Post-shock temperature equilibration to be revealed by spatially resolved spectroscopy of SN 1006 with XRISM/Resolve

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How thermal relaxation after shock heating progress?

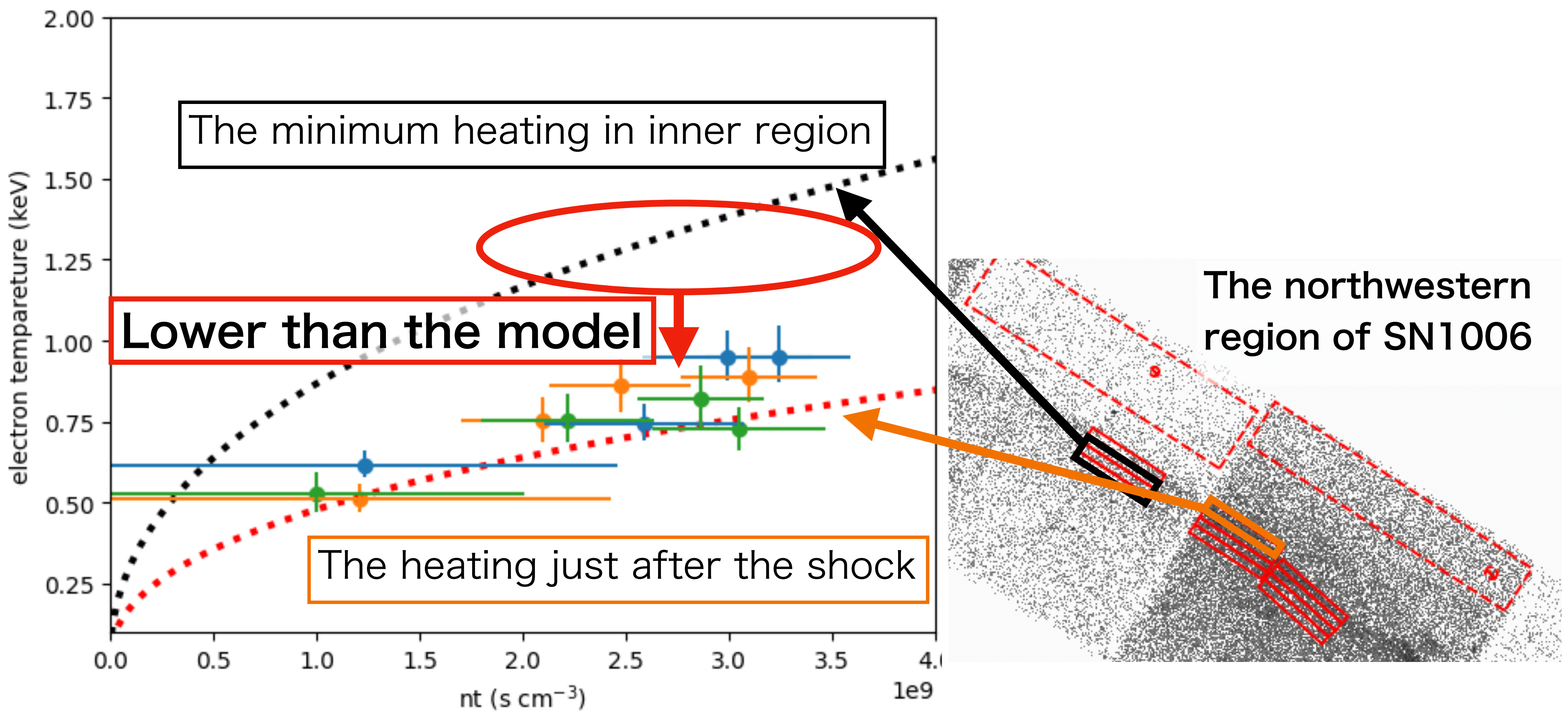
Our objective

Understanding the heating mechanism at collisionless shocks in supernova remnants

Method

Estimate **the spatial variation of the temperatures of each particle** and compare the Coulomb heating model

The comparison of electron temperature and Coulomb model

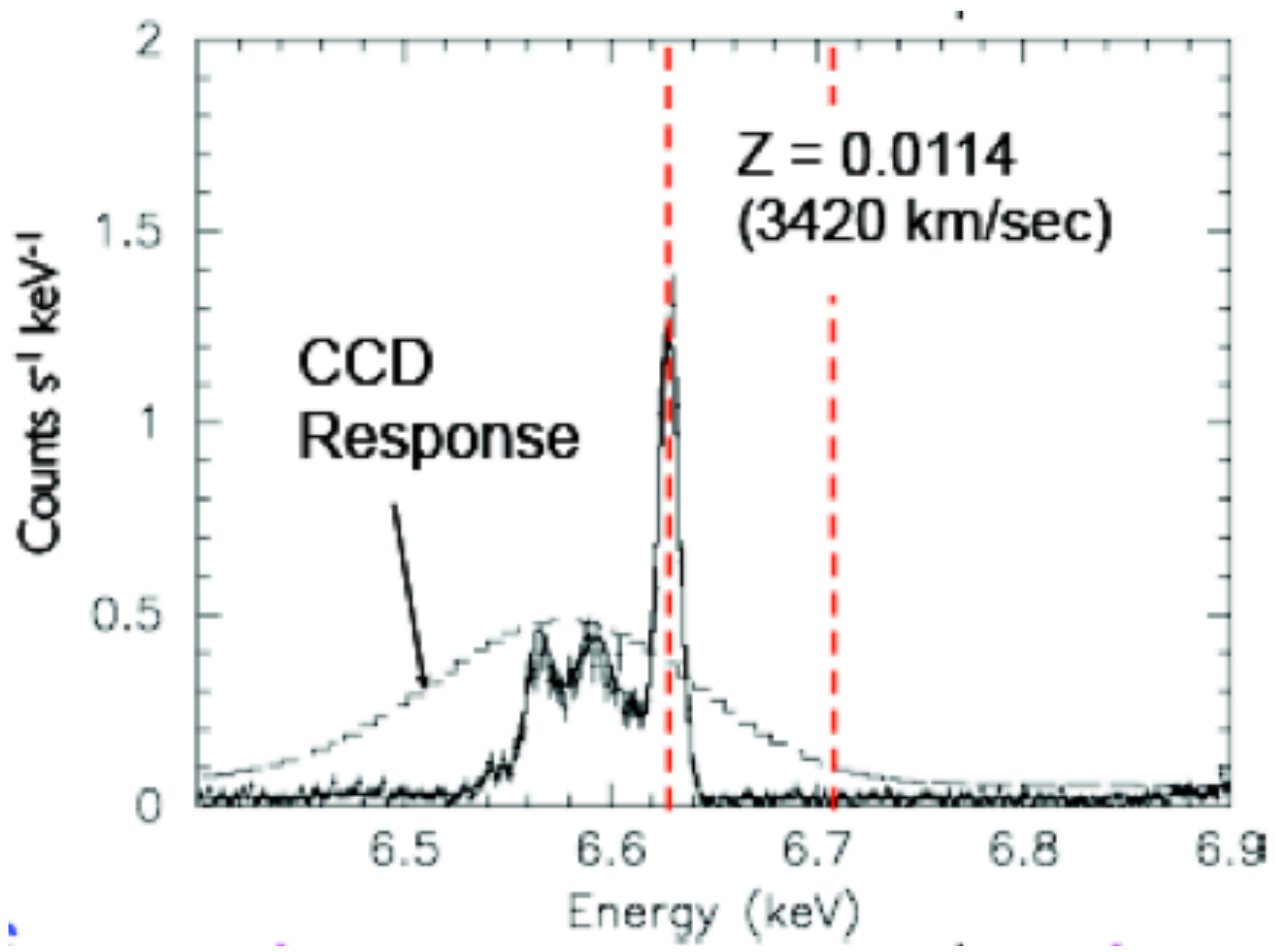


Chandra study of spatial variation of electron temperature in SN 1006

Increase just after the shock slower than the Coulomb heating model

→Some of the energy may have **leaked out into cosmic rays**

Prospect for XRISM : ion temperature estimation

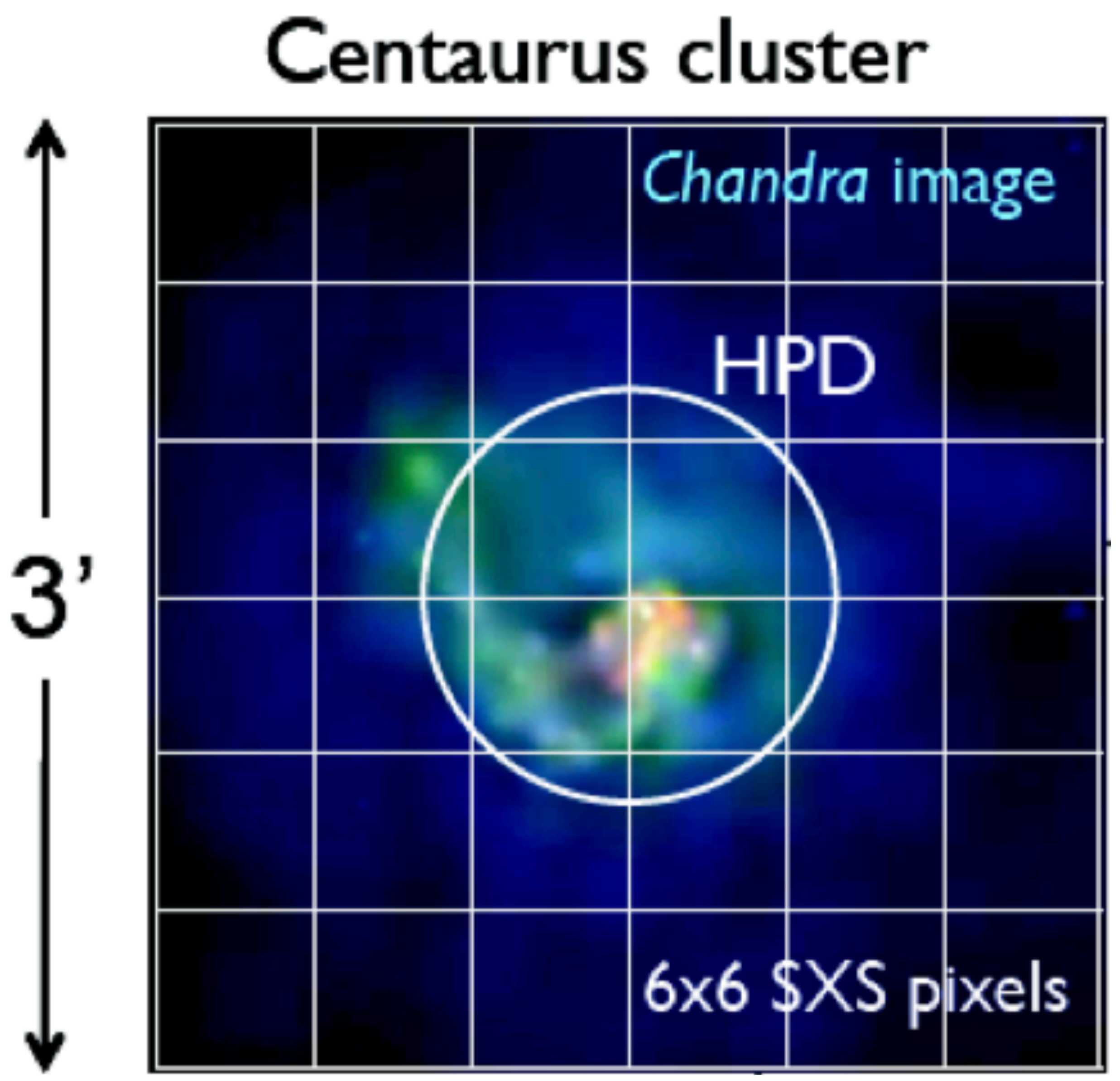


Estimation of the amount of energy leakage

→Need to **estimate the ion temperatures** (they have most of the energy)

→Cannot estimate due to **insufficient energy resolution of Chandra**…

XRISM has **sufficient energy resolution** to estimate ion temperatures from each line complex



Difficulty with XRISM :

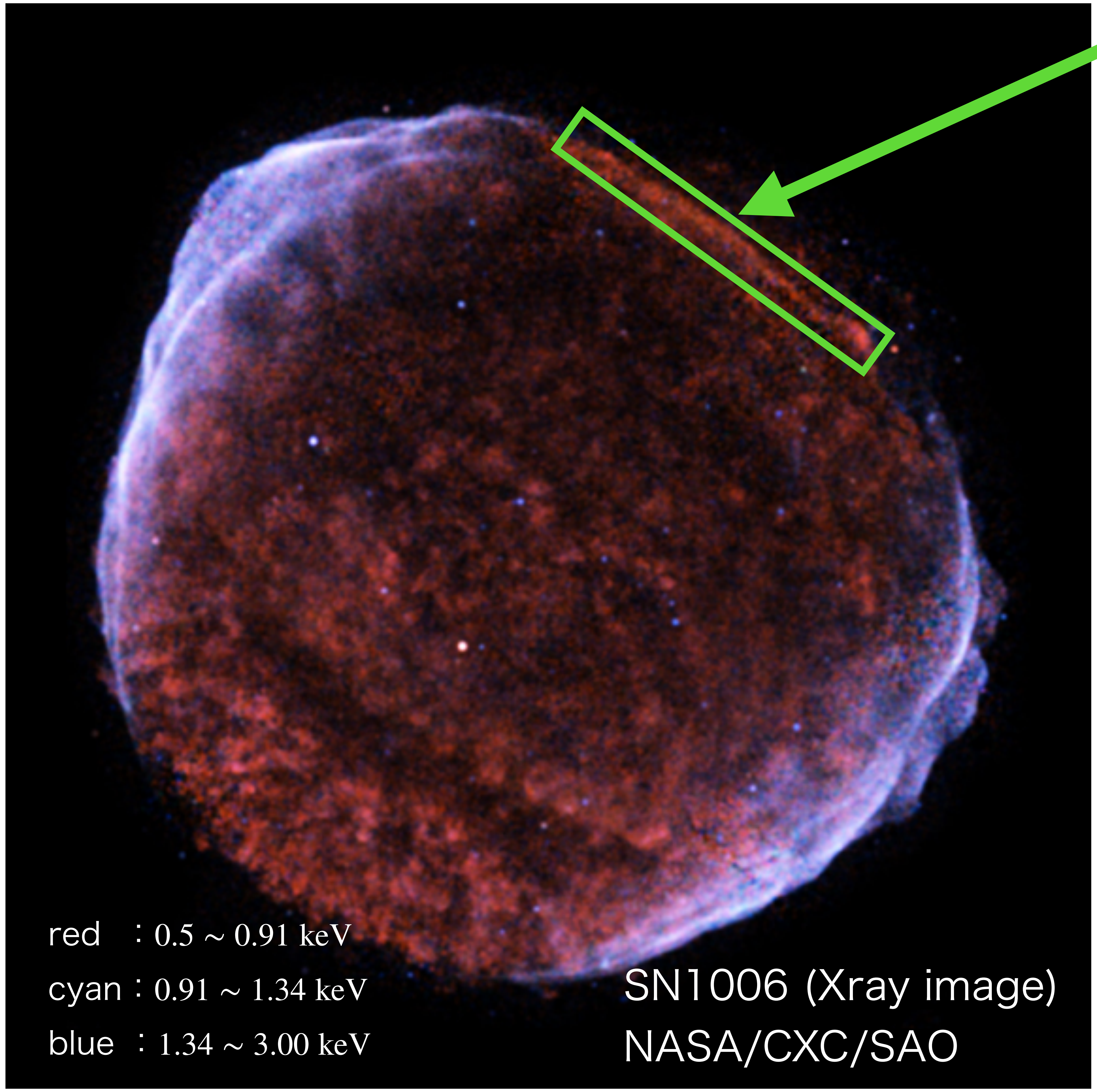
Moderate spatial resolution (HPD< 1.7 arcmin)

→XRISM is not suitable for the spatial resolved spectroscopy

→A direct comparison to the Coulomb heating model would be difficult

To what degree can we determine the spatial variation with XRSIM? And how?

X-ray bright filament of SN 1006



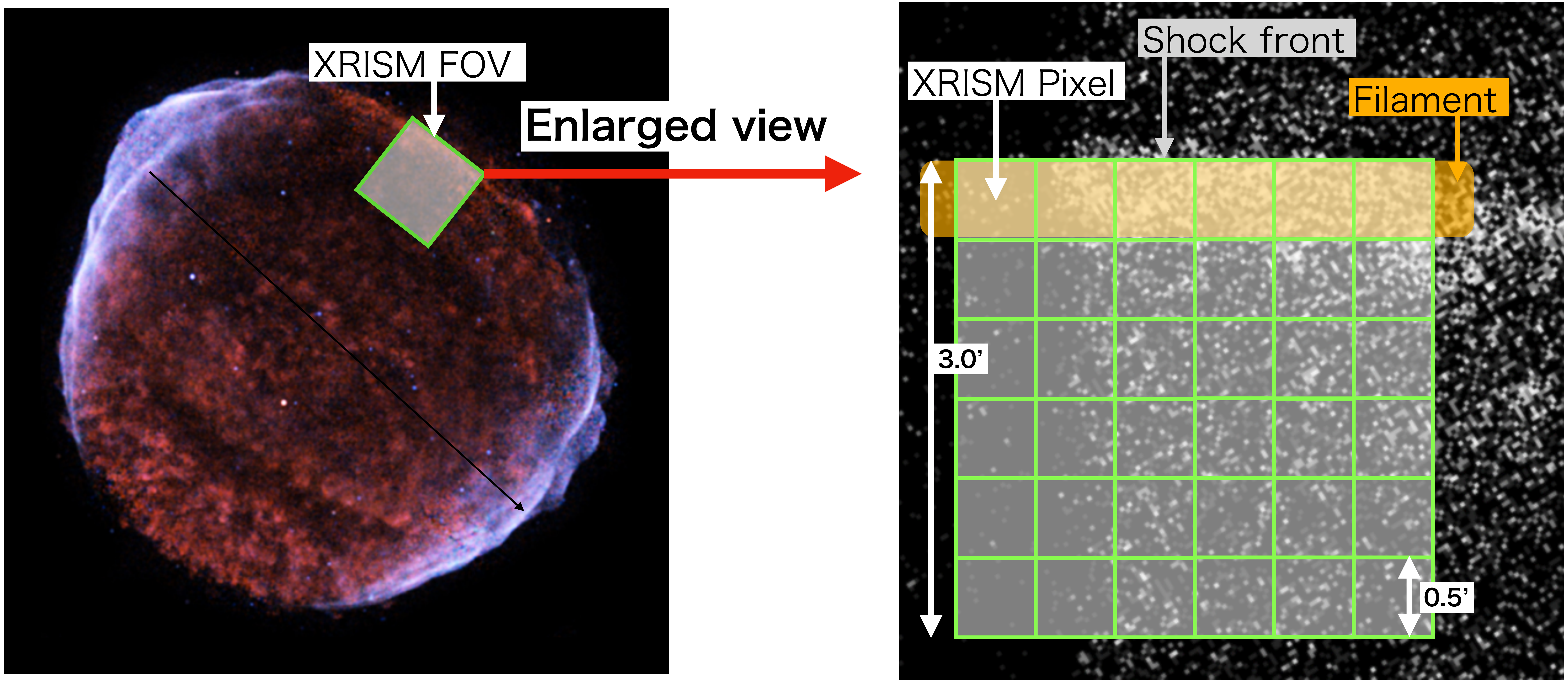
- **Bright filament in soft X-ray band** in the northwestern region of SN 1006
  →**Relatively less affected by the contamination** from the inner areas
- Already analyzed the northwestern region of SN 1006
  →Possible to compare to the spatial spectroscopy of Chandra

⬇

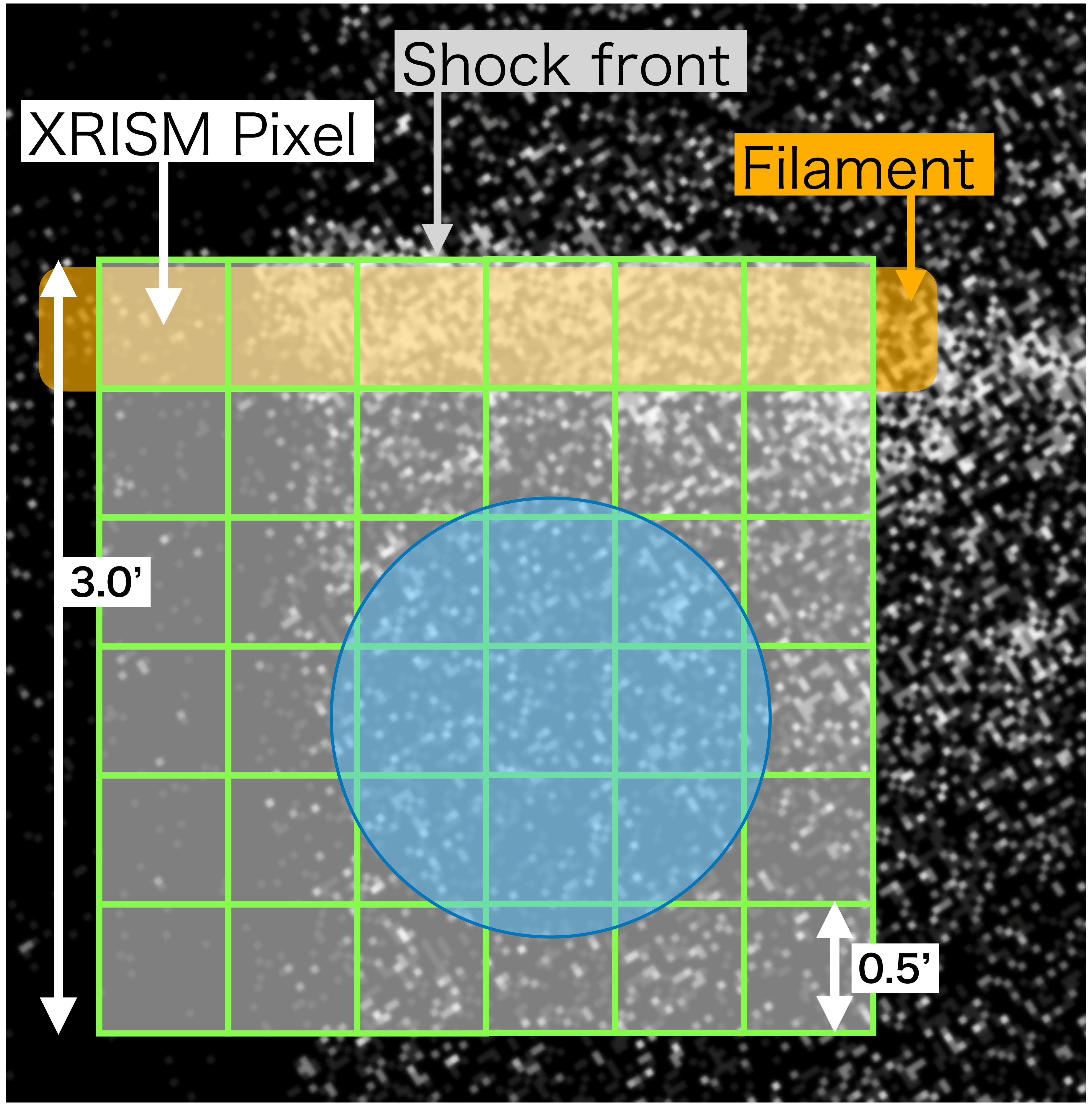
We **select the northwestern region of SN 1006 as the simulation target of the spatial analysis** with XRISM's large HPD

XRISM FOV at SN1006

The comparison of XRISM FOV and SN1006



The contamination of XRISM Resolve



Resolve pixel size (0.5 arcmin) < HPD (<1.7 arcmin)

→Difficult to do pixel-by-pixel analysis

→Need to simultaneous fitting considering the contamination

The requirement for the spatial resolved spectroscopy

1. **Group some pixels for increasing the purity of spectrum**
2. **Understand how the contamination exist**

Simulation target

Goal of this simulation

- **Find the pixel grouping** suitable for spatial spectroscopy of XRISM
- **Evaluate the degree of contamination** after grouping

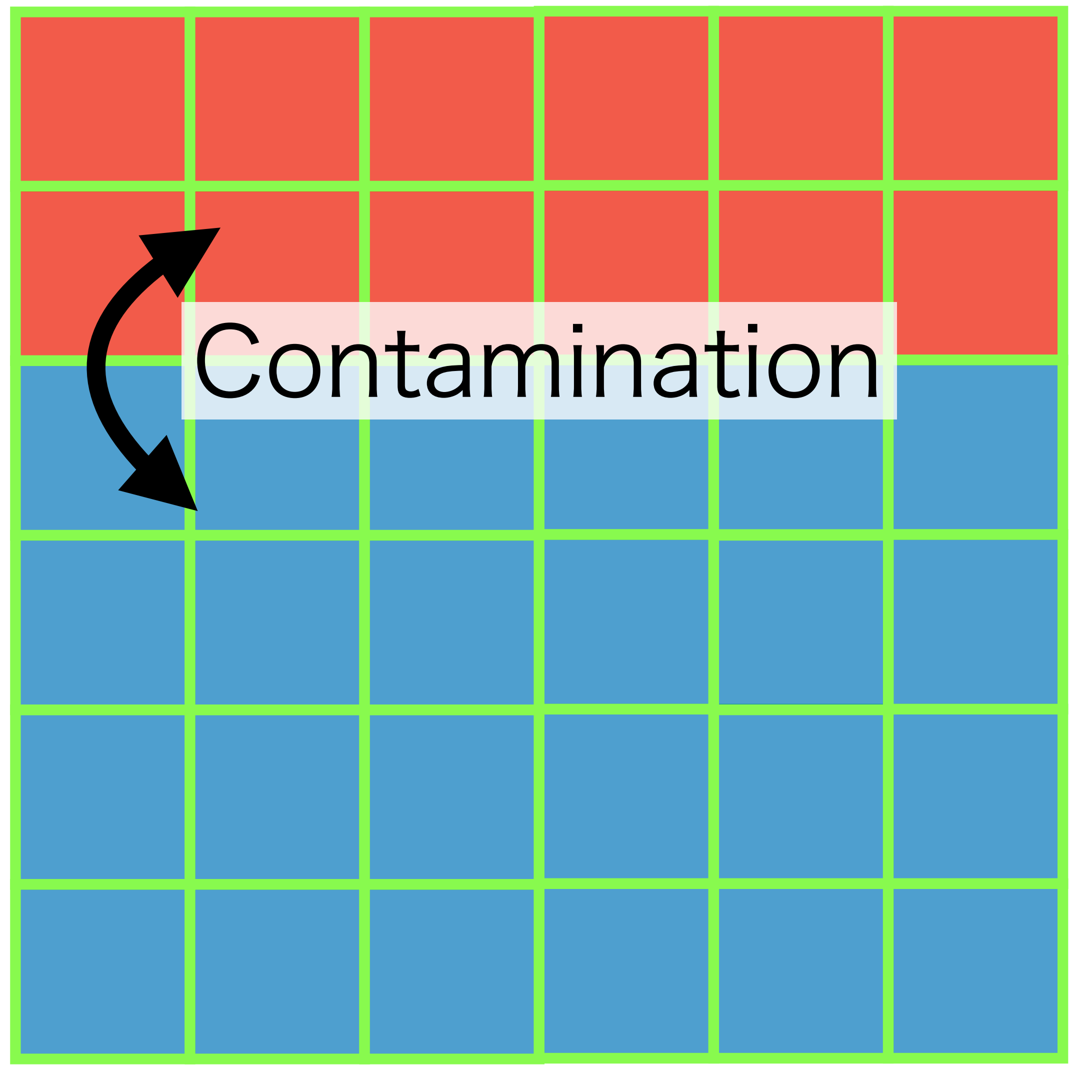
※Accuracy of ion temperature determination → Future work

<How to group pixels>

<u>Main research target</u>

Search the division of areas with **as little contamination as possible**

XRISM Pixel

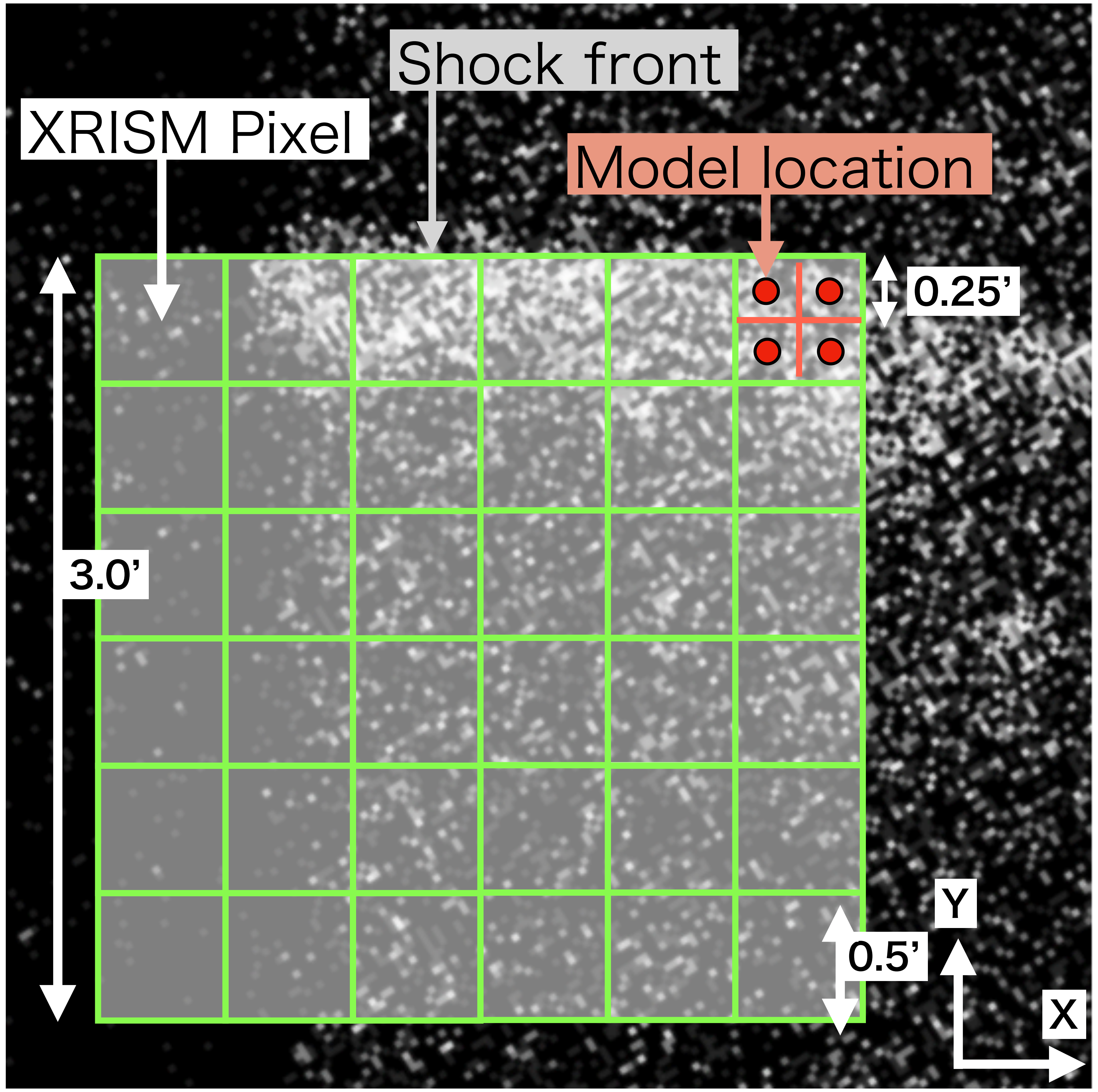


<The degree of contamination >

How the contamination exist?

→<u>**Simlutanious model fitting**</u> **with assuming the contamination ratio**

How to set models for XRISM simulation



Simulation method

1. Set the spectrum models to cover FOV
2. Smoothing models by XRISM HPD
3. Calculate the degree of contamination

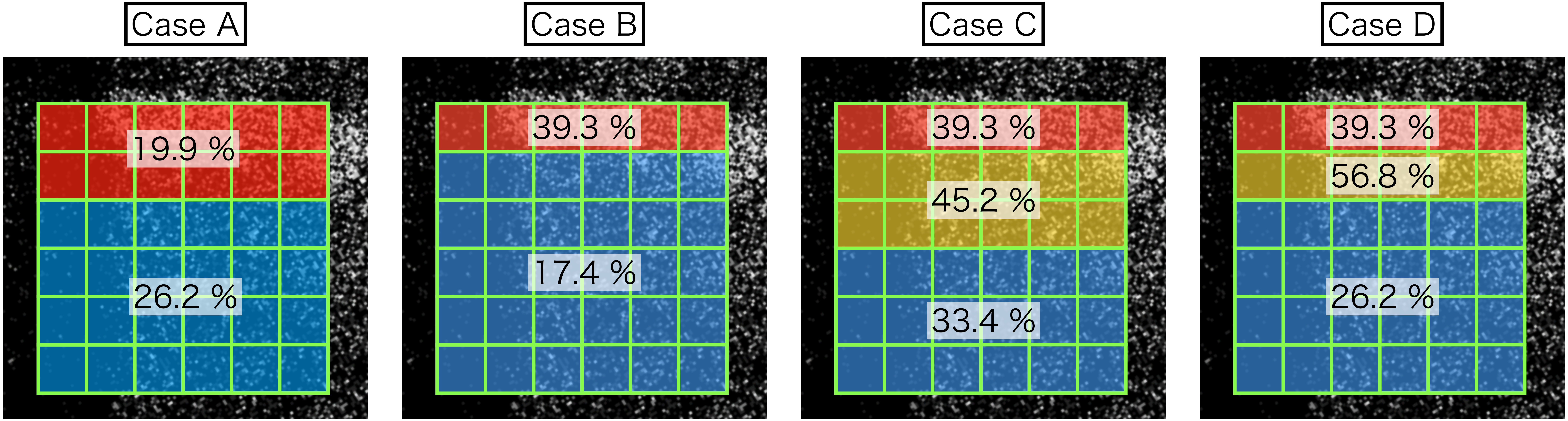
Simulation setup

- **The best-fit data of Chandra analysis** is used as the spectrum model
- The spectrum model is placed **2 x 2 for each pixel**
- Their parameter is **changed only in y axis direction** to consider spectrum gradient

The contamination after grouping

Check the contamination ratio under some grouping cases

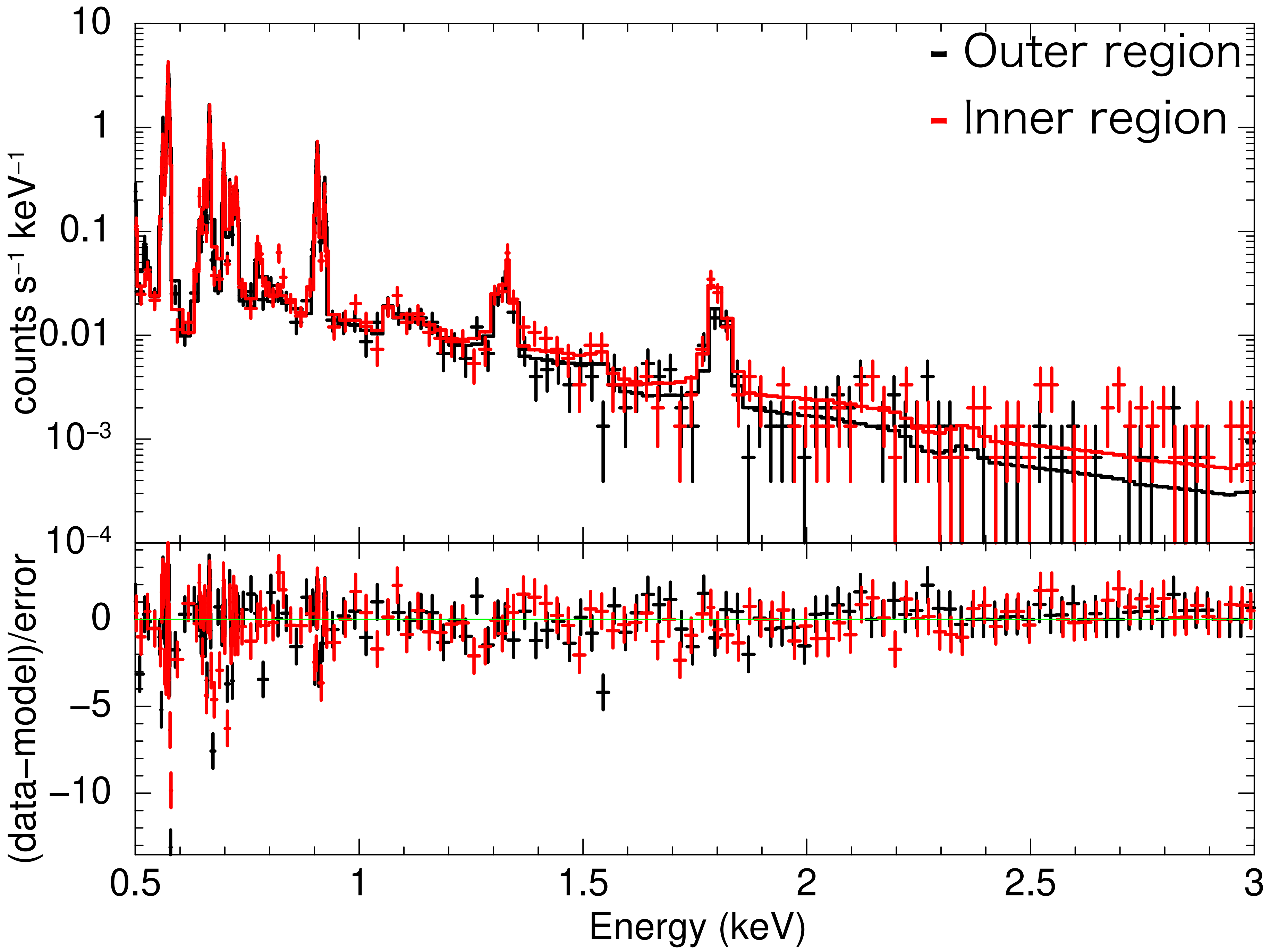
- Larger grouping area has **less contamination**
- **The contamination from blight filament** is large
- All of the region has **less than 50% contamination ratio** in some cases



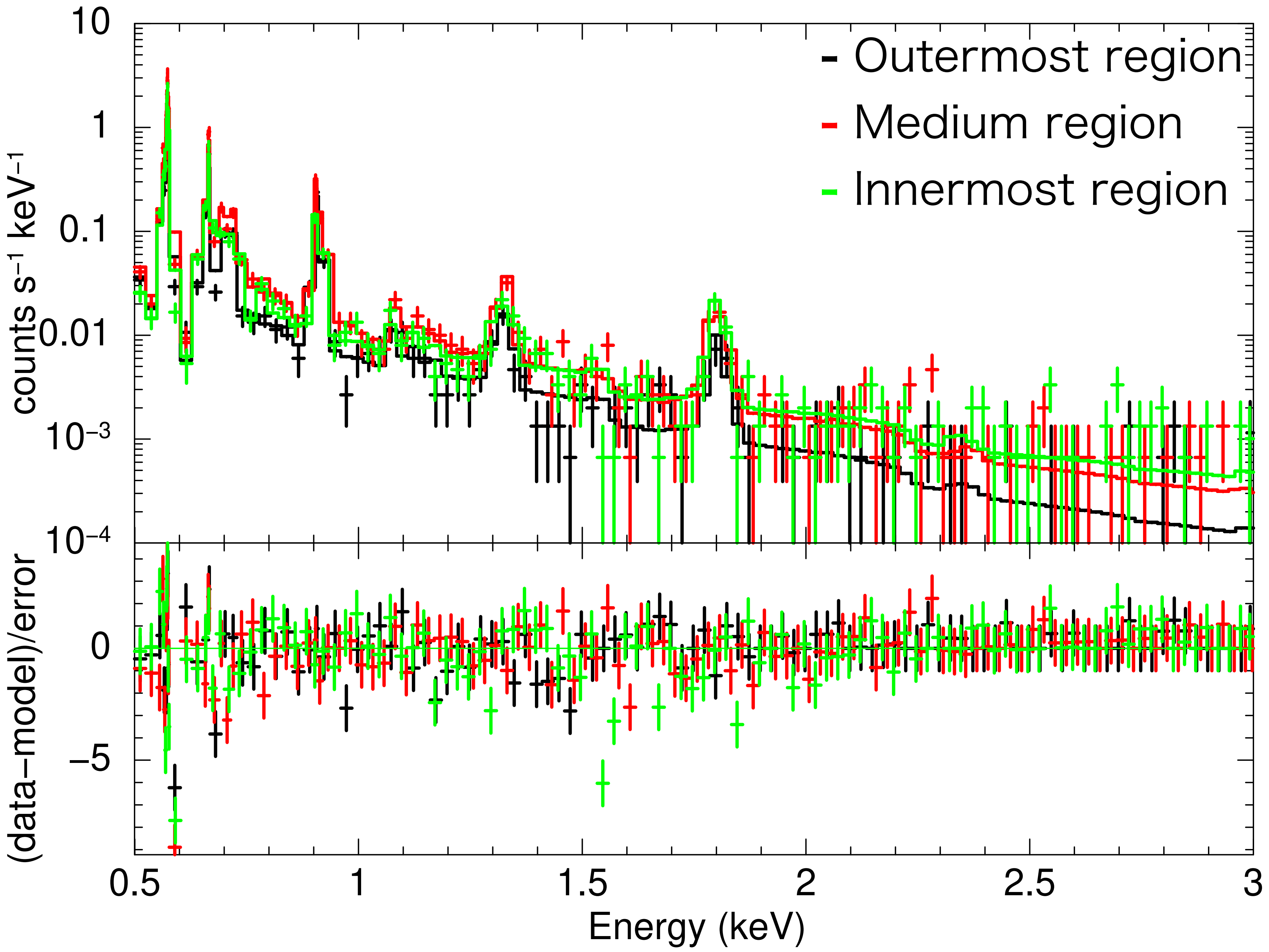
The spectra after grouping

The comparison of spectra of each grouping region

Case A



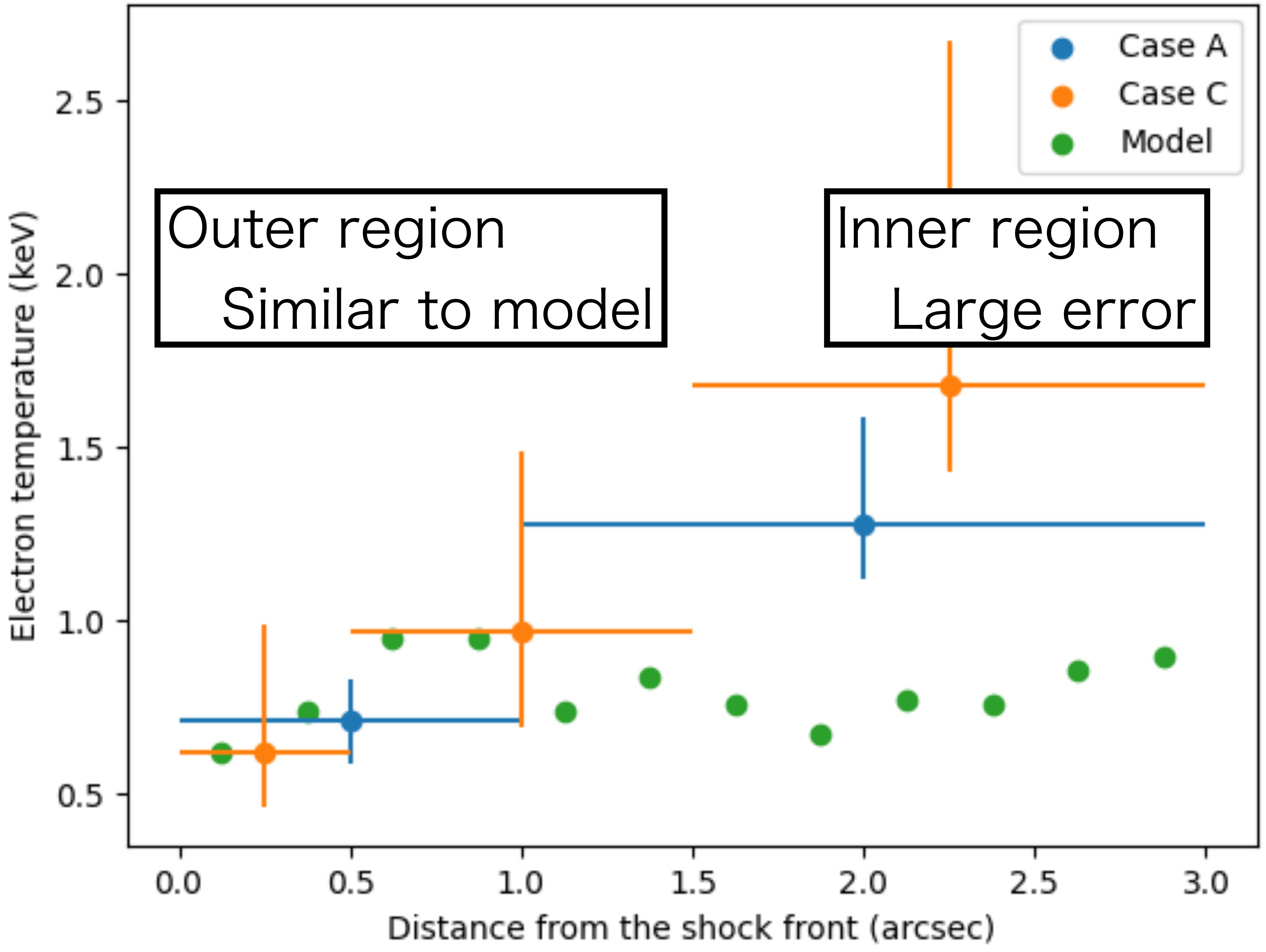
Case C

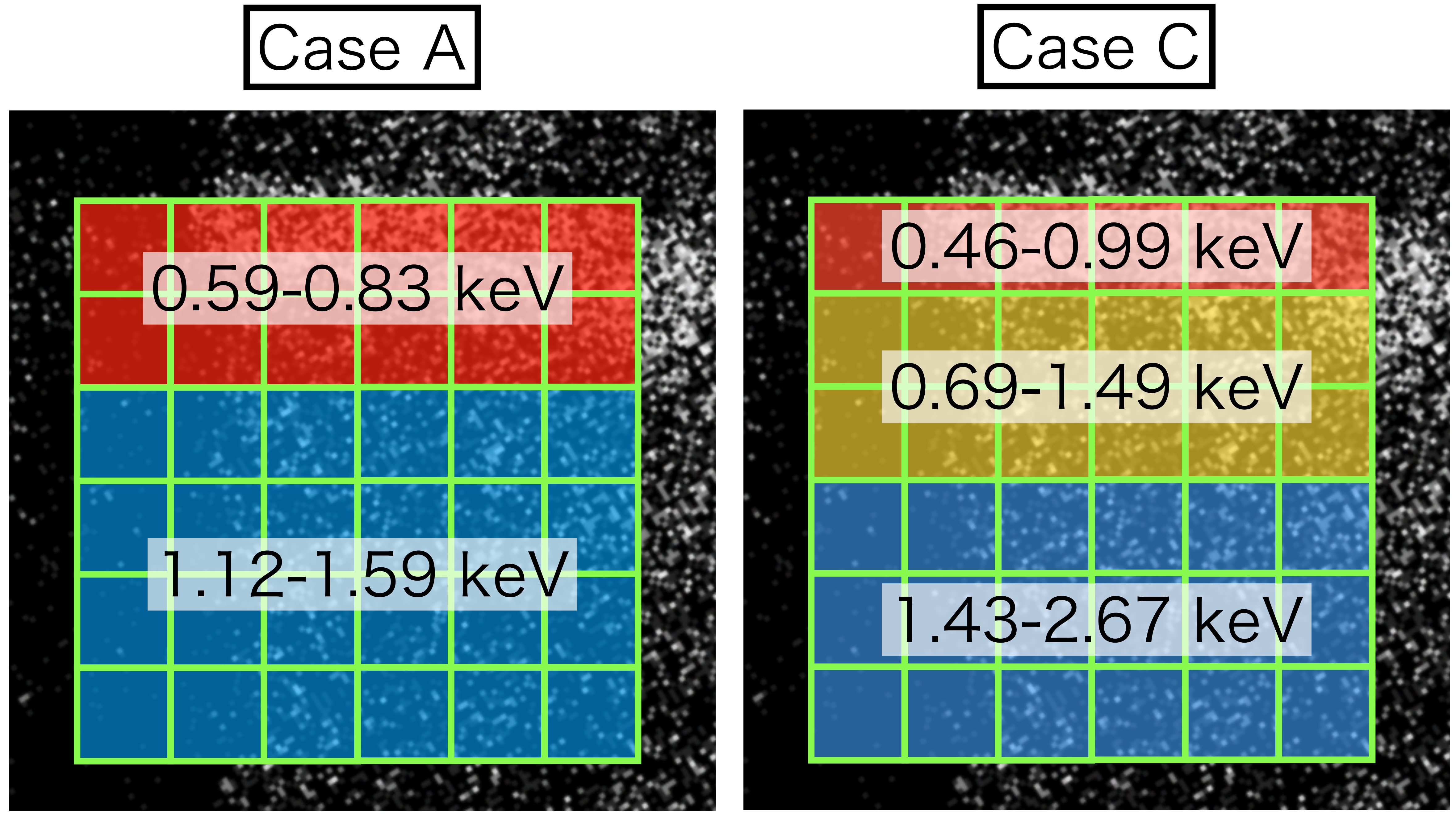


The difference of spectra can be observed (gradient, abundance, etc…)

The model fitting considering contamination is also done well

Spatial variation of the electron temperature





The spatial variation of electron temperature can be observed in the pixel grouping above

Outer region→Similar to the value of model

Inner region→ Large error, different to model

Si abundance is also significantly different

→Large indefiniteness of analysis in inner region

Summary

- Although XRISM can estimate ion temperatures due to its high energy resolution, it is difficult to estimate their spatial variation due to large HPD
- We simulate the XRISM observation of SN 1006 NW rim and research how to reduce the contamination by large HPD
- We divide the FOV of XRISM by 2 or 3 region. Their contamination are less than 50% in all region. This means that **their spectra remain some features of their regions**
- The spectra of each region is different to each other. This means that **we can observe the spatial variation of their parameter from XRISM Resolve**