

Real-Time Imaging of Solar X-ray Flares with Machine Learning

Situation

The Spectrometer/Telescope for Imaging X-rays (STIX) is a solar X-ray telescope on board ESA's Solar Orbiter mission, launched in February 2020 (see [1] and Figure 1). Designed, built, and operated by FHNW, STIX observes the X-ray radiation emitted by solar flares, i.e., large explosions occurring on the surface of the Sun. To date, STIX has collected a large dataset of flares, consisting of more than 80'000 events [2].

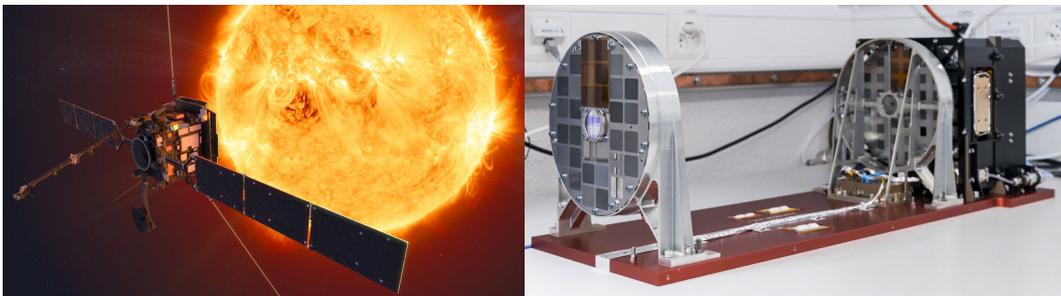


Figure 1. Left panel: the Solar Orbiter spacecraft [2]. Right panel: the STIX instrument [1].

STIX does not directly observe images, but images are reconstructed from STIX data using sophisticated algorithms. While effective, these traditional methods are computationally intensive and typically require up to a minute to generate a single image. To address this limitation, researchers at FHNW have recently developed a Deep Learning (DL) approach to reconstruct STIX images in real time. This model provides images of solar flares in a fraction of a second; however, the process still relies on reading and calibrating the raw STIX data, and this step remains a bottleneck in the overall efficiency of the pipeline. Therefore, we propose to implement and train a Machine Learning (ML) model for efficient calibration of the raw STIX data. This model, coupled with the recently developed DL method, will allow us to do imaging in real time.

Goals / Methodology / Tasks

The goal is to develop an ML model which reads the raw STIX data and provides an estimate of the flare location on the solar surface. This position is utilized to calibrate the raw STIX data, which are fed into the existing DL model for image reconstruction. The overall pipeline is shown in Figure 2.

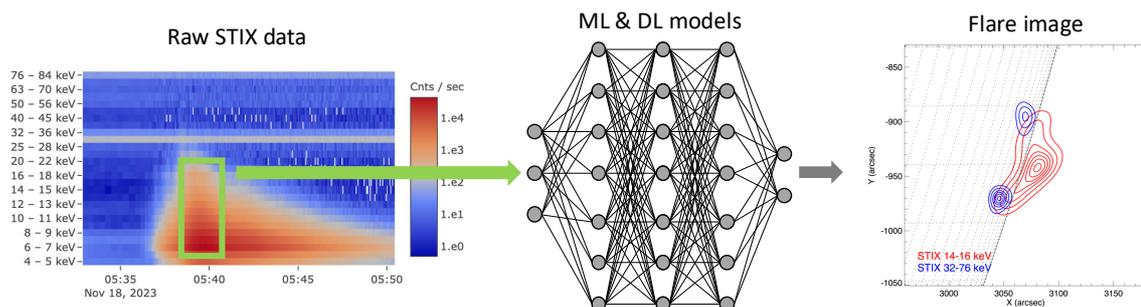


Figure 2: Pipeline for real-time imaging of solar flares from STIX data.

Required Skills

Prior knowledge in ML is desired. No prior knowledge of the physics of the Sun is required, however, enthusiasm for space related topics is highly desired.

Tasks for the Master Student

We foresee the following project phases.

P7: The first part of the project focuses on determining the flare location from raw STIX data across a large set of observed flaring events. This is achieved by reconstructing images of the X-ray emission over the full solar disk and identifying the position of the brightest region (see Figure 3). STIX images can be reconstructed using existing Python routines [3,4]. The outcome of this step is a dataset comprising raw STIX data paired with their corresponding flare locations, which will be used to train an ML model.

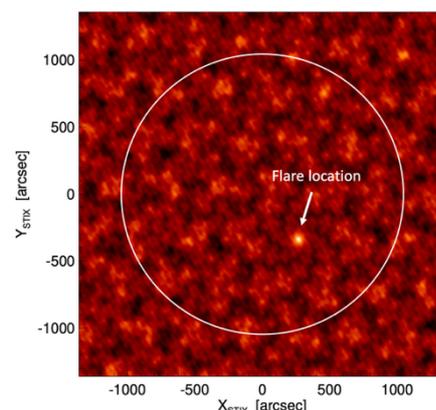


Figure 3: STIX image over the full solar disk and identified flare location.

P8: The second part of the project involves developing, implementing, and training a suitable ML model to predict solar flare locations directly from raw STIX data. Various algorithms and architectures will be tested, and the best-performing model will be selected based on accuracy and robustness.

Model development and training will be carried out using appropriate Python libraries, such as PyTorch [5].

P9: The final part of the project involves integrating the trained model into the data calibration and imaging pipeline. The resulting tool will be made available to the community through the STIX Data Center [6] and will enable real-time imaging of solar flares for preliminary online data analysis.

Full/Parttime: Full time study
 Part time study

Location:

The STIX team at FHNW is in Windisch in room 5.2C03.

Advisor:

Prof. Säm Krucker, Dr. Paolo Massa, and the STIX team.

References

- [1] Krucker et al. (2020), https://www.aanda.org/articles/aa/full_html/2020/10/aa37362-19/aa37362-19.html
- [2] https://www.esa.int/Science_Exploration/Space_Science/Solar_Orbiter
- [3] <https://github.com/TCDSolar/stixpy>
- [4] <https://github.com/TCDSolar/xrayvision>
- [5] <https://pytorch.org/>
- [6] <https://datacenter.stix.i4ds.net/>