A picture of X-ray coronal sources in combined observations of SDO and RHESSI

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Progress on EUV & X-ray spectroscopy and imaging II

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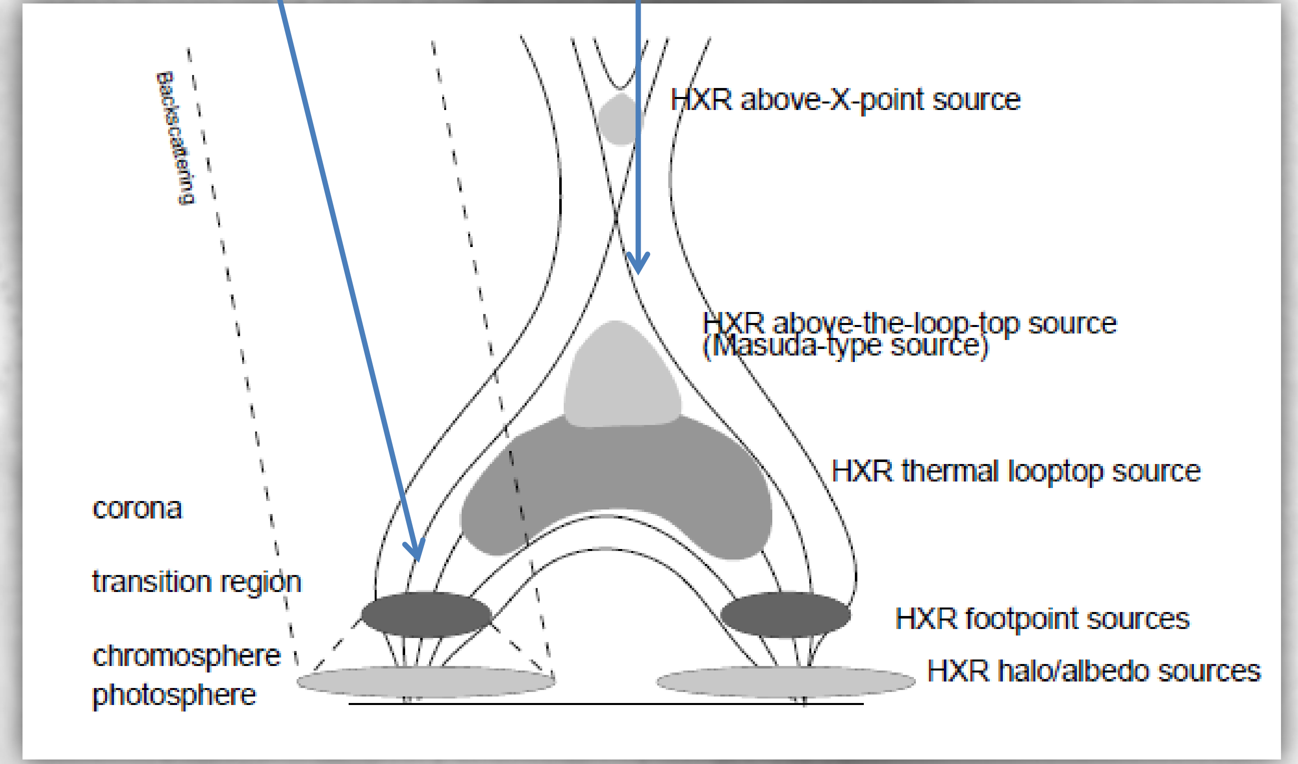
Sources in solar flares

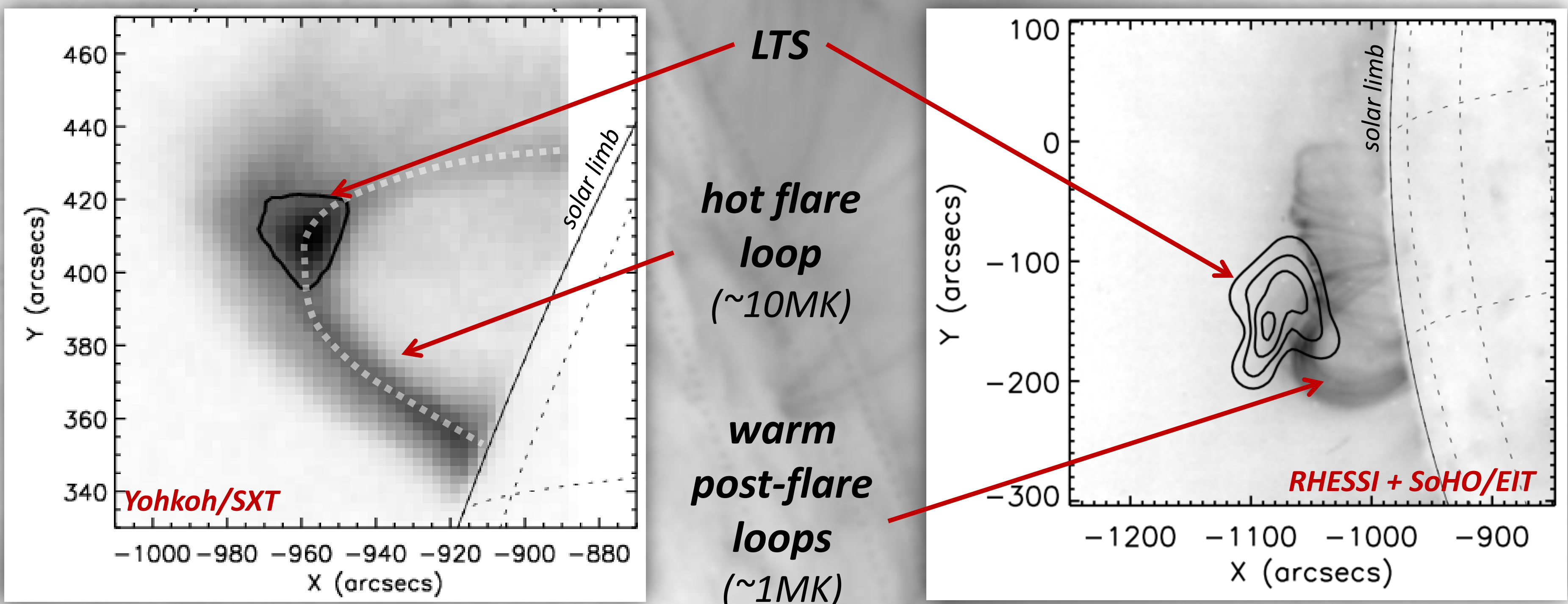
During flares X-ray radiation of the Sun is dominated by bright small centers of two types: **foot-point sources** and **coronal sources**.



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.



LTSs – motivation

In general:

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

In our study:

- What is a relation between the X-ray LTS and structures observed in EUV during the decay phase of the flare?
- Are LTS really diffuse or it's just a cause of some instrumental factor?

instrument	LTS seen as...
Skylab/ATM	(in large arcade flares) bright **diffuse** linear feature
Yohkoh/SXT	**diffuse** sources without internal structure
TRACE	**diffuse** sources (hot plasma) sharp, filamentary post-flare loops (warm plasma)
Hinode/EIS	**diffuse** sources (hot plasma) sharp, filamentary post-flare loops (warm plasma)
RHESSI	**diffuse** sources without internal structure

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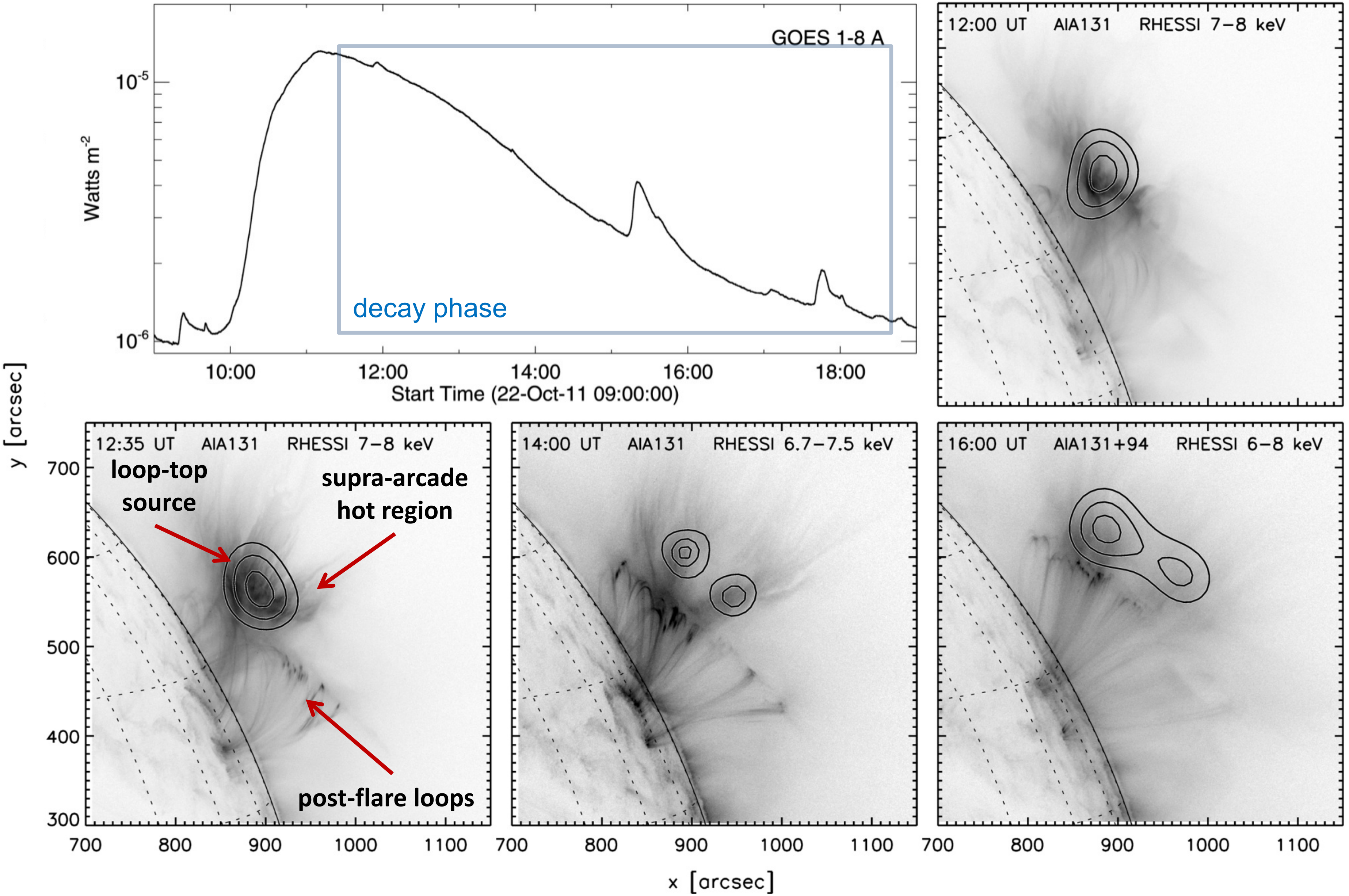
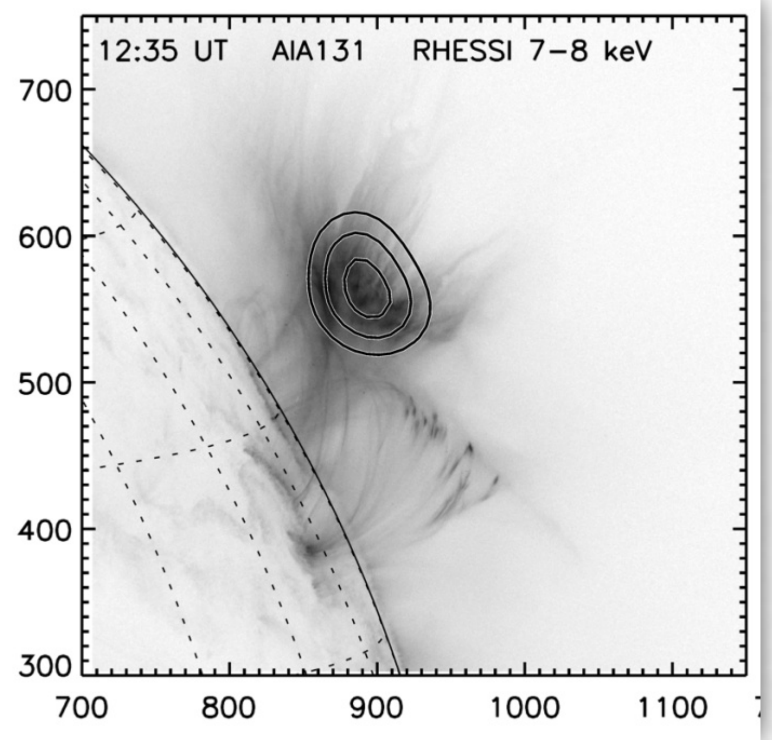


sLDE flare, duration: >9h, X-ray class: M1.3, location: N25W77, form: high arcade, data: SDO/AIA + RHESSI

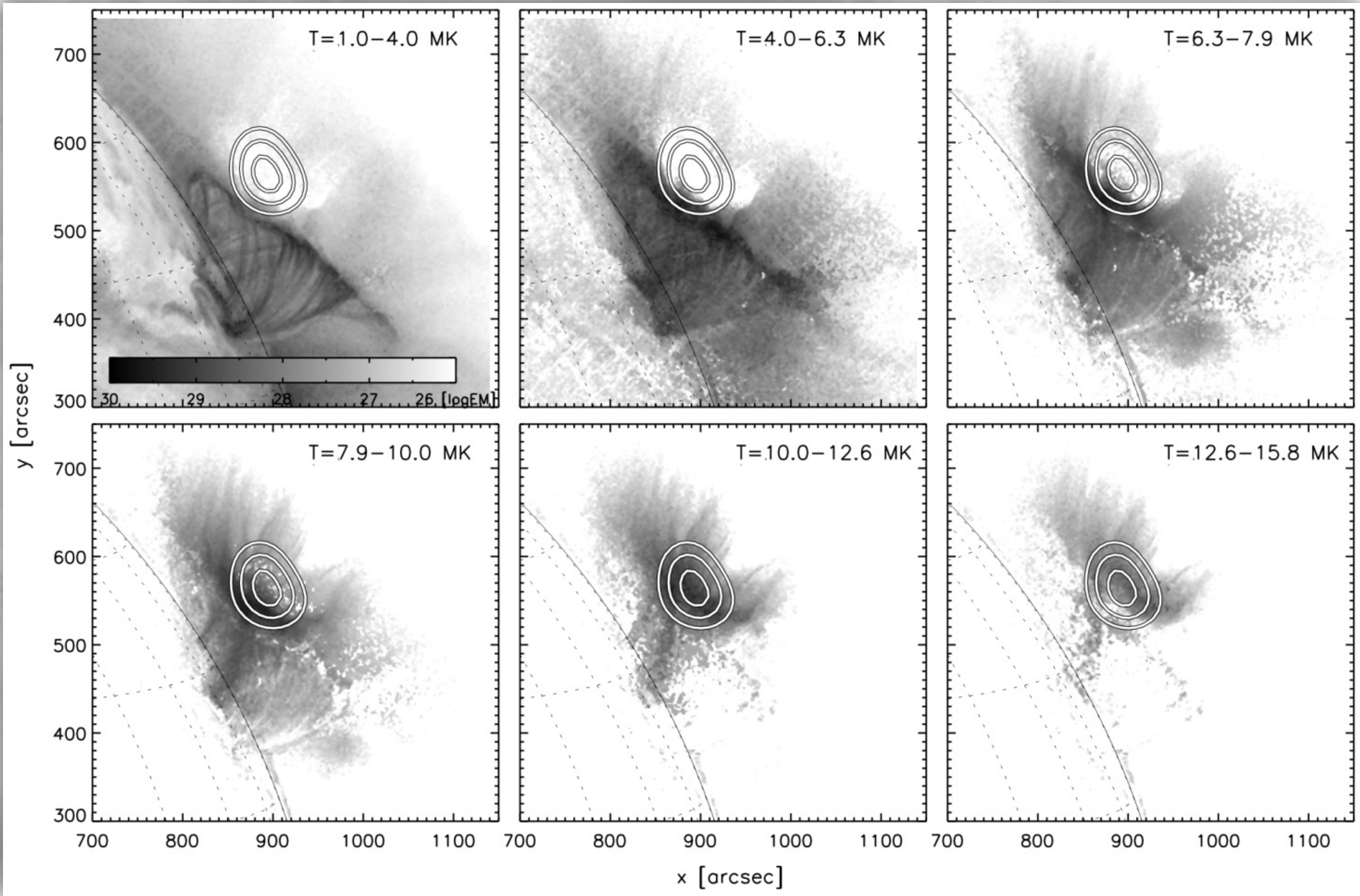
Differential Emission Measure



Why the LTS was observed in the lower part of the SAHR?

- We need to determine DEM for the flare
- Six EUV bands of AIA: 131, 94, 335, 211, 193, and 171 –> temperature coverage logT=5.5-7.5
- Determination of DEM is not straightforward -> uncertainty of obtained solution -> use more than one method
- Two methods: iterative forward fitting method (*xrt_dem_iterative2.pro,* Cheng et. al. 2012),
  regularized inversion technique (Hannan & Kontar 2012)
- AIA images resized down by factor of 2 (noise reduction)

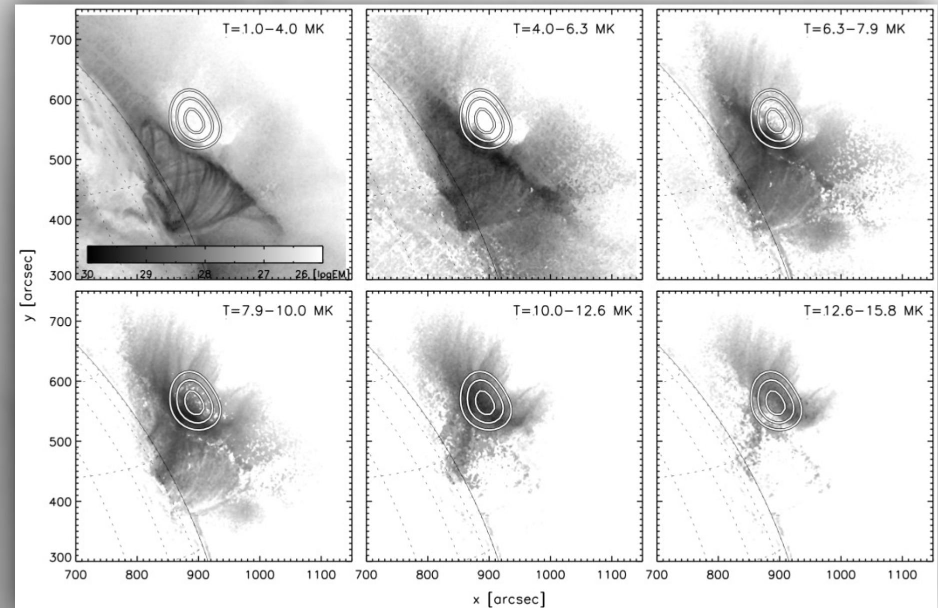
Differential Emission Measure



DEM maps for 12:35 UT (AIA) + LTS contours (RHESSI)

Differential Emission Measure

DEM maps for 12:35 UT (AIA) + LTS contours (RHESSI)



Results:

- Temperature gradient in SAHR: from 6 MK (lower edge) to 16 MK (above the LTS centroid)
- LTS co-aligned with a part of SAHR where EM in T range 6-16 MK was the highest
- Temperature of LTS (RHESSI imaging spect.): 8.5 + 14 MK
- EM of: LTS (RHESSI imaging spect.): ≈ 8.8×10^{48} cm^{-3}
  co-aligned part of the SAHR (for temperature range 6.3-15.8 MK) ≈ 9.3×10^{48} cm^{-3},
- Bright emission T<6 MK too cold for RHESSI
- Hot upper part of SAHR too faint for RHESSI (observed dyn. range 1000:1, observable - 10:1)

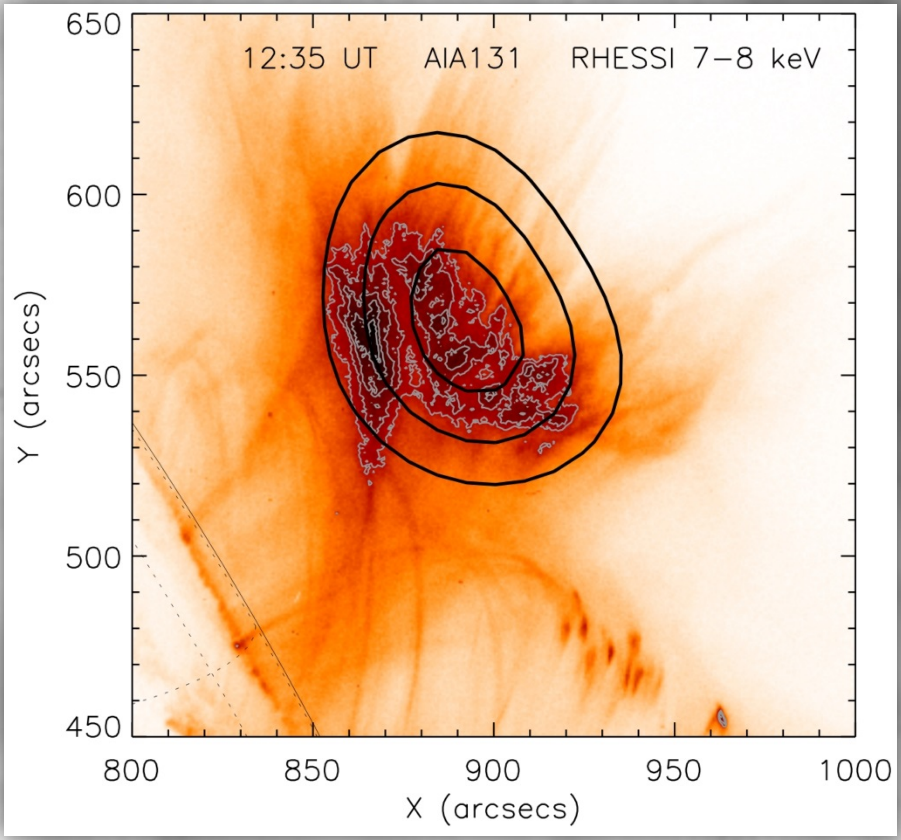
There should be some problem…

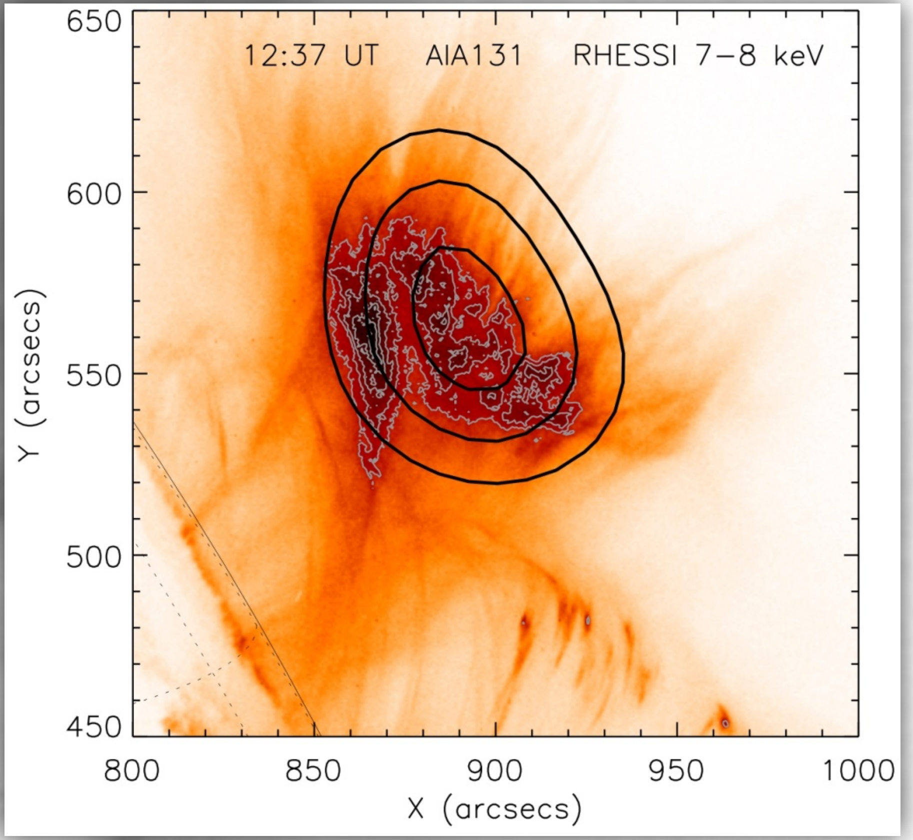
Result and problem:

- X-ray emission recorded by RHESSI as LTS came from the part of SAHR that had the highest EM and simultaneously T within the range of RHESSI thermal-response.

however…

- SAHR – **small-scale structure present**, LTS – **no small-scale structure**

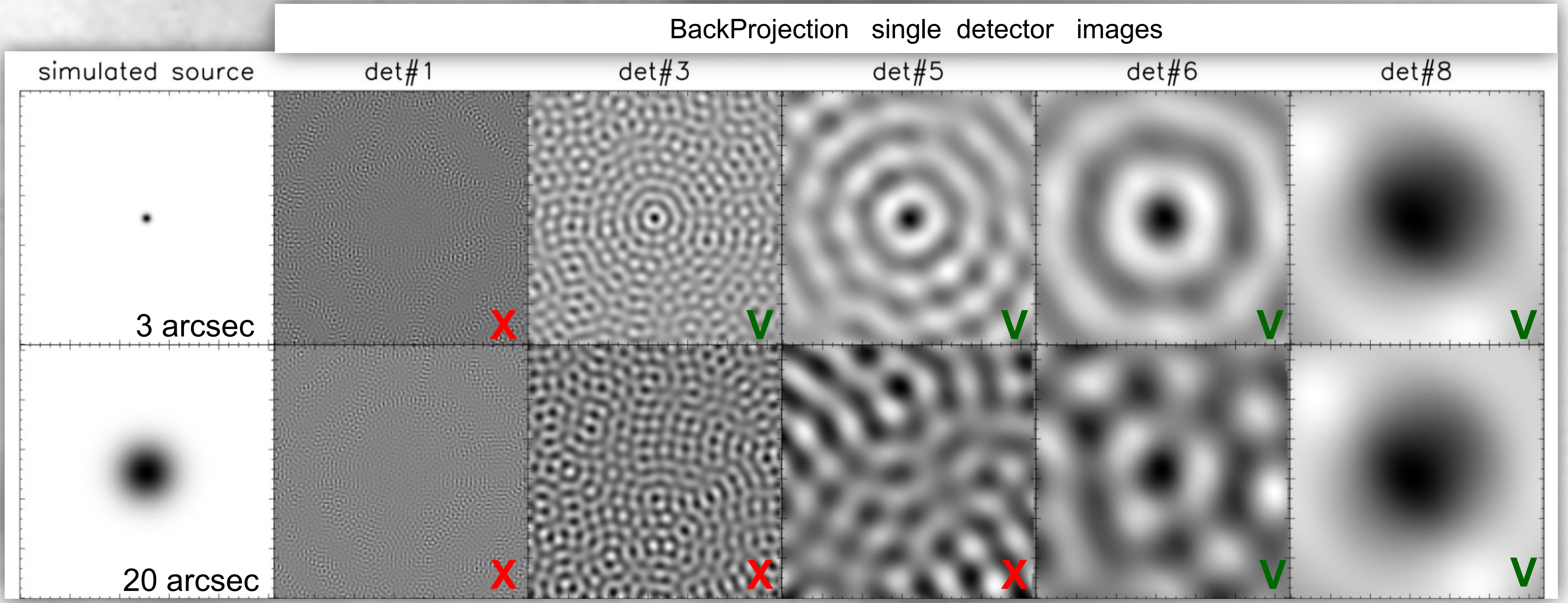




Modulation – key issue

Image reconstruction using RHESSI data

- RHESSI – rotating Fourier imager, 9 detectors+grids with different resolution (2.3-183 arcsec)
- Images are reconstructed base on modulation recorded by detectors
- No modulation if source size **>** grid resolution



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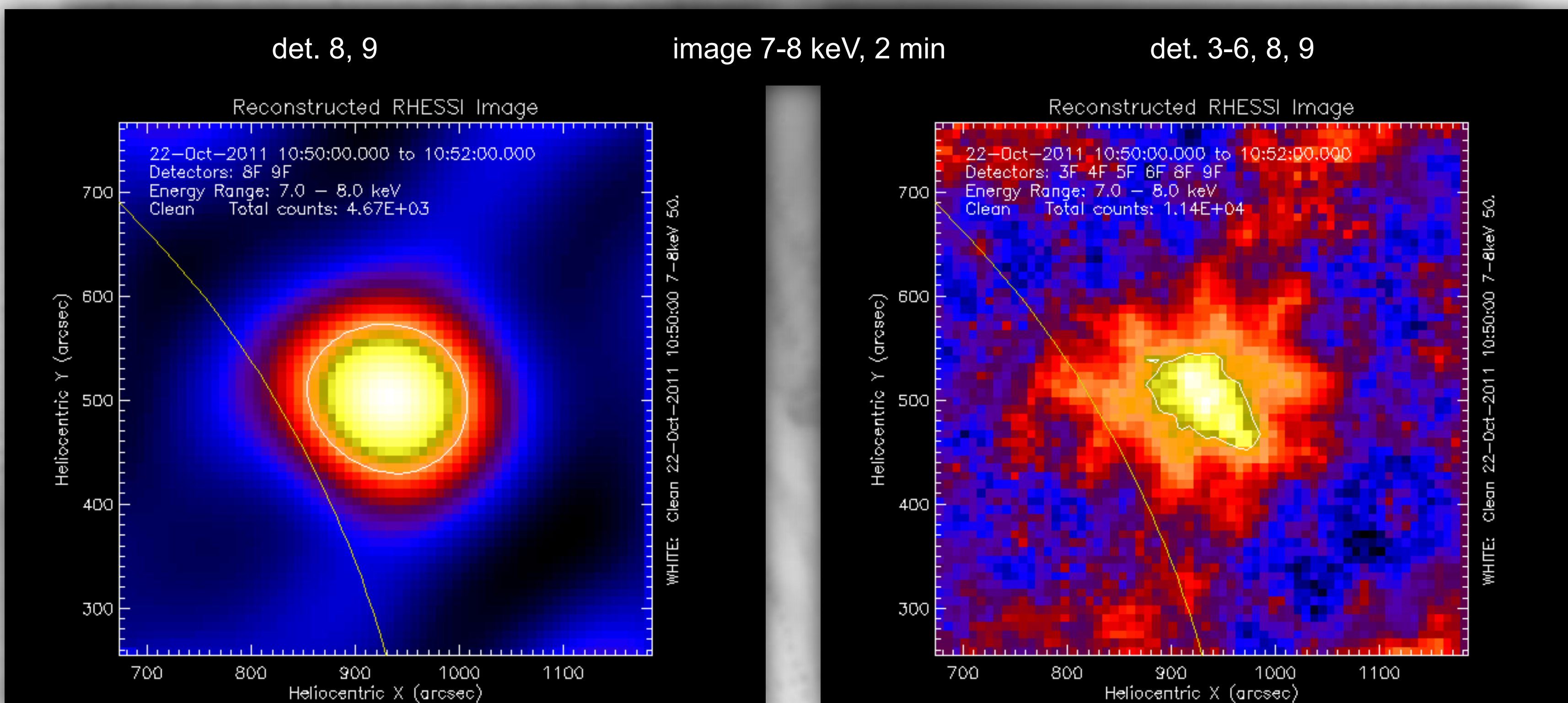
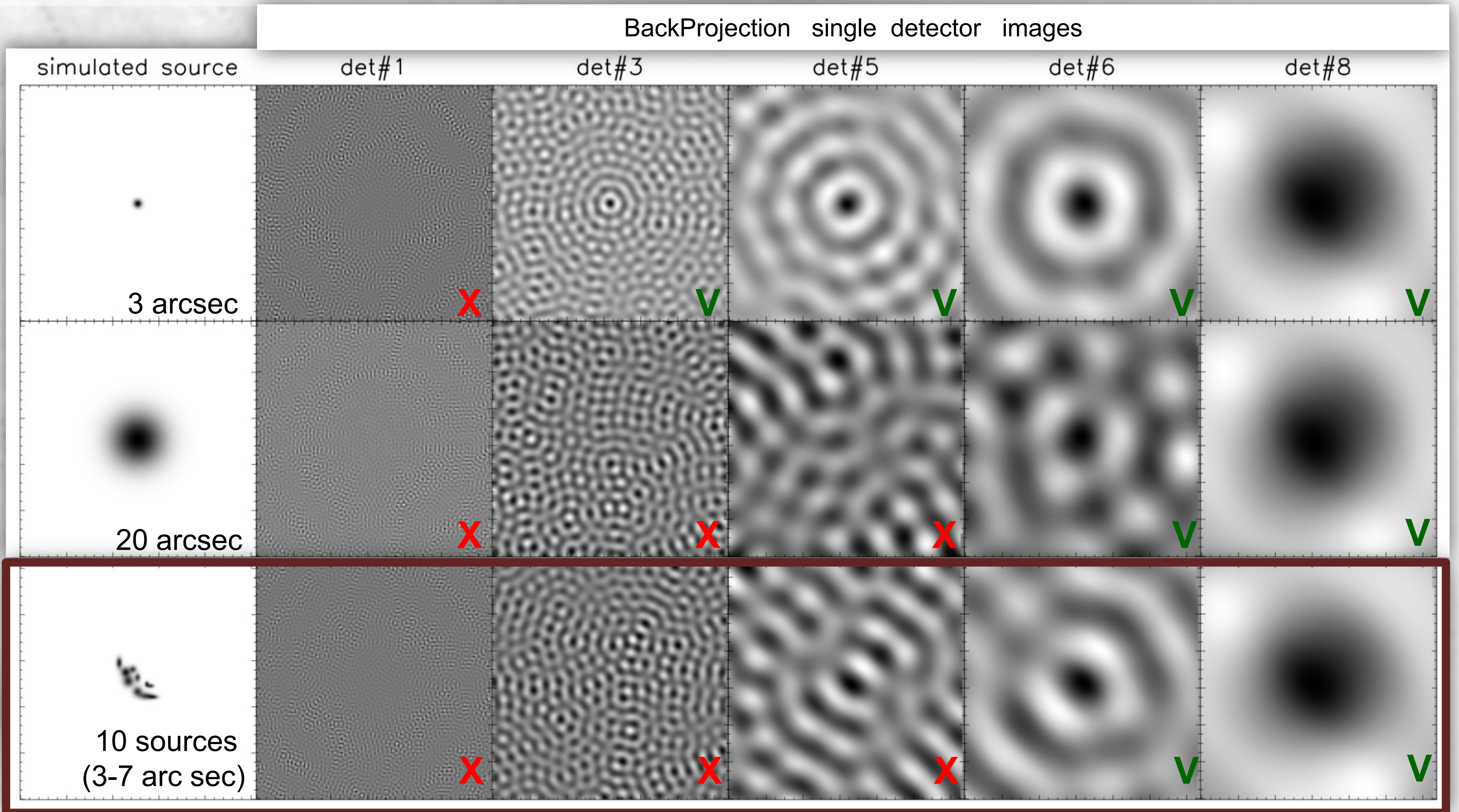
- No modulation if source size > grid resolution
- Detectors showing no modulation should not be use in image reconstruction



Modulation – key issue

What if source consists of many small sub-sources?

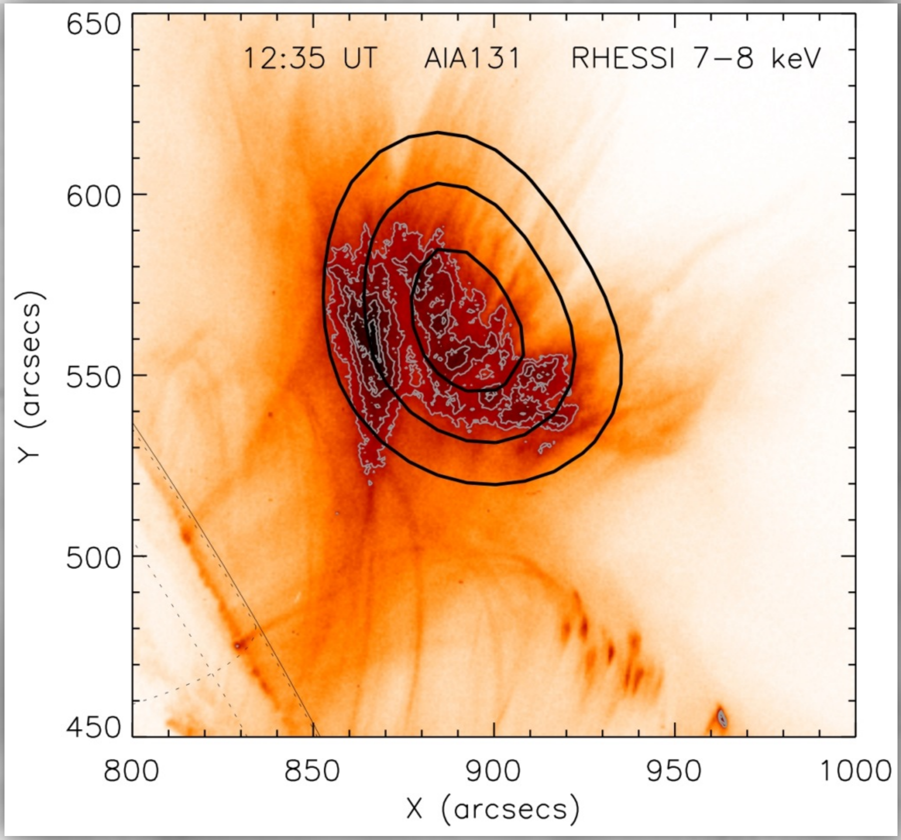
- Modulation is not present in finer grids.
- Source with small-scale structure look like single large source

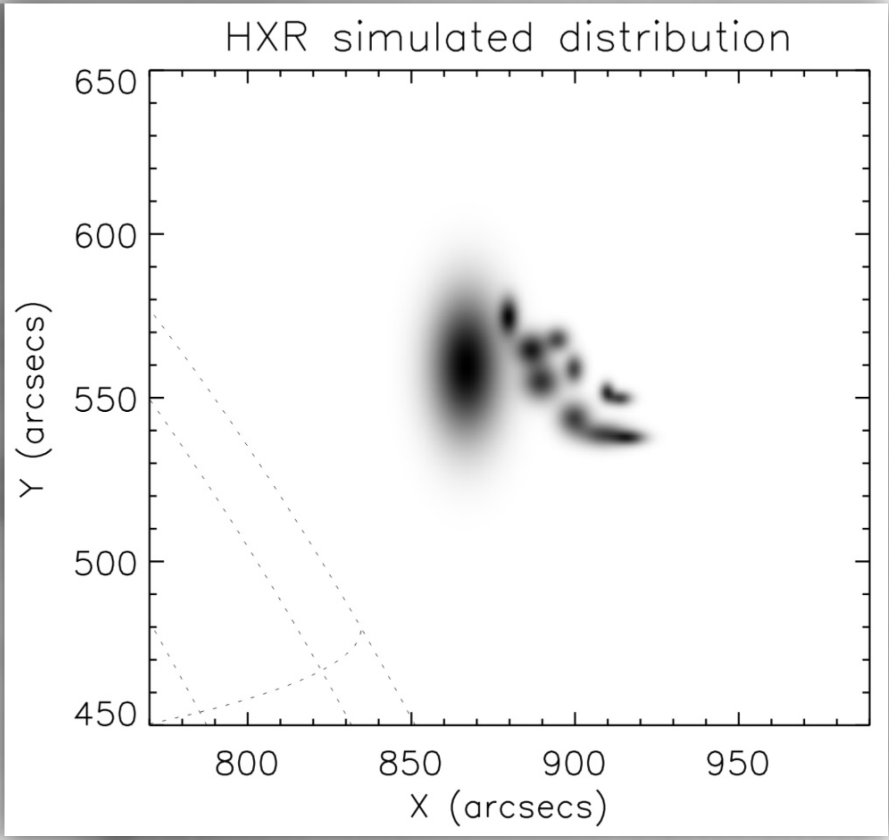


Simulations

Can possible small-scale structure be restored in RHESSI images?

- Simulation with RHESSI (synthetic data)
- Assumption: LTS has small-scale structure similar to structure of SAHR
- Synthetic LTS with small-scale structure: 11 sub-sources
- Reconstruction of images with grids 3-6, 8, 9

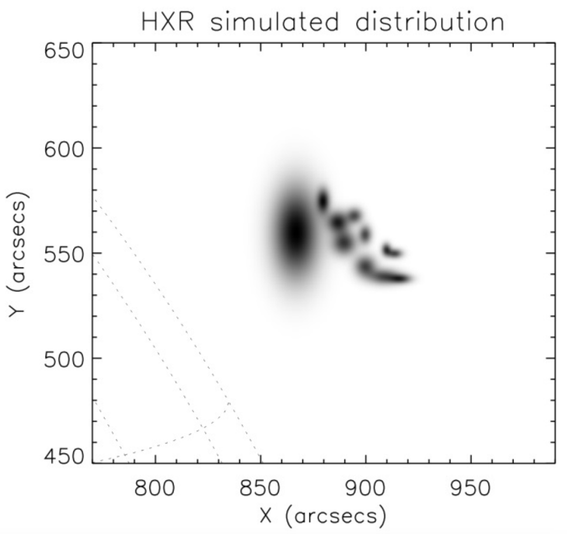


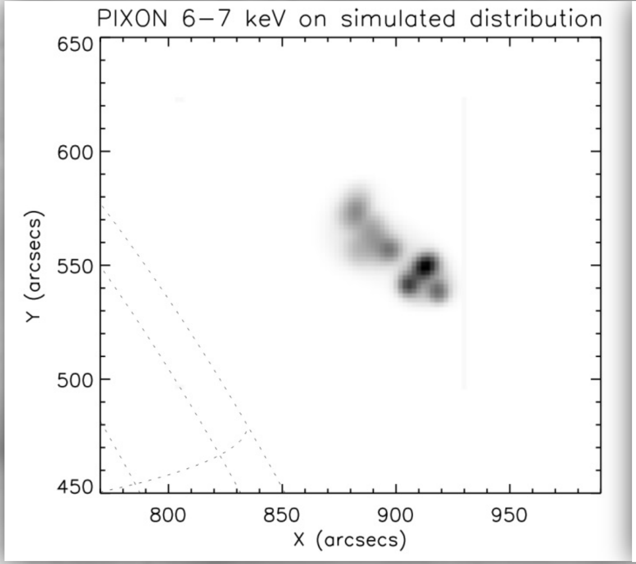


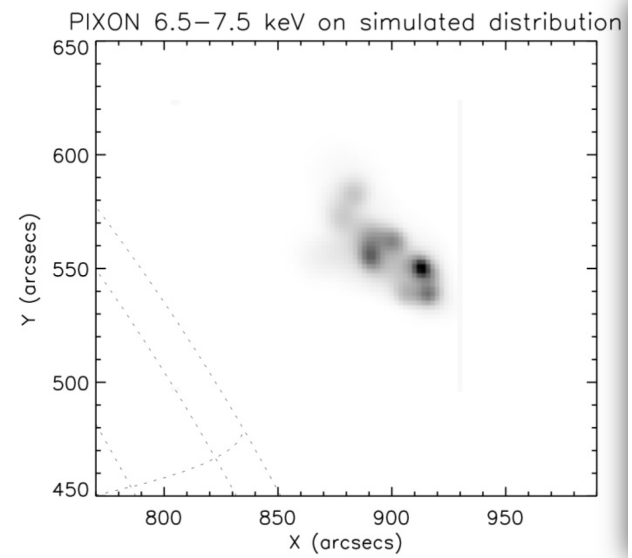
Simulations

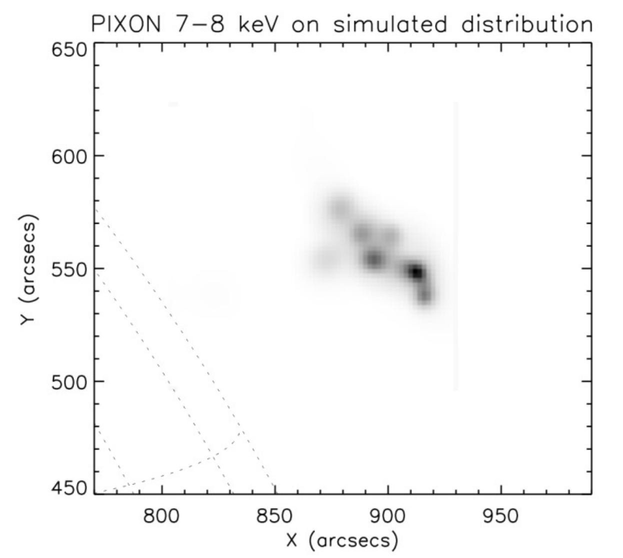
Results of simulations:

- reconstructed images show a set of small sub-sources but…
- their sizes, locations, and relative intensities are differ from the ones in the assumed model, and…
- result is not stable – images reconstructed for slightly different energy ranges show different set of sub-sources, and…
- the largest of sob-sources is missing (!)





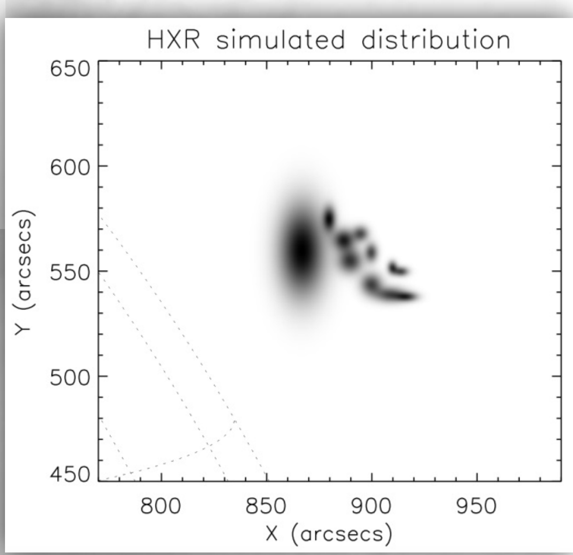


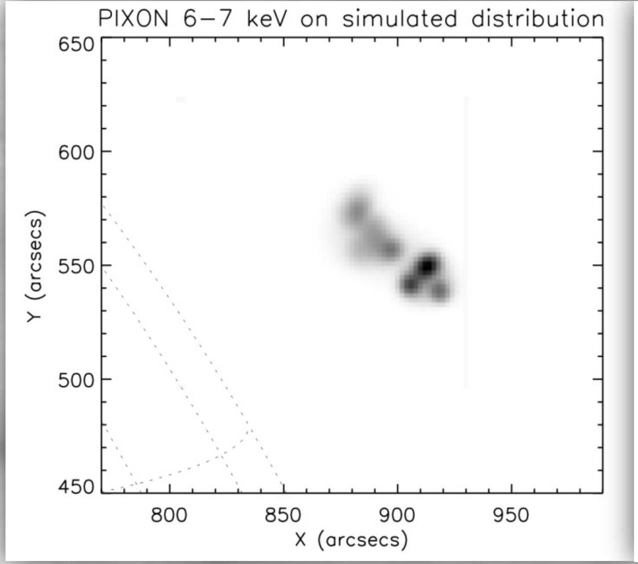


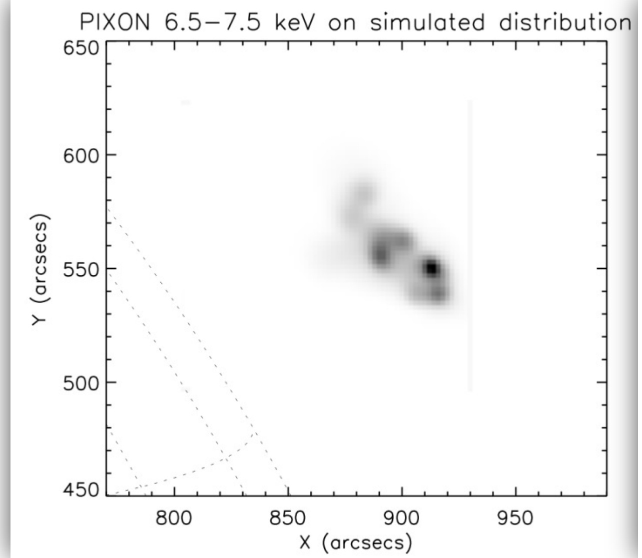
Simulations

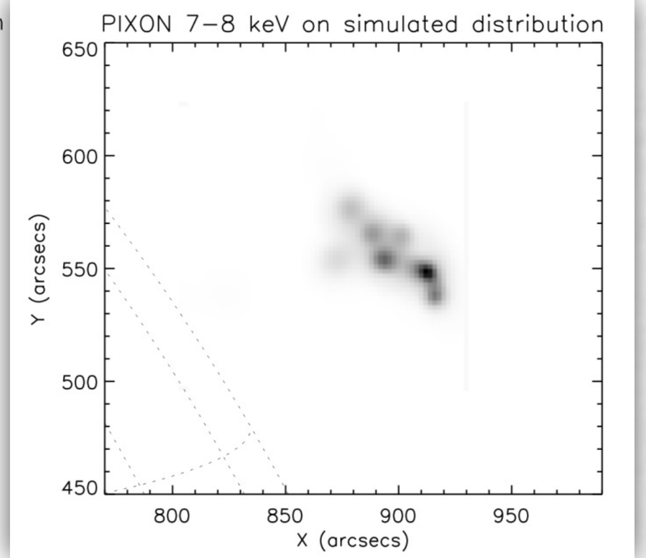
Results of simulations:

- however, there is one trace of small-scale structure: size of reconstructed sources ≈ size of simulated sources, so…
- check real data – reconstruction of images with grids 3-6, 8, 9





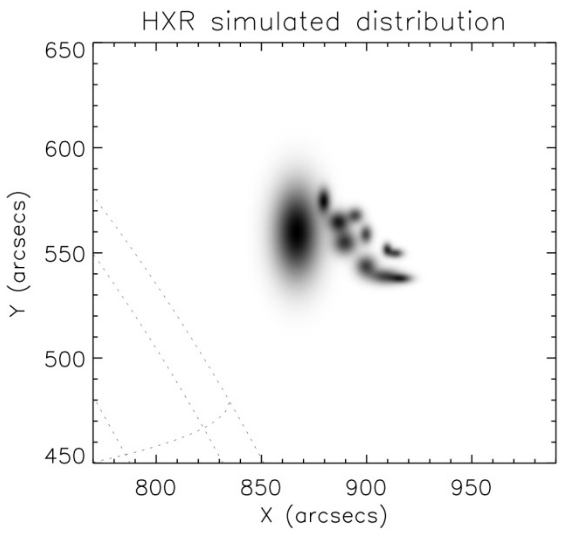


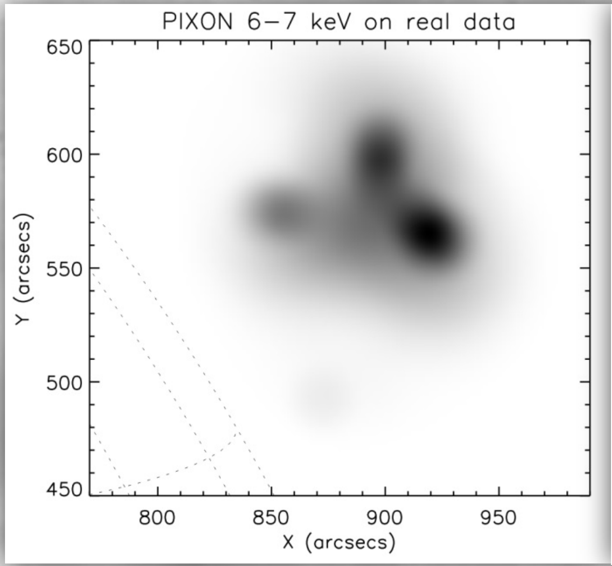


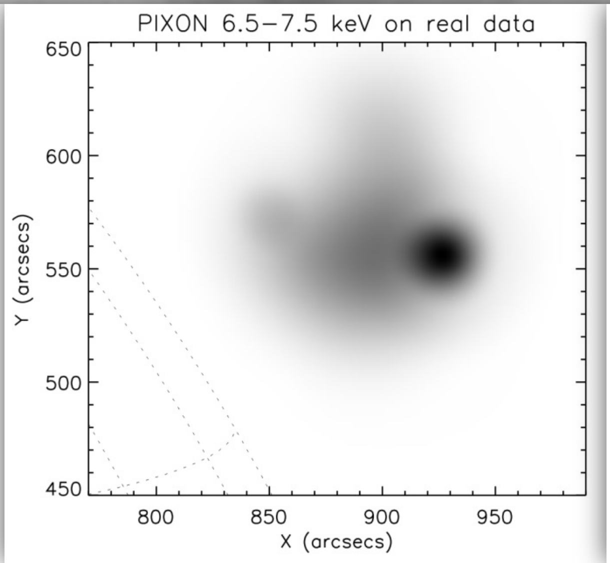
Simulations

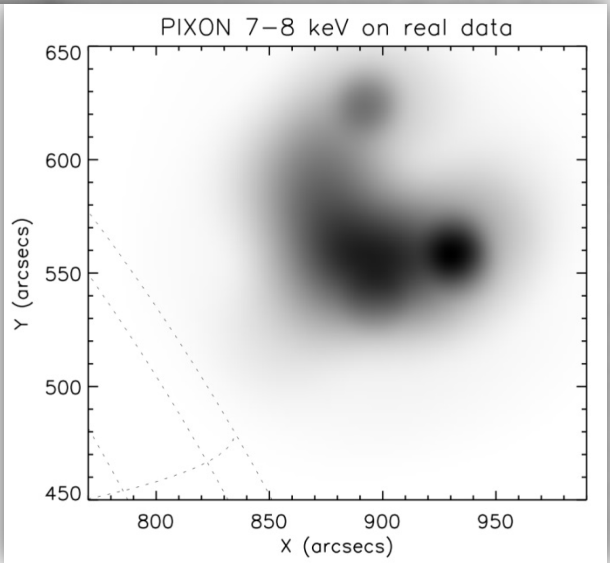
Results of simulations:

- check real data – reconstruction of images with grids 3-6, 8, 9
- result is not stable – images reconstructed for slightly different energy ranges show different set of sub-sources, but…
- sub-sources are significantly larger (> grid resolution and simulated sources)
- results do not depend on used reconstruction algorithm

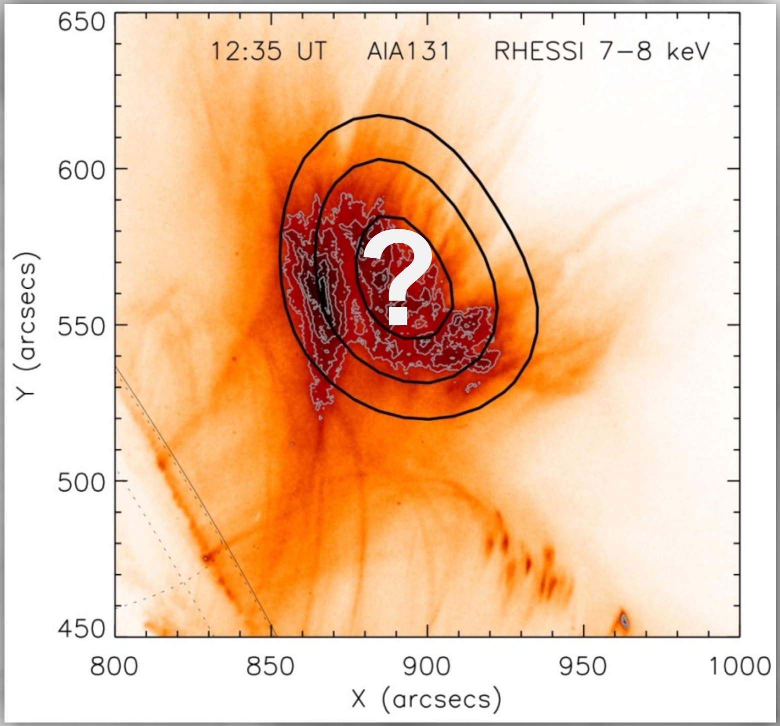








LTS – mystery continues (partially)

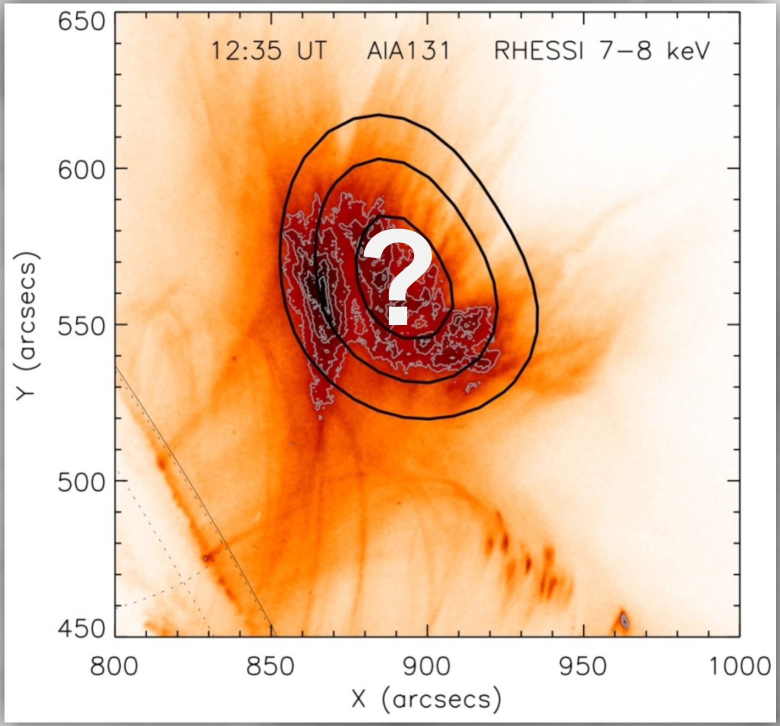


LTS paradox

- There is no strong evidence for small-scale structure X-ray LTS (RHESSI)
- SAHR is full of small-scale structures (SDO/AIA)

Next generation X-ray telescopes will solve the problem?

Conclusions



- X-ray emission recorded by RHESSI, visible as the LTS came from the part of the hot supra-arcade region that had the highest EM and the T within the range of RHESSI thermal-response.
- However, while the supra-arcade region was a region consisting of small-scale structures, the LTS seemed to be smooth, structureless.
- We run simulations using real and synthetic RHESSI data, but we did not find any strong evidence that the LTS had any small-scale structure.