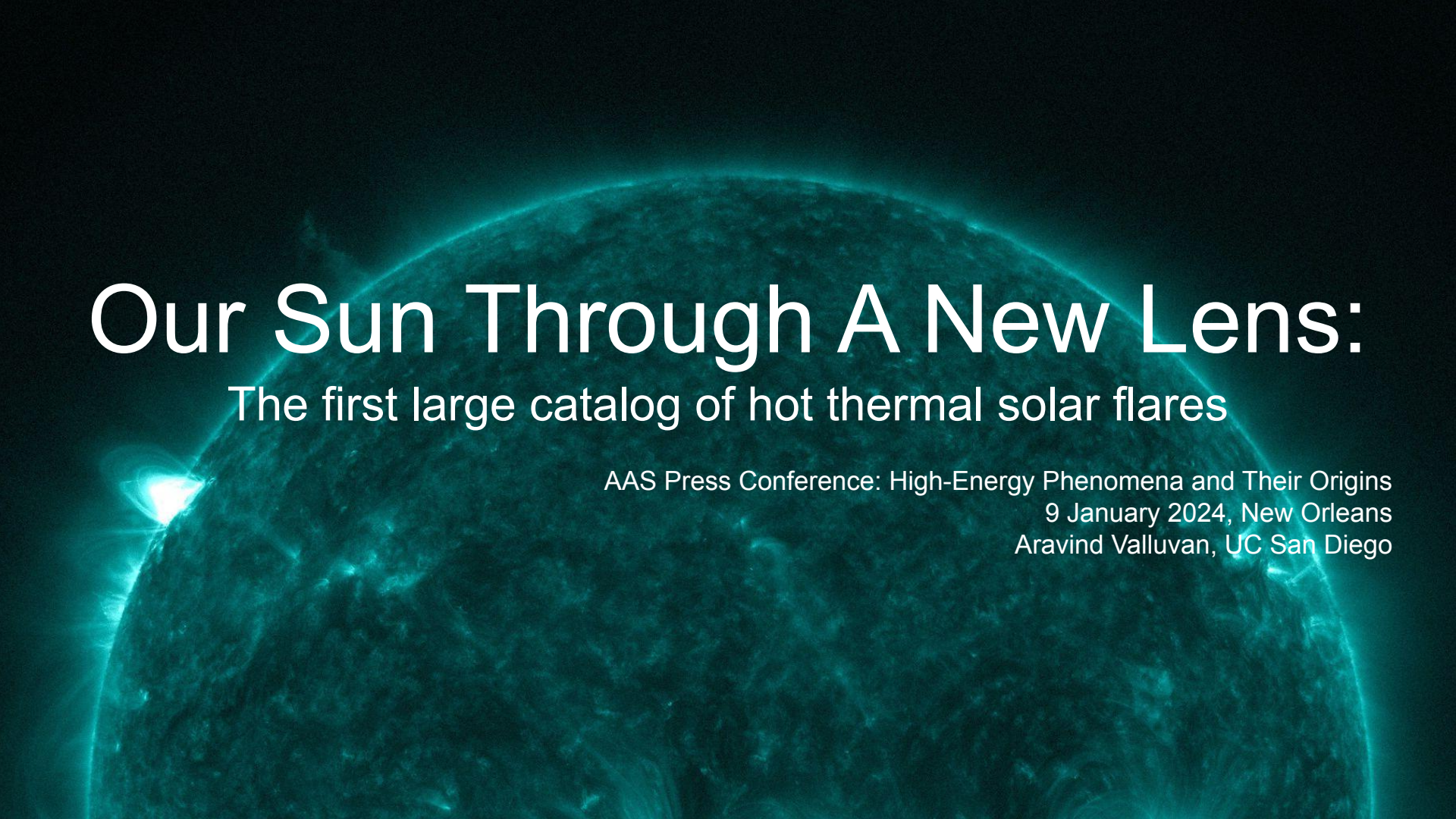


Our Sun Through A New Lens:

The first large catalog of hot thermal solar flares

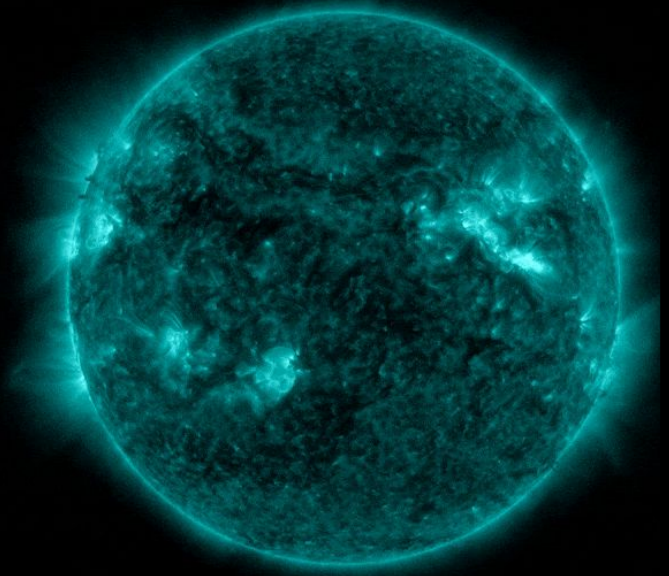
AAS Press Conference: High-Energy Phenomena and Their Origins
9 January 2024, New Orleans
Aravind Valluvan, UC San Diego

Solar Flares

- Randomly distributed, broadband bursts from radio waves to gamma-rays
- 20 minutes long on average but flares range from a few minutes to a few hours
- Most energetic explosions in the solar system – largest flares release 10^{26} J
- Triggers solar storms – a critical driver of human-impact space weather:
  - Damages electronics onboard spacecrafts (2022 *Starlink* failures)
  - Affects long-range radar signals and satellite communication
  - Increases radiation hazards to high-altitude, high-latitude aviation

Detecting Solar Flares

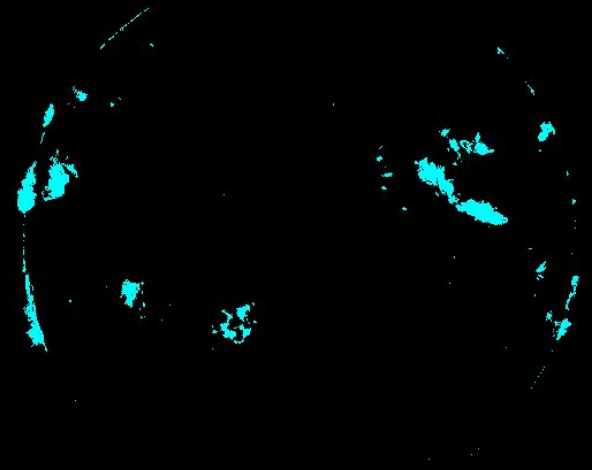
Solar flares are associated with hot plasma in the corona – brightest in X-ray



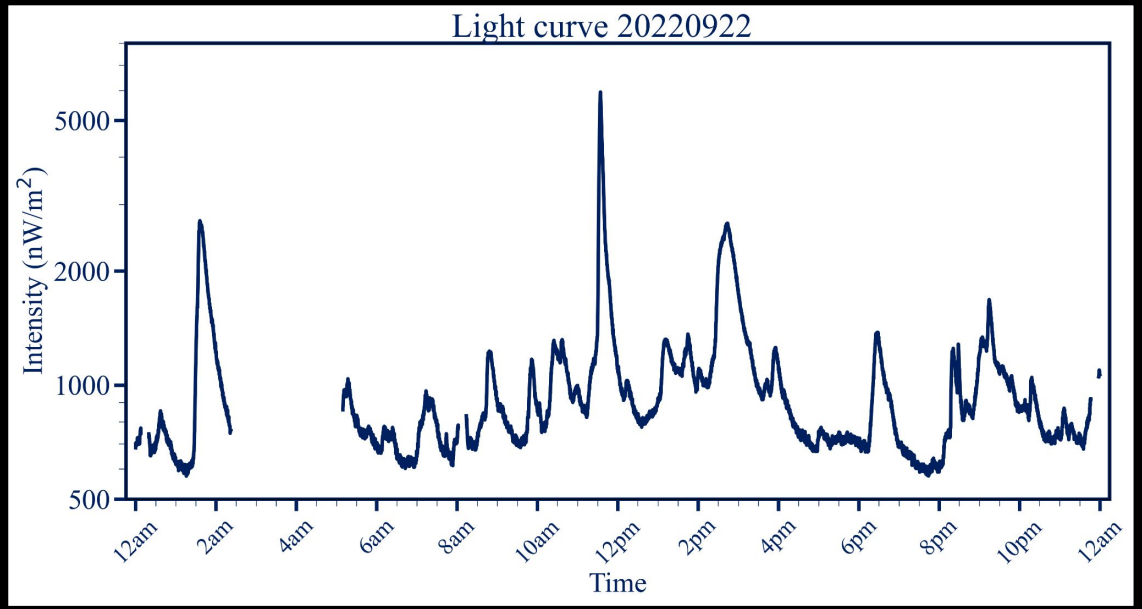
Ultraviolet

Detecting Solar Flares

Solar flares are associated with hot plasma in the corona – brightest in X-ray



X-ray Vision

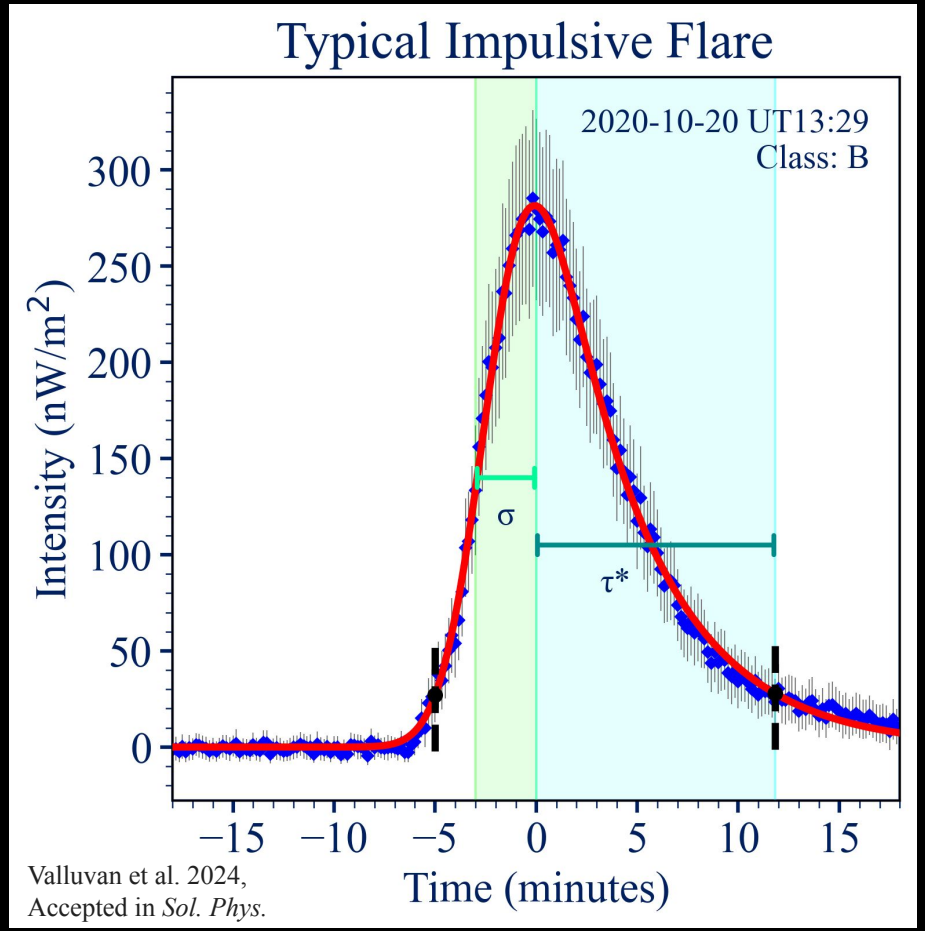


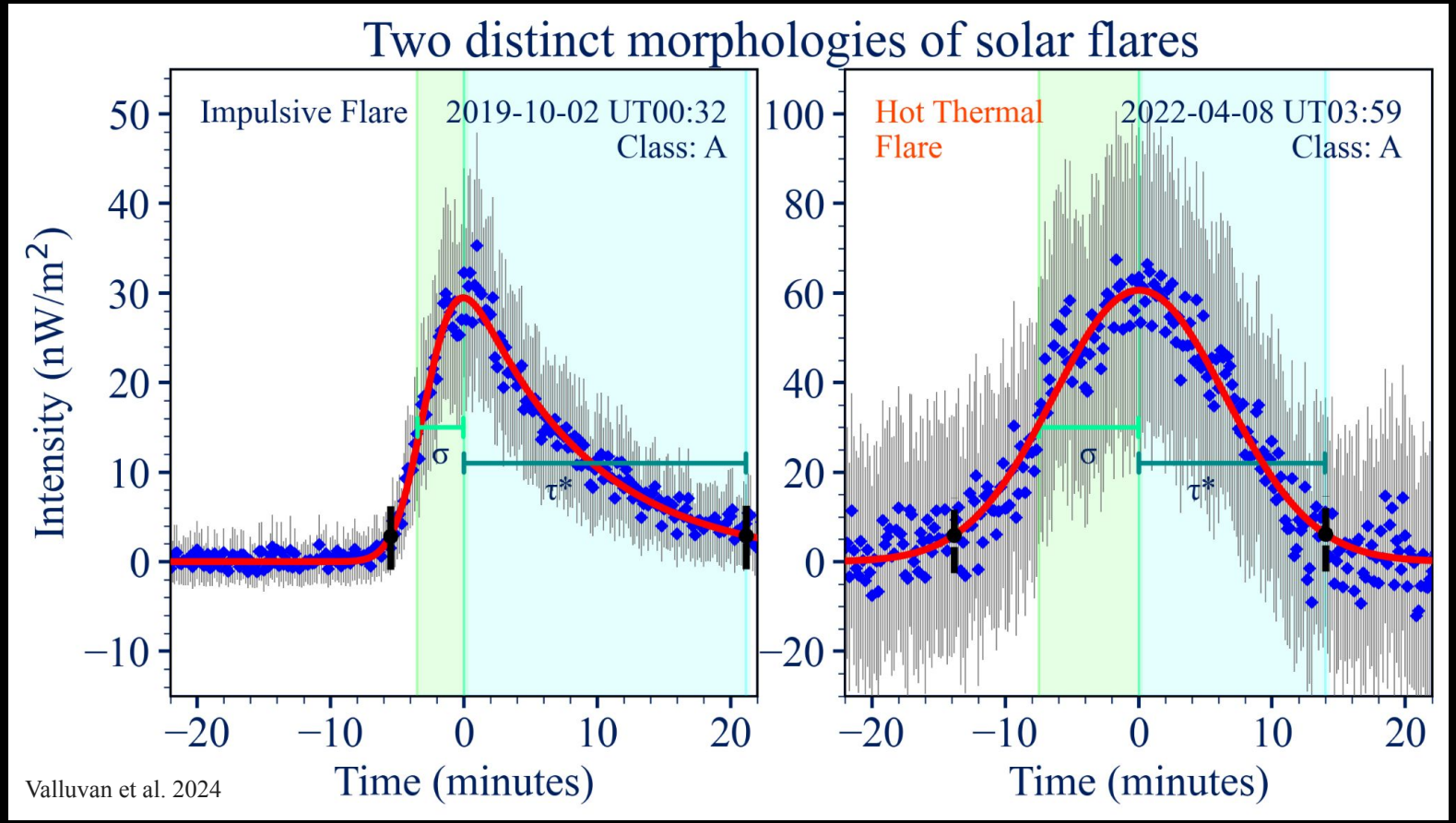
X-ray

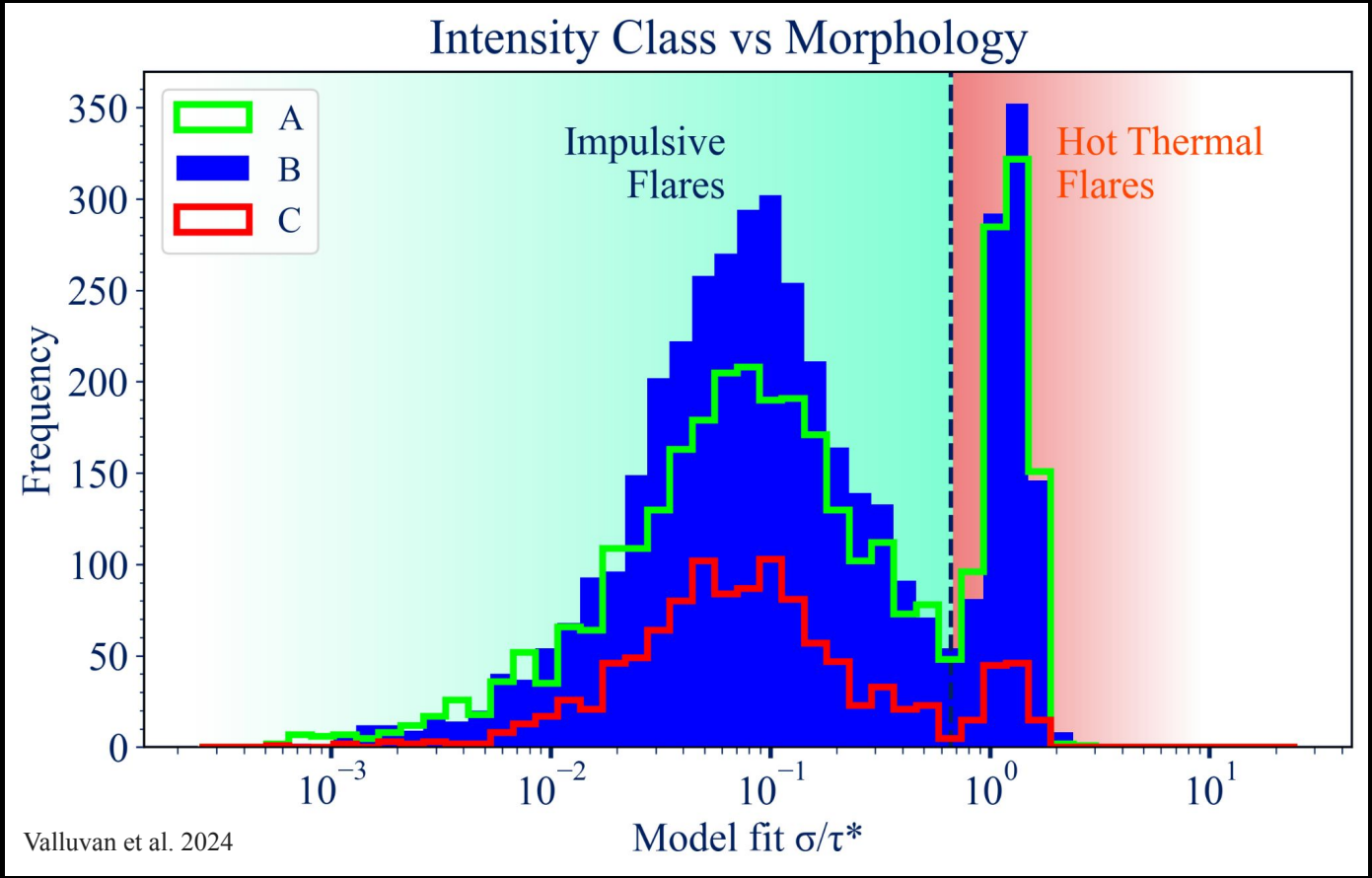
Impulsive Flare Model

I. Magnetic reconnection leads to **rapid** injection of energy into the corona (heating)
II. Thermal process slowly dissipates energy from the corona (cooling)

Intensity-based classification	
Class	**Peak int. (nW/m²)**
sub-A	$< 10^1$
A	$10^1 – 10^2$
B	$10^2 – 10^3$
C	$10^3 – 10^4$
M	$10^4 – 10^5$
X	$> 10^5$




Two distinct morphologies of solar flares
Impulsive Flare
2019-10-02 UT00:32
Class: A
Hot Thermal Flare
2022-04-08 UT03:59
Class: A
Intensity (nW/m^2)
σ
τ*
Time (minutes)
Valluvan et al. 2024


Intensity Class vs Morphology
A
B
C
Impulsive Flares
Hot Thermal Flares
Frequency
350
300
250
200
150
100
50
0
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
Model fit σ/τ*
Valluvan et al. 2024

Implications

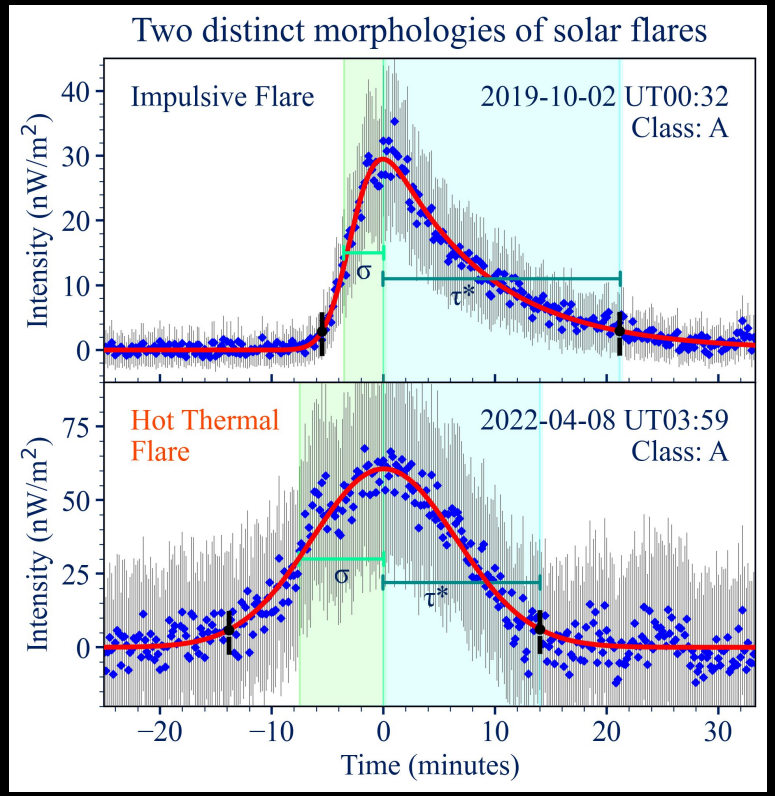
- There are two distinct flare morphologies under soft X-ray observations –
  Is the variation in heating rate a result of generation or propagation process?

- Are there any correlations between HTFs and other solar phenomena –
  Coronal mass ejections, solar particle events, … (some hints have been seen)

- Coronal plasma temperatures reach ~10^6 K while Sun's surface is at 6000 K!
  Could a potential propagation effect of HTFs provide a solution?

- Multiwavelength solar observatory Aditya-L1 has just been injected into orbit!
  Payloads: X-ray spectrometer (1 – 150 keV) and UV imager (200 – 400 nm)

Conclusion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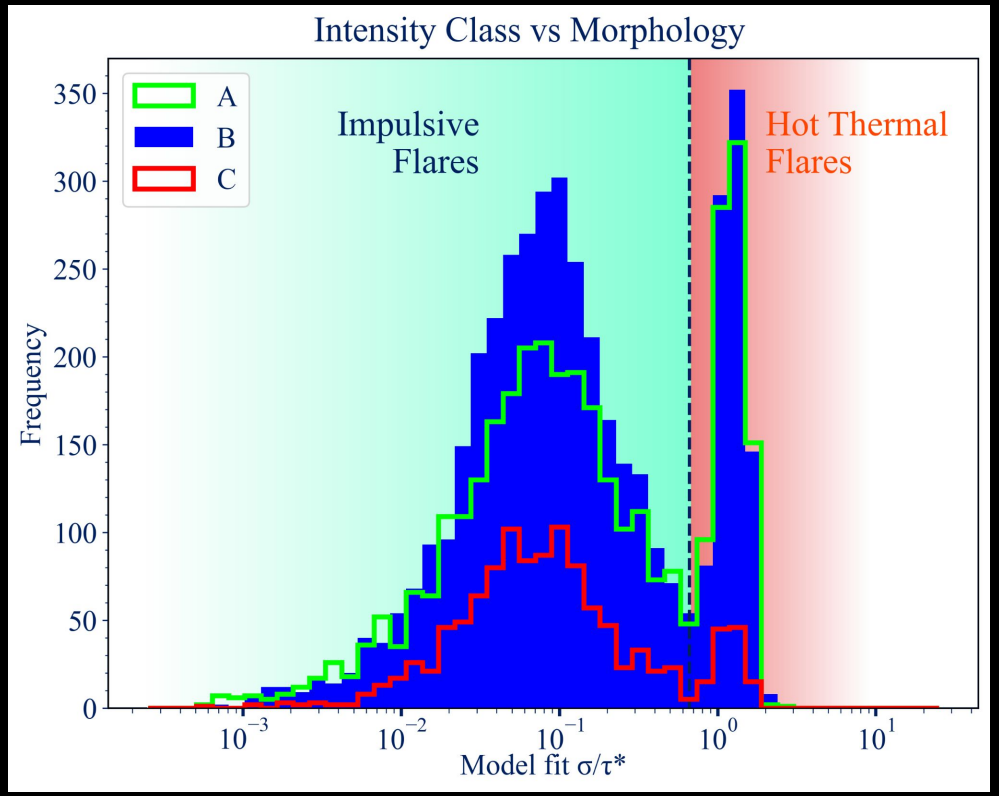

Intensity Class vs Morphology
A
B
C
Impulsive
Flares
Hot Thermal
Flares
Frequency
Model fit σ/τ*

Questions?

Acknowledgements and Image Credits

This work would not have been possible without my collaborators at the Indian Space Research Organisation and IIT Bombay

We acknowledge the use of data from the Chandrayaan-II, second lunar mission of ISRO, archived at the ISSDC. XSM was developed by PRL with support from various ISRO centers. We thank various facilities and the technical teams from all contributing institutes and the Chandrayaan-2 project, mission operations, and ground segment teams for their support.

Slides 1 to 3 Sun: AIA/SDO

Slide 7 Spacecraft: ISRO

Slide 7 News clip: Reuters

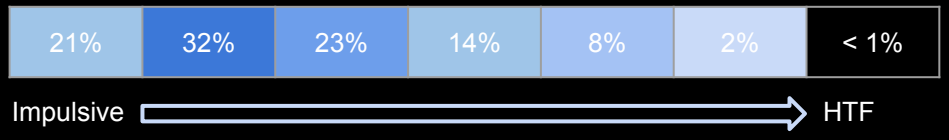
Slides 4 to 6 and 8 Figures: Valluvan et al. Accepted in *Sol Phys*, 2024

4 Year Summary of XSM/Chandrayaan-2 Flare Catalog

Class	Hot Thermal	Impulsive	Total	% HTF
sub-A	186	501	687	27%
A	952	2464	3416	28%
B	981	3193	4174	24%
C	140	986	1126	12%
M	5	106	111	5%
Total	2264	7250	9514	24%

Hot Thermal Flares

- HTFs were first discovered in 1983. Was conjectured to lie on a spectrum



- HTFs extend from sub-A to M class
- Similar cooling phase for both morphologies
- Duration of HTFs are longer by ~10%
- The relative number distribution between HTFs and impulsive flares have remained constant through the years (2019 –2023)
- However, fewer HTFs reach C or M class (11%) compared to A and B class (25%)