What can we see with Solar-B XRT?

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   how closely the spectral response of X-ray/EUV telescopes are related to their temperature responses

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3. What can we see with XRT?

   Uniqueness of the XRT in the spectral and temperature response

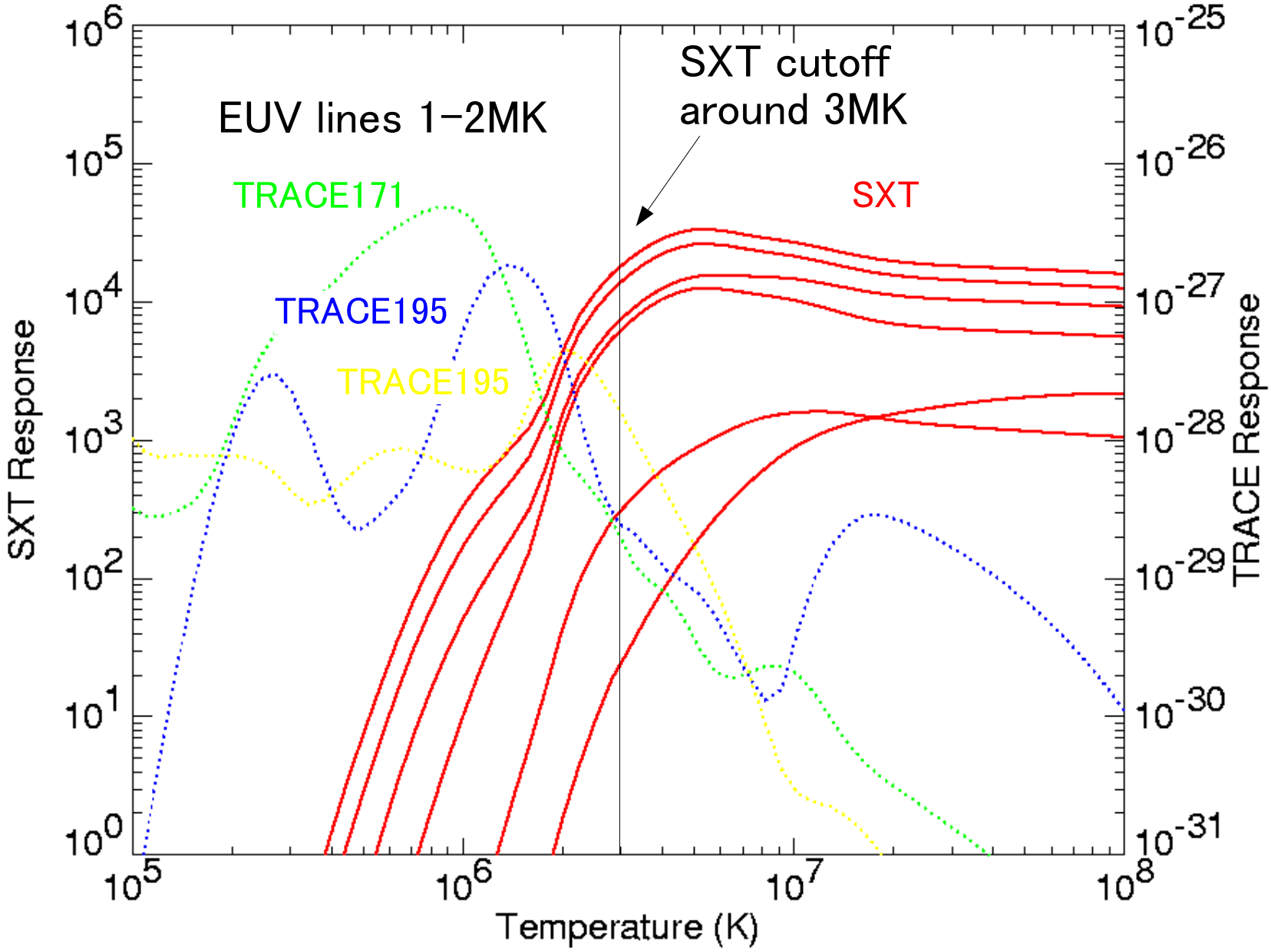
4. Summary

Spectral response and Temperature response

- A property of X-ray/EUV observation: the difference in spectral response of telescopes corresponds to difference in their temperature responses
  - Yohkoh SXT has high sensitivity in soft x-ray region (1-50A), thus high sensitivity to hot plasma (T>3MK)
  - EIT/TRACE observes the specific emission lines in EUV region and thus has sensitivity to rather cool plasma (1-2MK)

The whole temperature range of the corona (T>1MK) can be observed by combining Soft X-ray and EUV observations

Temperature response of SXT and TRACE

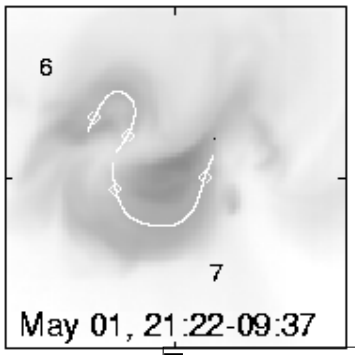


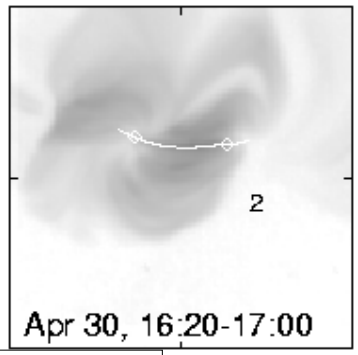
4-F

Hot (SXT) and Cool (EUV) coronal loops

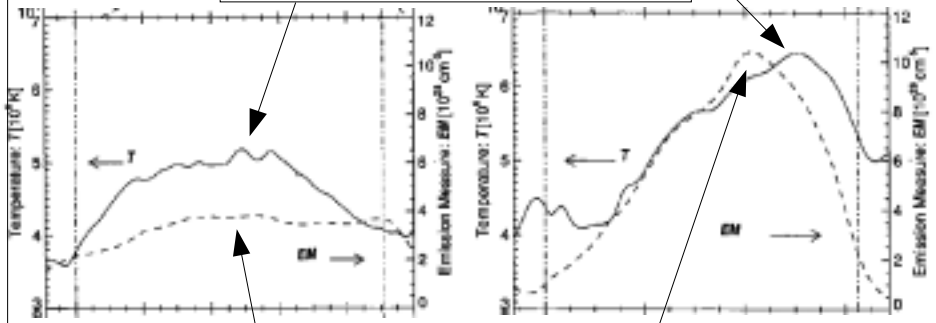
- Properties of coronal loops observed with SXT and EUV telescopes
- The relationship between hot and cool coronal loops

Kano & Tsuneta (1995,1996)

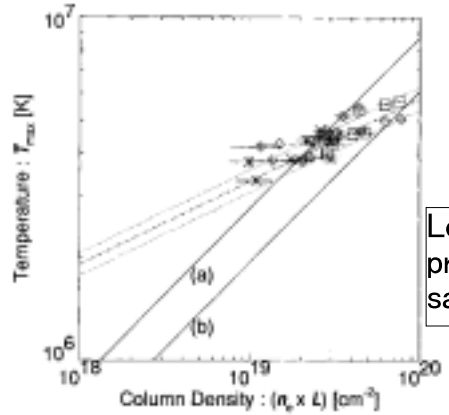




Temperature increases from the footpoint to the loop top



Emission measure increases from the footpoint to the loop top

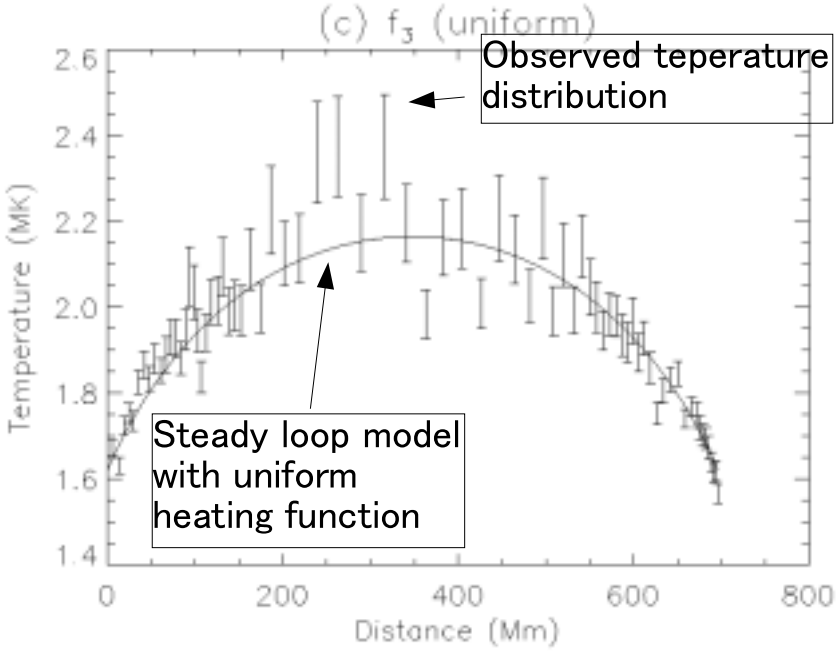


$T_{max} \propto (pL)^{1/3}$

Loop top temperature, pressure and loop length satisfy the scaling law

Priest et al. (2000)

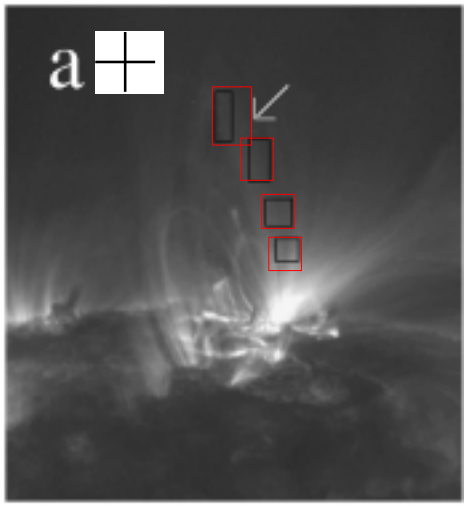
Temperature



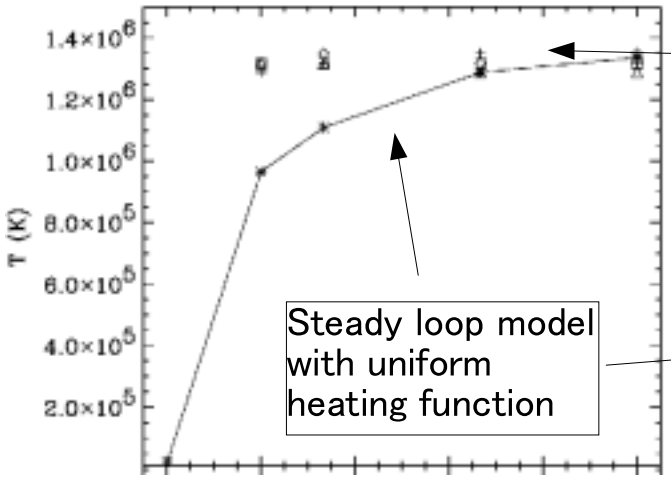
Characteristics of Hot loops

- Significant temperature gradient along the loop
- Emissiom measure increases from the footpoint to the loop top
- Temperature distribution can be explained by uniform or loop top heating function

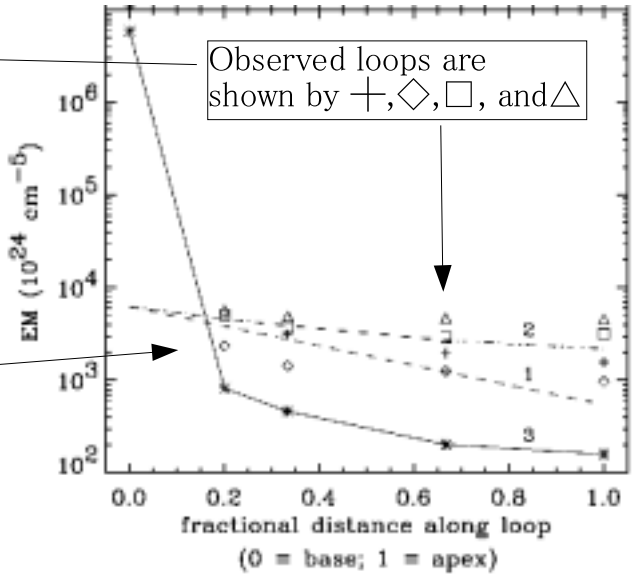
Lenz et al. 1999



Temperature

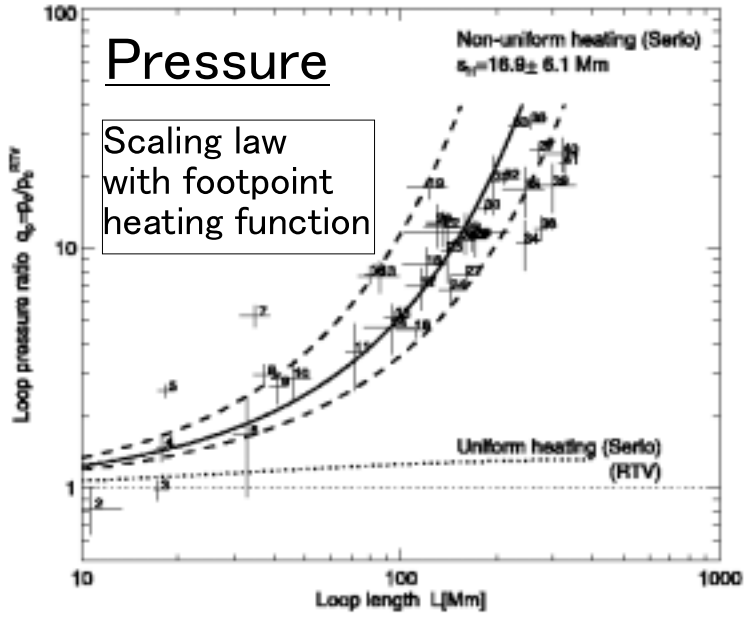


Emission Measure



Aschwanden et al. 1999

Pressure



Cool Loop Characteristics

- Nearly iso-thermal structure along the loop (flatter than scaling law prediction with uniform heating function)
- Emission measure decreases from the foot point to the loop top (overdense as compared with scaling law prediction)
- Foot point heating function can explain the observed loop structure?

Contrast between hot and cool loops

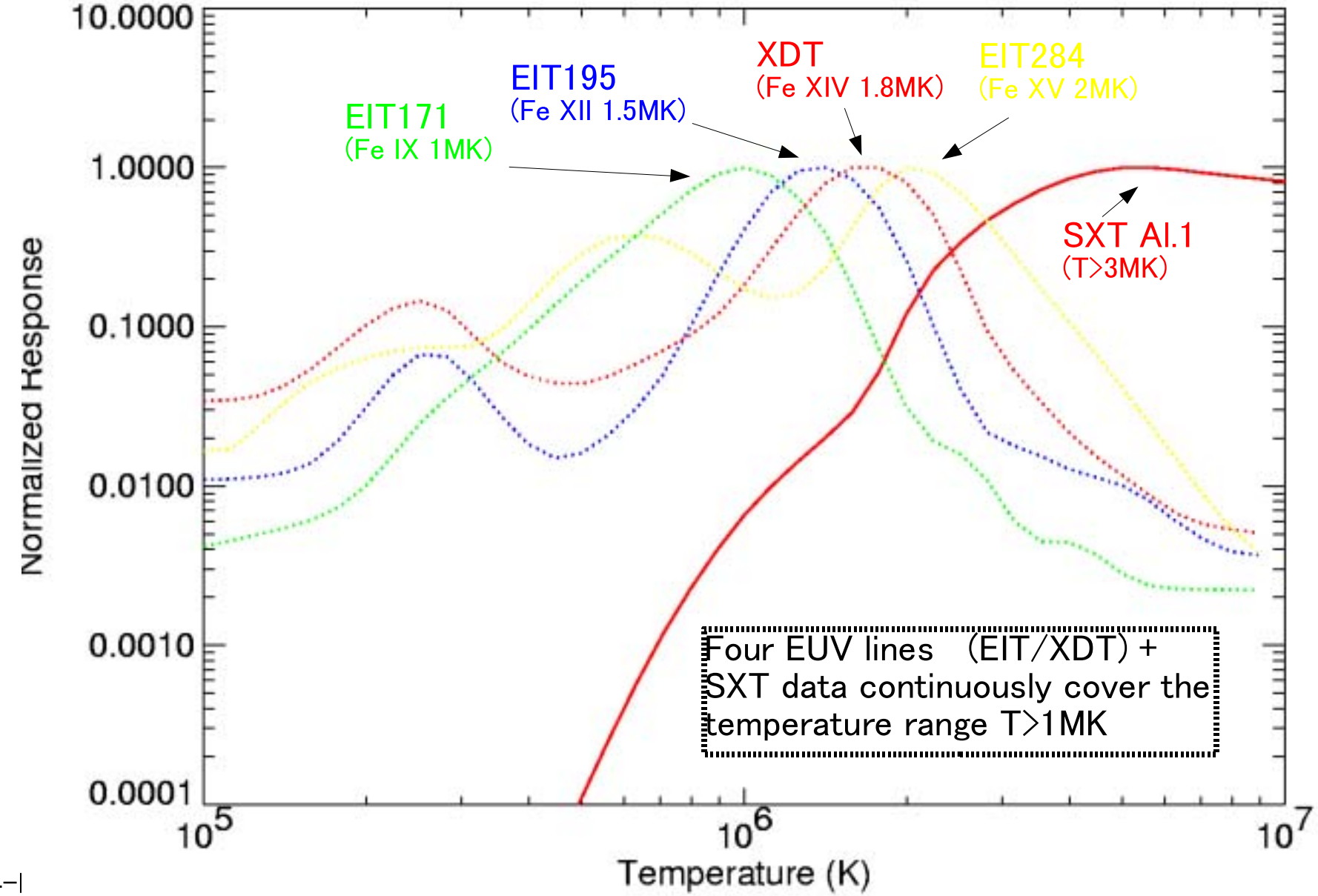
Parameter	Hot loop	Cool Loop
Temperature	Significant temperature variation along the loop	Nearly iso-thermal structure along the loop
Emission Measure	Increases from the foot point to the loop top (inverted with respect to the hydrostatic equilibrium)	Decreases from the foot point to the loop top (consistent with the hydrostatic equilibrium)
Heating Function	Uniform or Loop top	Foot point

It is noted that these studies were done separately by using SXT and EUV telescopes

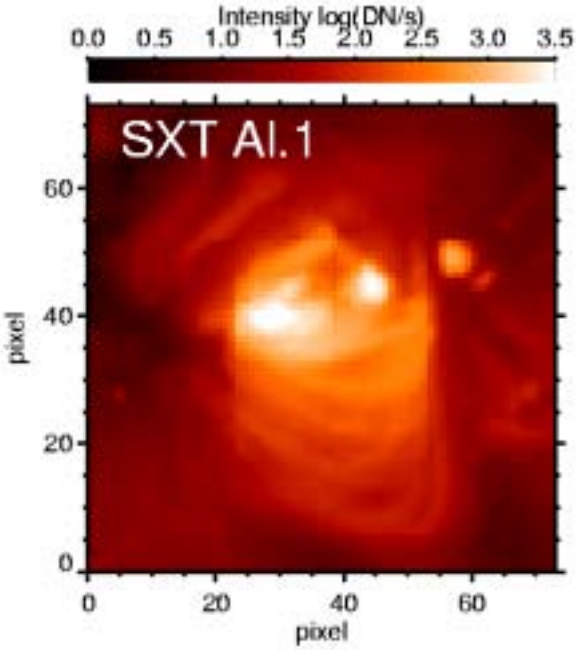
What is the relationship between hot and cool coronal loops?

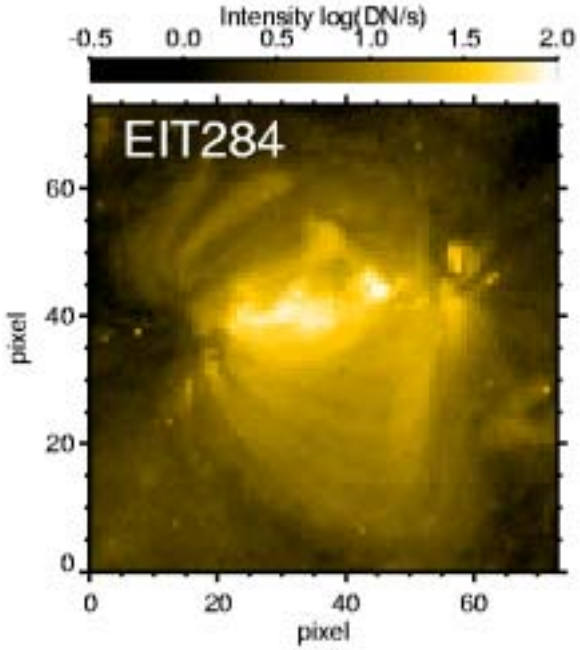
XUV Doppler Telescope Observation

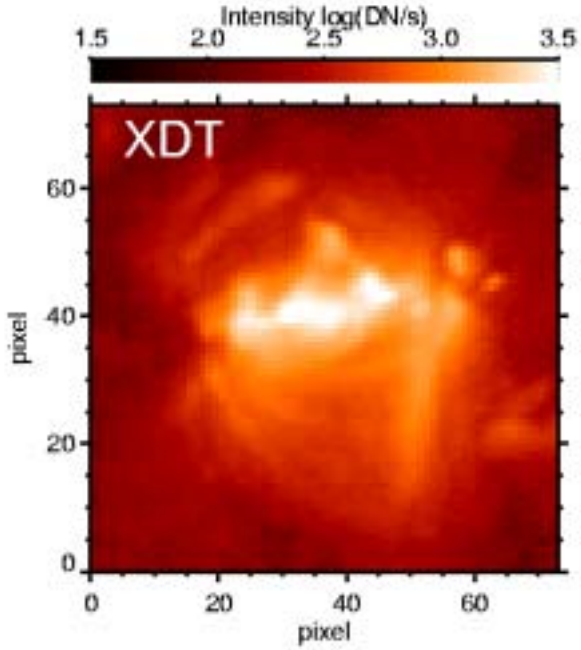
ISAS sounding rocket experiment 31-Jan-1998

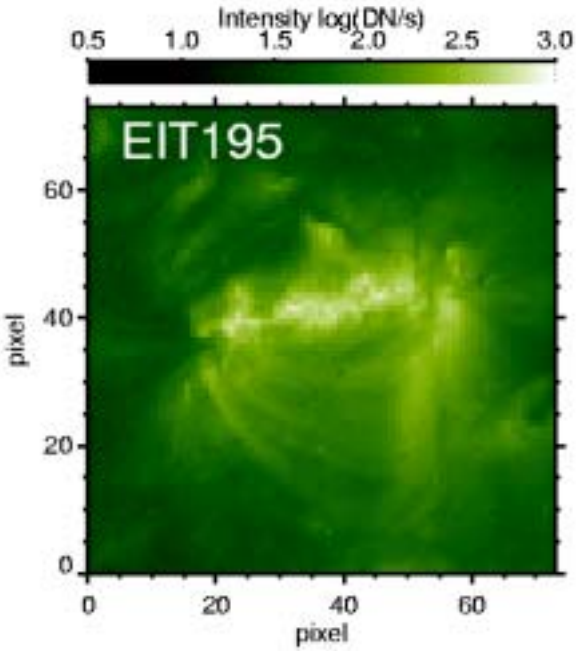


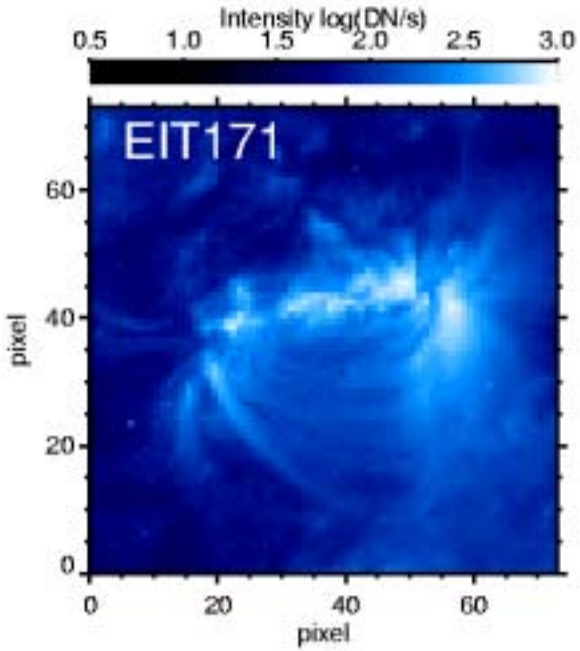
Spatial distribution of loops in various temperatures: NOAA8143





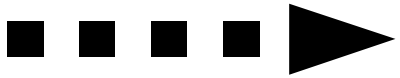




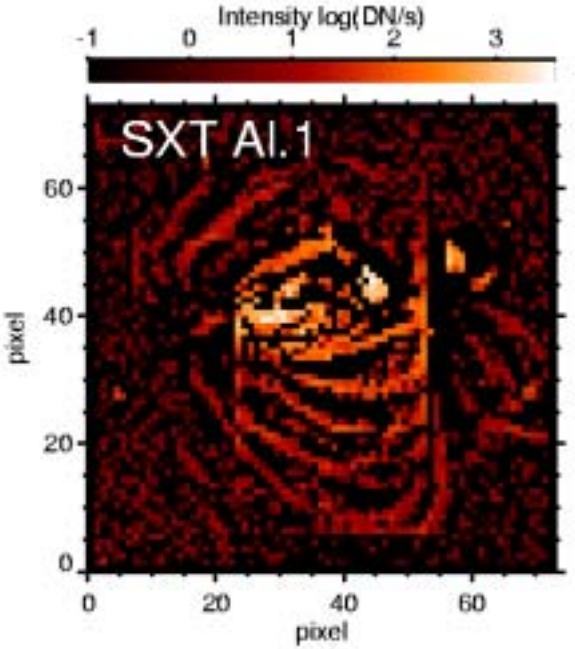


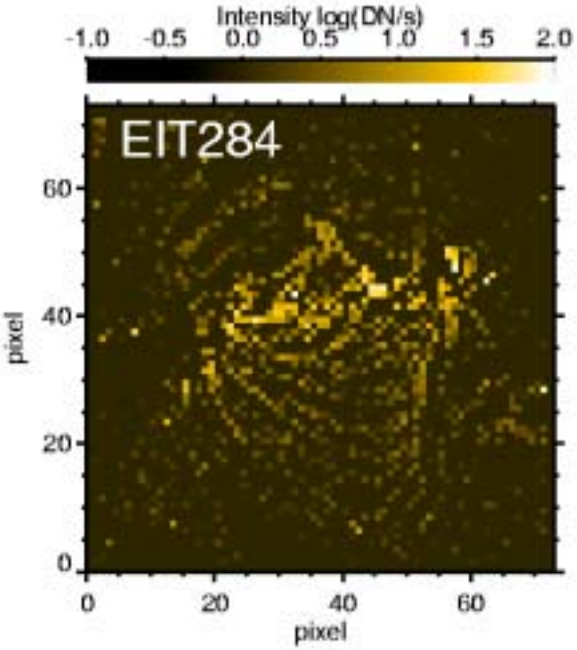
Determination of loop position

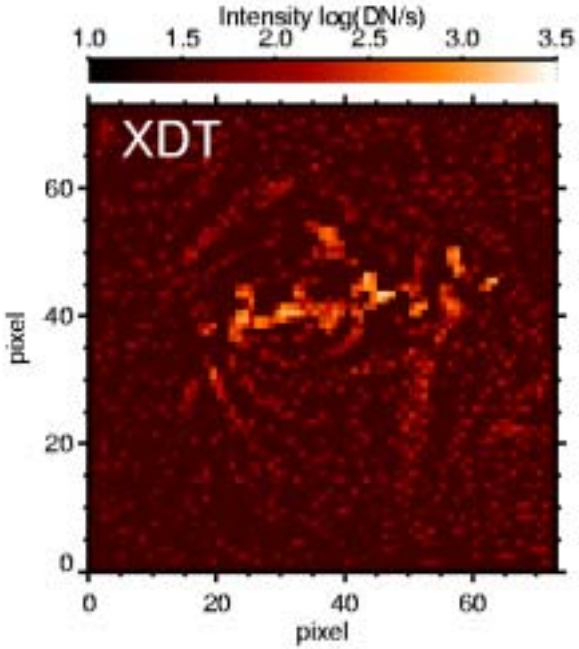
In order to see the location of loops embedded in fuzzy background, images are processed with Laplacian filter

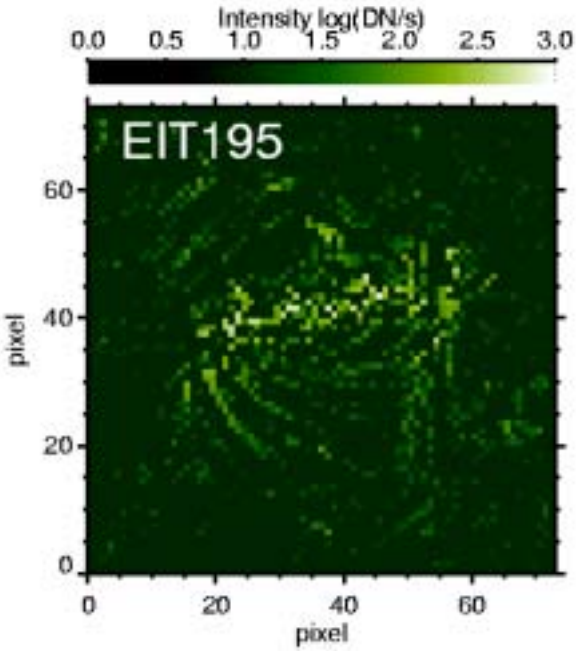


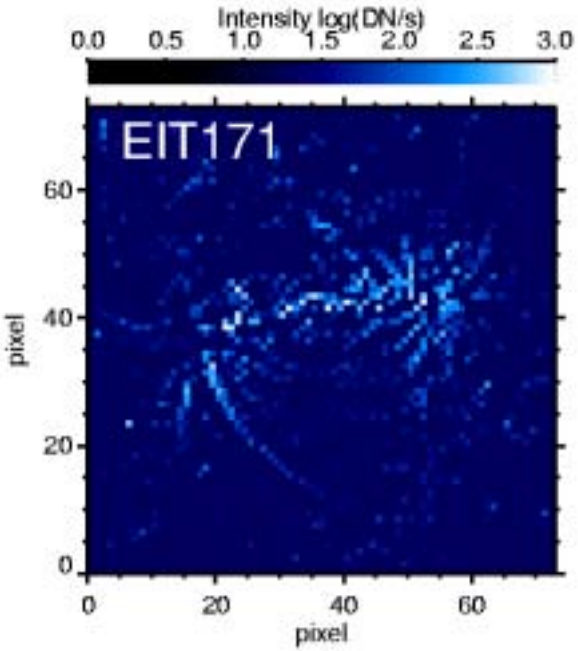
Laplacian-filtered images





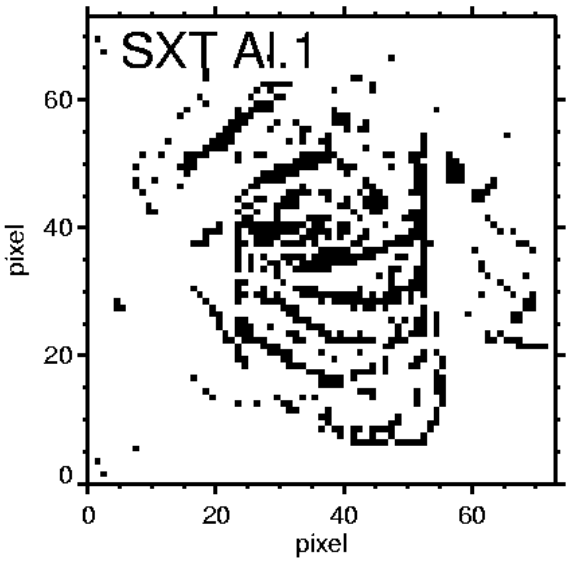


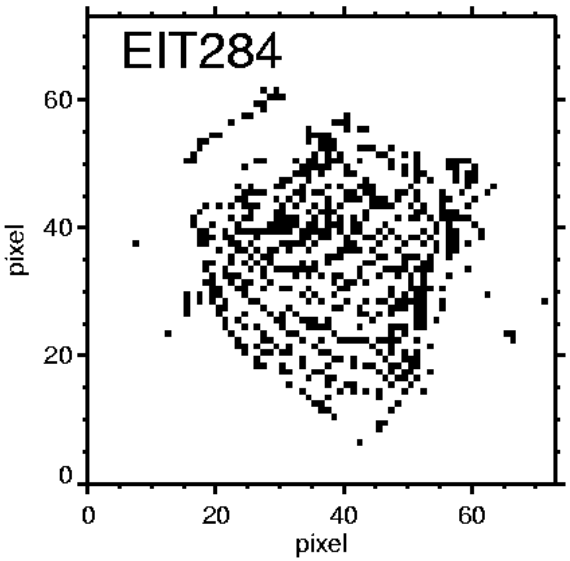


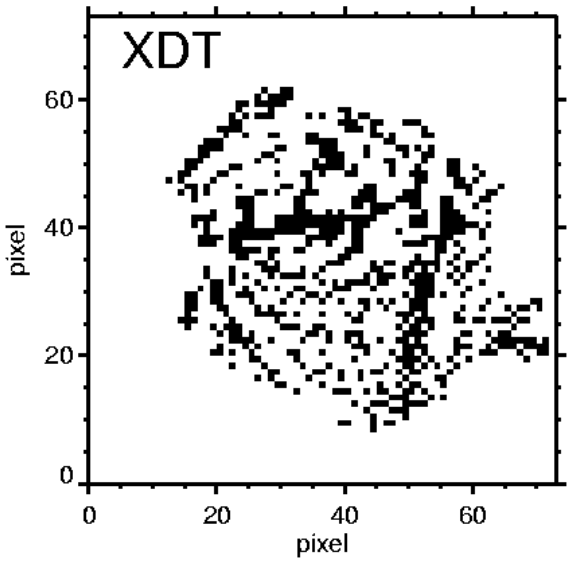


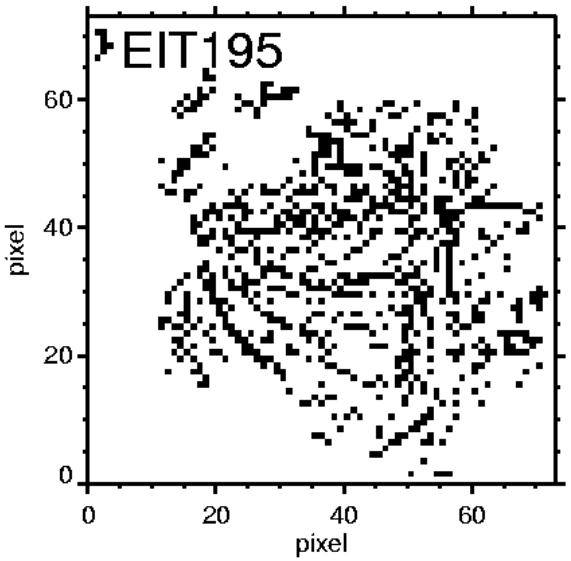
Ridge has negative large value, and valley shows positive large value in the Laplacian-filtered image. Loop position can be extracted by setting threshold on the filtered images.

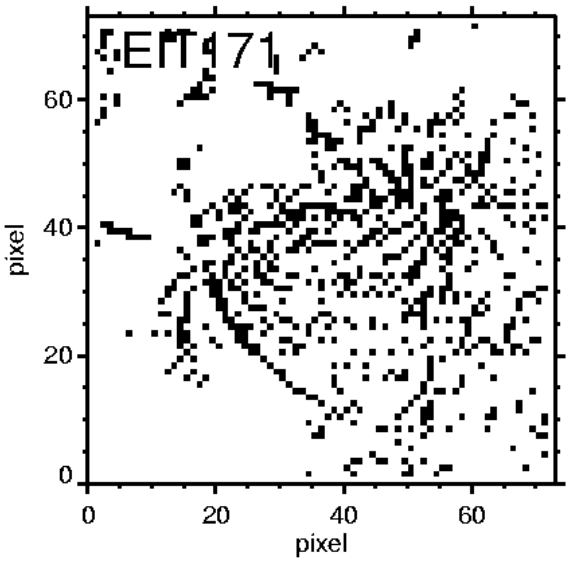
Loop distribution map



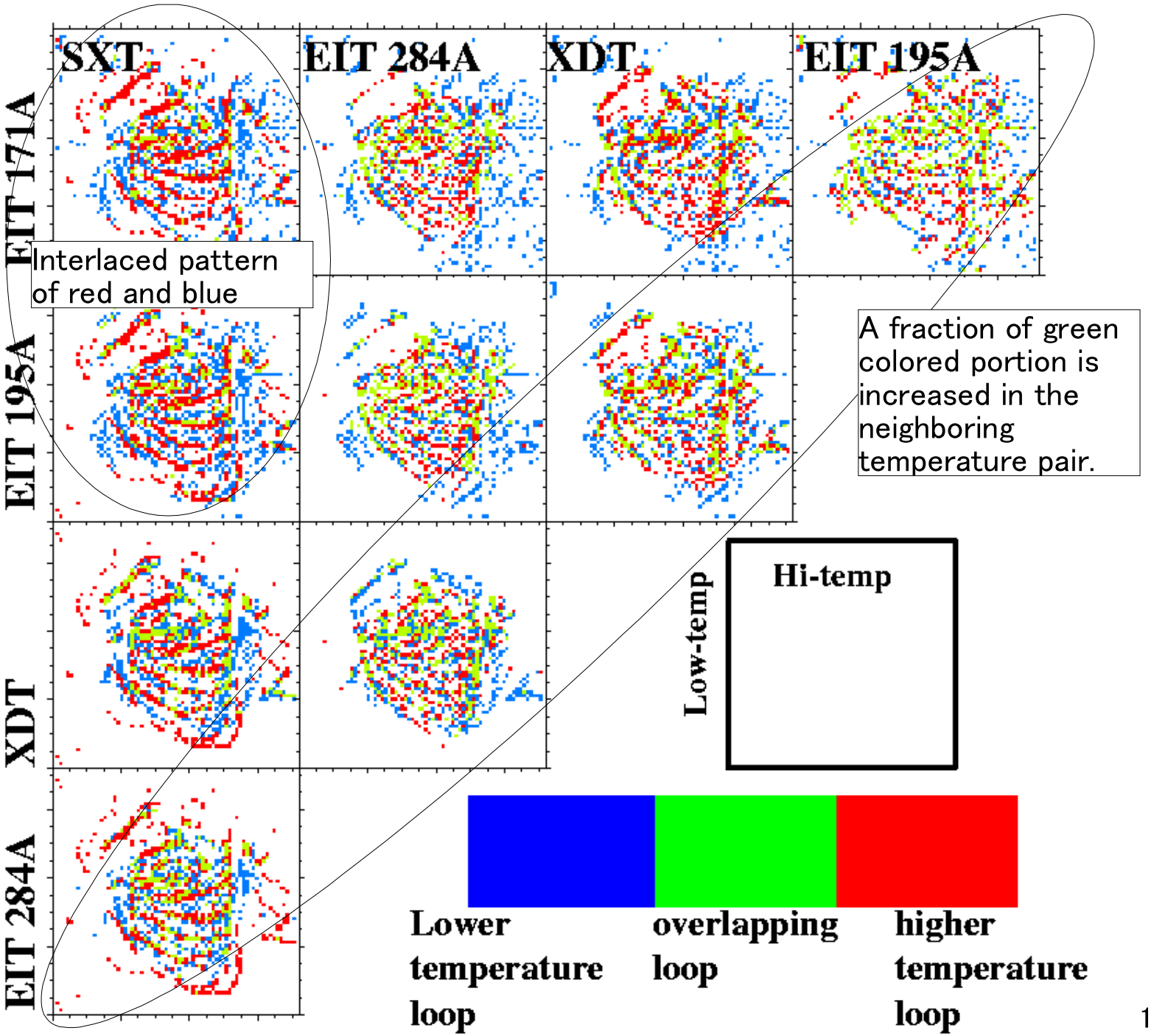






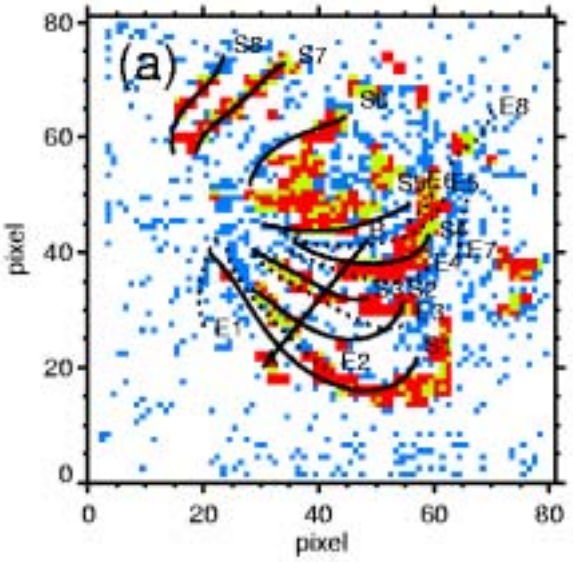


What is the spacial relationship among the loops?
Overlay of the loop distribution map

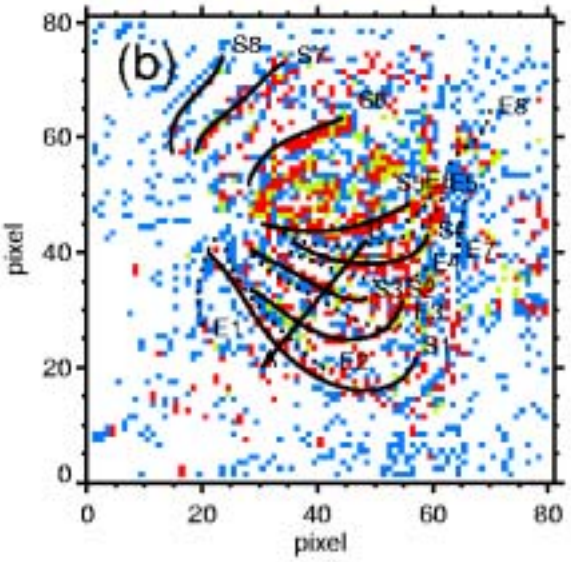

SXT
EIT 284A
XDT
EIT 195A
EIT 171A
EIT 195A
XDT
EIT 284A
Interlaced pattern of red and blue
A fraction of green colored portion is increased in the neighboring temperature pair.
Hi-temp
Low-temp
Lower temperature loop
overlapping loop
higher temperature loop

Time evolution (overlay of SXT and EIT195 loop):

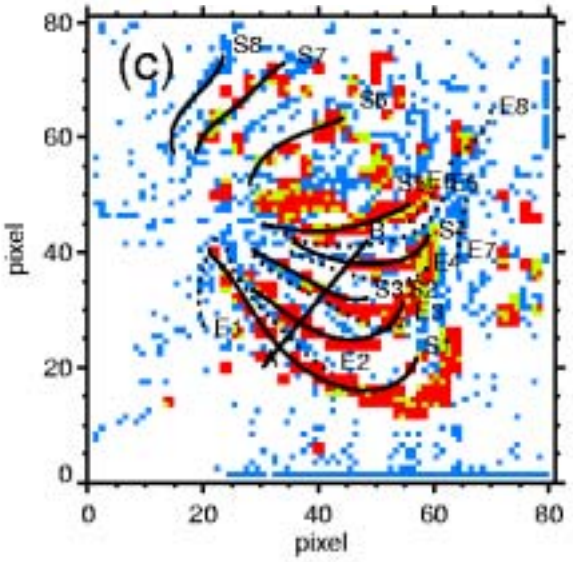
03:18:53/03:19:24



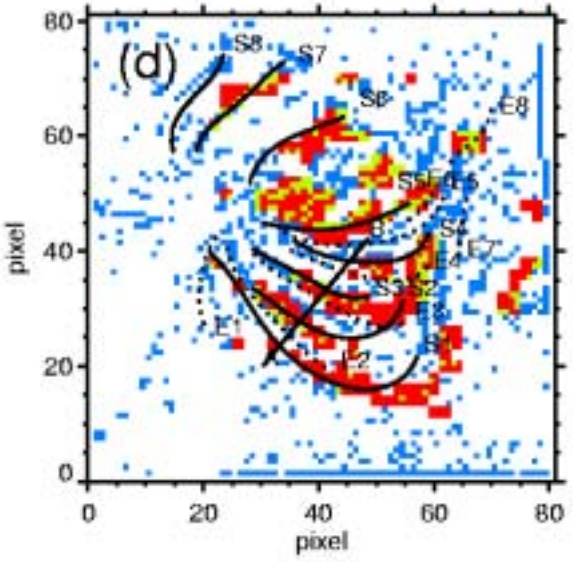
04:44:43/04:39:05



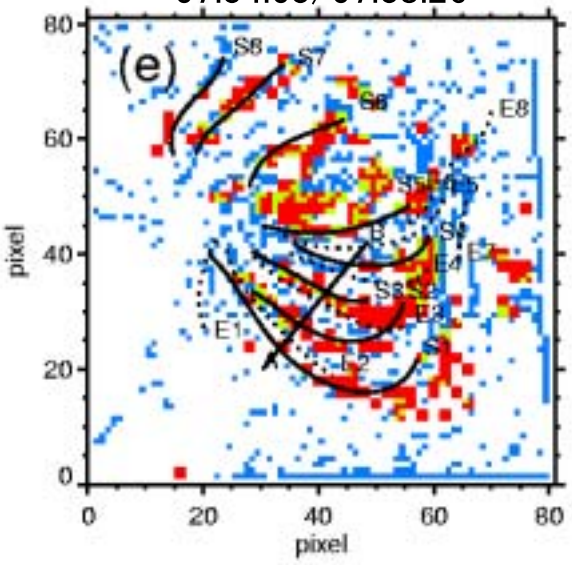
06:02:19/06:08:24



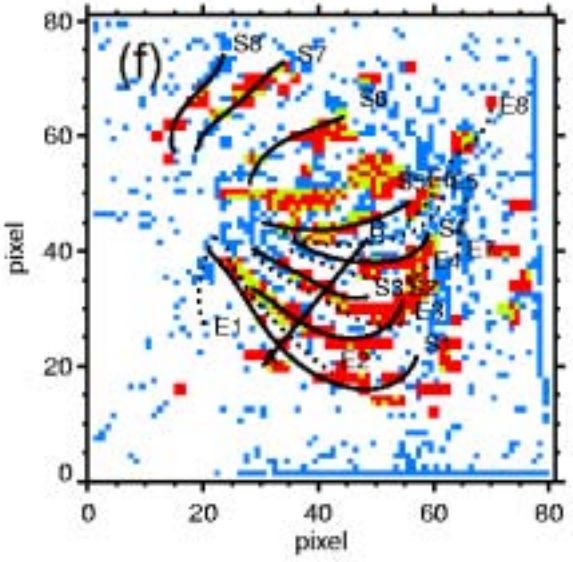
06:36:27/06:39:54

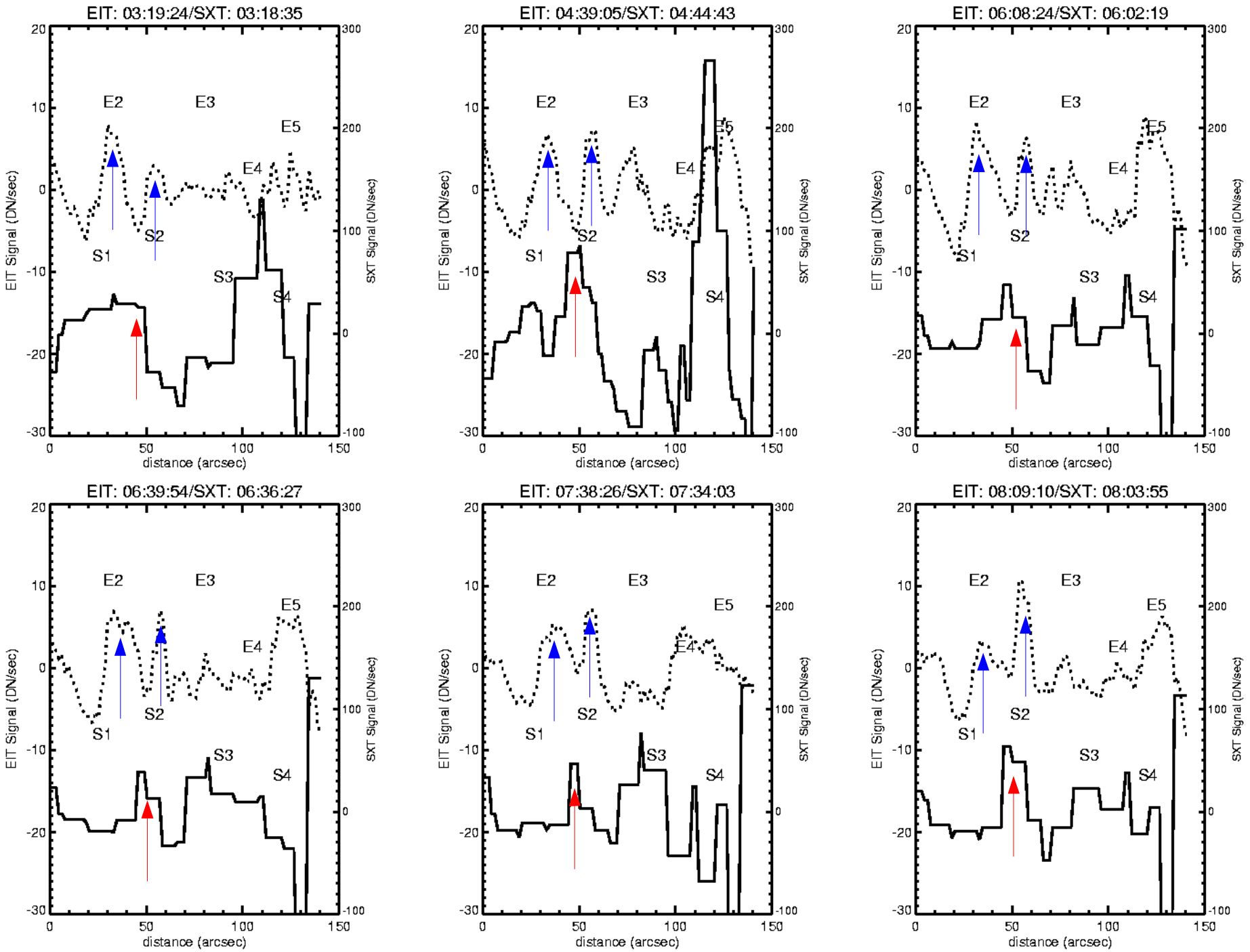


07:34:03/07:38:26



08:03:55/08:09:10




EIT: 03:19:24/SXT: 03:18:35
EIT: 04:39:05/SXT: 04:44:43
EIT: 06:08:24/SXT: 06:02:19
EIT: 06:39:54/SXT: 06:36:27
EIT: 07:38:26/SXT: 07:34:03
EIT: 08:09:10/SXT: 08:03:55
E2
E3
E4
E5
S1
S2
S3
S4
EIT Signal (DN/sec)
SXT Signal (DN/sec)
distance (arcsec)

Loop cooling time scale

Observed loop evolution can be estimated with the cooling time scales,

Conduction cooling time scale: $\tau_c = 3k_B n L^2 / \kappa_0 T^{5/2}$

Radiation cooling time scale: $\tau_r = 3k_B T^{1-\alpha} / n \chi$

L～10^{10} cm N～10^9 cm^{-3} T～1–3 MK

$\tau_c \sim \tau_r = 1 - 2\ hour \quad < \quad \tau_{obs} \sim 5\ hour$

Continuous heating is required for both the hot and cool loops to be sustained for duration observed

What we have learned

- Spatial and temporal properties:
  - Interlaced pattern of hot and cool loops
  - Conserved longer than cooling time scale
- Structure along the loop:
  - Sharp contrast on temperature and emission measure distribution of hot and cool loops
- Multi-temperature structure (differential emission measure) in a loop [See also Schmelz et al. (2001)]

What causes the difference?

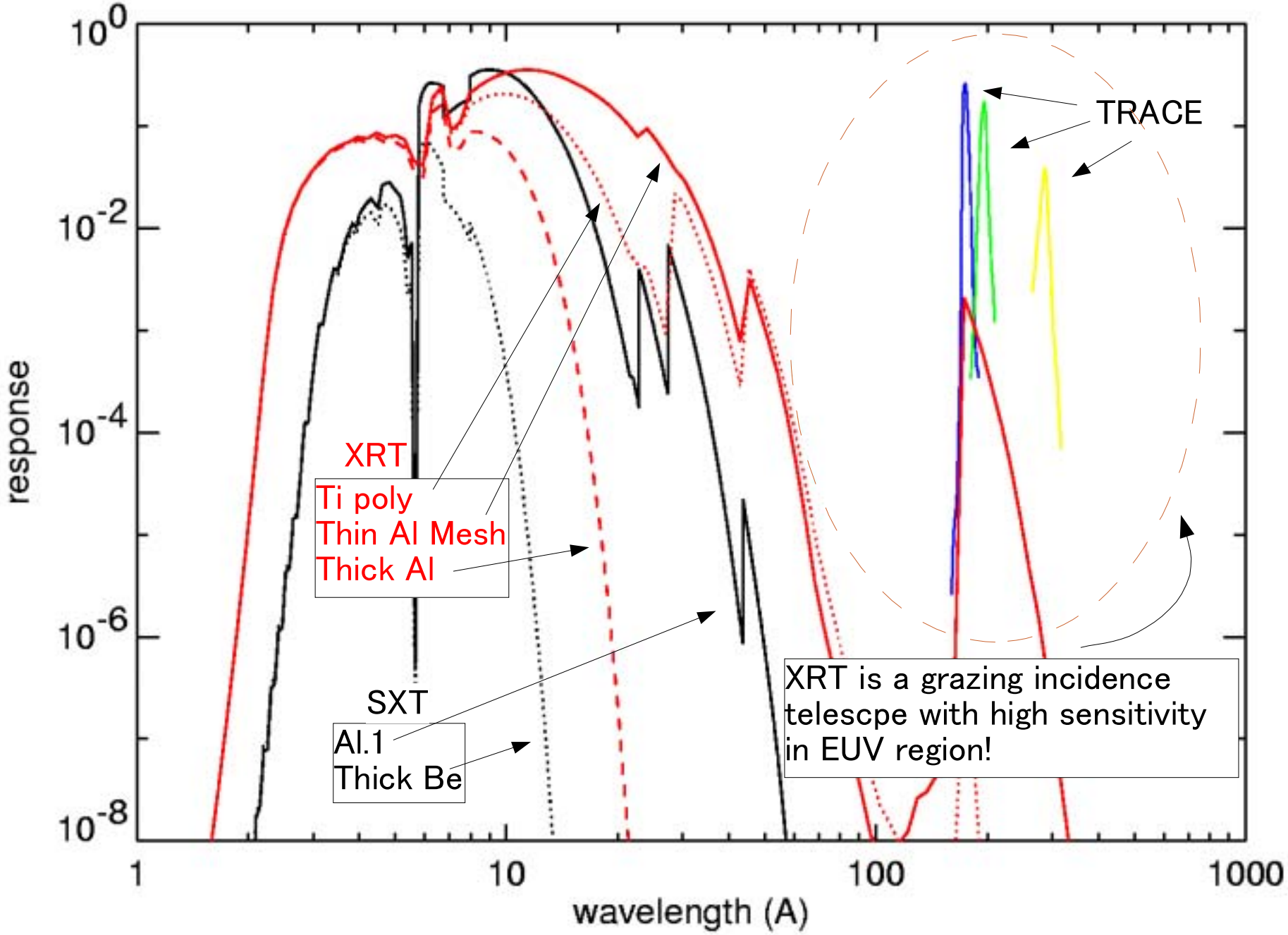
A suggestion from the observations up to now:

In order to answer this, in other words, to understand the coronal heating mechanism, wide temperature range observation combining the EUV and soft X-ray is indispensable.

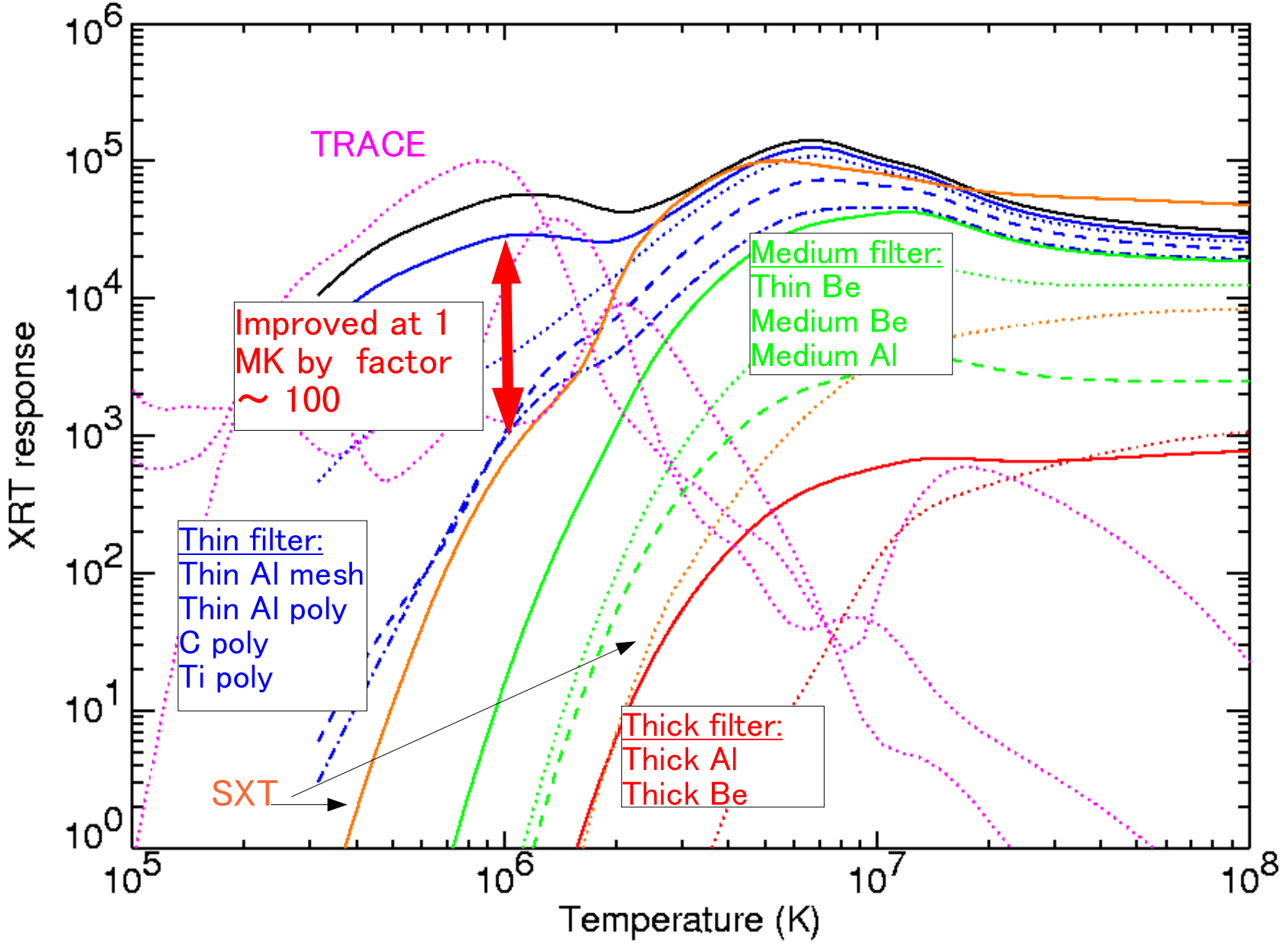
What can we see with XRT?

Uniqueness of the XRT in the spectral and temperature response

Spectral Response of XRT



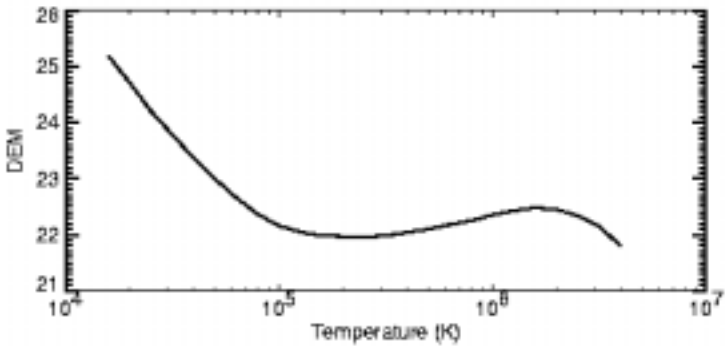
Temperature Response of XRT

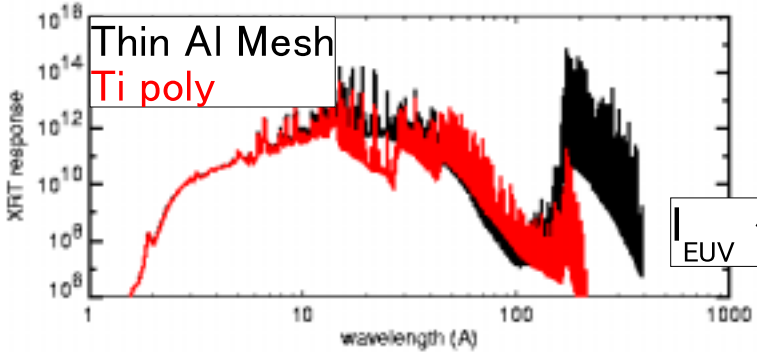


DEM and Spectral response

Significant amount of EUV signals are detected with thin filters while the contribution of EUV signal is almost negligible with medium filters

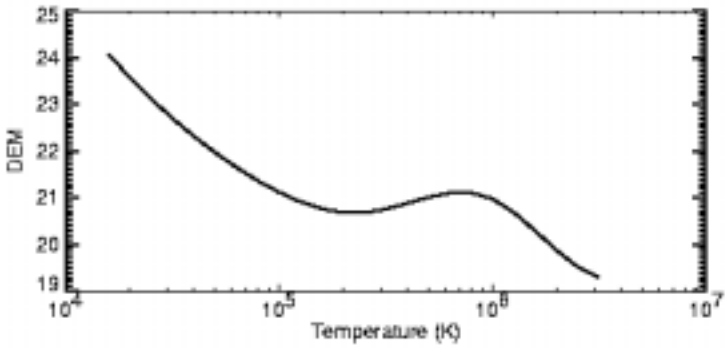
AR:

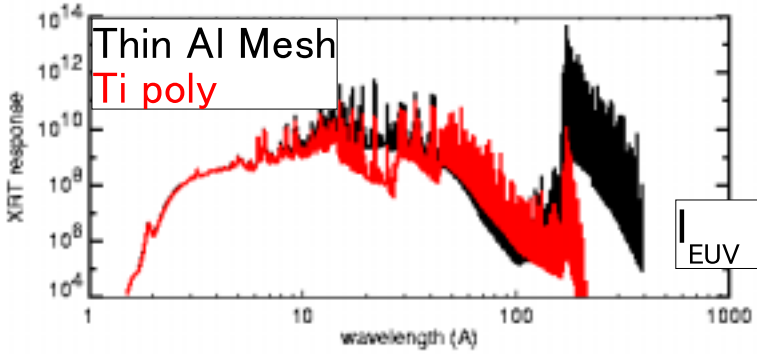




$I_{EUV} \sim 0.3 * I_{total}$

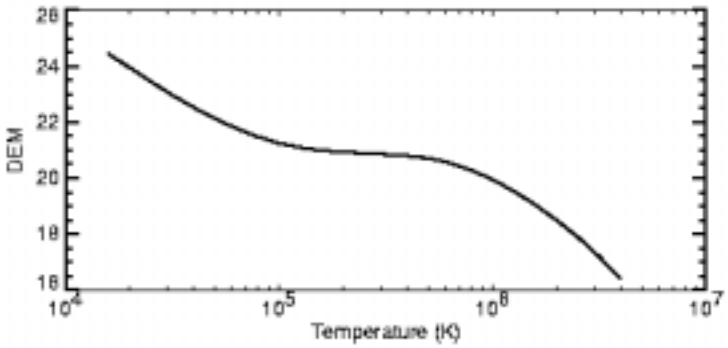
QR:

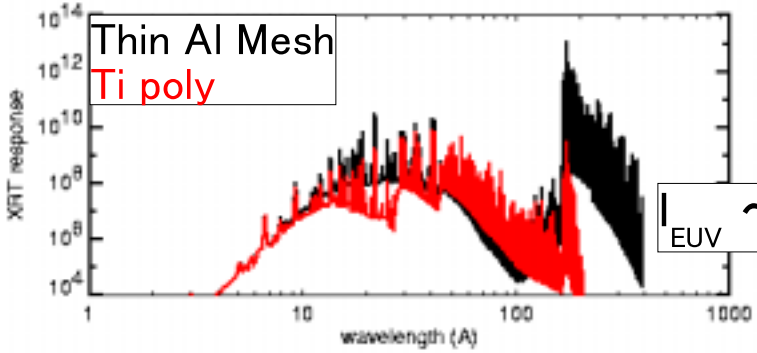




$I_{EUV} \sim 0.8 * I_{total}$

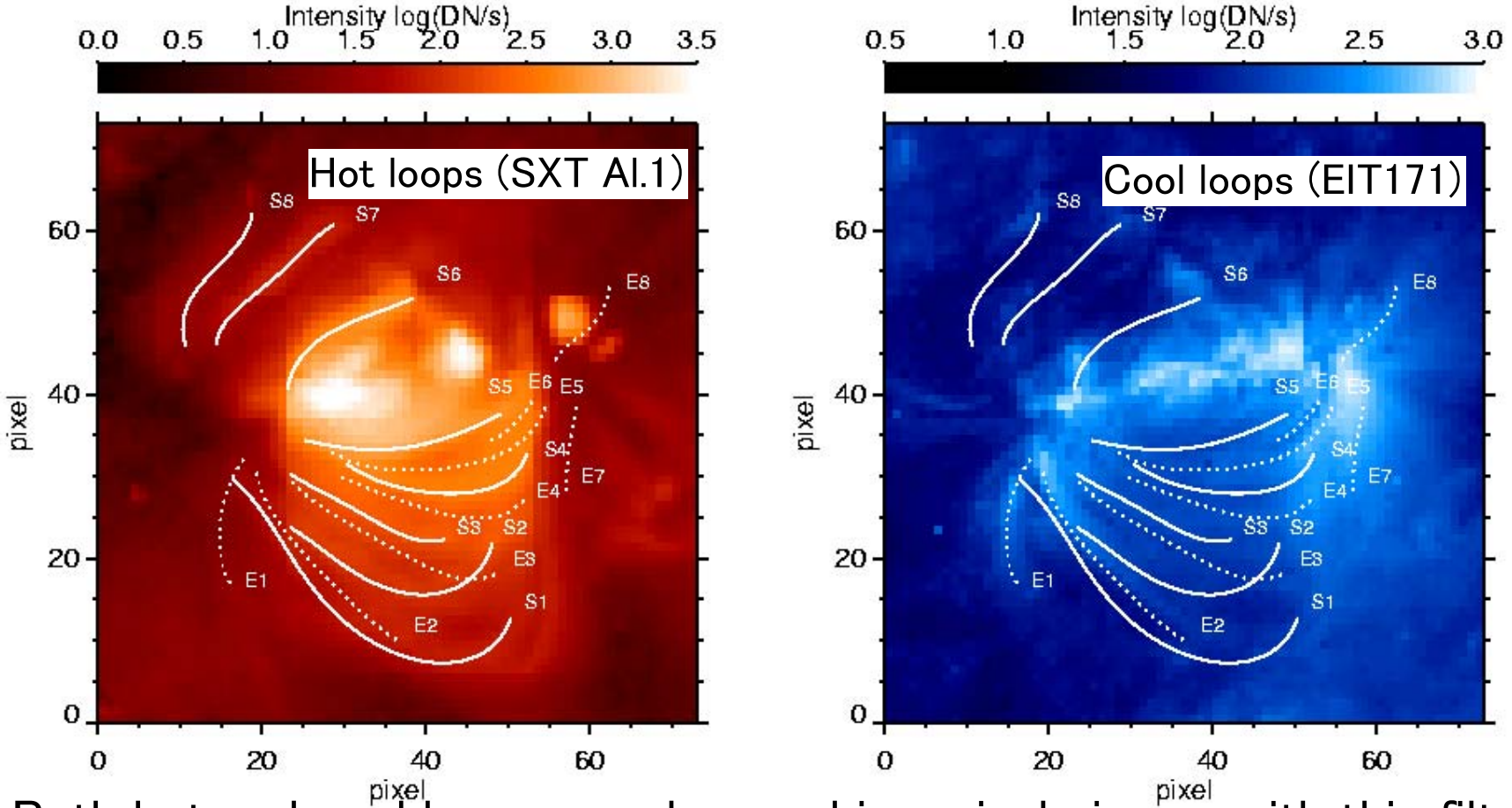
CH:





$I_{EUV} \sim 0.9 * I_{total}$

How Active Region Loops will be observed



- Both hot and cool loops are observed in a single image with thin filter.
  - XRT: response at 1MK (cool loop) ～0.6 × response at 3MK (hot loop)
  - SXT: response at 1MK ～0.01 × response at 3MK
- How to distinguish the hot and cool components on composited image?
  - Morphological comparison on the medium filter image and the thin filter image
  - Filter ratio analysis taking into account the differential emission measure distribution along the line of sight

Conclusion

- Hot coronal structures seen with SXT and cool coronal structures seen with EIT/TRACE shows sharp contrast
  - It is important to observed both of them simultaneously to understand the coronal heating mechanism
- XRT is a X-ray telescope which also has high sensitivity in the EUV region, XRT will make unique observations that have never done before
  - The whole coronal temperature range is covered by XRT
  - How to distinguish the hot and cool component