solar orbiter

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On the existence of hot X-ray onset precursor events in solar flares

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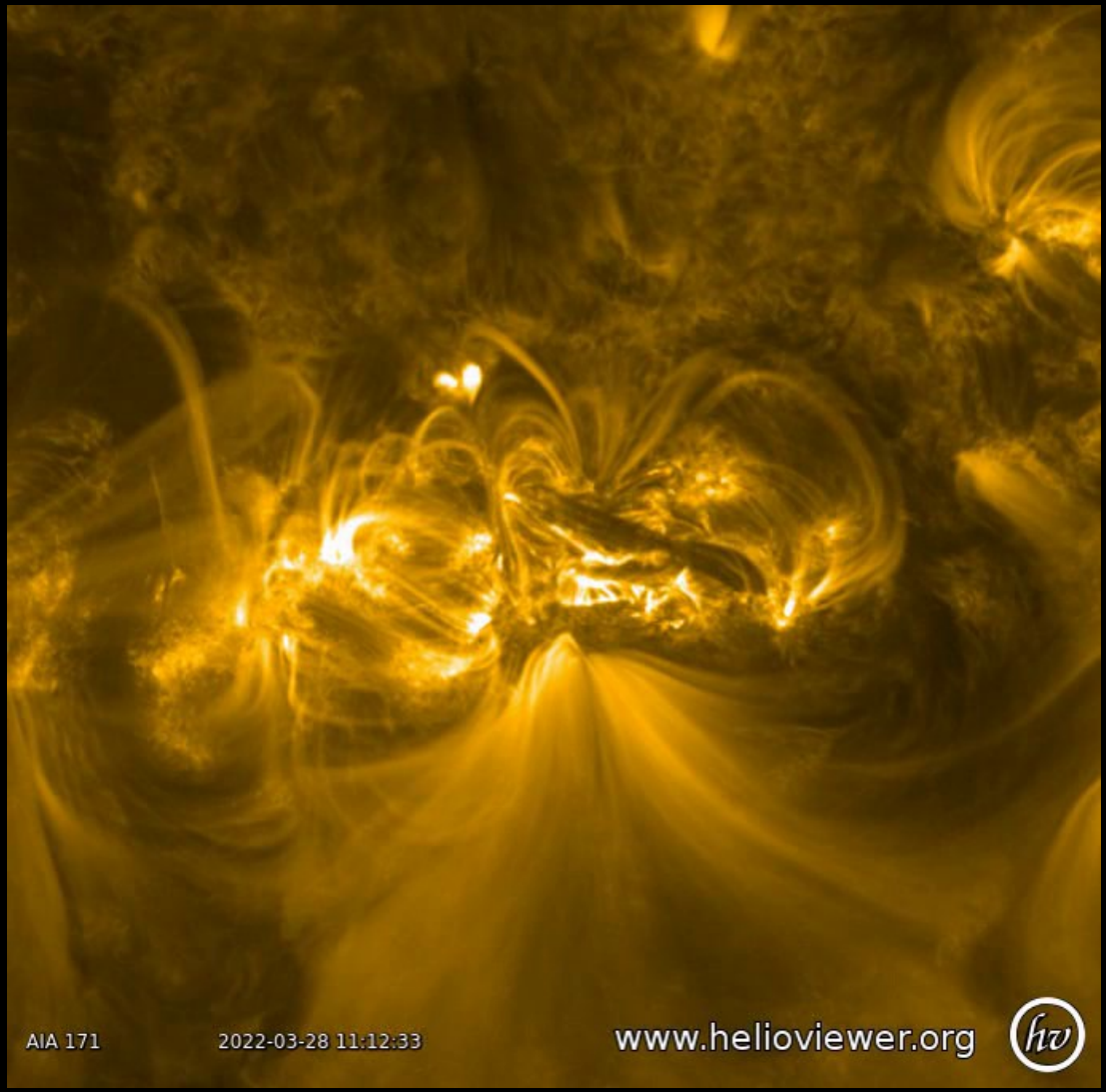
Credits: ESA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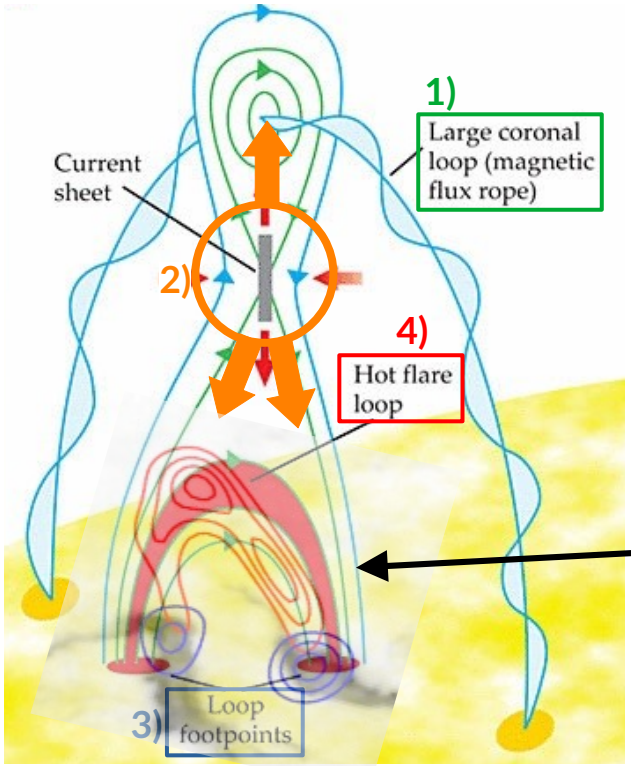
Introduction

The "standard„ flare cartoon



Holman (2012)

1) Rise of the flux rope (or filament)

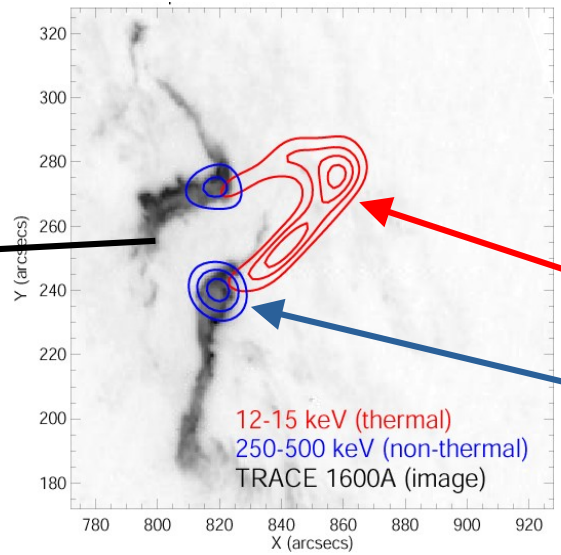
2) Magnetic reconnection and particle acceleration

3) Interaction with the *dense* chromosphere
→ Coulomb collisions: heating the ambient plasma

X-ray "non-thermal„ emission

4) "Chromospheric evaporation„
→ Heated plasma expands along flare loops

X-ray "thermal„ emission



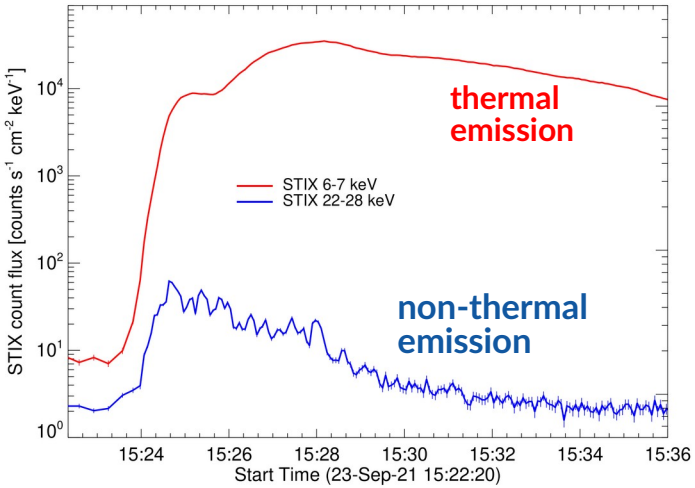
Production of X-rays via bremsstrahlung emission!

X-ray "thermal„ emission

X-ray "non-thermal„ emission

Introduction

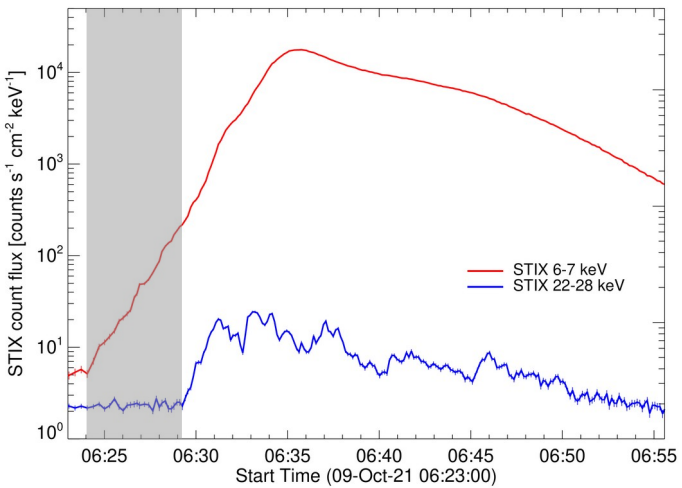
When does this energy release actually start, and in what form does it occur?
How is the energy transported?



Veronig et al. (2002)

503 flares in X-rays:
90% show clear pre-flare emission

pre-flare



Simultaneous increase of thermal and non-thermal emission

Pre-flare heating:

- Cannot be explained by lacking of HXR sensitivity (e.g., Benz et al. 1983; Jiang et al. 2006)
- *Thermal conduction*: heating in the corona → thermal conduction to the chromosphere (e.g., Dennis and Zarro 1993; Battaglia Marina et al. 2009)

Event Selection

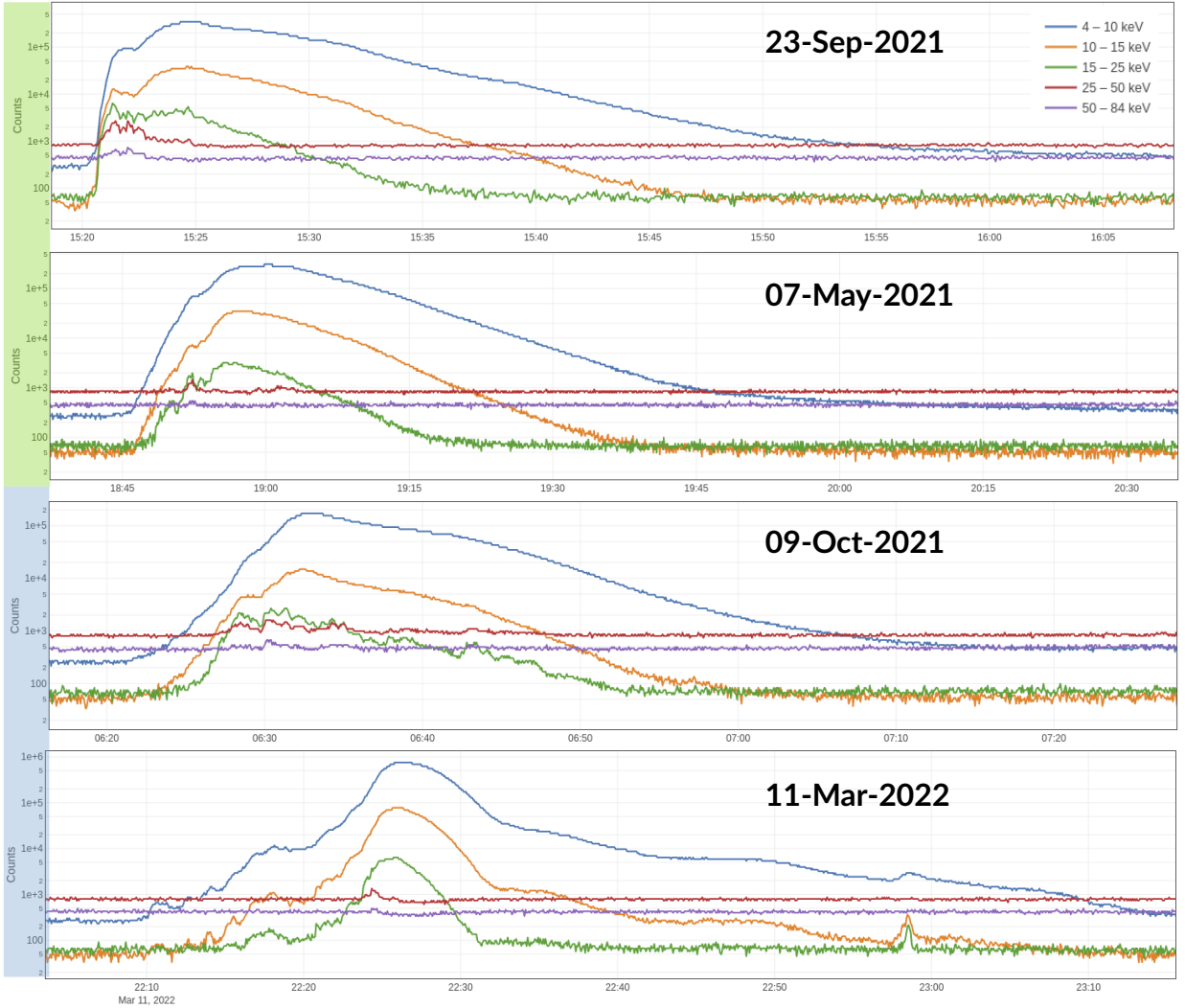
Selection criteria

- On-disk, jointly observed by STIX and GOES
- GOES class > M1
- Low solar activity (no simulaneous flares)

- Veronig et al. (2002):
  "*SXR emission starts on average 3 minutes prior the onset of the HXR emission*„

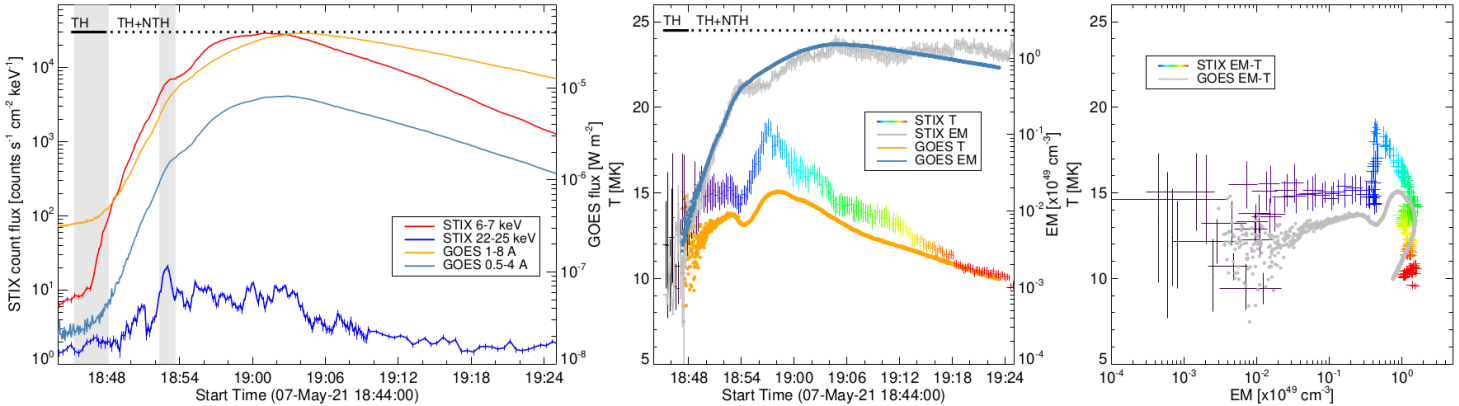
Flare	Pre-flare interval	Duration	GOES class
SOL2021-09-23	15:23:15 - 15:23:28	≤ 18 s	M1.8
SOL2021-05-07	18:45:55 - 18:48:40	165 s	M3.9
SOL2021-10-09	06:24:23 - 06:29:10	287 s	M1.6
SOL2022-03-11	22:14:03 - 22:28:08	845 s	M2.3

Battaglia et al. (in prep.)



Time Histories and Spectroscopic Analysis

1



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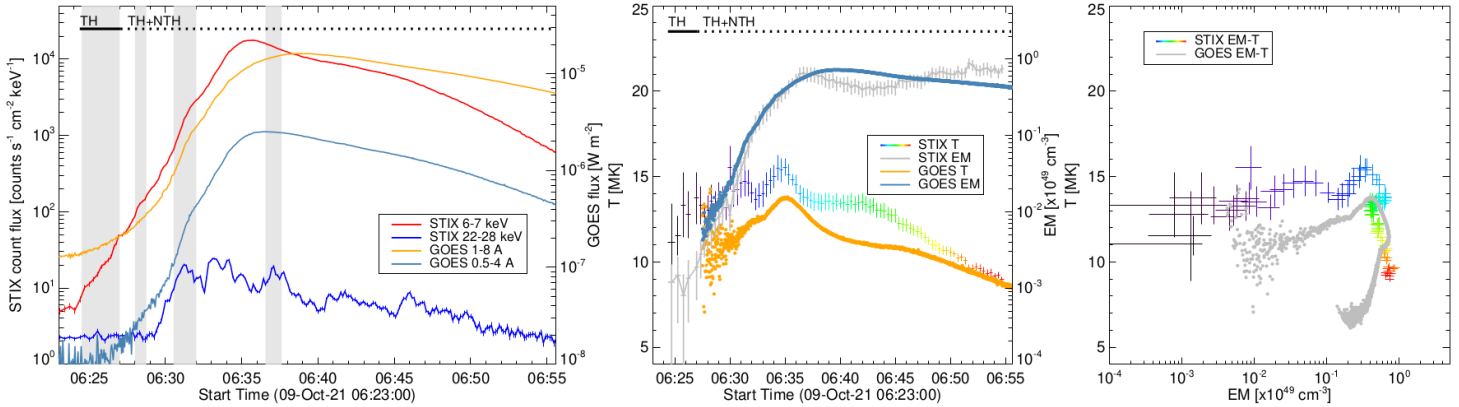
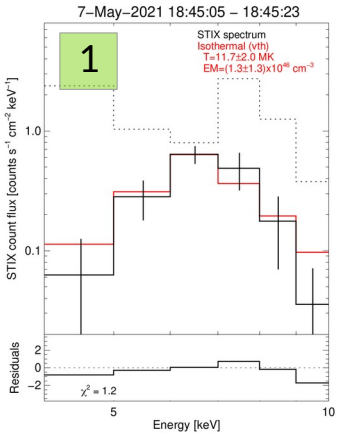
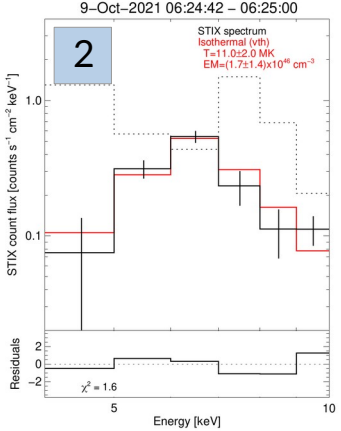




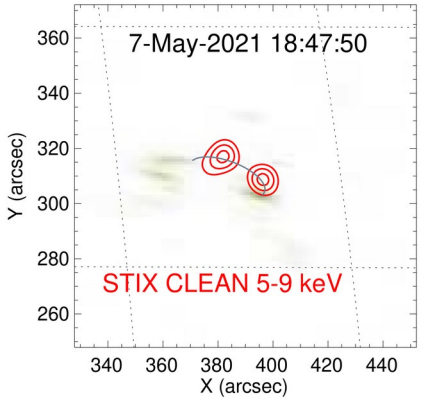


- Elevated temperatures since **the very beginning**
- Temperature → 10 – 16 MK
- Emission measure increases by ~2 orders of magnitude

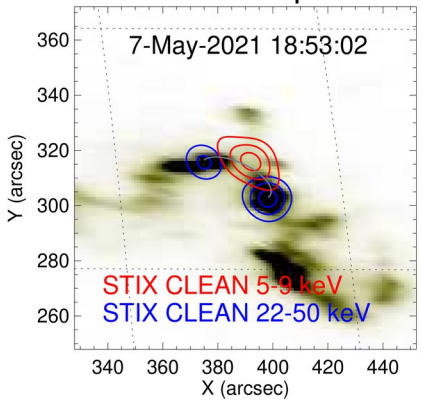
STIX Imaging of the Hot Onset Sources

Pre-flare interval < 3 min.

First few time-bins

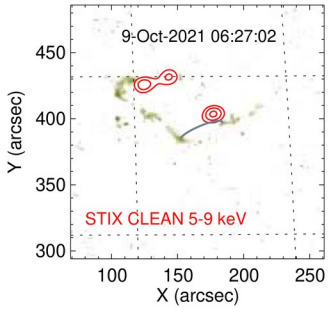


Nonthermal peak

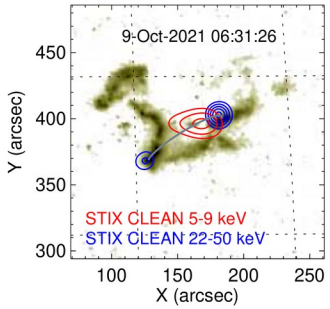


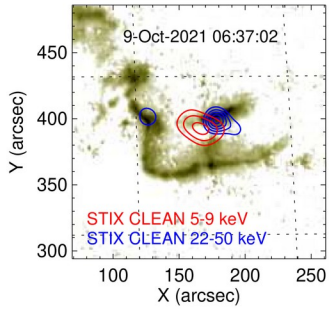
Pre-flare interval > 3 min.

Pre-flare interval



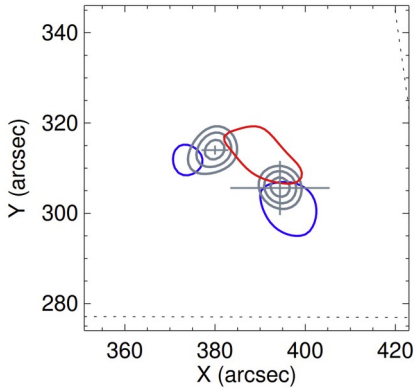
Around the nonthermal peak





Summary figure

SOL2021-05-07



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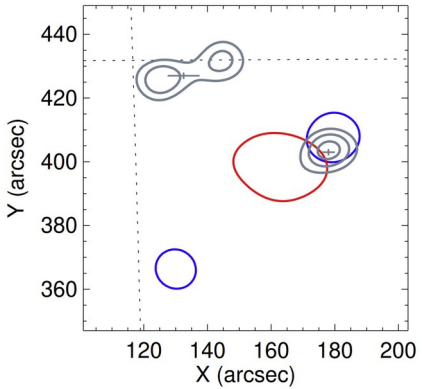


- Pre-flare sources at chromospheric altitudes
- Different from the thermal conduction interpretation

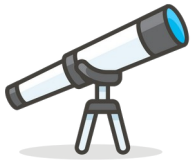
Conclusions and Outlook

- Elevated temperatures since the very beginning (10 – 16 MK)
- Emission measure increases by two order of magnitudes

In agreement with Hudson et al. (2021)

New from STIX observations: Pre-flare X-ray sources located at chromospheric altitudes

Based on typical active region temperatures (< 4 MK), there must be a phase *prior* to the detection in X-rays explaining these elevated temperatures. What is this phase?



Outlook

- What is the temperature distribution of these hot onsets?
- Is there any relation between the hot onsets and the non-thermal plasma velocity? (e.g., Alexander et al. 1998; Harra et al. 2013; Jeffrey et al. 2018)

THANKS FOR LISTENING!

Happy to answer any questions!