Coronal hard X-ray thin target bremsstrahlung emission from flare-accelerated electrons

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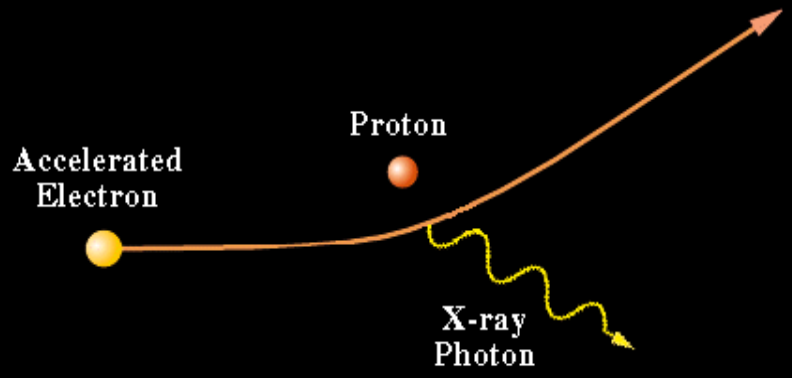
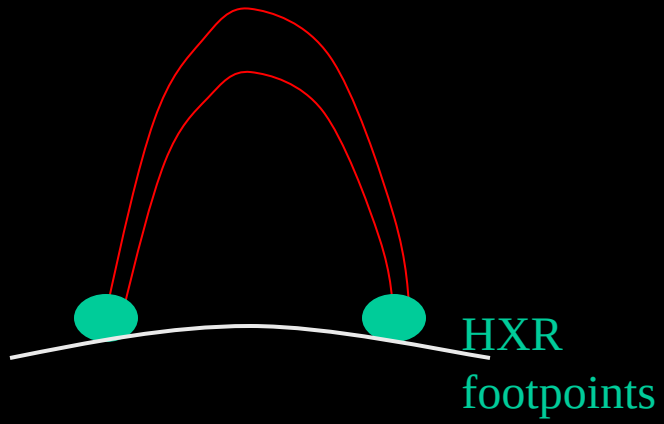
HXR emission as diagnostics of electron acceleration in solar flares

Non-thermal bremsstrahlung



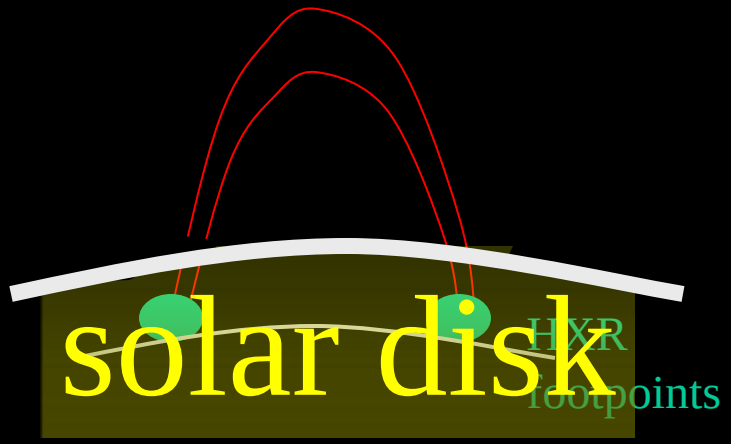
Standard flare scenario:
high density chromosphere
→ HXR footpoints

low density corona
→ very weak HXR emission



HXR emission as diagnostics of electron acceleration in solar flares

partially disk-occulted flares
→ purely coronal emission
can be studied



Statistical studies:
Roy & Datlowe 1975, McKenzie 1975,
Mariska et al. 1996,
Tomzcak 2001, Krucker & Lin 2008

HXR emission as diagnostics of electron acceleration in solar flares

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- RHESSI: hard X-ray
- HINODE: soft X-ray
- STEREO: EUV, different view-angle

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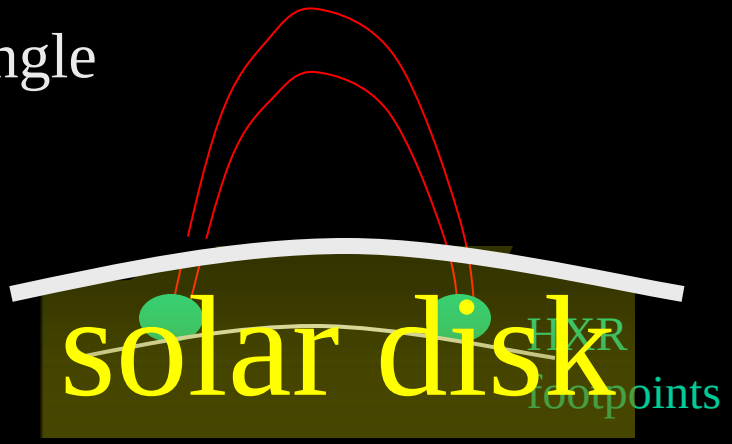
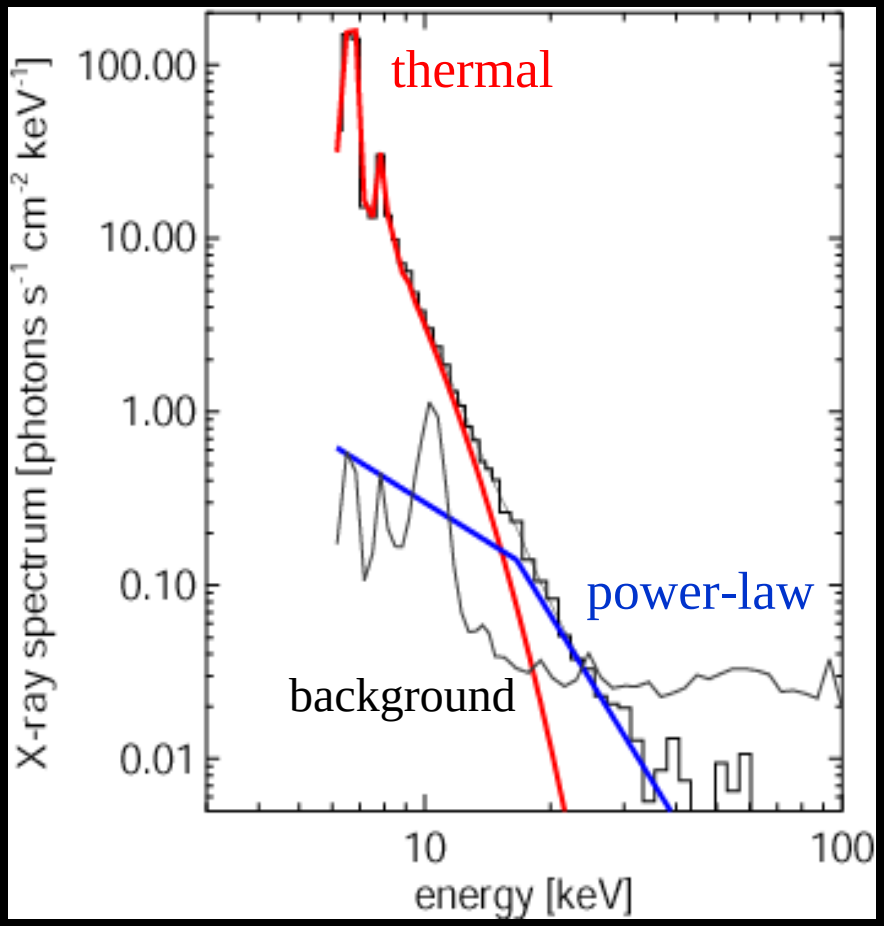
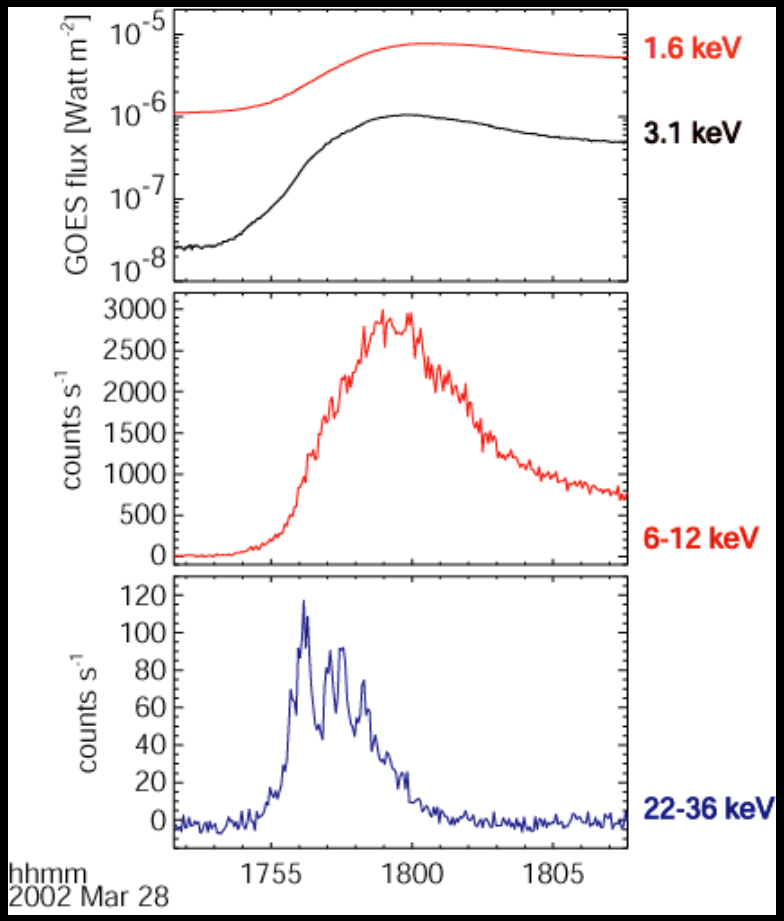


typical example of partially disk-occulted flare

Statistical study of partially occulted flares (Krucker & Lin 2008):
~90% of flares show non-thermal emission from corona





RHESSI observations

Statistical study of partially occulted flares (Krucker & Lin 2008):
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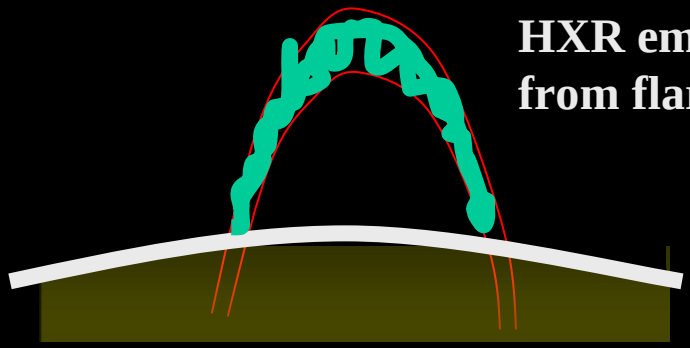
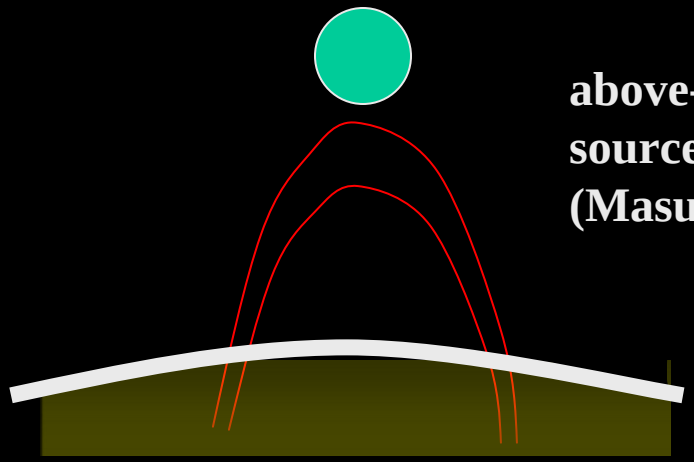
often seen:

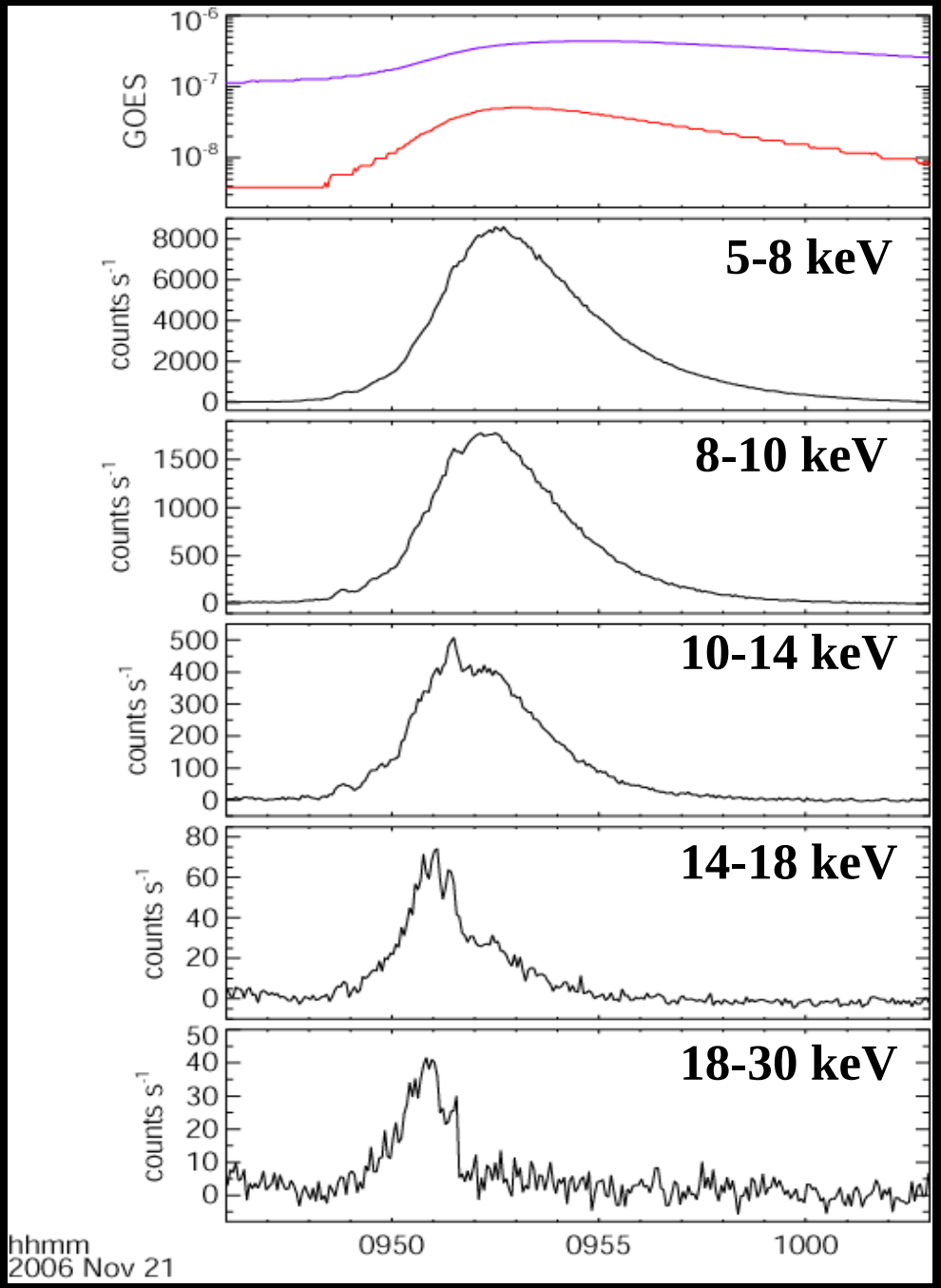


HXR emission from flare loop

rarely seen:



above-loop-top source (Masuda flare)



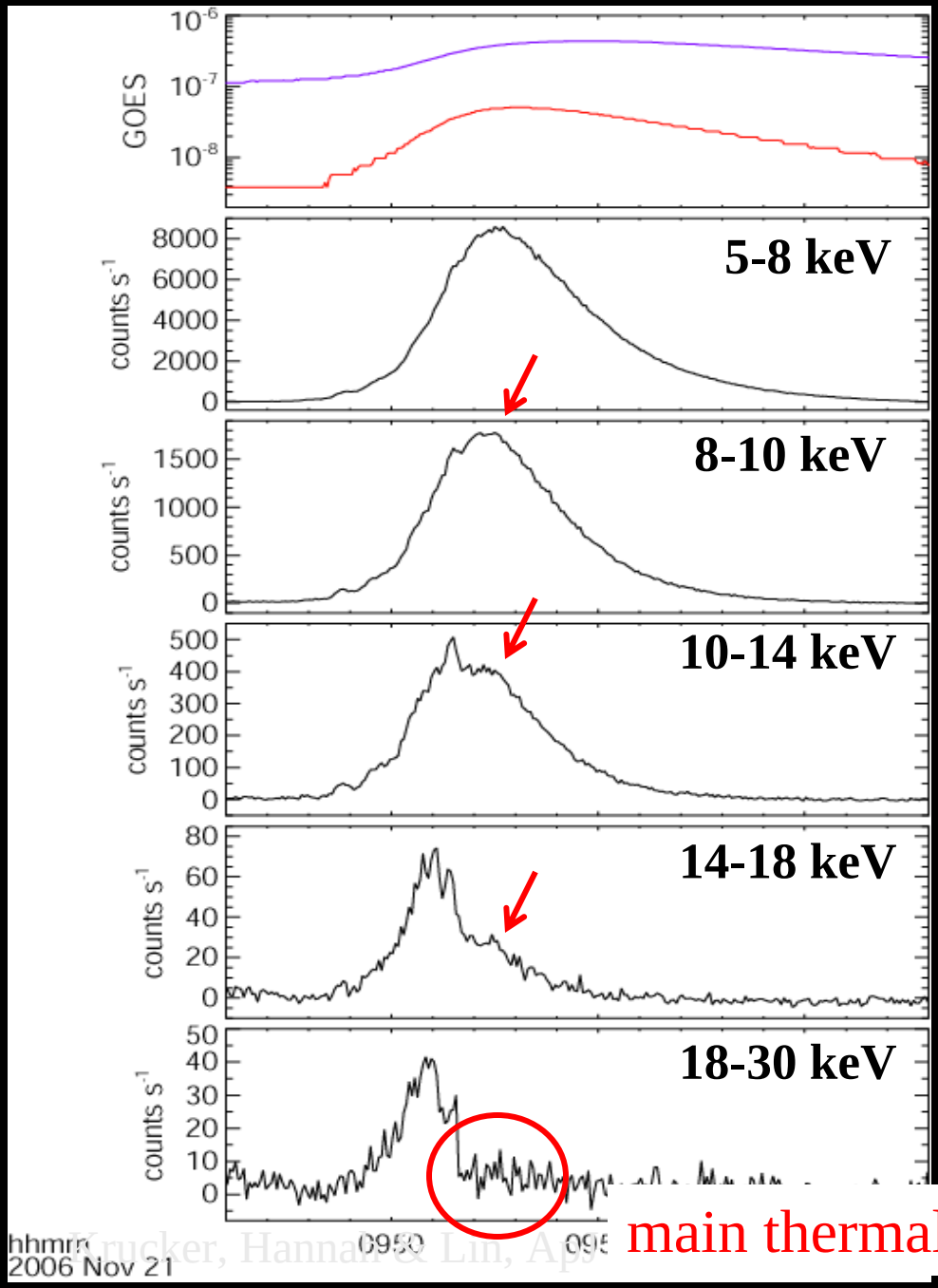
GOES B4 flare

Krucker, Hannah & Lin, ApJ Letter, 2007

Nov 2006:
many (~200) small flares with hard/flat non-thermal spectra (Hannah et al. 2007)

after Nov 20, AR behind the limb.

Nov 21 event:
Occultation height :
7” (5000 km)
γ ~ 4.1 (photon spectral index)



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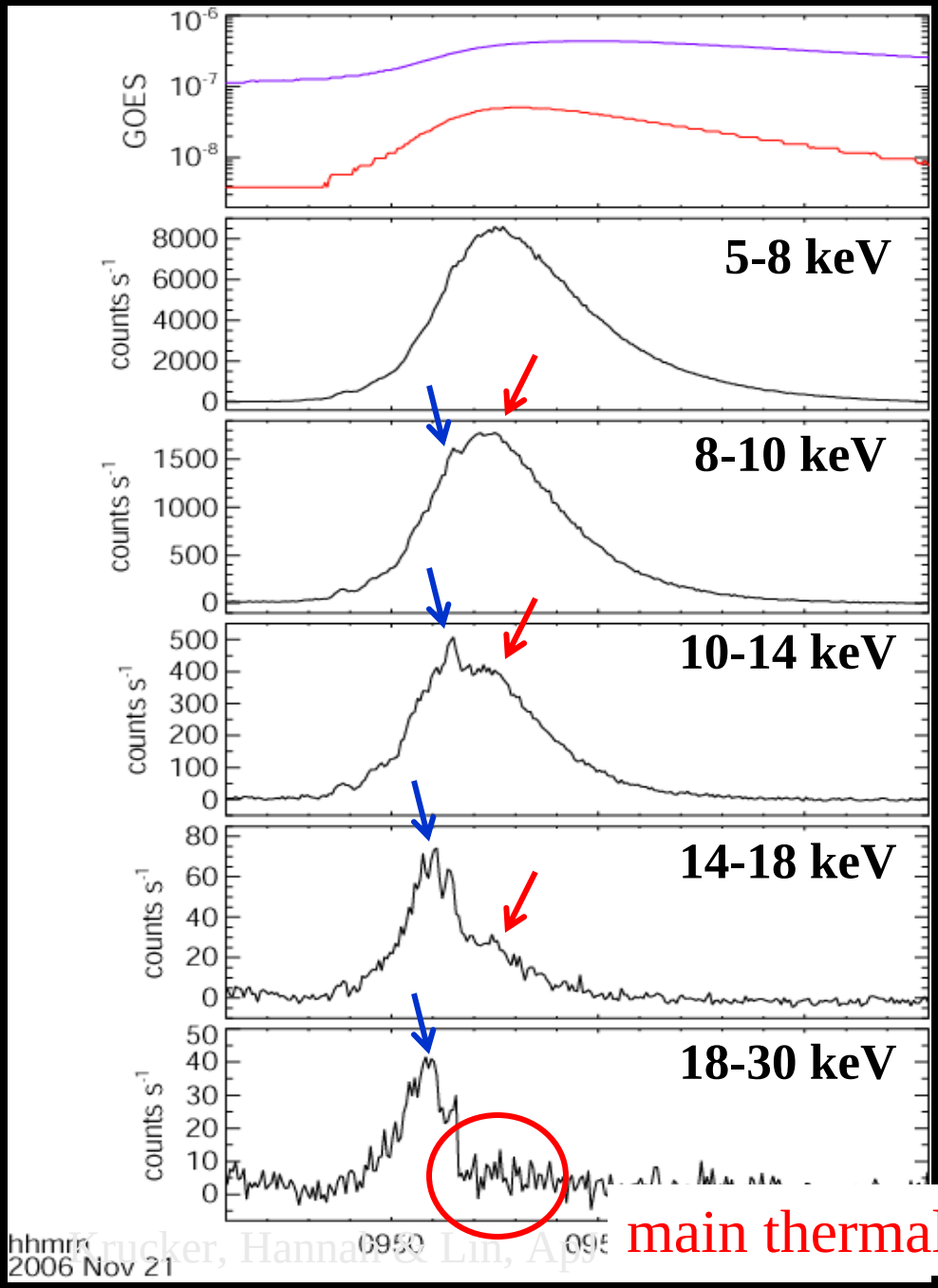
main thermal emission not seen above 18 keV



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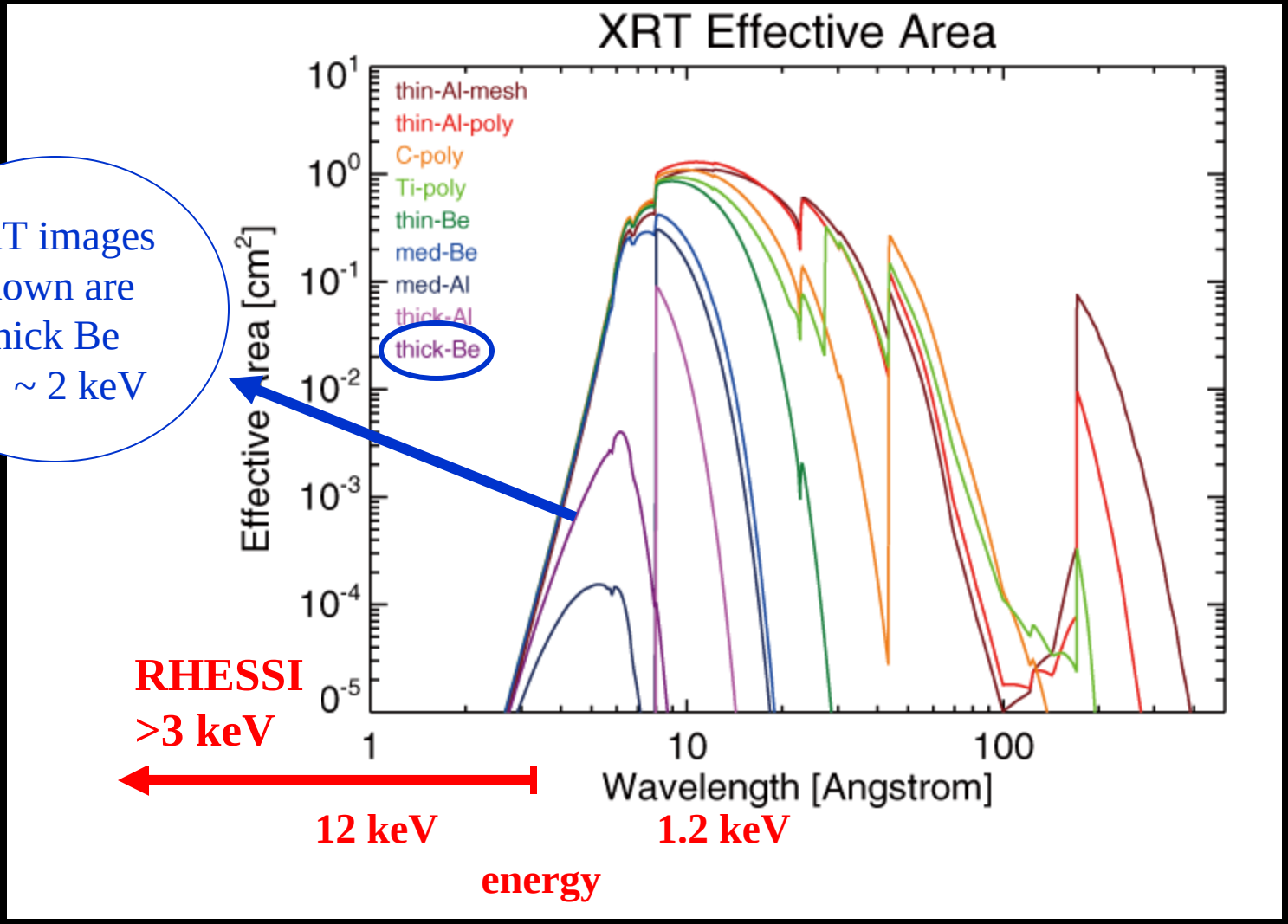
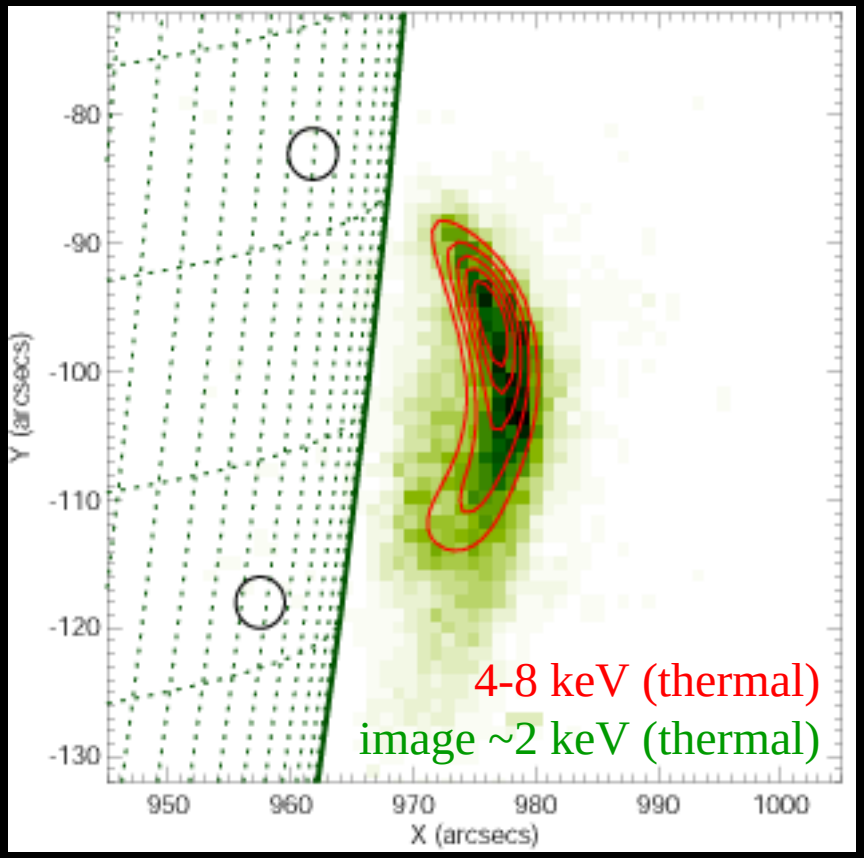
XRT & RHESSI observations

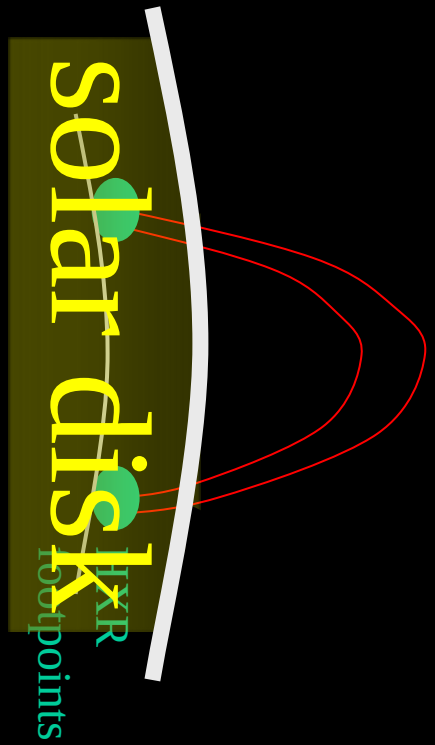


XRT & RHESSI thermal X-ray imaging

HINODE/XRT thick Be (image)
RHESSI (contours)

Thermal flare loop





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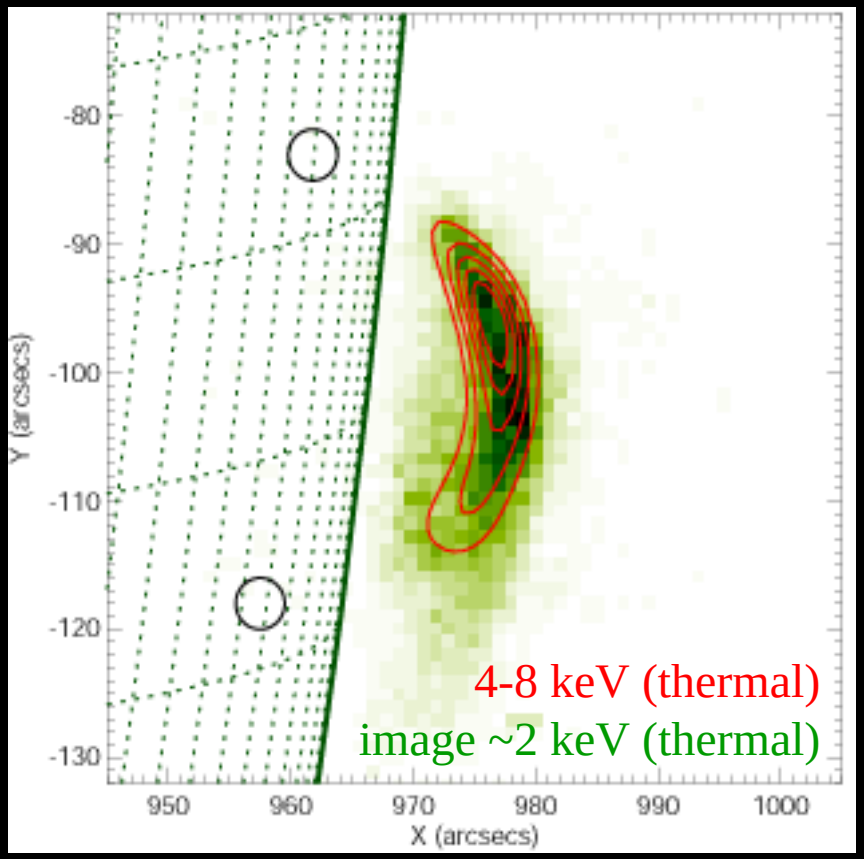
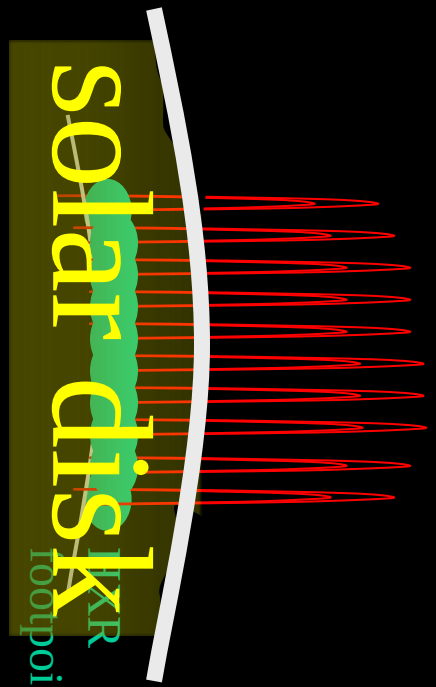


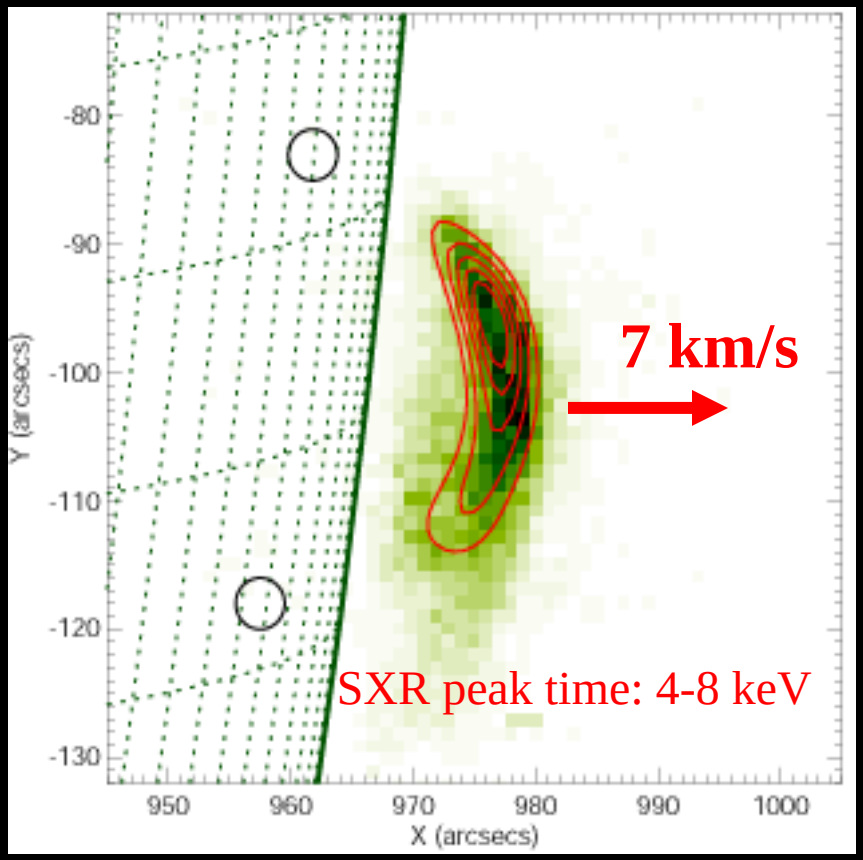


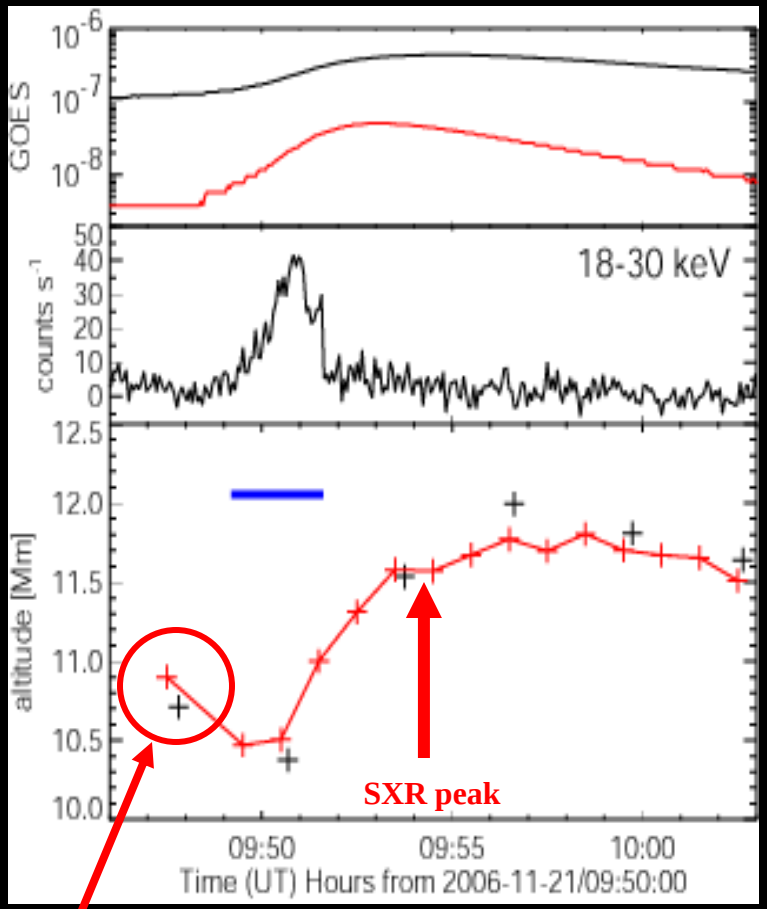
STEREO observation
will be useful for future events.

thermal source moves upwards

HINODE/XRT thick Be (image)
RHESSI (contours)

emissions from loop



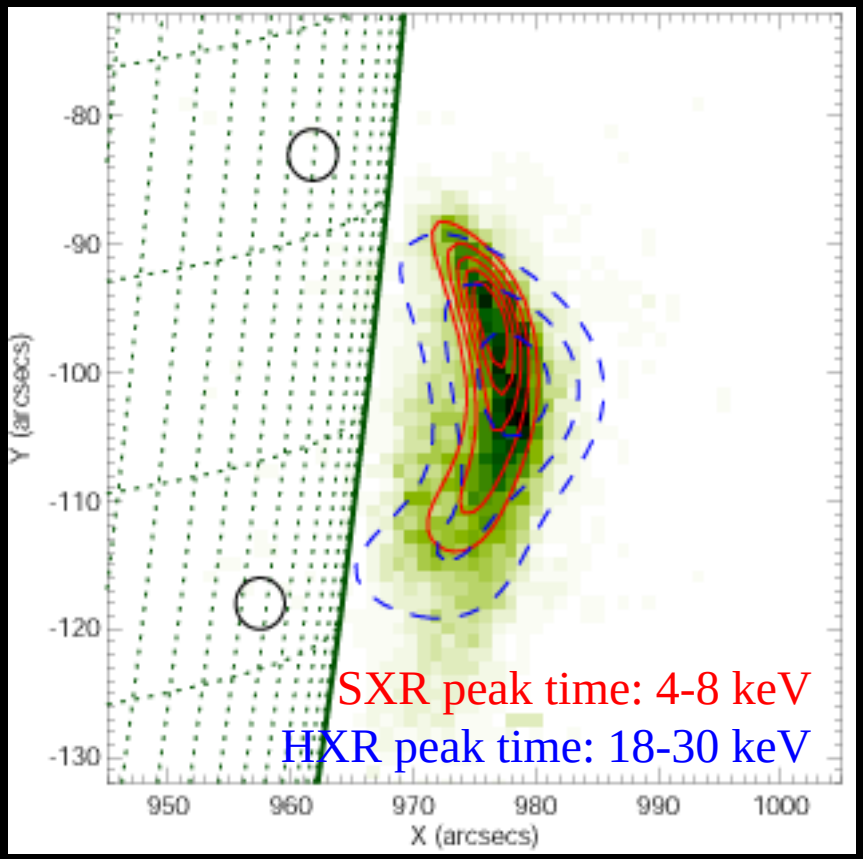


pre-flare emission (different loop)

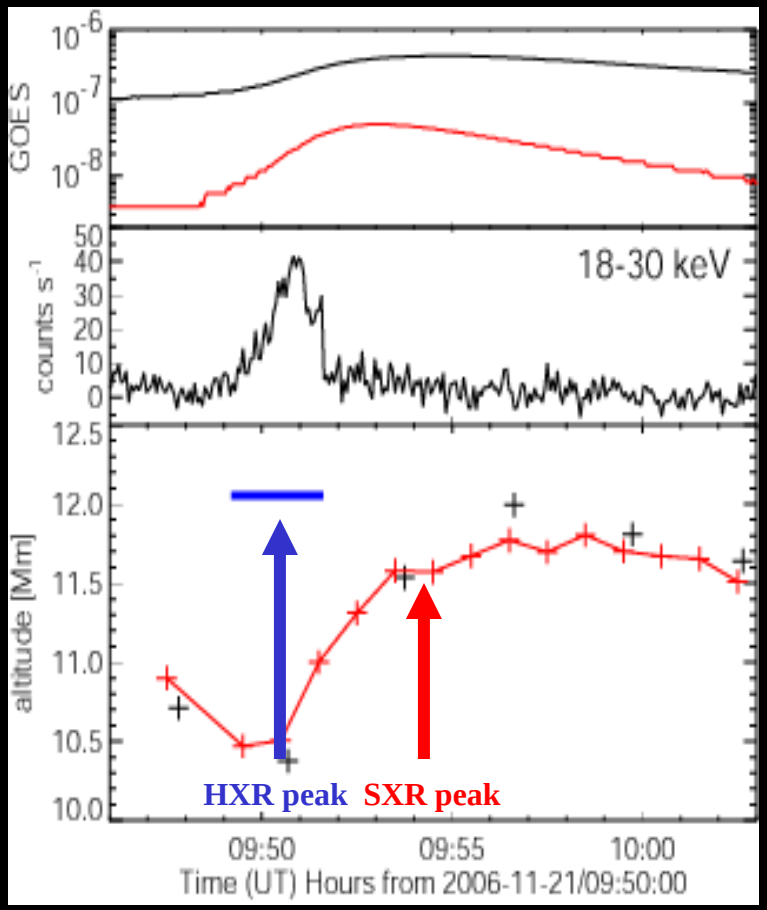
18-30 keV imaging

HINODE/XRT thick Be (image)
RHESSI (contours)

emissions from loop



Thermal loop at SXR peak time is earlier seen in non-thermal emission.



Krucker, Hannah, & Lin, ApJL, 2007

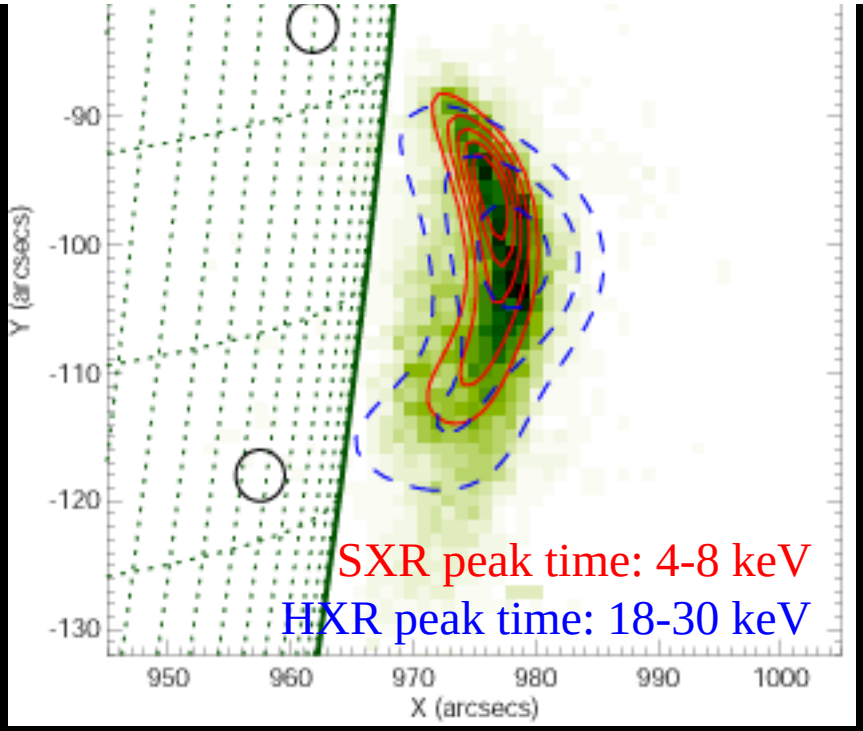
aging

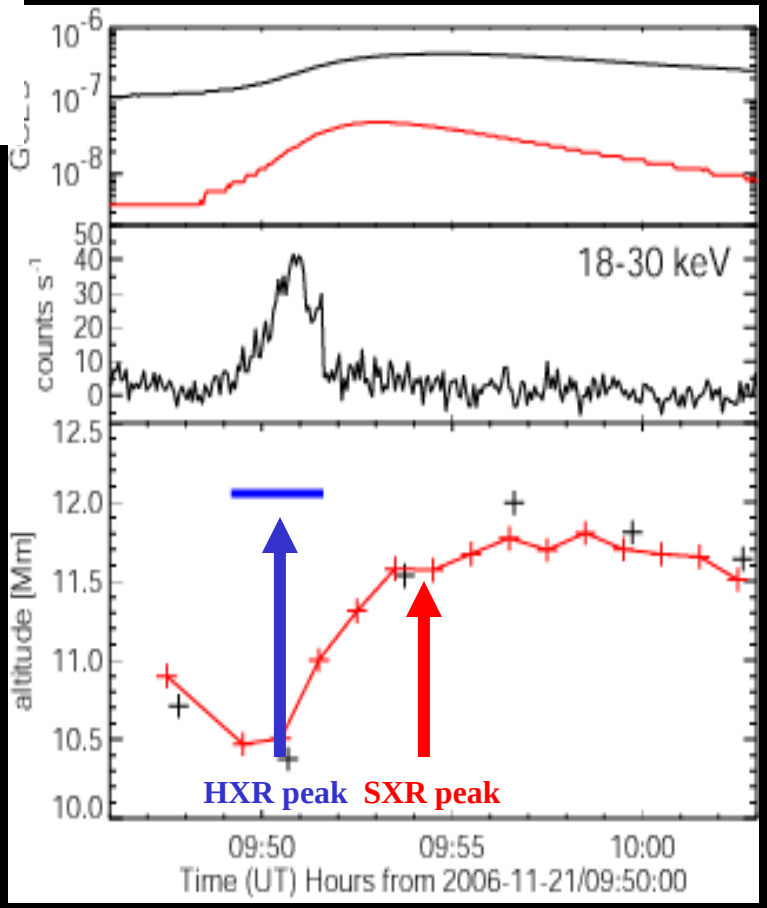
Simplest flare scenario:

1. non-thermal electrons in flare loop (thin target hard X-ray emission)
2. electron lose energy in footpoints
3. chromospheric evaporation makes flare loop visible in SXR

What is the loop density before flare?

Thermal loop at SXR peak time is earlier seen in non-thermal emission.





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Interpretation

- **Superhot (~100 MK)** explanation cannot be excluded. How to explain fast time variations is unclear.

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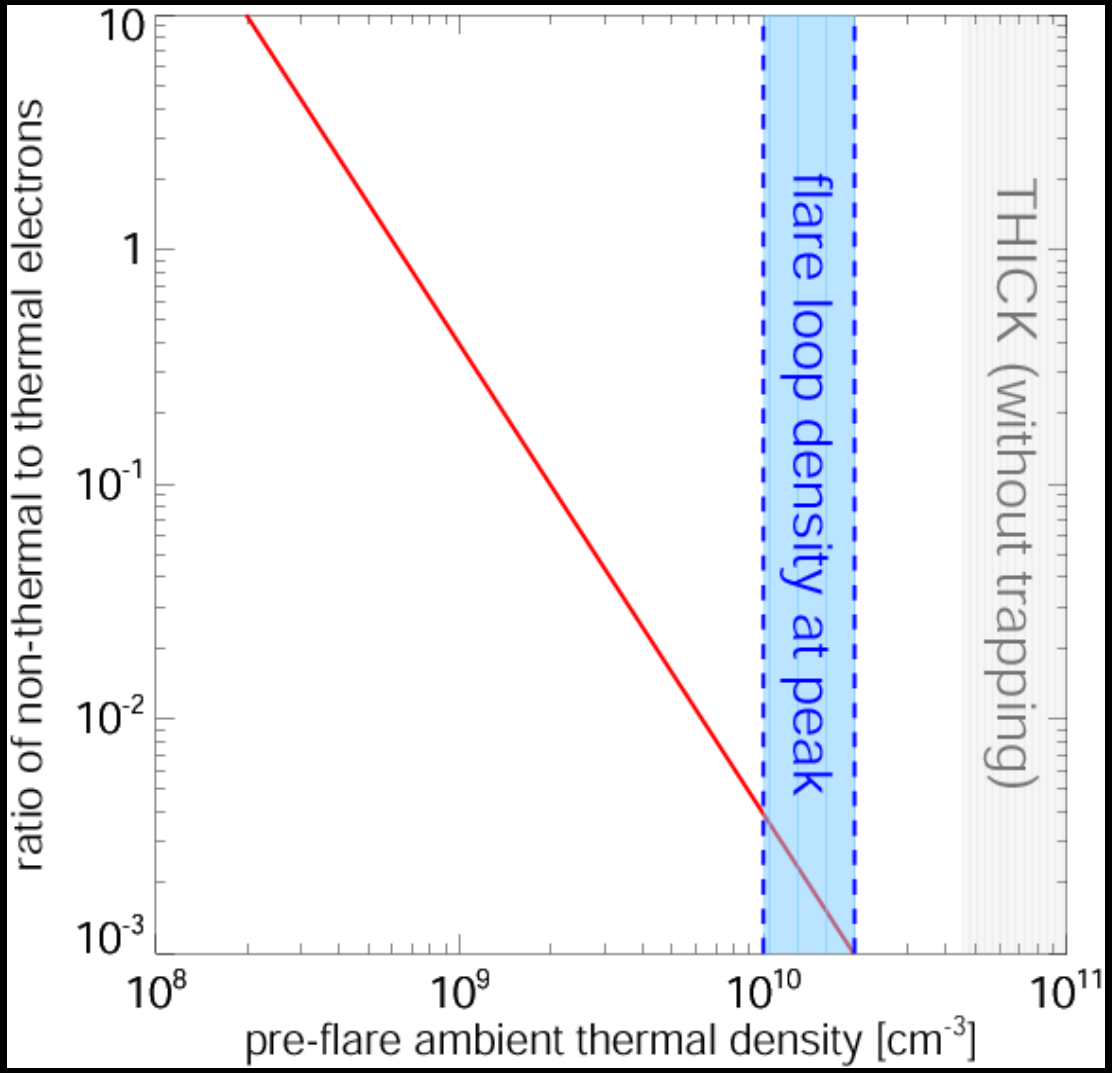
- **Superhot (~100 MK)** explanation cannot be excluded. How to explain fast time variations is unclear.
- **Thick target** (trapping needed): coronal energy deposition would increase temperature very rapidly to superhot values, i.e. thermal flare loop would be visible immediately in HXR.
- **Thin target** (density is unknown): non-thermal energy >> $2 \cdot 10^{28}$ ergs. This is enough to heat the loop (thermal energy ~ $4 \cdot 10^{28}$ ergs), immediate (direct coronal) heating smaller, but still large.

number of non-thermal electrons



Instantaneous number of HXR producing electrons is not anymore a tail on the ambient thermal distribution.

Energy in non-thermal electrons can be equal or even larger than energy of ambient plasma!

Is purely non-thermal plasma a better description?
maybe for larger events.

Summary

- Partially disk-occulted flare observations suggest that all flares show coronal HXR emission (i.e. large fraction of flare-accelerated electrons are in the corona). Review in A&AR, Krucker et al. 2008

- XRT & RHESSI event: best example of thin target emission.