Temperature Diagnostic of Coronal Loops

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Abstract

Solar active regions exhibit a discrete number of bright coronal loops which are subject to a series of heating and cooling events. The existence of those coronal loops is a consequence of small-scale energy deposition leading to the transport of heat along the loop. Based on a 1D multi-stranded hydrodynamic (MSHD) model, we describe the physical processes acting on a typical coronal loop subject to different energetization parameters (including heating and cooling). By comparing with Hinode/EIS and SDO/AIA, we thus provide temperature diagnostics of coronal plasma depending on the physical process at play: for the heating of loop, the amount of Doppler-shift provides an estimate of the loop temperature, whilst for the cooling, the timing of peaks of intensity allows to estimate the temperature of the plasma and the cooling profile.

The Multi-stranded Nanoflare Model (Sarkar and Walsh 2008, 2009)

Specifics of the model

- 1D hydrodynamic model for each indvidual strand.
- Lagrange remap algorithm (Arber et al. 2001).
- Random distribution of bursts/nanoflares
- Radiative loss function between 10^4 K to 10 MK

Characteristic Parameters

- Length of the loop: 100 Mm
- Min. energy for each burst: 10^{24} erg (hot), and 10^{23} erg (warm)
- Number of strands: 128
- Simualtion real time: 4hr 30min

Dopplershifts Observations in Coronal Loops

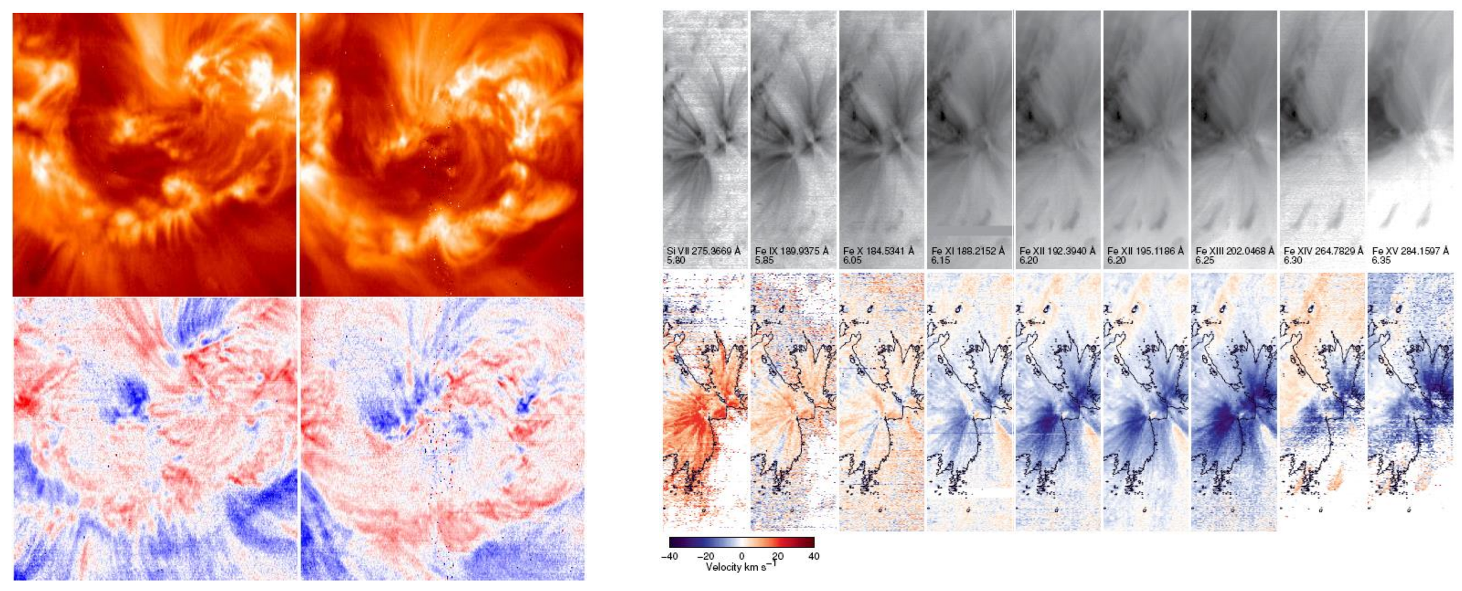


Fig. 1: (*left*) *Hinode/EIS Intensity map versus velocity map on 2007 Feb 02 (Image credit: K Dere); (right) Series of intensity and Dopplershifts observations by Hinode/EIS (Warren et al. 2011)*

Red and Blue-shift Distributions for Spectral Lines

We simulate the Doppler shifts that may by observed be the Hinode/EIS spectrometer for ten different spectral lines: from O V at 248.46 Å with a characteristic temperature of 0.25 MK, and Fe XV at 284.16 Å with a characteristic temperature of 2 MK. The loop is assumed to be semi-circular being viewed directly from above. The Doppler velocity is deduced from a line filtered emission measure weighted average (Sarkar and Walsh 2008) for the different spectral lines which can be observed by Hinode/EIS (Fig. 2). We also compute the statistics of red and blue-shifts in each emission line for a hot (3-4 MK apex temperature) and a warm (1.5-2 MK) loop (Fig. 3).

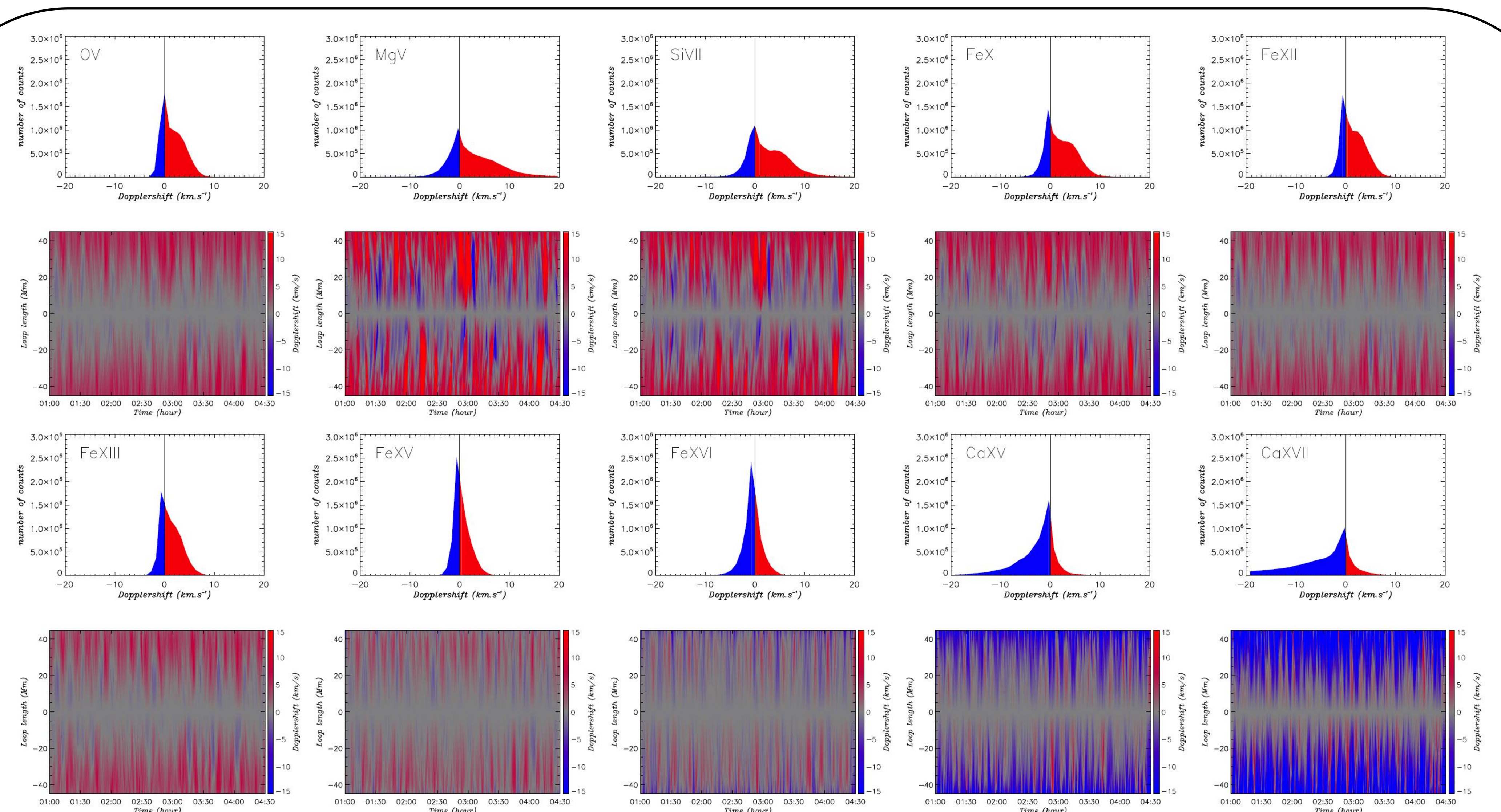


Fig. 2: *Distributions of Dopplershifts for ten different spectral lines showing the increase of blueshifts with temperature*

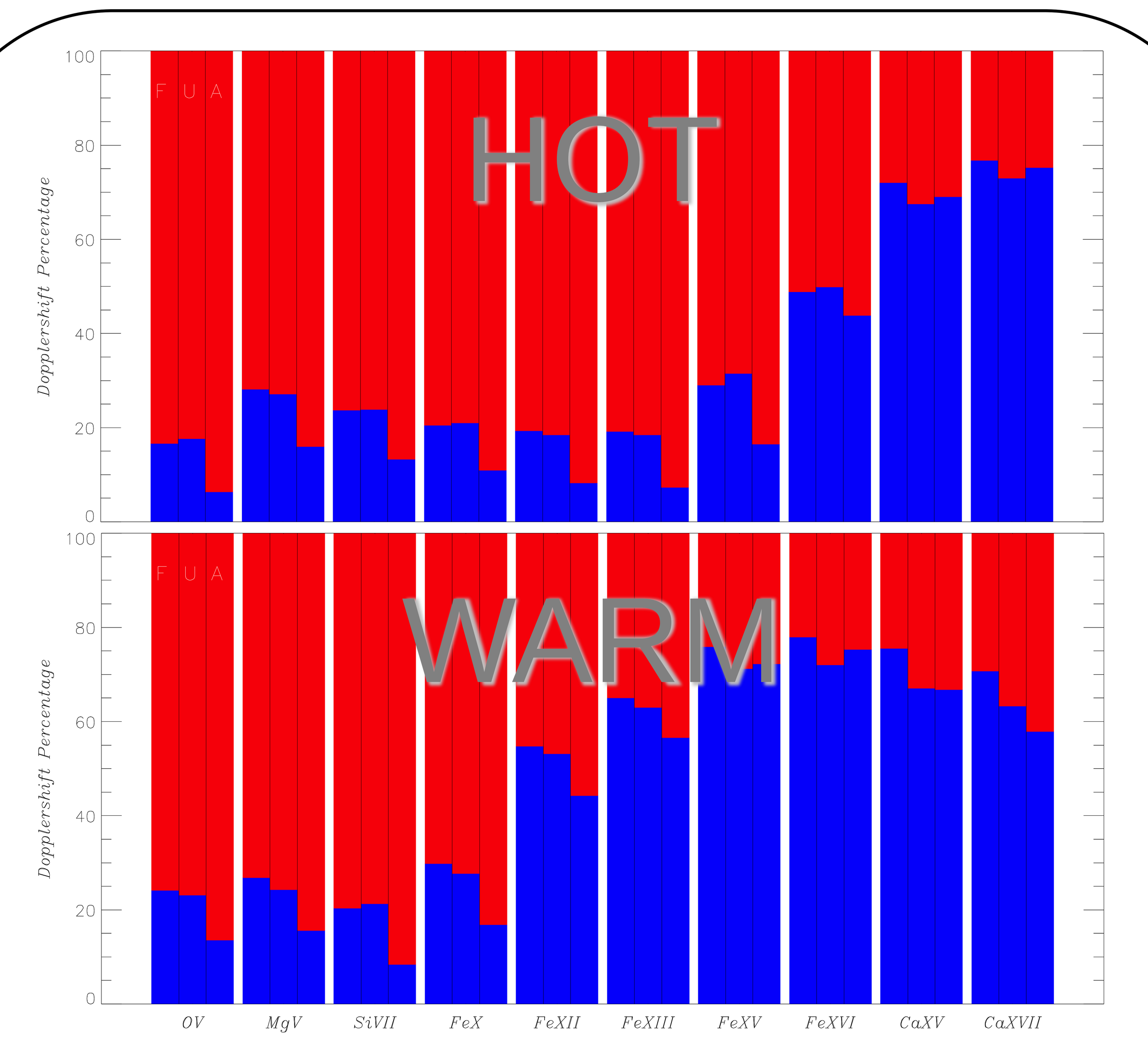
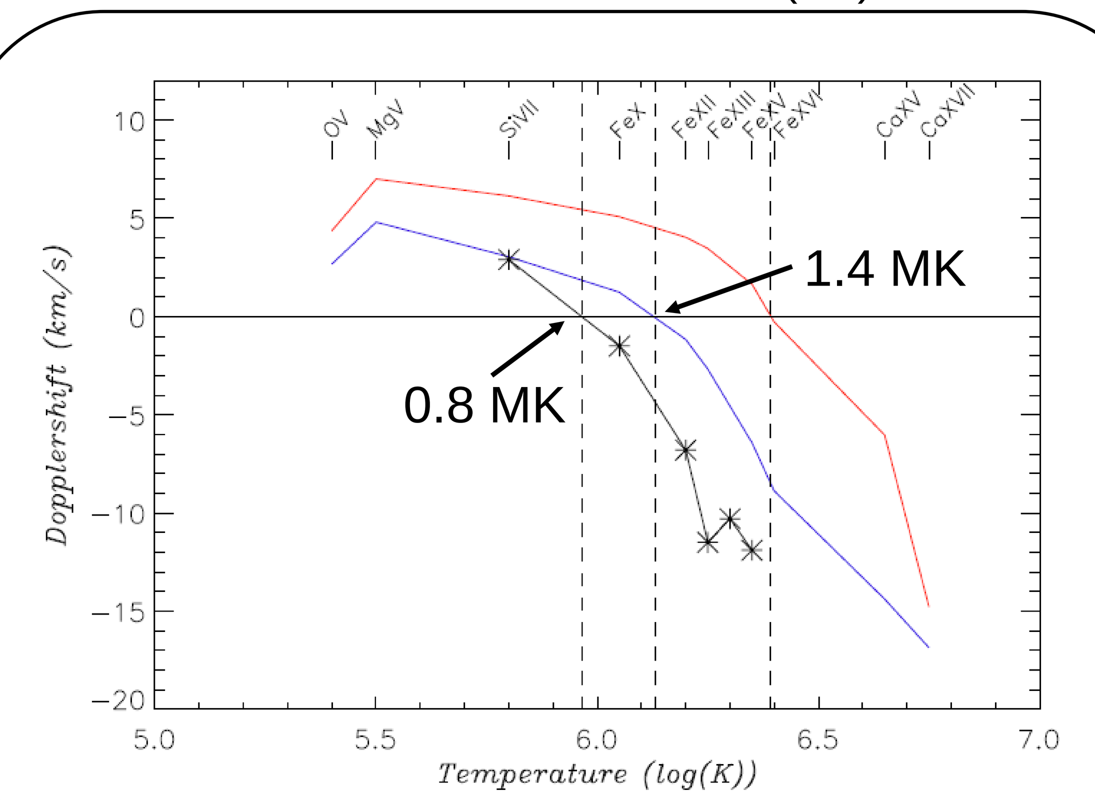
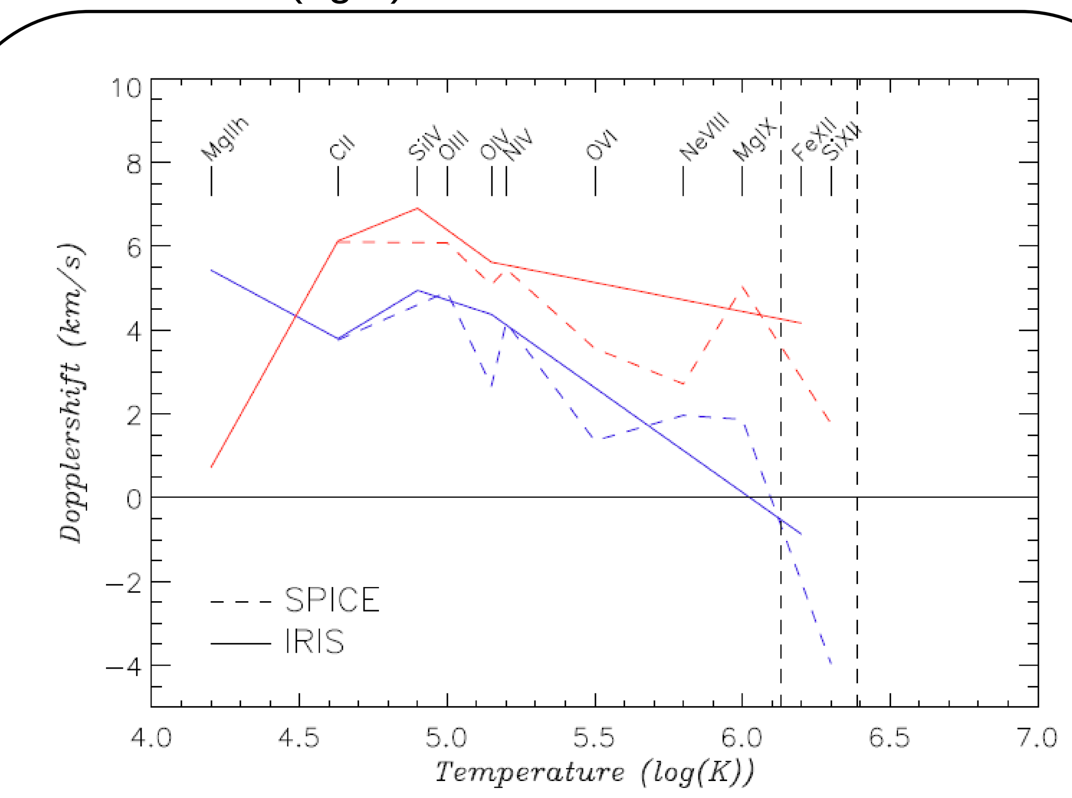


Fig. 3: *Statistics of Dopplershifts for individual lines for a hot and warm loop*

Temperature diagnostic

From the variation of the average Dopplershifts at the footpoint of the loop in the different spectral lines, it gives an estimate of the temperature when the average vanishes. This temperature diagnostic is demonstrated below for Hinode/EIS (left) and for IRIS and Solar Orbiter/SPICE (right).





Discussion and Future Work

Based on the multi-stranded loop model (Sarkar and Walsh 2008, 2009), we have found that:

- Red-shifts and blue-shifts (up to 20 kms^{-1}) can be reproduced for the different simulated Hinode/EIS spectral lines by employing a holistic multi-stranded approach.
- There is a strong temperature dependence of blue and redshifts observed in a coronal loop: (i) on the temperature of the observed emission line, (ii) on the mean/average temperature of the loop
- This provides a temperature diagnostic of the coronal plasma.

References

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