On the fine structure of solar flare X-ray loop top sources.

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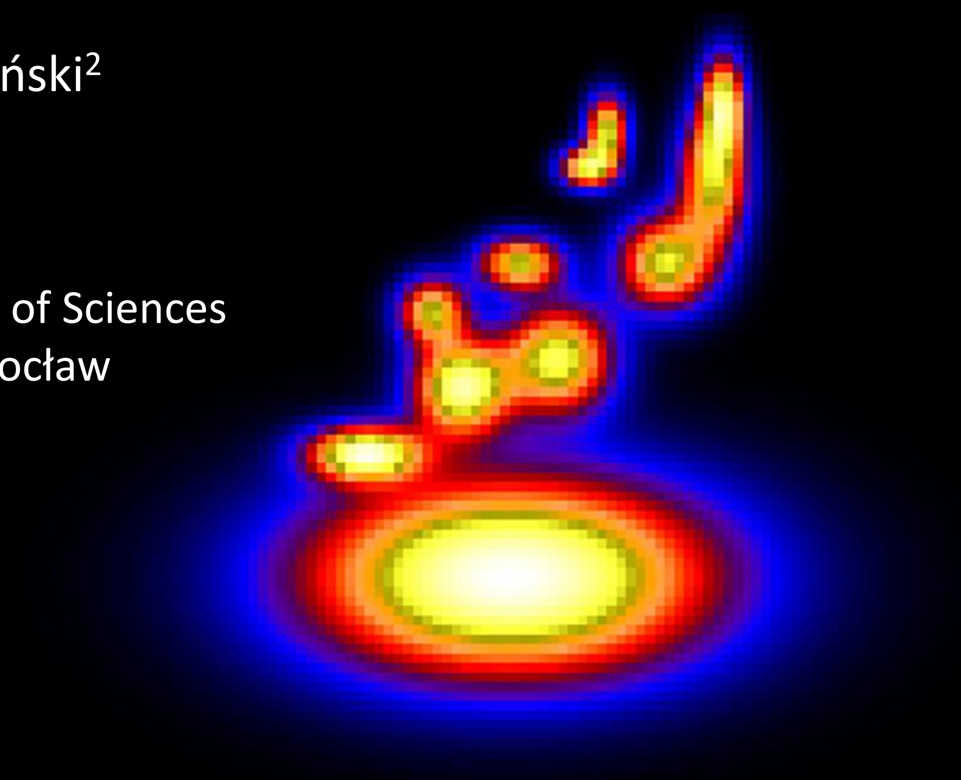
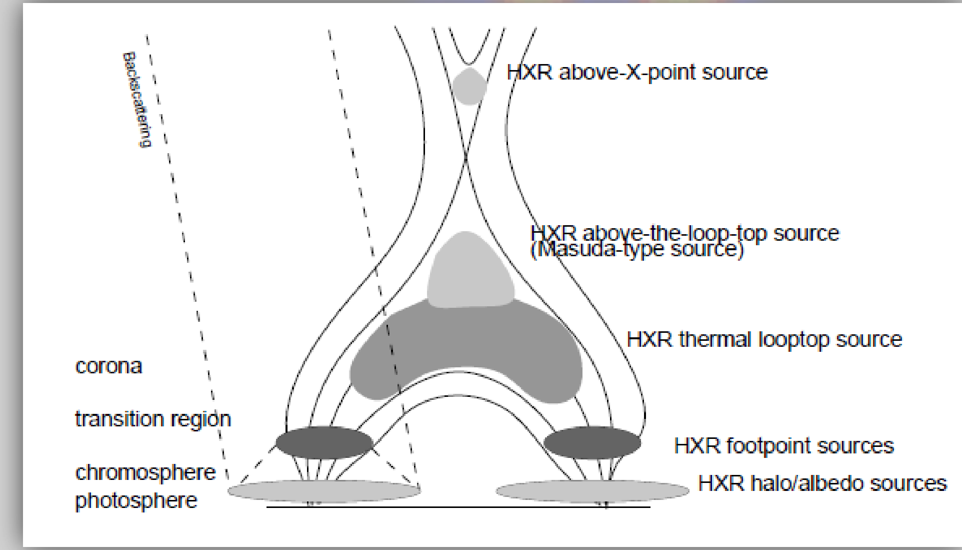


Loop Top Sources (LTS)

LTSs are **common characteristics of solar flares** regardless of the flare size, duration or power. Their main characteristics:

- filled with hot and relatively dense plasma
- mainly thermal emission, sometimes weak non-thermal
- physical parameters change smoothly with time
- hold large amount of energy released during flares
- continious energy input/release must be present
  to explain hot sources visible sometimes for several hours

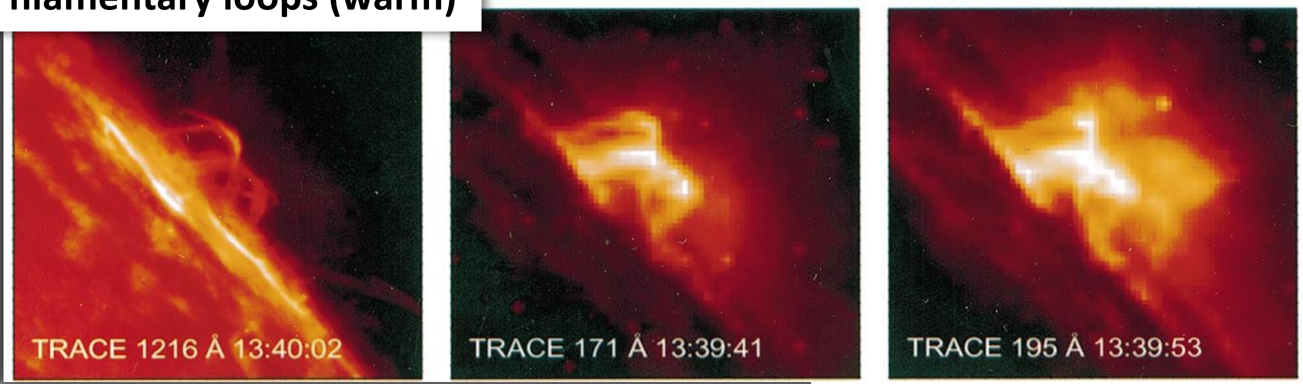
Vorpahl J. A. et al. 1977
Acton L. W. et al. 1992
Doschek G. A. et al. 1995
Feldman U. et al. 1995
Doschek G. A. & Feldman U. 1996
Jakimiec J. et al. 1998
White S. M. et al. 2002
Jiang Y. W. et al. 2006
Kołomański S. et al. 2011



Aschwanden 2005

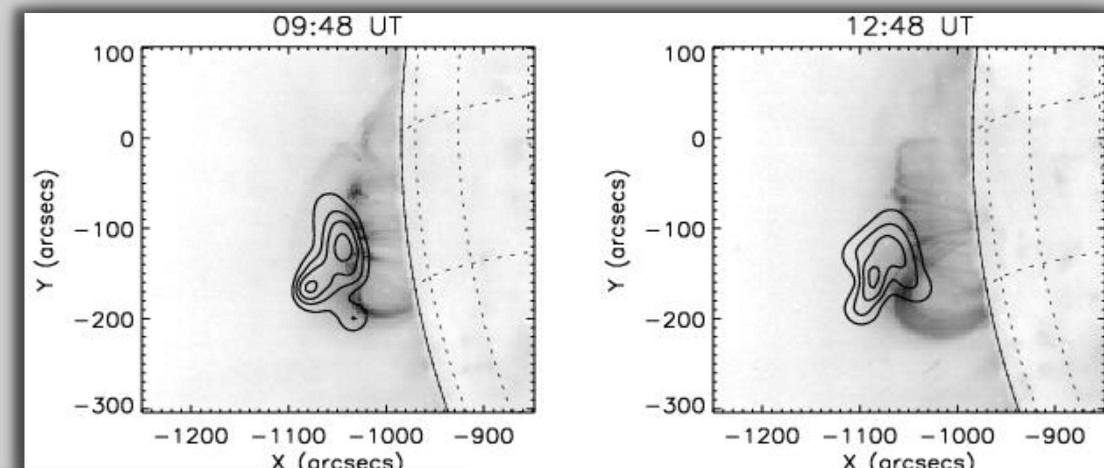
Different instruments – different points of view.

diffuse sources (hot)
filamentary loops (warm)



Warren & Bookbinder 1999

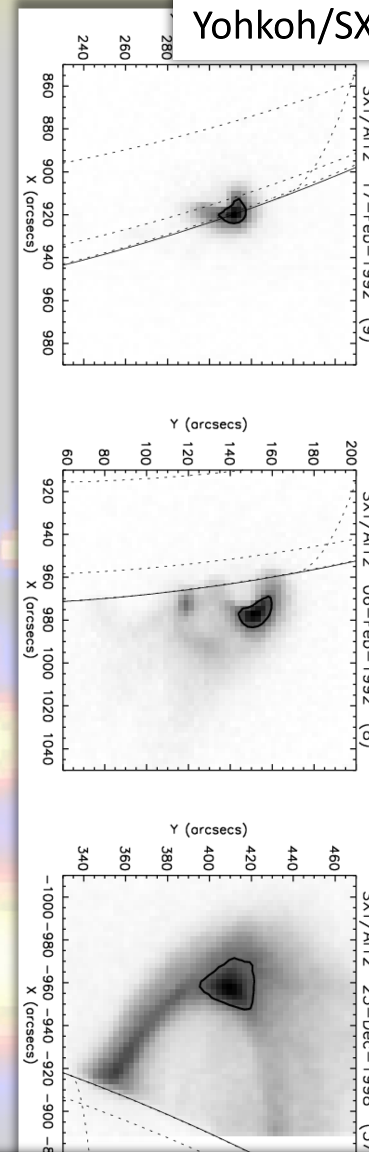
diffuse without internal structure



SoHO/EIT 195Å + RHESSI
7-8 kev

Kołomański et al. 2011

Yohkoh/SXT



diffuse sources without internal structure

Really diffuse or fuzzy appearance caused by instrumental imperfection?

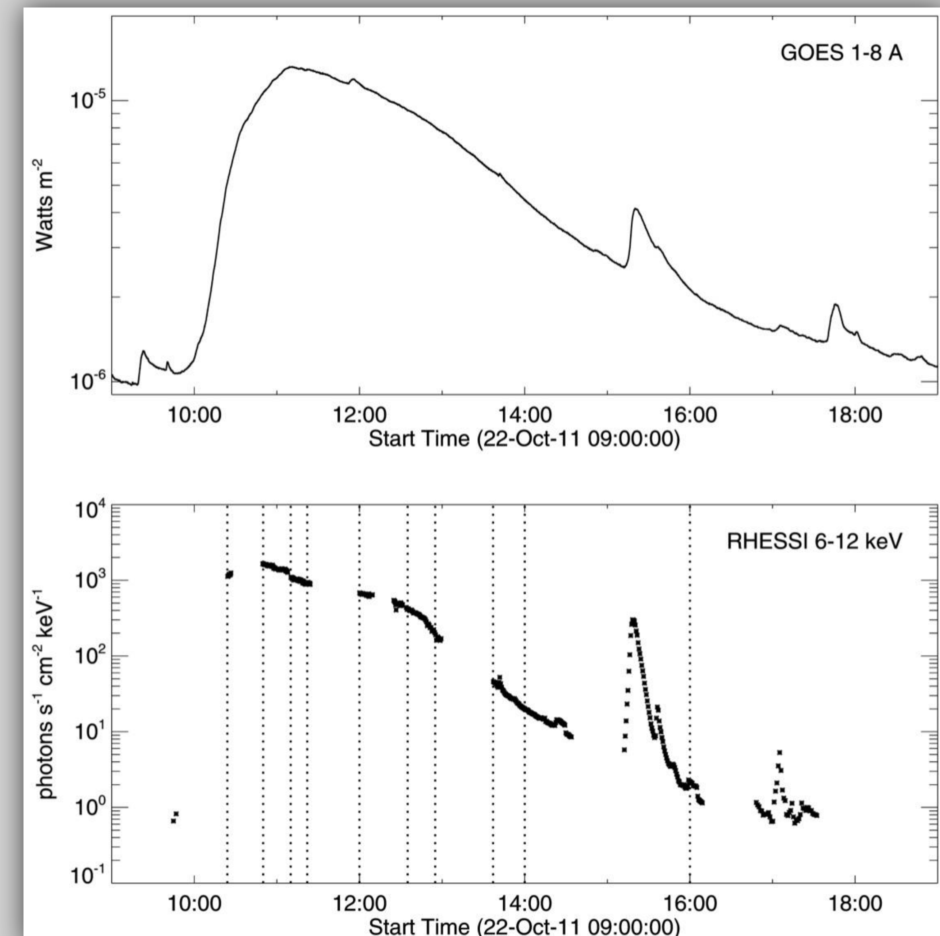
Instrument	LTSs seen as	remarks
Skylab/ATM	bright linear feature sometimes resolved into separate sources	low resolution broadband filters
Yohkoh/SXT	diffuse sources without internal structure	angular res. 3.7 arcsec broadband filters
TRACE	diffuse sources (hot) filamentary loops (warm)	angular res. 2.25 arcsec low thermal res. for hot plasma
Hinode/EIS	diffuse sources (hot) filamentary loops (warm)	angular res. 2.5(?) arcsec low temporal resolution
RHESSI	diffuse without internal structure (unless separation of the subsources is <2'')	rotating Fourier imager

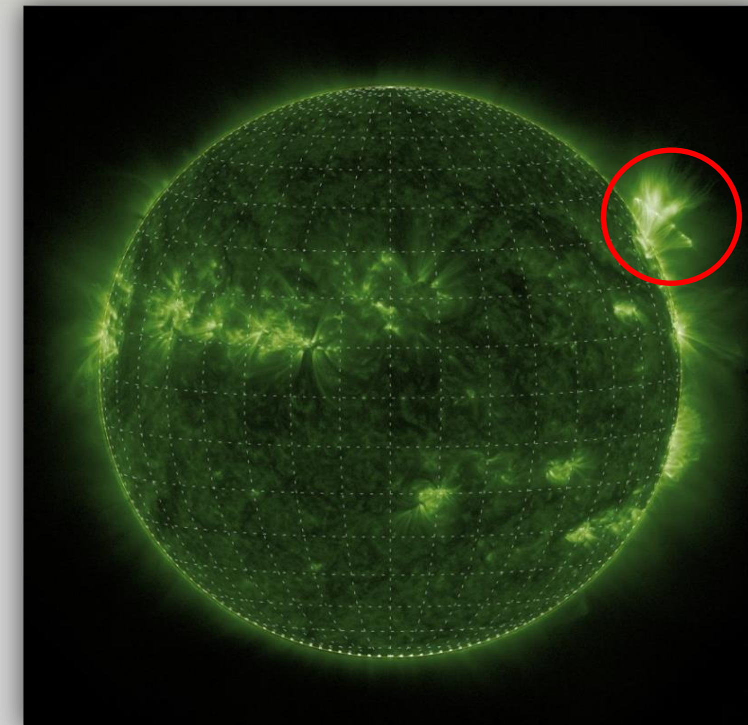
Open questions:

- What is a LTS?
- How they form?
- **Do they have internal structure? What is the characteristic scale of this structure?**
- Why their evolution is slow and gradual?

Case study: SDO/AIA + RHESSI

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





sLDE flare

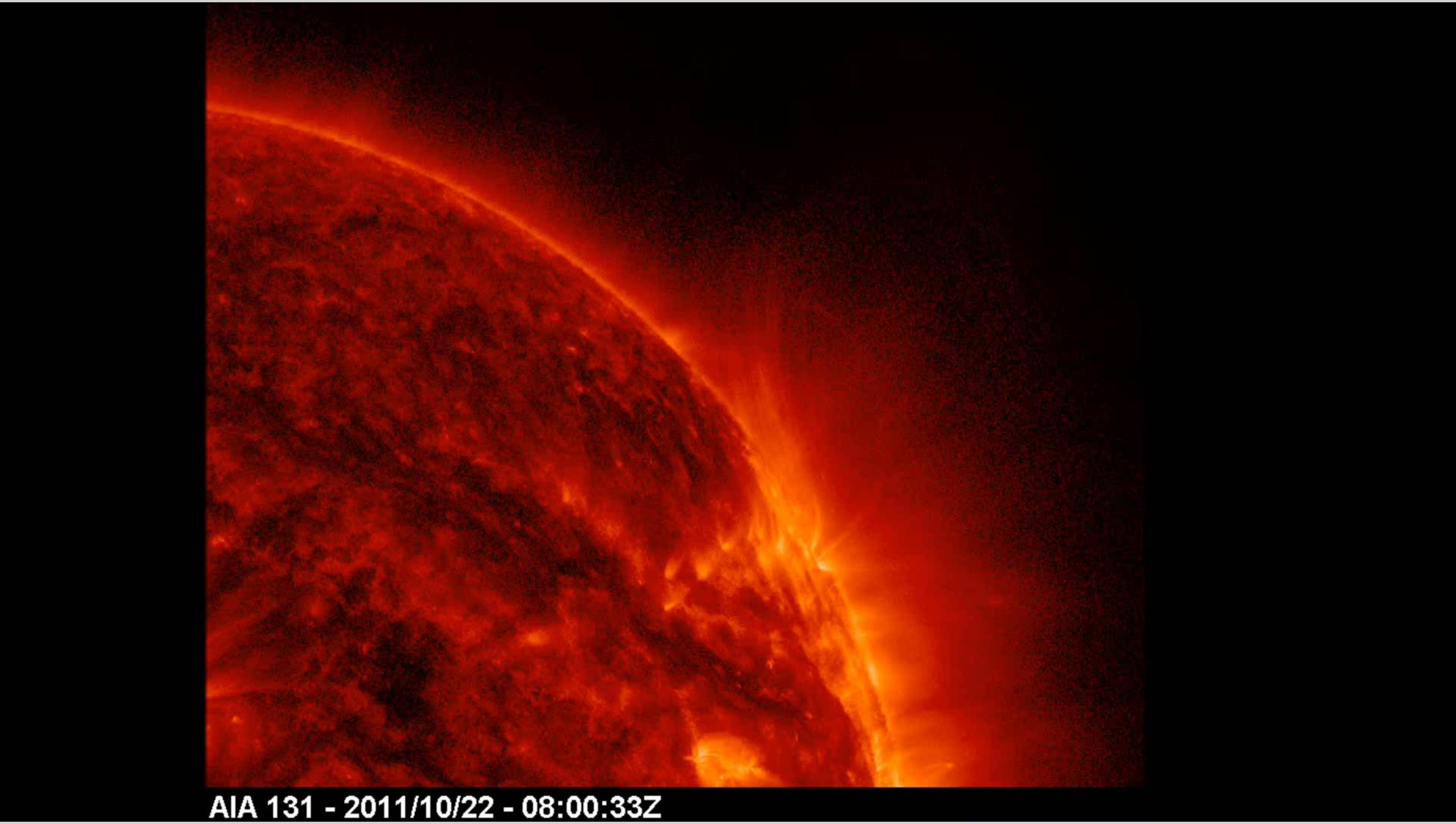
duration: >9h

X-ray class: M1.3

location: N25W77

form: high arcade

Loop Top Sources (LTS)

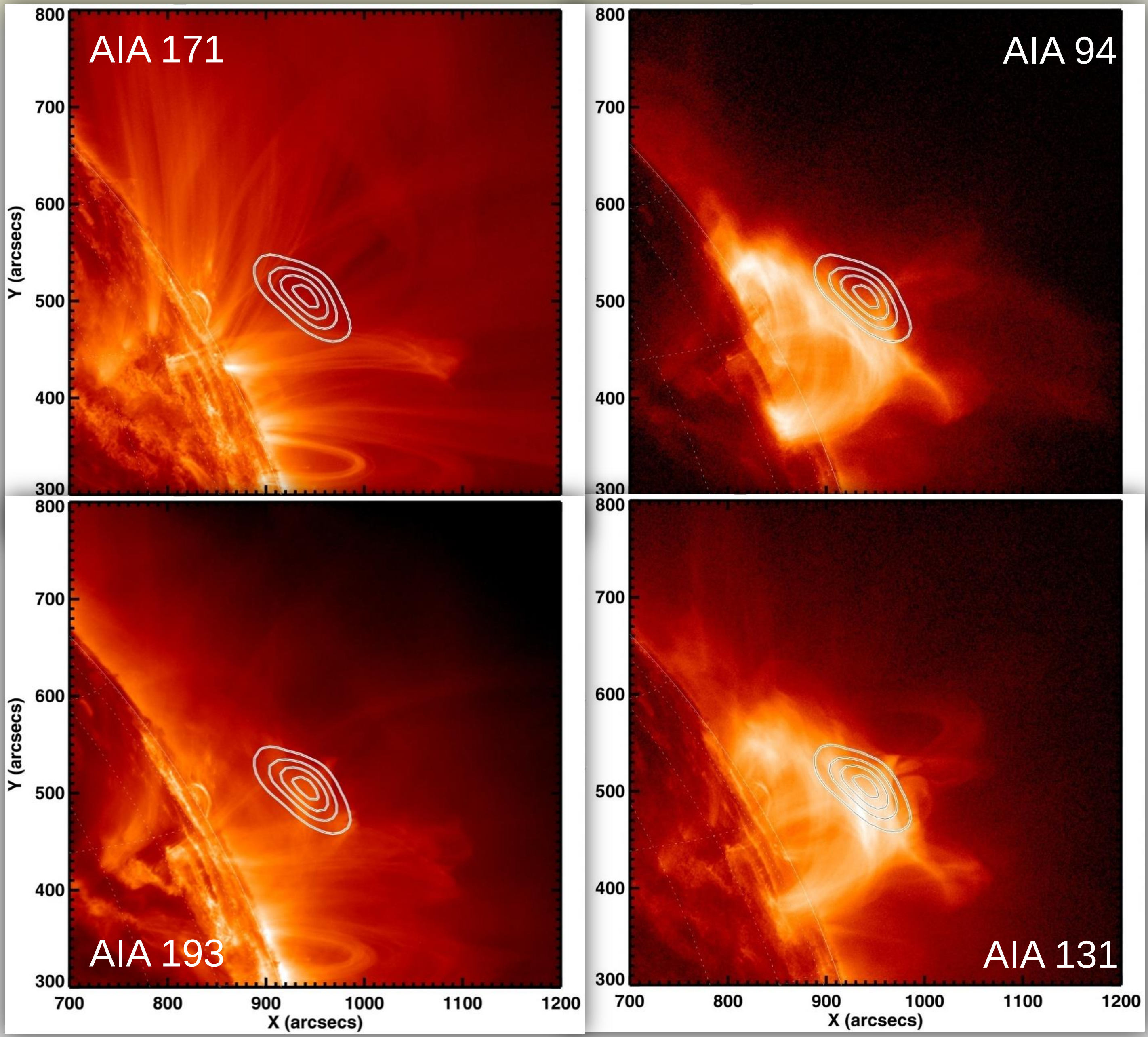


SDO/AIA + RHESSI

10:50 UT

SDO/AIA
image
+
RHESSI
contours
9-10 keV

LTS temp
T≈14 MK

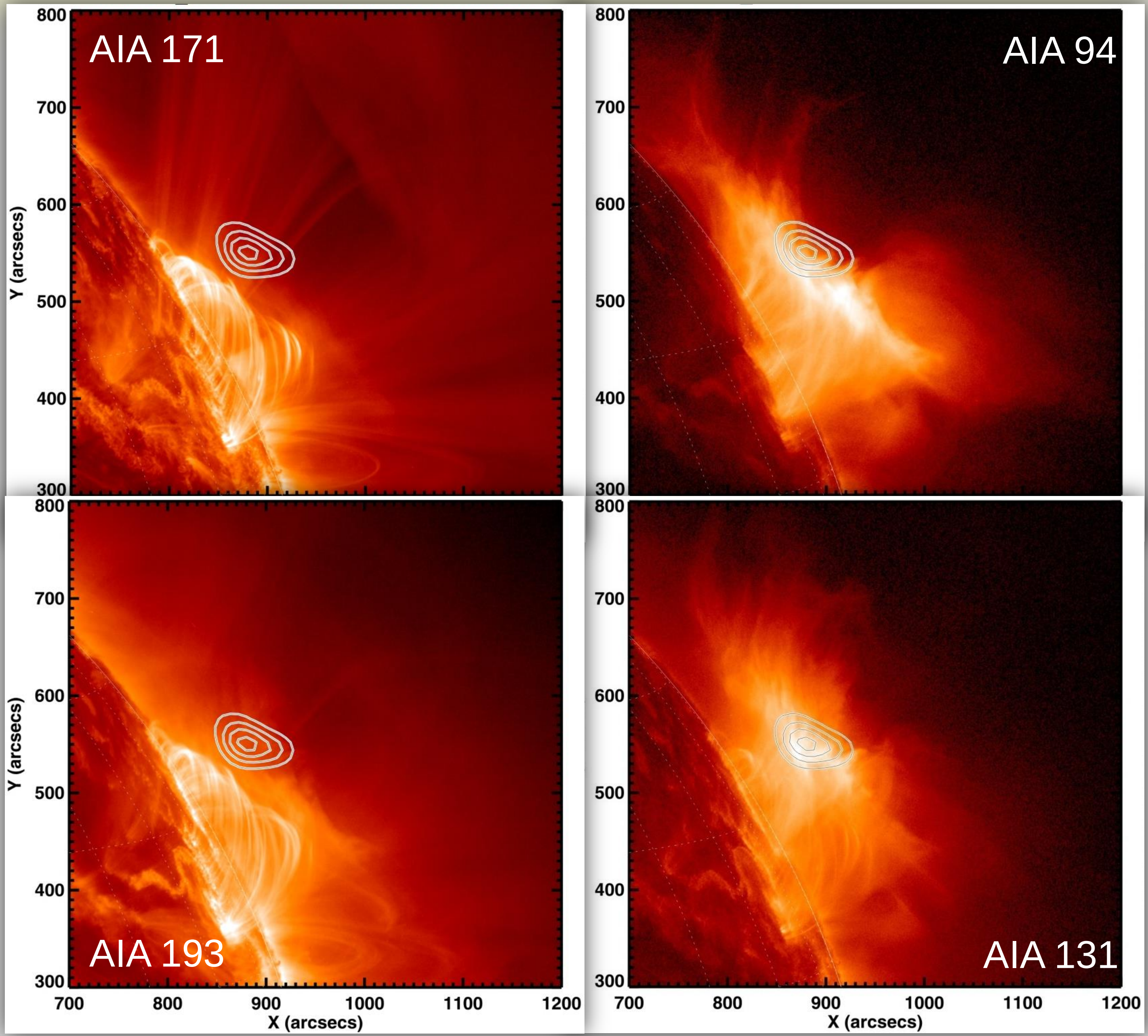


SDO/AIA + RHESSI

12:00 UT

SDO/AIA image + RHESSI contours 6-7 keV

LTS temp **T≈10 MK**

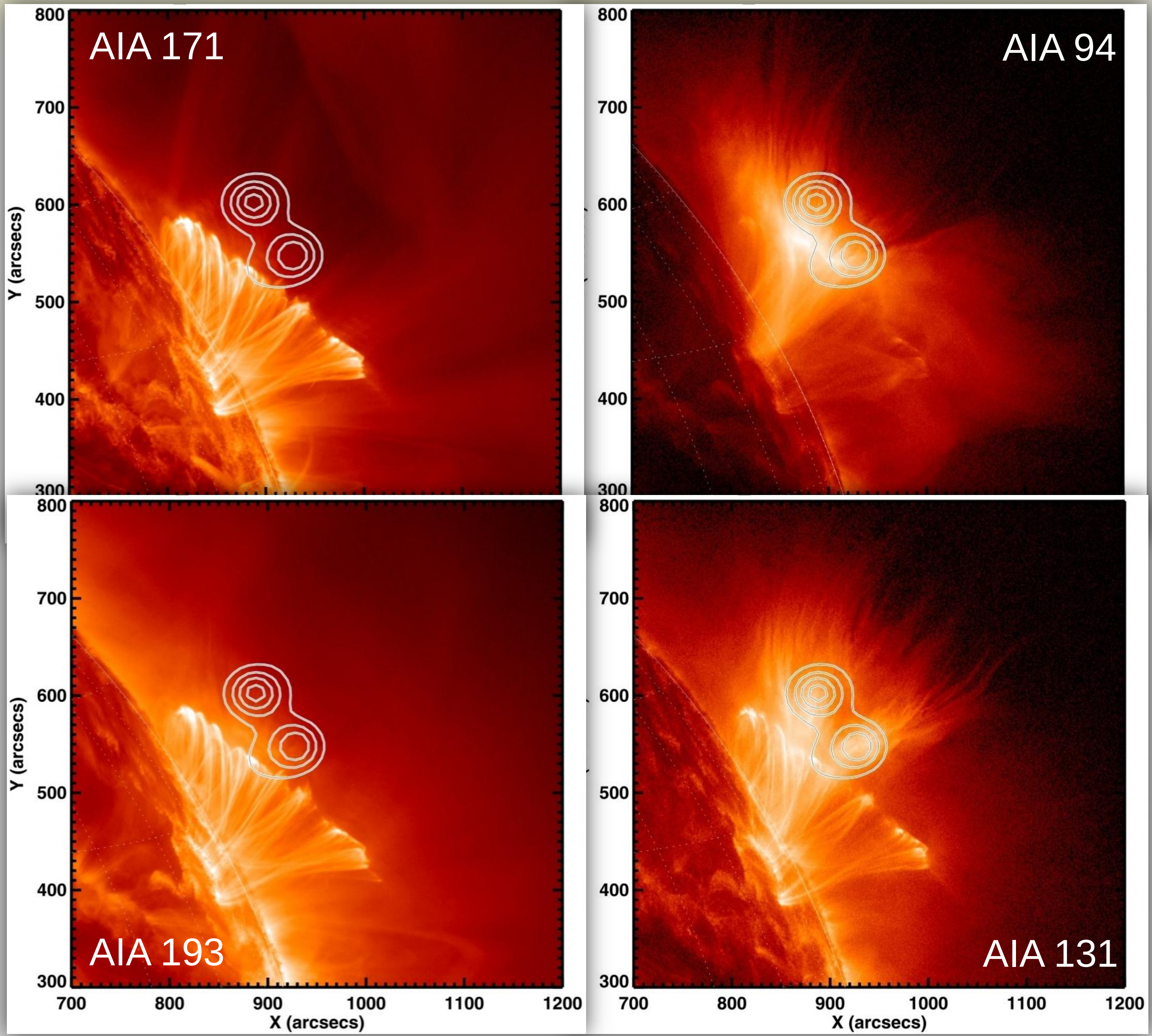


SDO/AIA + RHESSI

13:37 UT

SDO/AIA
image
+
RHESSI
contours
8-9 keV

LTS temp
T≈8.5 MK

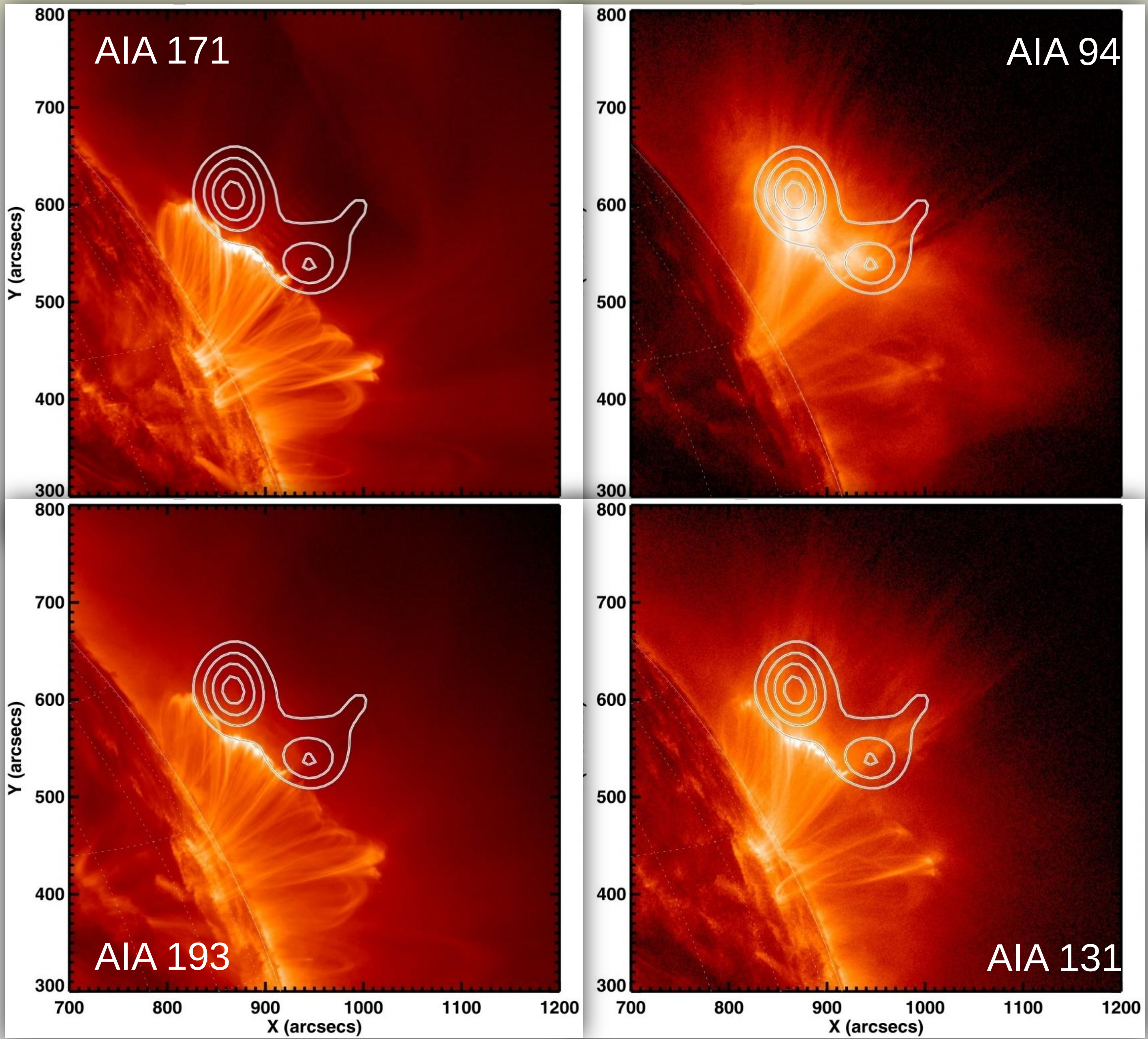


SDO/AIA + RHESSI

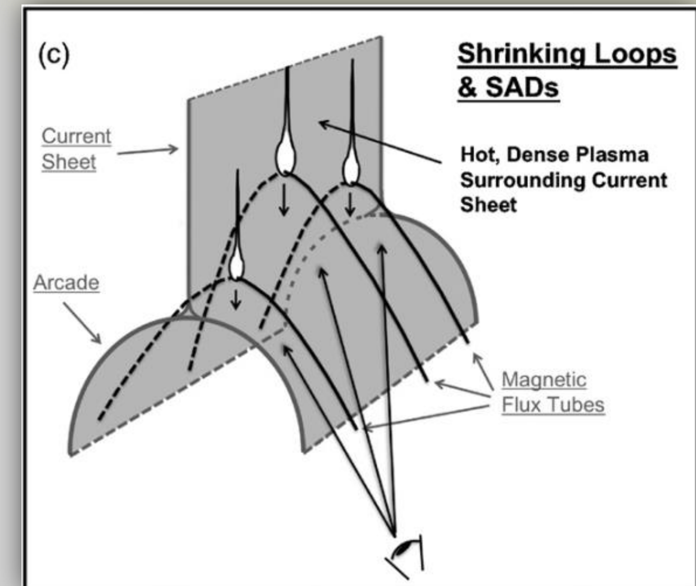
14:30 UT

SDO/AIA
image
+
RHESSI
contours
4-5 keV

LTS temp
T≈7.9 MK

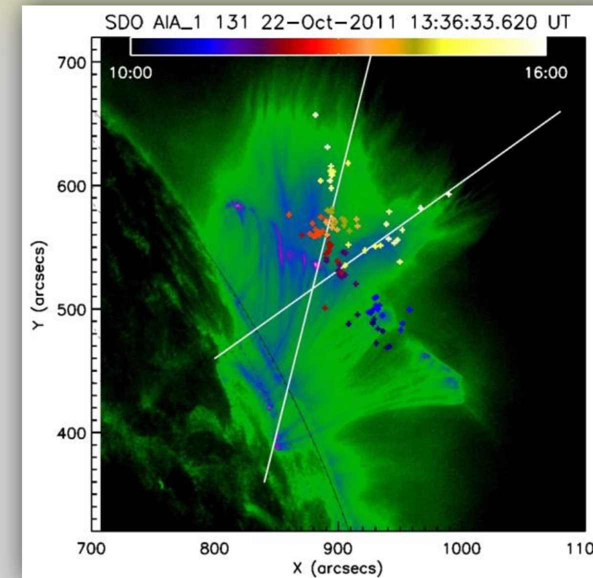


SADs deceleration region



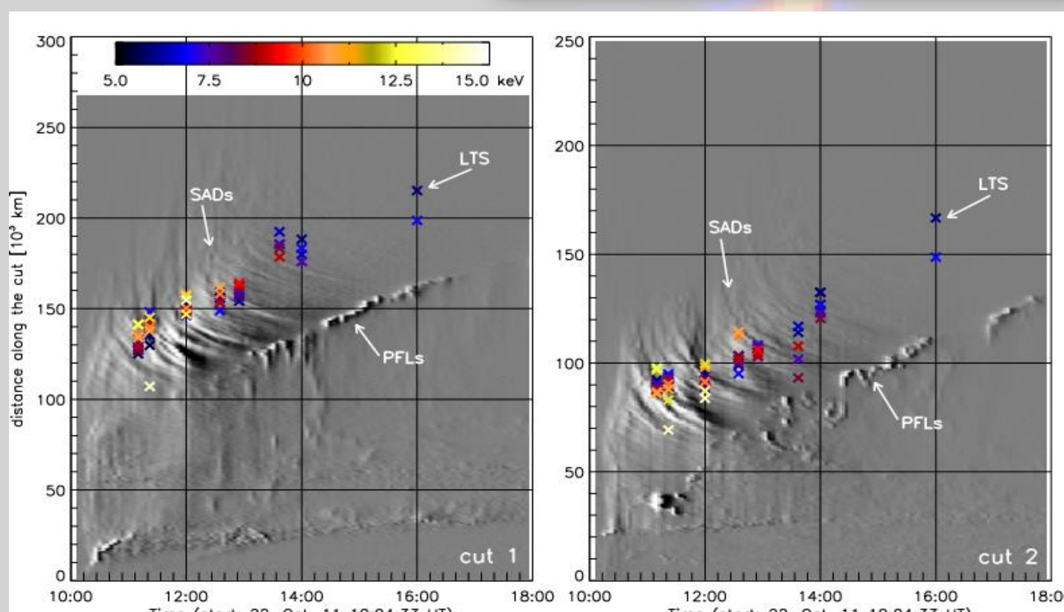
LTS was observed in the region of the SADs deceleration.

This region is turbulent with visible fine structure.



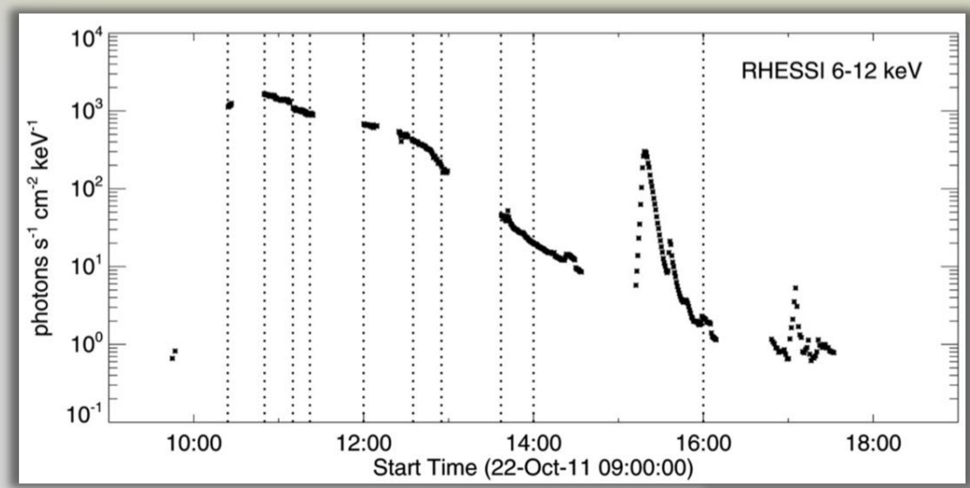
SADs (supra-arcade downflows) – dark structures above post-flare loops

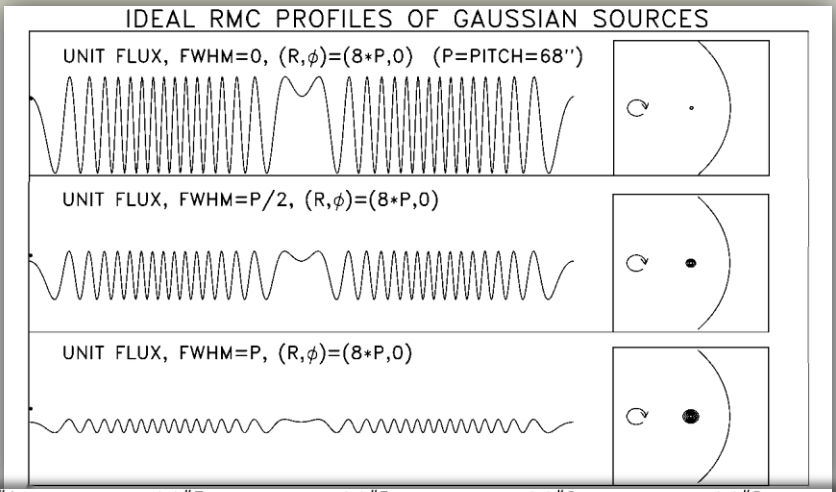
SAD is a plasma wake behind thin shrinking loop formed in hot plasma surounding current sheet (*Savage et al. 2012*)



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

Extremely weak RHESSI sources

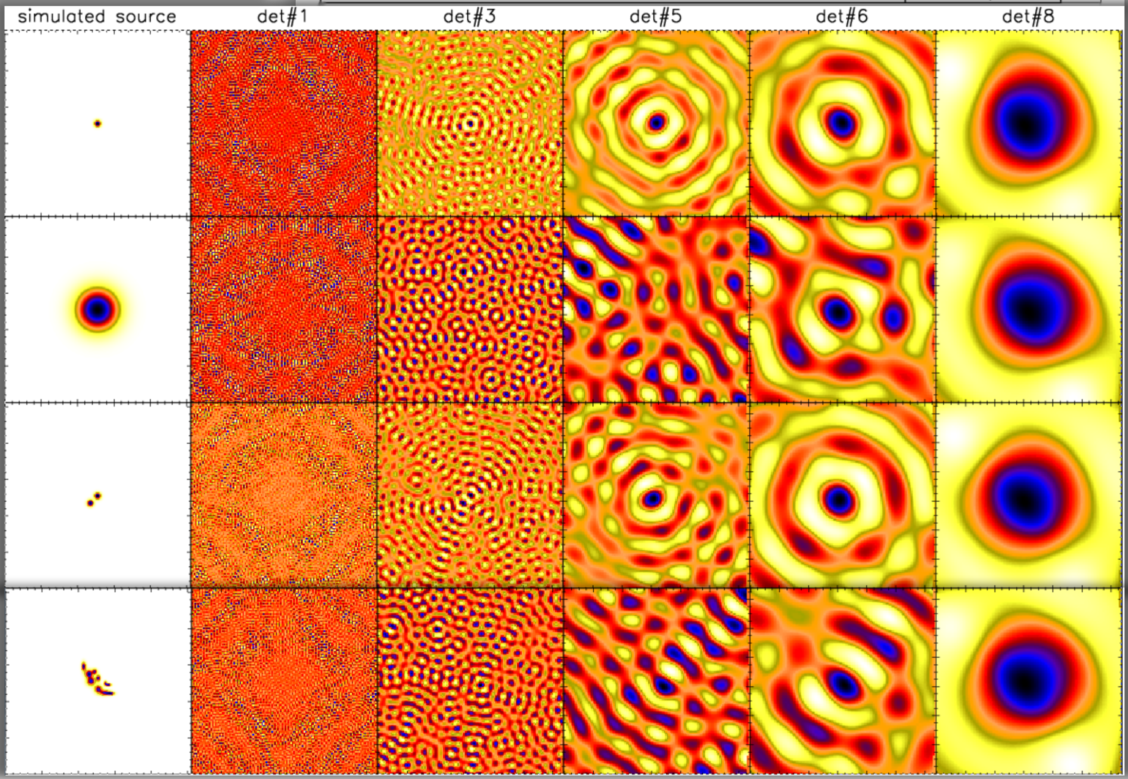




If source size is comparable to a resolution of a particular grid then detector records very weak or no modulation of signal.

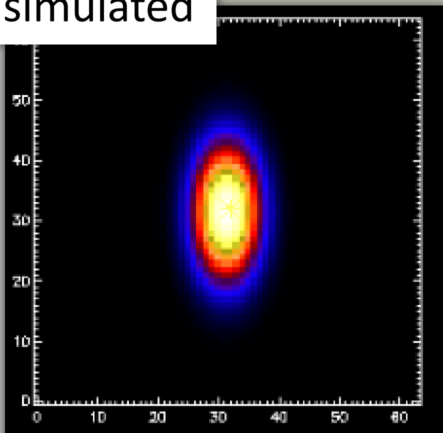
In our approach only grids with significant modulation are selected for image reconstruction.

We have to remember, however, that many small sources distributed on a small area may give similar modulation as one large source.



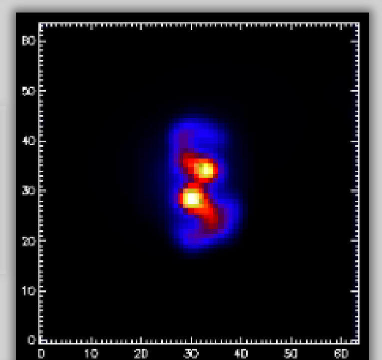
LTS internal structure - simulations

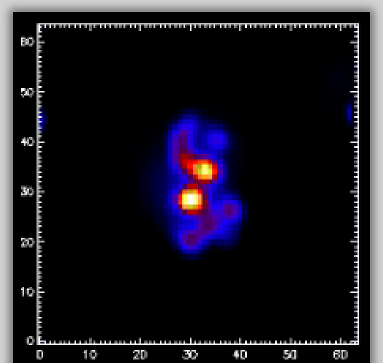
simulated

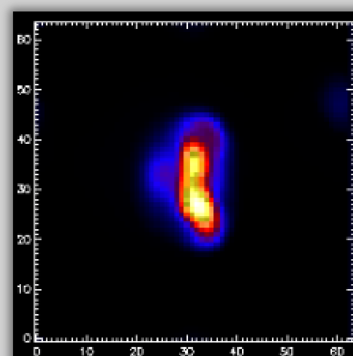


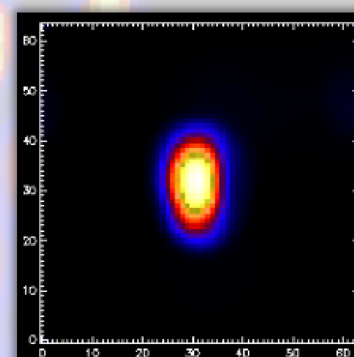
Grid#	1	2	3	4	5	6	7	8	9
FWHM	2.26	3.92	6.79	11.8	20.4	35.3	61.1	105.8	183.2

PIXON



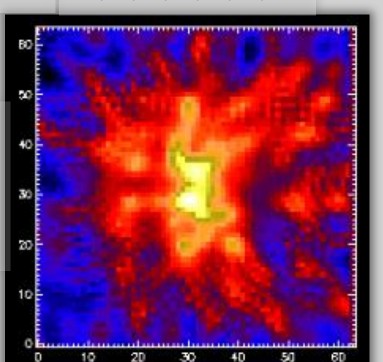


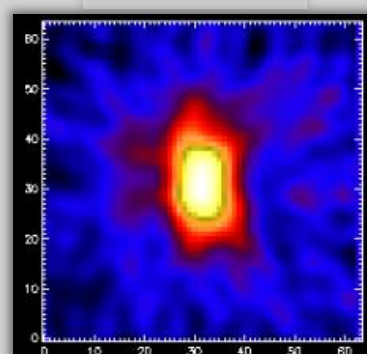


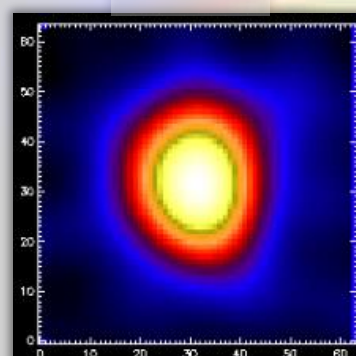


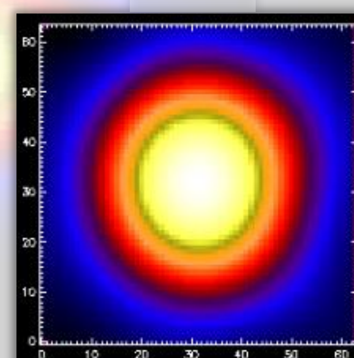
Grid: 1,3,4,5,6,8,9 | 3,4,5,6,8,9 | 5,6,8,9 | 6,8,9

CLEAN



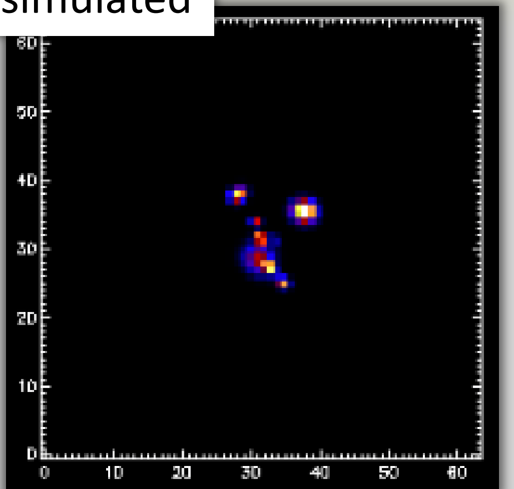




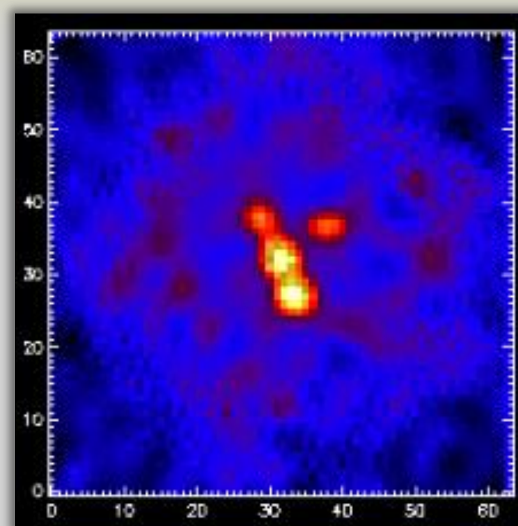


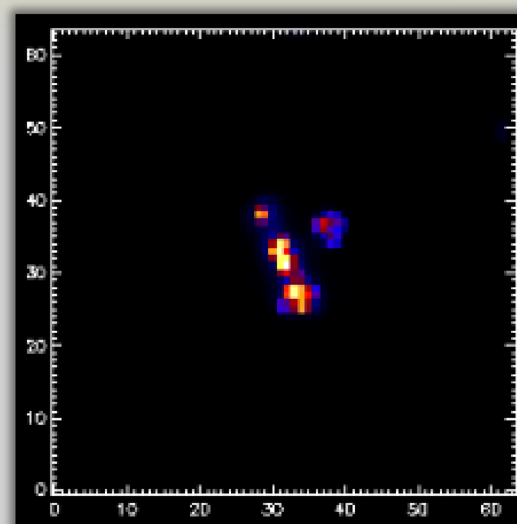
Loop Top Sources (LTS) - simulations

simulated



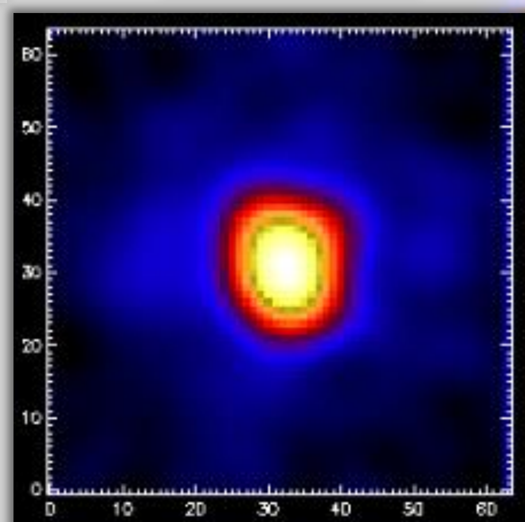
PIXON

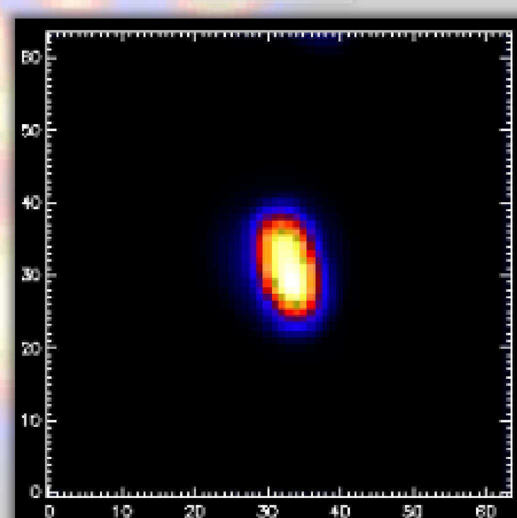




Grid: 1,3,4,5,6,8,9 5,6,8,9

CLEAN

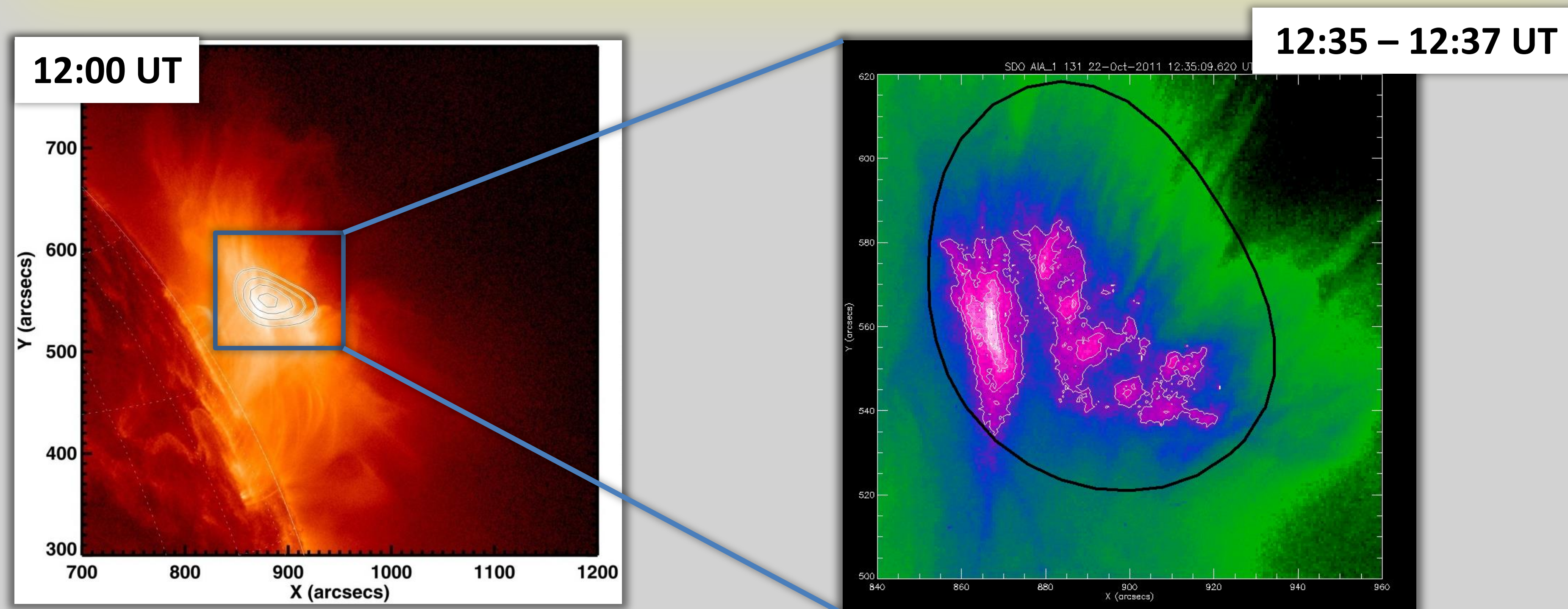


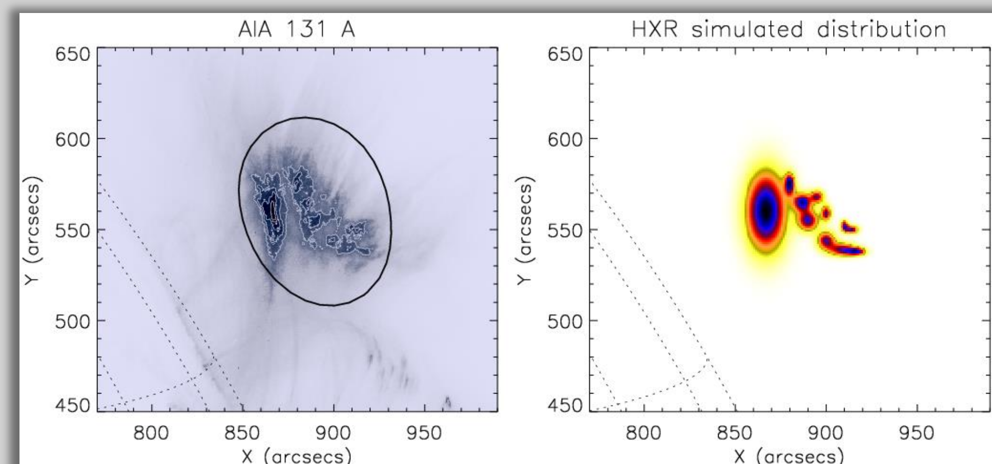


Set of ten small X-ray sources distributed randomly in eliptical area.

To coarse grids do not resolve small sources, but with fine grids sources are visible.

Loop Top Sources (LTS) - simulations

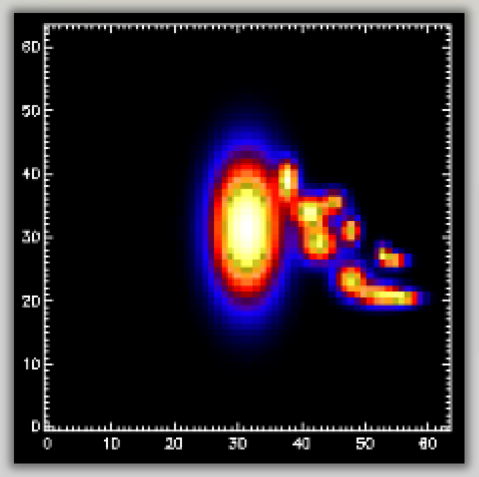




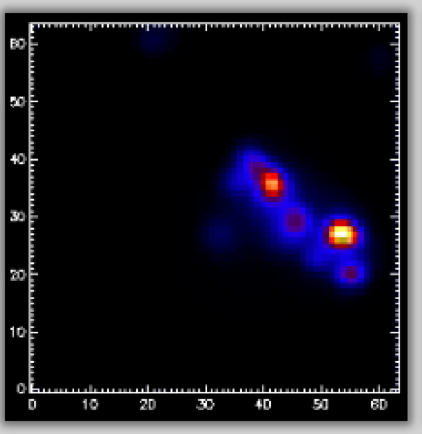
We built a distribution of X-Ray sources which are similar in shape, location, and relative brighness to EUV sources visible in AIA 131 Å images.

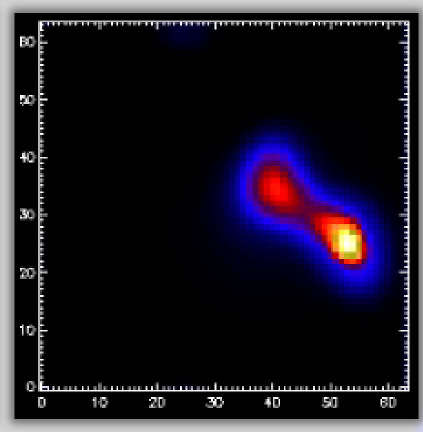
We used 2 min. integration time to reconstruct RHESSI image. During that time EUV sources did not change location, brightness, and size.

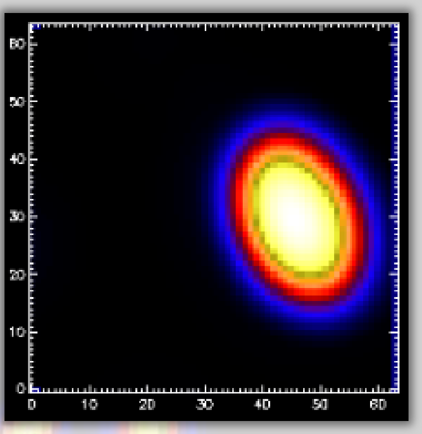
Loop Top Sources (LTS) - simulations



PIXON

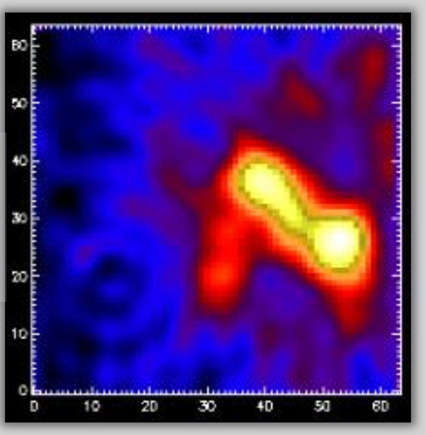


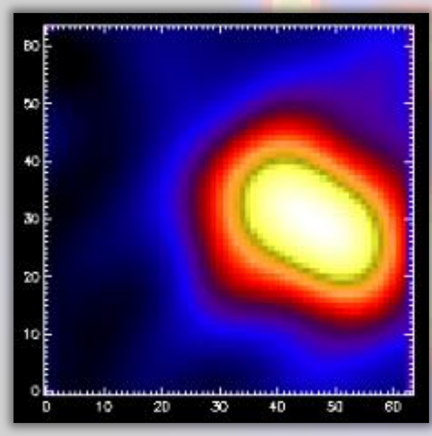


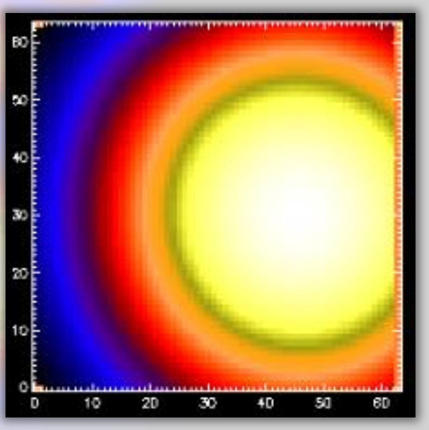


Grid: 3,4,5,6,8,9 | 5,6,8,9 | 8,9

CLEAN





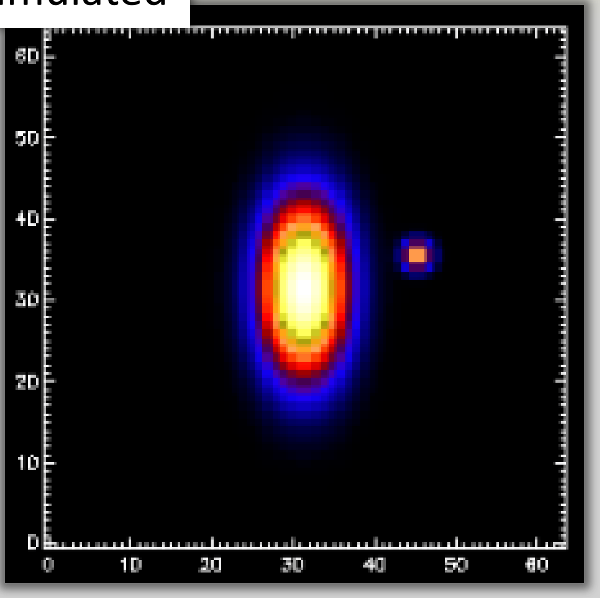


Small sources are not reconstructed in a proper way, but some structure is visible.

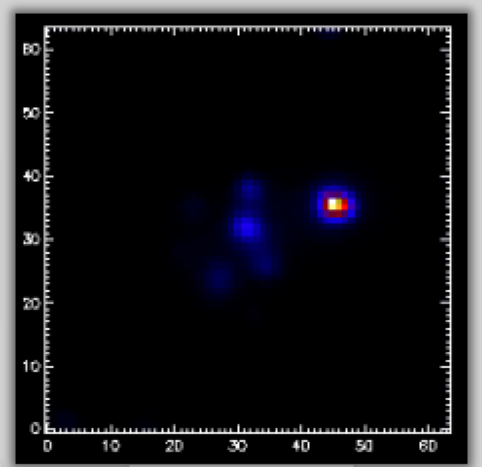
The largest source dissapeared. It is not visible in final image.

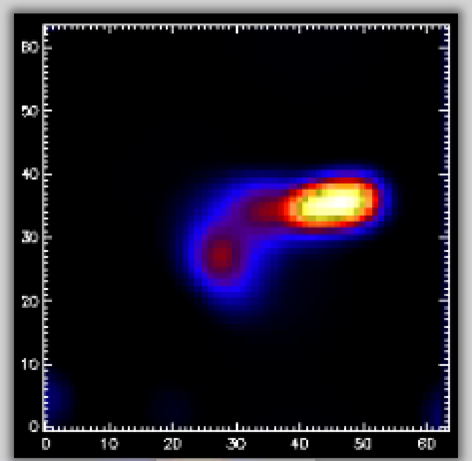
Loop Top Sources (LTS) - simulations

simulated



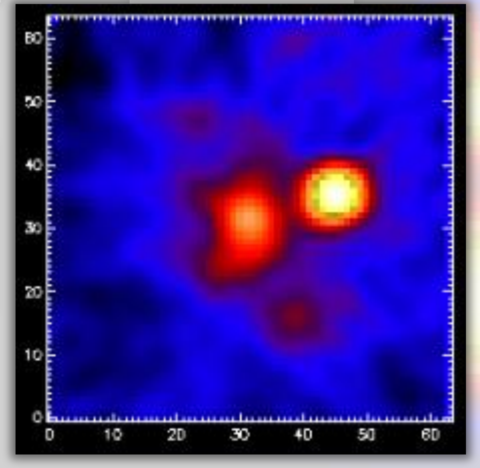
PIXON

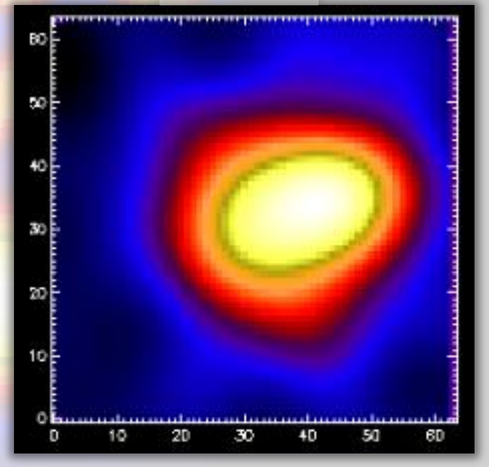




Grid: 3,4,5,6,8,9 5,6,8,9

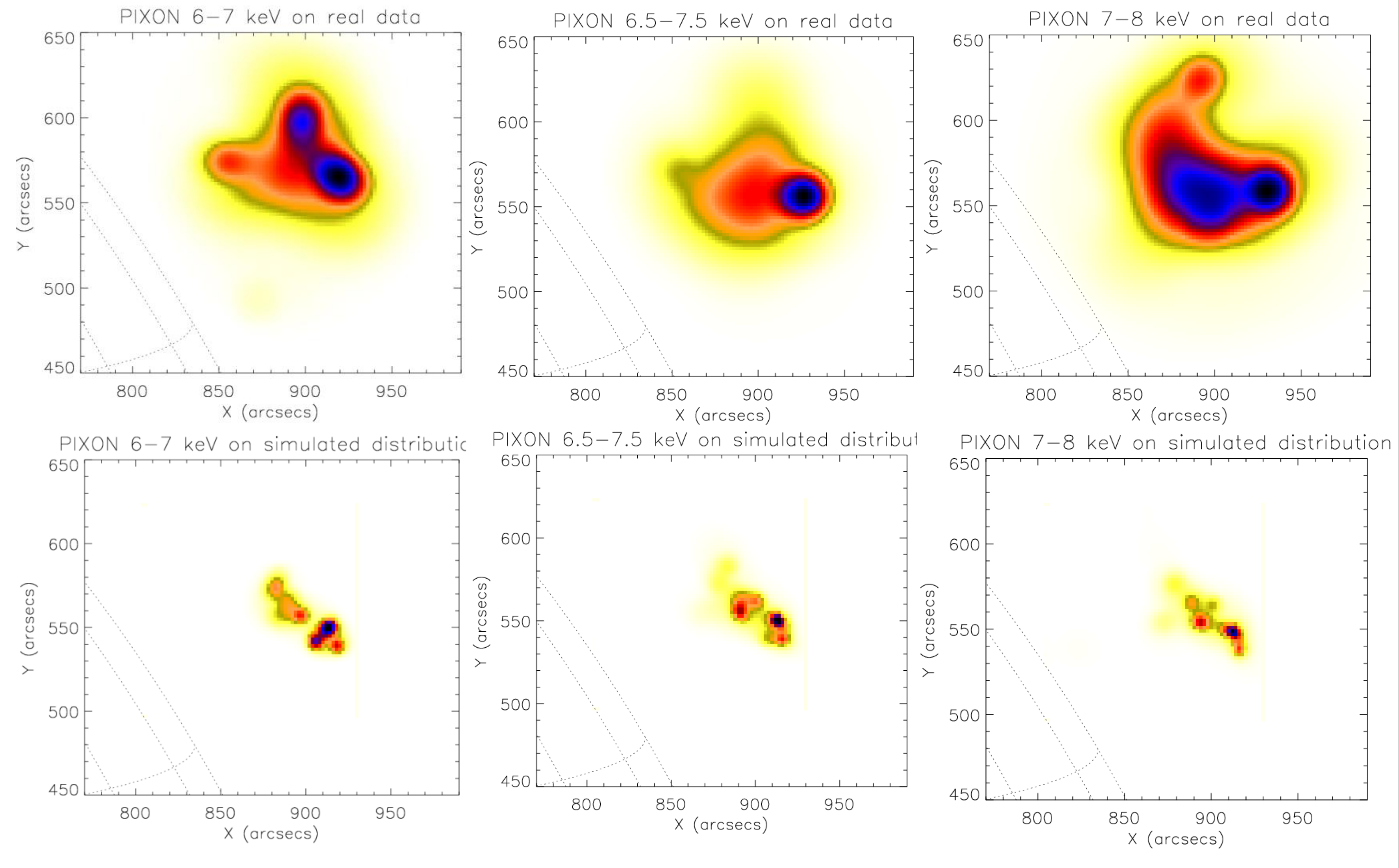
CLEAN





Even when configuration is very simple (1 small + 1 large), situation is the same: large source is not reconstructed or is barely visible despite the fact that in simulated distribution its peak value is 2 times higher than for small source.

Loop Top Sources (LTS) – simulations + observations



Overlapping intervals do not show repeatibility. Despite the same set of grids used for real data, reconstructed sources have significantly larger size than expected for set of tiny sources. Small-scale structures can not be decisively excluded, but they are less likely.

Summary

- Loop top sources (LTS) formed in the region of deceleration and accumulation of supra-arcade downflows (SAD). LTS was visible as long as SAD.
- Reconstructed images revealed one or two large HXR sources which are spatially correlated with diffuse EUV emission sources visible in AIA 131Å and 94 Å images.
- Reconstruction algorithm have signifant problems when sources differ in size significantly (more than order of magnitude). Large source is not reconstructed when small ones are present. It may have consequences in our understanding of coronal HXR sources.
- Small-scale structure of LTS can not be decisively excluded, but they are less likely.