The energy partition in solar flares: current state, new observations, and new models

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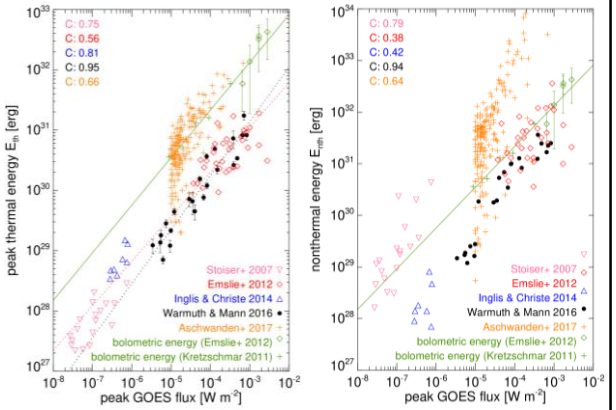
Flare energetics: the current state

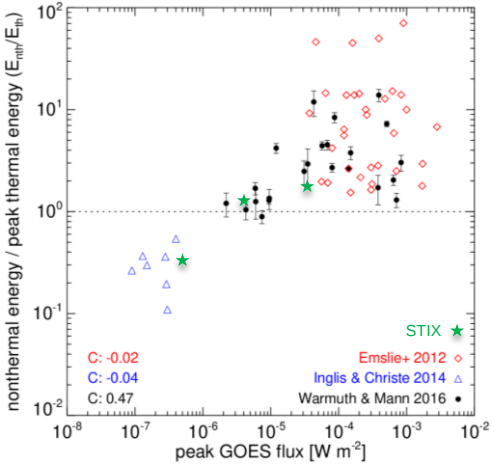
- Beam-driven evaporation is considered as the primary mechanism for generating the hot flare plasma.
- This should be reflected in energetics: input by nonthermal particles should be at least as large as the thermal energy of the plasma and its energy losses.
- However, recent studies using RHESSI, GOES and AIA data come to conflicting conclusions (electrons cannot/can/can easily heat the plasma).



- Thermal and nonthermal energies are plotted versus GOES peak flux (above) for five statistical studies we have recently evaluated (Warmuth & Mann 2020).
- The total bolometric energy loss (green) can be used as an independent constraint on energetics.
- Note discrepancies between different studies by up to an order of magnitude.
- Main reasons for discrepancies: determination of DEM distribution, importance of conductive losses, constraining the low-energy cutoff of accelerated electrons.

New observations: STIX on Solar Orbiter

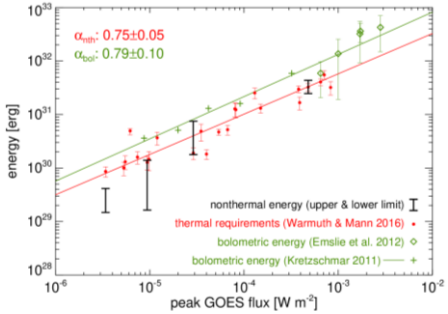
- STIX (Krucker et al. 2020) is an X-ray imaging spectrometer aboard Solar Orbiter providing diagnostics of thermal plasma and nonthermal electrons similar to RHESSI.
- Advantage of STIX: very stable background is beneficial for microflare studies.



- The fraction of nonthermal energy input by electrons over the peak thermal energy (above) as shown by previous studies has suggested a tendency for weaker flares to have a deficit of nonthermal energy input, albeit with a large scatter between studies.
- First results from STIX (three flares) confirm this tendency of changing nonthermal fraction.
- This implies both the need for an additional heating mechanism as well as an additional energy transport mechanism.

New models: warm-target

- Classical cold thick-target model only gives lower estimate of nonthermal energy input (since low-energy cutoff could be arbitrarily low).
- Recent development of improved warm-target model for inferring emission of energetic electrons (e.g. Kontar et al. 2019)
- Low-energy cutoff cannot get arbitrarily low (emission by thermalized electrons considered).
- Assuming thermal emission increase is solely due to thermalized energetic electrons, an upper limit on nonthermal energy input can be obtained.



- Preliminary result for four flares (above): upper limits on nonthermal energy from warm-target, lower limits from cold-target model.
- Even upper limits suggest there may be a deficit of nonthermal energy in weaker flares.

References

Kontar et al. 2019, ApJ 871, 225
Krucker et al. 2020, A&A 642, A15
Warmuth & Mann 2020, A&A 644, A172