Magnetic Coupling between Chromosphere and Corona Measured with HMI, AIA, and IRIS

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ABSTRACT

How is the chromospheric and coronal magnetic field related to each other ?
We calculated the time evolution of the free magnetic energy during the 2014-Mar-29 flare (SOL2014-03-29T17:48), the first X-class flare detected by IRIS. The free energy was calculated from the difference between the non-potential field, constrained by the geometry of observed loop structures, and the potential field. We use AIA/SDO and IRIS images to delineate the geometry of coronal loops in EUV wavelengths, as well as to trace magnetic field directions in UV wavelengths in the chromosphere and transition region. We find an identical evolution of the free energy for both the coronal and chromospheric tracers, as well as agreement between AIA and IRIS results, with a peak free energy of $E_{free}(t_{peak}) \approx (45 \pm 2) \times 10^{30}$ erg, which decreases by an amount of $\Delta E_{free} \approx (29 \pm 3) \times 10^{30}$ erg during the flare decay phase. The consistency of free energies measured from different EUV and UV wavelengths for the first time here, demonstrates that vertical electric currents (manifested in form of helically twisted loops) can be detected and measured from both chromospheric and coronal tracers.

DATA ANALYSIS :
2014 March 29, 17:35-17:54 UT Flare

(i) HMI/SDO Magnetogram decomposition into (buried) unipolar magnetic charges,
(ii) Automated tracing of curvi-linear structures (mostly magnetic loops) in AIA/SDO images, as well as in IRIS images, using the OCCULT-2 code (Aschwanden et al. 2013)
(iii)Forward-fitting of a nonlinear force-free field (NLFFF) solution of the vertical-current model (Aschwanden 2013),
(iv)Tracking evolution of free energy and dissipated magnetic energies (i.e., negative changes of free energy) as a function of time during flare.

CONCLUSIONS :

The curvi-linear structures automatically detected in (coronal) EUV and (chromospheric) UV images appear to delineate the (non-potential) magnetic field self-consistently, so that a magnetic field model can be forward-fitted to either of the EUV and UV images. Moreover, we used UV images from AIA (304, 1600 A) as well as from IRIS (2796 A Mg II h/k, 1330 A C II, and 1400 A Si IV) and obtained a self-consistent evolution of the dissipated (free) magnetic energy during a major flare (2014 Mar 29, 17:48 UT). Since the forward-fitted NLFFF model represents an (approximate) solution of a force-free field based on vertical currents (which introduces helical twist to loops), a relaxation of the untwisting flare loops is detected consistently in both the chromospher/transition region and corona.

REFERENCES :

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Aschwanden, M.J., De Pontieu, B., and Katrukha, E.A. 2013, Entropy 15(8), 3007.
Aschwanden, M.J. 2013, The Astrophysical Journal Letters, 804, L20.

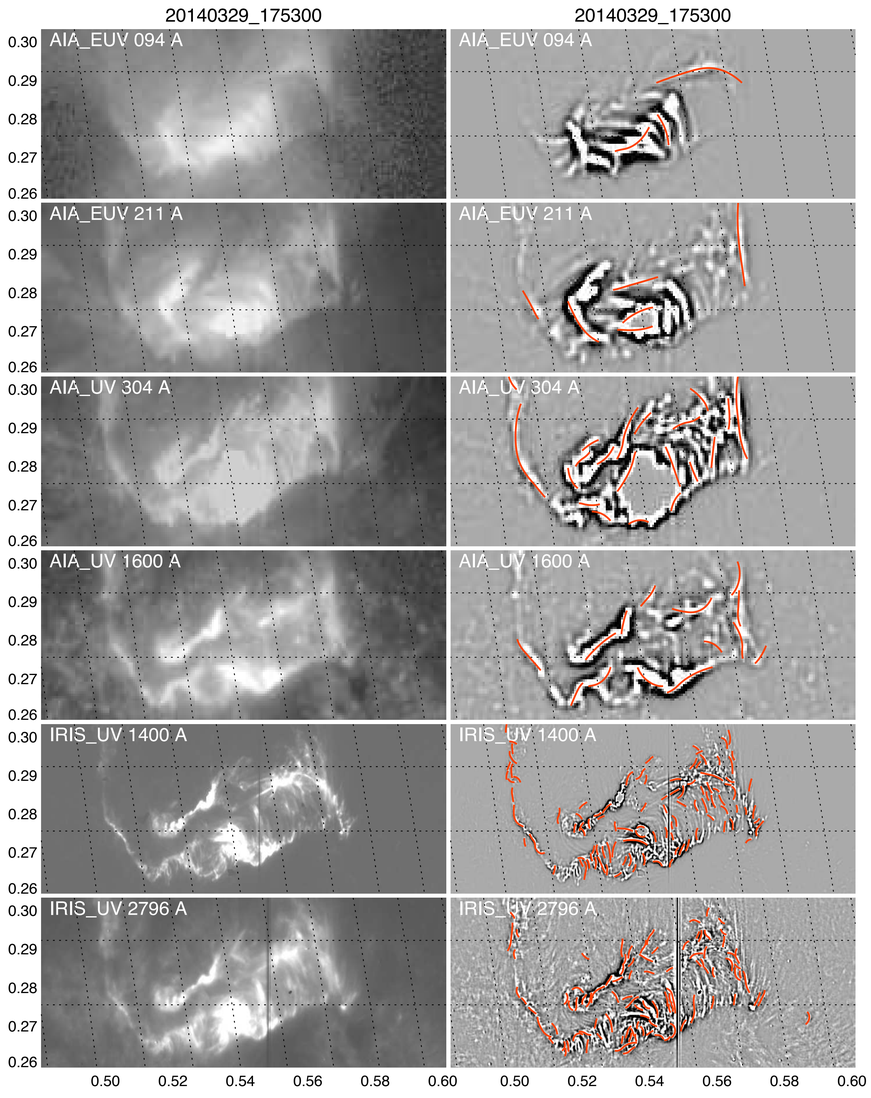

FIGURE 1 :

Original EUV and UV images are shown in intensity (left column) and as highpass-filtered fluxes (right column), with the overlaid loop segments automatically traced by OCCULT-2 (red curves in right panels). The six wavelengths include the least-saturated EUV images (94 and 211 A) of AIA, UV images of AIA (304 and 1600 A), and UV slit-jaw images of IRIS (1400 and 2796 A). Note the difference in spatial resolution (0.6" for AIA and 0.166" for IRIS).

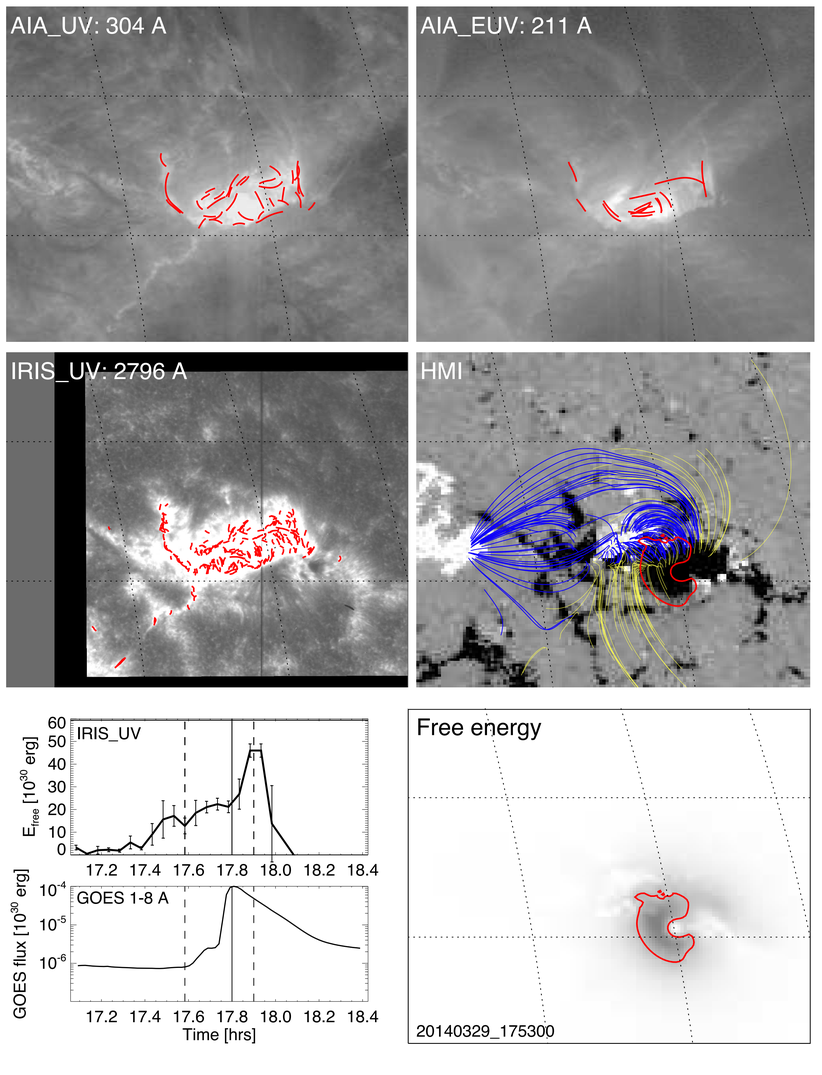

FIGURE 2 :

Highpass-filtered images from AIA 304 A (top left), AIA 211 A (top right), and IRIS 2796 A (middle left), with overlaid loop tracings using an automated pattern detection code (OCCULT-2: red curves), HMI magnetogram (middle right; with range $-1472 \le B_z \le 972$ G), with overlaid forward-fitted nonlinear force-free field lines (COR-NLFFF), delineating closed loops (blue curves) and open field lines (yellow curves), the spatial distribution of the free energy (bottom right), with a 50% contour level, the temporal evolution of the free energy measured from IRIS-UV (third left panel), and the GOES 1-8 A light curve (bottom left panel).

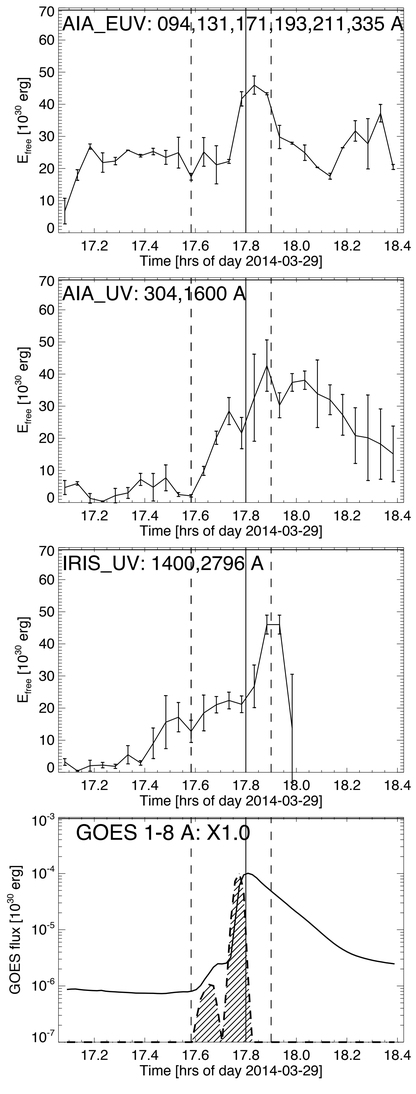

FIGURE 3 :

Time evolution of the free energy as measured from AIA in EUV wavelengths (top panel), from AIA UV wavelengths (second panel), from IRIS UV wavelengths (third panel), along with the GOES 1-8 A flux (solid linestyle in bottom panel) and GOES time derivative (dashed linestyle in bottom panel). The errors of the free energies are estimated from 3 different loop selections (fluctuation thresholds of 40%, 60%, and 80%.) The start, peak, and end time of the GOES event is indicated with vertical lines.