Combined Next-Generation X-ray and EUV Observations with the *FIERCE* Mission Concept

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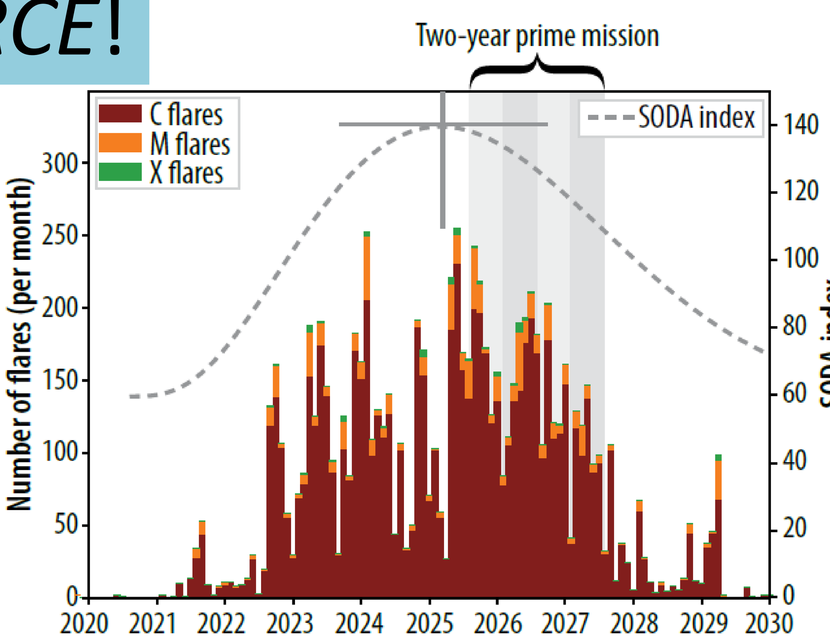
FIERCE

Fundamentals of Impulsive Energy Release in the Corona Explorer

Poster #764

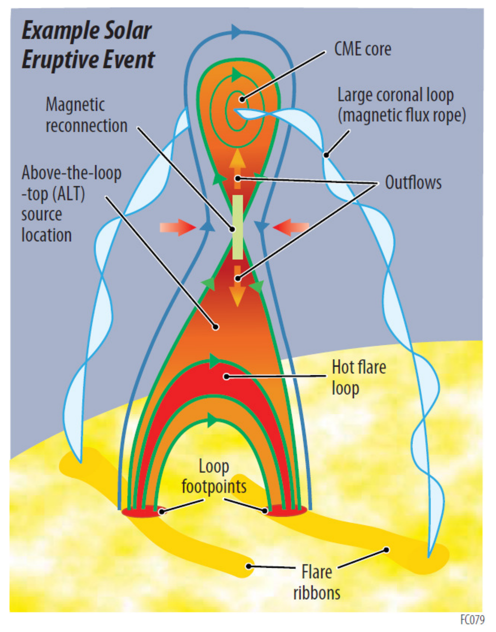
Now is the time for *FIERCE*!

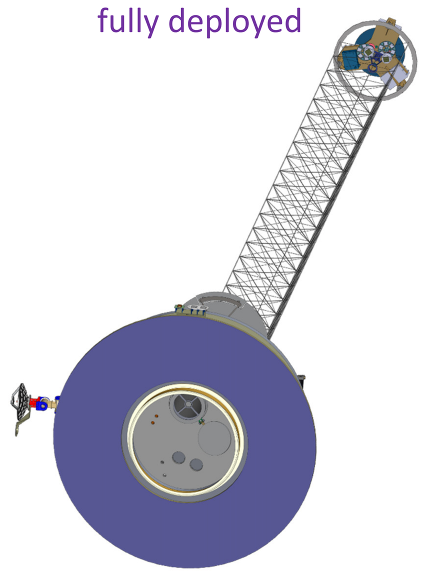
If selected, *FIERCE* will launch in mid-2025. Such a launch is well timed with the ~11-year cycle of solar activity (see figure for estimate). The next period of comparable scientific potential will not occur until ~2035. *FIERCE* supports future human space exploration (e.g., the Artemis program) via improving our understanding of space weather, complements *Parker Solar Probe* and *Solar Orbiter* during their perihelia, and fills a critical gap in the Heliophysics System Observatory.



The *FIERCE* mission concept

While there have been significant advances in our understanding of impulsive energy release at the Sun through past observations, there is a clear science need for co-optimized high-angular-resolution, fast-cadence X-ray and extreme-ultraviolet (EUV) observations. The *Fundamentals of Impulsive Energy Release in the Corona Explorer* (*FIERCE*) mission concept captures all elements of a solar eruptive event – the combination of a flare and a coronal mass ejection (CME) – and will identify the signatures of impulsive energy release in even the quiescent Sun. *FIERCE* is led by NASA Goddard Space Flight Center (GSFC) and has three instruments (described below): FOXSI, THADIS, and STC. *FIERCE* has been proposed to the recent NASA Medium-class Explorer (MIDEX) opportunity and is pending selection.




FIERCE observatory, fully deployed

Focusing Optics X-ray Solar Imager (FOXSI)

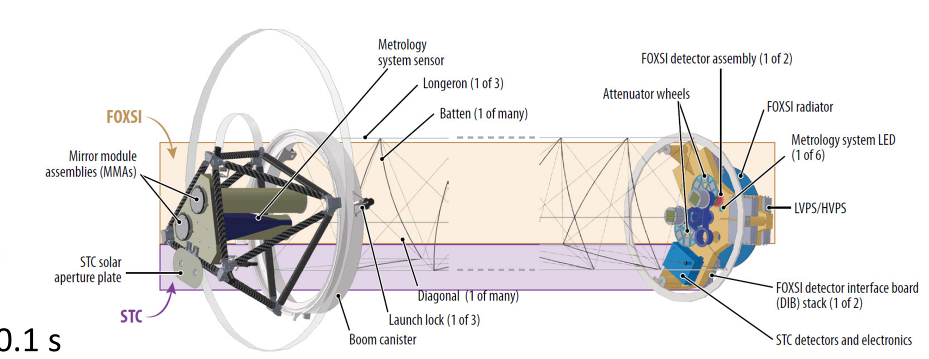
Led by GSFC, FOXSI will be the first-ever solar-dedicated, direct-imaging hard X-ray (HXR) spectroscopic imager. FOXSI observes the signatures of both energetic electrons and hot flare plasmas (≳5 MK). FOXSI uses grazing-incidence optics to focus HXR photons onto fast solid-state pixelated detectors, over a 14-meter focal length.

Key specifications

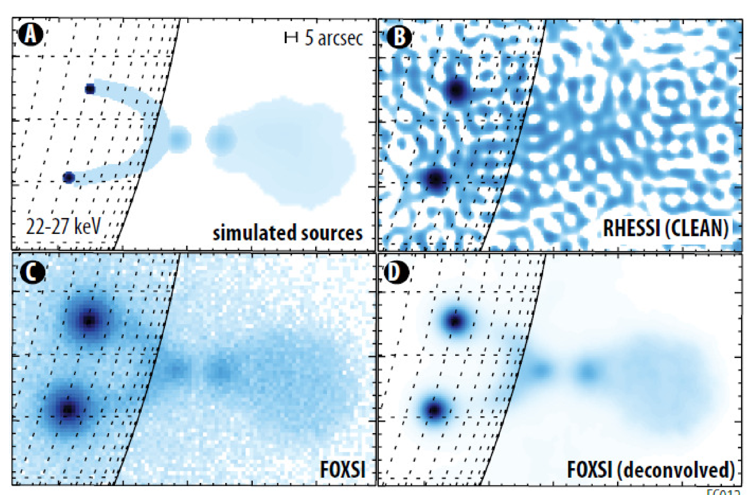
Energy range: 3–55 keV

Angular resolution: 6.3 arcsec FWHM

Imaging effective time resolution: 0.1 s



FOXSI observes all HXR sources in a solar eruptive event, such as faint coronal sources at the same time as bright chromospheric footpoints.



Thermal and Dynamic Imager for the Sun (THADIS)

Led by the Smithsonian Astrophysical Observatory (SAO), THADIS images coronal-plasma structures in two EUV passbands (284 Å and 133 Å). THADIS captures images at fast cadence and short exposure times to track quickly evolving features and avoid image saturation in flares.

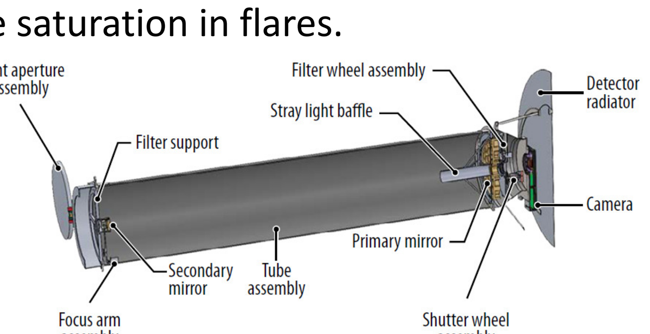
Key specifications

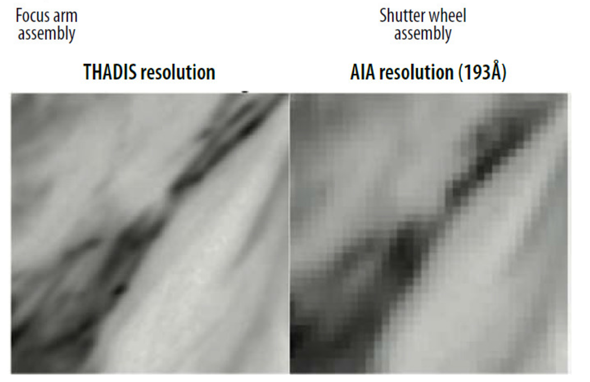
Passbands:
284 Å (peak at ~2 MK)
133 Å (peak at ~14 MK)

Angular resolution: 0.5 arcsec

Image cadence: >3 images in 10 s

Shortest exposure time: 0.5 ms

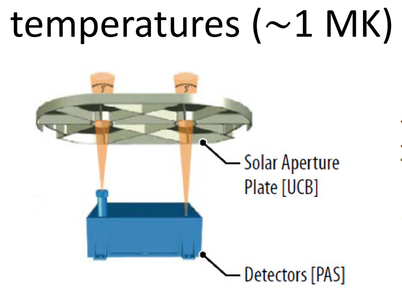




Simulated THADIS image shows structures not resolved by AIA

Spectrometer for Temperature and Composition (STC)

Led by the Polish Academy of Sciences (PAS), STC provides detailed thermal and elemental-composition diagnostics of coronal plasma imaged by THADIS and down to cooler temperatures (~1 MK) than FOXSI observes.

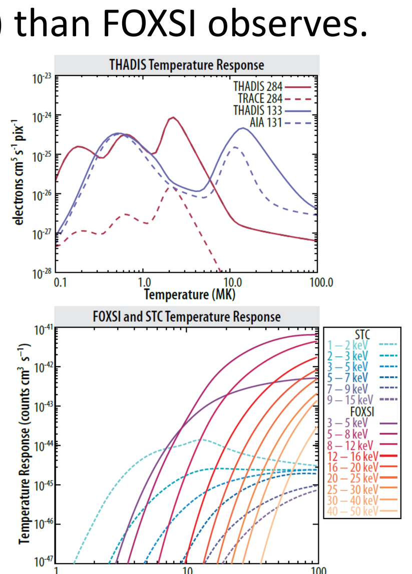


Key specifications

Energy range: 0.8–15 keV

Energy resolution: 0.2 keV FWHM

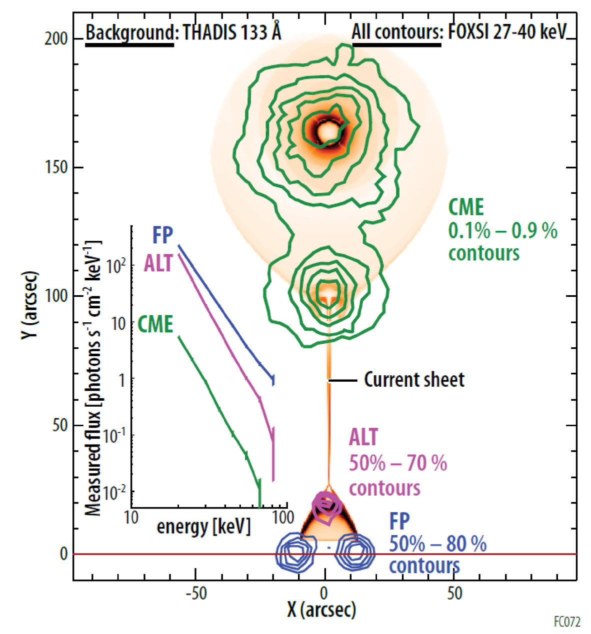
Spectrum cadence: 0.5 s



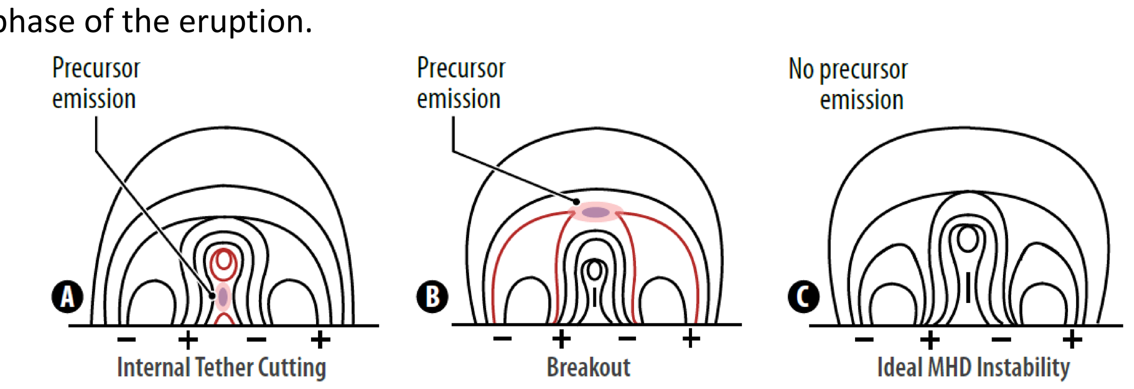
What are the physical origins of space-weather events?

- *Determine the dominant initiation mechanisms for flares and CMEs*
- *Determine the solar origins and properties of electrons escaping the Sun*

Right: *FIERCE* images EUV emission (orange background) and HXR emissions from the above-the-loop-top (ALT) source at the bottom end of the current sheet (purple contours) and from the CME core (green contours) even in the presence of intense HXR footpoints (FP, blue contours)–and obtains X-ray spectra for these individual sources (inset).



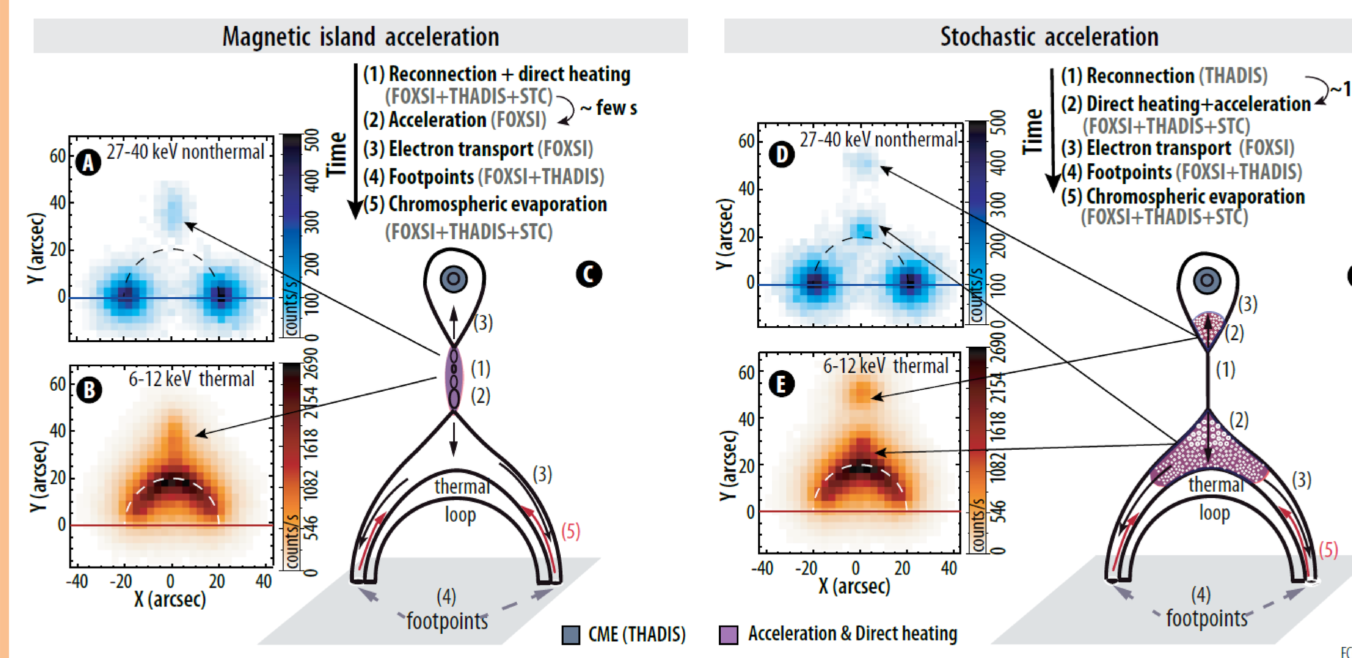
Below: *FIERCE* will distinguish among different models of the initiation of solar eruptive events by observing the differences in the timing and locations of X-ray sources from accelerated electrons and X-ray and EUV emission from heated plasma during the early rise phase of the eruption.



How are particles accelerated at the Sun?

- *Determine where and when electron acceleration and local plasma heating occur in evolving structures*
- *Test model predictions for the efficiency and sustainability of electron acceleration*

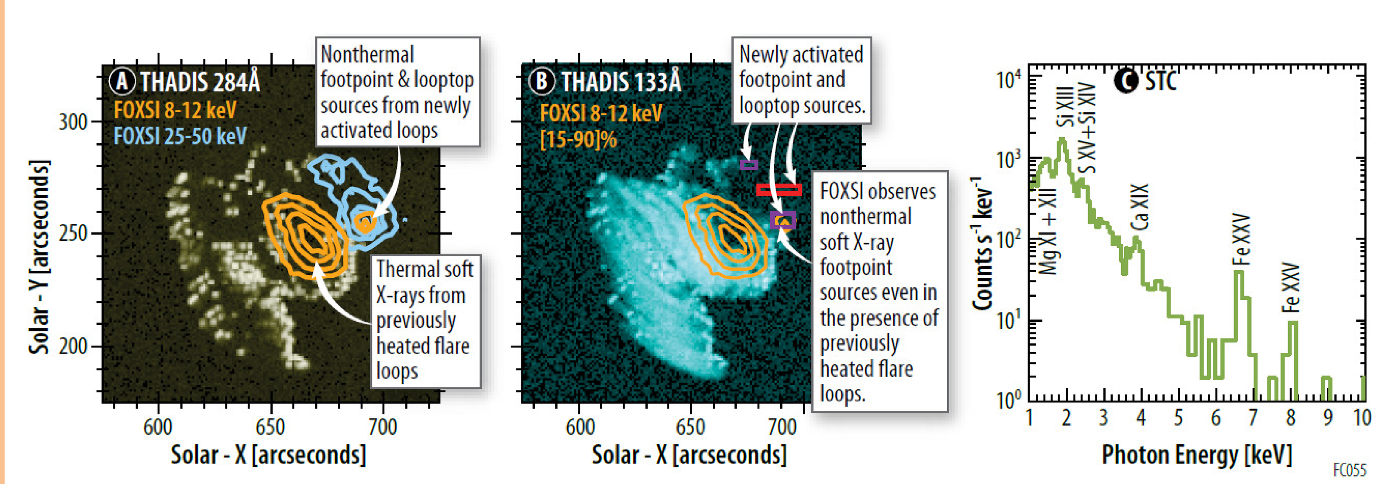
Below: *FIERCE* will distinguish between different models of flare electron acceleration. In these 2D flare cartoons, the locations and chronological order of various X-ray- and EUV-producing processes differ between the two most likely models of electron acceleration in eruptive flares: magnetic island-merging acceleration (left) and stochastic (second-order Fermi) acceleration (right). Simulated FOXSI images of nonthermal electrons (blue) and thermal plasma (orange) are shown as insets.



How is impulsively released energy transported throughout the solar atmosphere?

- *Determine how and where accelerated electrons lose their energy in the corona and chromosphere*
- *Test theories of the production and evolution of hot flare plasmas*

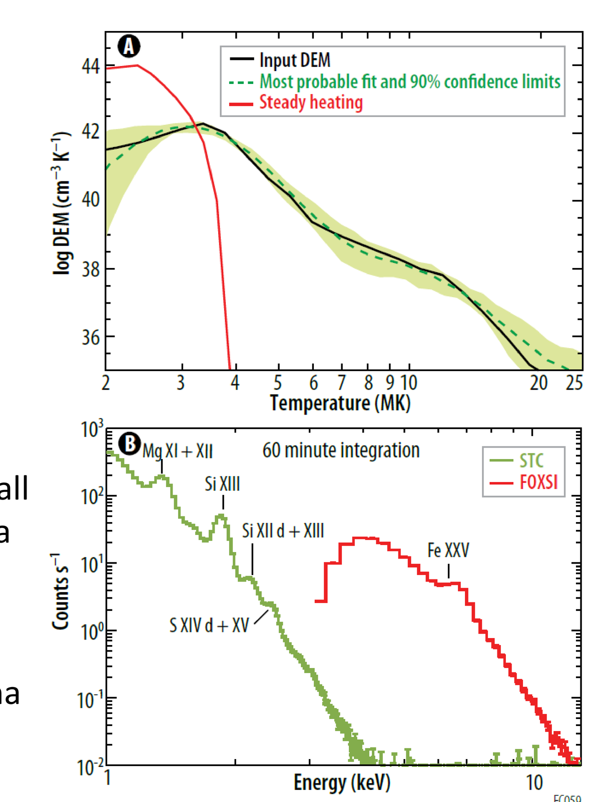
Below: *FIERCE* will observe flare arcades with exceptional sensitivity, resolution, and dynamic range. Panels (A) & (B) show synthetic THADIS 284 Å and 133 Å images, respectively, from an M3 flare arcade model, with 2 ms exposure times to avoid saturation. Contours show the X-rays imaged with FOXSI with an exposure time of 3 s. Both the footpoint and looptop sources (marked by the purple and red boxes, respectively) of the most recently activated loops are imaged simultaneously, and their spectra can be obtained independently. Panel (C) shows that STC observes the thermal continuum and diagnostic X-ray lines with good statistics at an integration time of 3 s.



How is the solar corona heated?

- *Determine whether energy release in small flares is fundamentally different from that in large flares*
- *Determine the ensemble properties of unresolvable heating events that heat active regions*

Right: *FIERCE* will constrain the temperature distribution of active regions. Simulated *FIERCE* observations show that the input temperature distribution (black) can be reconstructed (green curve), including at high temperatures, even in the presence of large amounts of cooler plasma. A small but detectable amount of high temperature plasma (>5 MK) is a key signature of nanoflare heating.



Below: THADIS reveals the spatial structures in the active region, and FOXSI detects hot thermal plasma in loops and footpoints with sufficient statistics to enable reconstruction of the spatial and thermal distribution of the hot plasma.