Photospheric Properties of Warm EUV Loops and Hot X-Ray Loops

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We investigated the photospheric properties (vector magnetic fields and horizontal velocity) in a well-developed active region, NOAA AR 10978, by using the *Hinode* Solar Optical Telescope (SOT), especially for discussing what makes coronal loops so different in temperature from "warm loops" (1–2 MK) observed in EUV wavelengths to "hot loops" (> 3 MK) in X-rays [1]. We found that outside sunspots the magnetic filling factor f in network varies with location, and anti-correlated with the horizontal random velocity v_{SD} (Figure 1). For explaining this anti-correlation, it is not necessary to use the hypothesis that the dense magnetic flux tubes suppresses their mobility on the photosphere [2]. If we accept that the observed magnetic features consist of unresolved magnetic flux tubes, this anti-correlation can be explained by the ensemble average of the flux-tube motion driven by small-scale random flows. This simple model suggests the equation of

$$v_{SD} = v_o d D^{-1} f^{-1/2} \quad \text{for } f<(d/\lambda)^2, \quad (1)$$

$$= v_o \lambda D^{-1} \quad \text{for } f>(d/\lambda)^2, \quad (2)$$

where d and D are the diameter of flux tube and the resolution of this analysis, respectively, and v_o and λ are the small-scale flow velocity and its spatial scale, respectively. The observed data are consistent with $d \sim 77$ km, $v_o \sim 2.6$ km s^{-1} and $\lambda \sim 120$ km as shown by the dashed line in Figure 1a.

We also found that outside sunspots there is no significant difference between warm and hot loops either in the magnetic properties except the inclination or in the horizontal random velocity at their footpoints, which are identified with the *Hinode* X-ray Telescope (XRT) and the Transition Region and Coronal Explorer (TRACE). The energy flux injected into the coronal loops by the observed photospheric motion of the magnetic fields is estimated to be 2×10^6 erg s^{-1} cm^{-2}, which is the same for both warm and hot loops (Figure 2). This suggests that coronal situation (e.g. loop length) plays more important role for making a variety of temperature in active-region coronal loops than the photospheric parameters.

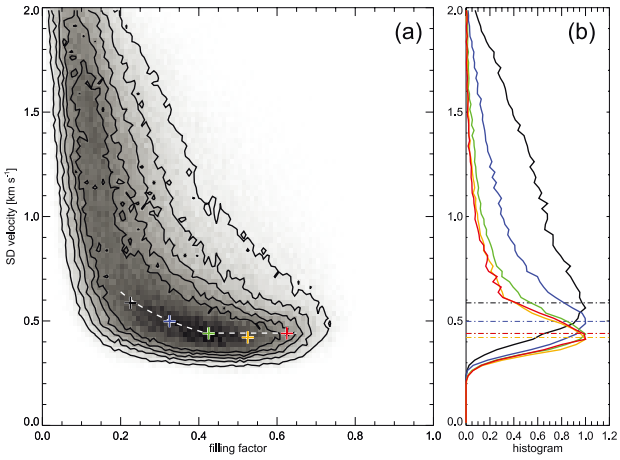

Figure 1: (a) Scattered plot between magnetic filling factor and horizontal random velocity. A gray scale and contours show the number density of the data points outside sunspots. (b) Histograms of the horizontal random velocity outside sunspots. Different lines indicate different filling factors: 0.20–0.25 (black), 0.30–0.35 (blue), 0.40–0.45 (green), 0.50–0.55 (orange) and 0.60–0.65 (red). The peaks indicated by dot-dashed lines are also shown by crosses in panel-(a).

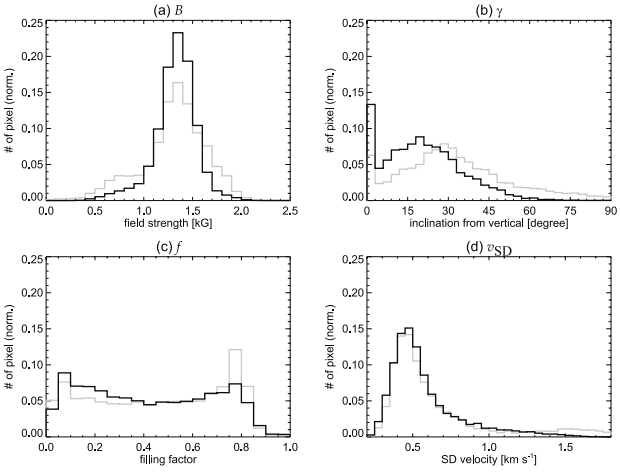

Figure 2: Histograms of photospheric properties at the footpoints located outside sunspots: (a) intrinsic field strength, (b) inclination and (c) filling factor of magnetic fields, and (d) standard deviation of horizontal velocity. Grey and black lines correspond the footpoints of warm and hot loops, respectively.

References

[1] Kano, R., Ueda, K., Tsuneta, S.: 2014, *ApJ*, **782**, L32.
[2] Katsukawa, Y., Tsuneta, S.: 2005, *ApJ*, **621**, 498.