HOPE springs eternal

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Definitions: Onset vs. Precursor

There is a huge literature on "***flare precursors***", because of their obvious significance for physics and flare forecasting. Many phenomena appear under this umbrella term. The ***"hot onset"*** of a flare has a narrower meaning: a continuous slow increase of soft X-radiation prior to the impulsive phase. Hudson et al. (2021) showed that these onsets do not exhibit "heating' in the sense of increasing temperature. Flares almost invariably begin with high (of order 10 MK) isothermal-fit X-ray temperatures. See confirmations by Battaglia *et al.* 2023, da Silva *et al.* 2023, and Telikicherla *et al.* (2024) of the basic **HOPE** phenomenon (Hot Onset Precursor Event).

A "horizontal branch"

Figure 1 shows a beautiful HOPE example, and Figure 2 a more recent but not quite so simple one. The key to both is the diagnostic diagram following the joint evolution of T *vs.* EM as a flare develops. Jakimiec *et al.* (1992) studied this diagnostic as an aid in understanding flare loop simulations.

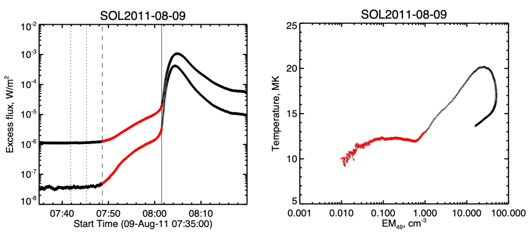

Figure 1: *Left, the GOES timeseries for SOL2011-08-09 (X6.9), showing a precursor increase that also appears as a* ***HOPE.*** *The vertical lines show background interval, thehot onset, and HXR onset. Right, the diagnostic diagram showing the evolution of the GOES isothermal fits.*

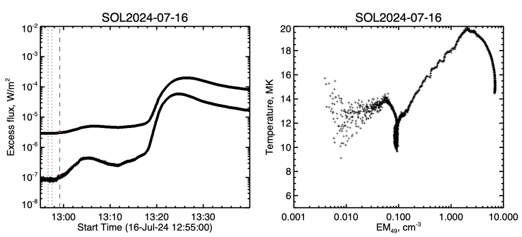

Figure 2. *A more recent example using GOES 1-s sampling. In this case the HOPE horizontal branch is confused by a discrete precursor burst, which often happens with Sun-as-a-star observations.*

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Poster layout

[1] Background
[2] New results and applications
- HOPE appears in "stealth" CMEs
- We can reliably anticipate flare occurrence
[3] Significance

Is HOPE truly universal?

Published results have revealed the ubiquitous presence of HOPE prior to solar flares above B class, and this is the basis for the "Flare Anticipation Index" described below. Figure 3 shows that CMEs with minimal low-coronal emission (the "stealth" filament-eruption events) also indeed have HOPE. So, "yes."

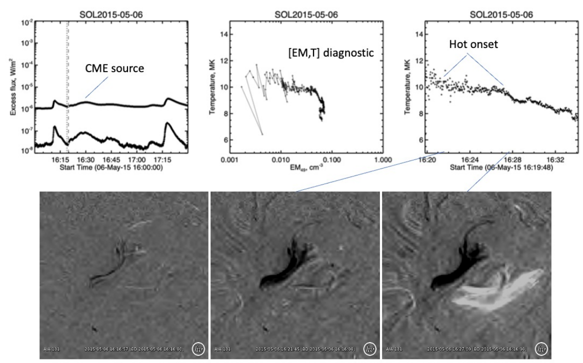

Figure 3: *An event with minimal GOES soft X-rays, but a major CME (Nitta et al., 2021). Upper panel, the GOES time and the diagnostic diagram. Top right shows that the HOPE temperature exceeded the flare peak. Lower panels show the AIA image development (base differences).*

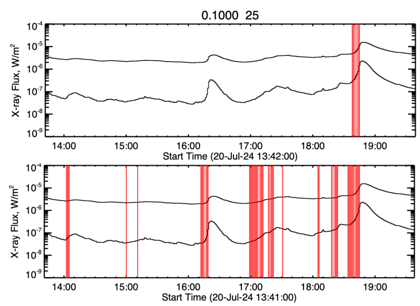

Figure 4: *The GOES-based "Flare Anticipation Index": upper panel, at an M-flare threshold; lower, for C class. This scheme gives 10-minute flare warnings and has no false positives or negatives at these levels (Hudson, 2024).*

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Significance

Because a HOPE phase always occurs, it seems likely that this process itself - the loading of the corona with slowly injected hot plasma, containing relatively little mass - actually reflects the fundamental instability of the flare process, and that everything else (particle acceleration, CME ejection, reconnection, and all of CSHKP) occur as secondary effects enabled by the development of this initial instability.

So what? And who cares?

There's a practical application here (the FAI; see Figure 4). But the main importance here is that the HOPE physics underlies all flare and CME activity, and so it should be a primary object of theoretical and modeling studies. It appears that HOPE was not foreseen by theorists, nor has it appeared (even if unanticipated) in numerical simulations.

Challenges:

1) What is the systematic nature of HOPE evolution, and why does it proceed so slowly?
2) What is the microphysics that regulates the electron temperature to a narrow range, and why can we not detect the actual *increase* of temperature?

What next?

The GOES soft X-ray views of HOPE have led the way, but have serious limitations. We next need to apply the full array solar observational tools, eventually to map out the HOPE magnetic-field signatures. This will not be easy!

References

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