How to form and feed a flare coronal source?

RHESSI and SDO/AIA combined observations of loop-top sources

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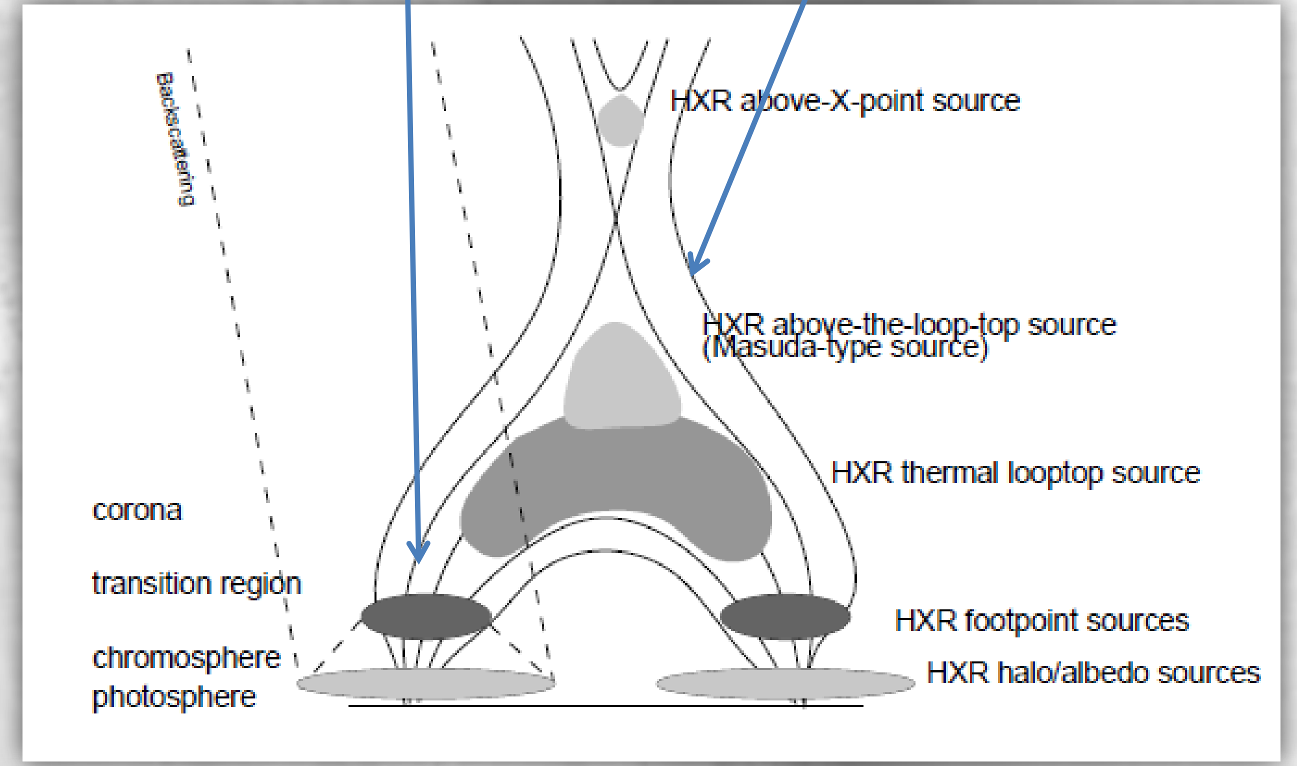
Sources in solar flares

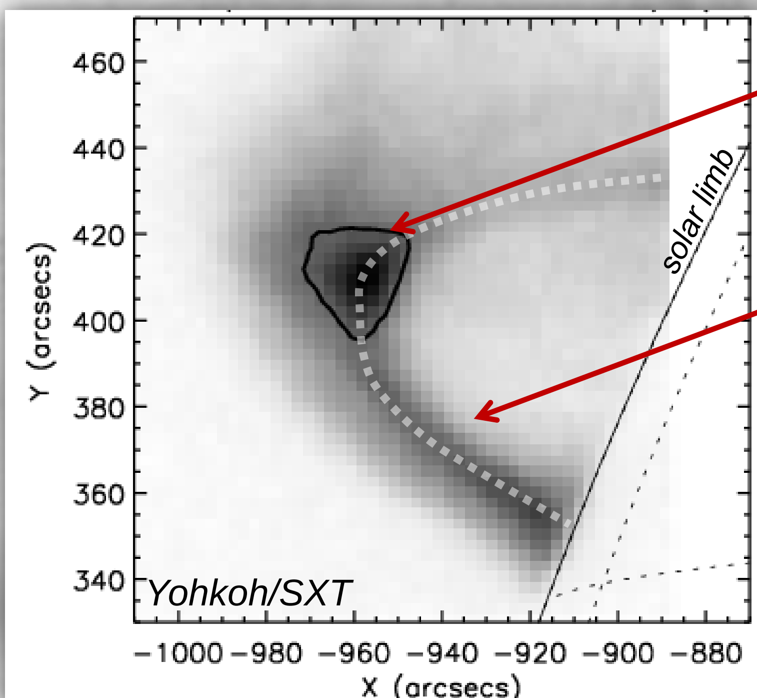
During flares high energy radiation of the Sun is dominated by bright small centers of two types: **foot-point sources** and **coronal sources**.



Aschwanden 2005

What is LTS?

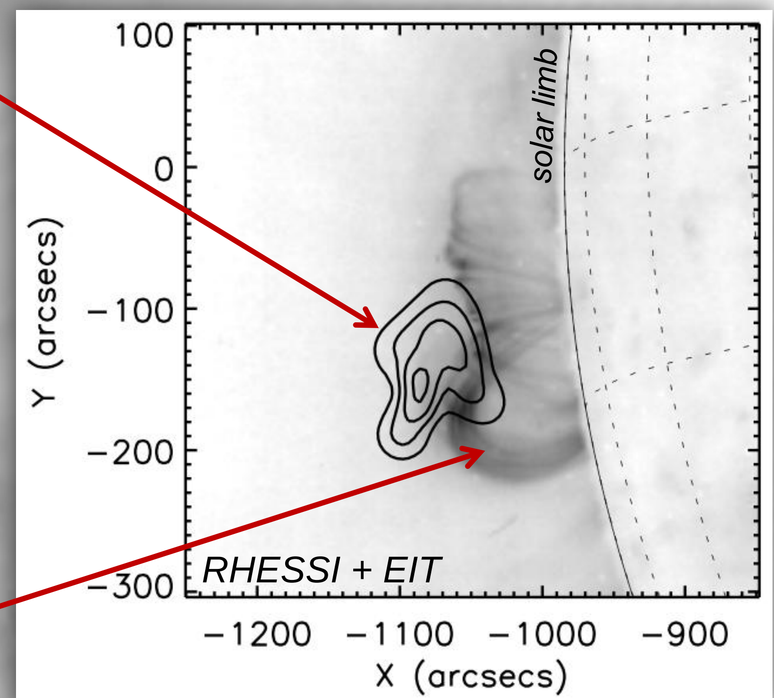
LTS (loop-top source) – a coronal source observed in X-rays at the top of hot flare loops, just above warm 'post-flare' UV loops.



LTS

hot flare loop
(~10MK)

warm 'post-flare' loops
(~1MK)

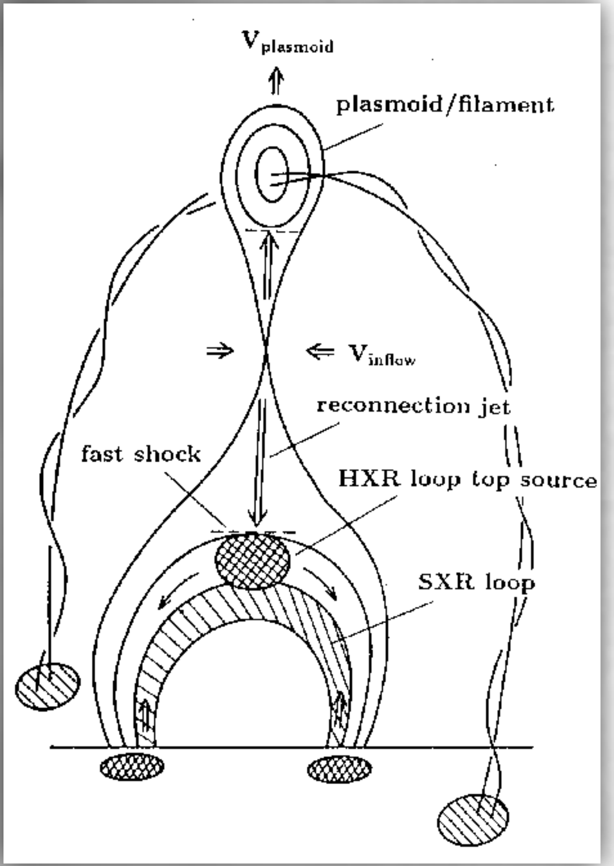


LTSs – motivation

LTSs are **common characteristics of solar flares** regardless of the flare size, duration or power. Have to be included in solar (stellar) flare models.

The sources are **close to the primary energy release site**. They may give information on this site.

LTSs hold **large amount of energy** released during flares. They are important component of energy balance of solar flares.

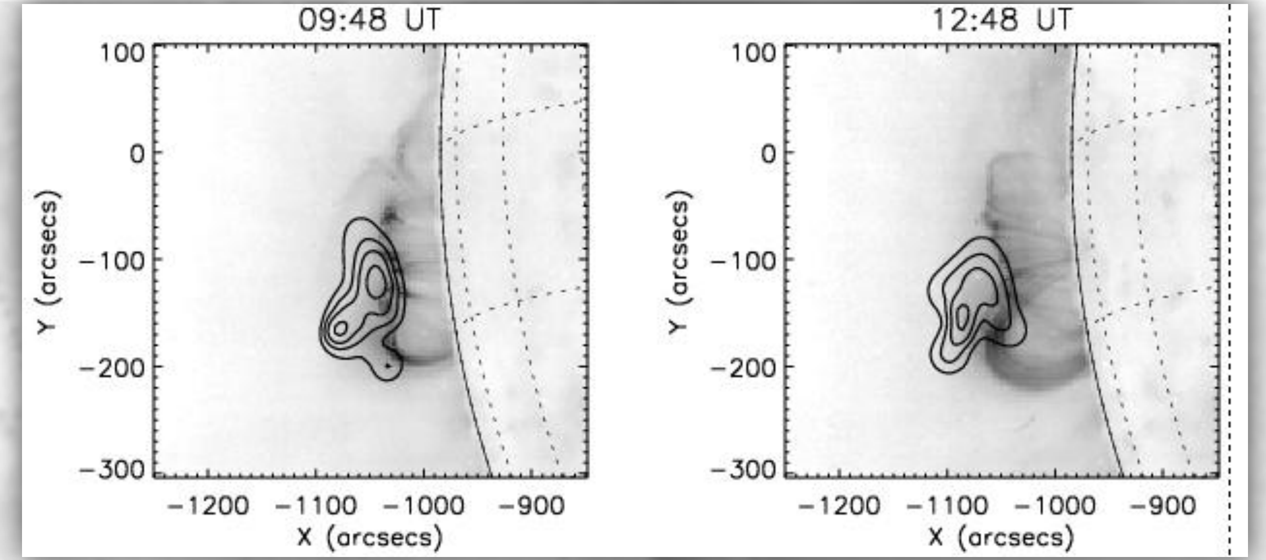


LTSs – structure, formation?

Possible instrumental drawbacks

Observations made by many instruments showed LTSs as quite large, diffuse sources.

However, this could be caused by instrumental effects. Too low angular, thermal or temporal resolution can 'hide' important information on formation, structure and dynamics of LTSs.



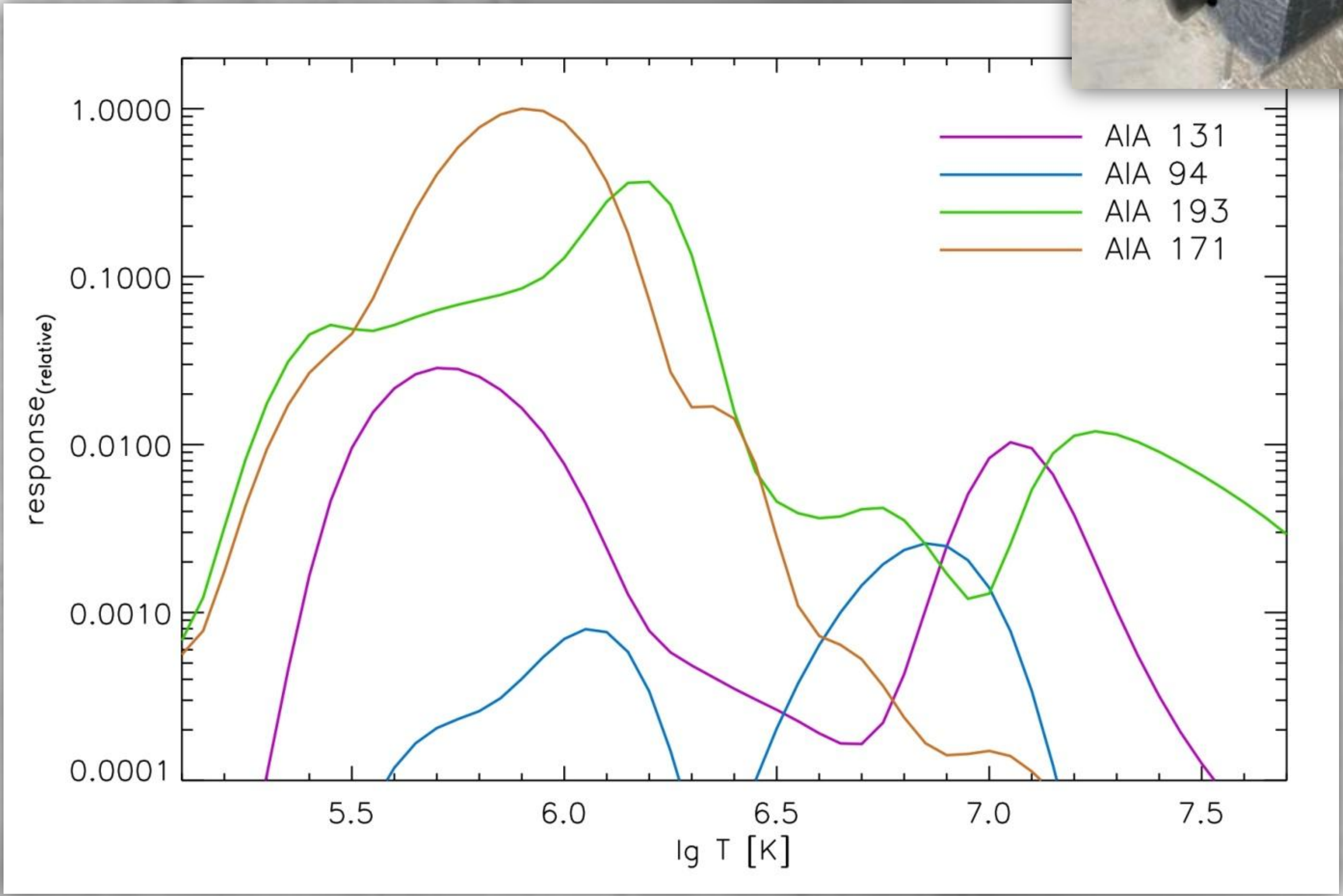
Kołomański et al. 2011

SoHO/EIT 195Å + RHESSI 7-8 kev

Promising instrumental solution

SDO/AIA + RHESSI = dynamics and structure of warm and hot plasma (high res.), geometrical and physical parameters of LTSs

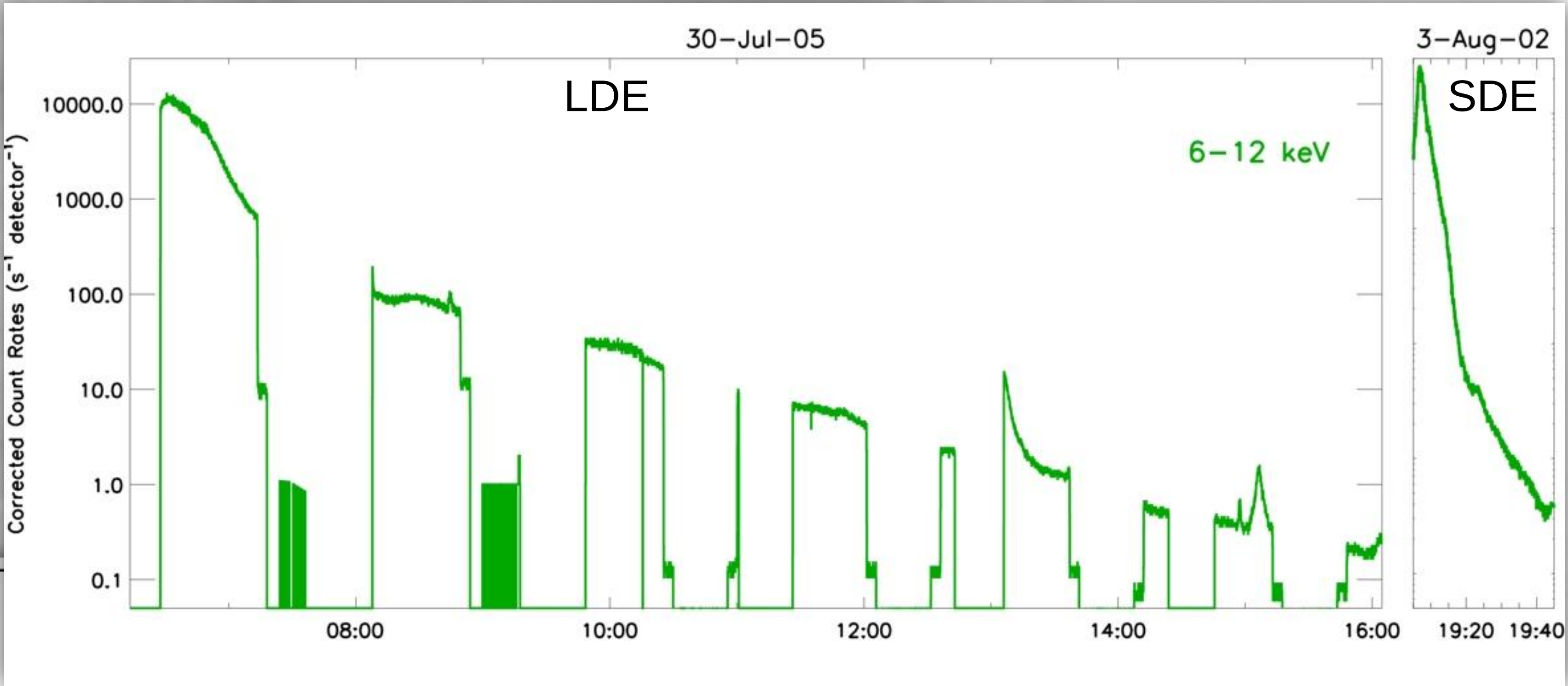
SDO/AIA – new possibilities

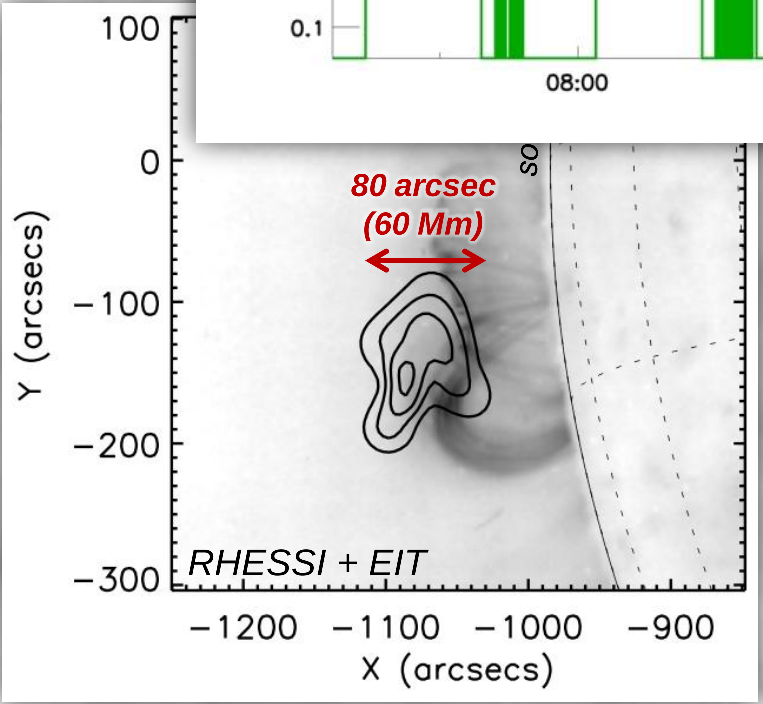


Atmospheric Imaging Assembly (AIA)

7 bands in EUV; angular resolution:1.5 arcsec; temporal resolution: 10 seconds; fov 41×41 arcmin

Flare selection





Long Duration Events (flares) are slowly evolving, large-scale structures – instrumental drawbacks may be less limiting (painful)

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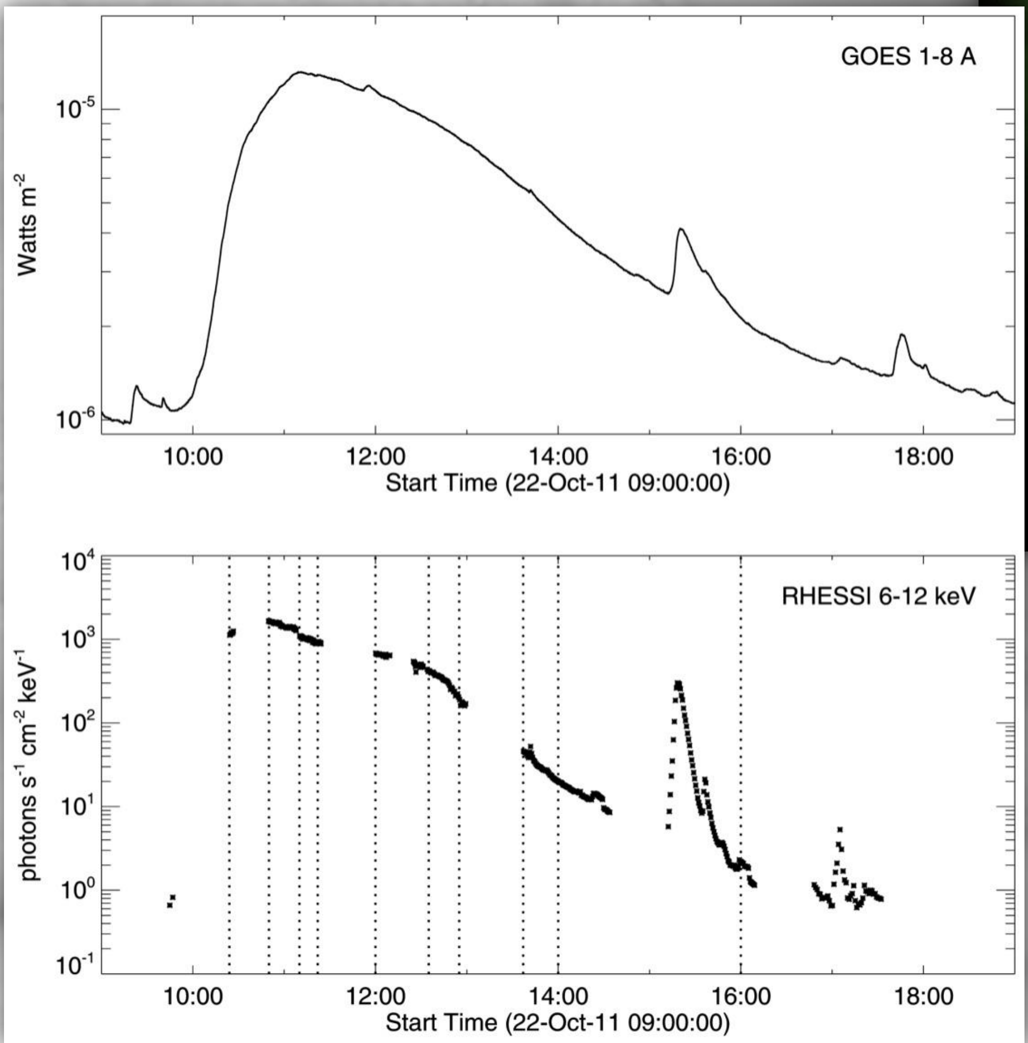

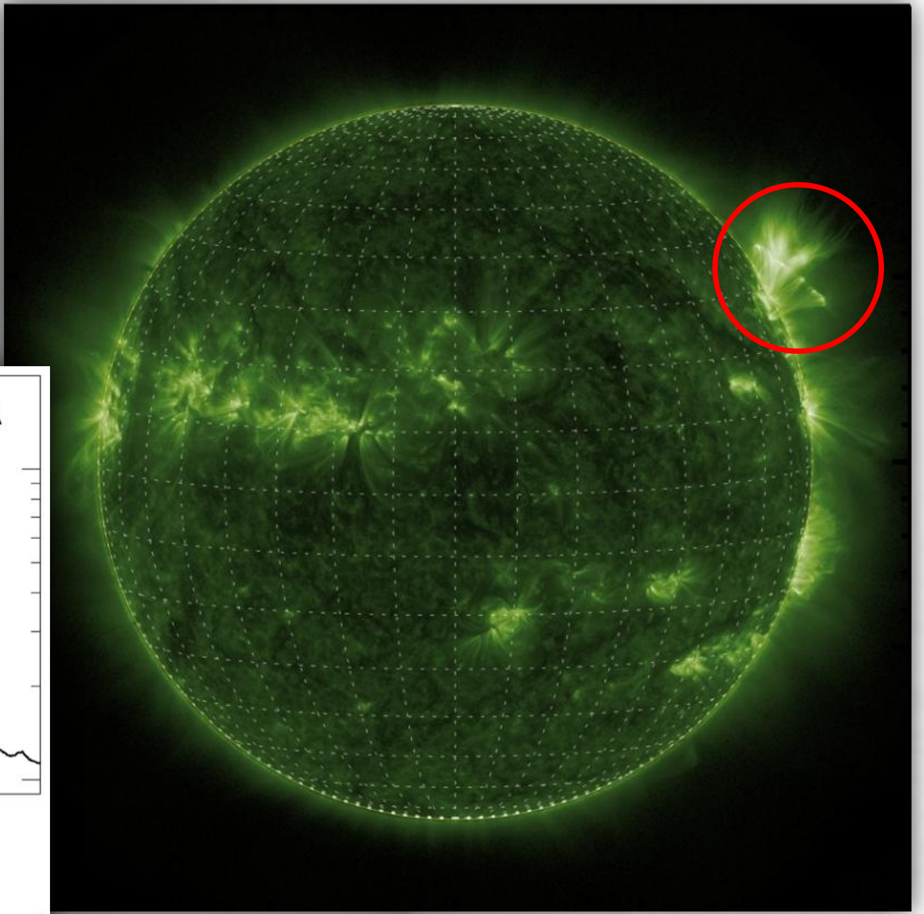

sLDE flare

duration: >9h

X-ray class: M1.3

location: N25W77

form: high arcade

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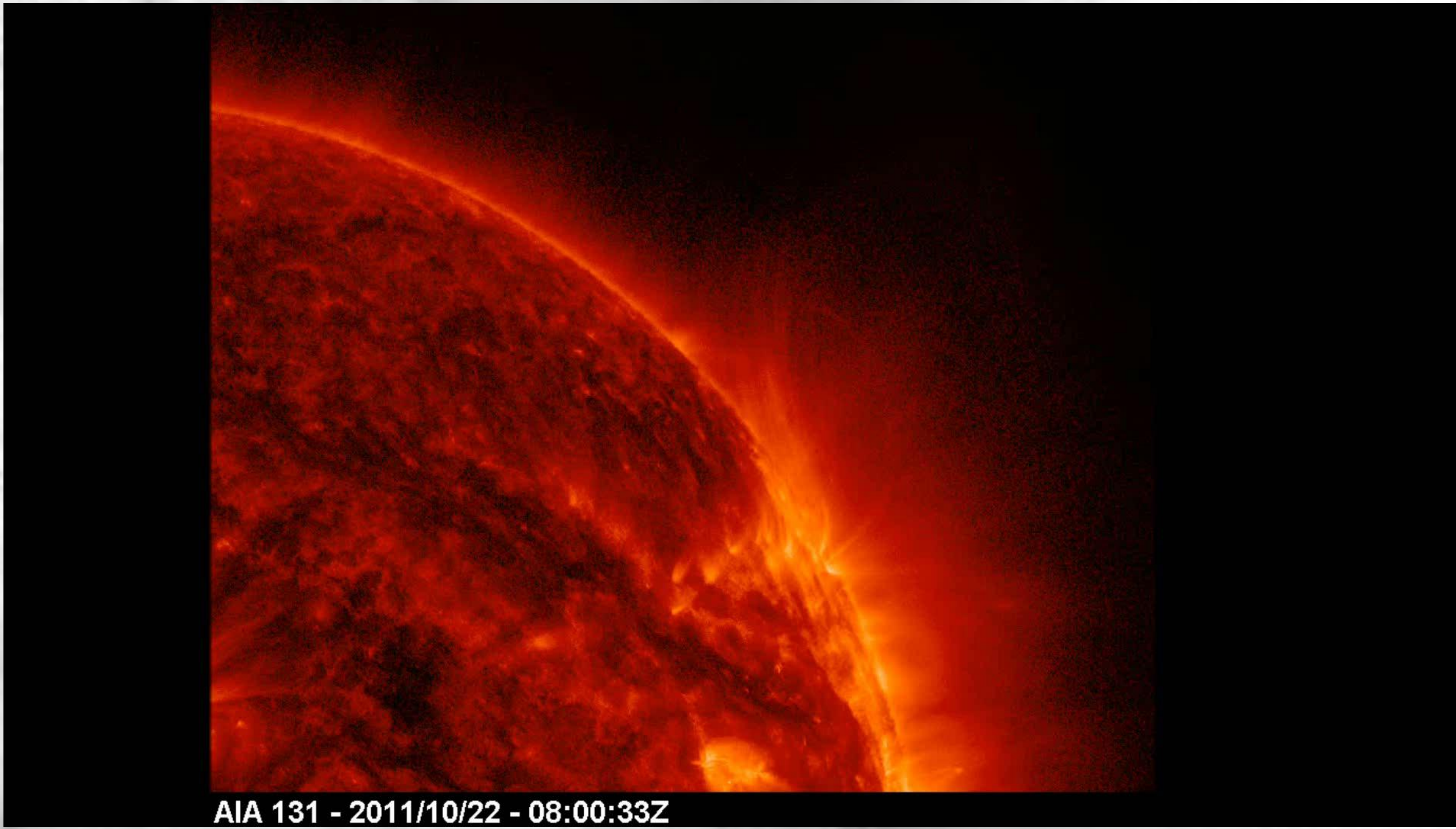


AIA 131 (0.5MK + 12 MK)

LDE flares – image reconstruction method

Problem 1

if source size ≈ resolution of a particular grid then detector records very weak or no modulation of signal

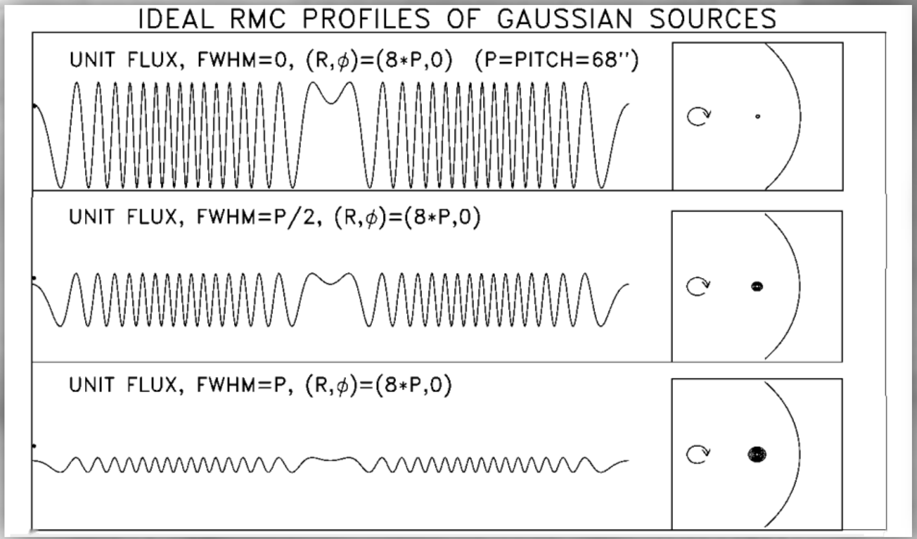
Problem 2

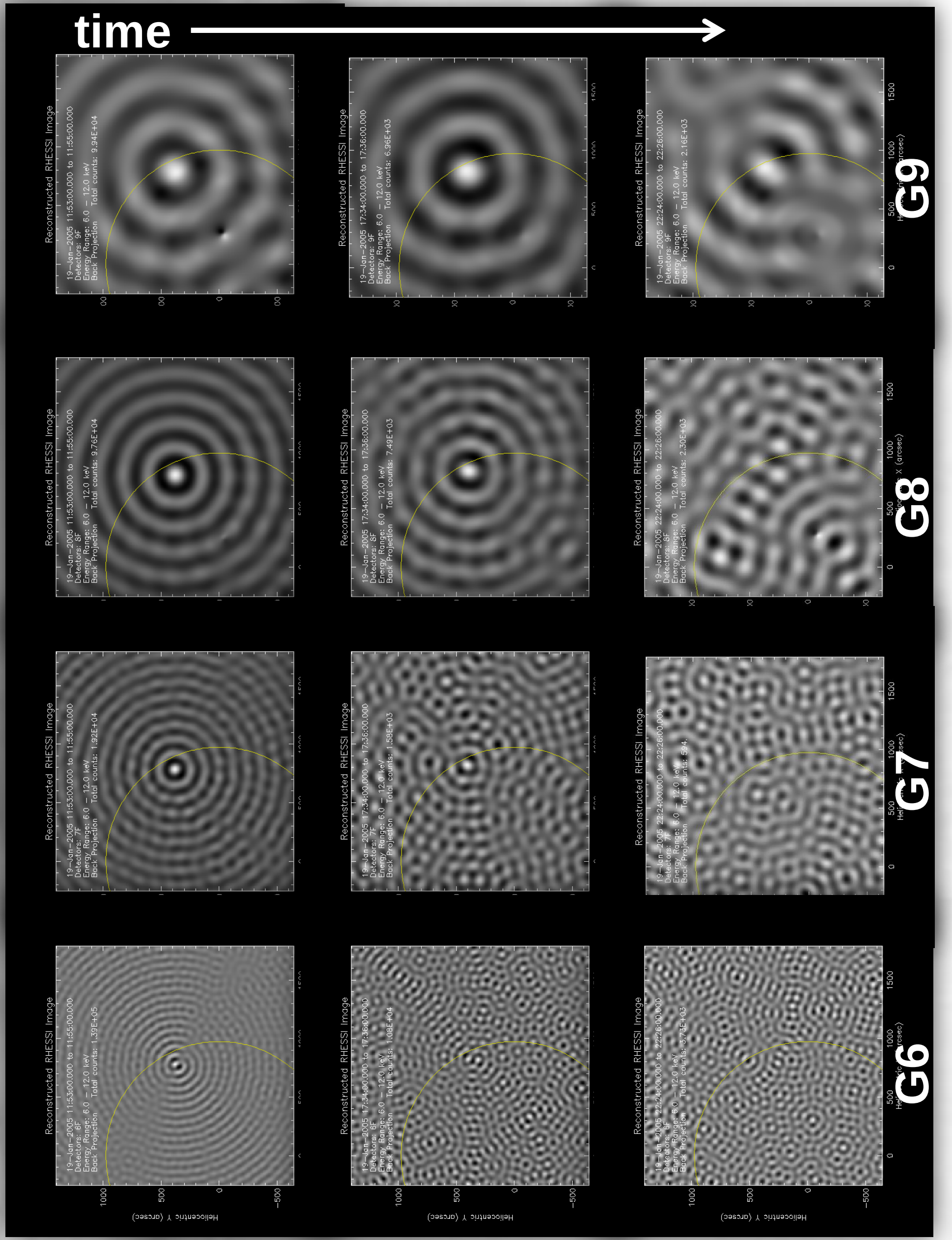
the higher the energy the lower the signal

Solution

- select only those grids that show a definite source in a single detector image
- increase time or energy intervals for higher energies to get enough signal

Kołomański et al. 2011, Kołtun 2011



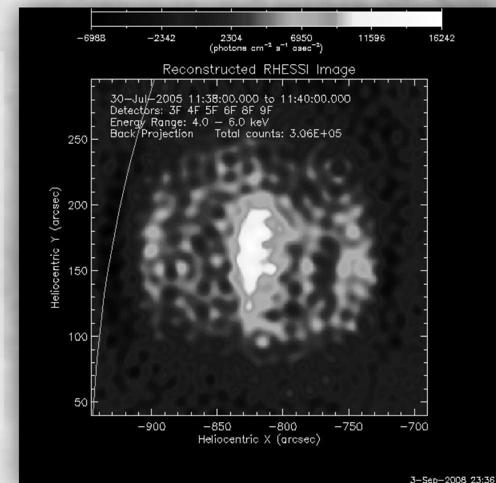


LDE flares – image reconstruction method

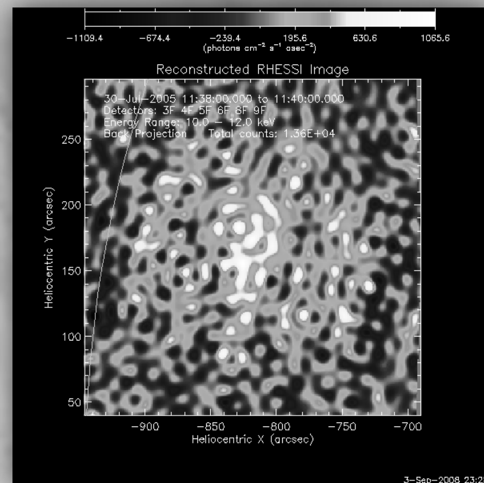
Sol2005-07-30T06:36 @11:38 UT, integration120 s

grids: 3 - 6, 8, 9 back projection

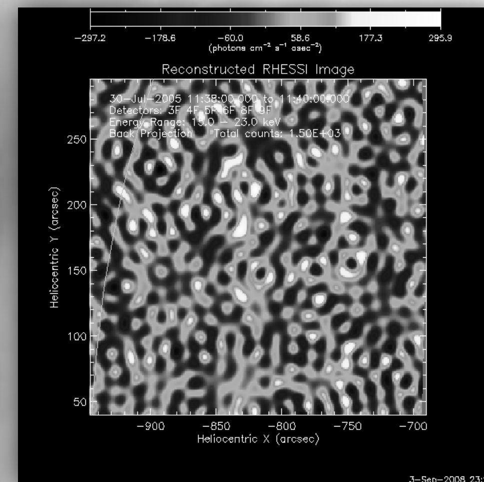
4-6 keV



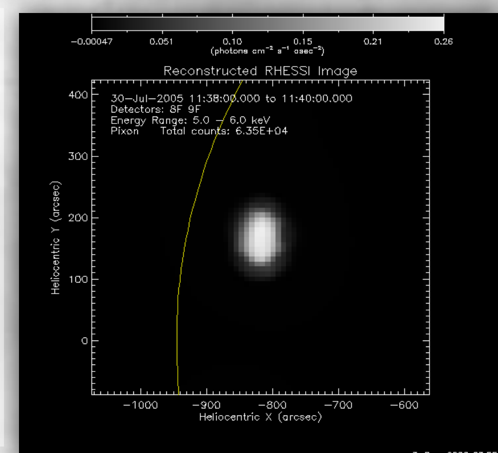
10-12 keV



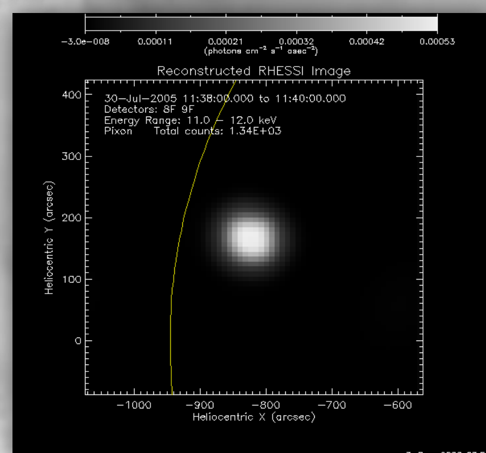
15-23 keV



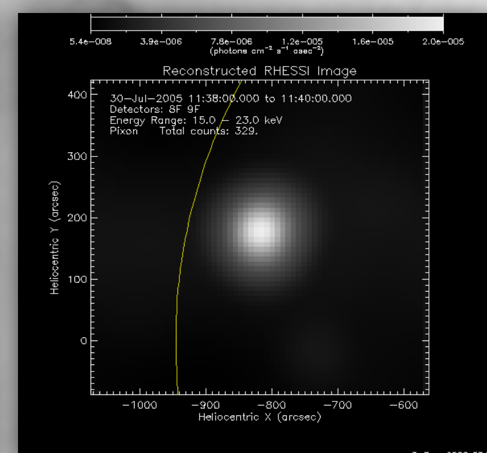
grids: 8, 9 pixon stacked modulations



5-6 keV



11-12 keV



15-23 keV

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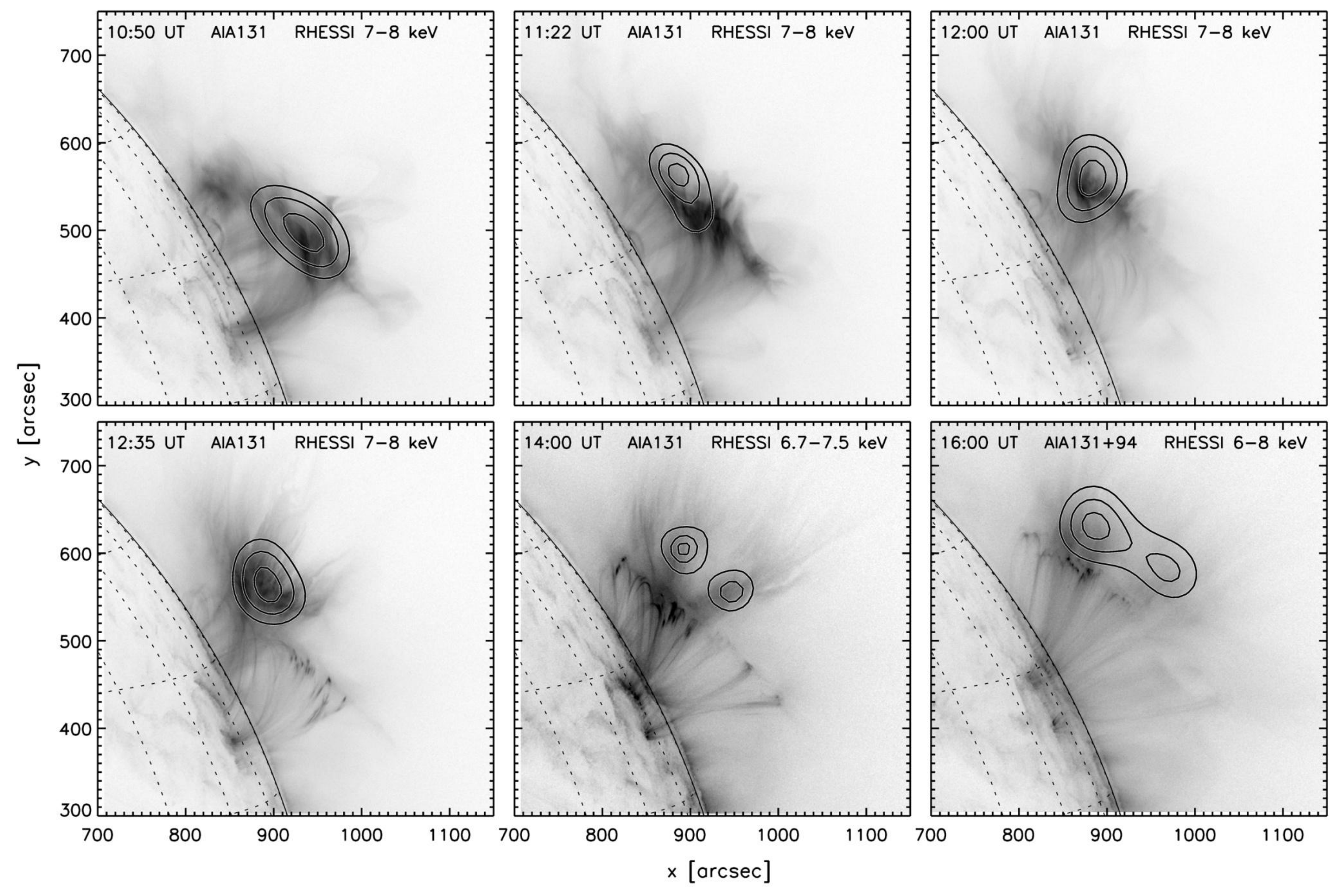
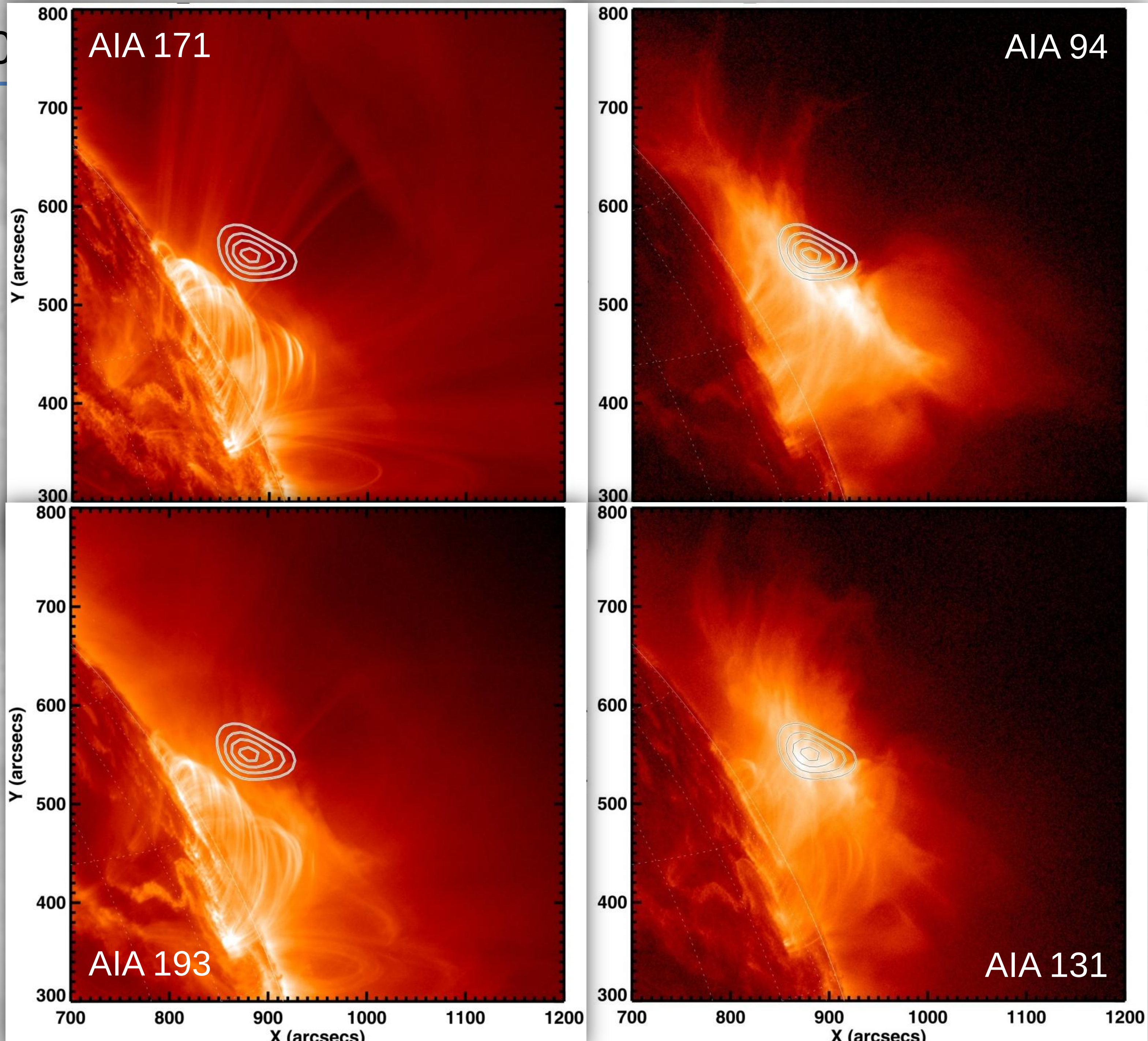


RHESSI imaging spectroscopy for LTS – two thermal components: **8-9MK**, **13-23MK**

Sol2011-10

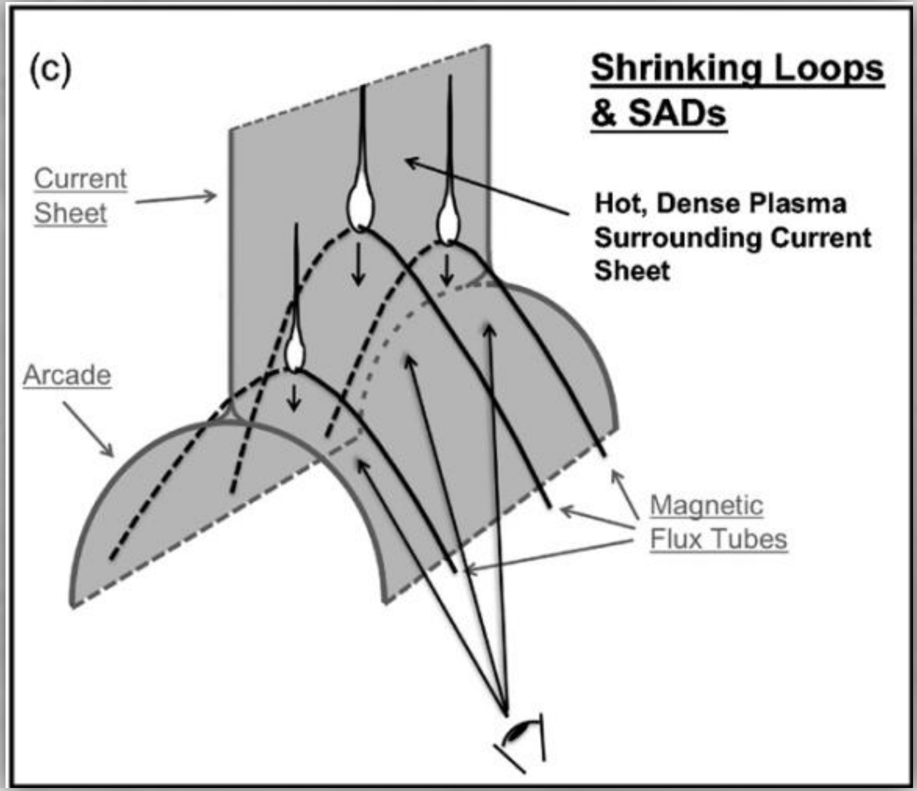
12:00 UT

SDO/AIA
+
RHESSI
6-7 keV



Supra-arcade downflows

SADs (supra-arcade downflows) – dark structures above post-flare loops



SAD is a plasma wake behind thin shrinking loop formed in hot plasma surounding current sheet (*Savage et al. 2012*)

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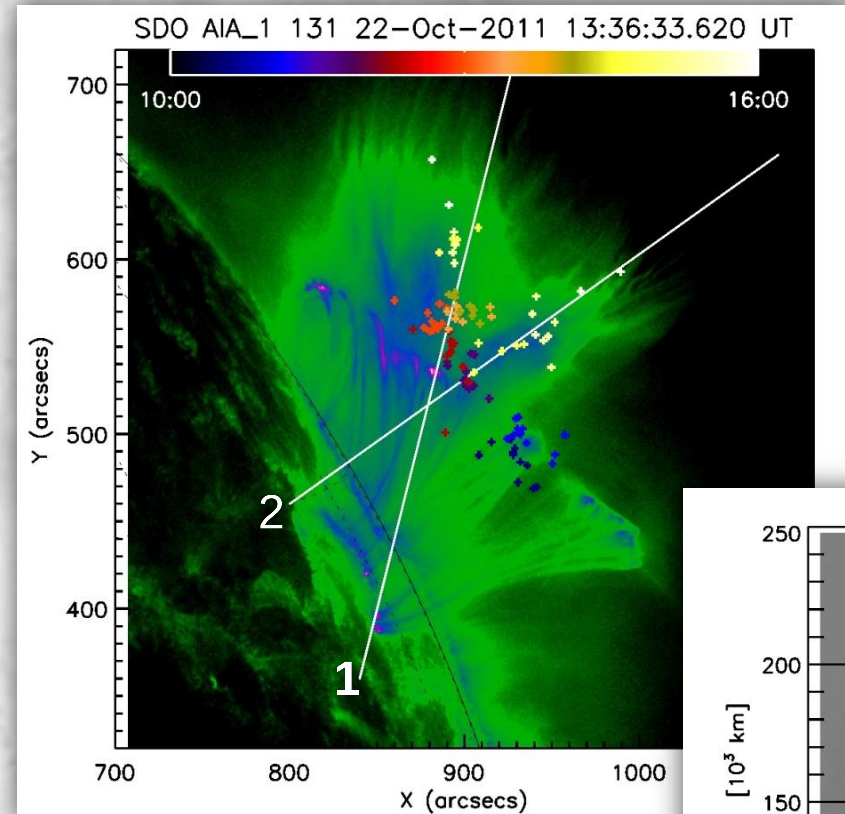
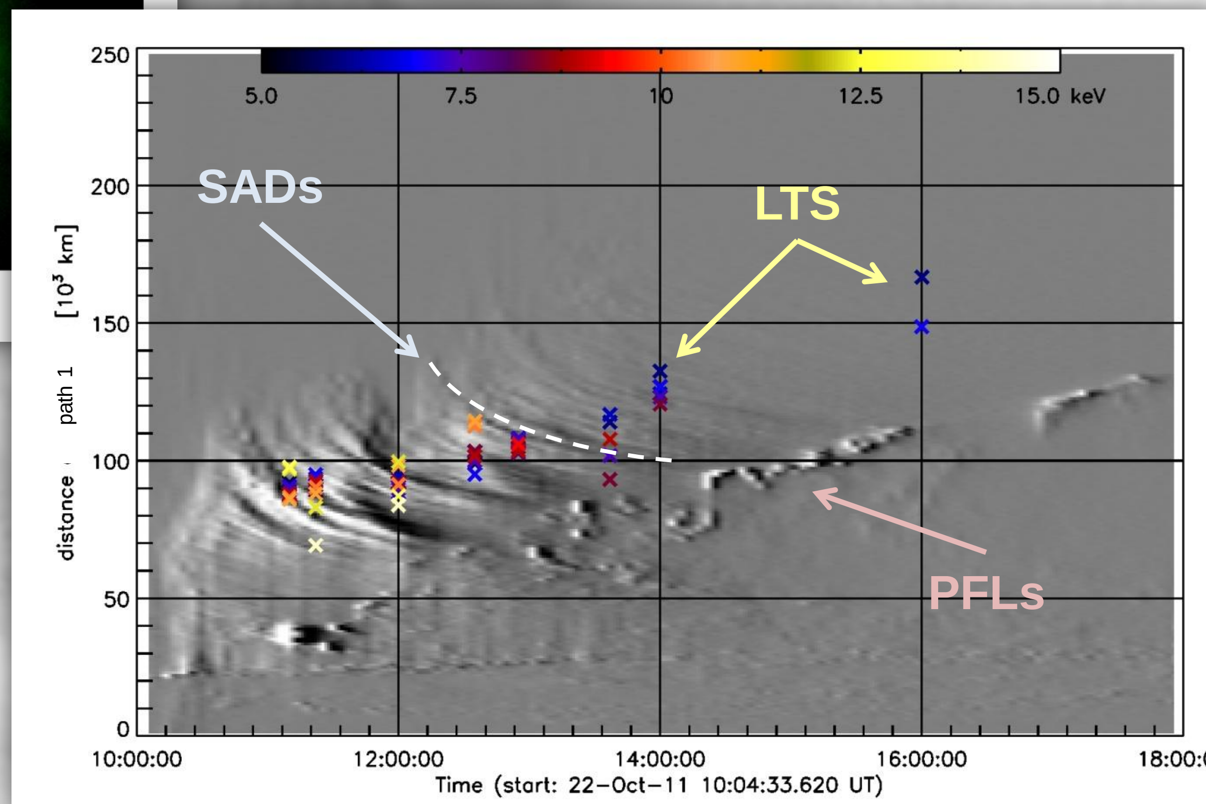


AIA difference dynamic maps (AIA 131A + 94A and RHESSI centroids of LTS (path 2)



Why the hot LTS was observed in the region of the SADs deceleration?

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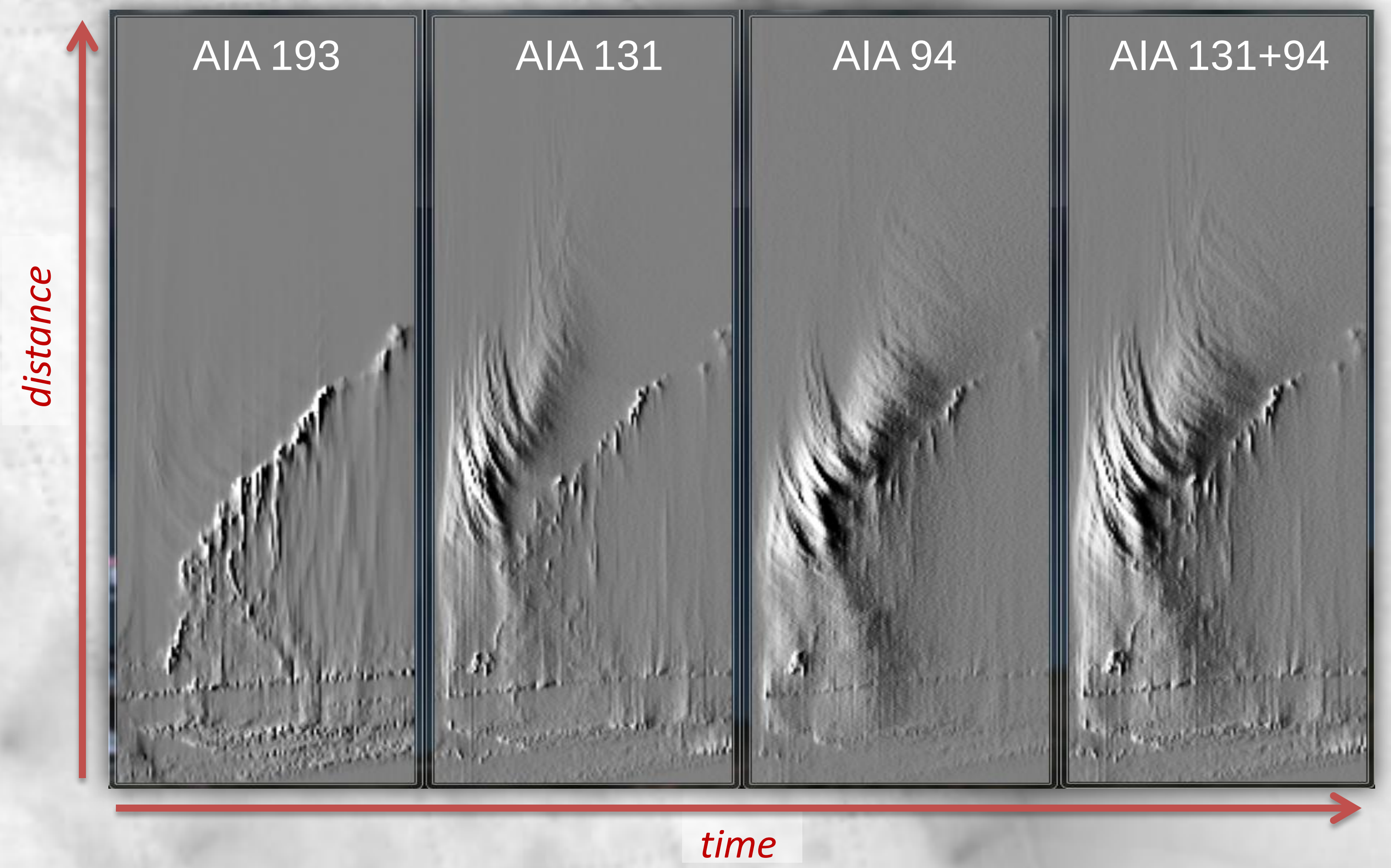
heating and cooling – where is the hottest region?



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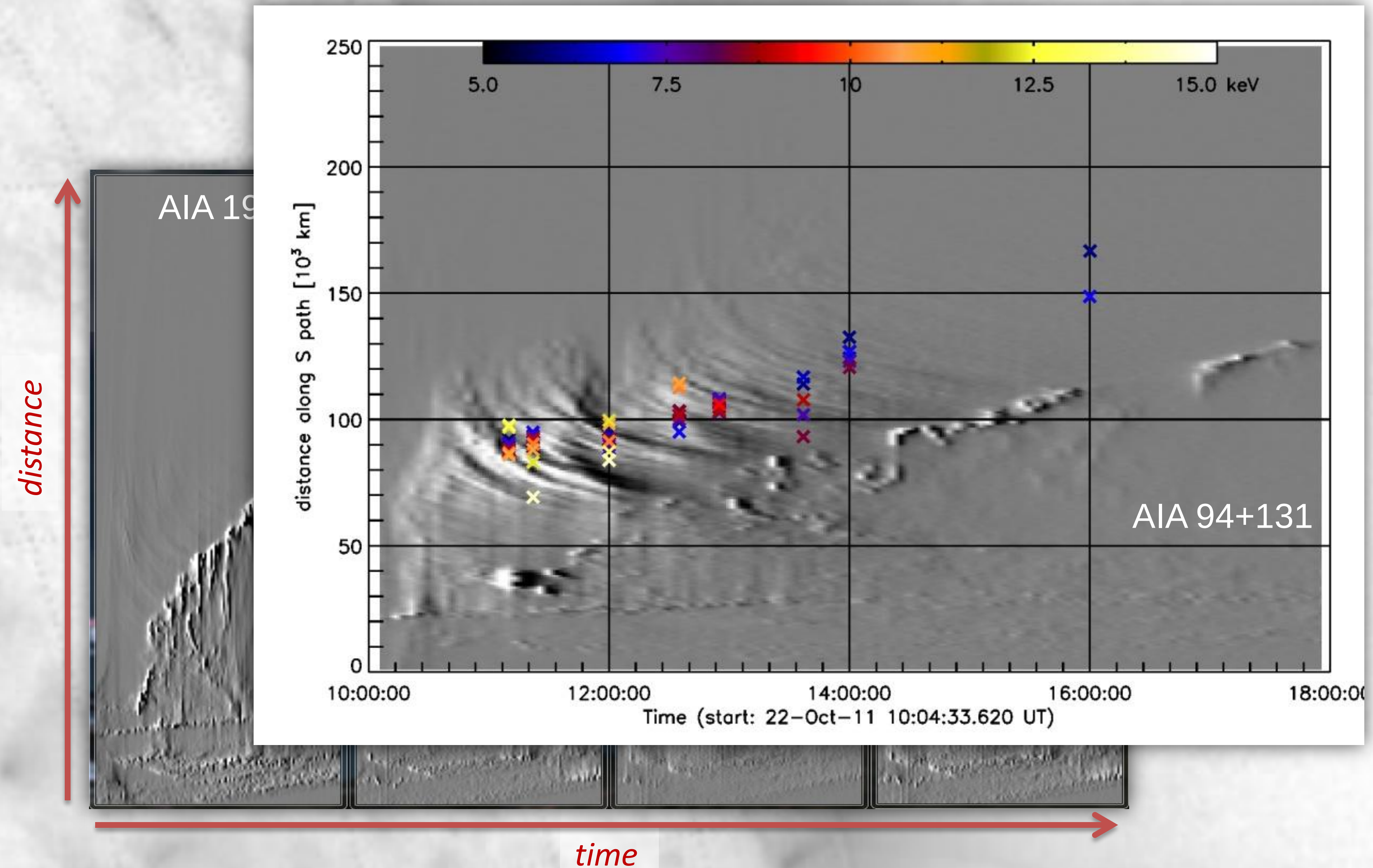
heating and cooling – where is the hottest region?



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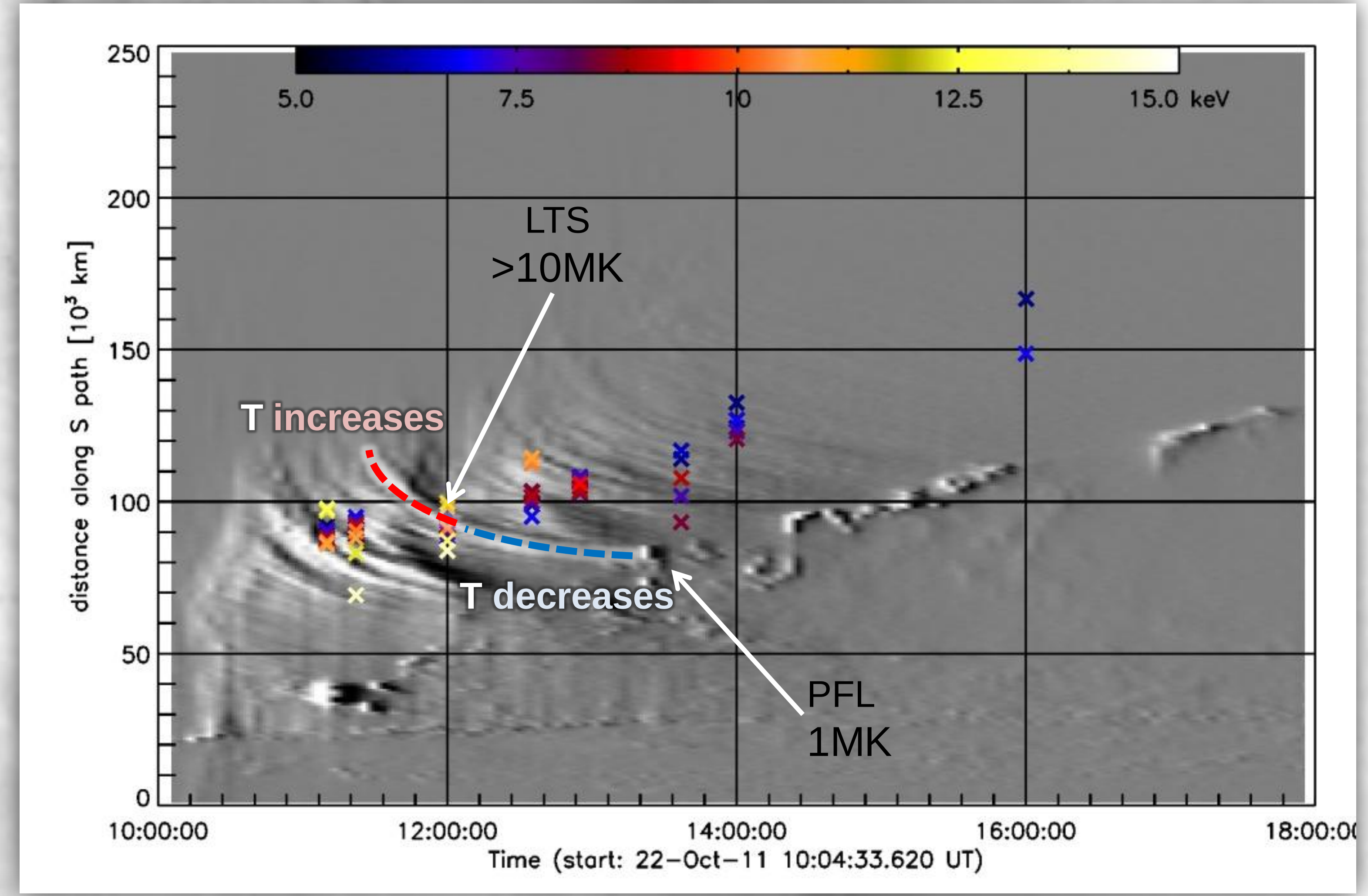
heating and cooling – where is the hottest region?



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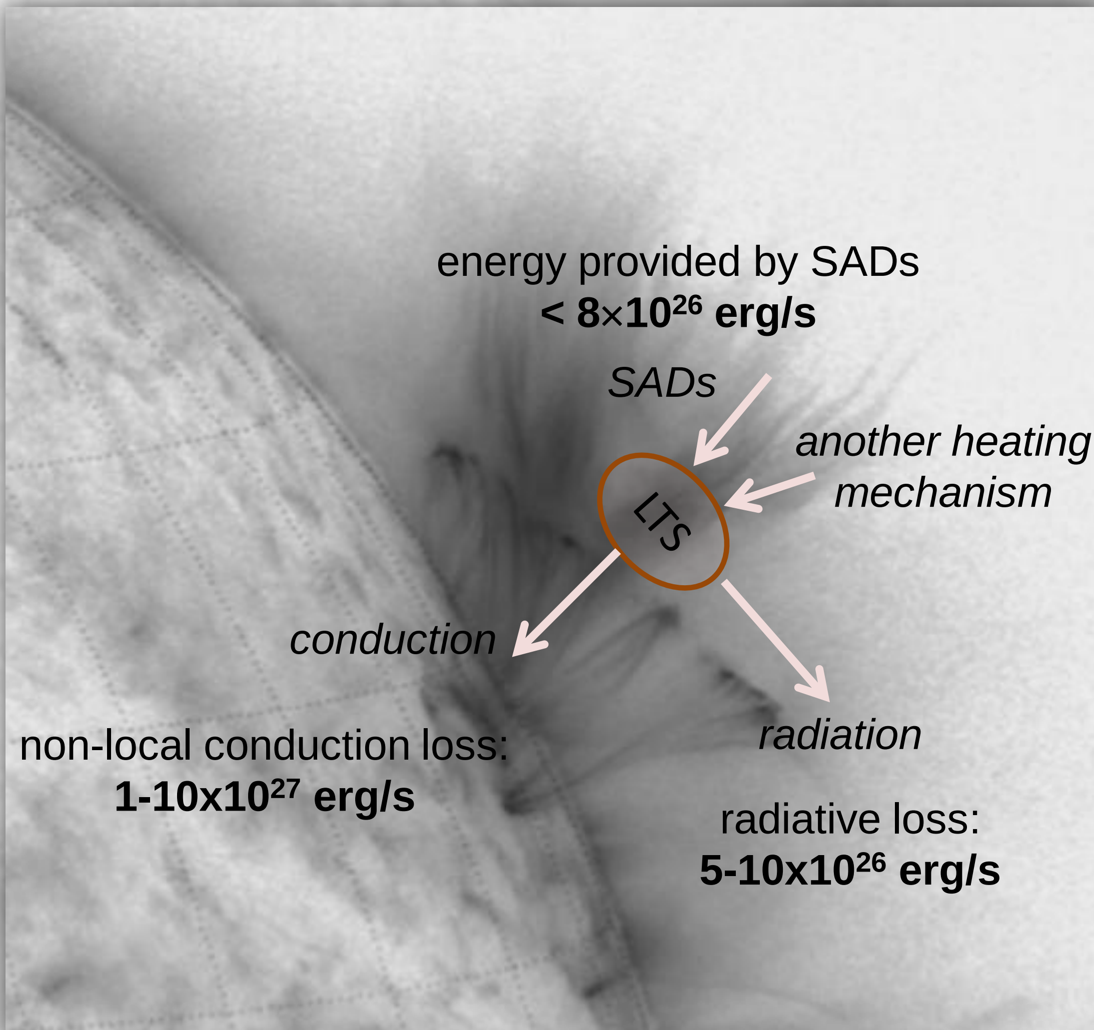
Energy balance



- cascading reconnection (Karlicky and Barta 2011)
- gas-dynamic shocks (Longcope et al. 2010)
- …

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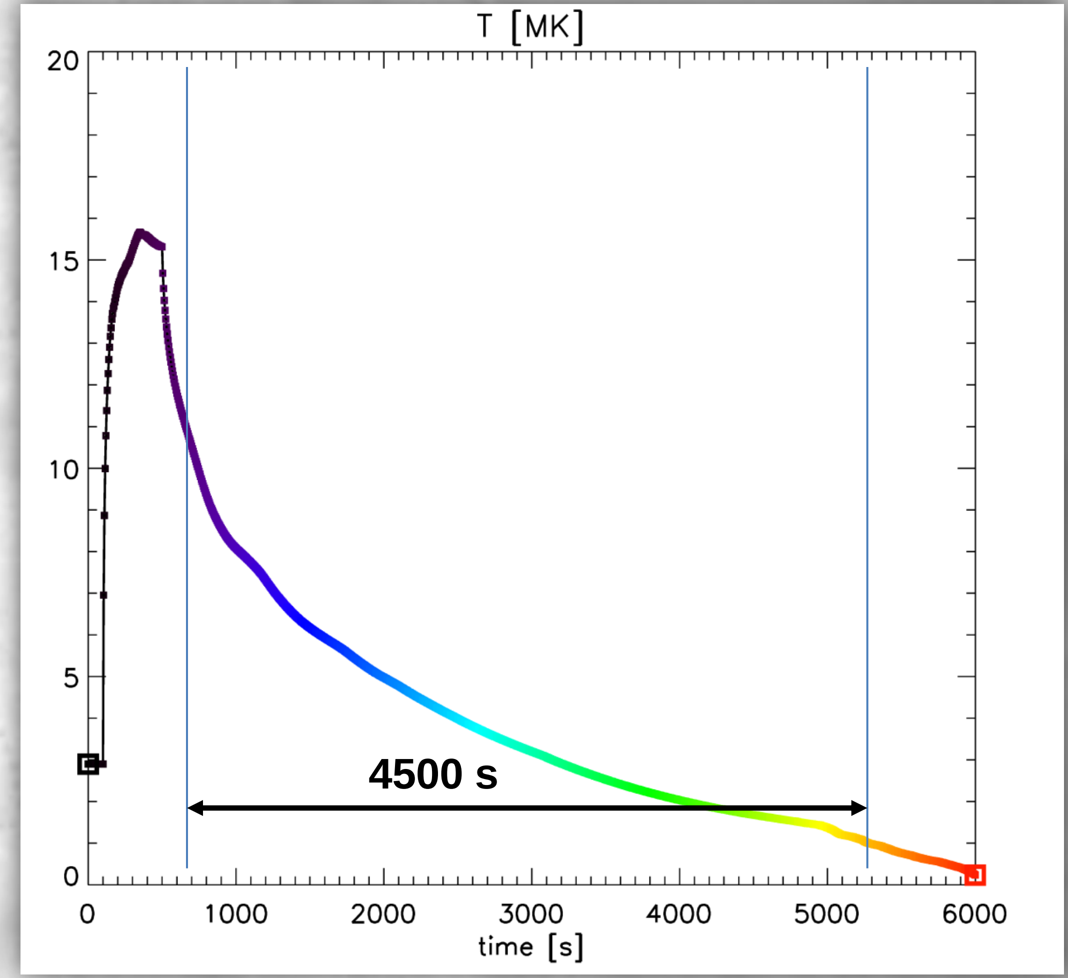

Cooling times of loops

Loop length: 90-100 Mm

Heating scheme:

- heated from 100-500(1500)s – parameters in loop's apex: 10-15 MK, 5-10×10^9 cm^{-3}
- after that the heating was abruptly switched off ('free cooling')

Cooling time: 3500 – 5500 s

Palermo-Harvard hydrodynamical model *(Peres i in. (1982), Betta i in. (1997))* used to study cooling of contracting loops after they passed through the LTS region.

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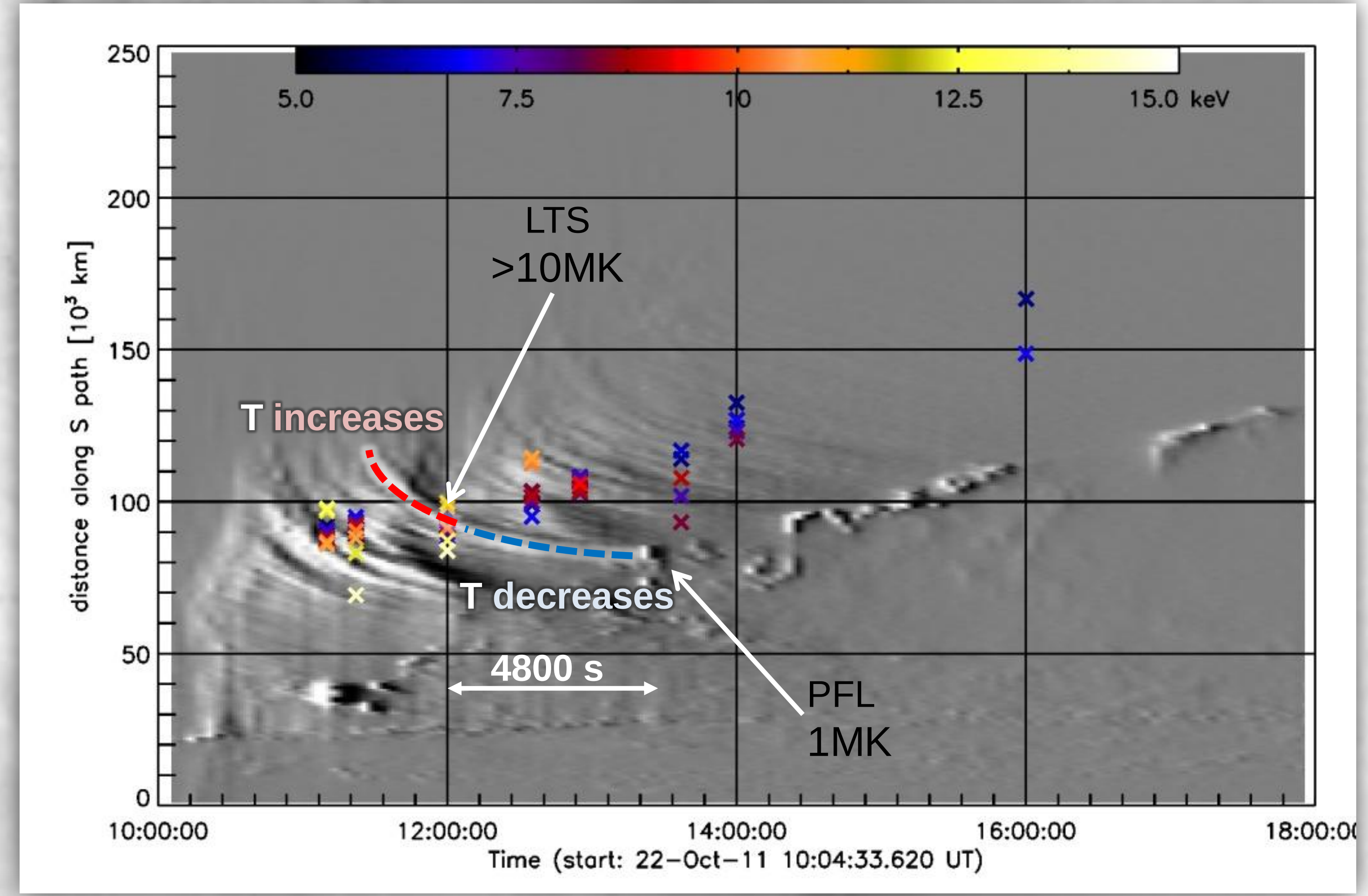
heating and cooling – where is the hottest region?



Conclusions

- Loop top sources (LTS) formed in the region of deceleration and accumulation of supra-arcade downflows (SAD). LTS was visible as long as SAD.
- Shrinking loops (SAD) underwent effective heating during deceleration – plasma was heated >10MK and became visible as X-ray LTS.
- After that shrinking loops cooled down to form post-flare loops (~1MK). The cooling did not involved any significant heating or plasma/energy outflow restriction (PH modeling).
- The heating mechanism should be very efficient and long-lasting – hot plasma of LTS was observable for RHESSI for at least 6 hours. During that time LTS lost about 10^{31} erg (radiation, conduction). Energy provided by SADs ('streaming' down plasma) seems to be not enough efficient.