# Connecting RPW and FIELDS with X-rays

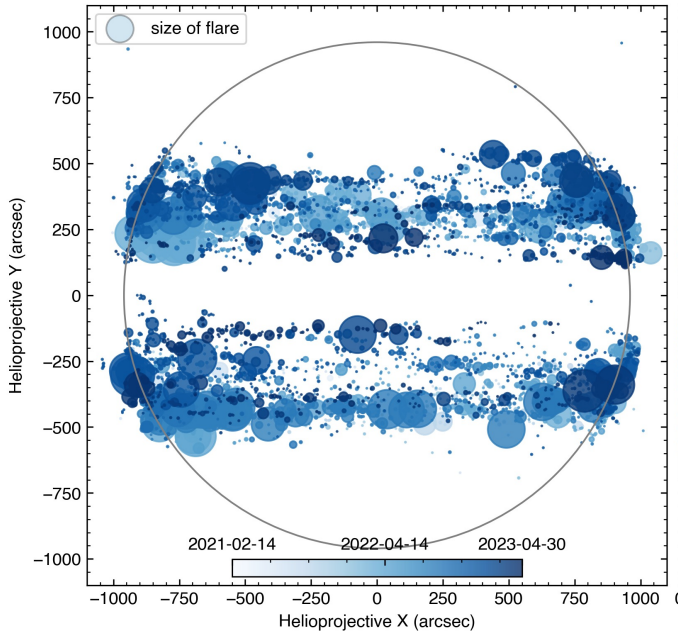
Säm Krucker

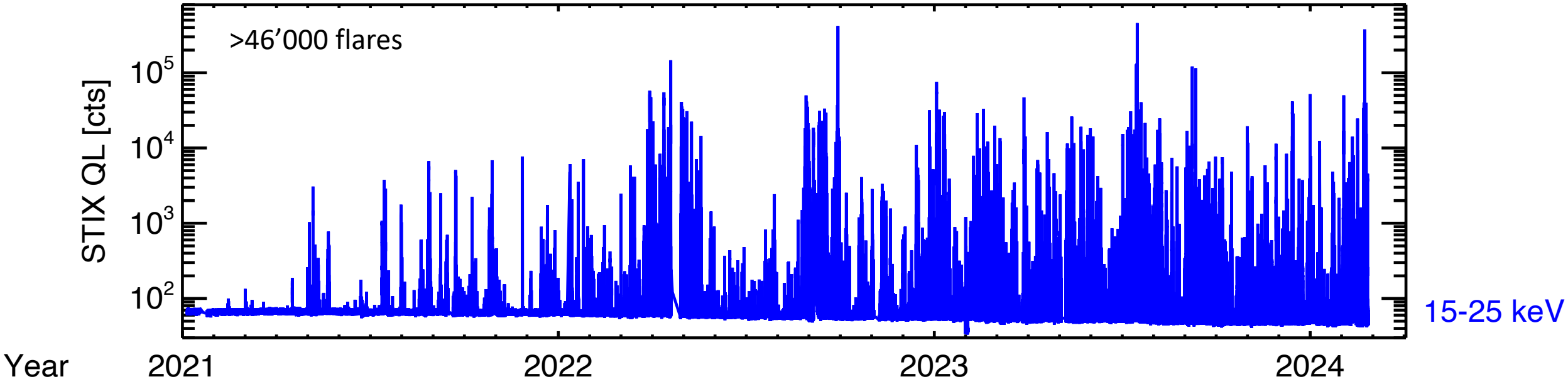
UC Berkeley & University of Applied Science Northwestern Switzerland (FHNW)

# STIX onboard Solar Orbiter

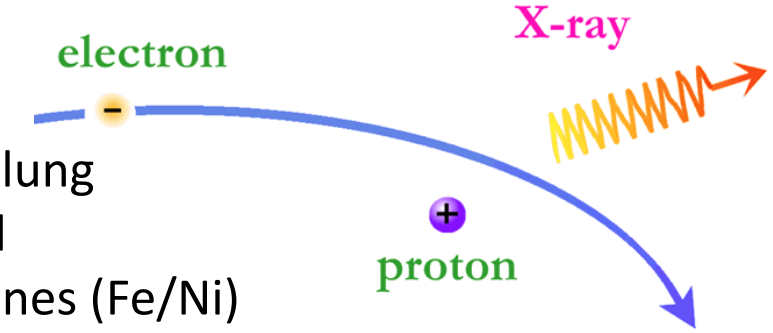
4-150 keV
Thermal bremsstrahlung (‘flare loop’)
Non-thermal bremsstrahlung (‘accelerated electrons’)

[STIX data center: https://datacenter.stix.i4ds.net/](https://datacenter.stix.i4ds.net/)

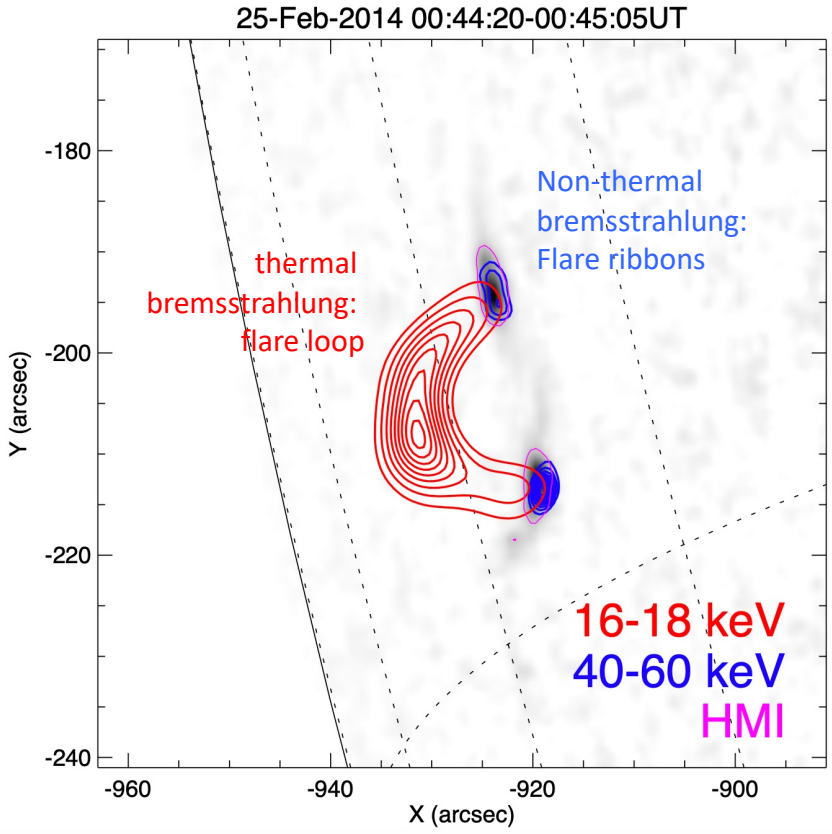


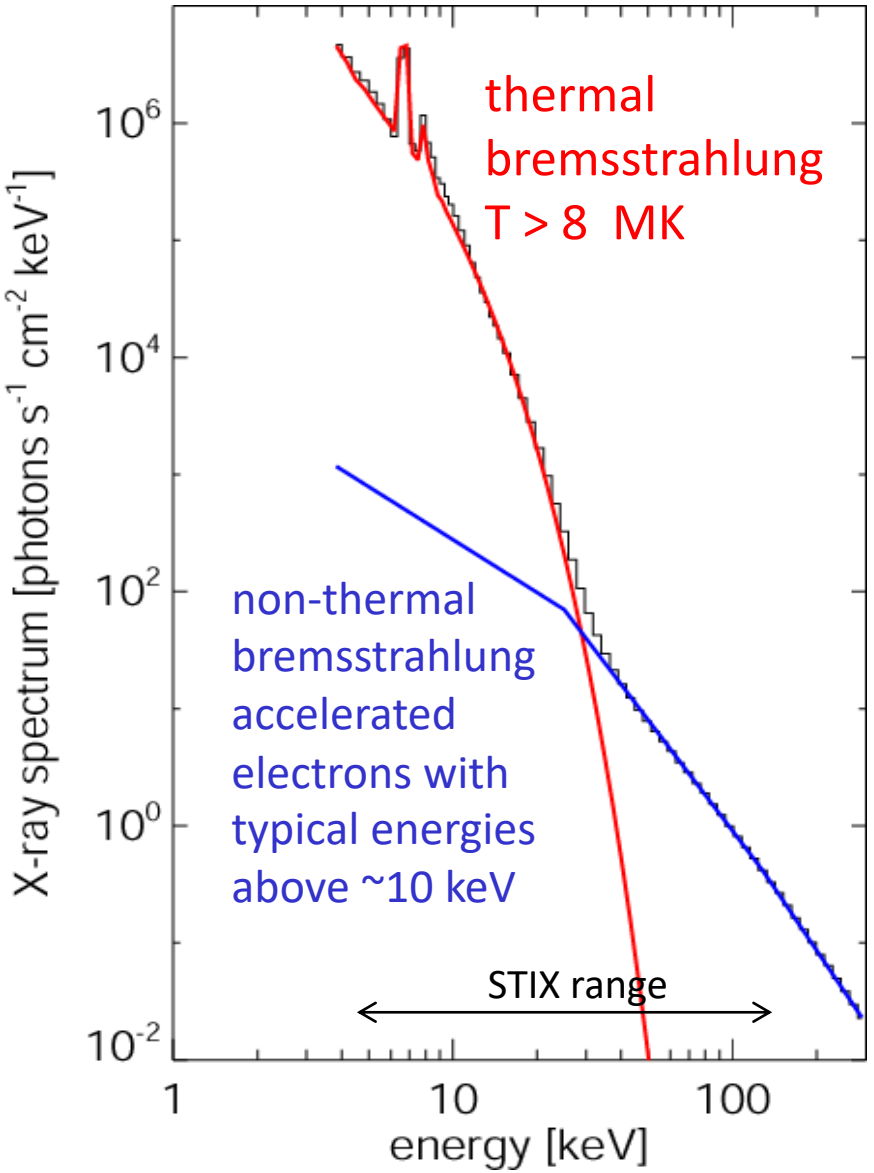



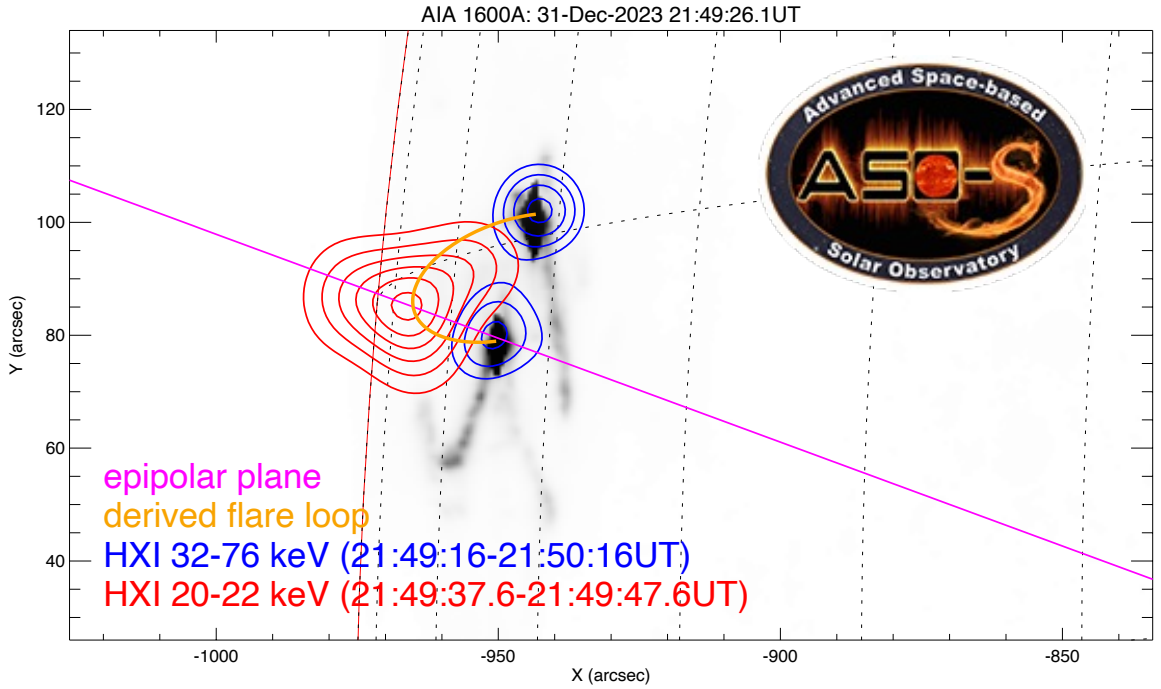
# Hard X-ray diagnostics

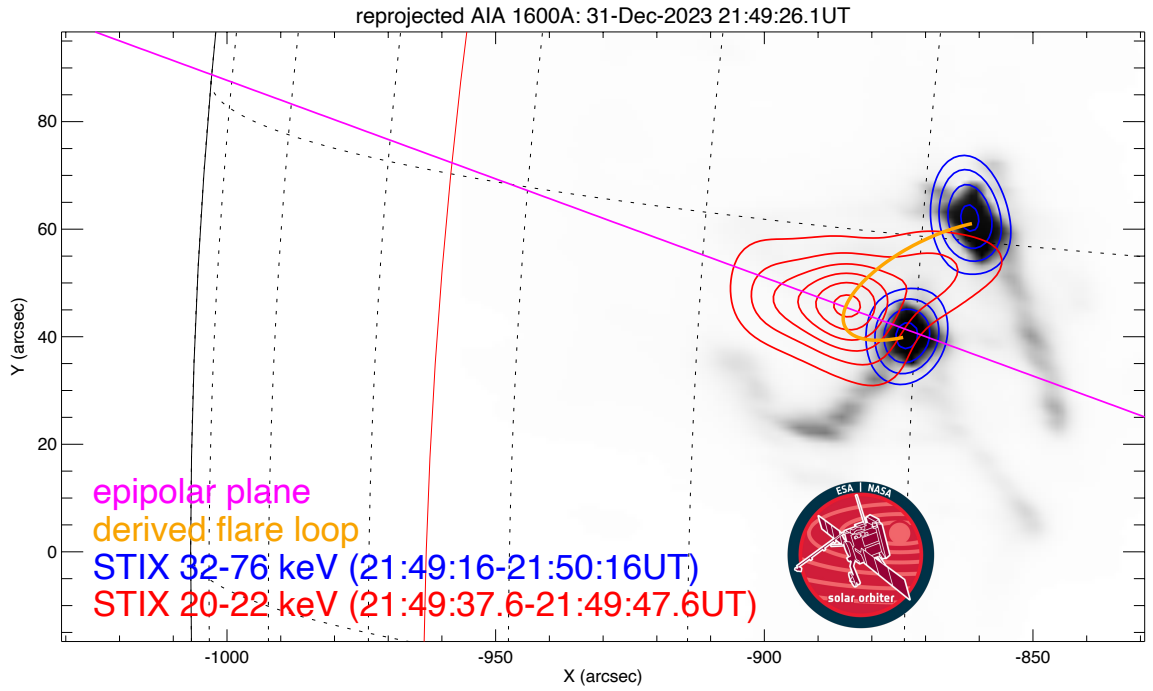



Bremsstrahlung
Free-bound
and a few lines (Fe/Ni)



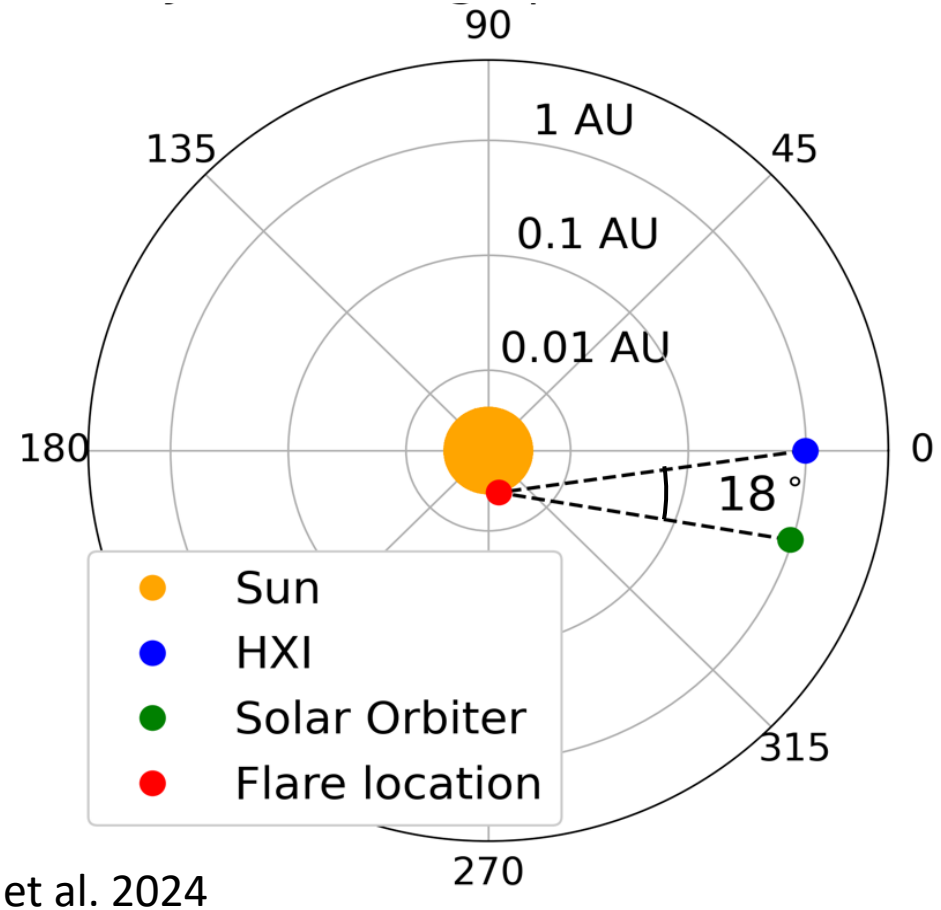






# China's ASO-S mission: Hard X-ray Imager (HXI)

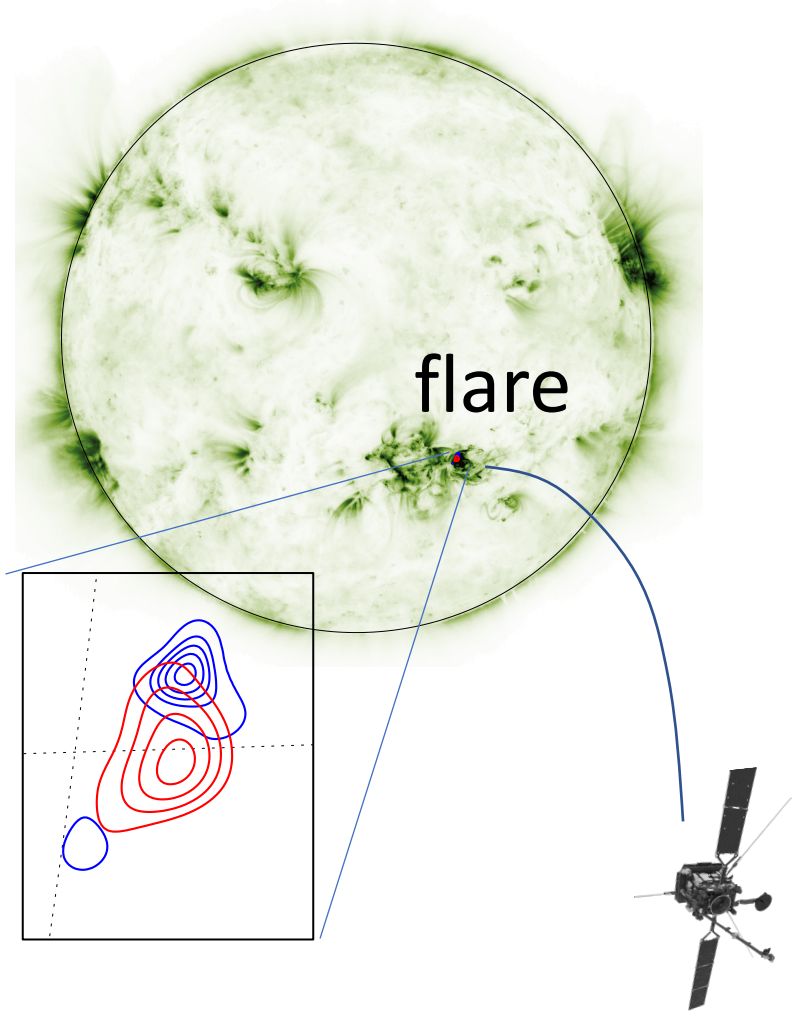
Stereoscopic observations with STIX



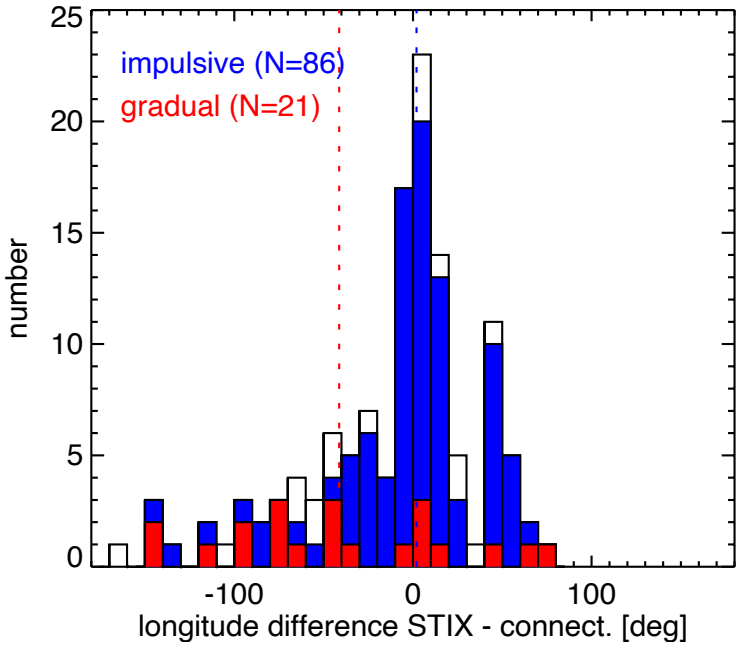

Ryan et al. 2024

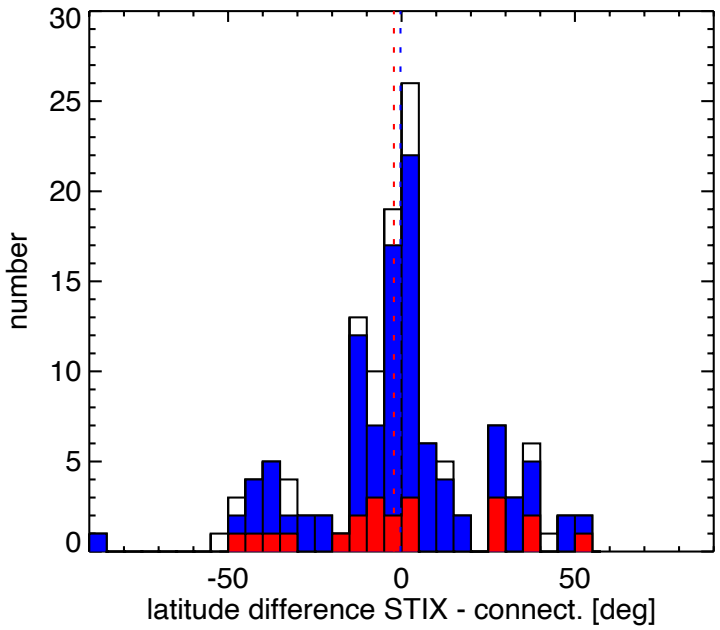
# Solar Energetic Particles seen by Solar Orbiter

*STIX-EPD-RPW-EUI working group (Alexander Warmuth)*




Identify flare location with STIX and compare with connection given by IRAP tool
Initial results (events up to 2022).



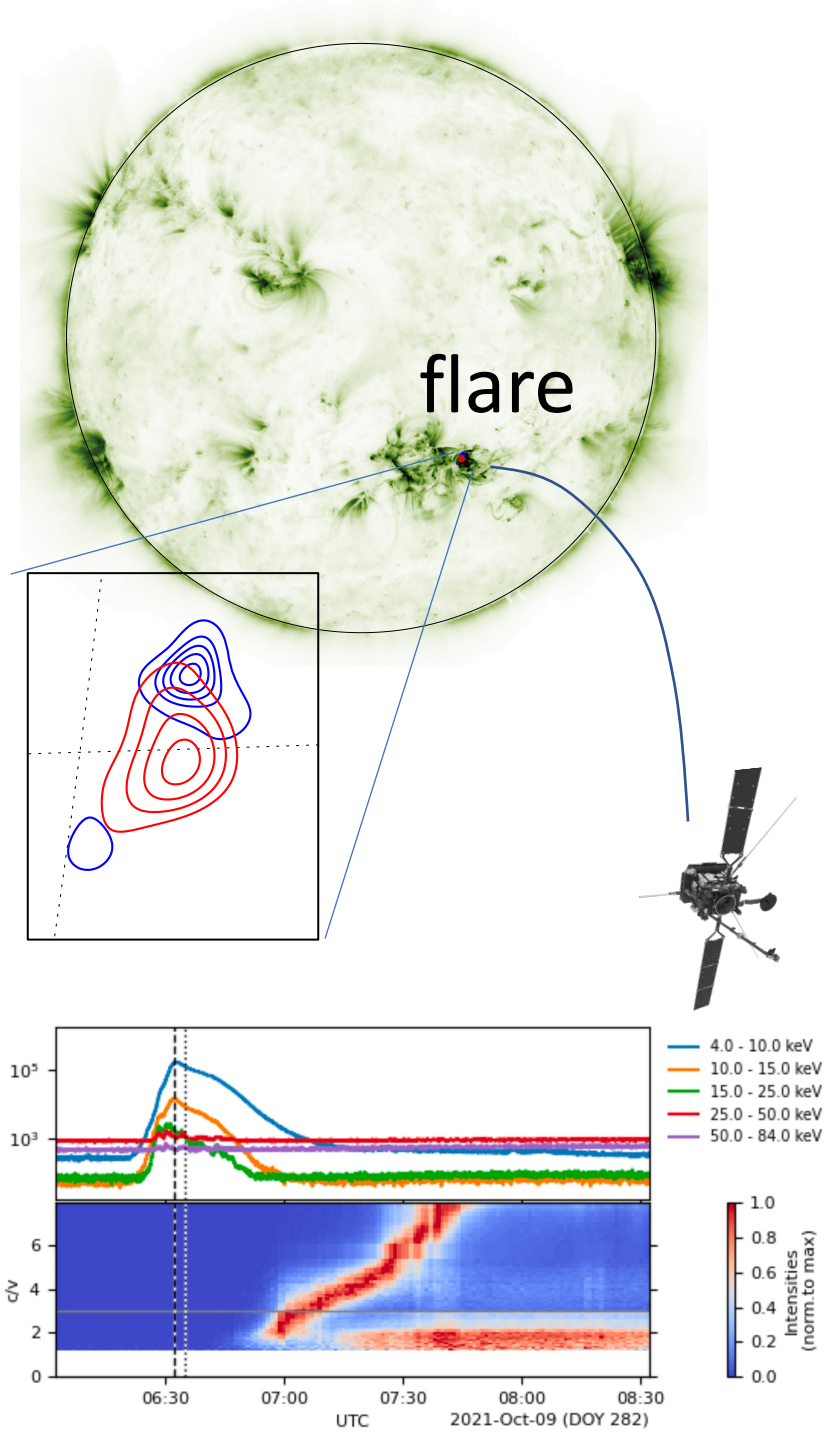




In about half of the events, the locations of associated flares agrees well with footpoints from IRAP tool.

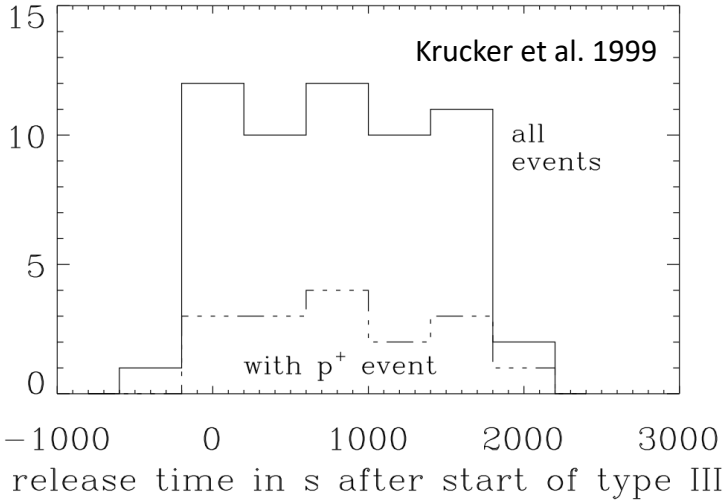
# Solar Energetic Particles seen by Solar Orbiter

*STIX-EPD-RPW-EUI working group (Alexander Warmuth)*

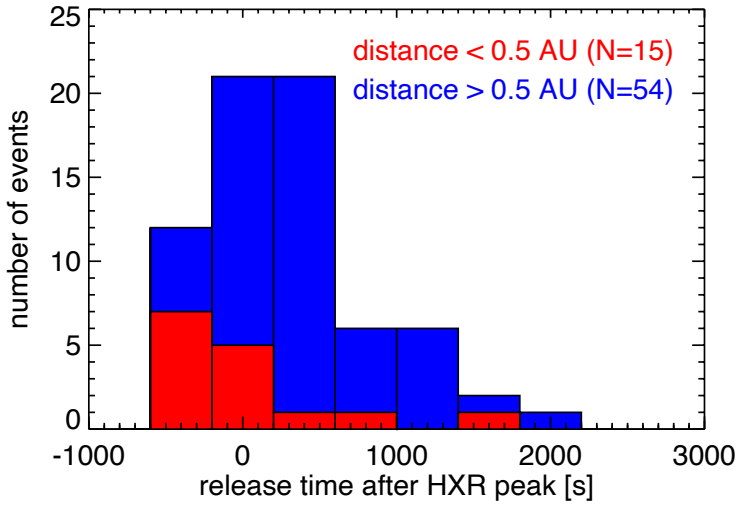
Timing between estimated SEP release time and X-ray flare




WIND/3dp results from 1 AU

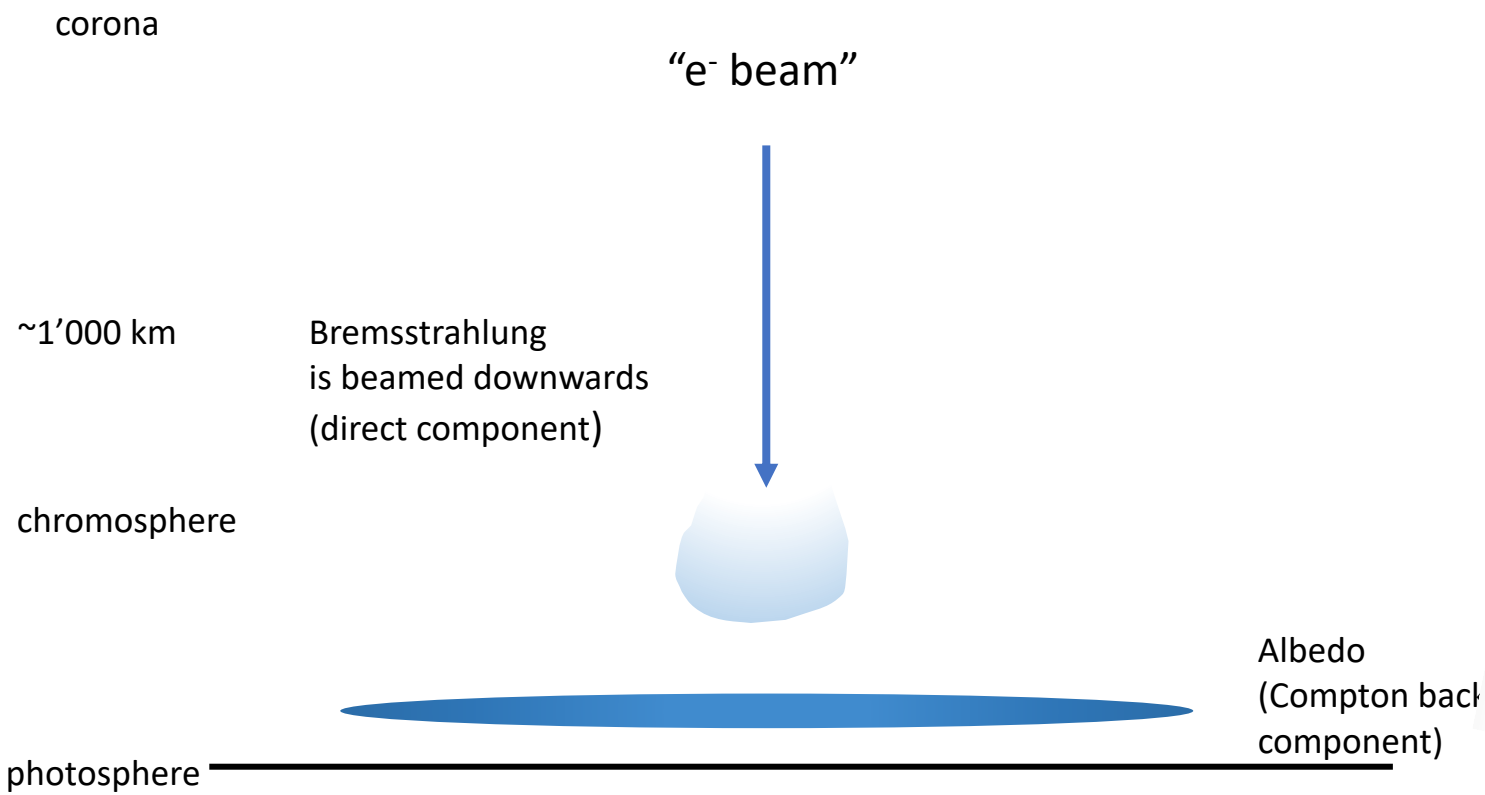


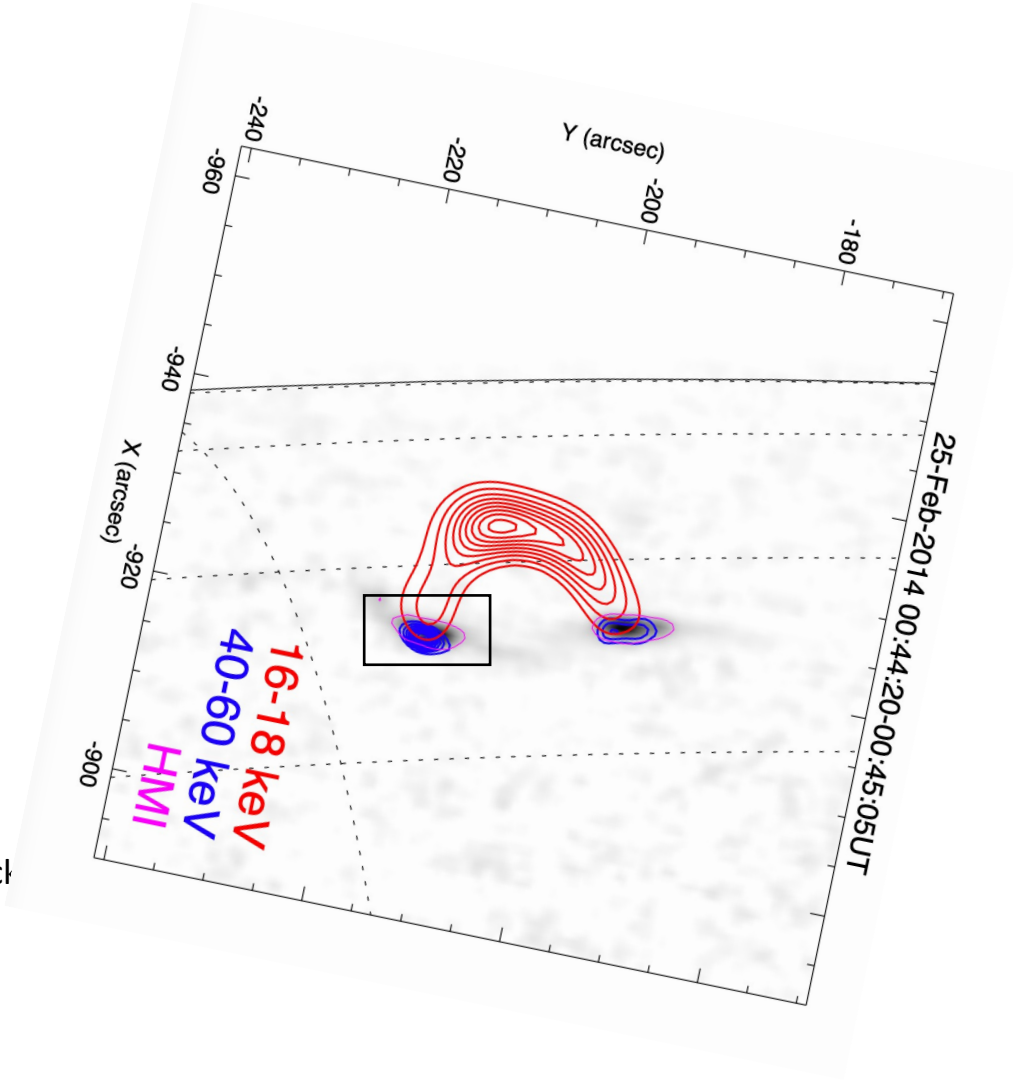

Solar Orbiter (only events with velocity dispersion)




less spread compared to previous studies done at 1 AU (i.e. scatter-free transport assumption not always fulfilled for events seen at 1 AU).

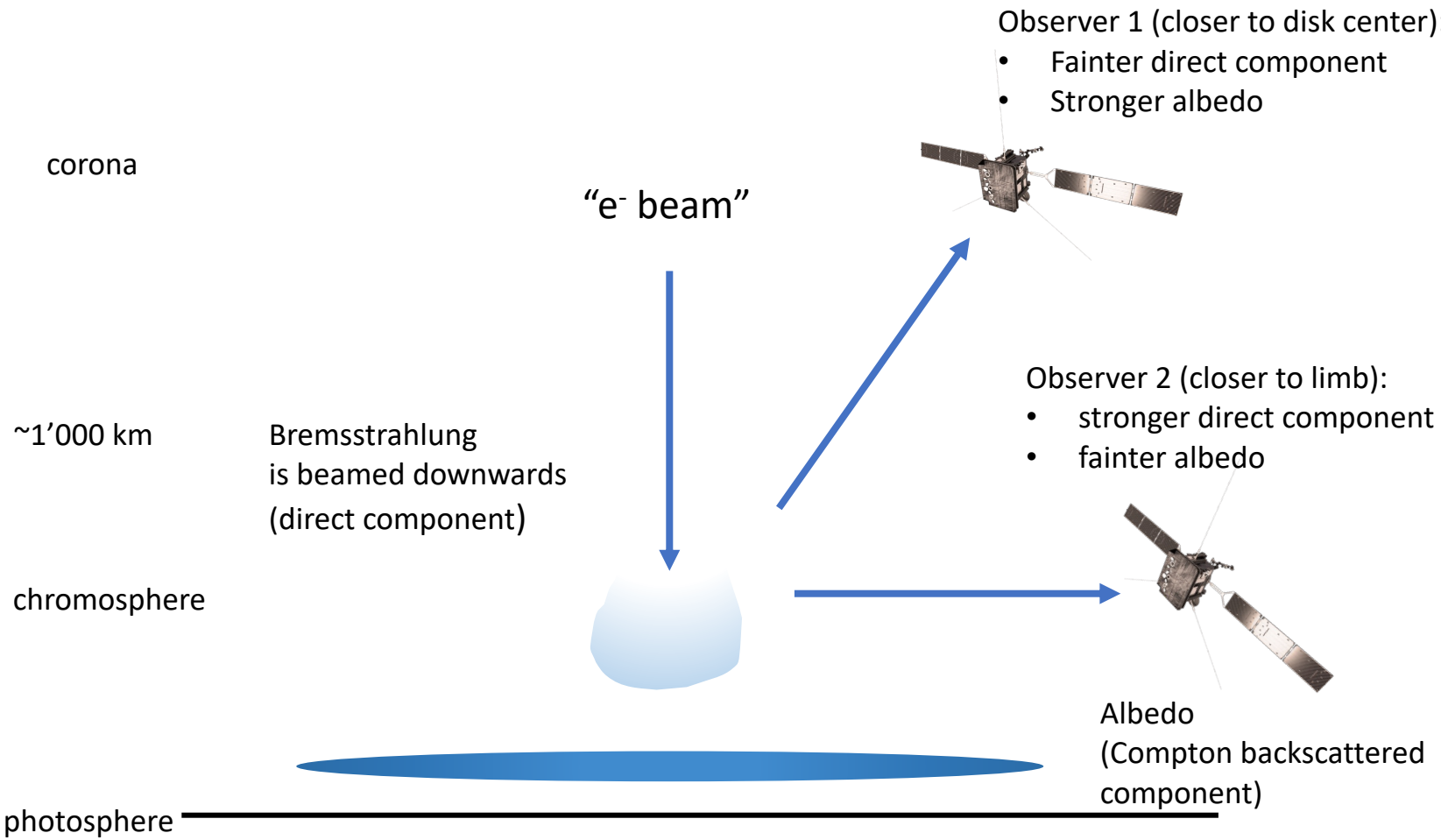
# Electron beams produce anisotropic X-ray emissions




Simulations: Jeffrey et al. 2024

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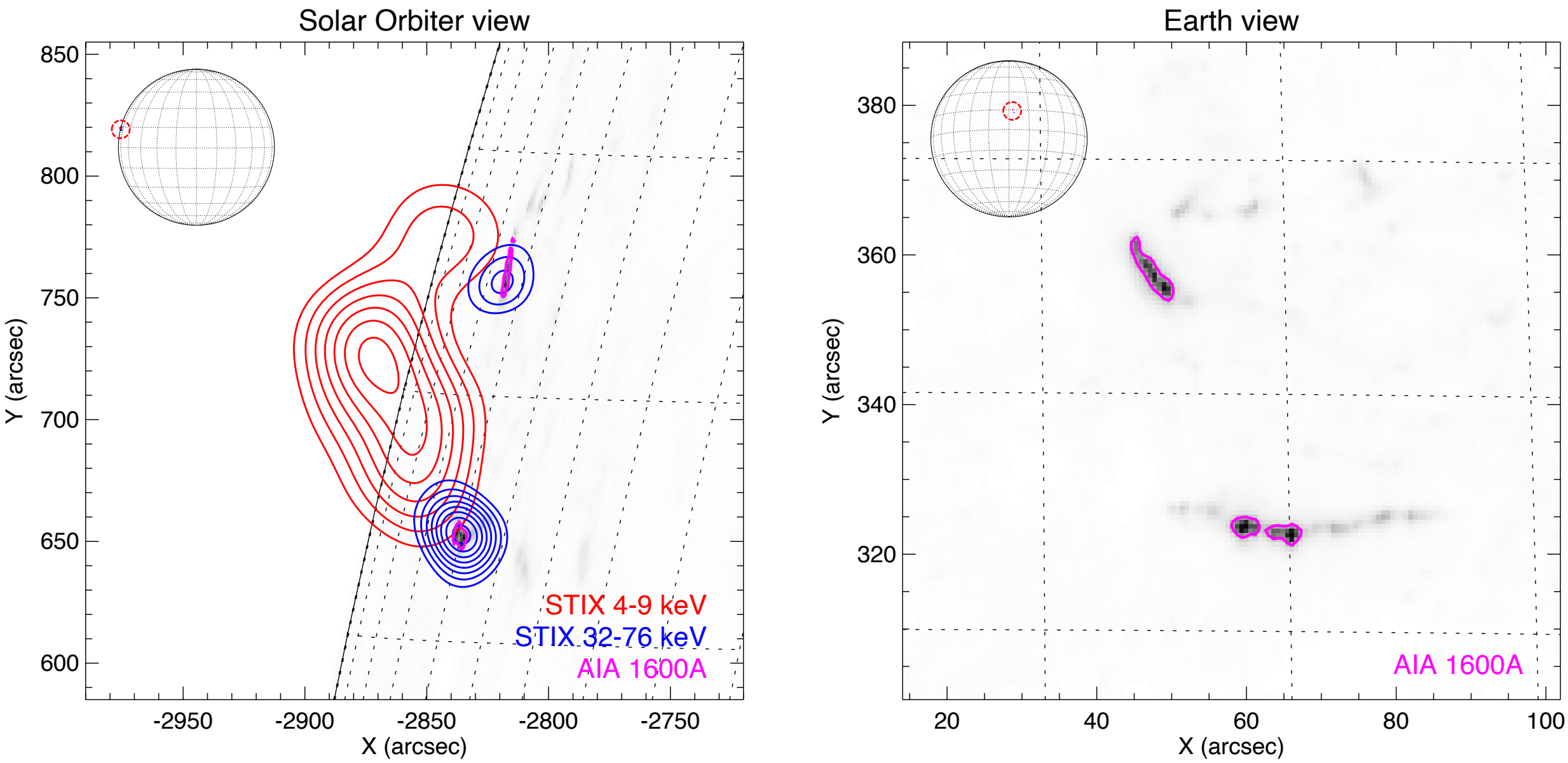
Two X-ray instrument at different viewing angles see a different X-ray signal.

Albedo dependents on viewing angle and can be calculated is known (Kontar et al. 2006).

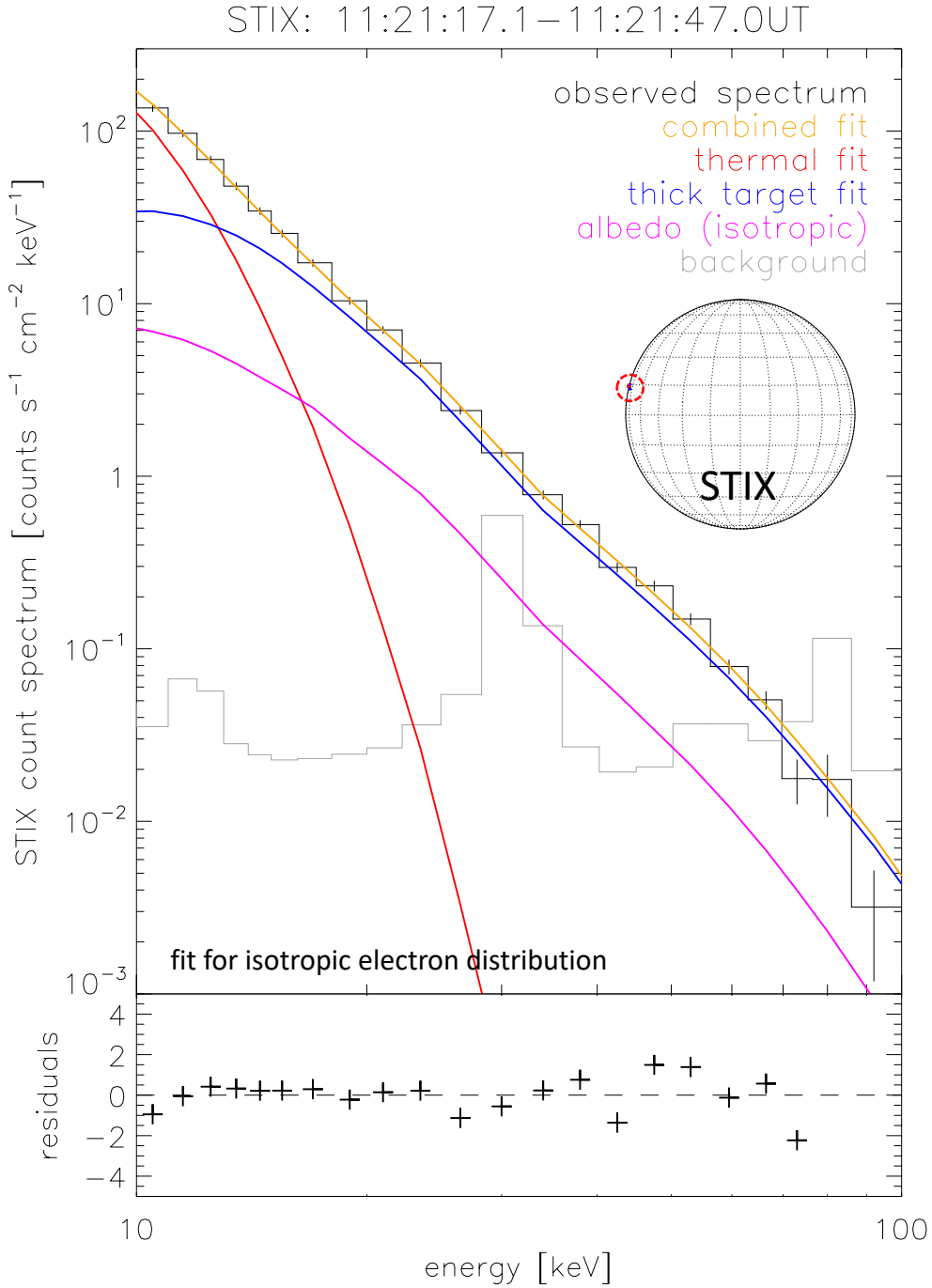
Observations from two different viewing angles allow to measure the degree of beaming.

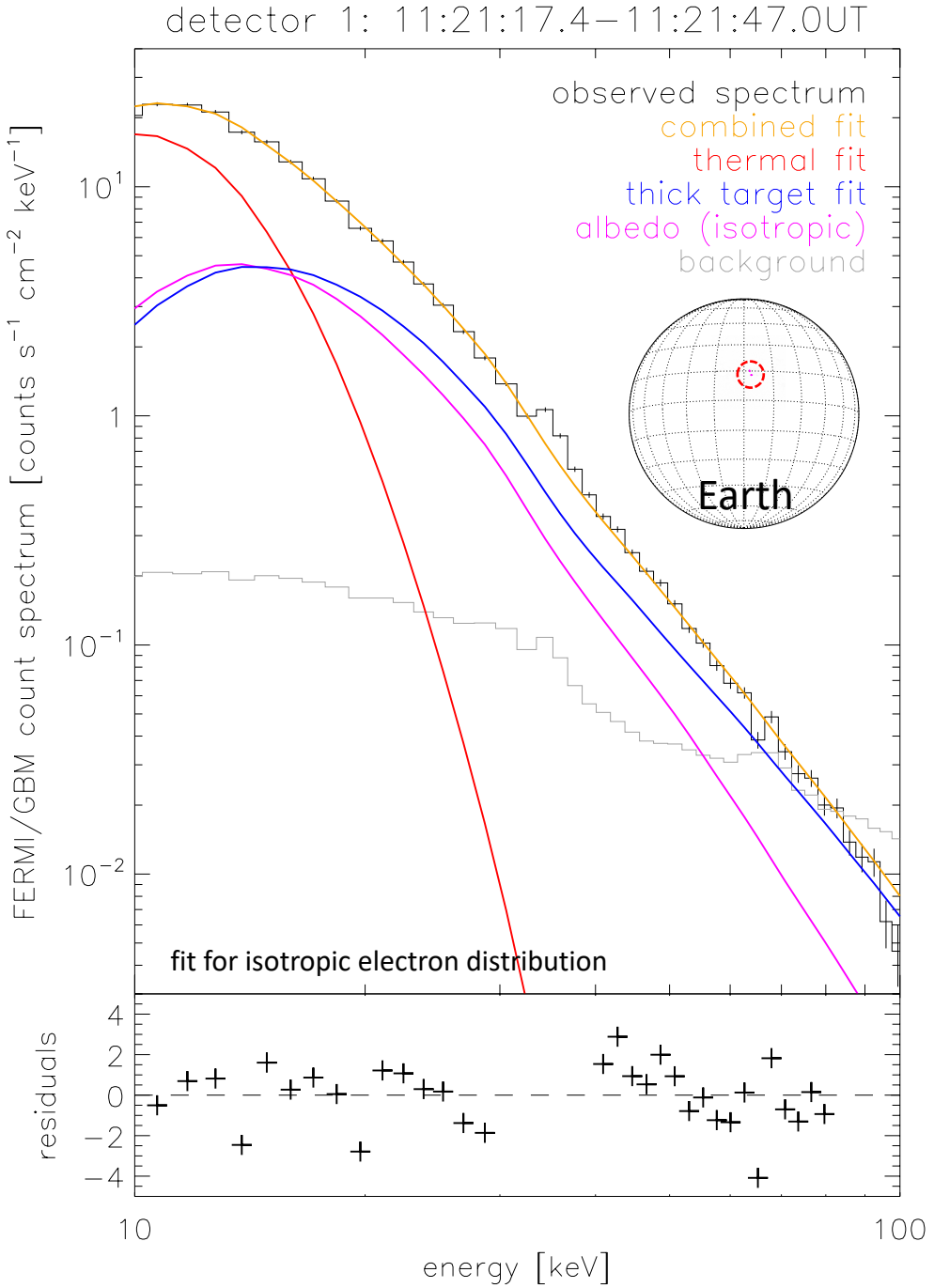
Solar Orbiter/STIX
FERMI/GBM

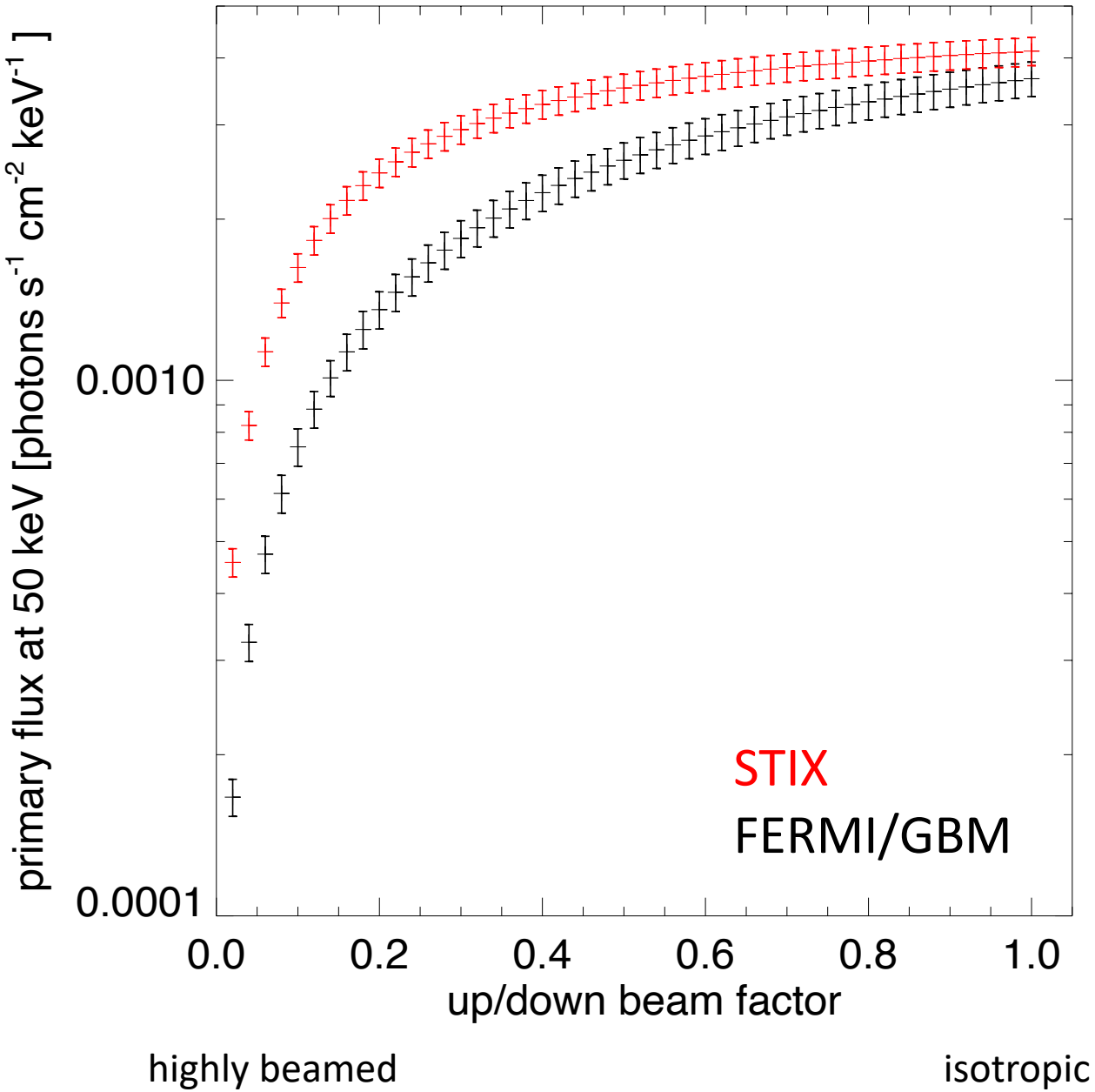
Future:
HEL1OS onboard Aditiya-L1
ASO-S/HXI
PADRE cubesat mission




Solar flare SOL2022-03-28T13 (GOES M4)


STIX: 11:21:17.1–11:21:47.0UT
observed spectrum
combined fit
thermal fit
thick target fit
albedo (isotropic)
background
STIX
fit for isotropic electron distribution
STIX count spectrum [counts s$^{-1}$ cm$^{-2}$ keV$^{-1}$]
residuals
energy [keV]


detector 1: 11:21:17.4–11:21:47.0UT
observed spectrum
combined fit
thermal fit
thick target fit
albedo (isotropic)
background
Earth
fit for isotropic electron distribution
FERMI/GBM count spectrum [counts s$^{-1}$ cm$^{-2}$ keV$^{-1}$]
residuals
energy [keV]




For consistent result:
Fit needs to provide the same primary flux

HXR emission seems not to be produced by electrons beam!

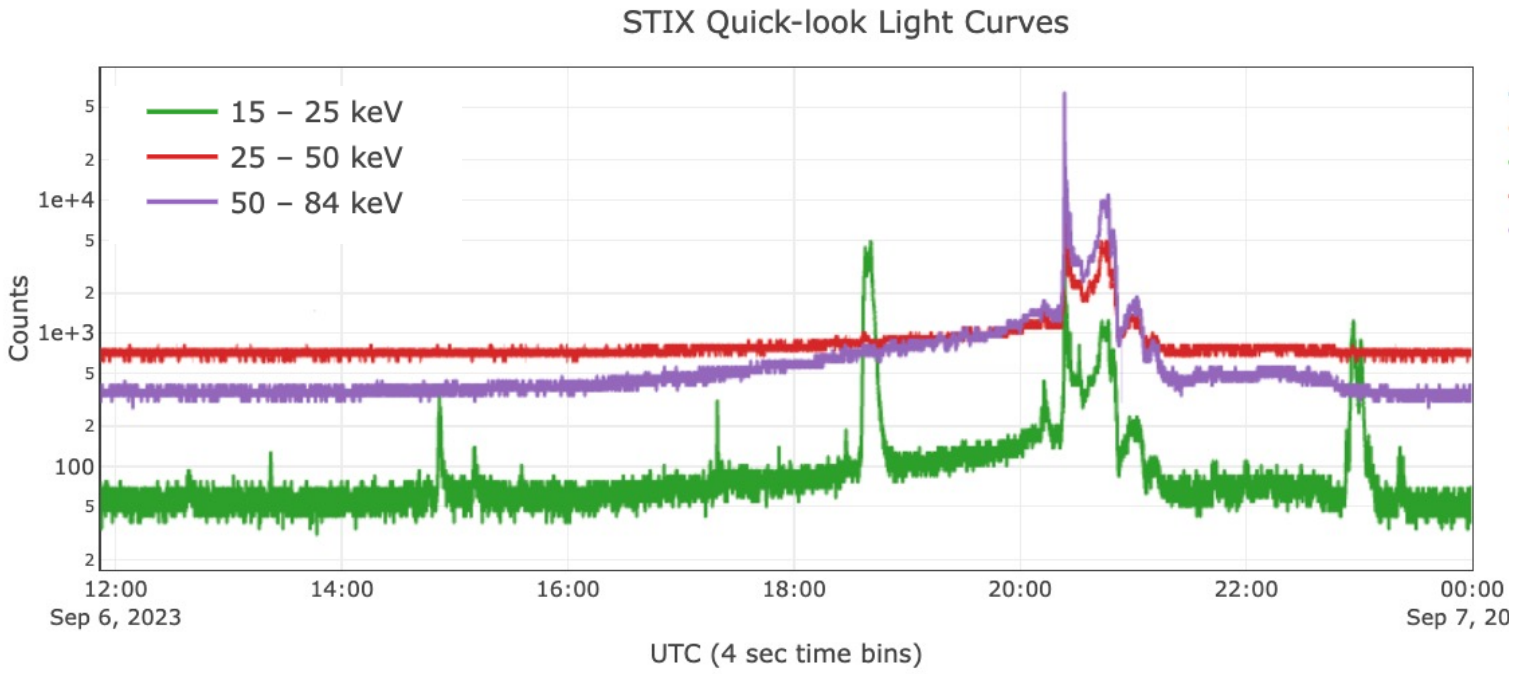
Only isotropic works. Confirms earlier results using single vantage point observations (e.g. Kontar et al. 2006, Dickson et al. 2013).

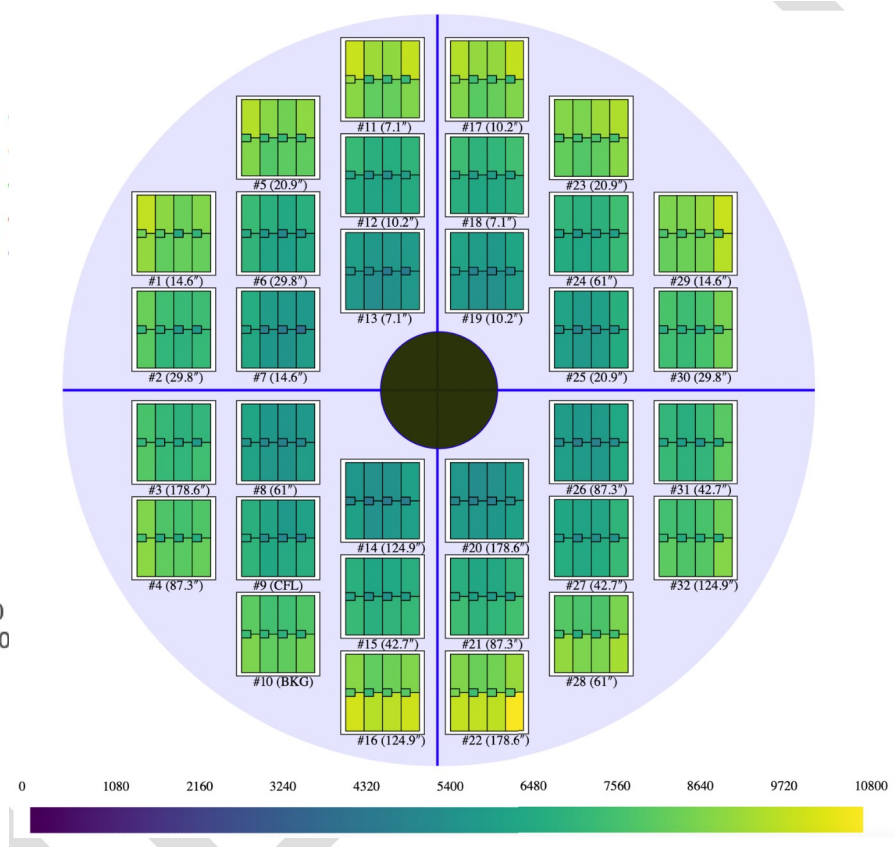
**At the time of the X-ray production: electrons are not beams, but clouds.**

Implications for

- Acceleration mechanism
  - Beams or clouds
- Electron transport
  - Start as beam ends as cloud?
  - Transport as cloud?

# What does STIX detect during passage of a shock?




SEPs interact with the spacecraft/instruments creating secondary X-rays.
Some are directed towards the STIX detectors.
GeV electrons are the main contributor.

Collier et al. 2023