ID: 35

Track Classification : Flare and Nanoflare heating

26 May 2021 11:25 - 11:38 (Talk 10 + Q&A 3)

Study of Time Evolution of Thermal and Non-Thermal Emission from the M-Class Solar Flare

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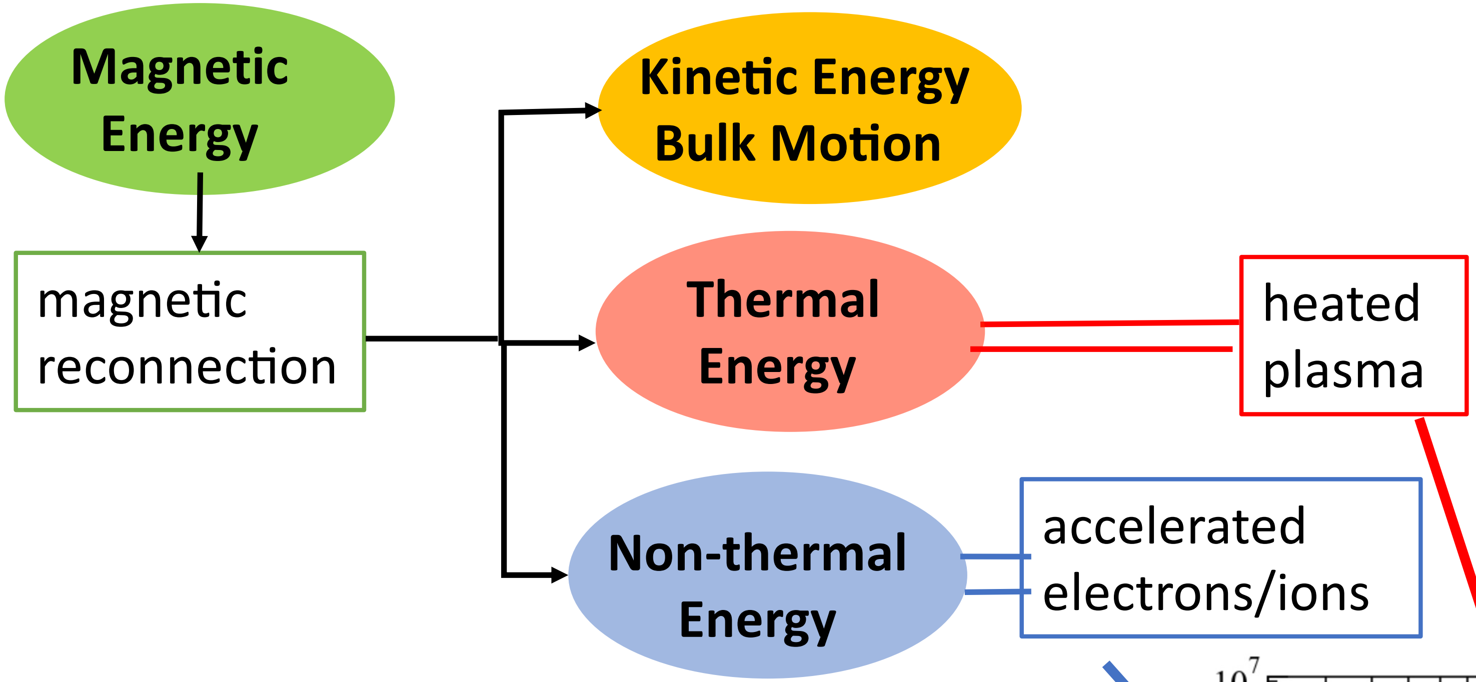
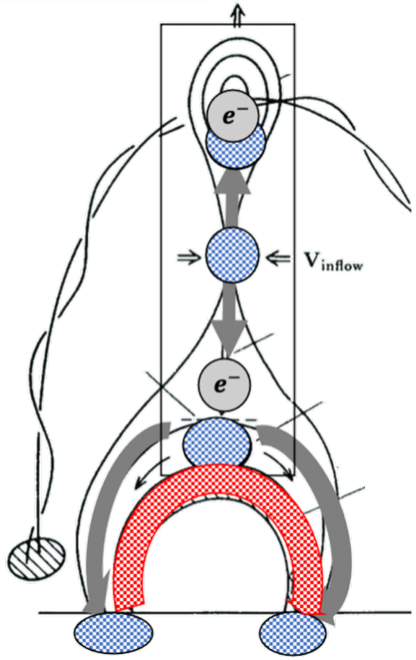
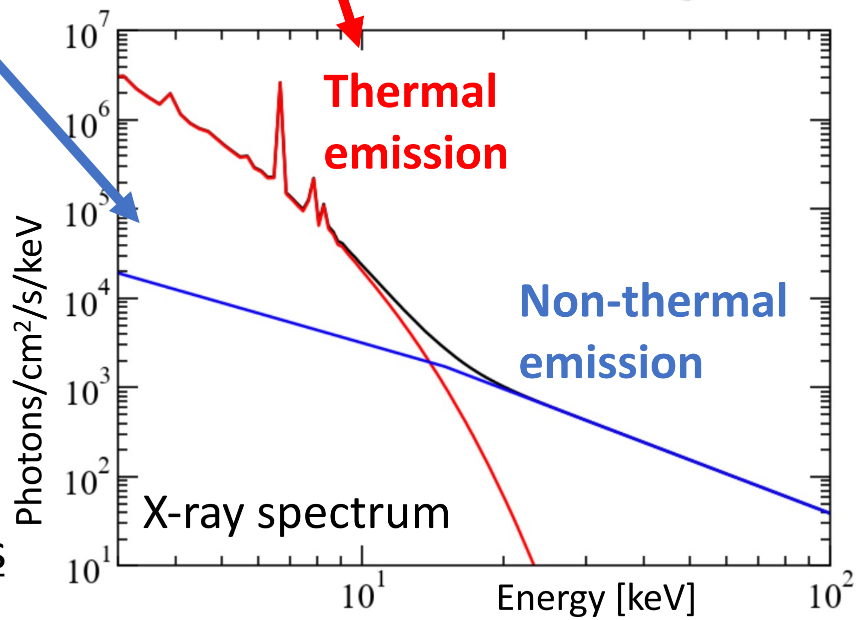
Thermal and Non-thermal Emission



(Shibata 1999)





Q. When and How particles are accelerated?

Q. What is the process of plasma heating/cooling?

etc…

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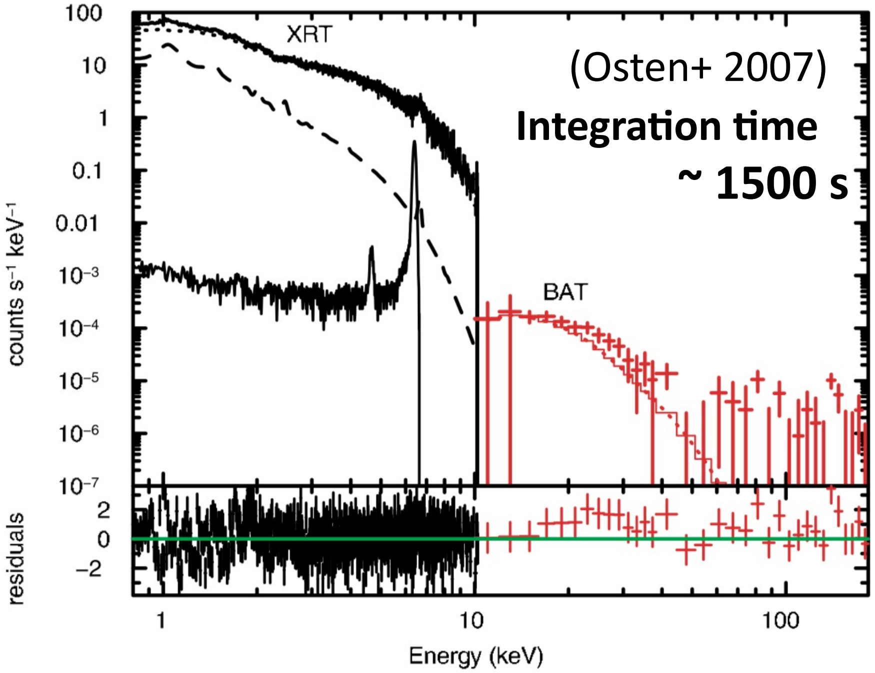
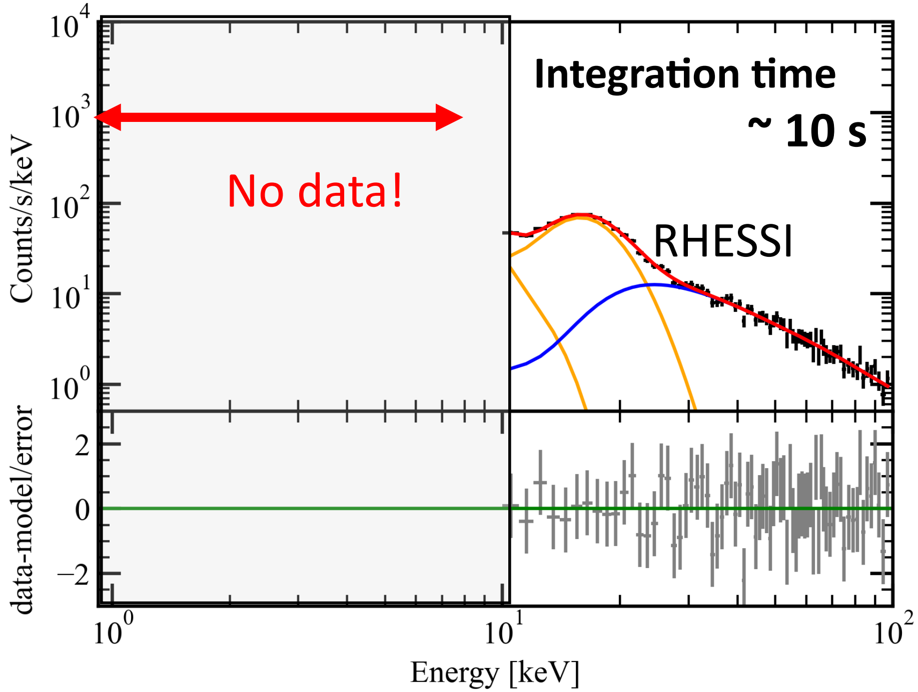
As a first step, it is important to resolve and track the time evolution of Thermal and Non-thermal emission based on spectra analysis

Lack of spectroscopic observation in SXR band

Stellar flare II Peg: Swift XRT + BAT



Solar flare M7.6 class: RHESSI



✓ To study time evolution and energetics of solar flares,
Spectroscopic observation with <u>**high energy and high time resolution** is required</u>

Current status: GOES SXR fluxes (1.6-12 keV and 3.0-25 keV)
→ Only estimate the temperature and emission measure by assuming isothermal

MinXSS: Miniature X-ray Solar Spectrometer

MinXSS CubeSat

✓ 3U CubeSat Small Satellite by **LASP**

1U = 10 cm X 10 cm × 11.35 cm

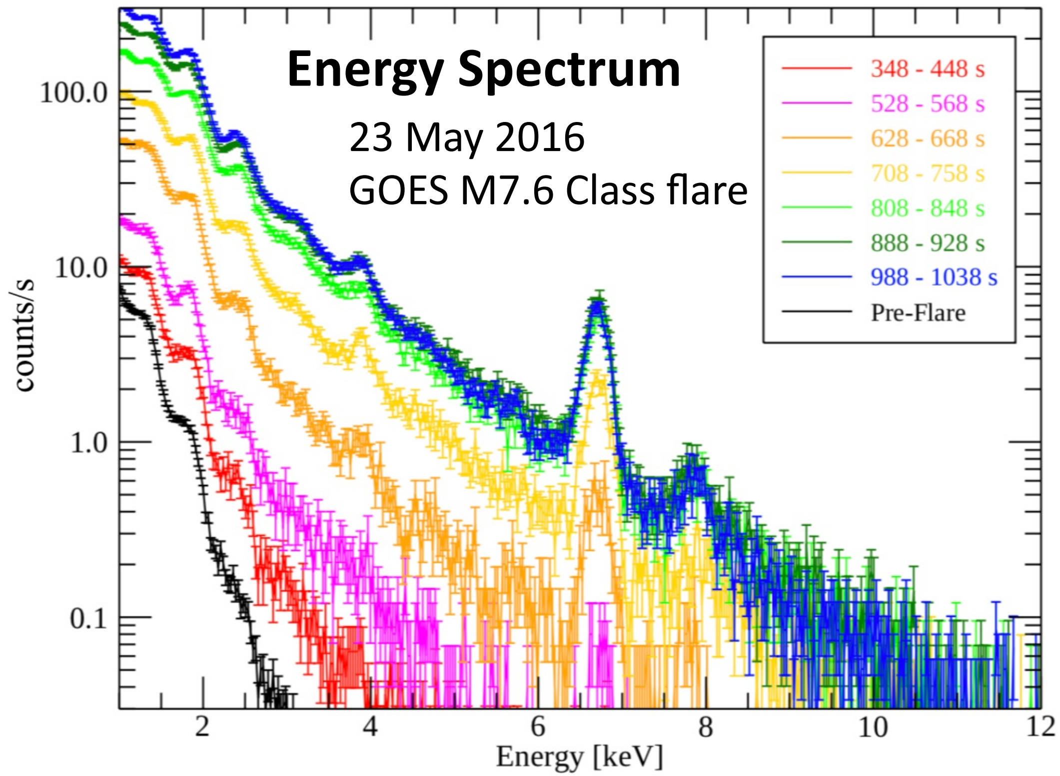
✓ Energy range: 0.8 keV to 12 keV

Energy resolution: 0.15 keV (FWHM) @5.9 keV

Spectrum is obtained every 10 seconds

* no spatial information (Moore+ 2018)

↑ realized by using Silicon Drift detector



Analysis target flare

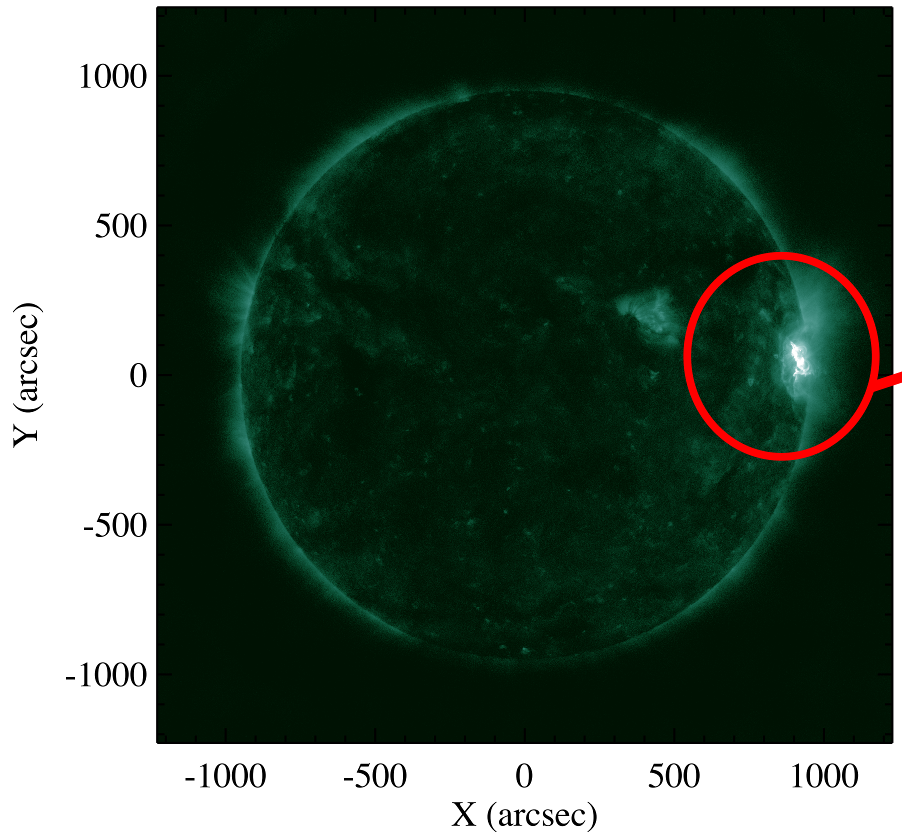
GOES M7.6 Class Flare

Start: 2016-07-23 05:00:06

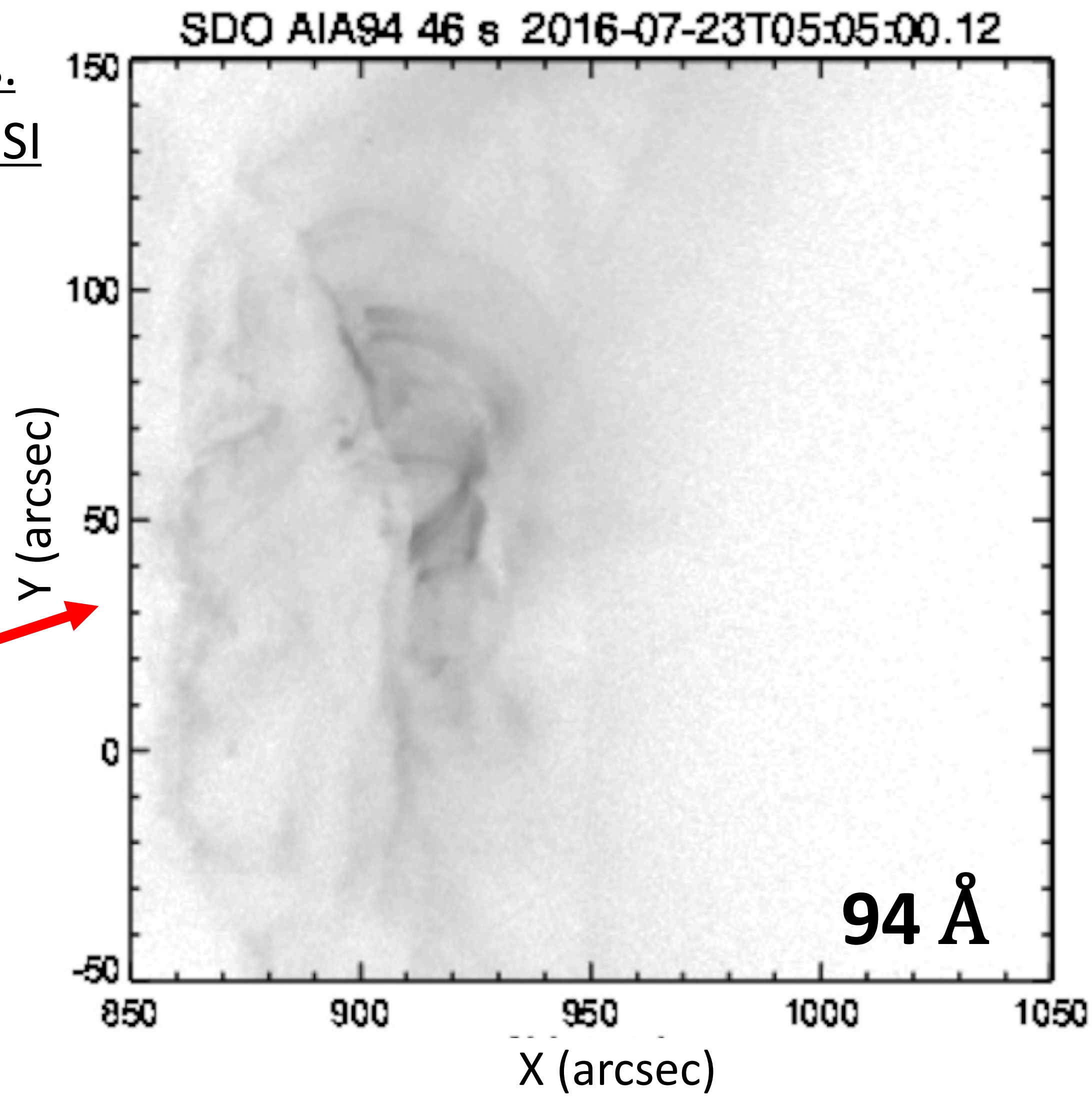
✓ The most intense flare in MinXSS obs.

✓ Simultaneous observation with RHESSI

Position (911 arcsec, 64 arcsec)



Movie of SDO/AIA 94 Å



Lightcurve

Spectral analysis

HXR and 17GHz radio flux are rapidly increased in ~650 sec. and 850 sec.
= Non-Thermal emission
↓
X-ray flux decreases gradually and rises again around 1700 sec.

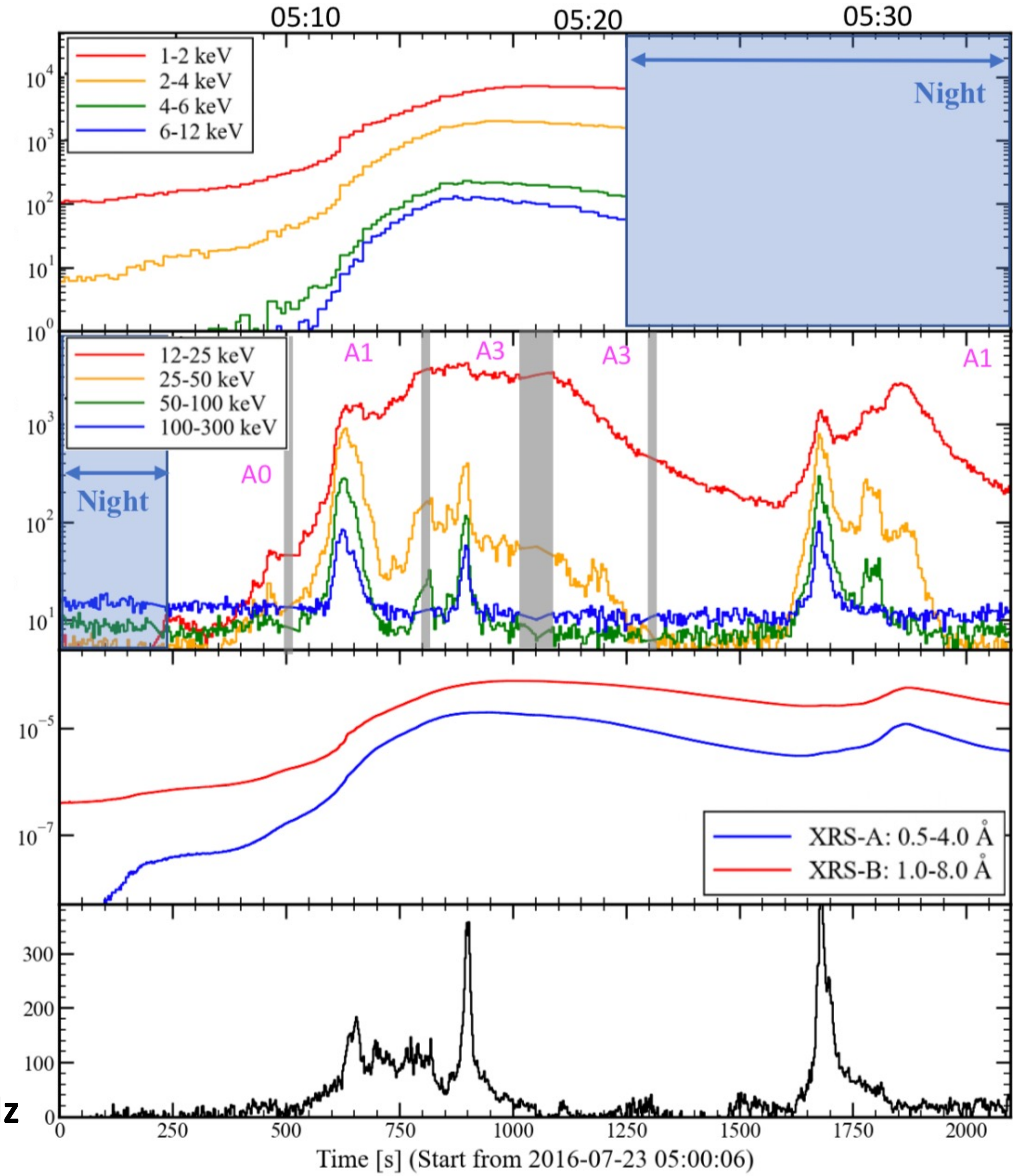
<u>To follow the time evolution of thermal and non-thermal emission,</u>
<u>spectral analysis is conducted in 10 sec. cadences</u>

MinXSS
[counts/s]
SXR

RHESSI
[counts/s/det]
HXR

GOES
[watts/m²]
SXR

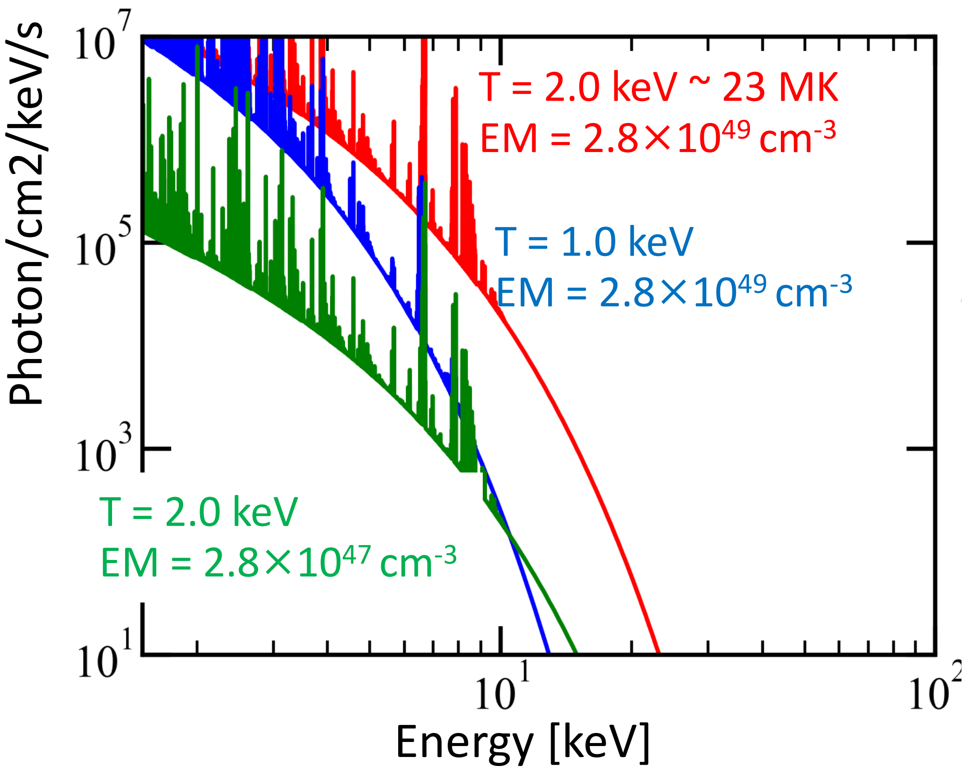
NoRP
[watts/m²]
Radio 17GHz



Spectrum models

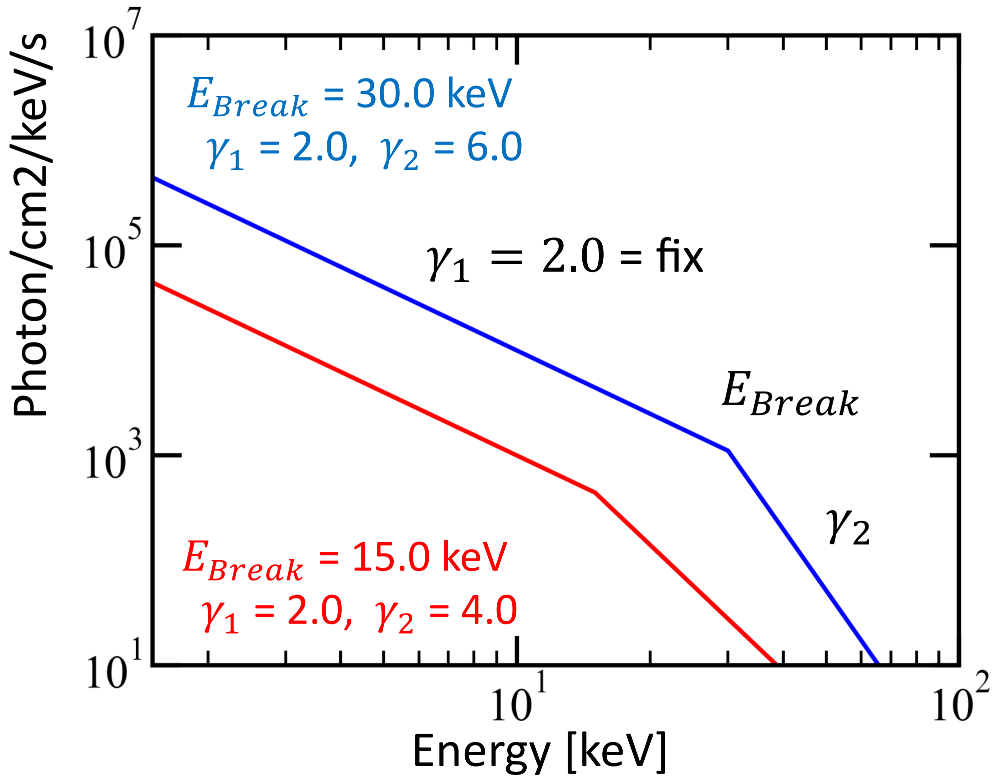
Thermal: APEC emission spectrum

- T : Plasma Temperature
- EM : Emission Measure
- Si, Ca, Fe abundance

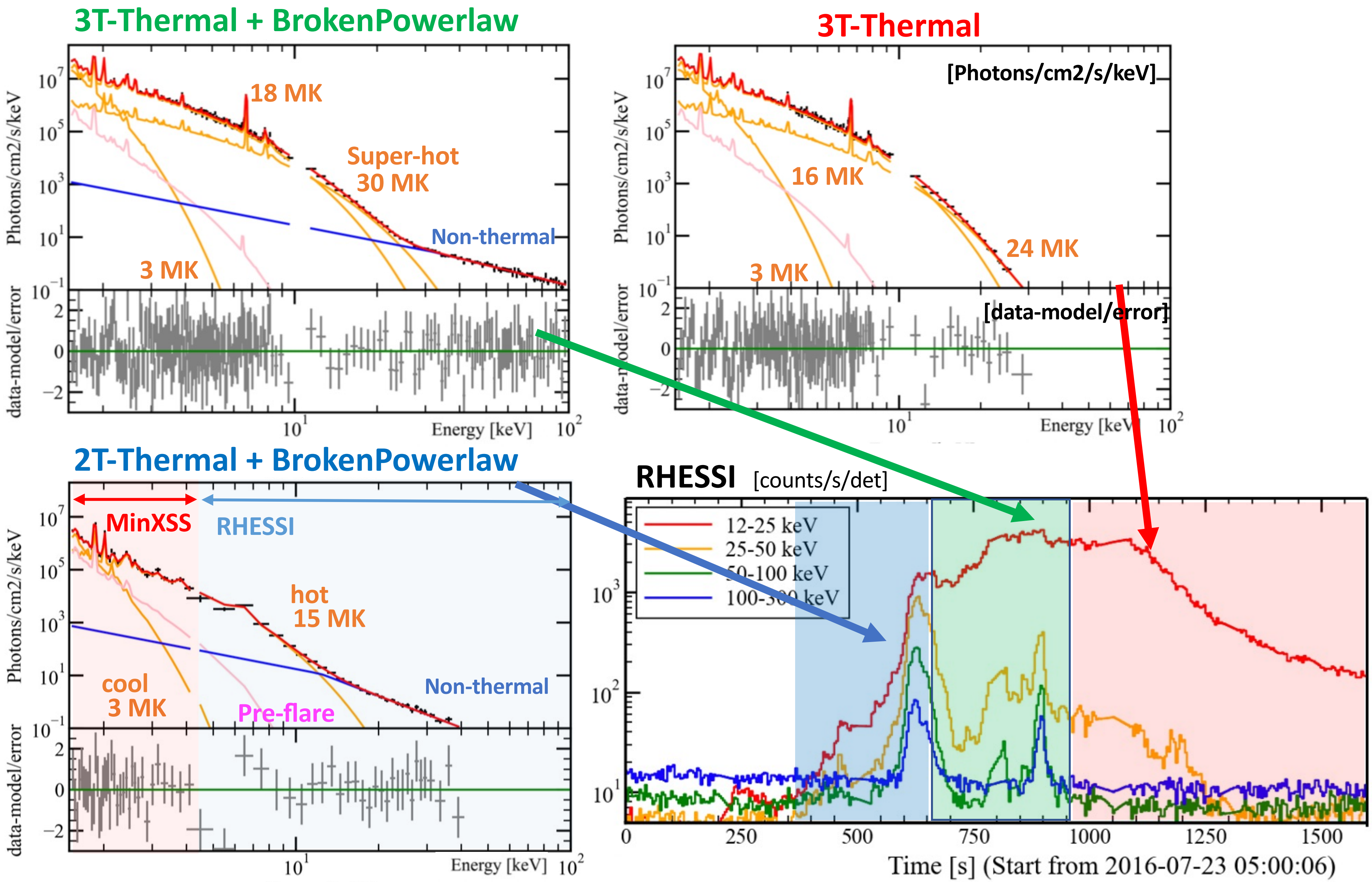


Non-thermal : Broken power-law

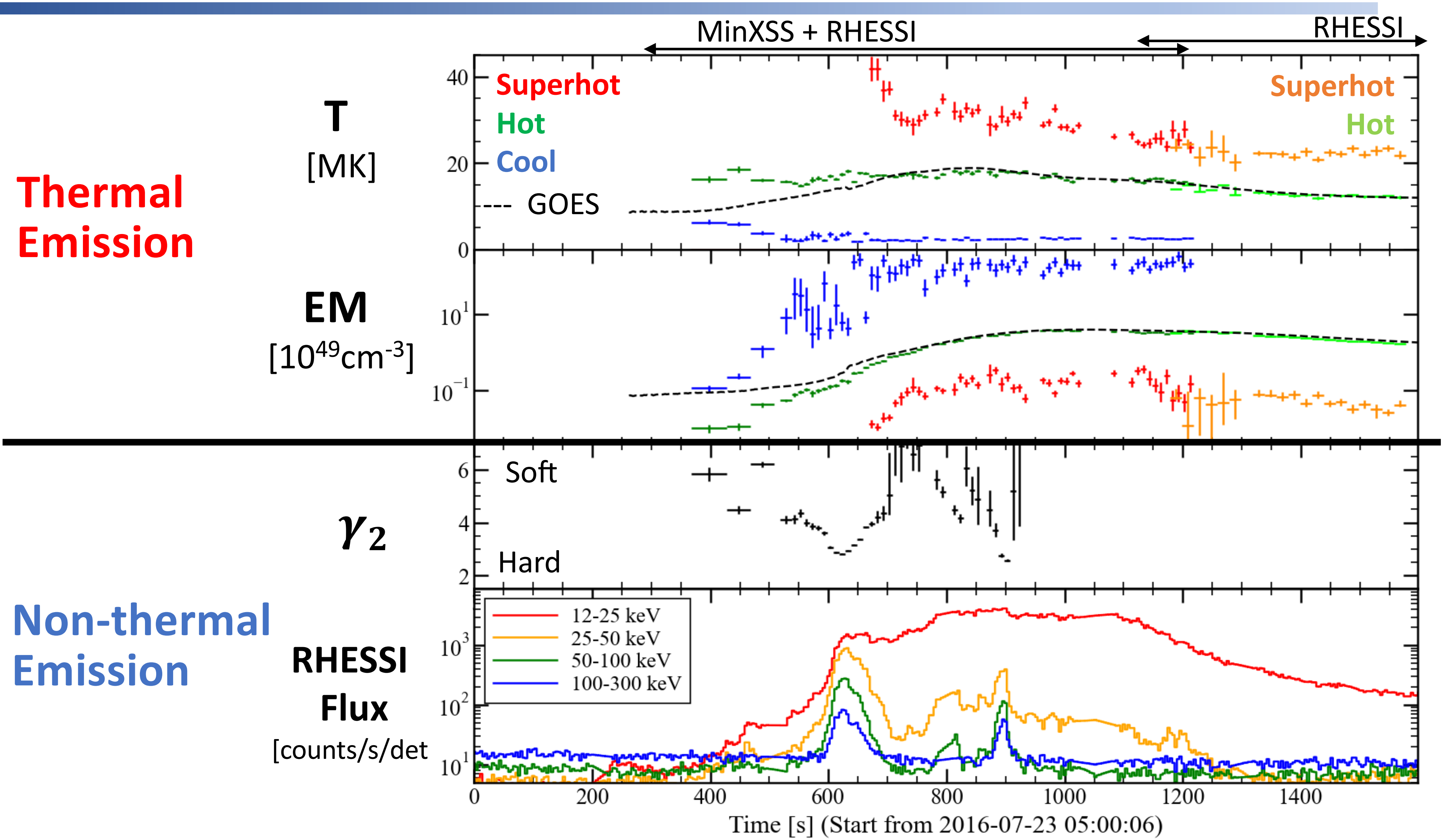
- E_{Break} : Break Energy
- γ_1: Index before E_{Break} → fix at 2.0
- γ_2: Index after E_{Break}



Three different spectra during flare



Time evolution of Temperature, EM, Spectral Index



✓ Time evolution of three components can be resolved with a **10 seconds cadence, independently**

Findings by MinXSS+RHESSI

From spectrum

Non-Thermal Emission

clearly detected by RHESSI, power-law photon index $\gamma \sim 2.8$

Thermal Emission

MinXSS provides the information on **three thermal emission** components

1. Cool plasma (T~3 MK) , 2. hot plasma (T~15 MK), 3. superhot plasma (T~30 MK)

From combined time evolution

Cool (T~3 MK) plasma:

- Emission measure is increased by three orders of magnitude

  EM : 1×10^{48} cm^{-3} → ~ 2×10^{51} cm^{-3}

Hot (T~15 MK) plasma:

- Emission measure is increased by two orders of magnitude

  EM : 1×10^{47} cm^{-3} → ~ 3×10^{49} cm^{-3}

Superhot (T~30 MK) plasma:

- gradually taking place after the first HXR peak

✓ **Time evolution of three thermal emission components are clearly resolved by adding MinXSS data**

The origin of cool thermal component

Cool component:

Time evolution

according to the first HXR peak
- EM is increased by three orders of magnitude

  $1\times10^{48}\,cm^{-3} \rightarrow \sim 2\times10^{51}\,cm^{-3}$

+

Spatial information

Calculating DEM using SDO/AIA six EUV filter observation by Regularization method

Hannah & Kontar (2012)

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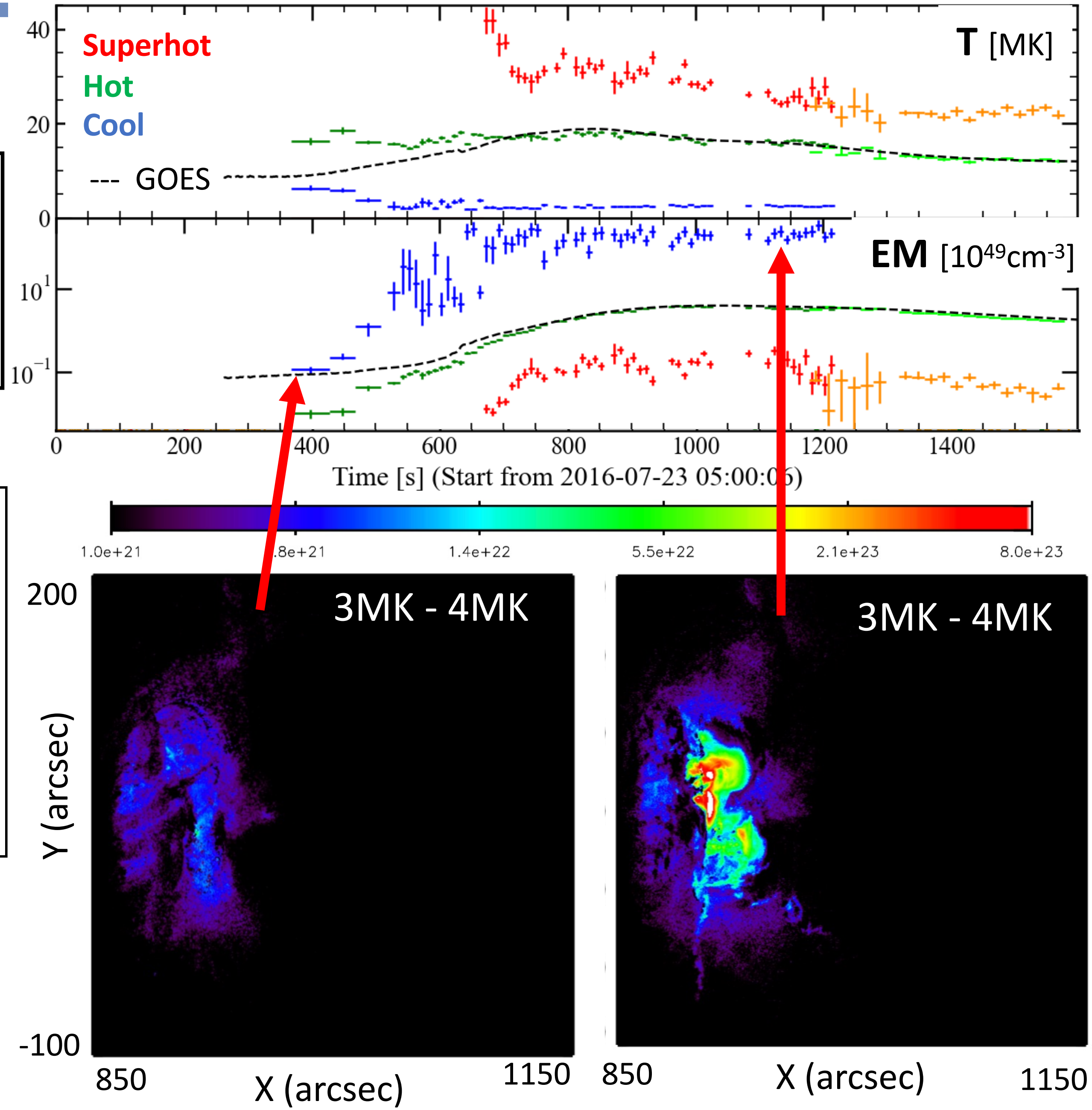
DEM of 3-4 MK plasma increases within the flaring loop

✓ the plasma that fills the flaring loop associated with chromospheric evaporation



The origin of hot and superhot thermal component

Hot component:

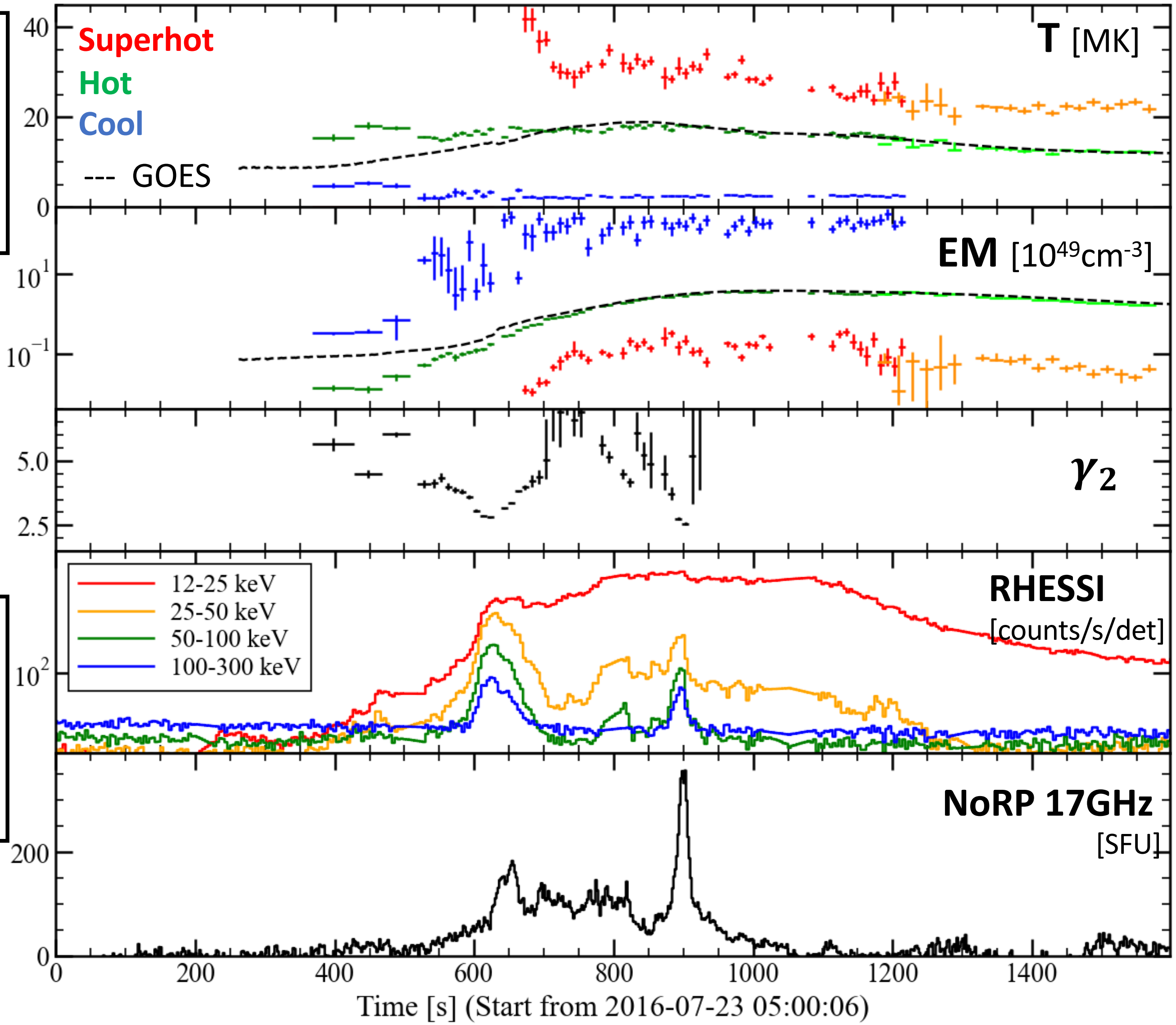
Same time evolution with Cool
- EM is drastically increased by two orders of magnitude 1×10^{47} cm^{-3} → ~ 3×10^{49} cm^{-3}

✓ the plasma that fills the flaring loop associated with chromospheric evaporation

Superhot component:

- Spectral indices became softened → Superhot emerged
- 17GHz radio wave continuously emitted

✓ thermalization of the non-thermal electrons trapped in the flaring loop ?



Summary

Spectra analysis for M7.6 Class Flare combining MinXSS and RHESSI
every 10 seconds for the entire flare event in the energy range 1.5 keV to 100 keV

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Thermal Emission

three thermal emission components are detected
+ these time evolution are followed **with a 10 seconds cadence** for the first time

Cool (T~3 MK) and Hot (T~15 MK) plasma:
emission measure is increased by more than two orders of magnitude
+ DEM increases within the flaring loop → chromospheric evaporation ?

Superhot (T~30 MK) plasma:
gradually taking place after the first HXR peak + 17GHz radio wave emission
→ thermalization of the non-thermal electrons trapped in the flaring loop?

→ Next:
- Study of relationships between each thermal and non-thermal emissions
- Imaging spectroscopy by future experiments such as FOXSI-4(2024) and PhoENiX