

# First joint NuSTAR and STIX X-ray observations of solar microflares

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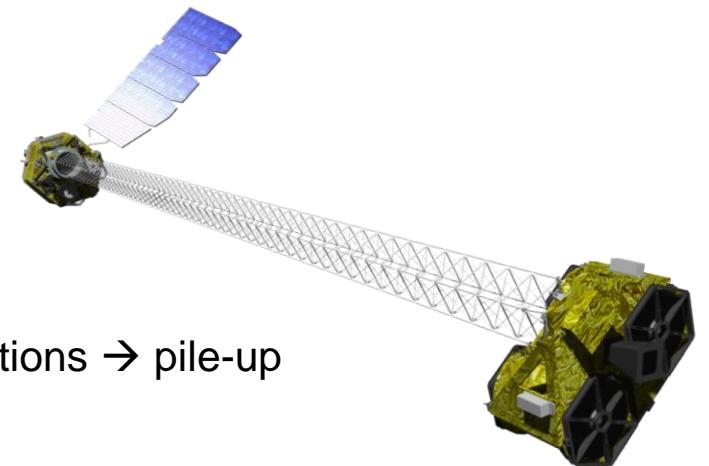
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# Introduction

- All events are on the limits of both instruments so need careful processing
- Motivation behind joint NuSTAR and STIX observations:
  1. **Better constraint on fitted model parameters**
    - NuSTAR has very good energy resolution at low energies
    - STIX doesn't suffer from pile-up (for GOES B class microflares) at higher energies
    - Cross-check instrumental calibrations
  2. **Observing the same event from different viewing angles**
    - NuSTAR is in geostationary orbit and STIX is in an elliptical orbit around the Sun-Earth line
    - Possibility of observing both the X-ray coronal source and the X-ray footpoints

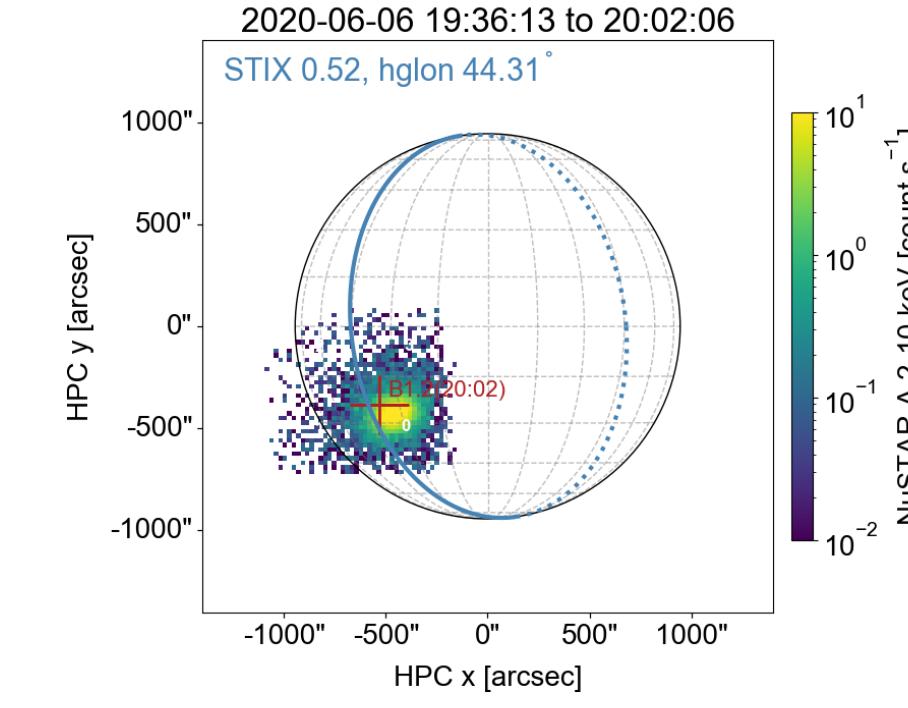
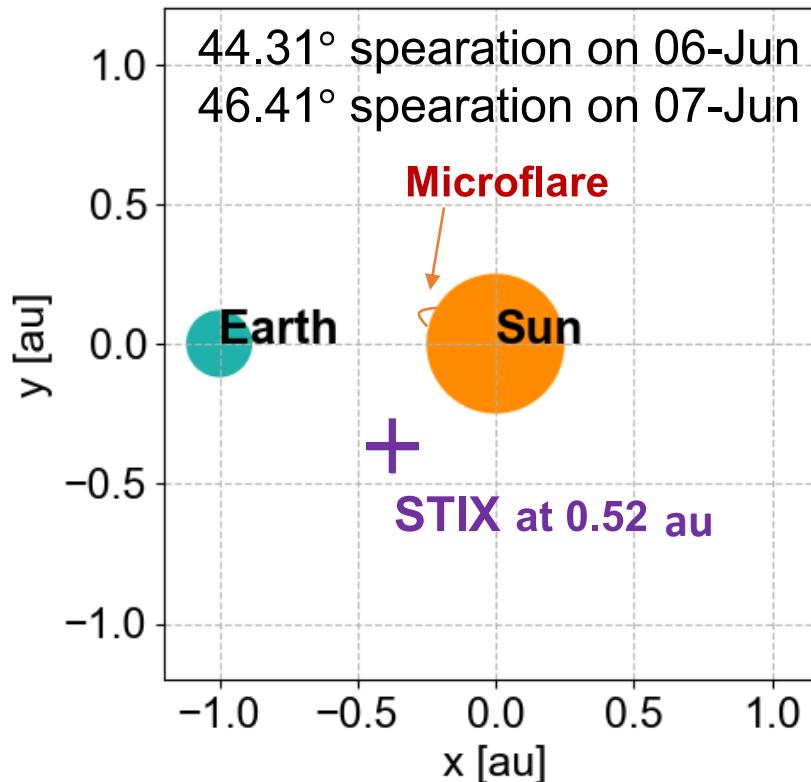
# NuSTAR: Nuclear Spectroscopic Telescope ARray

- Sensitive HXR focusing telescope capable of observing the Sun above 2.5 keV
- Two focal plane modules (FPMA&B)
- Limited FOV to  $12' \times 12'$
- An astrophysical focusing optics spectrometer
  - Limited throughput to 400 cts/s/detector → low livetime during solar observations → pile-up
  - Pile-up for Higher GOES A and lower B class microflares
  - Event rejection from mid GOES B class
- Observes active regions and quiet sun

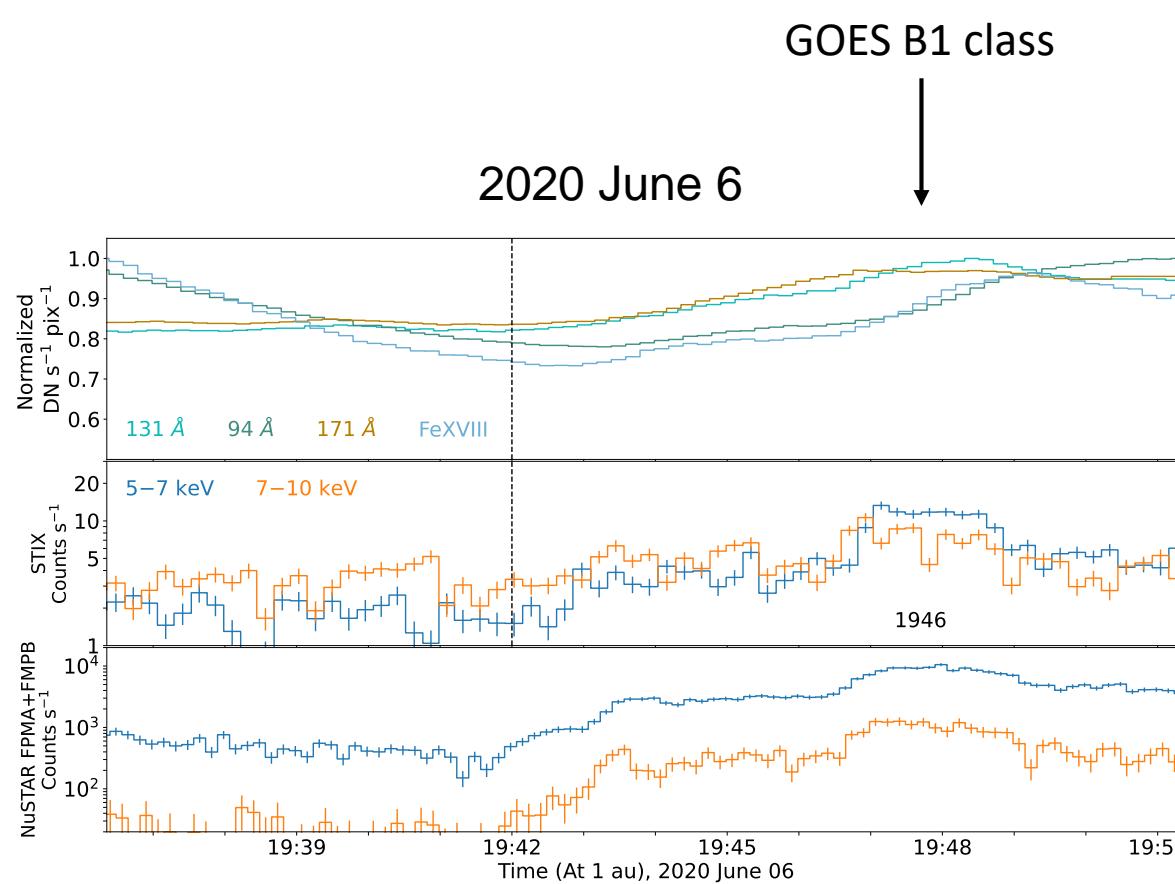


# Overview of the joint observations

- Repeated flaring activity from active region AR12765

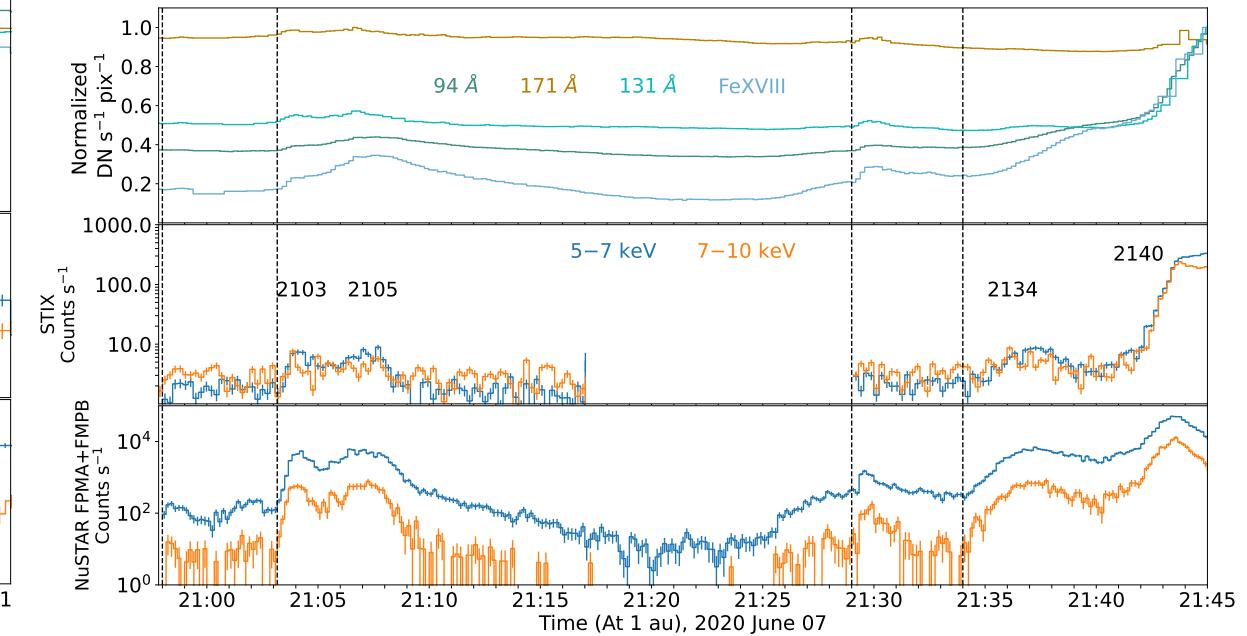


# Overview of the joint observations



GOES A7 class

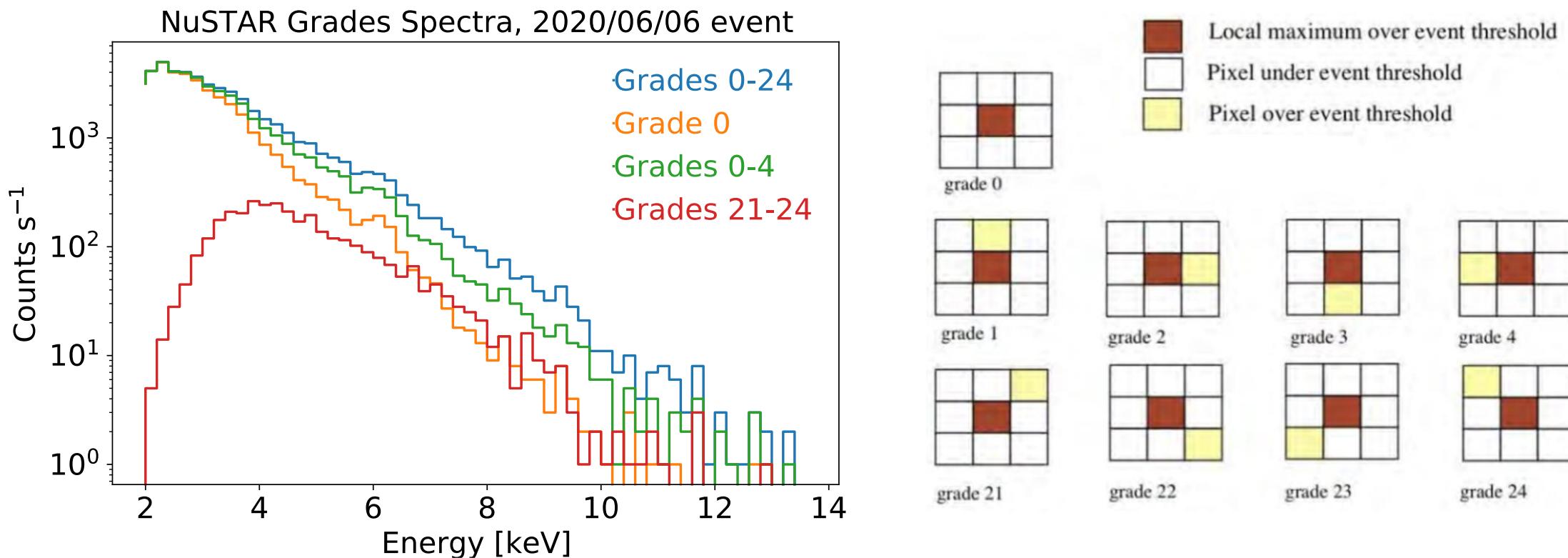
2020 June 7



GOES B6 class  
 \*Highlighted region is  $\sim$  GOES B2

# Pre-fitting processing

- Due to <1% NuSTAR livetime, all NuSTAR had to be pile-up and gain corrected



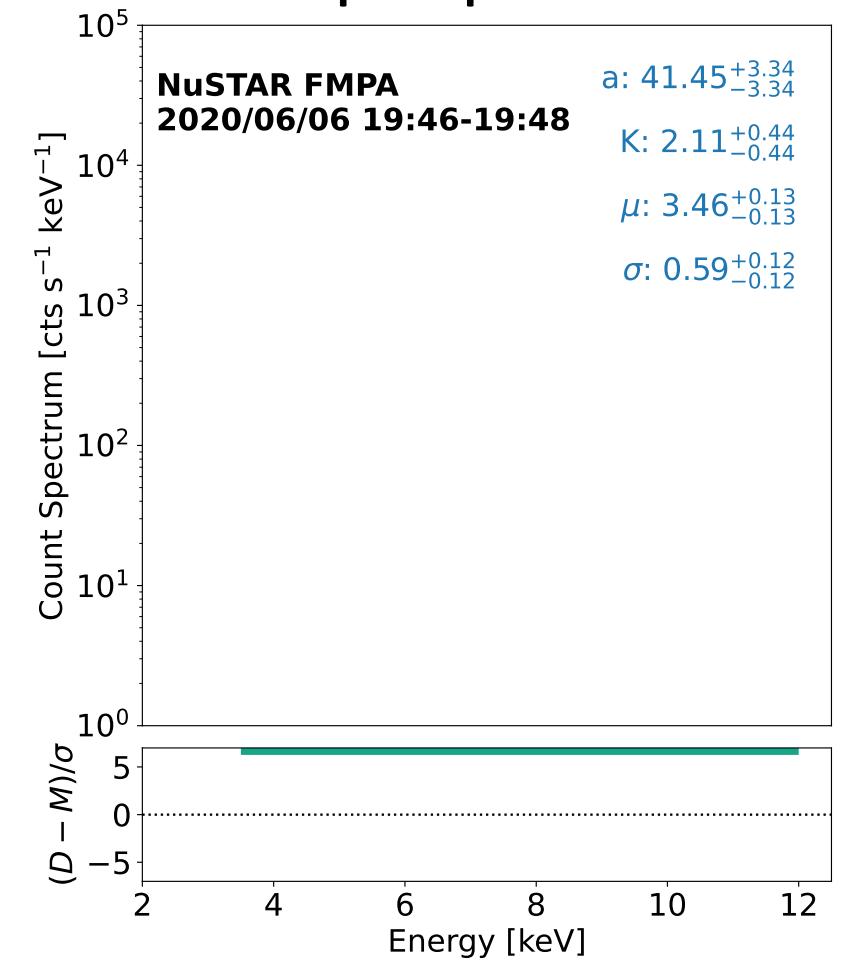
# Pre-fitting processing

- Example of NuSTAR pile-up model from the June 6 event

$$f(x; \mu, \sigma, \lambda) = a \left( \frac{\lambda}{2} e^{\frac{\lambda}{2}(2\mu + \lambda\sigma^2 - 2x)} \operatorname{erfc} \left( \frac{\mu + \lambda\sigma^2 - x}{\sqrt{2}\sigma} \right) \right)$$

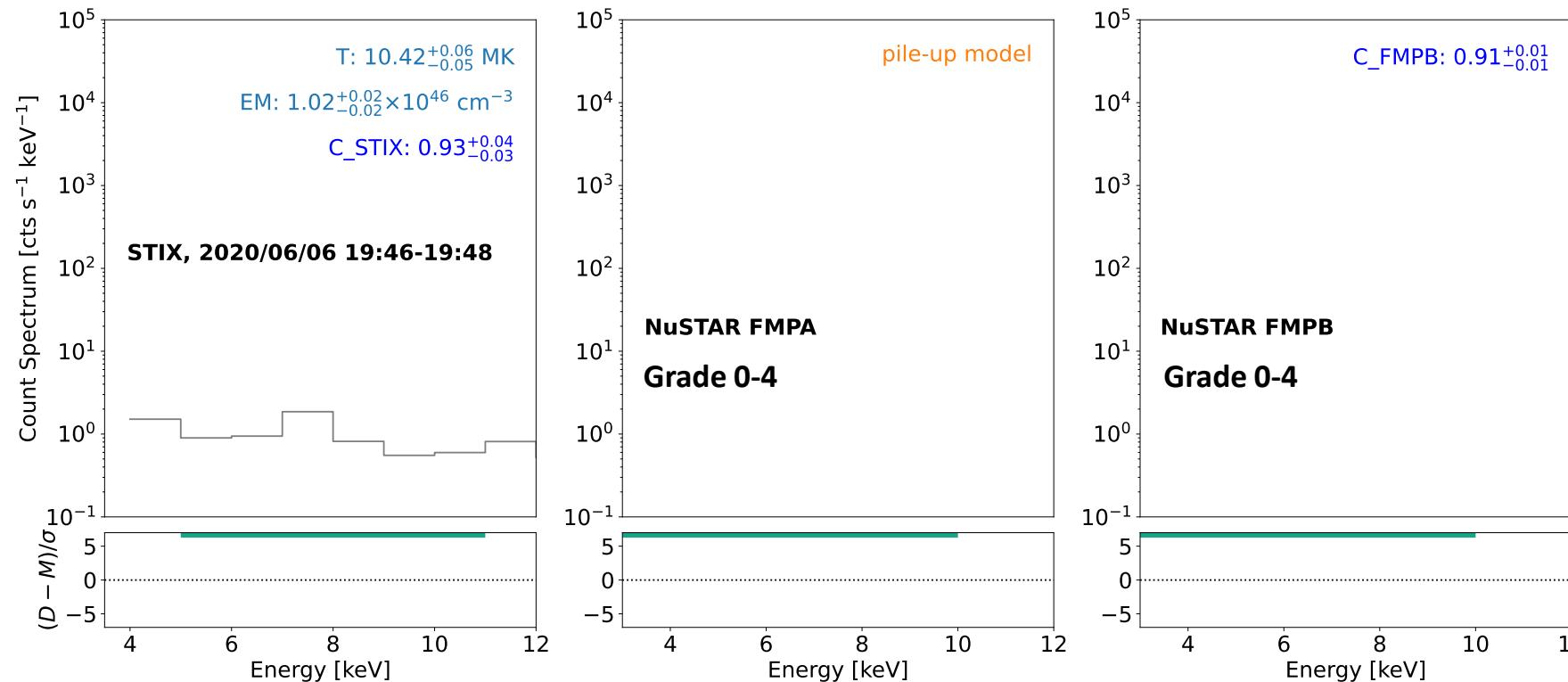
- Pile-up model is scaled by a 5/4 factor during grade 0-4 spectral fitting

NuSTAR Grade 21 -24 spectrum  
used for pile-up correction



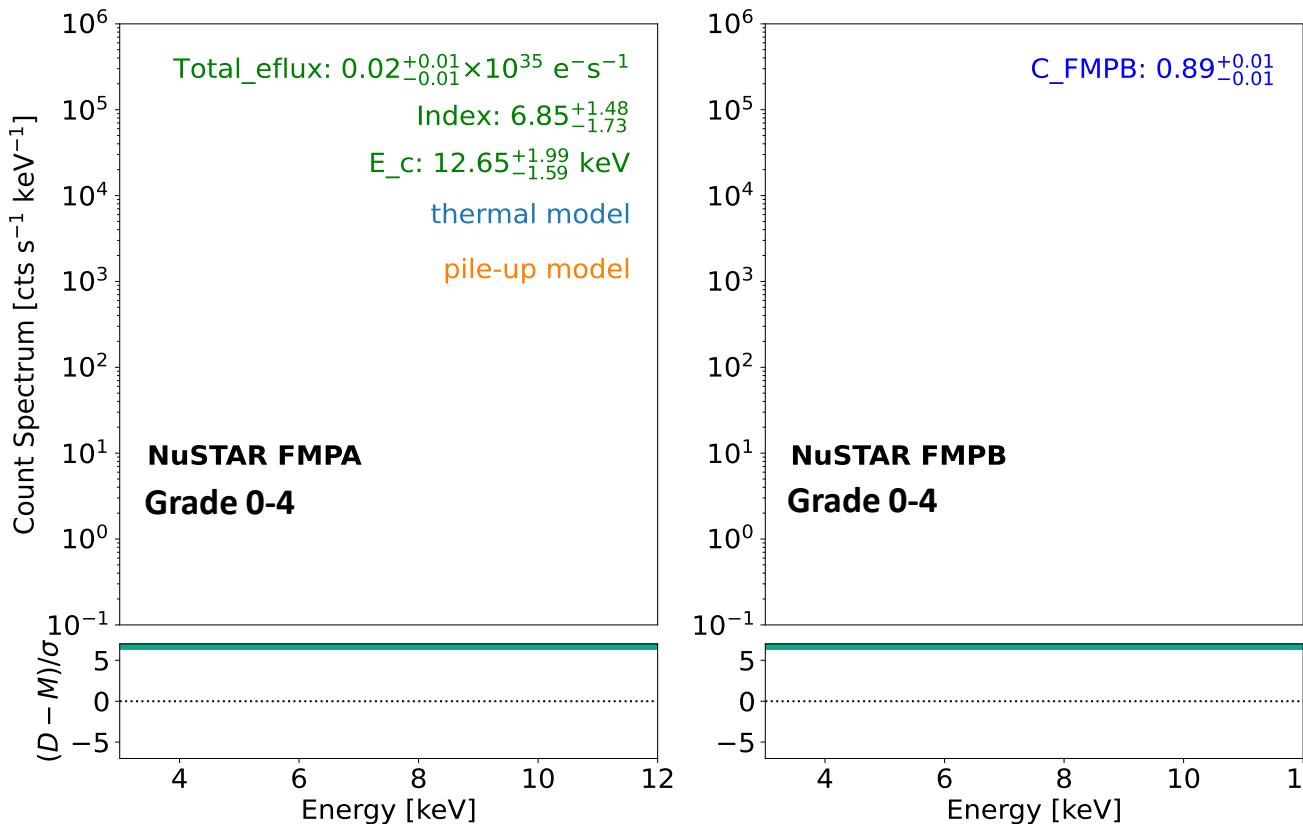
# June 6 microflare joint single isothermal fit

- Limited STIX energy range, therefore could only fit single isothermal
- C\_STIX = model scaling factor with respect to FMPA

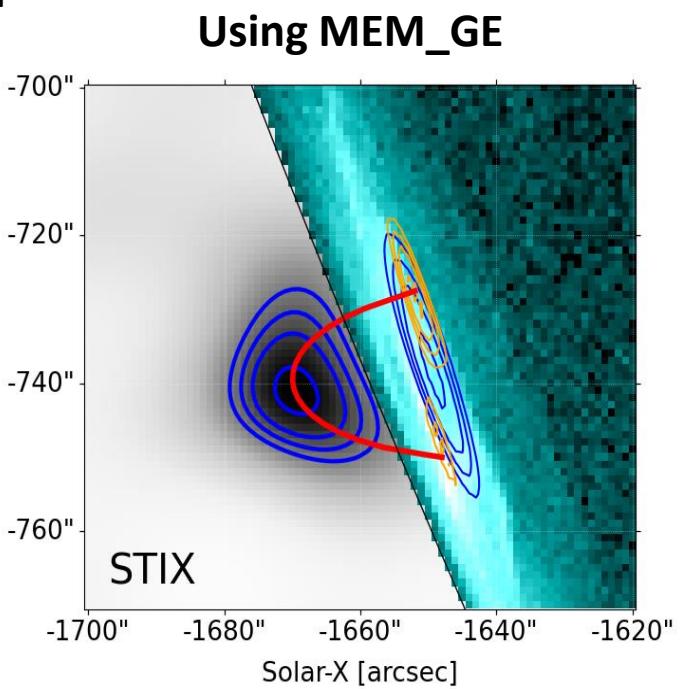
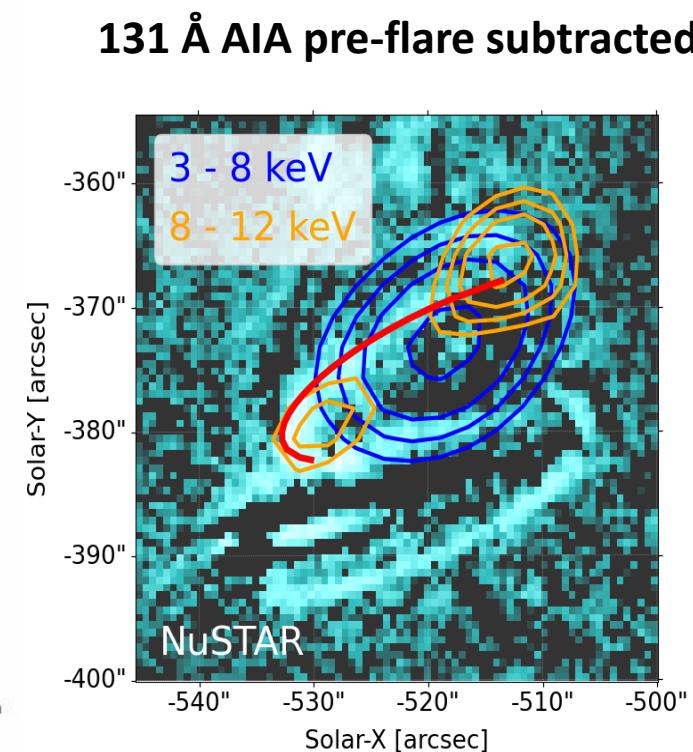
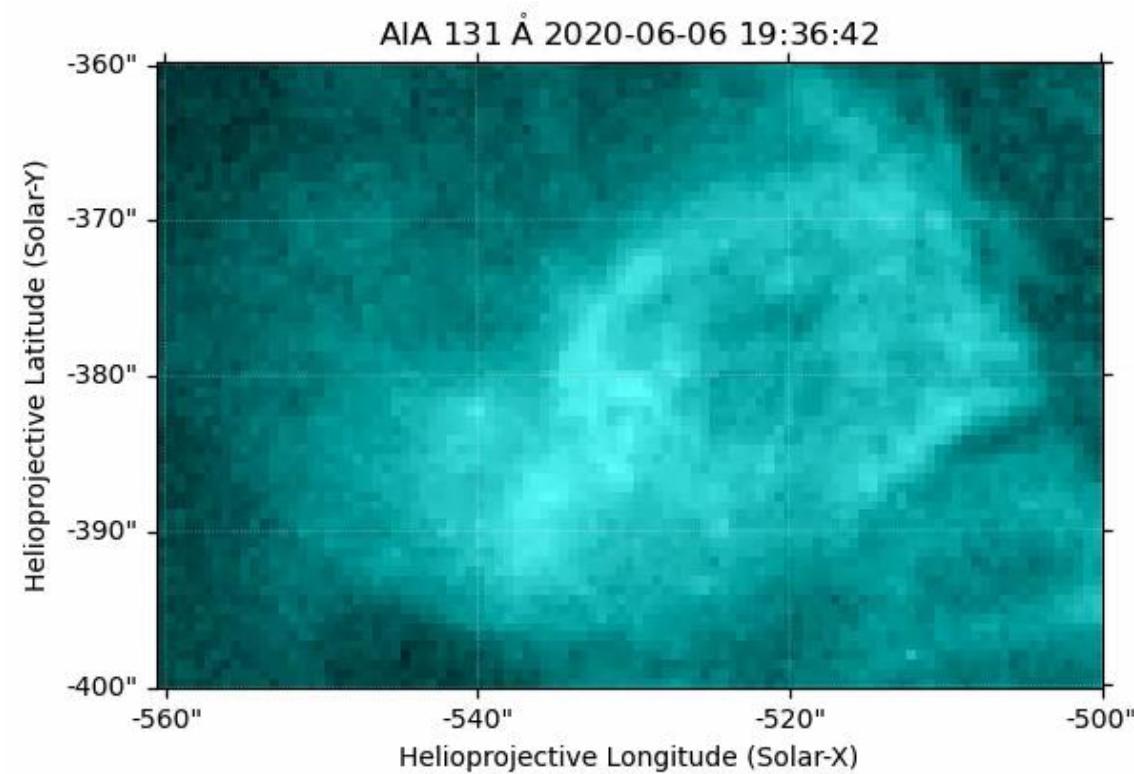


# Adding non-thermal to STIX

- Using the T and EM values found with joint fitting as fixed parameters and fitting thermal + non-thermal + pile-up to NuSTAR only:

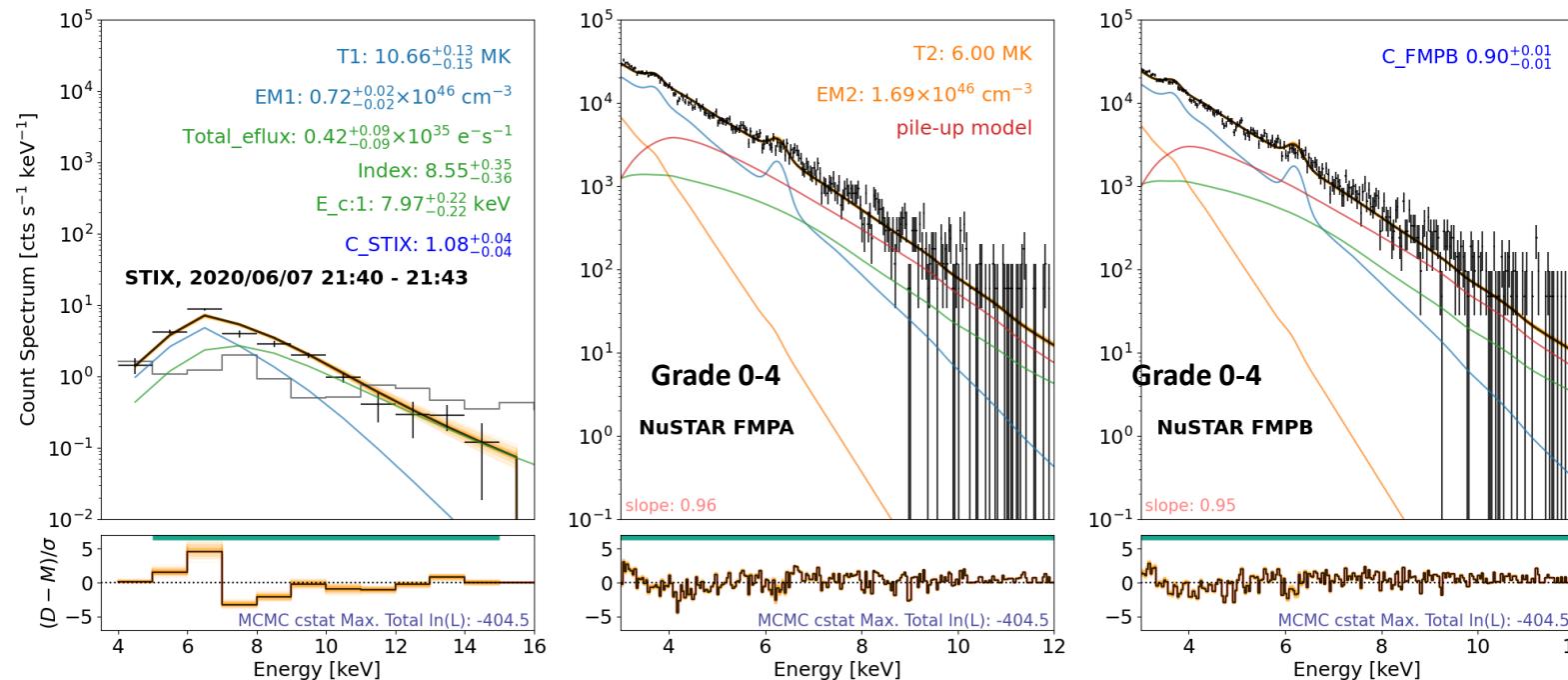


# June 6 microflare joint imaging

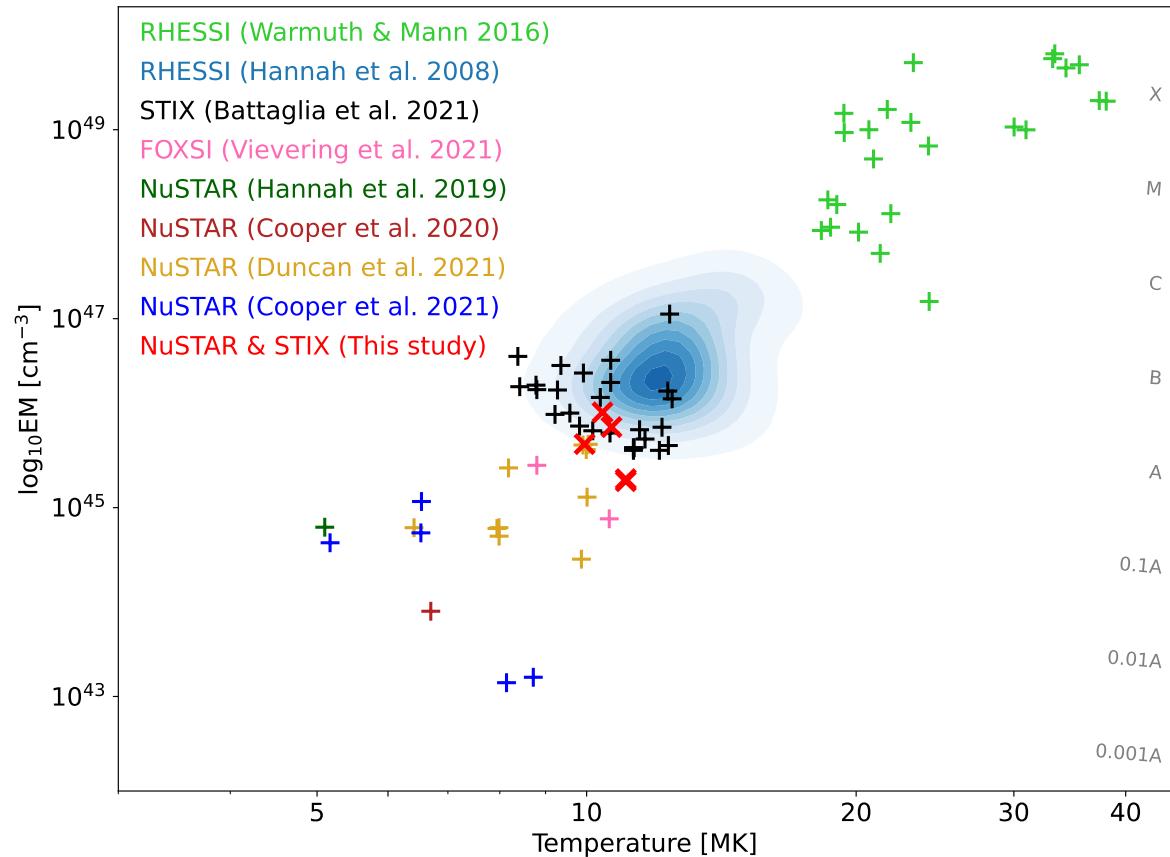


# June 7 microflare joint isothermal + thick-target fit

- Only impulsive part of GOES B6 class microflare as futher NuStar counts rejected
- Only event with STIX up to 15 keV
- NuSTAR's 6.7 keV Fe line is smoothed out by pile-up



# Model parameters from the joint fits in the context of other microflares



## Non-thermal thick-target parameters:

Electron flux:  $0.2 - 5 \times 10^{35} \text{ e}^- \text{ s}^-$

Low energy cut-off: 8 – 12 keV

Index: 5 – 9

Non-thermal power:  $10^{25} - 10^{26}$

Within RHESSI  
microflare  
parameter range

**C\_STIX with respect to FMPA: 0.93 – 1.10**

# Conclusion

- Model parameters consistent with other microflare observation
- $C_{STIX} < 10\%$  for all the joint fits
  - Both instruments are consistent with each other → good calibration
- Ideal configuration for future joint observations:
  - Flare (> Higher GOES B class) occulted for NuSTAR and on-disk for STIX
  - A class flare on disk for both instruments but STIX at  $\sim 0.3$  au