EVE Coronal Dimmings and their AIA Counterparts

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ABSTRACT: The EVE instrument on SDO detects post-flare dimmings, mainly in the spectral regions of Fe IX-XII in its MEGS-A range. Data are available for all of the 31 X-class flares that occurred between SDO launch and the end of April 2014. Based upon earlier X-ray observations we interpret these dimmings as the result of CME mass ejection from the low corona. The can exceed 10% of the pre-event emission from the whole Sun, with a broad spectrum of ionization states of Fe. The maximum dimming typically occurs more than one hour after GOES peak. The dimming signature is generally cleanly measurable in the EVE/MEGS-A spectral samples at 10 s cadence, with the dominant source of uncertainty stemming from the "sun-as-a-star" integrations; for example flare-related excess emission at a given wavelength tends to compensate for the dimming, and in this sense the mass estimate must be considered a lower limit. The AIA images also show the dimmings, but they differ from the signatures in the EVE spectral lines.

Background

Stepwise decreases ("depletions") in coronal brightness result from coronal mass ejections (Hansen et al., 1974); Skylab data revealed that these depletions correspond to transient coronal holes (e.g., Rust, 1983). The Yohkoh soft X-ray observations confirmed that similar dimmings occur in active regions and result from mass loss associated with the CME flow (Hudson & Webb, 1997). It turns out that the EVE/MEGS spectrometers can see these dimmings quite well (Mason et al., 2014), and in this poster we describe these EVE spectral-line dimmings and relate them to their AIA image counterparts.

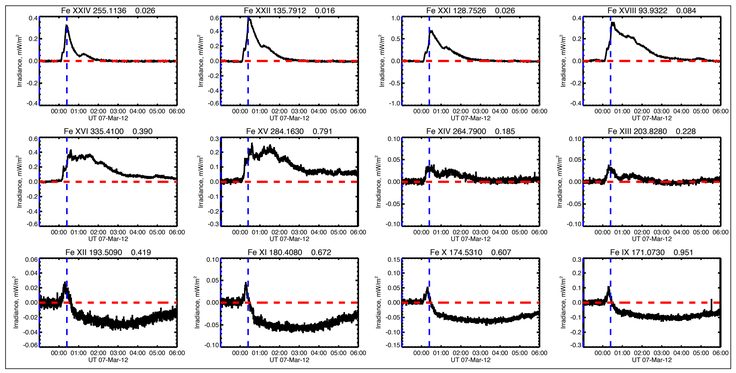

Figure 1: *"Fe cascade" plot for SOL2012-03-07 (X5.4), showing the many ionization states of iron as detectable by SDO/MEGS-A. The blue dashed line shows GOES maximum. The lower ionizations (Fe IX – Fe XII) show the dimming especially well; in this case, at Fe XI, it is about 10% of the total coronal brightness.*

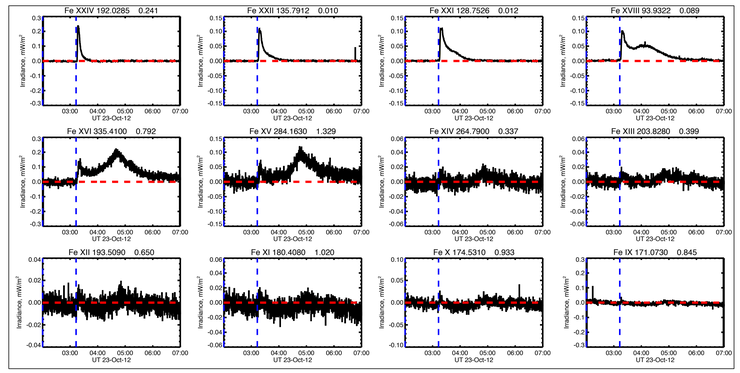

Figure 2: *"Fe cascade" plot for SOL2012-10-23 (X1.8, at S10E55), a clear example of an X-class flare with no dimming and no CME. Note the presence of an "EVE late phase" brightening (Woods et al., 2011).*

The "Fe cascade" plots

Plots such as that in **Fig. 1** and **Fig. 2** show EVE time histories for the various ionization states of Fe, ranging from Fe IX to Fe XXIV. In each panel the number at upper right is the preflare irradiance at line peak. No attempt is made to correct for blends, astigmatism, or Doppler shifts (Hudson et al., 2011). For X-class flares with CMEs, these plots reveal several things: the hot loops and their cooling cascade (high excitation), the impulsive footpoints (low excitation), and the CME-related dimming (low excitation) shows. **Fig. 3** shows charge-state distributions, reflecting broad DEMs..

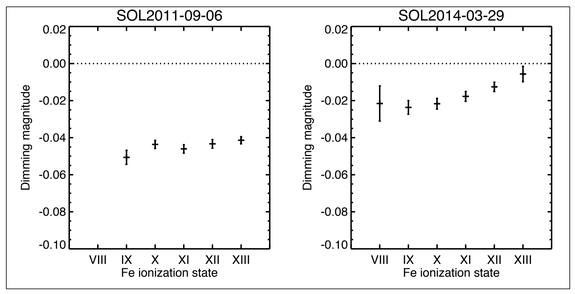

Figure 3: *Two selected dimming profiles, showing the fractional depletion of Fe lines observed by EVE. Not all are as well-behaved as these, and frequently Fe VIII and Fe XIII may not have clean signatures.*

A negative DEM??

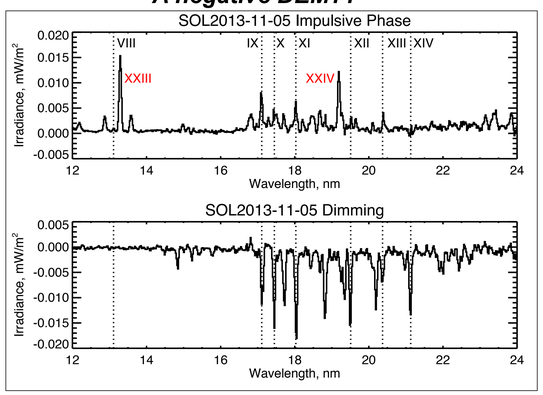

Figure 5: *EVE/MEGS-A difference spectra for the impulsive phase and the dimming phase (GOES max plus 1 hour) for SOL2013-11-05. The dashed lines show the strongest Fe VIII – Fe XIV lines, in order left to right, in the impulsive phase one also sees high-excitation lines. These suggest a broad DEM in the footpoint regions. The dimming signature clearly represents mass lost from the active-region loops previously existing in the active region. This mass probably forms a part of the CME mass.*

Some morphology

Fig. 4 shows the solar positions of the EVE dimming events;
Fig. 5 shows the correlation of dimming magnitude with GOES class.

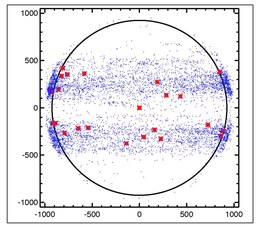

Figure 4: *Flare locations from the RHESSI catalog, with the X-class events shown in red.*

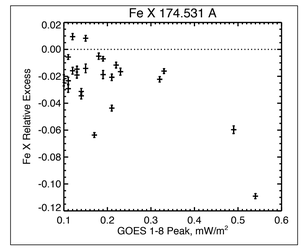

Figure 5: *Correlation of EVE dimming magnitude with GOES 1-8 A peak flux.*

What does AIA see?

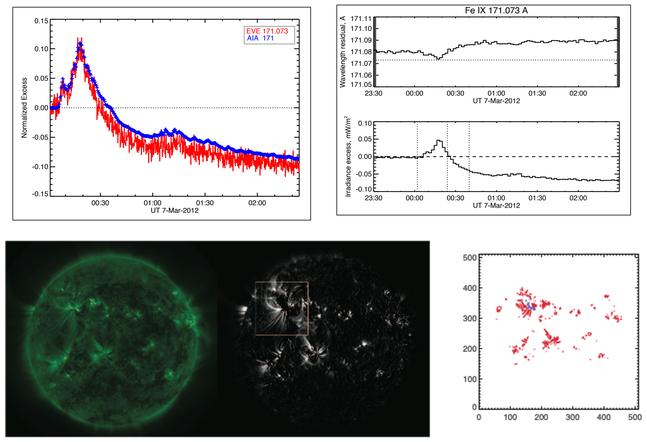

Figure 6: *The AIA view is complicated. The dimmings are confused by brightenings. The box shown around the active region itself shows a "negative dimming," possibly the result of free-free continuum from the flare loops. Upper right, EVE Fe IX, showing dimming and correlated wavelength shift. Lower, AIA view of the same event; the cutout box shows emission but the global pattern of bright and dark is confused (lower right panel shows the difference image, with the blue contour at the FWHM and the red contour at -5%).*

Conclusions

EVE/MEGS-A has given us a clear view of the CME mass injected from the low corona, but the AIA images complicate the picture. The association of dimming and CME occurrence is nearly 1-1 and correlates with GOES magnitude; the "negative DEM" of the dimming points to a broad temperatures and large masses.

Please volunteer if you'd like to help with the CME side of this survey!

References

Hansen, R. et al., PASP 86, 500 (1974) – Identification of depletions with CMEs
Hudson, H. et al., Solar Phys. 273, 69 (2011) – EVE spectral shifts
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