Hot Onsets of Solar Flares: GOES-R

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We have found, using data from GOES-15 and earlier, that solar flares almost always commence at an elevated isothermal X-ray temperature of 10-15 MK (see the Simões contributed talk and the published paper, Hudson et al. 2021). Recognizing this effect requires delicate treatment of the GOES background signals, given that the hot onset appears at the very beginning of the flare when emission measure is minimal.

This poster describes a confirmation of the effect via use of the newer GOES-16 and GOES-17 data, which have much better data sampling at low (background) levels.

Nitty- Gritty

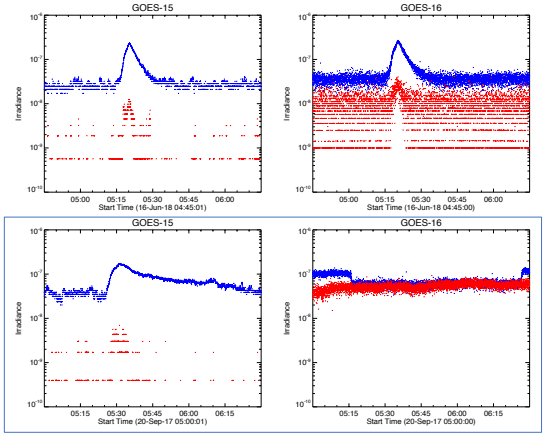
GOES-R Data Properties and Caveats

The well-known GOES XRS sensors (Machol & Viereck 2016) have now evolved to use Si photodiodes to generate signal currents, rather than the earlier ion chambers. These have slightly different responses but generally match the two spectral bands, nominally 1-8 Å and 0.5-4 Å, used to make the familiar Isothermal fits to volumetric emission measure and electron temperature. The figure below shows an arbitrary wee event.

GOES-R Caveats

What do we see in the data products at low flux levels, approaching these data as a naïve user of GOES-R/XRS (Machol et al. 2020)?

- GOES-15 has better irradiance sampling at low flux levels
- GOES-16 has better time sampling (1 s)
- GOES-16 has much higher background levels in channel A (short wavelength, high energy)
- The artifact at lower right is a (rare) eclipse (noted by C. Peck)
- High background in 0.5-4 Å may limit 1-s resolution to C class



Science

Two GOES-R Test Cases

The plots at the right show two test cases that confirm the published results for the hot onset phenomenon. We hope to extend this systematically and in particular hope to learn, from the new data, whether or not this precursor signature anticipates flare properties in any way or is consistent with other precursor signatures.

GOES/XRS fluxes

These panels show the XRS time series, with dashed lines (zero if not shown) at background times

GOES temperatures

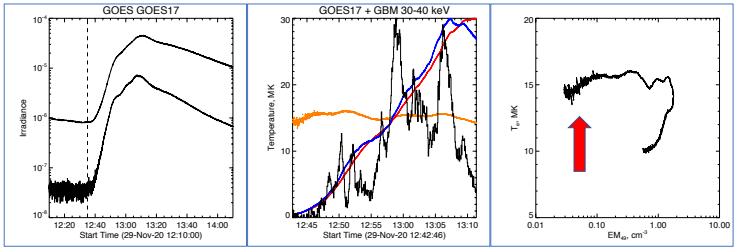
GOES isothermal T_e in gold, GBM 30-40 keV in thin black, with the GOES light curves.

Loopdeloop

Correlation of GOES T_e with volume emission measure for the isothermal fits. Red designates the hot onset.

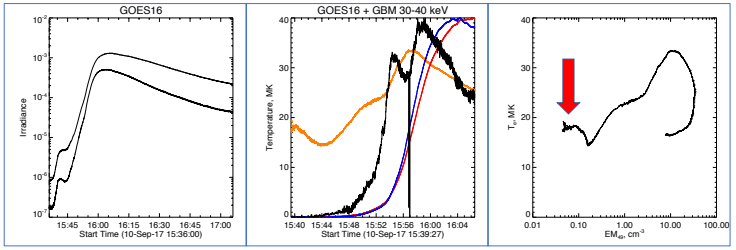
SOL2020-11-29

A typical M-class flare event. The hot onset appears prior to the hard X-rays (30-40 keV) as observed by Fermi/GBM, according to the pattern from the GOES-15 and earlier cases discussed in Hudson et al. 2021



SOL2017-09-10

This remarkable X10 flare has a huge literature already. It is not the best case for the hot-onset effect because of its limb location and because the high level of activity possibly confusing the GOES background estimation. As noted in the published paper, occulted events do seem to behave differently (with still higher onset temperatures), and this may also be a factor here.



Analysis issues

- The trickiest part of characterizing the hot onsets lies in the picking the background reference. But even then, the flare excess emission is fundamentally ill-determined even if the background is well behaved; Bornmann (1990) noted that the flare might actually alter the background sources physically. We do not think that this is the case ("What is there before a flare?" – *cf.* the Fletcher presentation at this meeting). This Sun-as-a-star problem largely vanishes when one has imaging (cf. the Simões presentation at this meeting).

- How distinct is the hot onset phase from the impulsive phase? This depends upon the sensitivity of the HXR observations, since the non-thermal bremsstrahlung signature is highly non-linear,

- This poster just sets the stage for a large-scale survey assessment, and we are grateful that GOES-R and Fermi/GBM data (plus others) are now copiously available as the Sun turns back on.

So what? And who cares?

I think that this is fundamentally interesting for the SolFER community, because it suggests energy transfer in a manner that may be inconsistent with the absence of HXR (non-"Neupertian"), but amenable to modeling. How can the T_e be regulated, with little sign of "heating" in the sense of finte values of $\dot{T} = dT/dt$, while the emission measure drastically increases? See the upper-rightmost plot above.

Bibliography

Bornmann, P. L., "Limits to derived flare properties…", ApJ 356, 733, 1990.

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