Comment on "Energy partition in two solar flare/CME events," by A. G. Emslie et al.

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Abstract. *Emslie et al.* [2004] have not correctly described the observations of the dominant term in flare energetics, namely the electromagnetic radiation. Earlier observations, now amply confirmed by new data from the SORCE[1] spacecraft, showed the total radiant energy to exceed the X-ray energy by a substantial factor. The inclusion of this additional term means that Emslie et al. cannot properly conclude that "...the coronal mass ejection has the dominant component of the released energy..." for the two flares they study.

1. Comment

By general agreement the energy of a flare and/or CME[2] comes from the coronal magnetic field. This energy, released by an unknown and largely invisible process, then appears in detectable forms as radiation and mass motions; the latter frequently include CME flows extending into the solar wind. As observations have become more comprehensive, research has attempted to characterize these components as accurately as possible; notable efforts in this respect appear in the *Skylab* and *Solar Maximum Mission* workshop series [*Sturrock*, 1980; *Kundu & Woodgate*, 1989, respectively], as well as in various research papers. The current paper by *Emslie et al.* [2004] represents an excellent next step in this process, taking advantage of recent much-improved observations such as those from RHESSI[3].

Unfortunately *Emslie et al* do not consider the dominant observed component of flare energy, namely that radiated in the visible and UV continuum. This greatly exceeds the energy instantaneously stored in the hot coronal plasma, the basis of the *Emslie et al.* energy estimate for the flare itself. Carrington's original observations of white-light flare emission, from the mid-19th century, showed immediately that electromagnetic radiation contains huge amounts of energy. Two of the best-studied sensitive signatures of solar flares, namely emission in Hα (chromospheric) and soft X-rays (coronal) have lesser and comparable radiant energies [e.g., *Thomas & Teske*, 1971]; either one comprises only 5-20% of the total radiant energy [*Hudson and Willson*, 1983; *Hudson*, 1991; *Shimizu*, 1994] or perhaps even less. The discrepancy in the *Emslie et al.* analysis clearly results from ignoring conductive losses from the coronal plasma. The energy resident in the hot coronal plasma at any given time represents only a part of the total as individual loops of the arcade evolve quasi-independently.

No controversy about the large energy involved in radiation exists observationally, even though the relevant UV observations remain surprisingly incomplete. Recently actual detections [*Woods et al.*, 2004] of the total irradiance of a solar flare by the SORCE spacecraft have appeared. *Kopp et al.* [2004] find a total radiated energy $U_R = 4.6 \times 10^{32}$ ergs for the X17 flare of 28 October 2004, which had an integrated GOES energy of 5.4×10^{30} ergs, based on the published start/end times and using the 1-8Å channel. We do not have total-irradiance observations for the flares analyzed by *Emslie et al.*. However this direct measurement indicates that the ratio of total radiant luminosity to X-ray luminosity L_{total}/L_X may approach two decades, significantly larger still than the factor 5-20 cited above.

Scaling the above result by GOES X-ray fluence (peak power × tabulated duration, for the 1-8Å band) to the two flares analyzed by *Emslie et al.*, we estimate total radiant energies U_R for these flares. Table 1 compares these values (U_R in boldface) with the *Emslie et al.* estimates of magnetic energy (U_B) and CME kinetic energy (U_K). The flare radiant energies match the CME kinetic energies within error estimates, and indeed each component roughly matches the total magnetic energy available as estimated by *Emslie et al.* [2002]. The error estimates themselves have large uncertainties for all of the entries; we cannot make an accurate estimate of the systematic uncertainties for any of the components at the present time.

Table 1. Energy Partition, $\log_{10}$ ergs[a]

		21 April 2002	23 July 2003
Magnetic energy	U_B	32.3 ± 0.3	32.3 ± 0.3
CME kinetic energy	U_K	32.3 ± 0.3	32.0 ± 0.3
Radiant energy	$\mathbf{U}_R$	**31.7**	**31.6**

[a] U_B and U_K estimates from *Emslie et al.* [2004]

2. Conclusion

The energy partition of a solar coronal disturbance still remains difficult to assess, but newer data (and theory) has sharpened our estimates of the energy components. Flares and CMEs each constitute large energy releases from coronal storage. In this Comment we have essentially added an estimate of the total radiant energy for the two events studied by *Emslie et al.* [2002], finding an approximate equality with the CME kinetic energy. We have no evidence that CME energy exceeds flare energy for major flare/CME events. contrary to the ("cautious") conclusion drawn by *Emslie et al.*: "First, it is clear that in both events the coronal mass ejection has the dominant component of the released energy...". Observations of flare radiant energy show instead that flare electromagnetic radiation has a comparable magnitude and that the CME does cannot have a dominant component of the energy partition.

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Notes

1. Solar Radiation and Climate Experiment

0148-0227/05/$9.00

2. Coronal Mass Ejection
3. The Reuven Ramaty High-Energy Solar Spectroscopic Imager

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