IMPRESS: A CubeSat-Based Scintillation Detector for Solar Flare Hard X-Ray Observations

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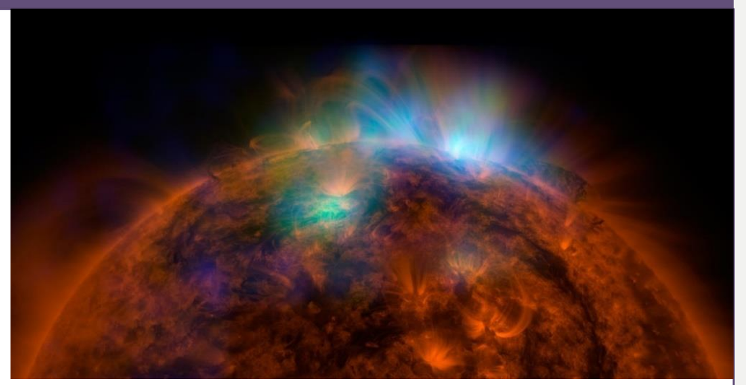
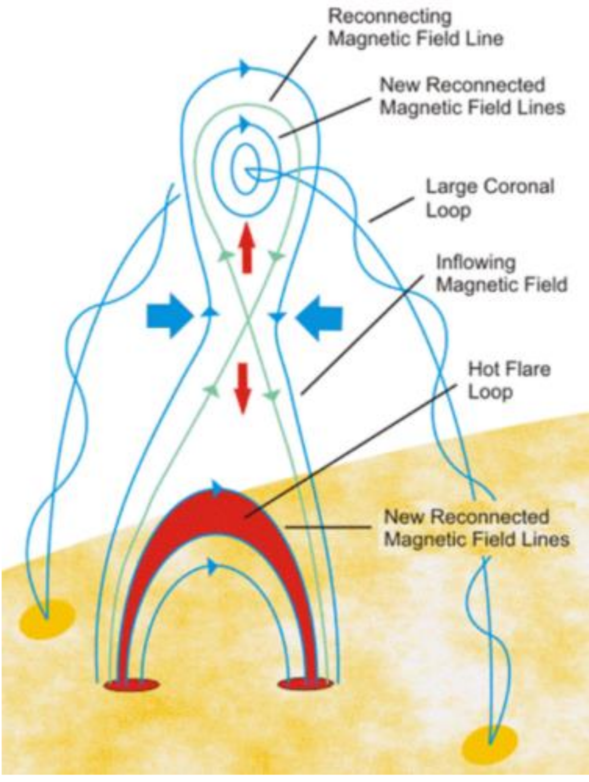
Abstract



The 3U Cube Satellite IMpulsive Phase Rapid Energetic Solar Spectrometer (IMPRESS), is an NSF mission that contains a scintillation detector for hard X-ray (HXR) and soft X-ray detection. IMPRESS's main objective is to investigate solar flares by resolving sub-second fluctuations in the HXR flux that are closely related with the electron acceleration processes. Data from IMPRESS will give insight on the mechanisms of energizing particles accelerated in solar flares by measuring X-rays from 5-100keV at a 32Hz cadence and by locating the transition from thermal to nonthermal energy emissions. Studying electron acceleration in solar flares can help to understand and predict the impact of space weather events. The project is a collaboration between UMN, MSU, UCSC, and SwRI.

Introduction



This mission will focus on detecting X-ray emissions from solar flares by resolving fluctuations in the X-ray flux with small-timescales. Solar flares occur on the surface of the sun in regions with strong unstable magnetic fields. Coronal loops undergo a process called magnetic reconnection. As the magnetic flux tubes reconnect, electromagnetic radiation outbursts occur. This radiation or energy ejection results in an emission of X-rays caused by accelerated electrons colliding with ions. Coronal mass ejections impact the Earth and can cause solar storms, damaging or disrupting radio communications. A scintillator detector was designed to detect these X-rays in order to better understand these phenomena.

The scintillation detector consists of four cerium bromide crystals coupled to a SiPM array, attached to an eMorpho board from Bridgeport Instruments. The high energy photons observed by the detector are scintillated by the cerium bromide crystals resulting in lower energy photons which can then be absorbed by a silicon photomultiplier (SiPM) array. Testing of the detector system is done using sealed radioactive sources to establish gain calibration and energy resolution.

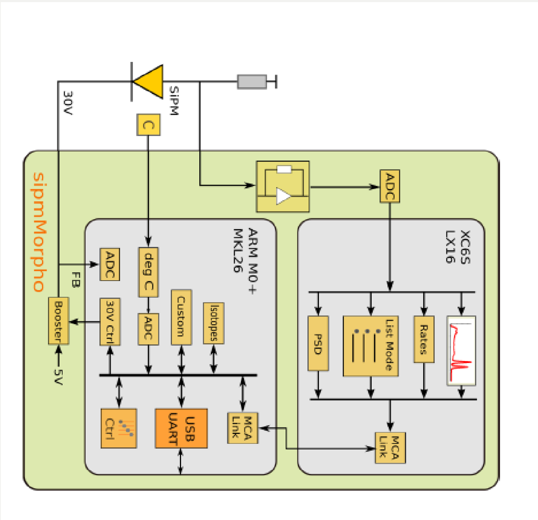


Figure 1: Block Diagram of SiPM eMorpho Board

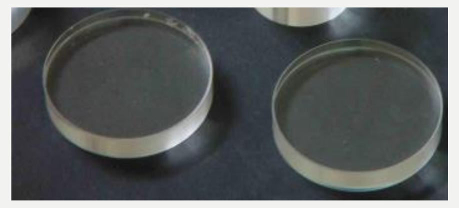


Figure 2: Cesium Bromide archetype Crystals used to absorb X-Rays

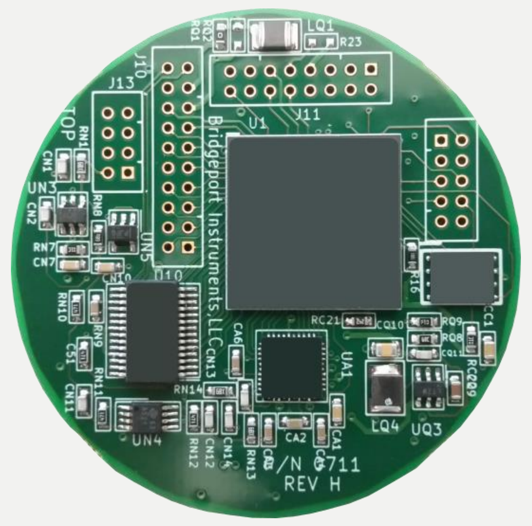


Figure 3: Detector Component SiPM eMorpho Board

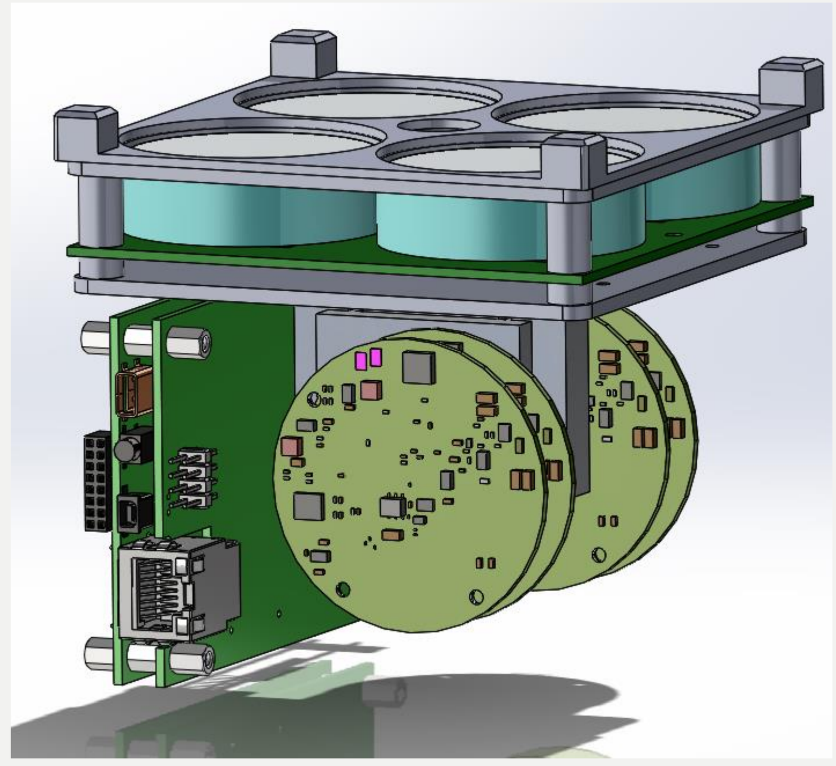


Figure 4: Model of the Scintillator Detector

Figure 5: Model of the Cube Satellite

Requirements

ID	Requirement
MR-1	IMPRESS shall make X-ray observations of at least 1 flare that exhibits subsecond pulsations.
MR-2	IMPRESS shall operate with sufficient energy resolution to distinguish thermal and nonthermal X-ray flux.
MR-3	IMPRESS shall operate with the ability to detect the presence of the 6.7 keV iron line.
MR-4	IMPRESS shall create time profiles with a temporal resolution sufficient to resolve subsecond pulsations.
MR-5	IMPRESS shall observe solar flares during the proposed observation times of the STIX instrument onboard Solar Orbiter.
MR-6	IMPRESS shall be calibrated for absolute photometry at 20%.
MR-7	The IMPRESS detector shall observe an incident photon count rate of 320,000 counts/s without significant pileup/saturation.
MR-8	The IMPRESS detector shall have a minimum effective area of 25 cm^2.

Scientific Goals

Solar flares release large amounts of magnetic energy and a significant portion of this energy goes into nonthermal electrons. Methods of analyzing these acceleration mechanisms are sparse. The goal of this satellite is to observe solar flare X-rays in the 5-100 keV range with high time precision (~32 Hz histograms). Figure 6 shows a simulated solar flare X-ray spectrum, used in the design and development of the detector system. Figure 7 shows the nonthermal X-ray spectra for flares of various sizes. A key aspect of the detector design is the inclusion of a soft X-ray spectrometer, giving IMPRESS a large, thermal to nonthermal detector range.

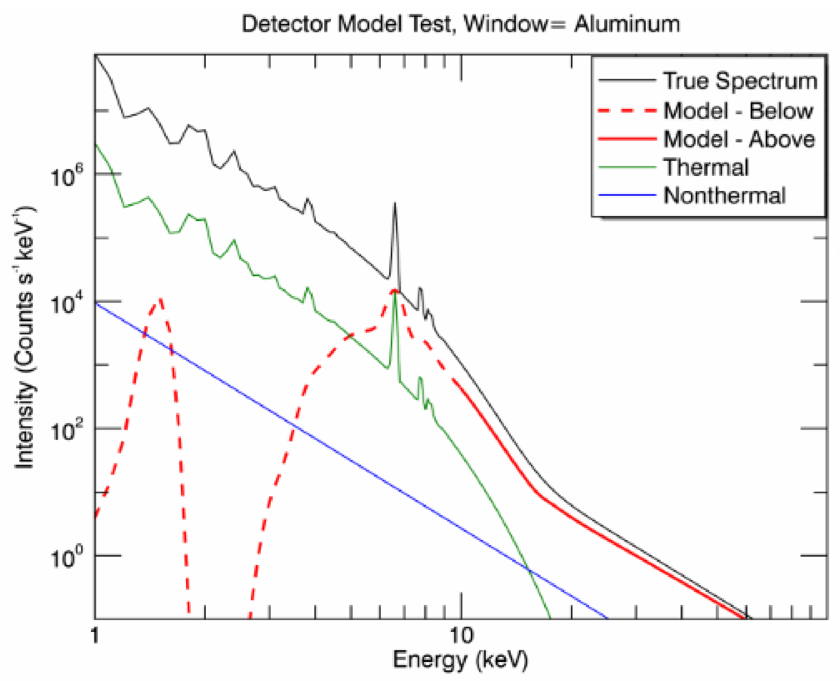


Figure 6: Solar Flare Spectrum

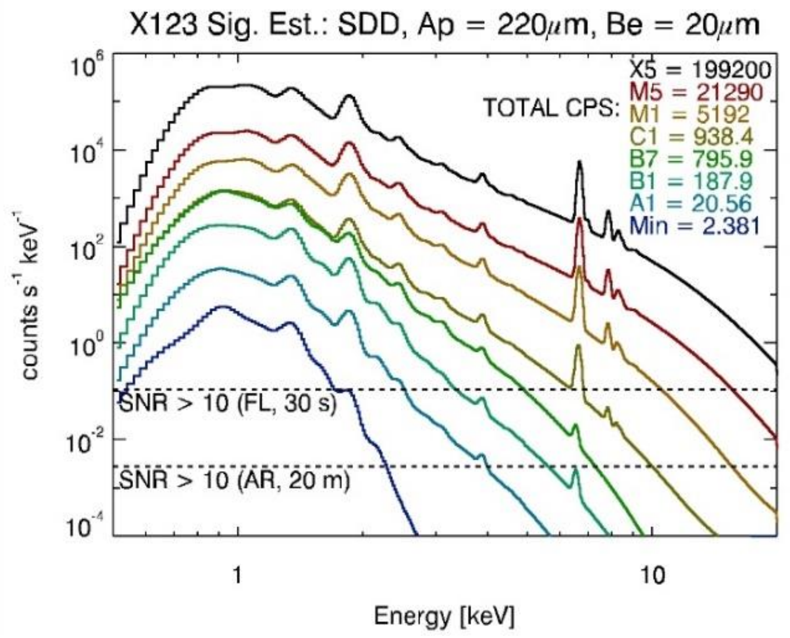


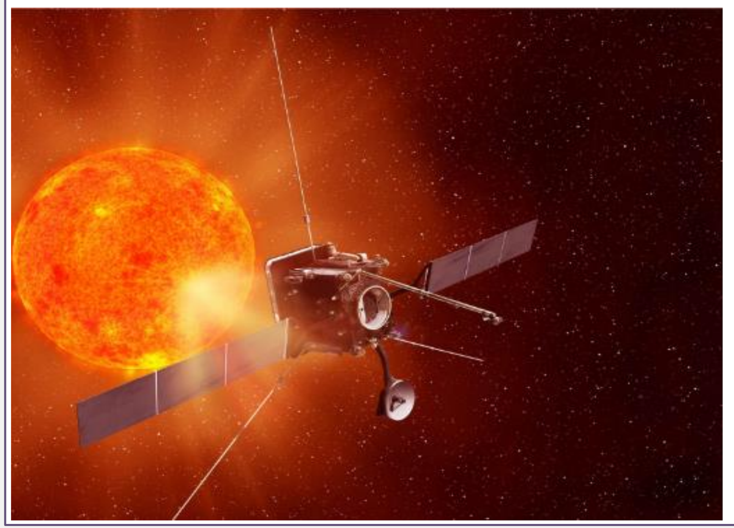
Figure 7: Nonthermal X-ray graph

Previous Work

A similar scintillator detector (CITIES) was designed by the detector team from the SmallSat Lab at the University of Minnesota and was launched in November as a part of the SOCRATES CubeSat. The detector for IMPRESS is based on this previous design.

Conclusion and Future Work

The satellite IMPRESS will provide information to better understand these mass ejections and the impact they can have on the Earth's environment. This information can also be used to better understand high-energy plasma physics which is a topic not yet understood.



Unlike other satellites, IMPRESS will provide better time resolution with small-time scale fluctuations in X-ray flux, used to determine accelerated timescales of the particles ejected from the magnetic reconnection. IMPRESS will launch in late 2022.

Tasks	Time Frame	Tasks	Time Frame
Detector Development	5/19-7/21	Fabricate flight units and subsystem flight component testing	1/21-7/21
Prototype Assembly and Testing	11/19-2/20	Test Flight Detector	3/21-6/21
Test Detector ETU	7/20-9/20	Detector environmental testing	6/21-7/21
Subsystem ETU testing and iteration	1/20-5/20	Fit check of detector unit with spacecraft	9/21
Contingency and Detector + spacecraft ETU testing	5/20-11/20	Electrical check of detector unit in spacecraft	9/21
IMPRESS Critical Design Review	9/20	Vibration and thermal testing	10/21-12/21
Final Optimization	9/20-11/20	Contingency	12/21-1/22
Iterate designs	11/20-1/21	Delivery and Launch	1/22-6/22

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References

NASA/NuSTAR
ESA/Airbus
Bridge port instrument
Impulsive Phase Rapid Energetic Solar Spectrometer, (IMPRESS) Mission Overview (Trevor Knuth)
The Science of EXACT(Trevor Knuth)
IMPRESS-Sensor (John Sample, David Smith, Amir Caspi)

Acknowledgements

Collaborative, NSF-funded project
University of Minnesota
Lindsay Glesener – Science and Lead PI
Demoz Gebre-Egziabher – Engineering PI
Trevor Knuth-Project Scientist
Montana State University
John Sample – Detector Co-PI
University of California, Santa Cruz
David Smith – Detector Co-PI
Southwest Research Institute-
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Georgia Tech Research Institute