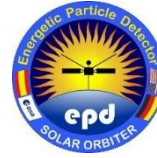




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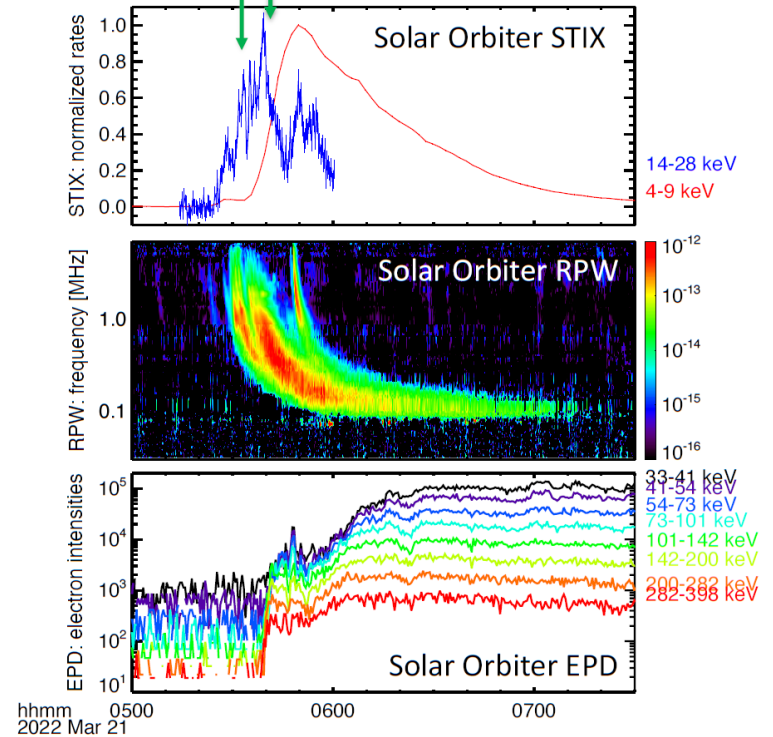
Update on interplanetary electron events observed with remote-sensing and in-situ instruments on Solar Orbiter

Alexander Warmuth

on behalf of the joint STIX-EPD-RPW-EUI working group

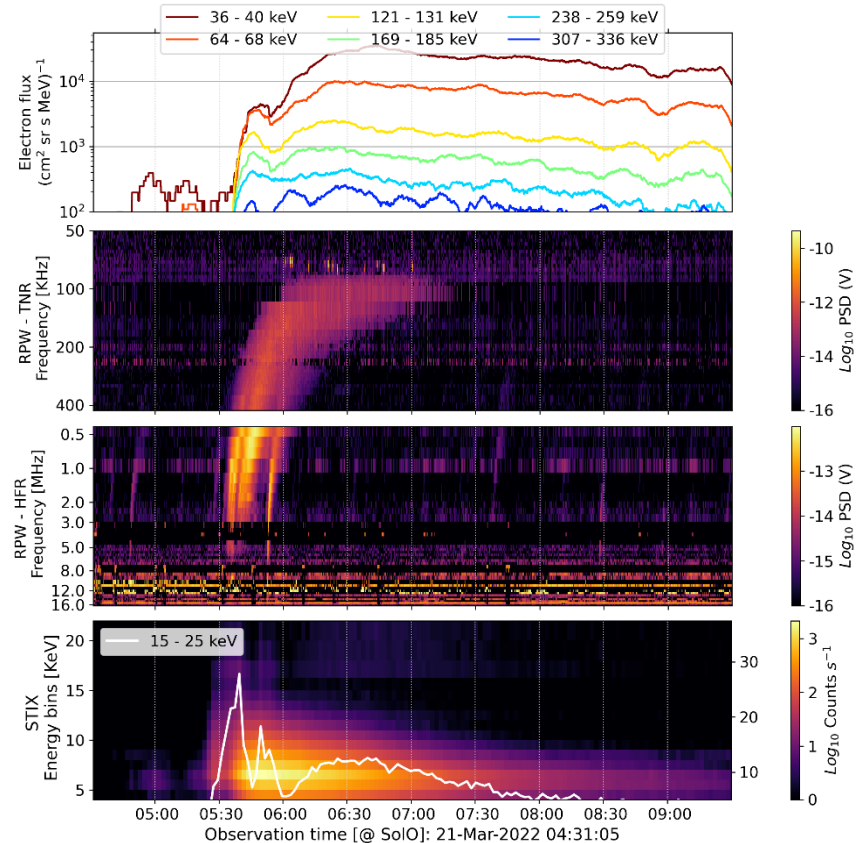
Solar electron events (SEEs)

- remote-sensing (HXR, radio) and in-situ observations of energetic electrons
- strong evidence for acceleration of impulsive electron events in solar flares: correlations in timing and spectra, associated type III bursts, composition
- if same accelerator: gain insight into particle acceleration and propagation by comparing remote-sensing and in-situ observations
- however: some discrepancies between

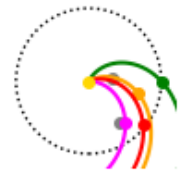
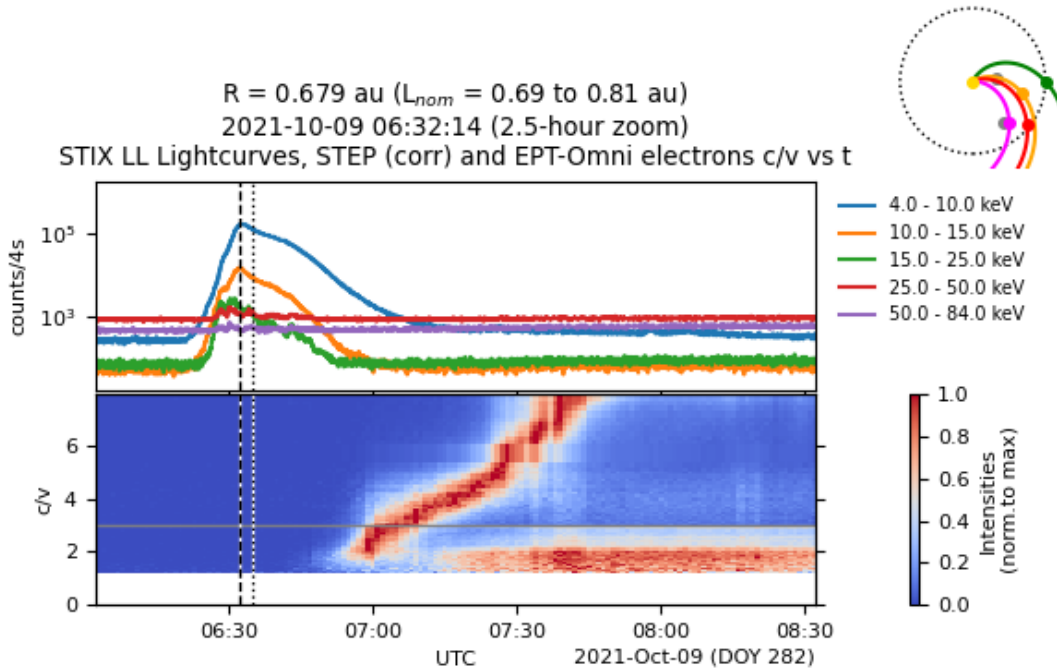


Solar Orbiter: all essential assets on a single platform, sampling inner heliosphere

- **in-situ particles: EPD**
 - timing (including injection times), fluxes, spectra, composition, and anisotropy
- **X-rays: STIX**
 - timing, fluxes, spectra, and source location
- **radio: RPW**
 - presence and timing of type III bursts
- **EUV: EUI**
 - timing, position, morphology of EUV flare



Associating in-situ electron events with solar flares: timing

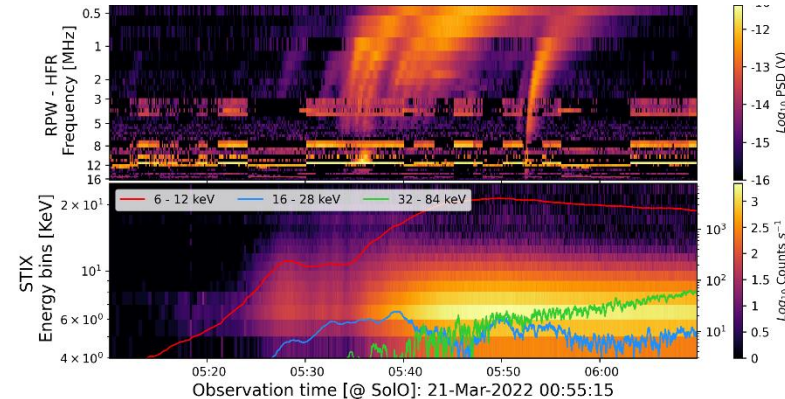
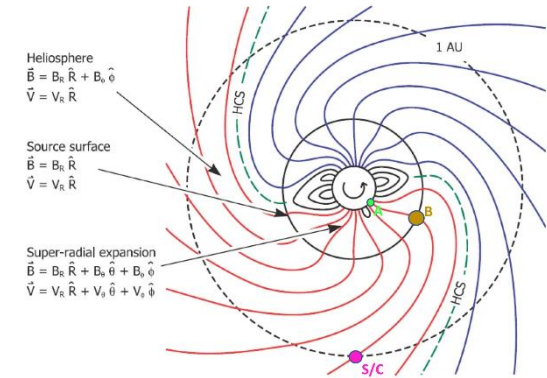


Dashed line: TSA SRT + LT
 Dotted line: VDA SRT + LT

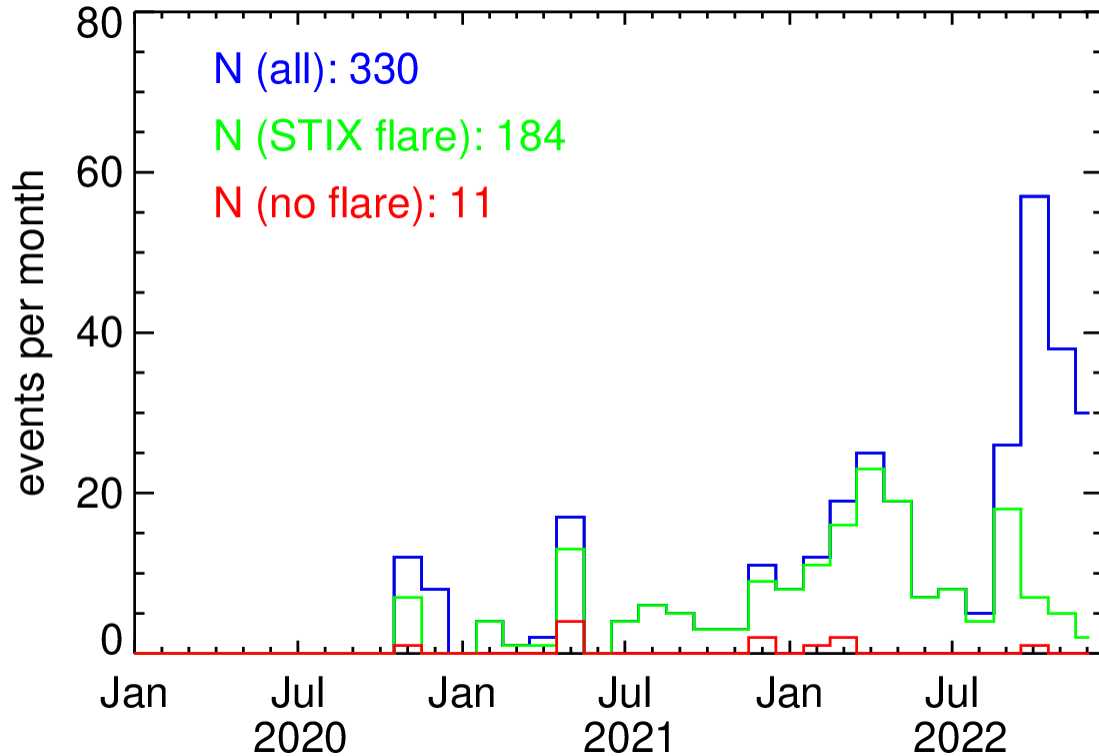
- infer injection time from EPD:
 - Time-shift analysis (TSA; needs to assume path length)
 - Velocity dispersion analysis (VDA; yields path length)
- compare with STIX HXR lightcurves

Associating in-situ electron events with solar flares: flare location and type III bursts

- evaluate STIX flare location in context of magnetic connectivity:
 - comparison to footpoints of magnetic field lines connecting to SoLo using IRAP magnetic connectivity tool
- compare with type III burst timing:
 - get type III burst timing from RPW: how does it compare to STIX peaks and injection times?



Event occurrence

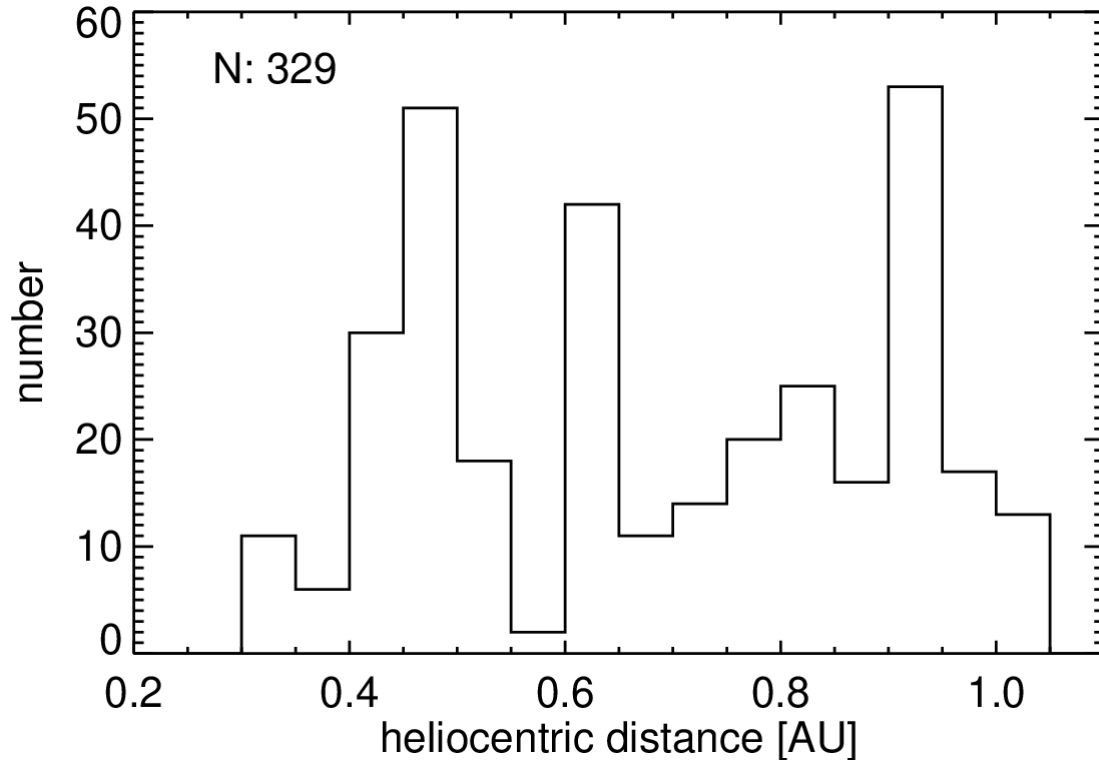


Nov 2020 – Dec 2022:

- EPD:
 - 330 event entries
 - 307 with TSA injection
 - 83 with VDA injection
- 184+ EPD events with potentially associated STIX flare
- 11+ STIX non-

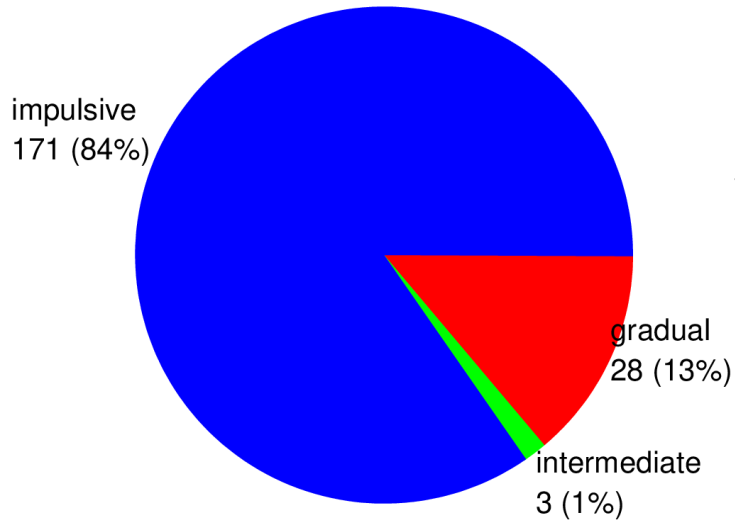
detections

Heliocentric distances

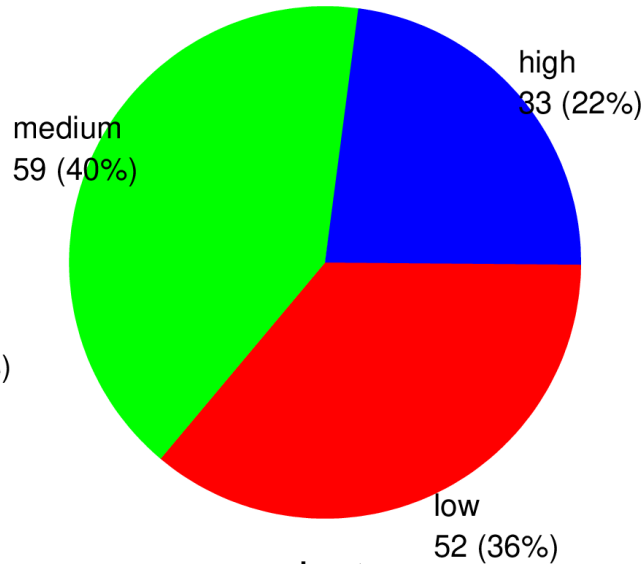


- distances: 0.32 – 1.02 AU
- mean distance: 0.7 AU
- 98 events (30%) below 0.5 AU

Composition and anisotropy



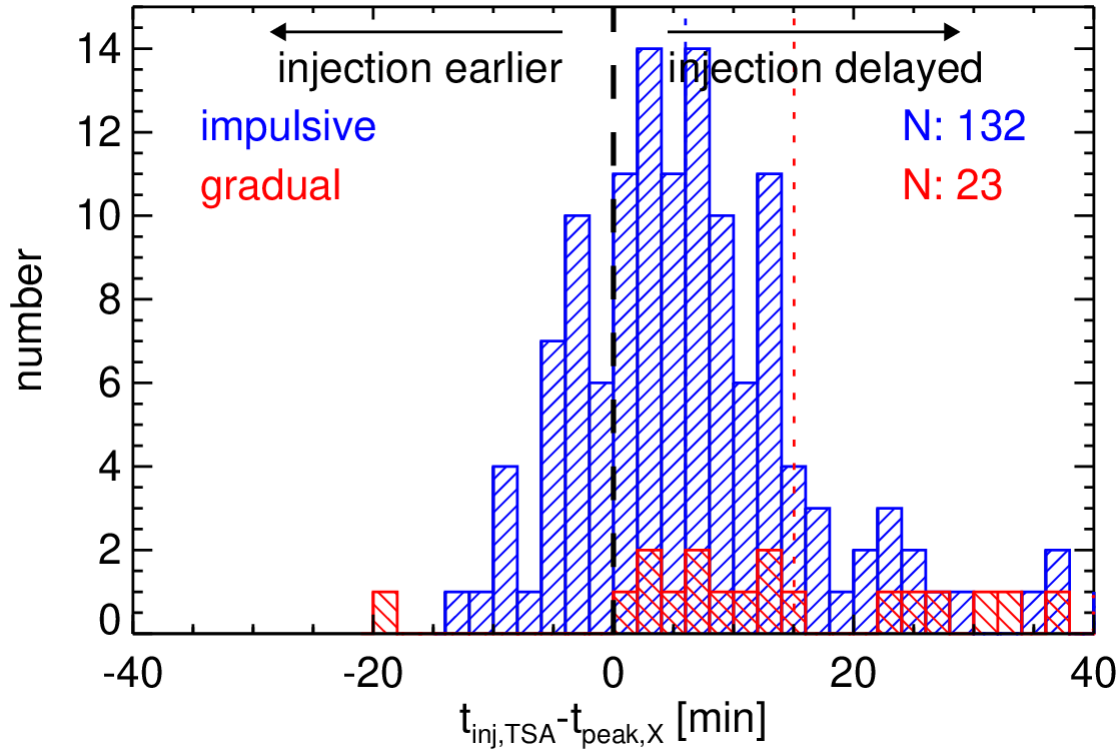
composition
(202 events)



anisotropy
(134 events)

- majority of events has impulsive composition
- ~2/3 of events have medium or high anisotropy

Time difference TSA injection – main nonthermal STIX peak



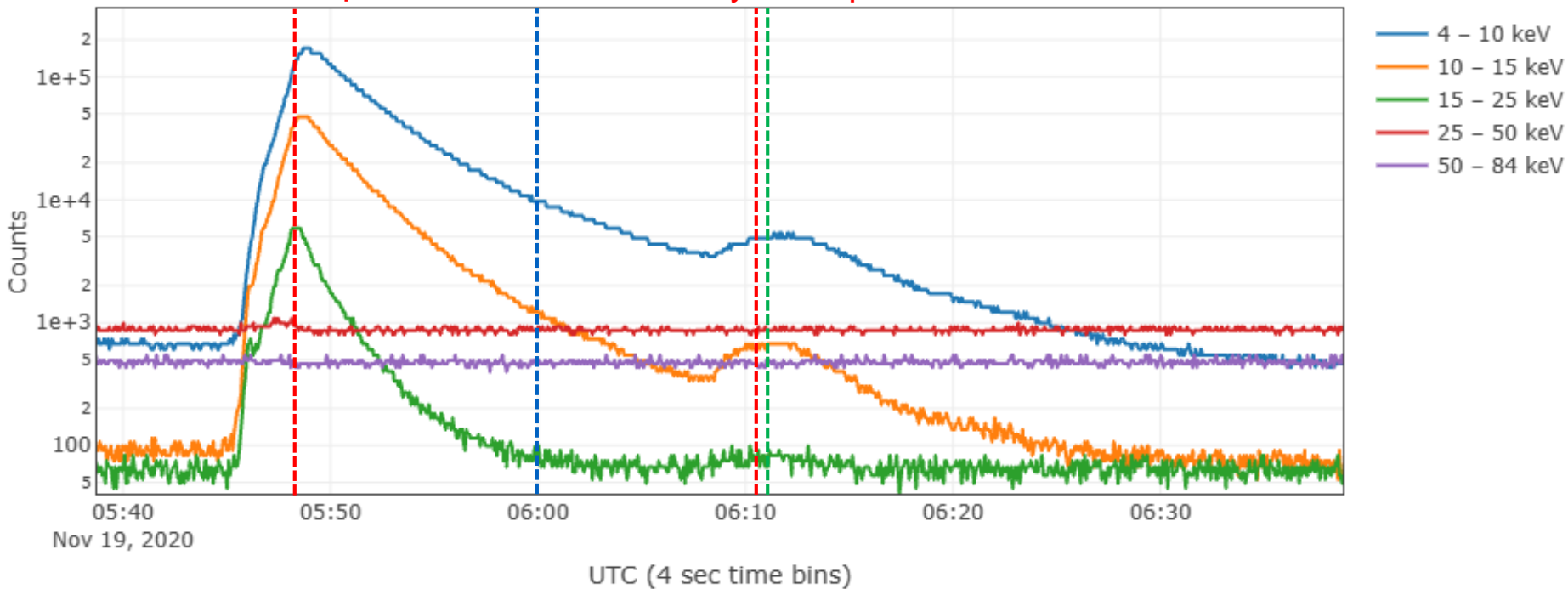
- median delays:
 - impulsive: 6 min
 - gradual: 15 min
- significantly better temporal association for impulsive events

Main and secondary nonthermal STIX peaks

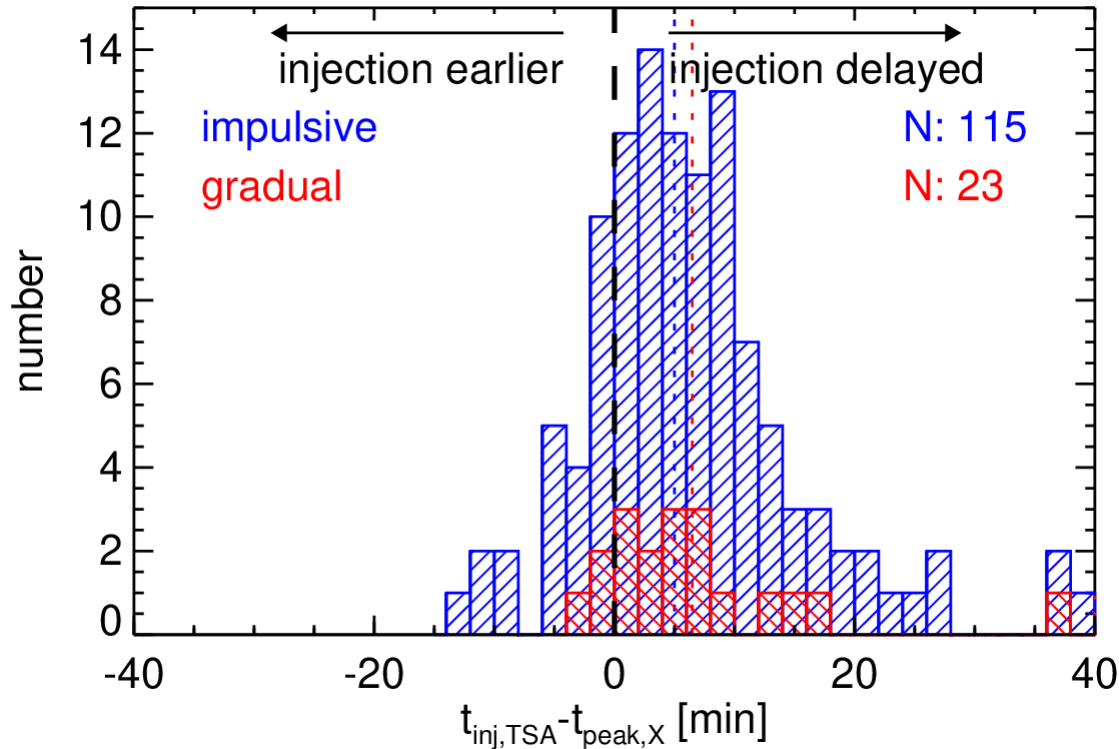
TSA injection type III onset

main STIX peak

secondary STIX peak

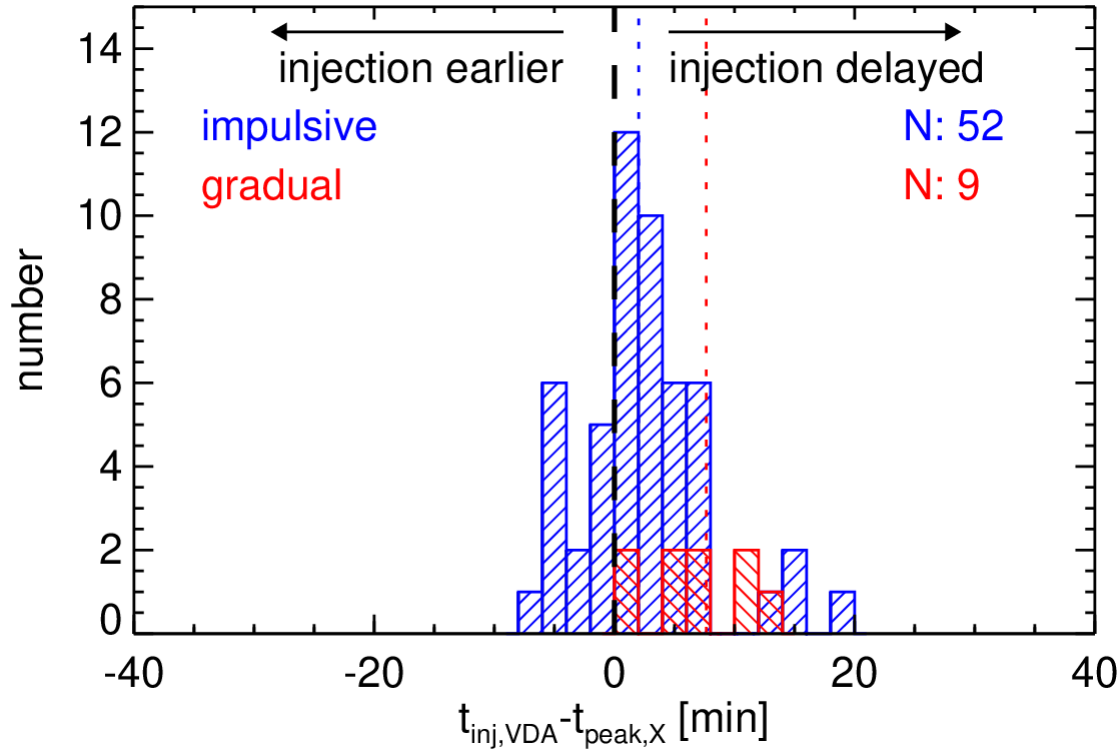


Time difference TSA injection – STIX peak closest to injection



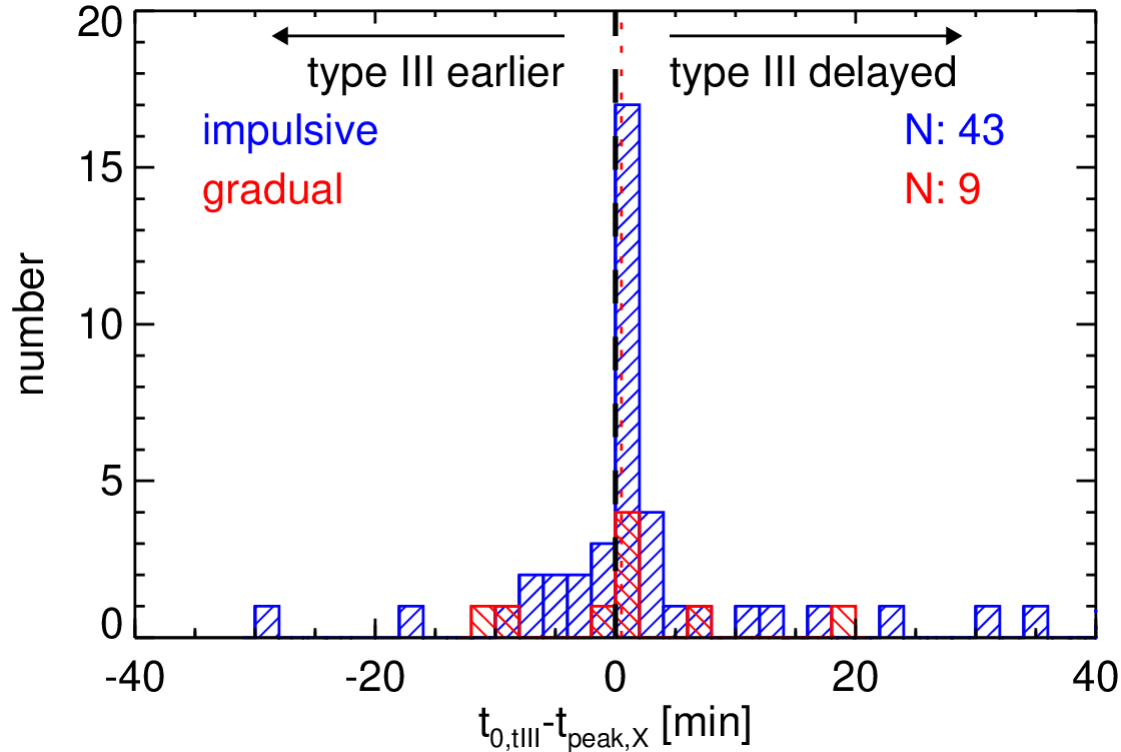
- secondary STIX peaks used in ~50% of event
 - median delays:
 - impulsive: 5 min
 - gradual: 7 min
- similar correspondence for impulsive and gradual events (due to minor STIX peaks in decay phase of LDEs)

Time difference VDA injection – STIX peak closest to injection



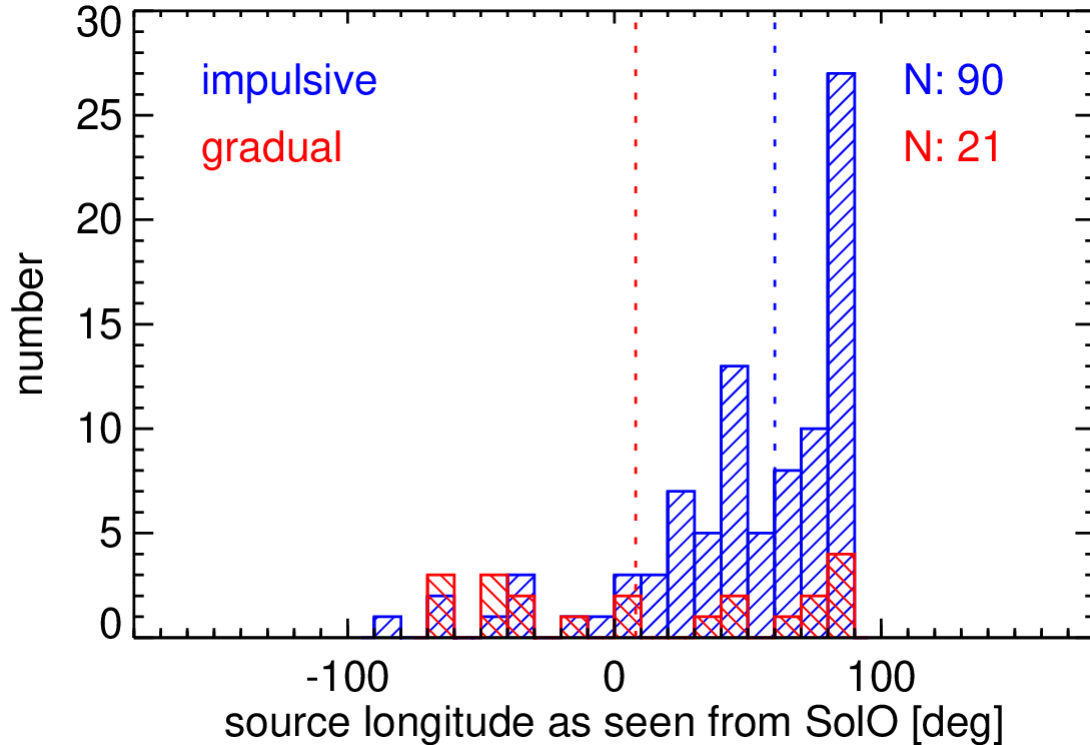
- median delays:
 - impulsive: 2 min
 - gradual: 8 min
- better temporal association than for TSA
- significantly better temporal association for impulsive events

Time difference type III onset – nonthermal STIX peak



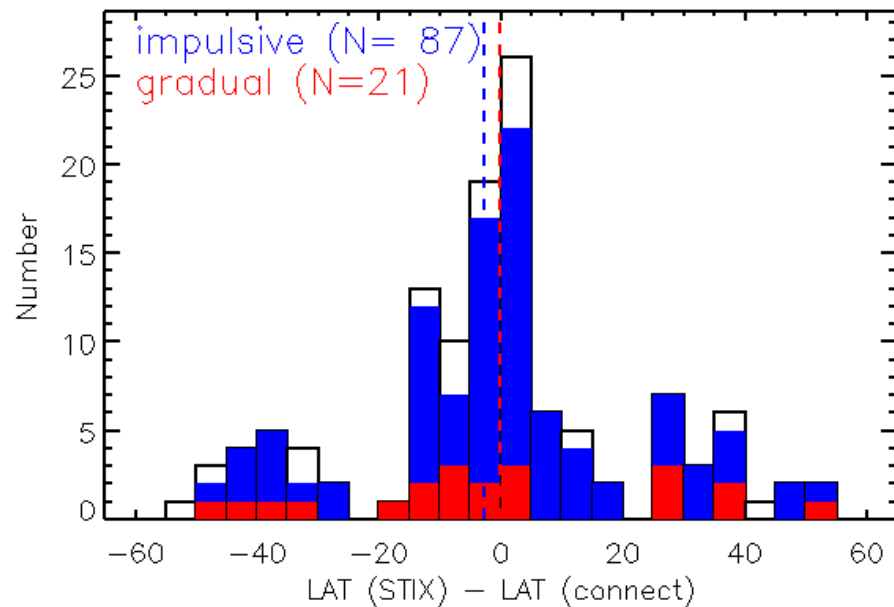
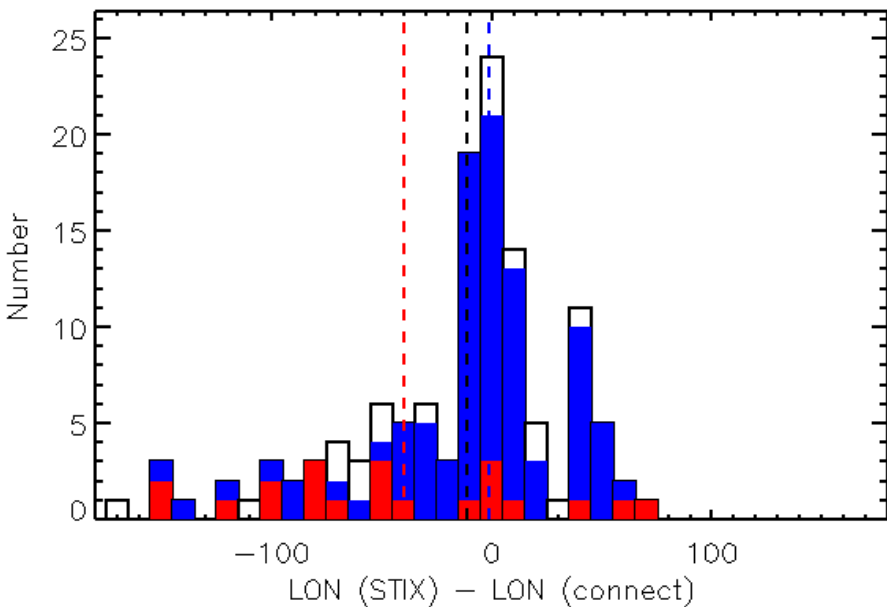
- impulsive events show slightly better temporal association
- within ± 5 min:
 - impulsive: 69%
 - gradual: 63%

Flare longitude as seen from Solar Orbiter



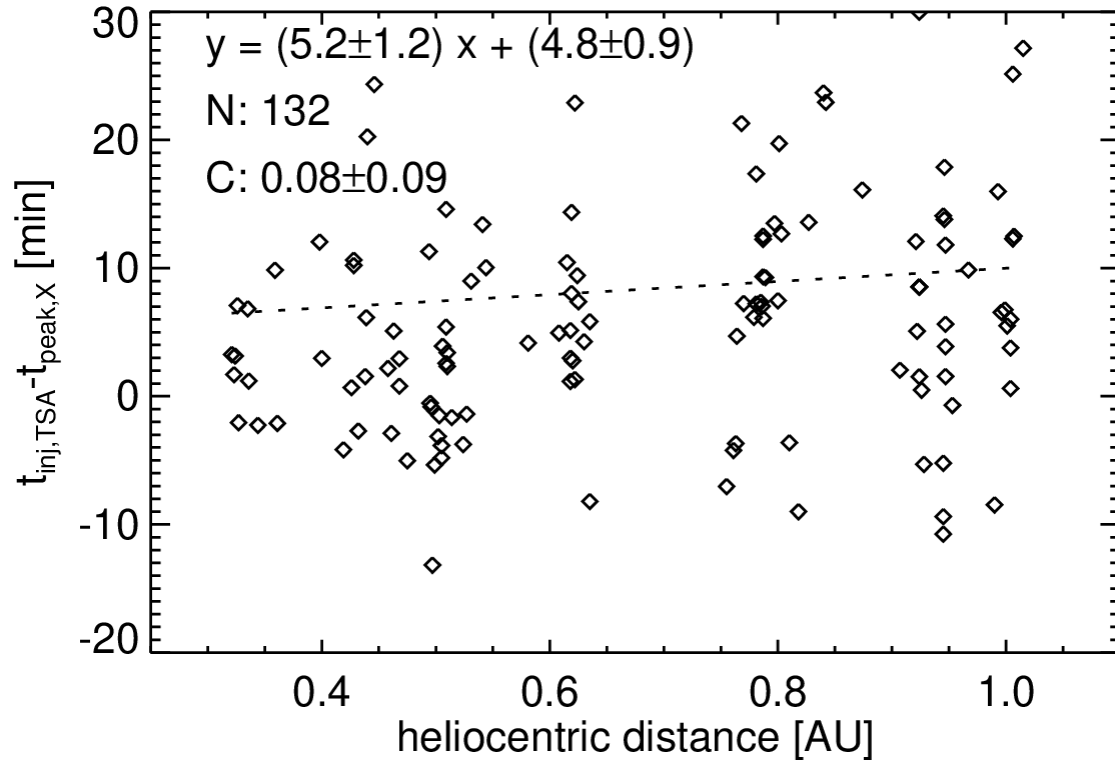
- impulsive:
 - range: E87 – W90
 - median: W60
 - gradual:
 - range: E67 – W90
 - median: W08
- gradual events show flat longitude distribution

STIX flare location compared to footpoint of connecting field line



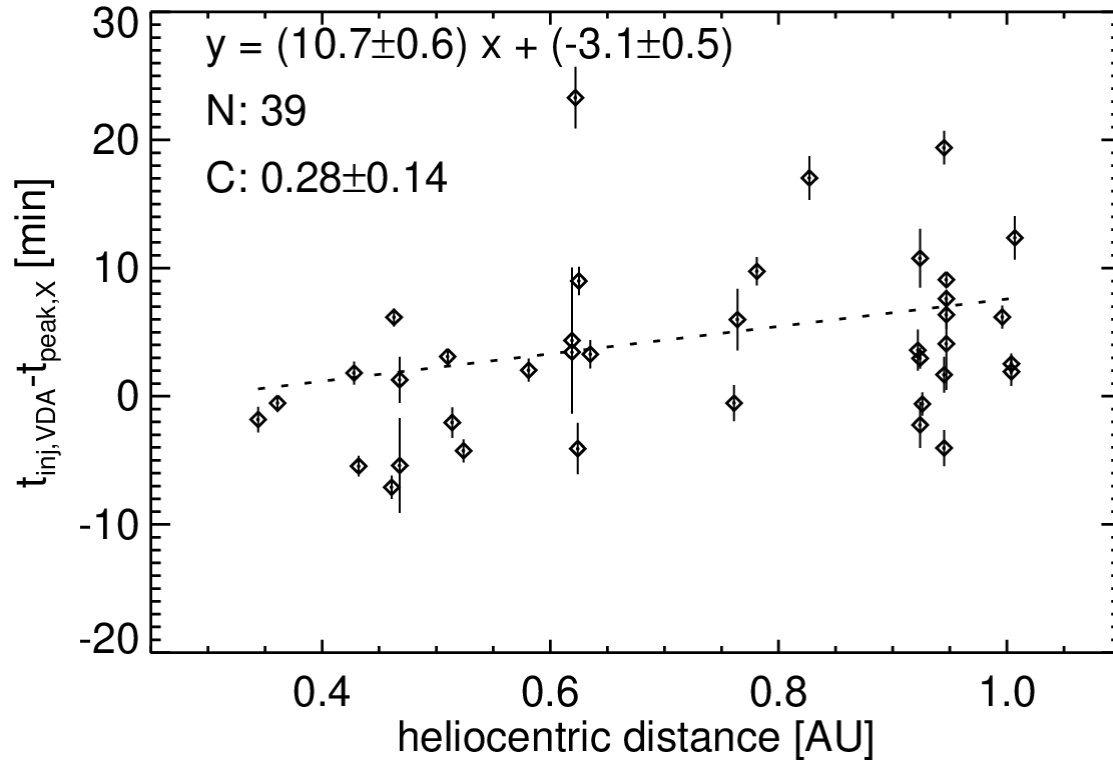
→ impulsive events show much better correspondence

Time difference TSA injection – nonthermal STIX peak vs. distance: impulsive events



- no correlation with distance

Time difference VDA injection – nonthermal STIX peak vs. distance: impulsive events with high & medium anisotropy



- weak trend of time delay increasing with distance

Outlook



- complete event list until end of 2022
- establish associations more firmly based on type III bursts and connectivity
- add CME information (will be provided by Metis team)
- publish first statistical results and joint event list
- perform spectral analysis with STIX and EPD, study relation as function of distance
- include in-situ electron observations from other locations in the heliosphere