Cross-analysis of X-Ray, particle, and radio spectra as seen by STIX and EPD onboard the Solar Orbiter and ground radio telescopes in selected solar events

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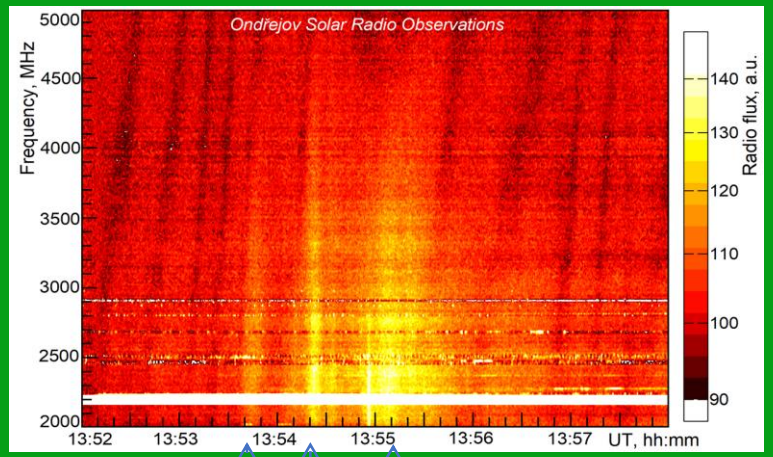
We perform a cross-analysis of STIX (Spectrometer Telescope for Imaging X-rays), EPD (Energetic Particle Detector) both aboard the Solar Orbiter mission, and the ground-based solar radio spectra to understand better which parameter in STIX may contain information about accelerated high-energy particles. In this respect, well-observed C4, C6 and C1 X-ray class solar flares on May, 9 and 22 of 2021 were selected.

1. We found exceptional temporal correlation between the hardness of non-thermal electrons' spectral index from STIX measurements with the solar type III radio emission enhancements both in decimeter and meter waveband. (Fig.1)



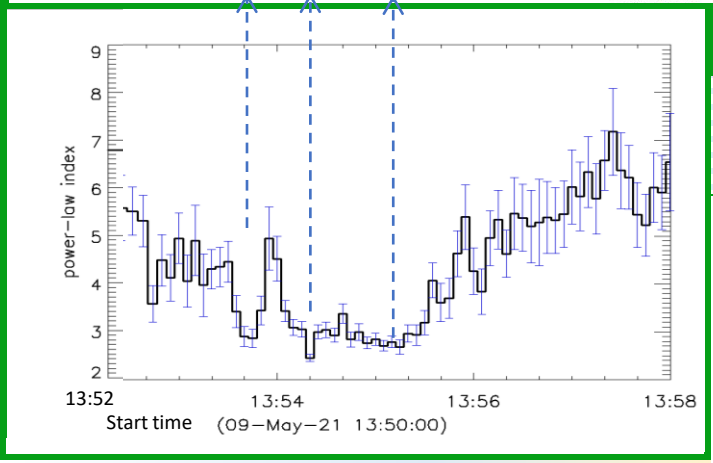
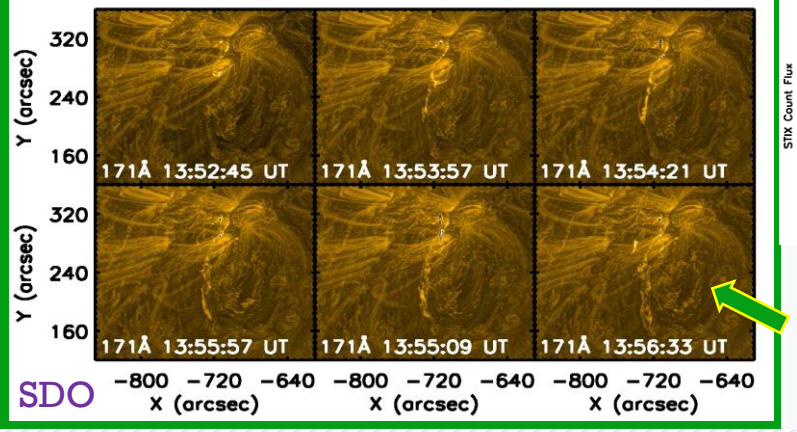


Fig.1. Solar radio bursts detected by Ondřejov radiospectrograf around 13:52-13:58 UT on May 9, 2021 (**upper panel**), and the hard X-ray power-law index obtained from the fit to non-thermal part of STIX X-ray spectrum (**bottom panel**)

2. Rapid prominence material eruption is associated with the hard X-rays and type III solar radio emissions in decimeter and meter waveband. (Fig.2)



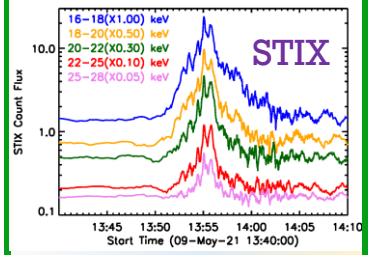


Fig.2. Extreme Ultraviolet (EUV) dynamics **at 171 Å (T=1 MK, Fe IX)** of flaring region at the time instances when multiple peaks in the hard X-ray are pronounced (see the above STIX lightcurves).

3. High-energy electron fluxes observed in-situ by EPD/Solar Orbiter (for the preceding flare) are unfolding in energy being delayed by ~15 - 20 minutes with respect to the hard X-rays and solar radio bursts as observed over a wide energy band (Fig.3)

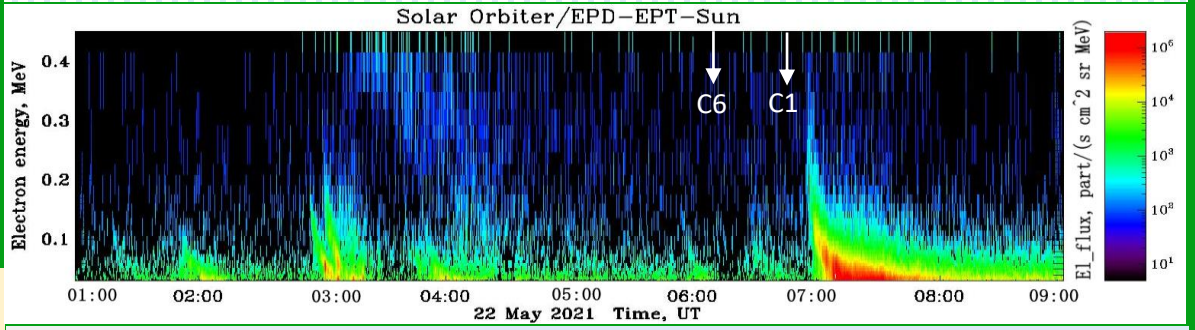


Fig.3. Evolution of the upward-propagating in-situ electron's energetic spectra on May 22, 2021 in time intervals: 01:00-09:00 UT recorded by the Solar Orbiter Electron Proton Telescope (EPT) of EPD .