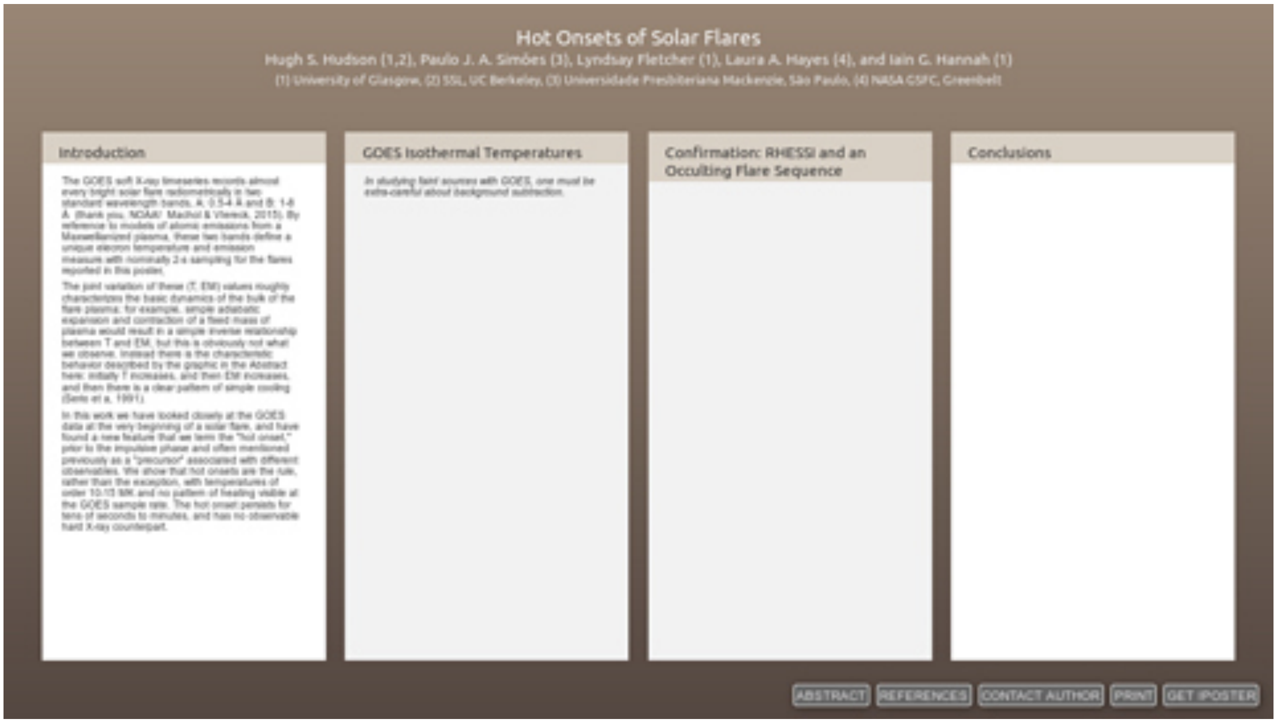
Hot Onsets of Solar Flares



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AGU FALL MEETING
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INTRODUCTION

The GOES soft X-ray timeseries records almost every bright solar flare radiometrically in two standard wavelength bands, A: 0.5-4 Å and B: 1-8 Å (thank you, NOAA! Machol & VIereck, 2015). By reference to models of atomic emissions from a Maxwellianized plasma, these two bands define a unique elecron temperature and emission measure.with nominally 2-s sampling for the flares reported in this poster,

The joint variation of these (T, EM) values roughly characterizes the basic dynamics of the bulk of the flare plasma; for example, simple adiabatic expansion and contraction of a fixed mass of plasma would result in a simple inverse relationship between T and EM, but this is obviously not what we observe. Instead there is the characteristic behavior described by the graphic in the Abstract here: initially T increases, and then EM increases, and then there is a clear pattern of simple cooling (Serio et a, 1991).

In this work we have looked closely at the GOES data at the very begnning of a solar flare, and have found a new feature that we term the "hot onset," prior to the impulsive phase and often mentioned previously as a "precursor" associated with different observables. We show that hot onsets are the rule, rather than the exception, with temperatures of order 10-15 MK and no pattern of heating visible at the GOES sample rate. The hot onset persists for tens of seconds to minutes, and has no observable hard X-ray counterpart. See Hudson et al. 2020 for full details.

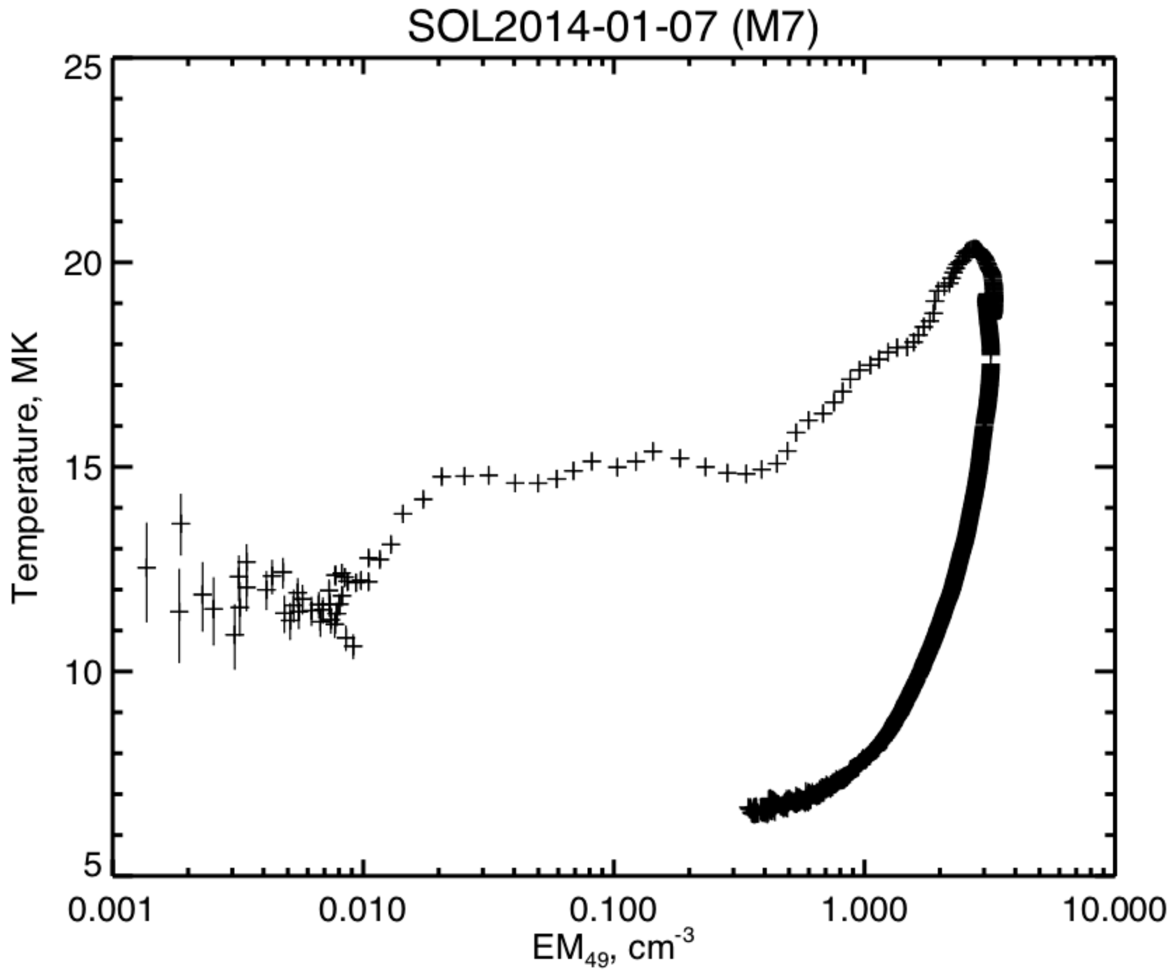


Figure 1: *Correlation of GOES isothermal temperature and emission measure for an M-class flare. Note the high temperatures at the very beginning (at left, the lowest emission measure). The lower right corresponds to the Serio et al. (1991) cooling track.*

GOES ISOTHERMAL TEMPERATURES

*I*n studying faint sources with GOES, one must be extra-careful about background subtraction. The example in Figure 2 show the problems off.

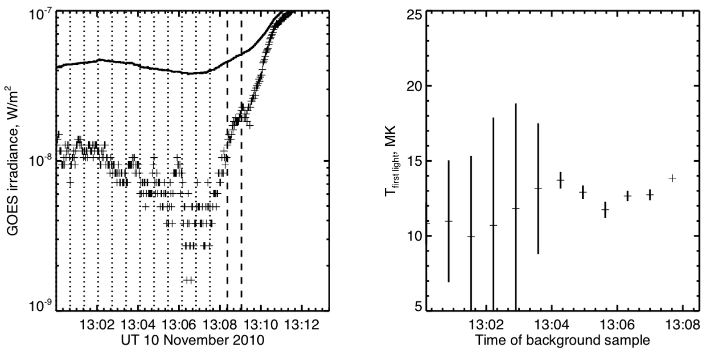


Figure 2*: On the left, the two GOES channels, showing the onset of a flare. The dashed lines show the "hot onset" interval at the beginning, and the dashed lines show a sequence of choices for the background subtraction. The right panel shows the derived temperatures, which stabilize when the background interval is closest to the measurement time*

The problem is that GOES is not an imager, and the 0.5-4 Å channel in particular is always varying. In an otherwise nice paper, Ryan et al. (2012) proposed the "TEBBS" method for GOES backgrounds, as illustrated in Figure 3. This does not work for hot onsets because it allows for a quiescent level of emission, rather than isolating the flare excess,

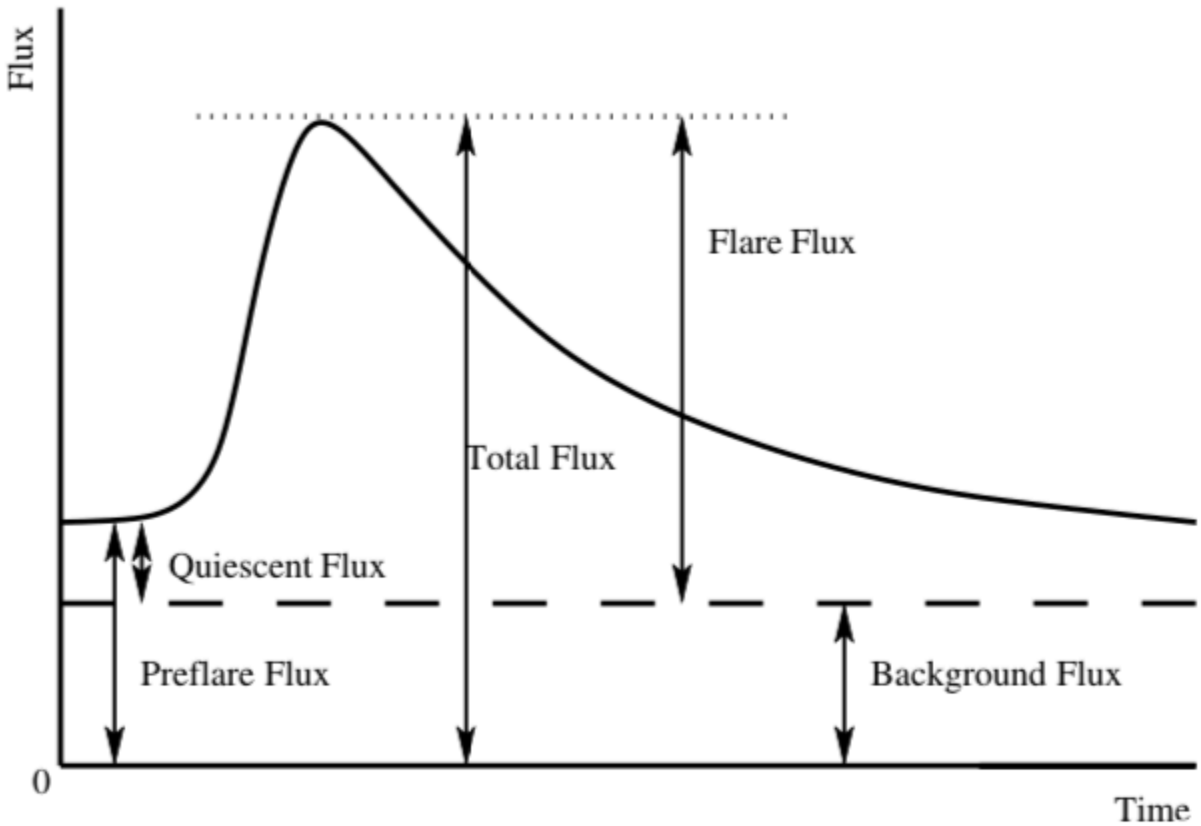


Figure 3: *The TEBBS method adds the flare excess signal to a pedestal determined from a daily minimum. This systematically biases the result that one would get for flare excess alone.*

CONFIRMATION: RHESSI AND AN OCCULTING FLARE SEQUENCE

The example flare shown in Figure 1, SOL 2014-01-07, is here in more detail in Figure 4, again showing the GOES data., and in FIgure 5, confirming the temperature evolution with RHESSI spectrum analysis.

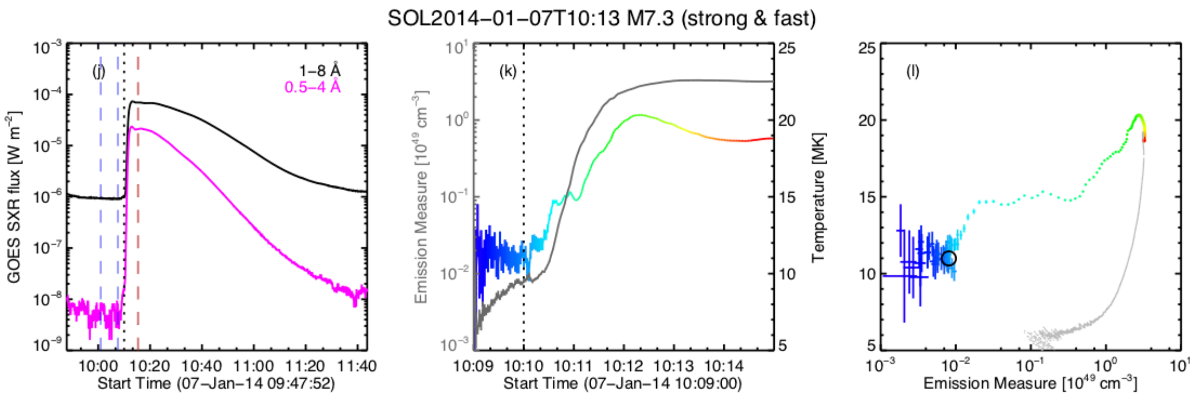


Figure 3: Left, the GOES irradiances; middle, time variations of the inferred temperature and emission measure; and right: same as Figure 1 but color-coded to match the time ranges.

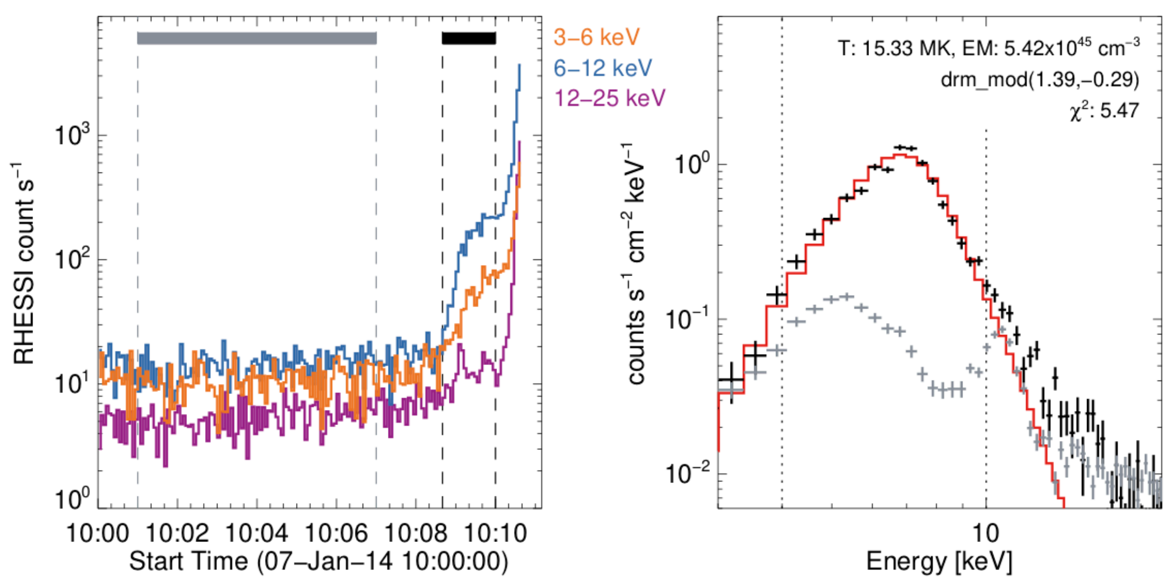


Figure 4: *RHESSI data for the same event. Left, the time series; right, the spectra at the epoch of the hot onset. The legend shows the thermal parameters, and the temperature agrees with that obtained from GOES.*

This comparison shows that the hot onset is not some weird artifact resulting from a misunderstanding of the GOES data, noting that this very useful database comes from an operational measurement, rather than from a research database with possibly better understanding of the instrument limitations.

As a further test of the ubiquity of the "hot onset" phenomenon, we looked at the flares in a single active region as it rotated into view at the E limb. Figure 5 shows that the initial temperatures dropped to the hot-onset level of 10-15 MK when the occultation revealed the lower-altitude flare components (footpoints and/or compact loops). The higher temperatures of the occulted flares can result from large-scale arcade loops.

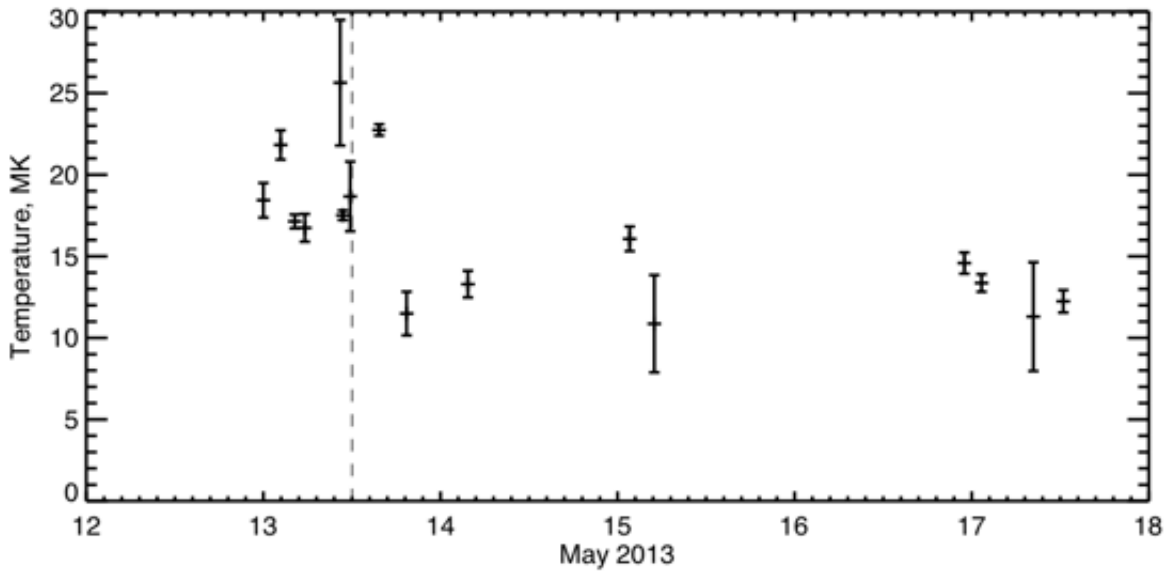


Figure 5: *Flares in an active region rotating across the E limb at the time shown by the dashed line. Earlier occulted events have hotter, large-scale loops; later fully visible flares have hot-onset temperatures of 10-15 MK.*

CONCLUSIONS - HOW IS MODELING INVOLVED?

The phenomenon we describe here, the "hot onset," appears to be the rule, rather than the exception, among flares of all types. A full survey is needed, but our present sample is 12/13 cases at least.

This hot material is not the result of thick-target beamed energy transport at a detectable hard X-ray level. Because it definitely precedes the impulsive phase, a different mechanism probably applies. How do we model this? None of the cartoons in http://www.astro.gla.ac.uk/cartoons/ (http://www.astro.gla.ac.uk/cartoons/) hint at its existence, and so some innovation may be needed.

Bulletization

• The "hot onset" looks like a ubiquitous feature of flare development

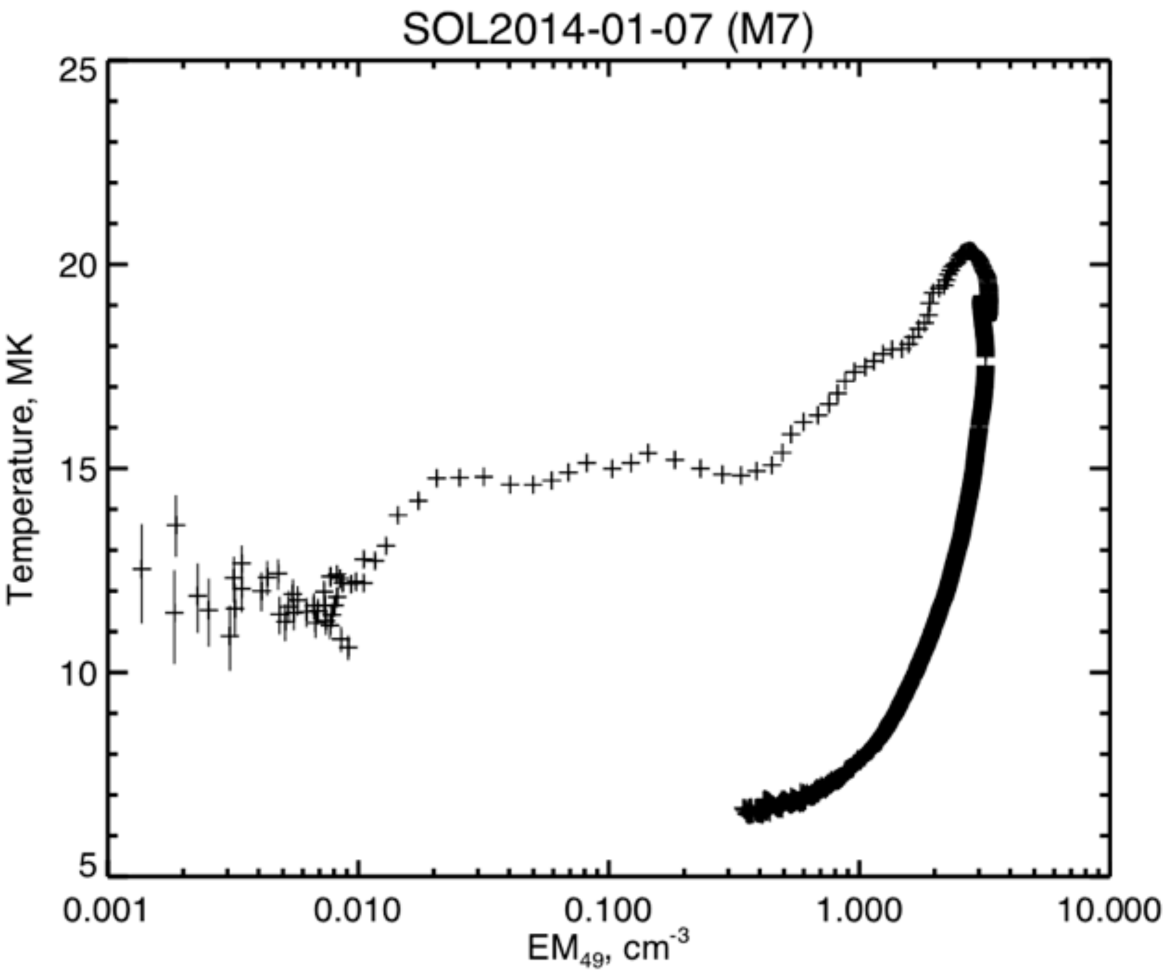
• At the earliest possible times, within GOES sampling, we see 10-15 MK already

• No theories currently exist*

*The paper is not actually accepted yet...

ABSTRACT

The study of the localized plasma conditions before the impulsive phase of a solar flare can help us understand the physical processes that occur leading up to the main flare energy release. We have studied the GOES soft X-ray data in flare precursors, prior to the hard X-ray onset, and find evidence that high-temperature plasma (10-15 MK) already has come into existence at these earliest times. We have confirmed the generality of this result for all classes of flares and checked the GOES isothermal temperatures for four events against RHESSI spectra. The use of AIA imagery and a limb-occultation flare sequence establish that these "hot onset" sources occur in or near the chromosphere. The absence of hard X-rays implies heating without particle acceleration. There is no indication of a gradual increase of temperature in the hot onset intervals, implying heating time scales below the temporal resolution of the data.



(https://agu.confex.com/data/abstract/agu/fm20/7/2/Paper_703527_abstract_670507_0.png)

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