Global Energetics of Solar Flares

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Abstract

We determine the thermal energies of ~400 M- and X-class flares as part of a multi-study project to better understand the energy partition of solar eruptive events. We improve upon previous studies in the following ways: 1) We determine thermal energy using spatially resolved multi-thermal differential emission measures (DEMs) rather than relying on the isothermal assumption; 2) We determine flare volumes by thresholding these DEM maps rather than relying on single passband; 3) We analyze a greater number of events than previous studies. The flare thermal energies lie between $10^{26.8}$—$10^{32}$ erg. This is 2%—40% of the dissipated magnetic energy (Aschwanden et al. 2014). This is an order of magnitude higher than previously found, suggesting that flare thermal processes are more important than previously thought.

Method

1. Create DEM Map
   a. Divide AIA image centred on flare into “macro-pixels” of 4x4 pixels.
   b. Using the response functions of coronal AIA filters (94, 131, 171, 193, 211, 335 Å) find the Gaussian DEM (in log$_{10}$(Temperature)-space) which best fits the observations for each macropixel.
   c. Sum DEMs from all macropixels to get total DEM.

2. Determine Flare Volume
   a. Threshold DEM maps at $10^{23}cm^{-5}K^{-1}$ or 50% of the peak, whichever is lower.
   b. Flare area, $A$, is area greater than this threshold.
   c. Flare volume, $V$, is given by $V = A^{3/2}$.

3. Determine Flare Multi-Thermal Energy at Flare Peak Time

   Given by: $E_{th} = 3k_B V^{1/2} \int T(\text{DEM})^{1/2} dT$

Results

Fig. 1: DEM map built up from an AIA image by increasing number of macro pixels.

Fig. 2: DEMs at different times during a flare for varying number of macro pixels ($N_{\text{bin}}$). Note that it diverges from a Gaussian with increasing $N_{\text{bin}}$.

Fig. 3: Histogram of thermal energies for all flares in this study.

Fig. 4: Thermal Energies as a function of total dissipated magnetic energies from Emslie et al. (2012) (left) and this study combined with magnetic energies from Aschwanden et al. (2014) (right).

Conclusions & Future Work

- Flare thermal energies much greater fraction of dissipated magnetic energy than previously thought.
- Future studies will examine other elements of energy partition in solar eruptions to better determine their relative importance.

For more info see Aschwanden et al., ApJ, 2015

Fig 2: DEMs at different times during a flare for varying number of macro pixels ($N_{\text{bin}}$). Note that it diverges from a Gaussian with increasing $N_{\text{bin}}$. 