. Different line colors represent different times, as indicated by the color bar showing the time in seconds since 09:32:04 UT. All spectra are taken at the location along the slit in the middle of the loop crossing the slit.

Density evolution in the loop

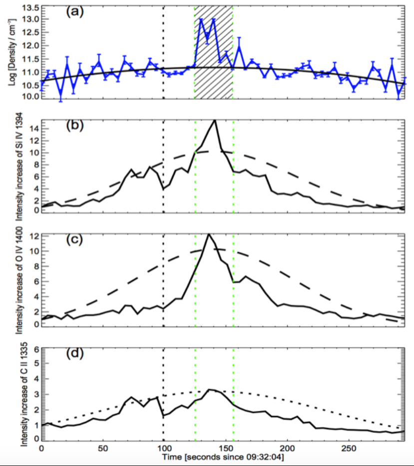


Fig. 4.

Panel a:

the electron density in the source region of O IV in the transition region derived from the ratio of the O IV lines at 1401 and 1400 Å. The black solid curve shows the overall trend of the density variation excluding the shaded area, which is not reliable.

Panels b to d:

black solid curves :

the normalized intensity $\frac{I(t)}{I(t=0\,s)}$ of Si IV 1394 Å, O IV 1401 Å, and C II 1335 Å.

black dashed curves :

The black dashed curves in panels b and c show the normalized density squared ($\left(\frac{n_e(t)}{n_e(t=0)}\right)^2$) while the black dotted curve in panel d shows the normalized density $\frac{n_e(t)}{n_e(t=0)}$.

The dotted vertical lines label the boundary between the two phases.

Flows in and below the loop

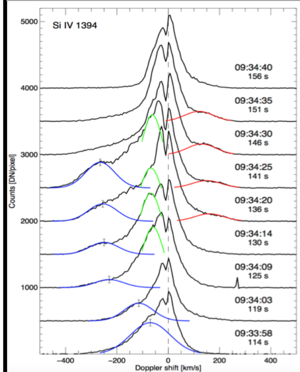


Fig. 5. These are stacked profiles, i.e., each time step is plotted with an intensity increased by 500 counts. The colored Gaussian profiles indicate by-eye fits to the obvious spectral features in the line wings. The blue profiles are shifted by −70 km/s, −115 km/s, −230 km/s, −250 km/s, −255 km/s, and −265 km/s, from bottom to top.

Evolution of magnetic flux

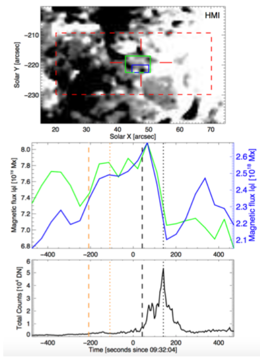


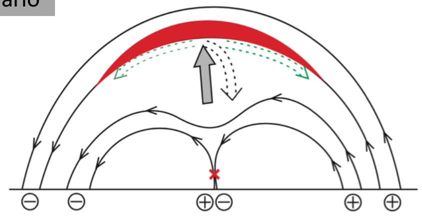
Fig. 6.

Top panel: magnetogram obtained by the HMI at 09:34:40 UT.

Middle panel: the total magnetic flux in the regions shown by green and blue rectangles in the top panel.

Bottom panel: the total intensity in Si IV 1394 Å. The black dashed and dotted lines show the onset of the brightening and the maximum brightening, respectively.

Possible scenario



Conclusion and discussion

- During the possible heating phase, the heating of the loop is probably due to the interaction between the loop and the high speed upflow from the magnetic reconnection between small-scale flux tubes.
- Except for the possible heating phase, the intensity variation is mainly contributed by the density variation without no significant heating.
- This scenario is probably too simple to truly catch the processes that underlie this observation. It still emphasizes that even a comparably simple loop might be more complex than thought initially. The full 3D nature of the atmosphere should be considered to describe this loop, which appeared to be 1D in the imaging observations.

Poster

1. Fundamental physical processes and modeling

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Different models for the heating of solar corona assume or predict different locations of the energy input: concentrated at the footpoints, at the apex, or uniformly distributed. The brightening of a loop could be due to the increase in electron density n_e, the temperature T, or a mixture of both. Based on the simultaneous imaging and spectral observation from Interface Region Imaging Spectrograph (IRIS), we investigate possible reasons for the brightening of a cool loop at transition region temperatures. The loop first appears at transition region temperatures and later also at coronal temperatures, indicating a heating of the plasma in the loop. During the heating phase, the appearance of a possible accelerating upflow in Si IV and the 3D magnetic field lines extrapolated from the HMI magnetogram suggest that the loop heating is probably affected by accelerating upflows, which are probably launched by magnetic reconnection between small-scale magnetic flux tubes underneath the envelope loop. Before and after the possible heating phase, the intensity changes in the optically thin (Si IV) and optical thick line (C II) are mainly contributed by the density variation without significant heating. This study emphasizes that in the complex upper atmosphere of the Sun, the dynamics of the 3D coupled magnetic field and flow field plays a key role in thermalizing 1D structures such as coronal loops.