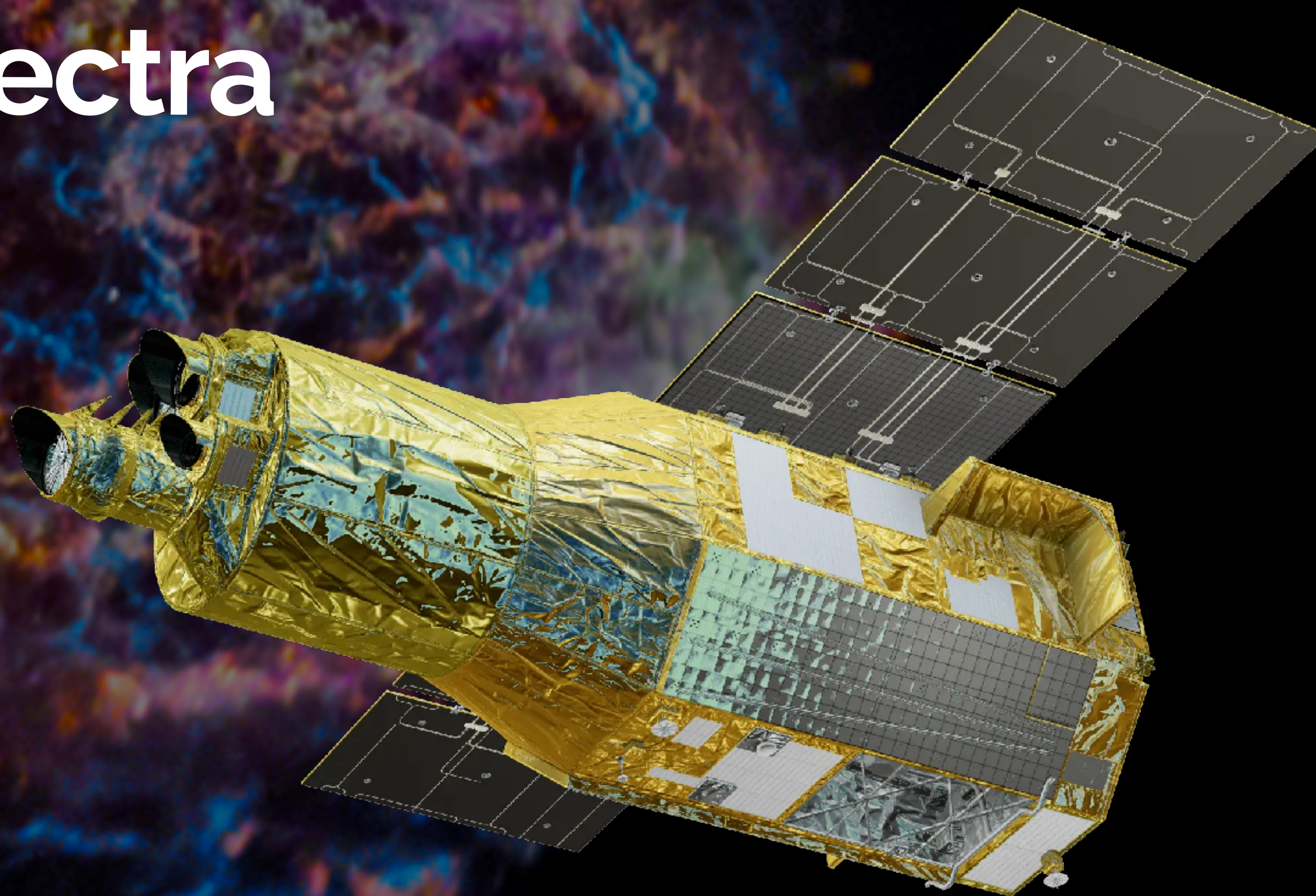


# XRISM/Resolve insights on Cassiopeia A spectra

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IACHEC | 21 April 2026 | Pelham, Germany



# Cassiopeia A

*dead-star of the show*



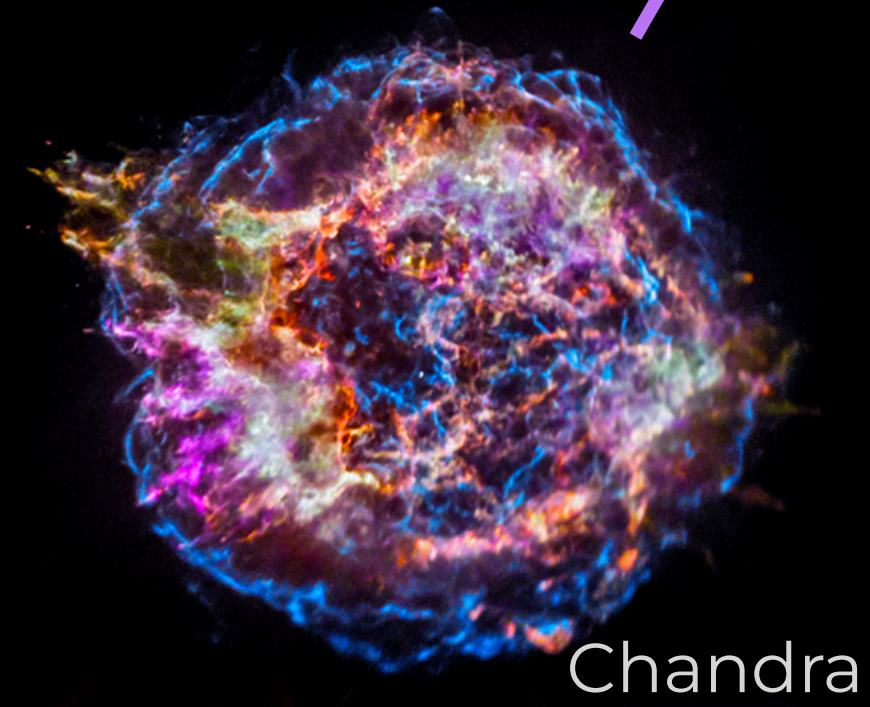
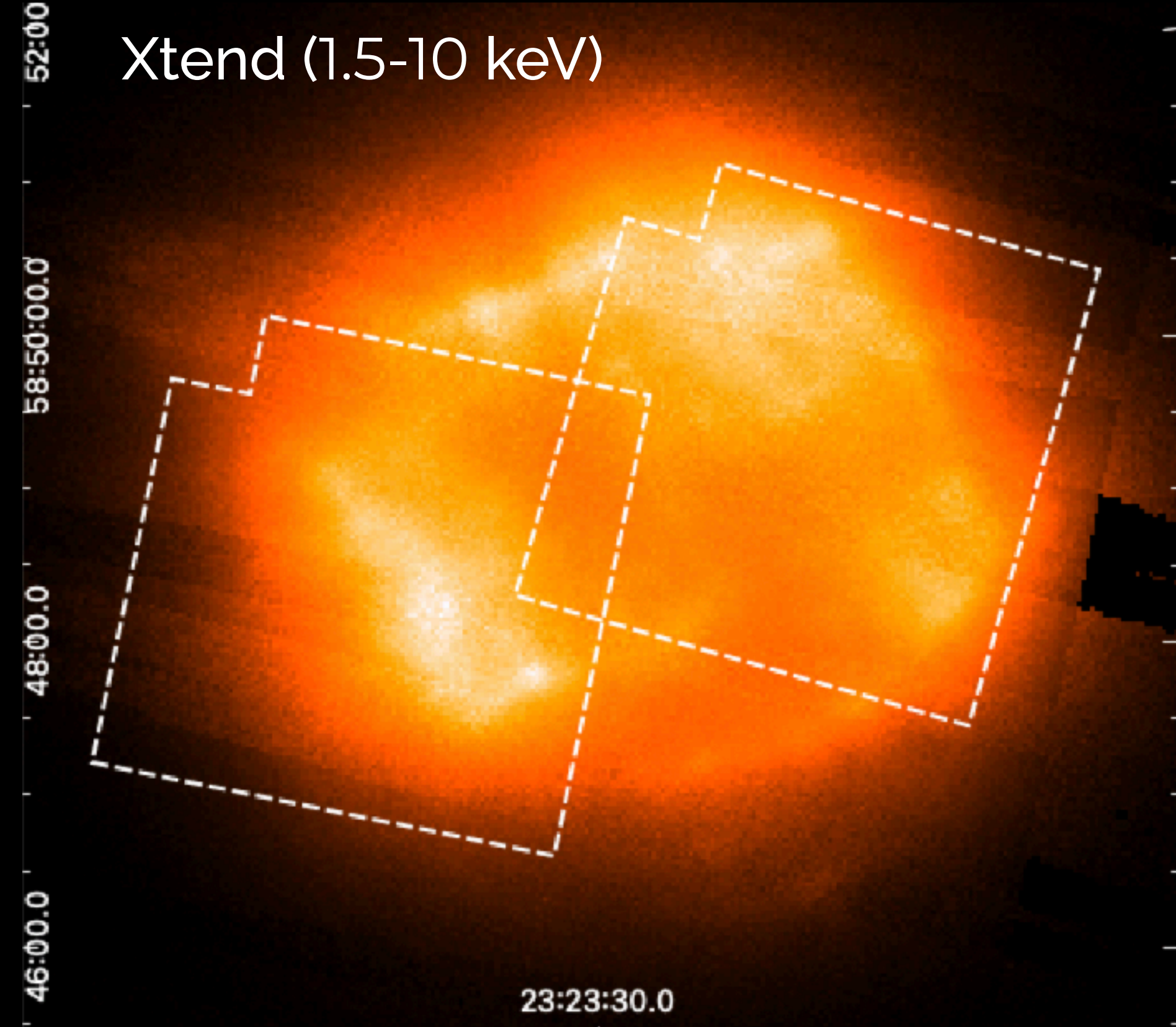
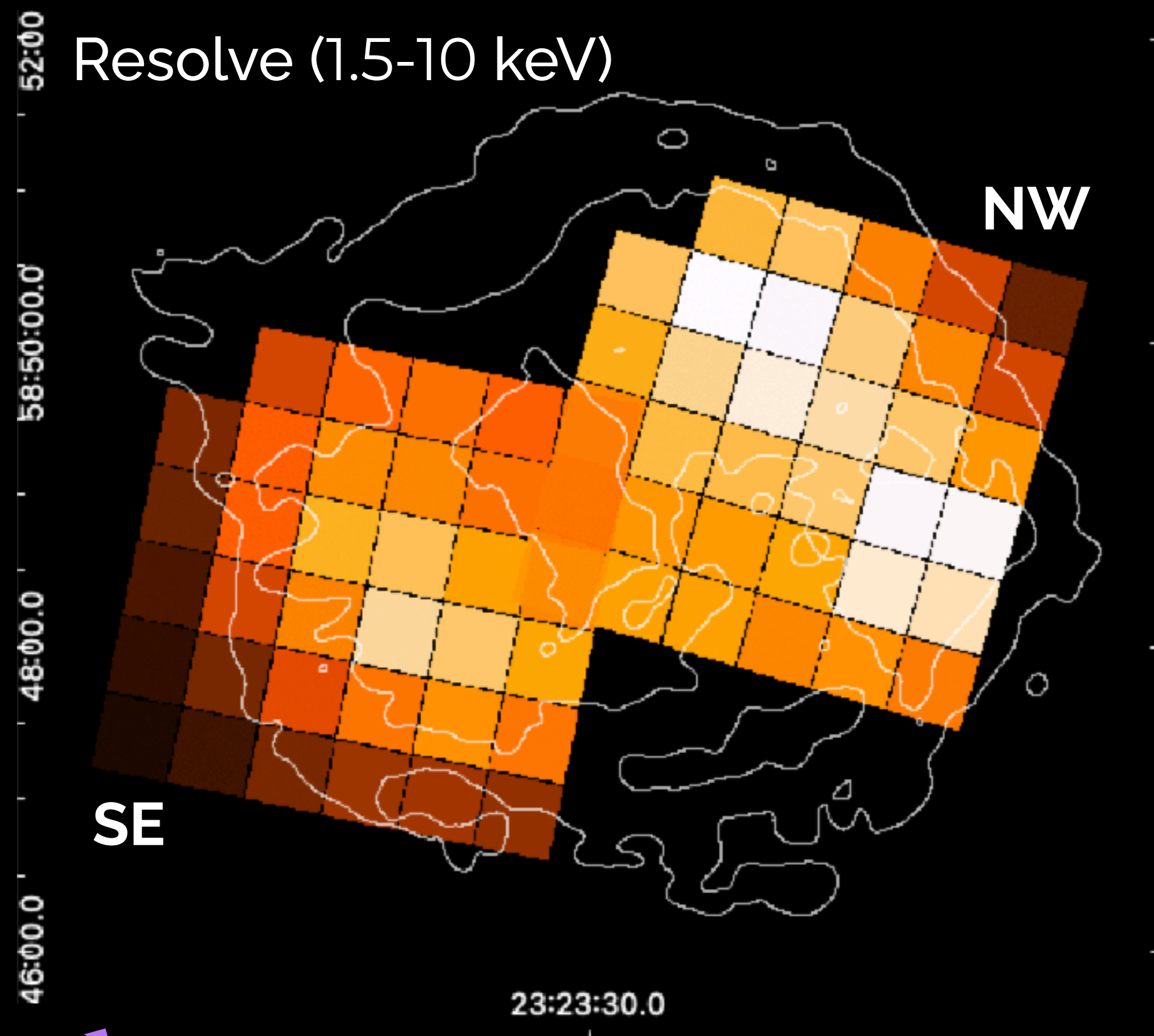
- **Youngest galactic core-collapse supernova** (~350 years)
- Nearby (~3.4 kpc or ~11,000 light-years)
- Light Echoes (Rest et al. 2008, Krause et al. 2008)
  - Secure spectroscopic classification (**Type IIb**) i.e. stripped envelope explosion of a red supergiant (15-25  $M_{\odot}$ )
  - Light echoes from different vantage points show asymmetric explosion
- Neutron star
- Benchmark system to study the formation and destruction of dust
- Brightest object in radio, and very bright in X-ray thus very well-studied across all wavelengths



*Chandra*  
(1999)

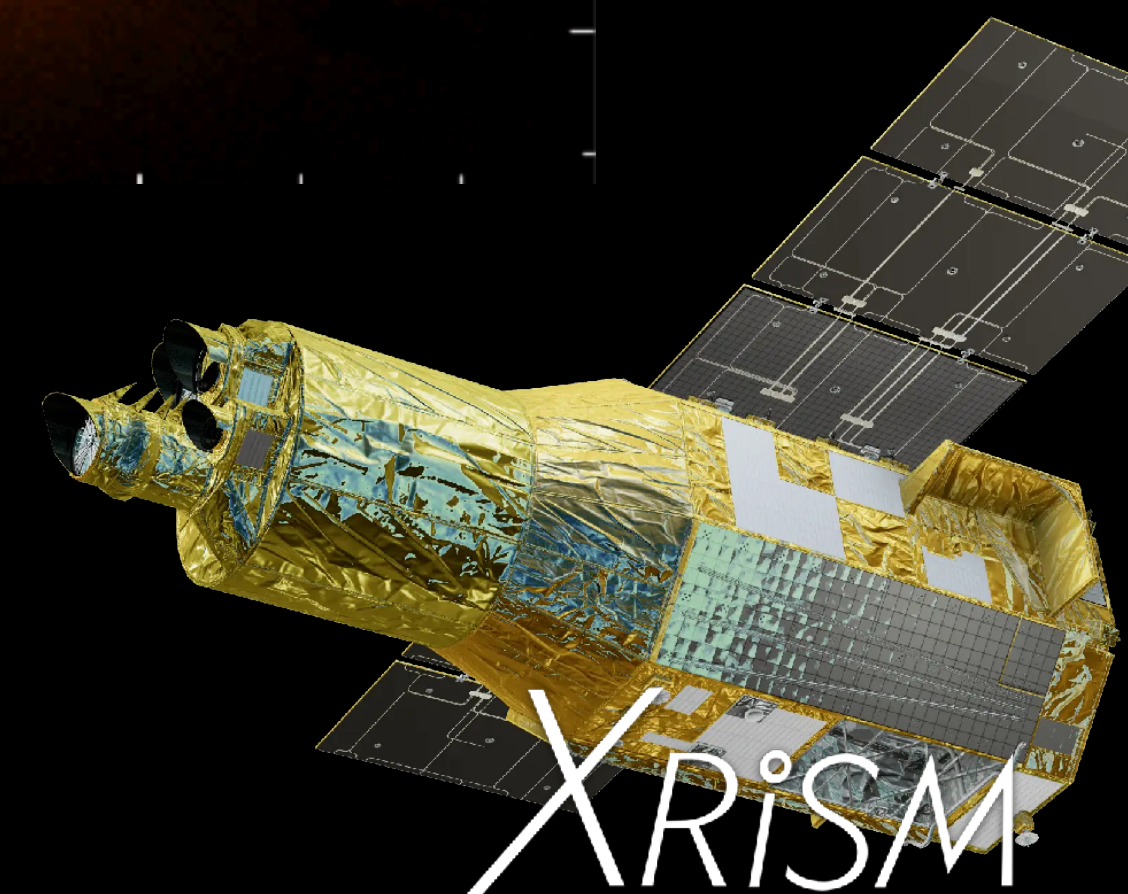
# XRISM Observations of Cas A

PI: Paul Plucinsky



Chandra

ObsID	Exposure (ks)	%Hp events
00129000 (SE)	182	96.6
00130000 (NW)	167	96.2



次回

# XRISM Cassiopeia A

- **Overview paper**

Plucinsky P., Agarwal M.,+ 2025 (*PASJ XRISM special issue*)

- **Mapping Dynamics of Si/S ejecta**

Vink J., Agarwal M.,+ 2025 (*PASJ XRISM special issue*)

Suzuki+ 2025 (*PASJ XRISM special issue*)

- **Mapping Dynamics of Fe ejecta**

Bamba A., Agarwal M.,+ 2025 (*PASJ XRISM special issue*)

- **Detection of P, Cl, and K**

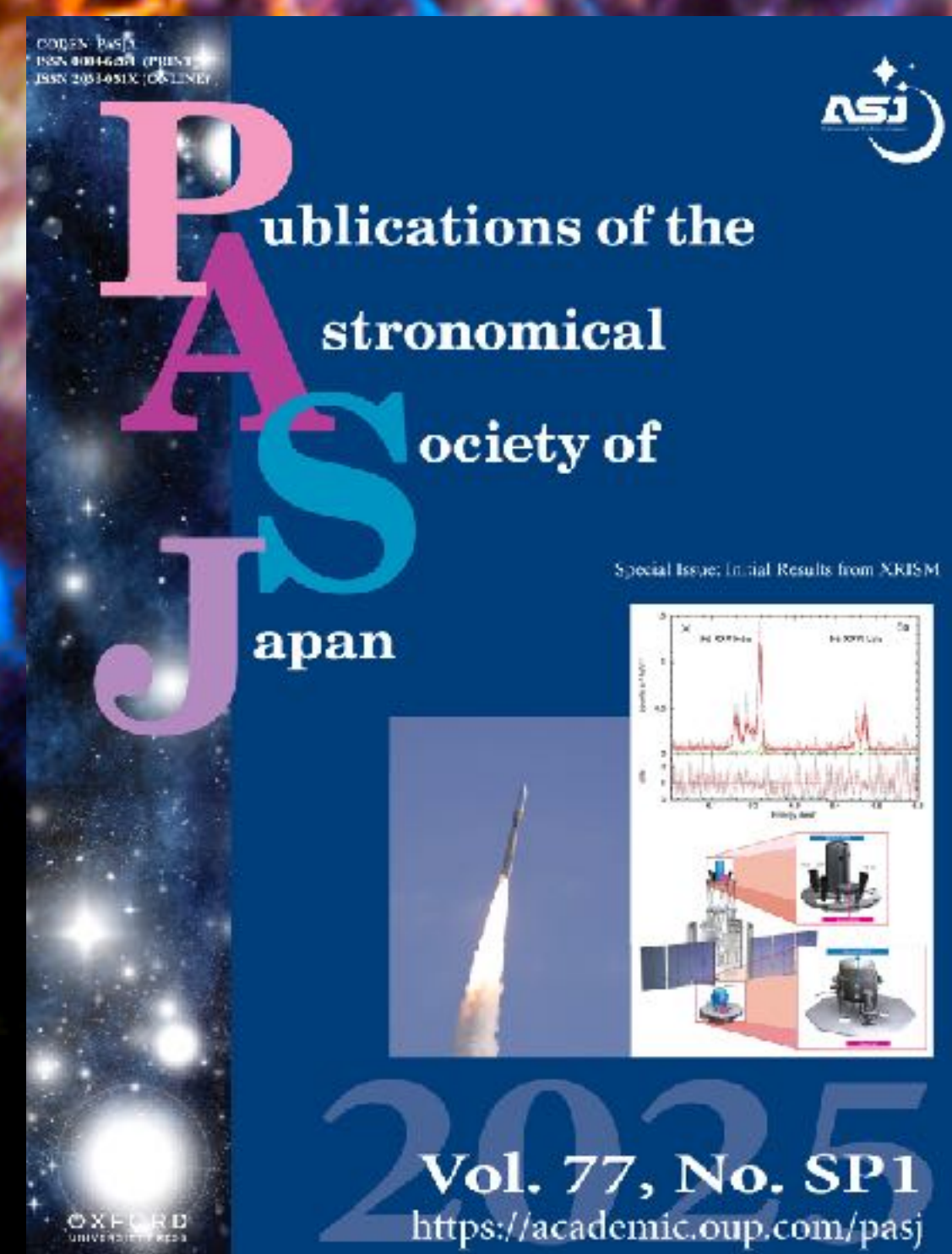
XRISM Collab.,+ 2025 (*Nature Astronomy*)

- **Mapping Plasma properties - Physical model - UltraSPEX**

Agarwal M.,+ 2026 (*ApJ*)

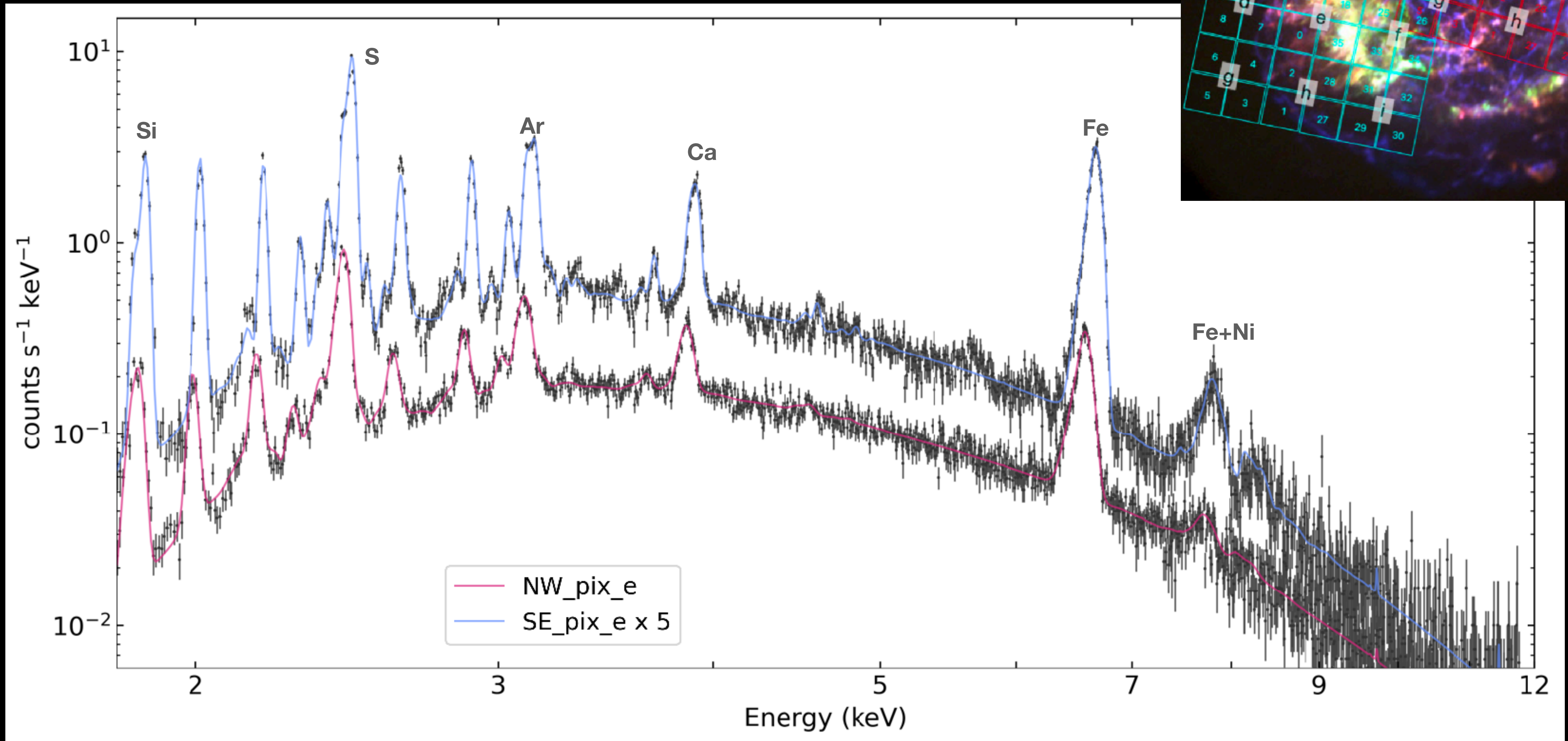
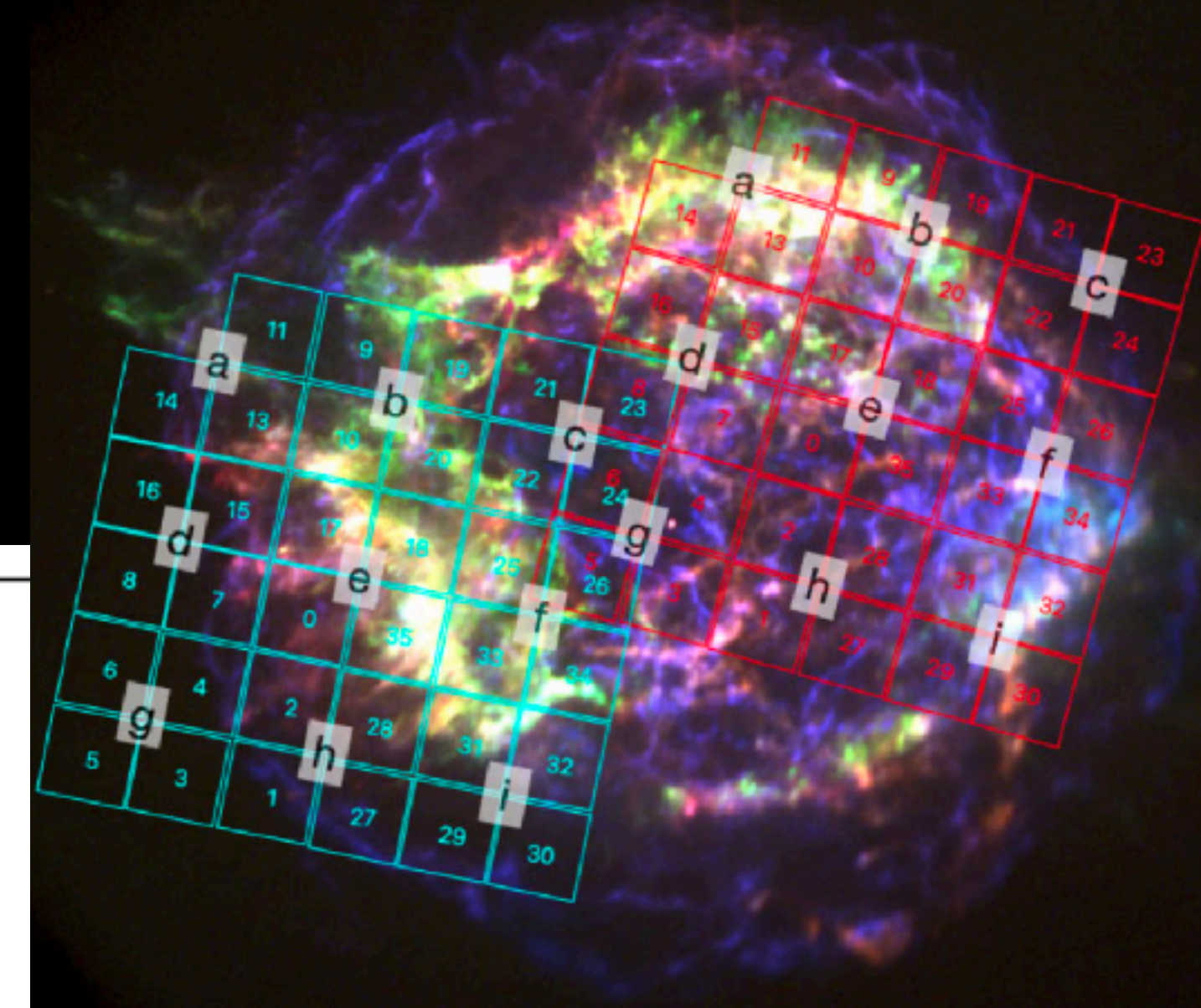
- **Fe-peak elements - Ti, Cr, Mn, Fe, Ni**

Sato T.,+ 2026 (*ApJ*)

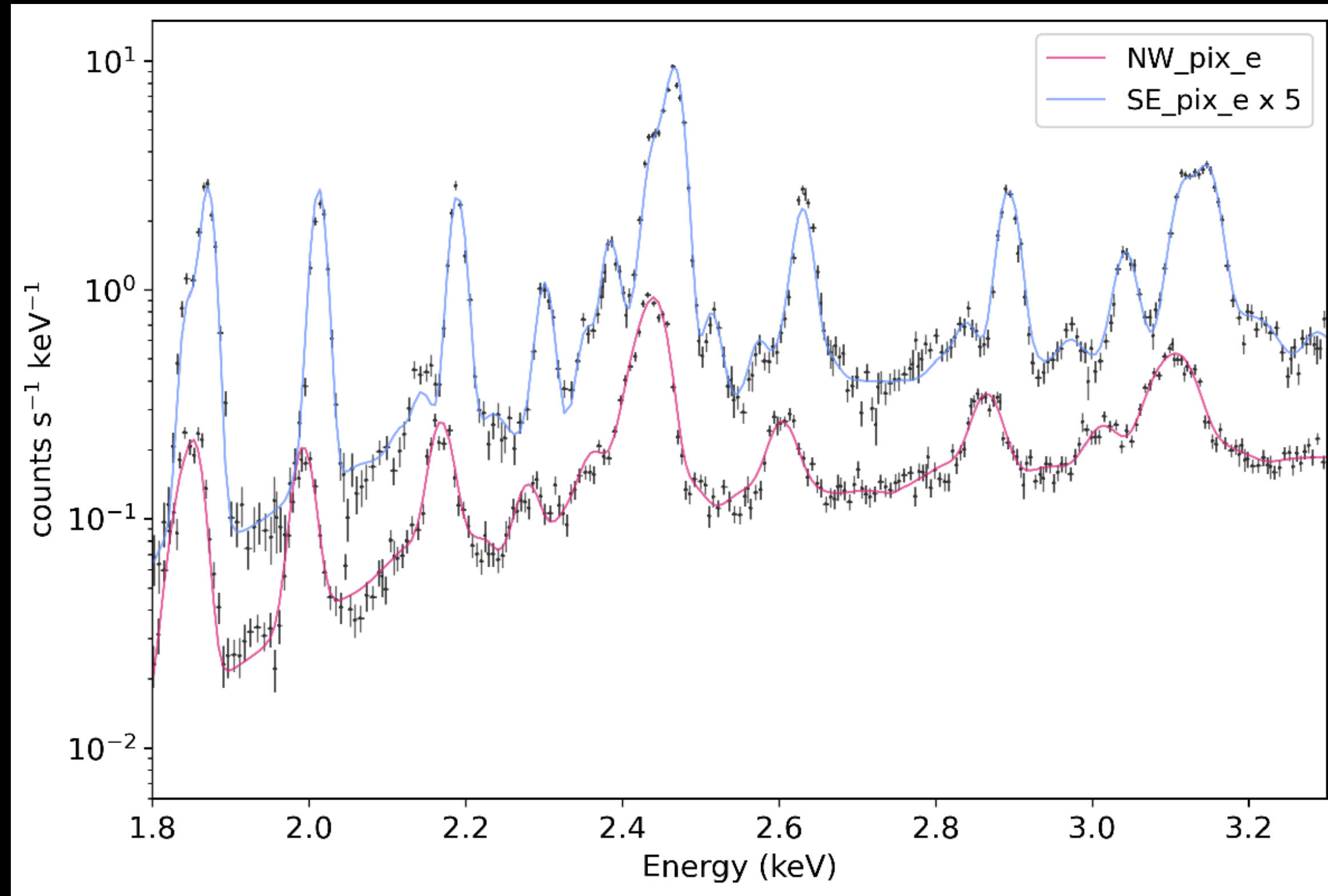


# XRISM/Resolve 2x2 pixel spectra

Differences in redshift, line broadening, non-thermal contribution

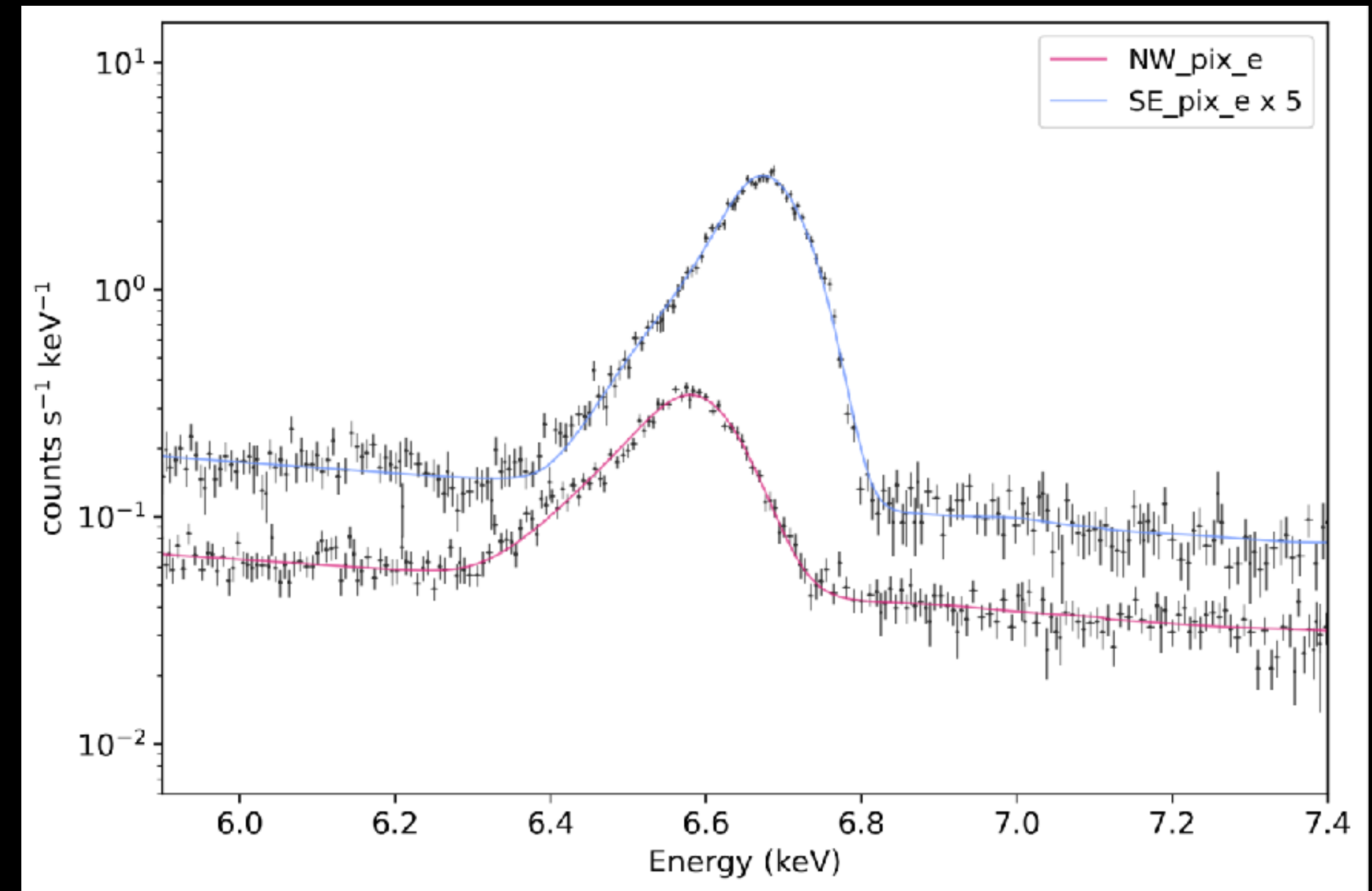


# Si/S



Clearly separated lines  
from different charge states

# Fe-K



Prominent red-tail  
Low-charge state ions  
Model with *pshock* (plane-parallel shock)

NB: *pshock* model is now available in SPEX!  
modelled as a linear combination of 200 NEI shells

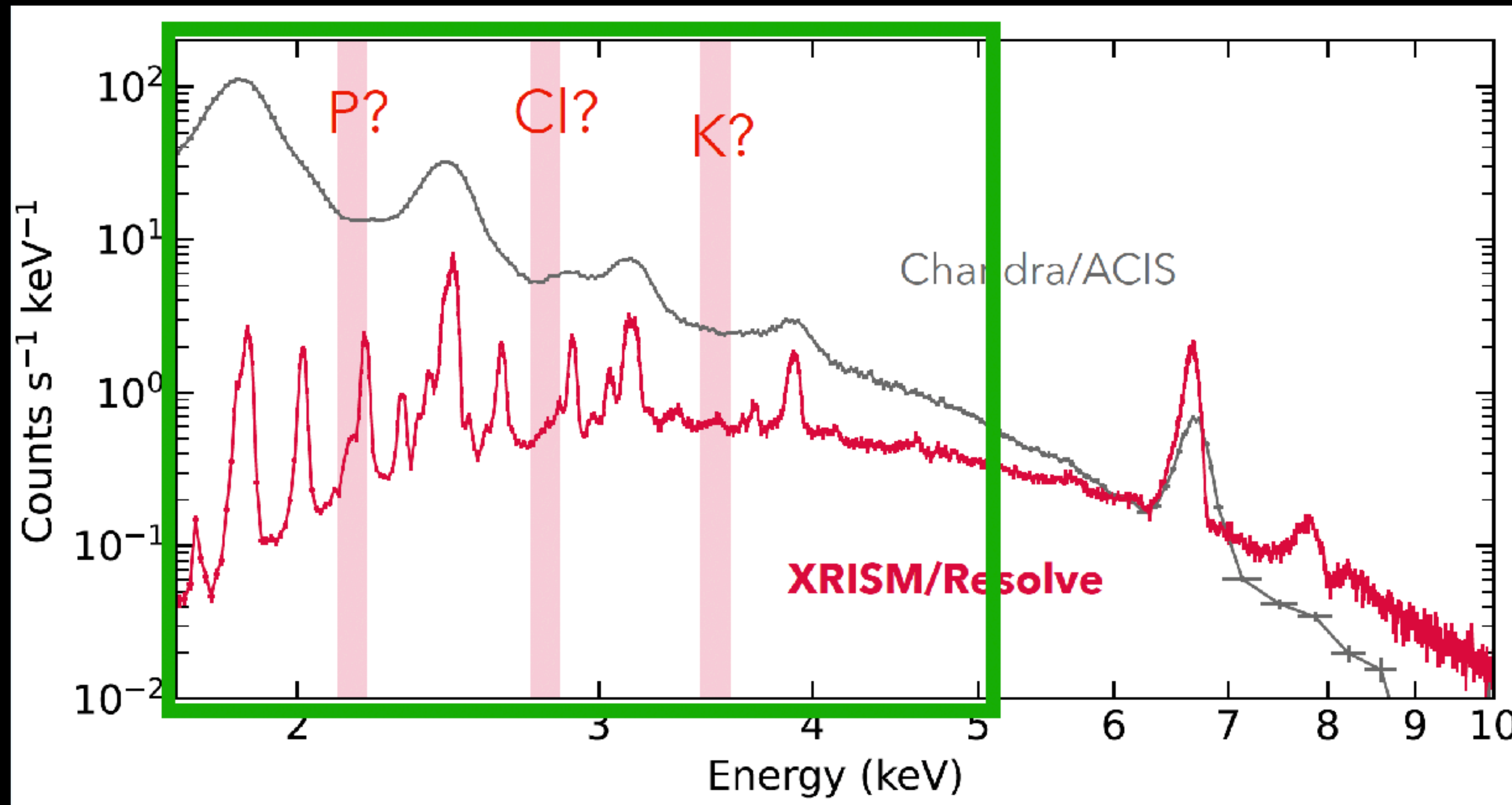
New spectral features:

# I. Detection of trace elements

# Looking for odd-Z elements with XRISM

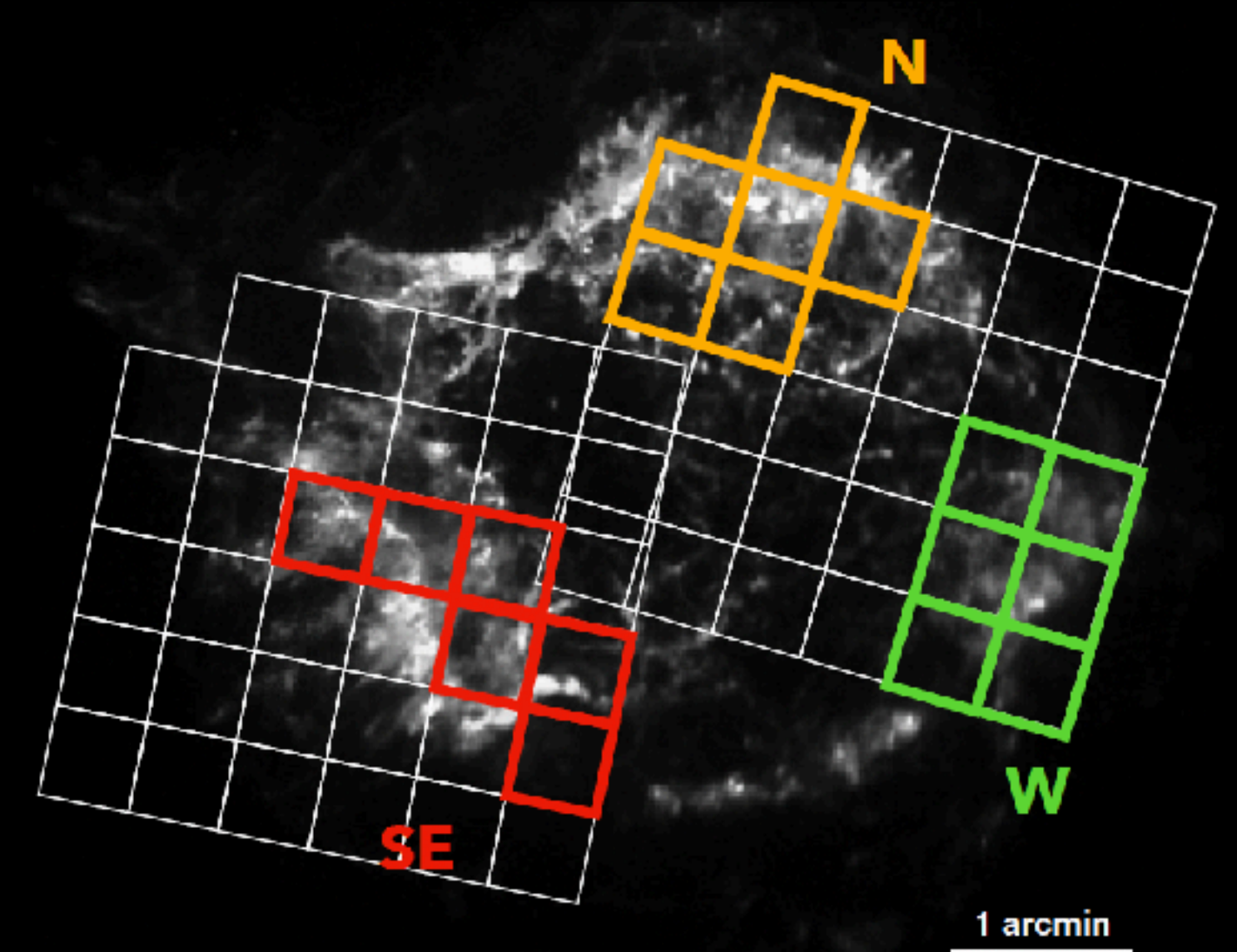
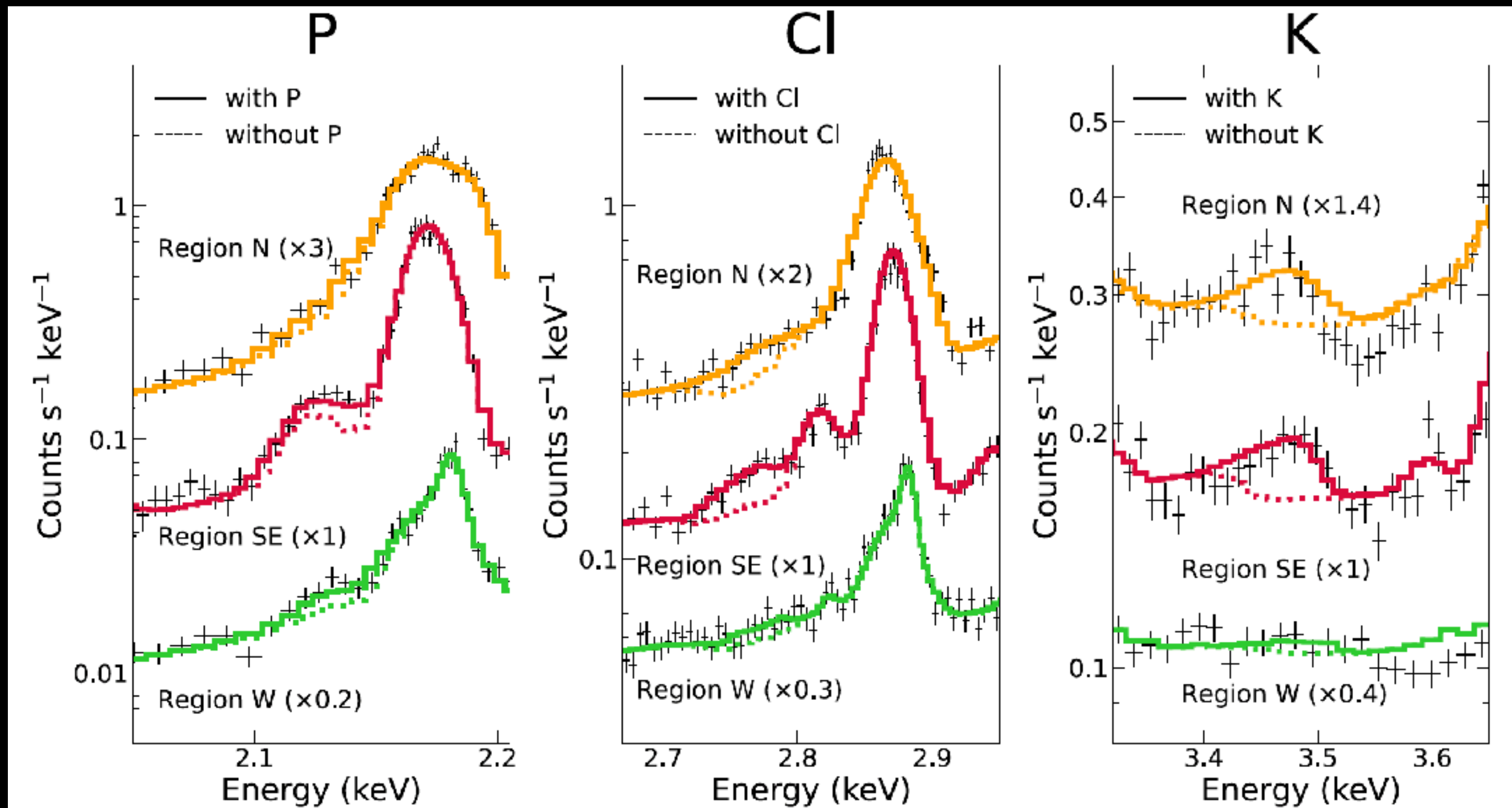
Potassium (K), chlorine (Cl), and phosphorus (P) are trace yet essential odd-Z elements that play crucial roles in planetary formation and biology. However, their cosmic origins are still poorly understood.

Cas A is the only SNR where **near-infrared** emissions from **P** have been detected (Koo+ 2013)



Credits: T. Sato,  
K. Matsunaga,  
H. Uchida

# First detection of Cl and K (XRISM Collab.+ 25, *Nature Astronomy*)



Credits: T. Sato,  
K. Matsunaga,  
H. Uchida

In the SE and N regions,

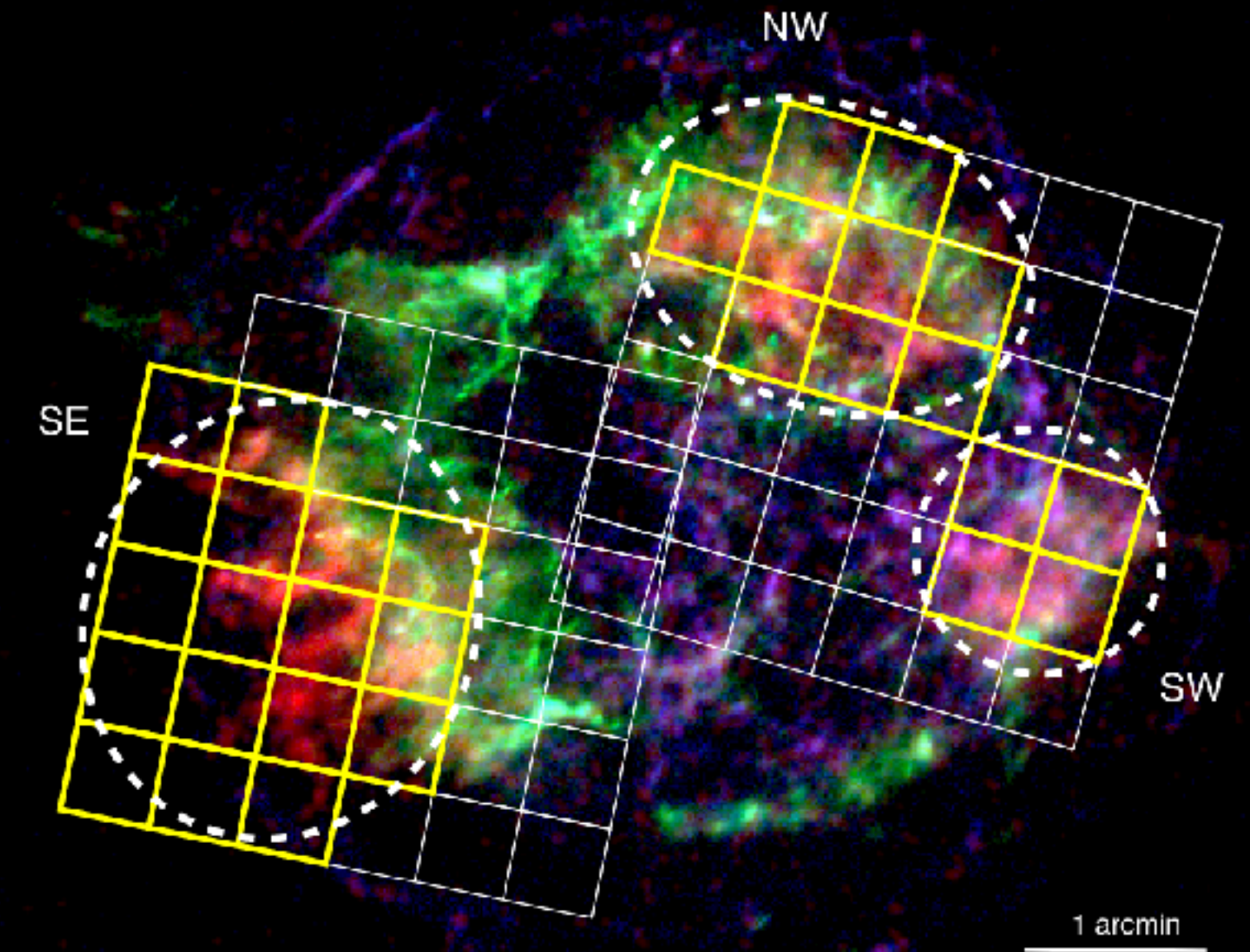
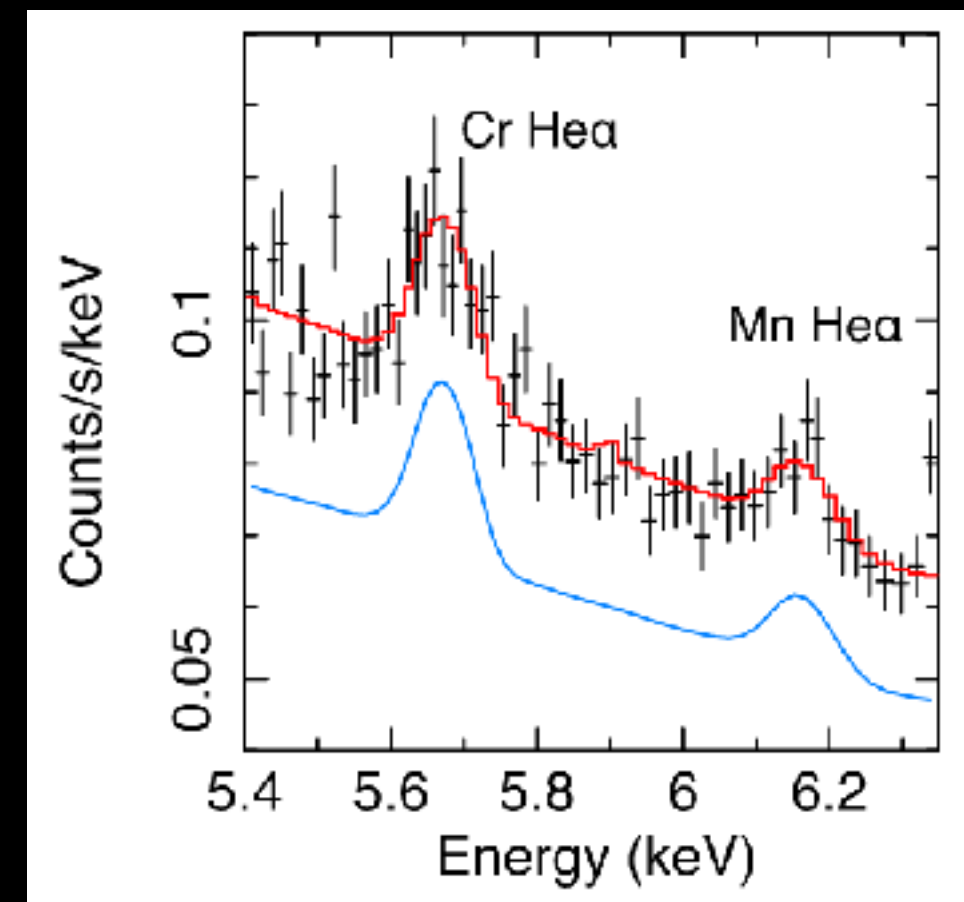
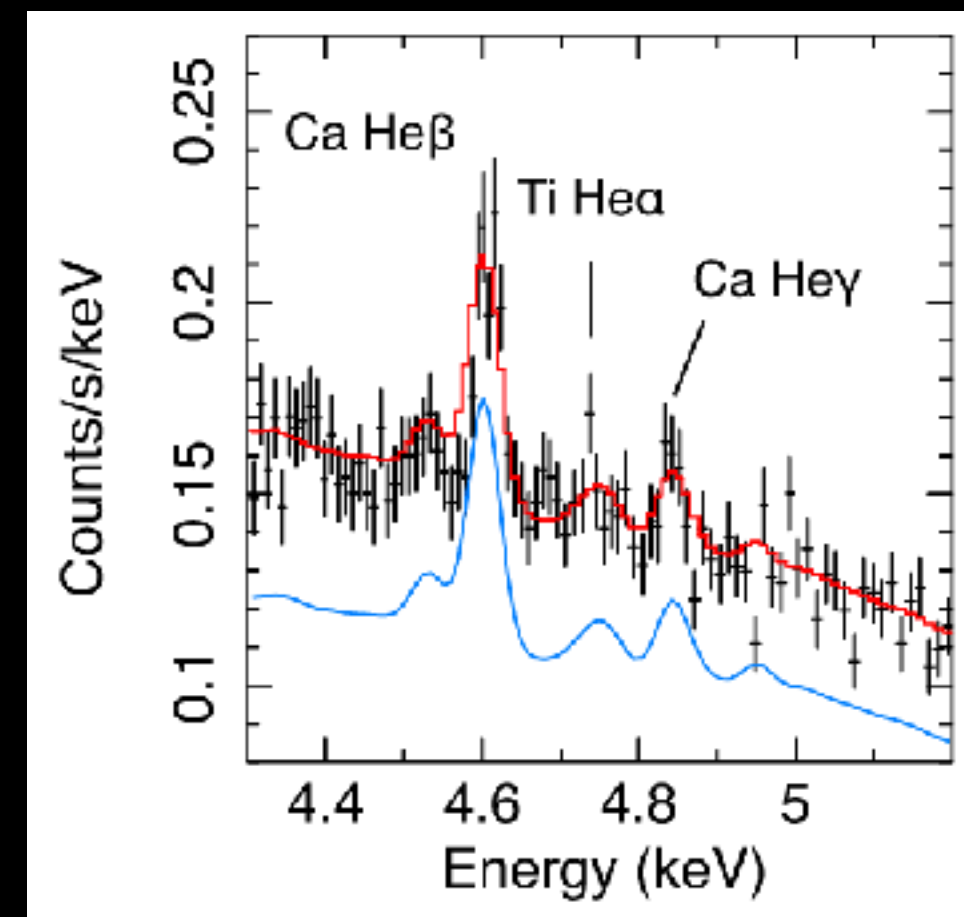
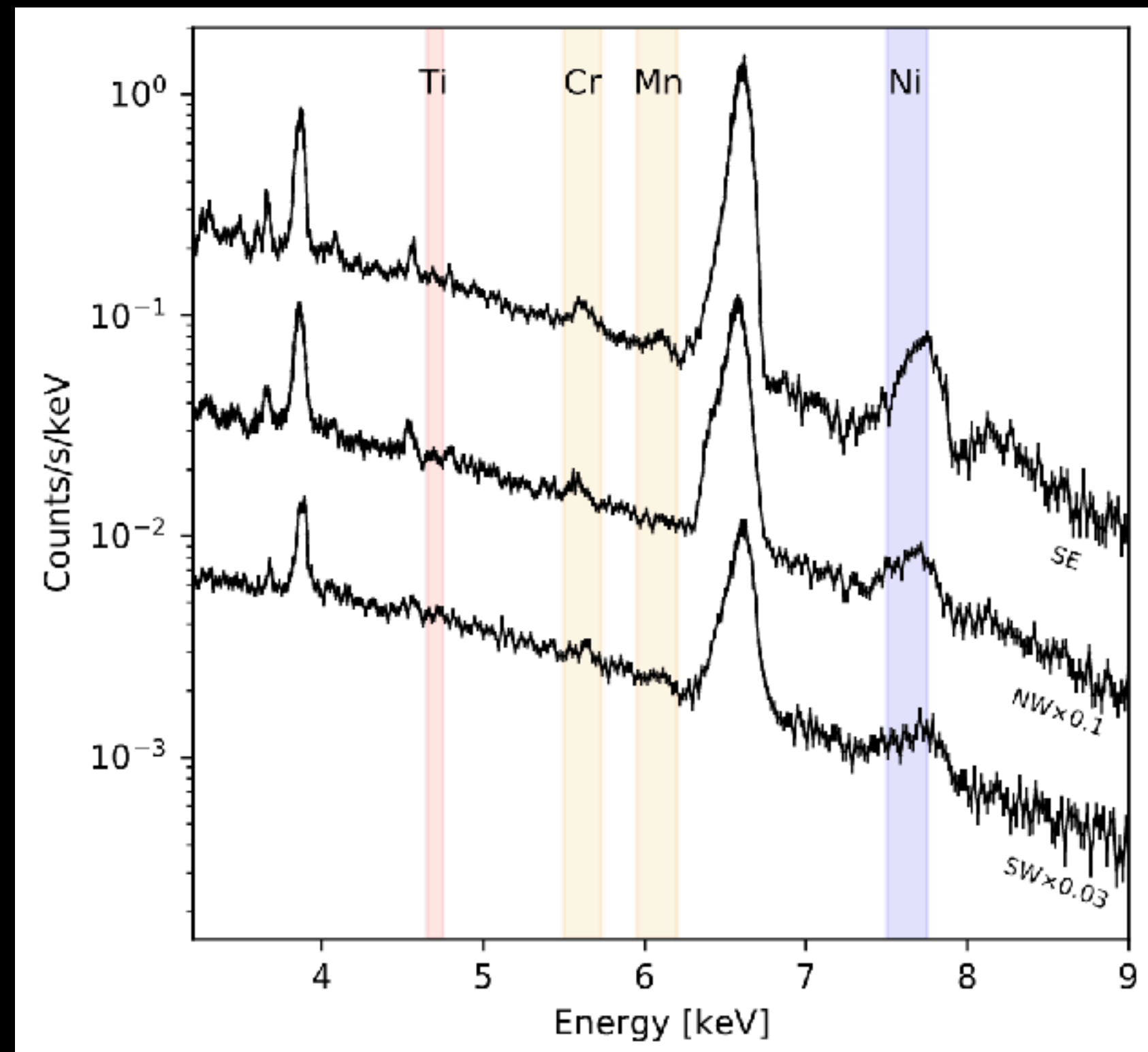
Chlorine (Cl) -  $\gtrsim 5\sigma$

Potassium (K) -  $> 6\sigma$

Phosphorus (P) less significant due to line broadening

Inhomogeneous distribution of elements

# Fe-peak elements (Sato T.+26, *ApJ*)



In the SE regions,

Titanium (Ti) -  $\sim 2 - 3\sigma$

Chromium (Cr) -  $> 8\sigma$

Manganese (Mn) -  $\sim 4\sigma$

Inhomogeneous distribution of elements

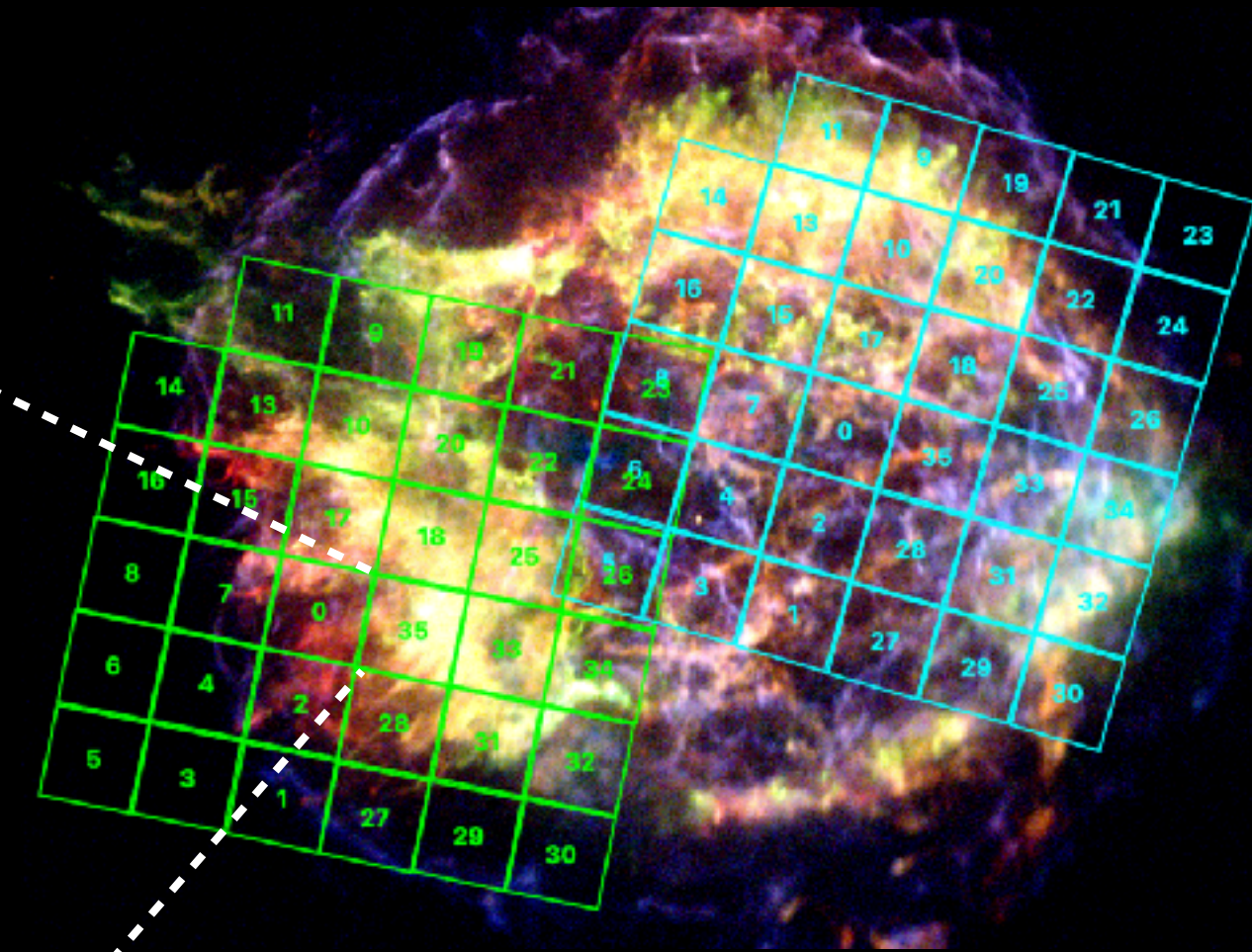
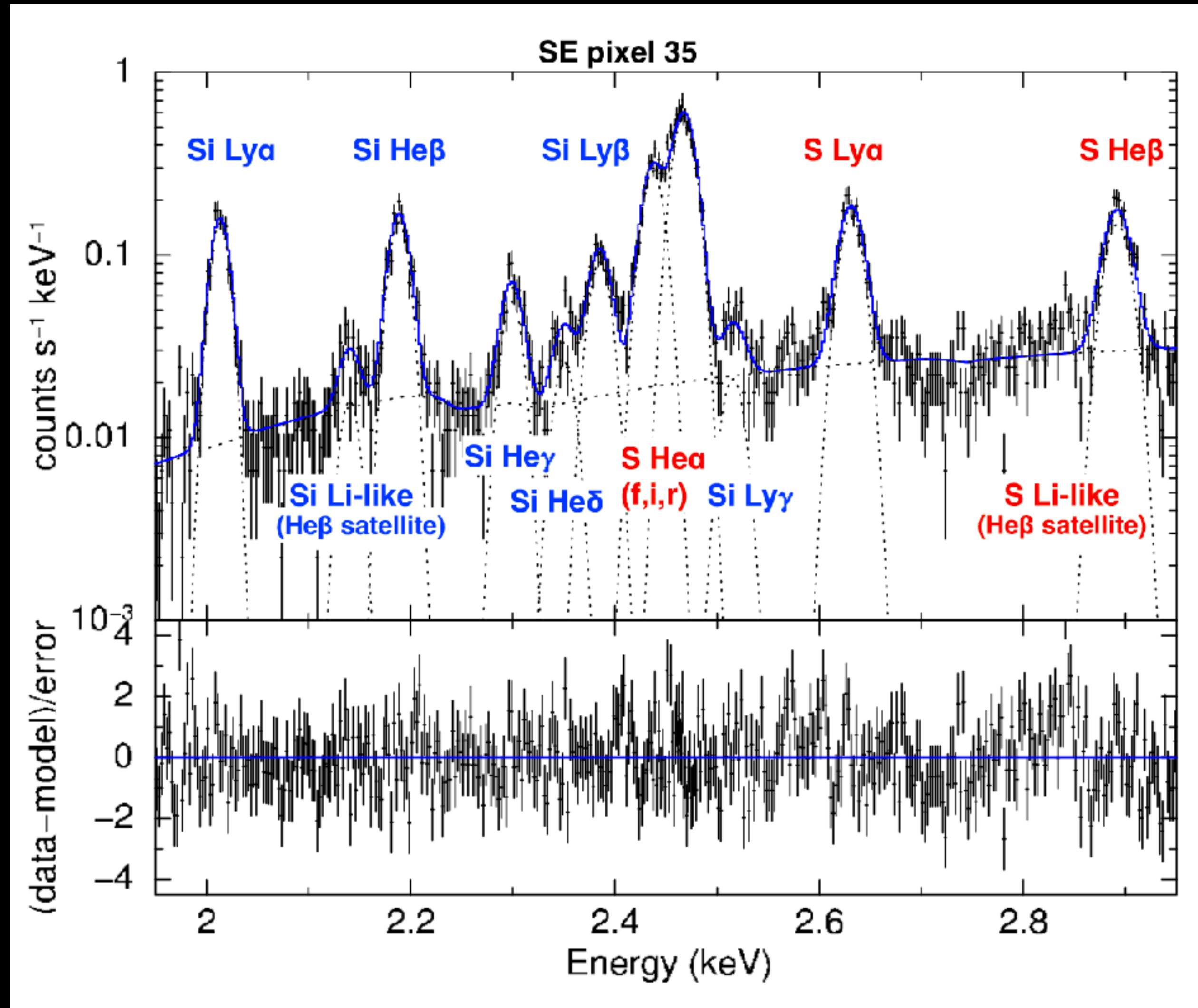
New spectral features:

**II. Line velocity variation with  
ionisation state**

**III. Line Broadening**

# Mapping dynamics of Si/S ejecta - Gaussian analysis

Vink J., Agarwal M.,+ 25 (PASJ special issue)



Goal: understand asymmetries

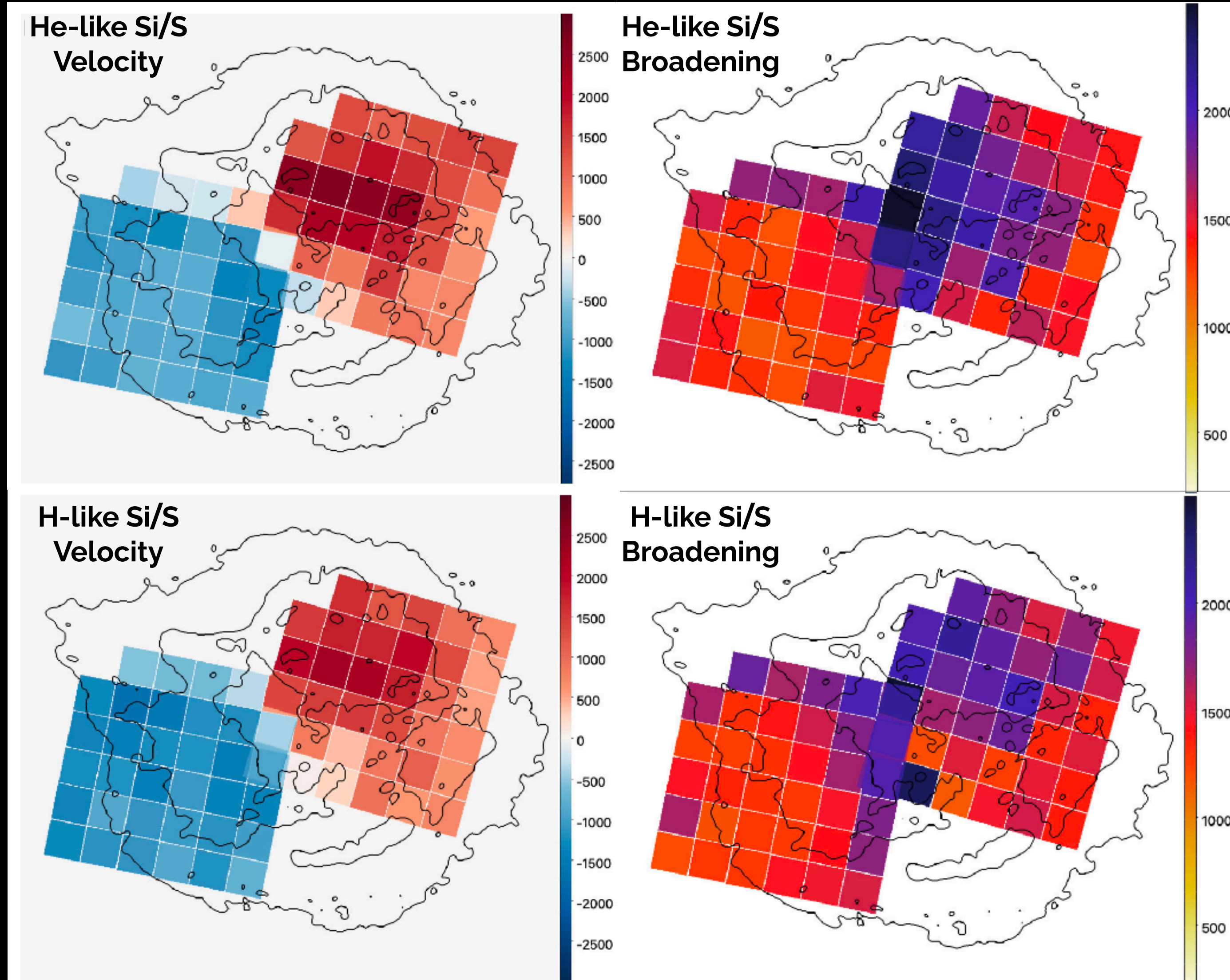
**1.95 - 2.95 keV**

Resolved individual lines of Si XIII, Si XIV, S XV, and S XVI

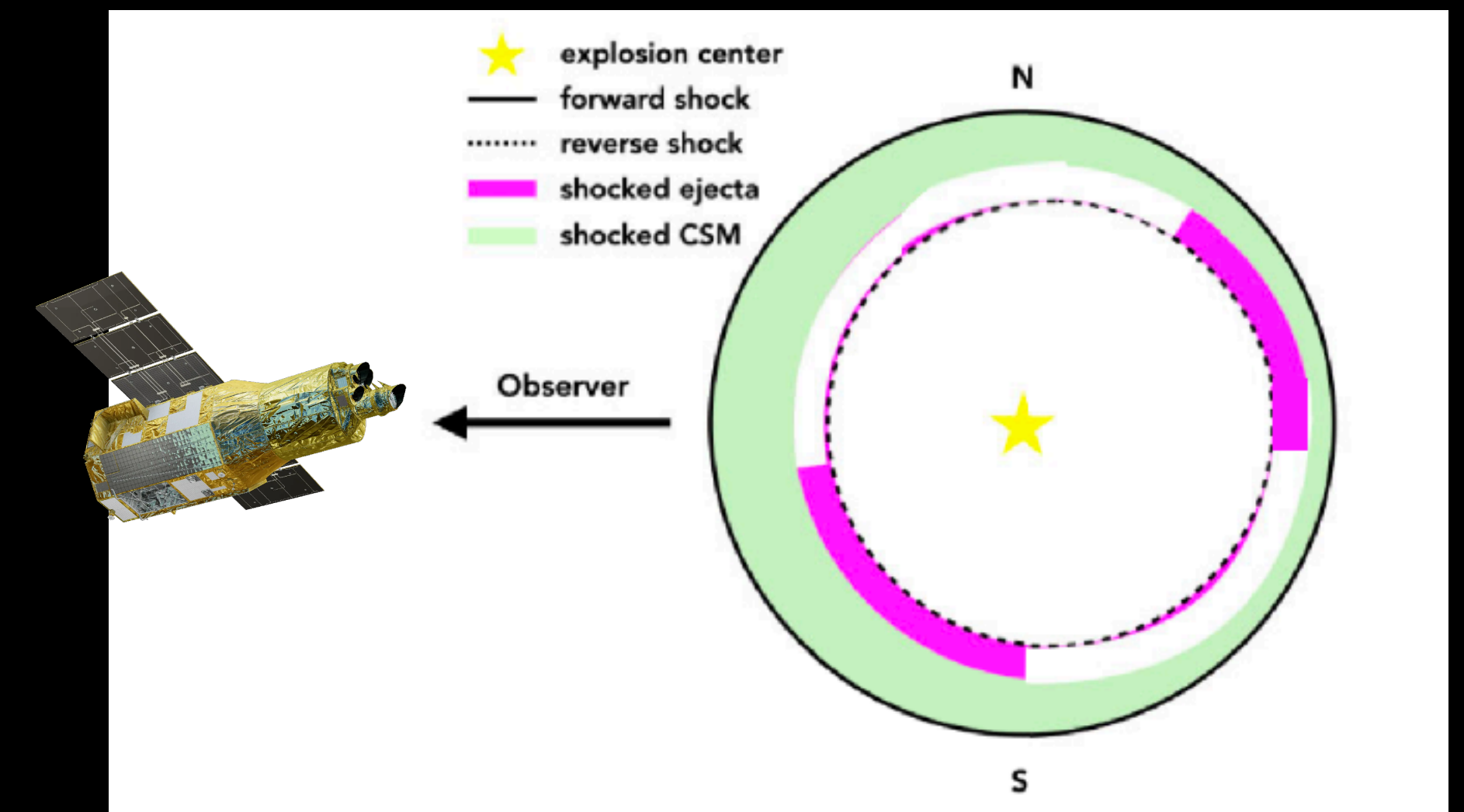
**H-like and He-like lines have systematically different Doppler shifts across the remnant**

# H-like lines faster than He-like

Vink J., Agarwal M.,+ 25; Sukuki S.,+ 25 (PASJ)

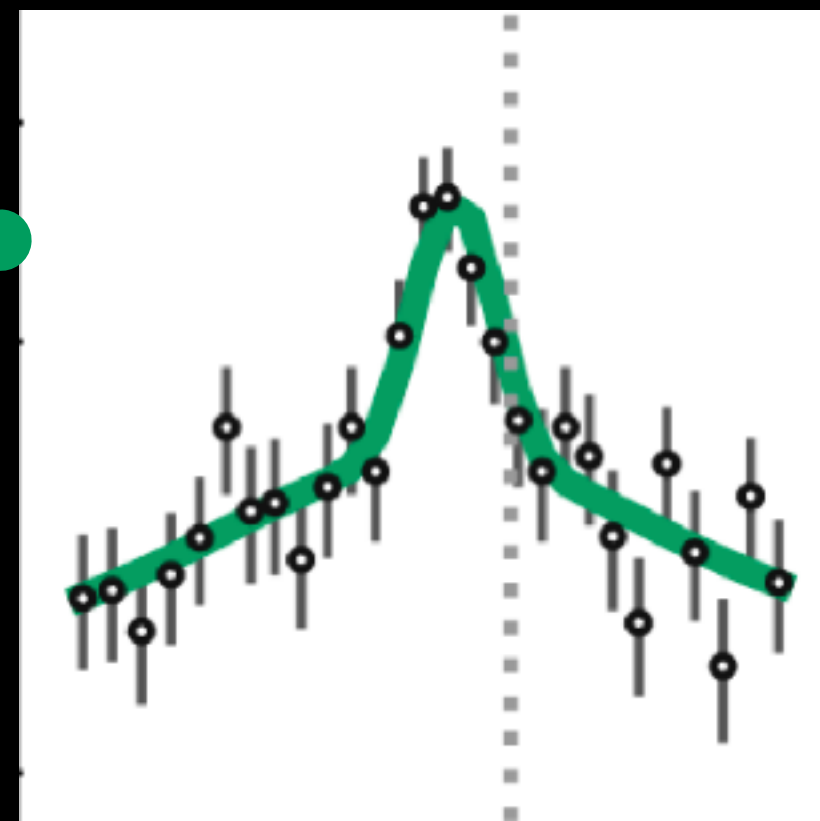
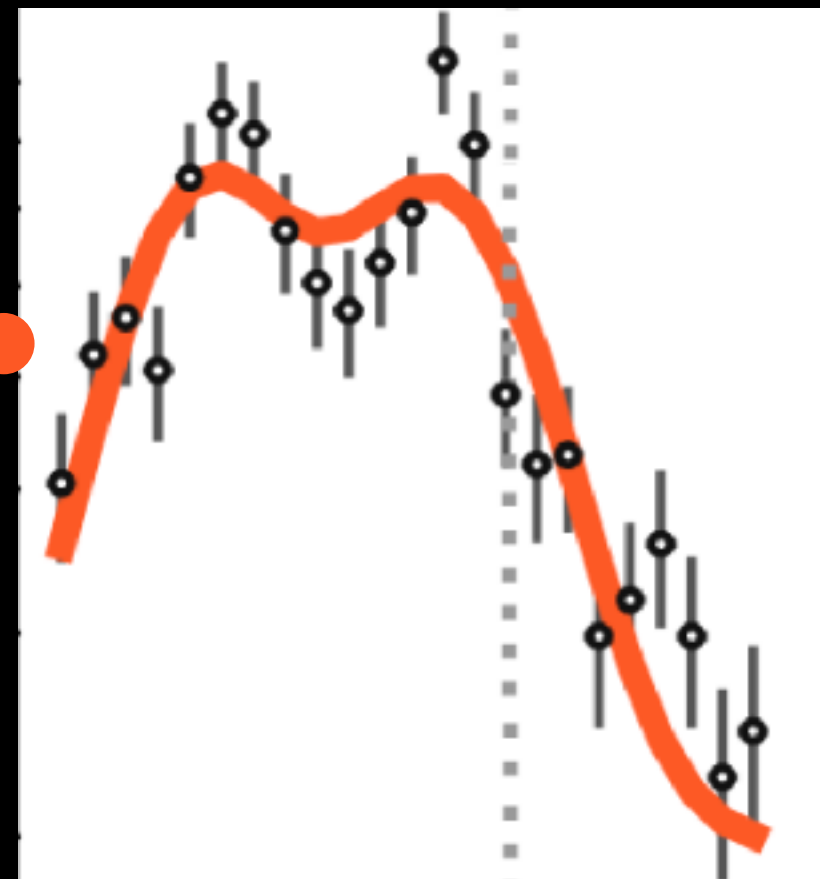
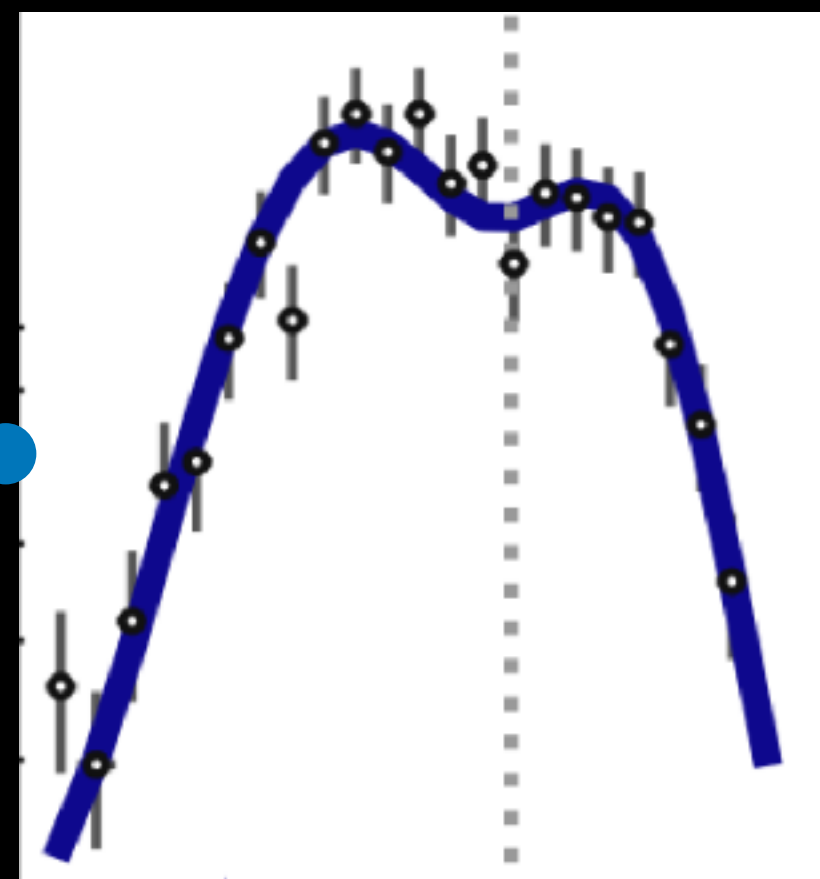
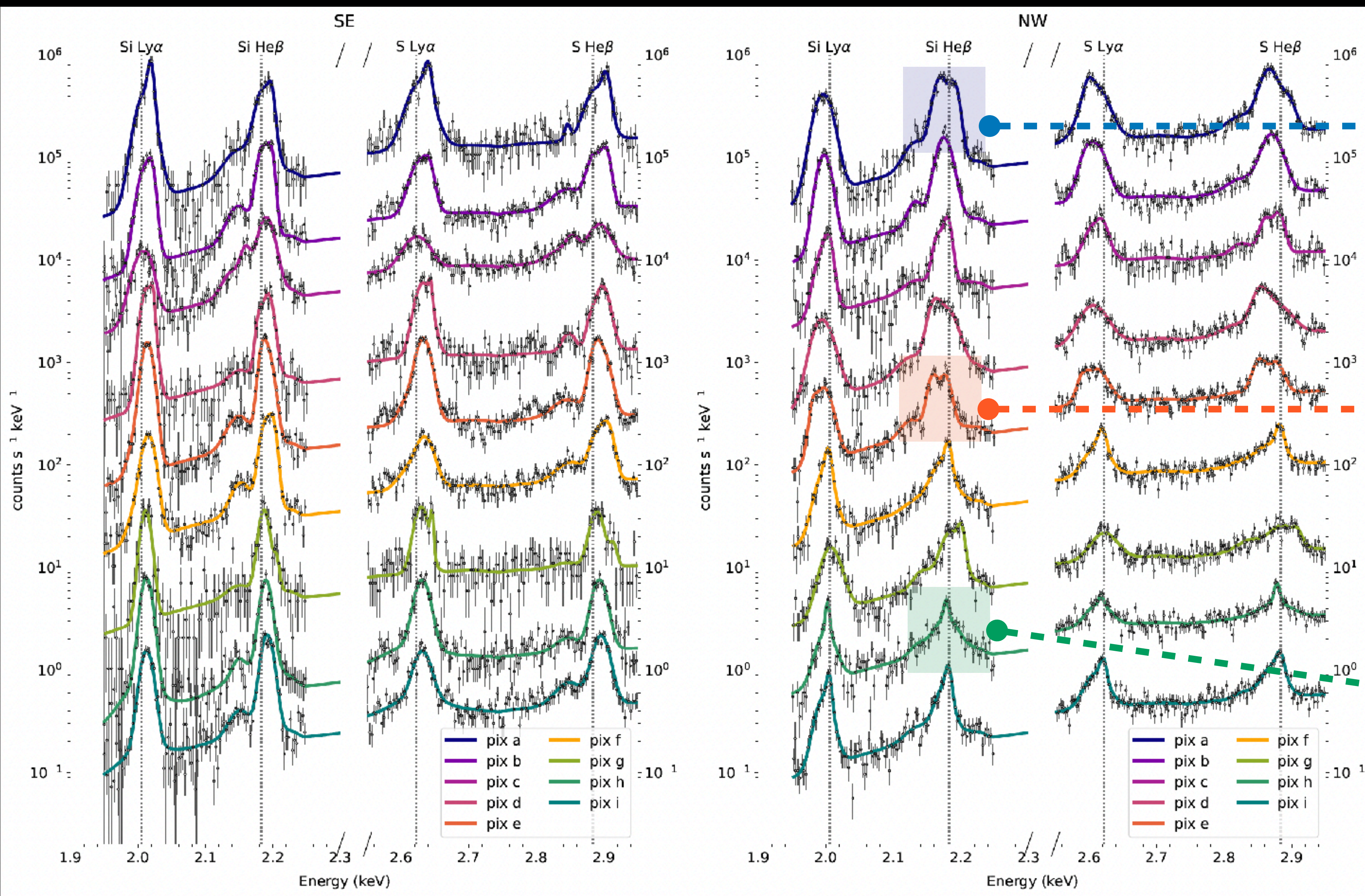


- Generally, the **H-like lines have a higher absolute velocity** compared to He-like lines
- Suzuki+ 25, we explain this with a two-component NEI model - the **ejecta with a higher velocity** are shock heated earlier, and thus a **higher ionization** is achieved
- Caveat: In some regions in NW we find He-like lines to be faster



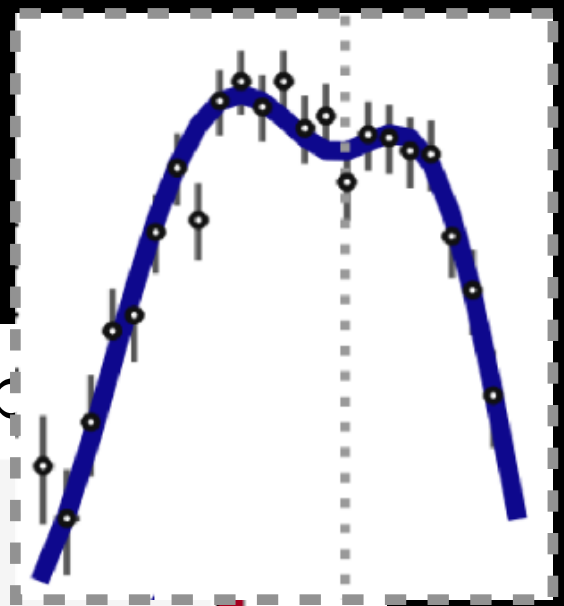
# Double Gaussian fitting - line profiles (Vink J., Agarwal M.,+ 25)

Si He $\beta$

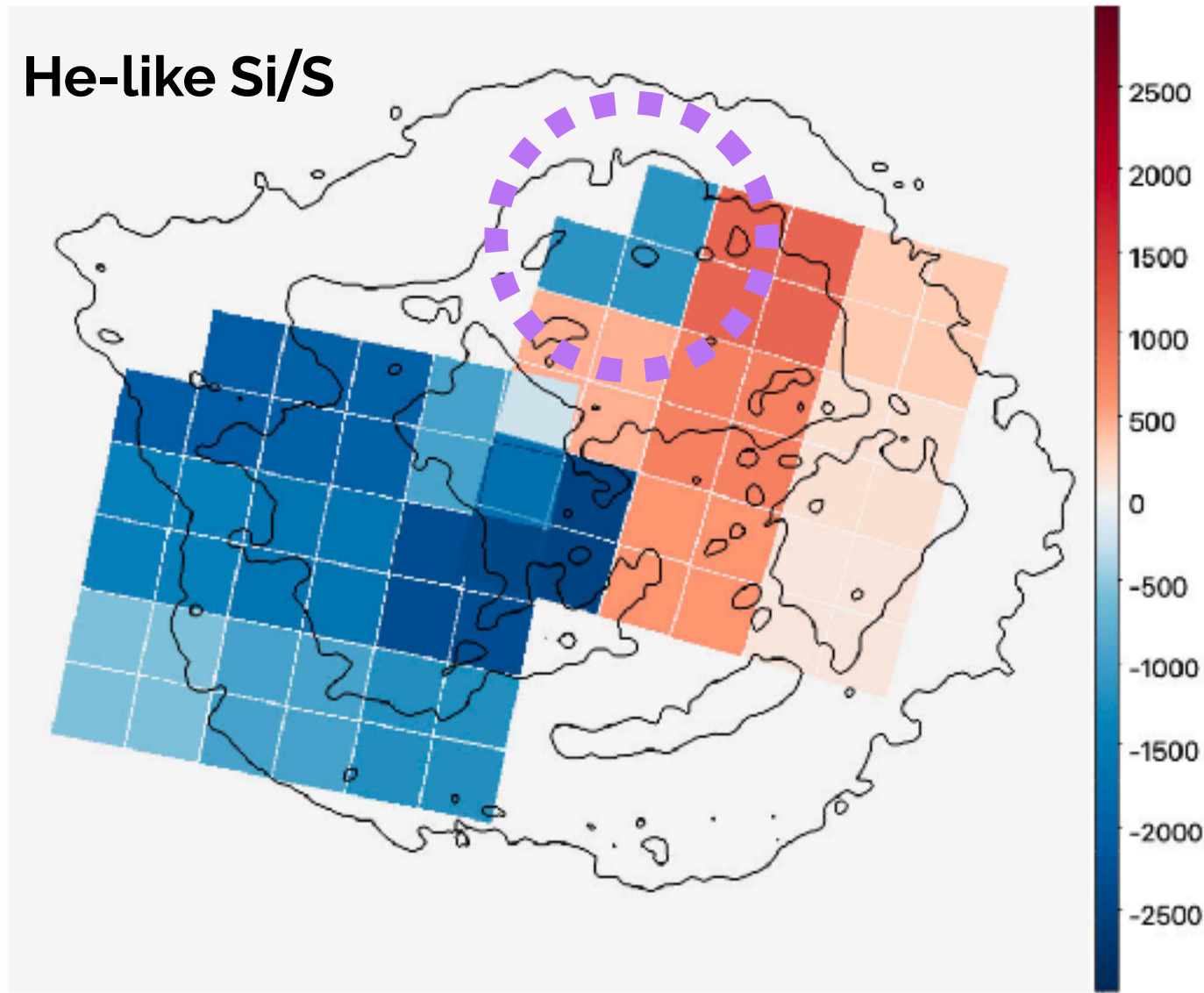


# Redshift of Si and S ejecta

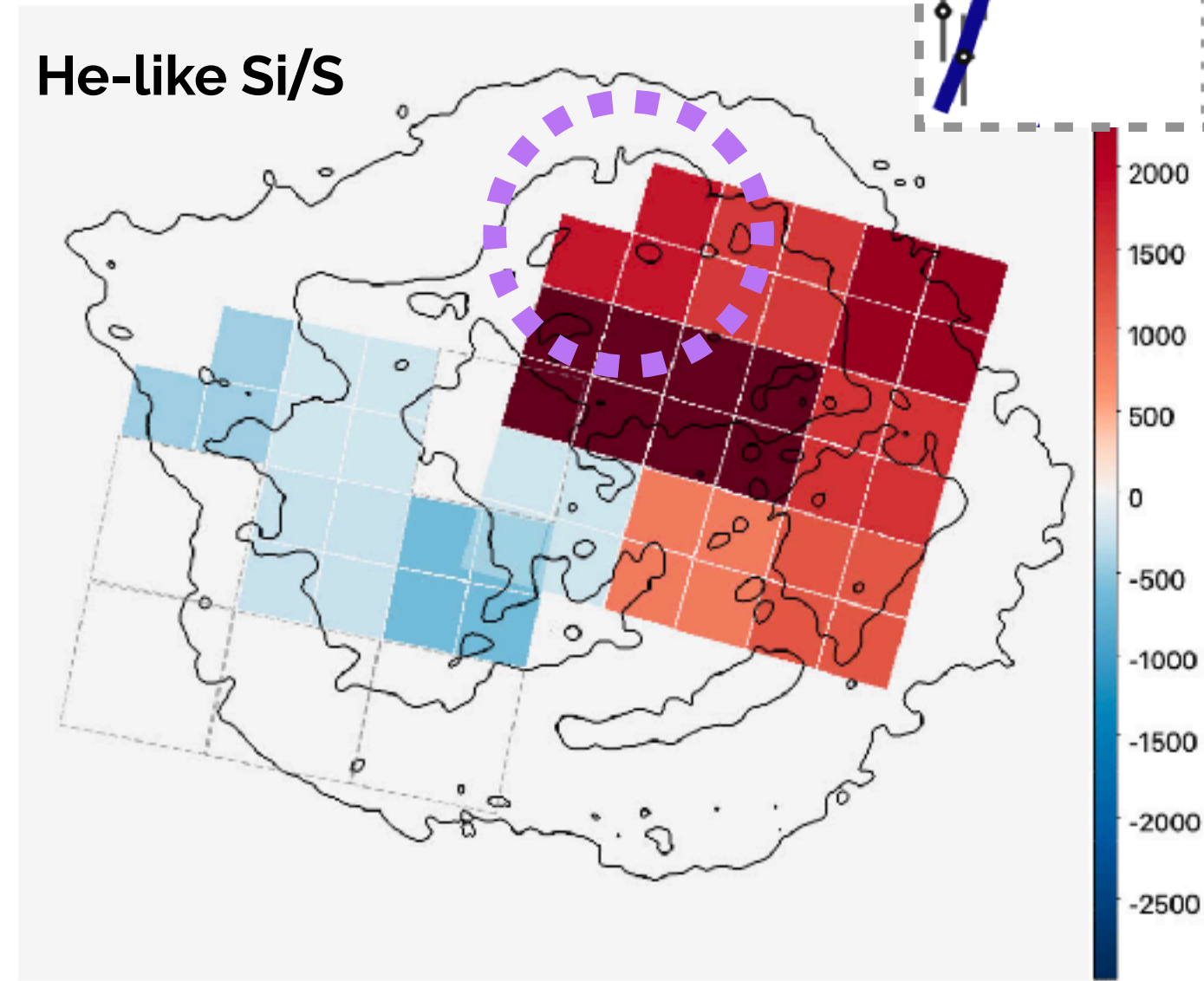
Vink J., Agarwal M., + 25



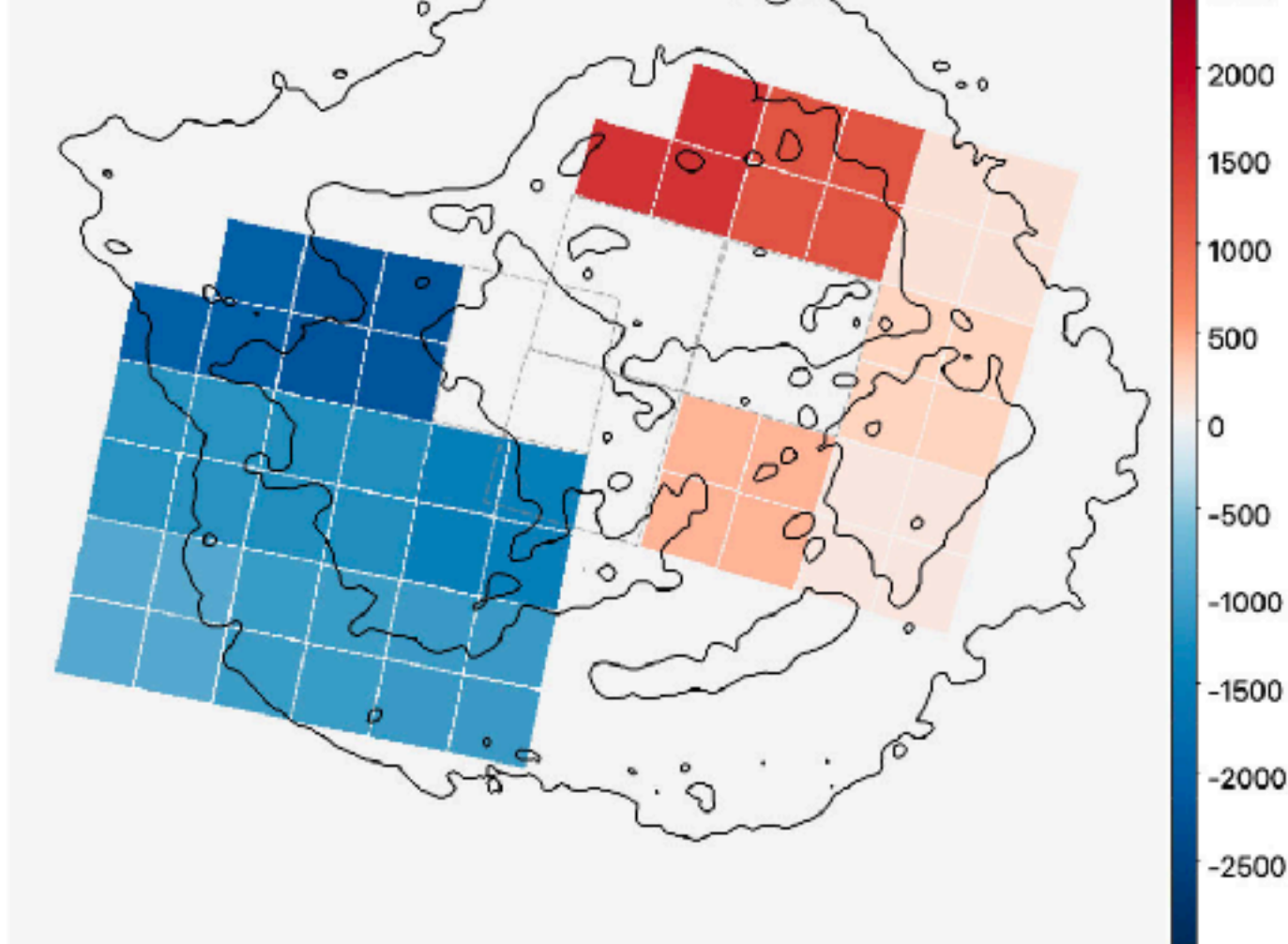
Relatively **blue**-shifted component



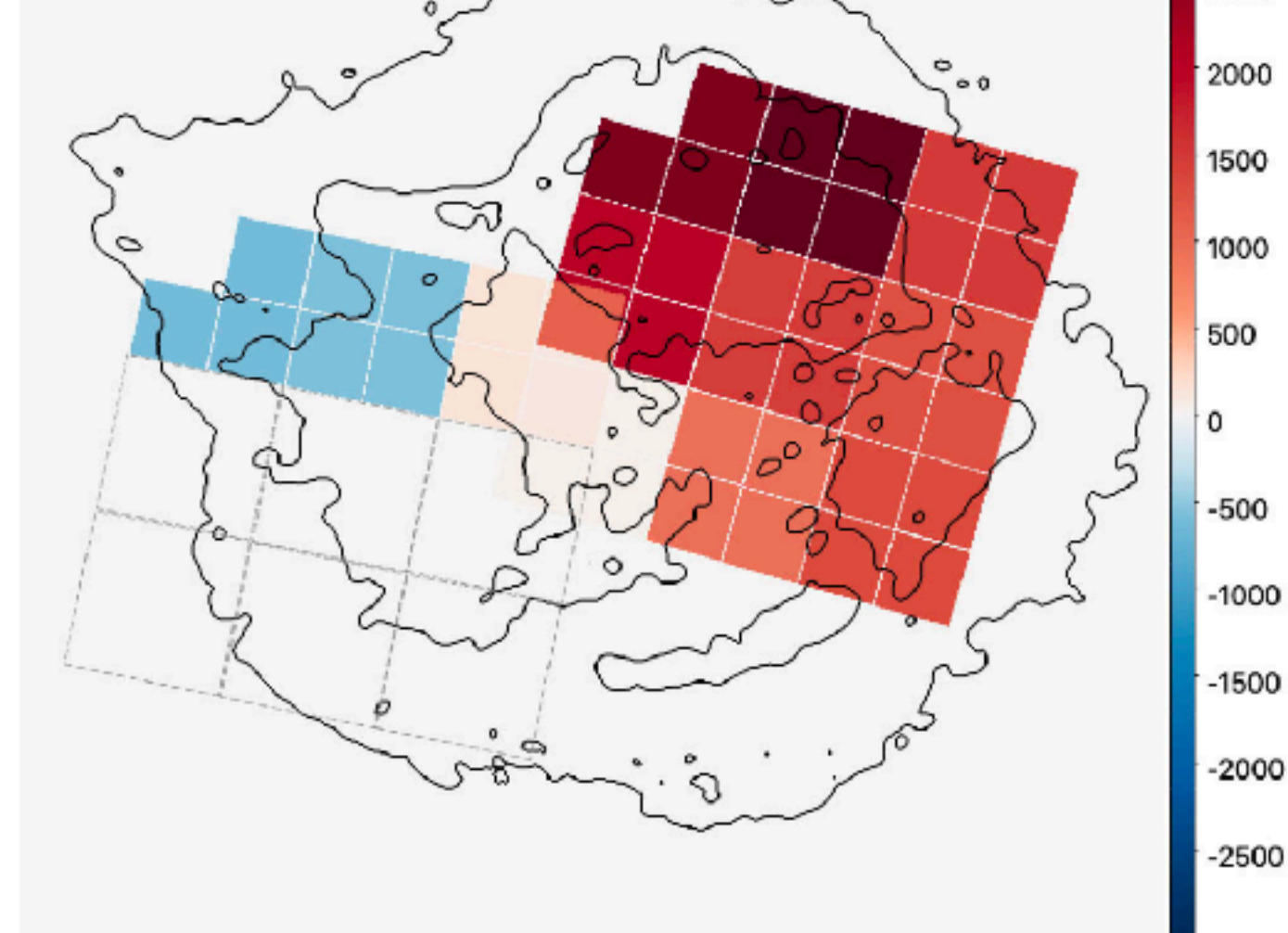
Relatively **red**-shifted component



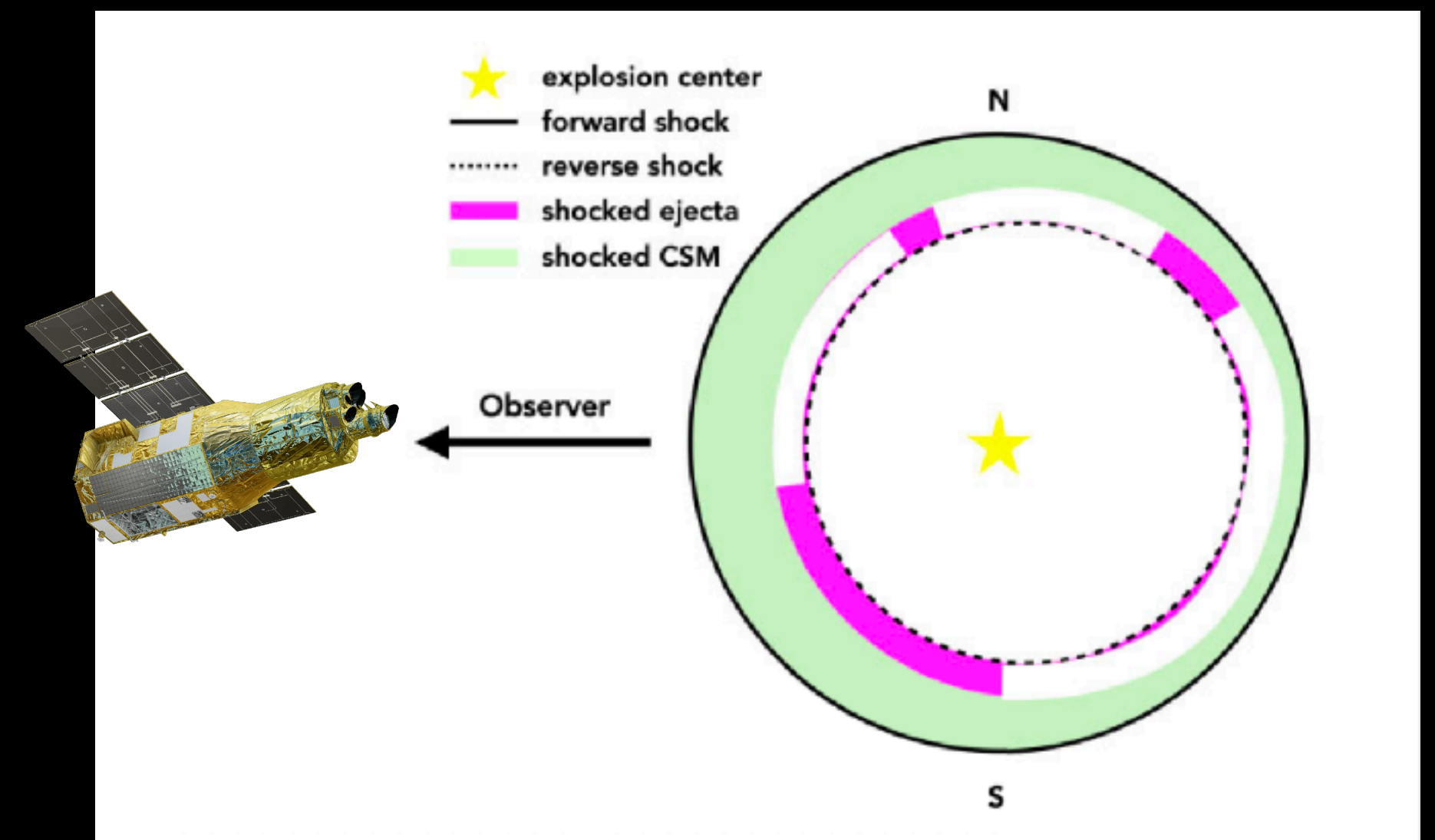
H-like Si/S



H-like Si/S



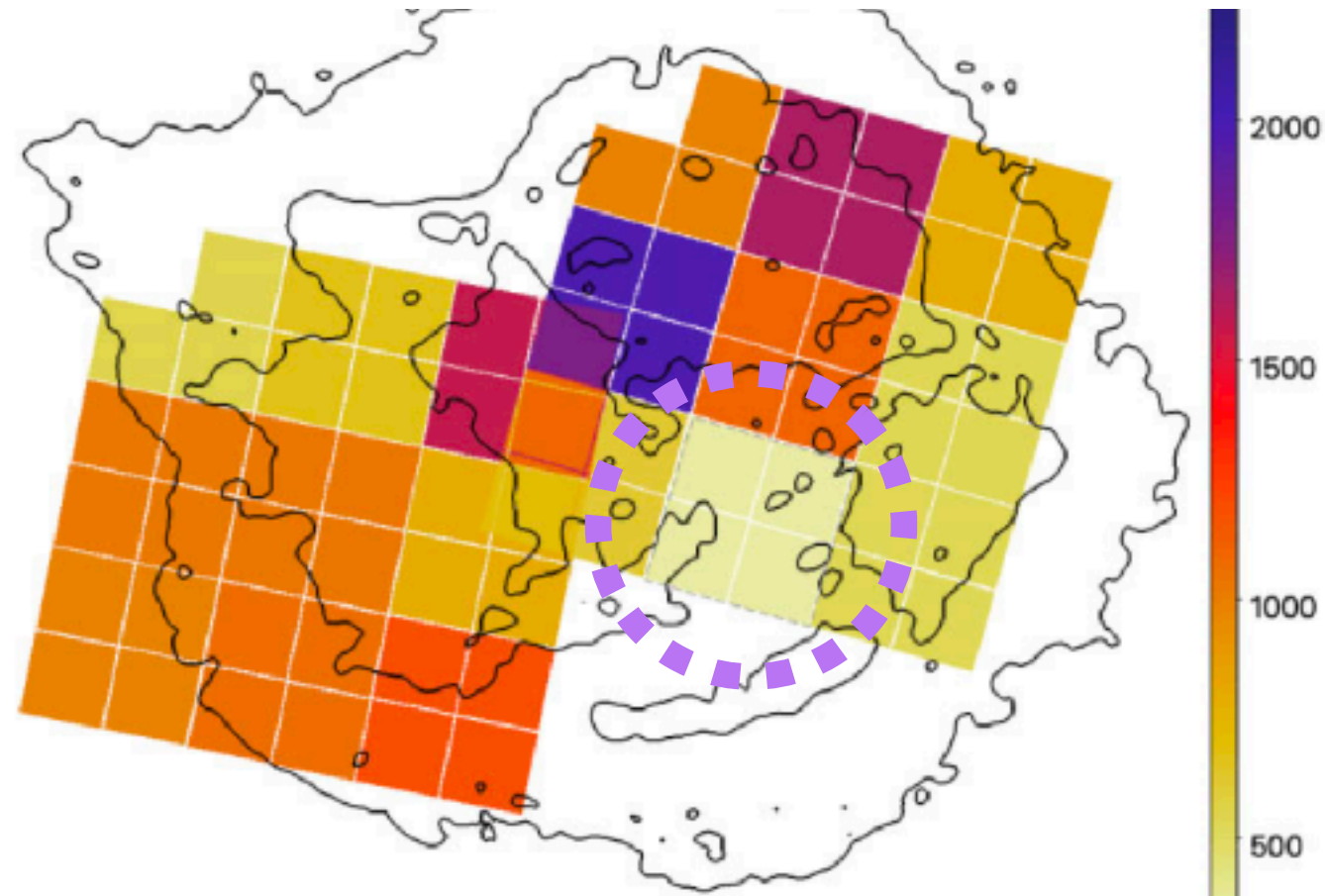
- Both components are either red-shifted (NW) or blue-shifted (SE)
- Except north, distinct red-shifted ( $1850 \text{ km/s}$ ) and blue-shifted ( $-1150 \text{ km/s}$ ) components
- Narrow, low-velocity components near the center likely originate from shocked CSM, but their exact origin remains ambiguous



# Broadening of Si and S ejecta

Vink J., Agarwal M., + 25

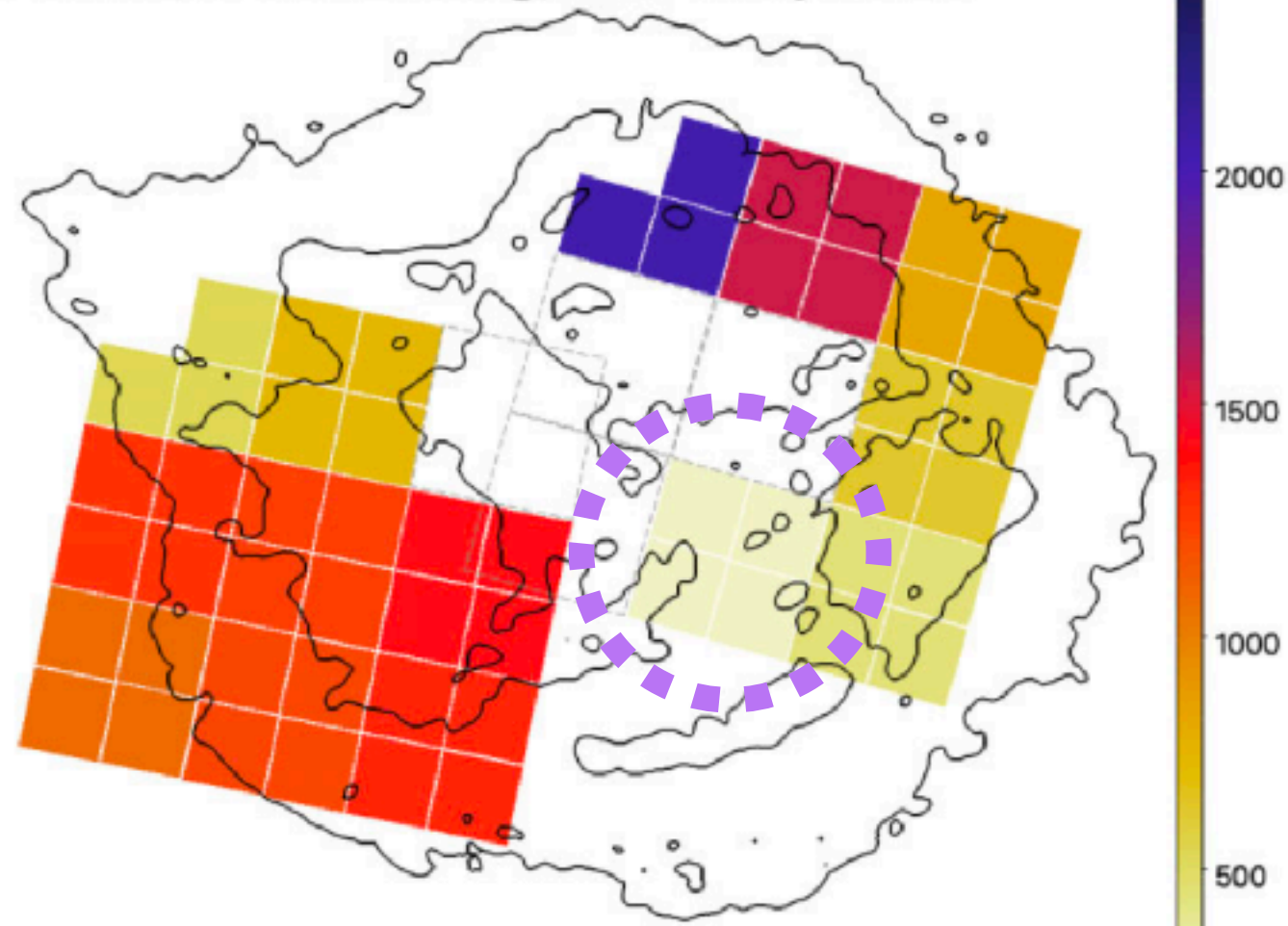
Relatively **blue**-shifted component



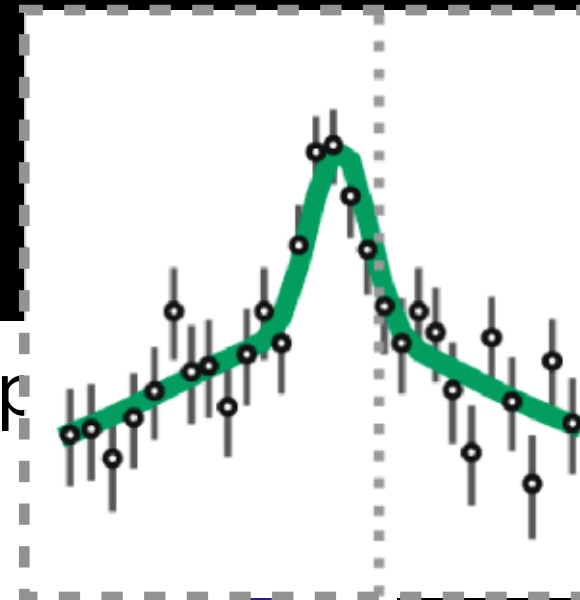
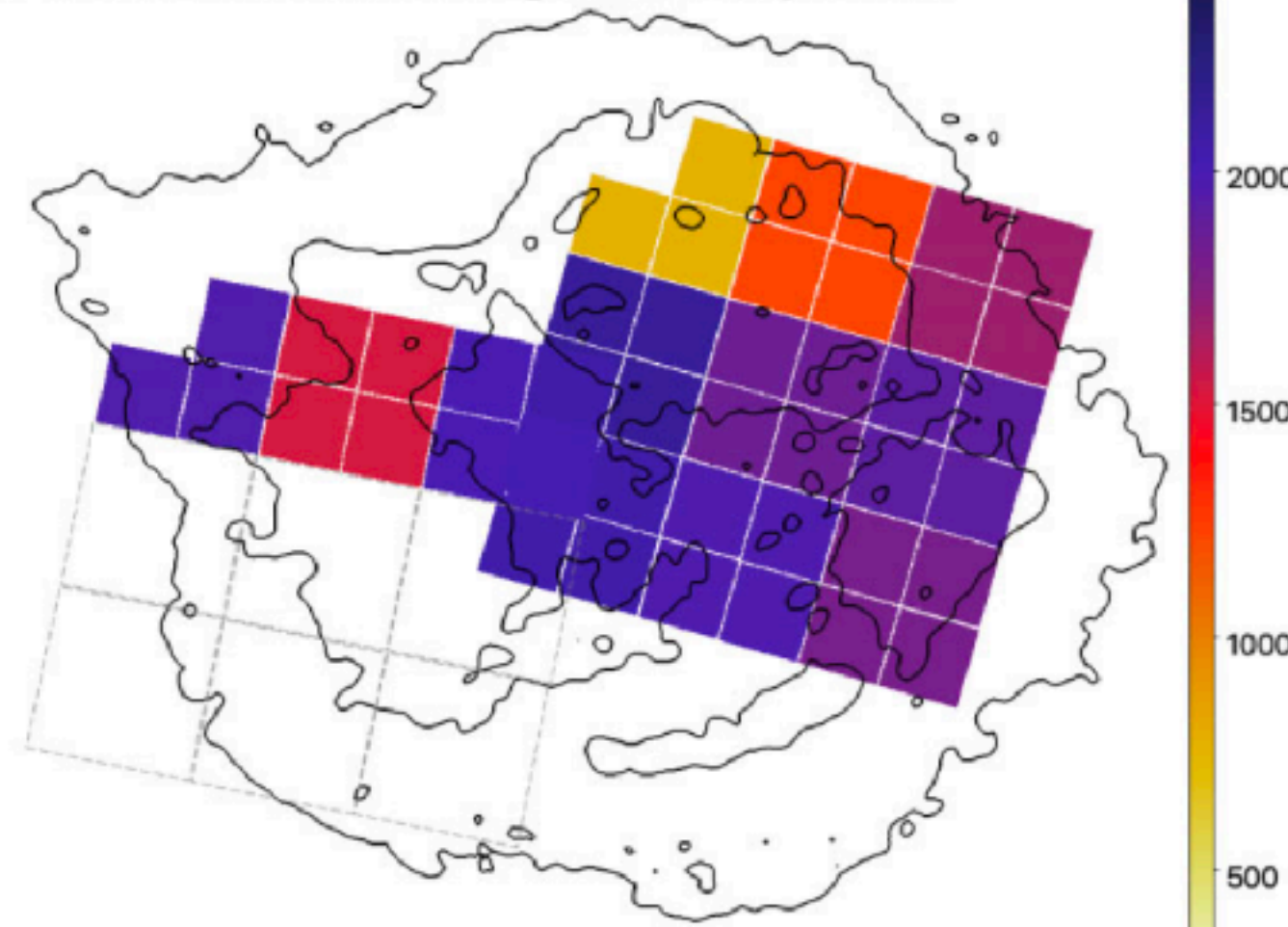
Relatively **red**-shifted component



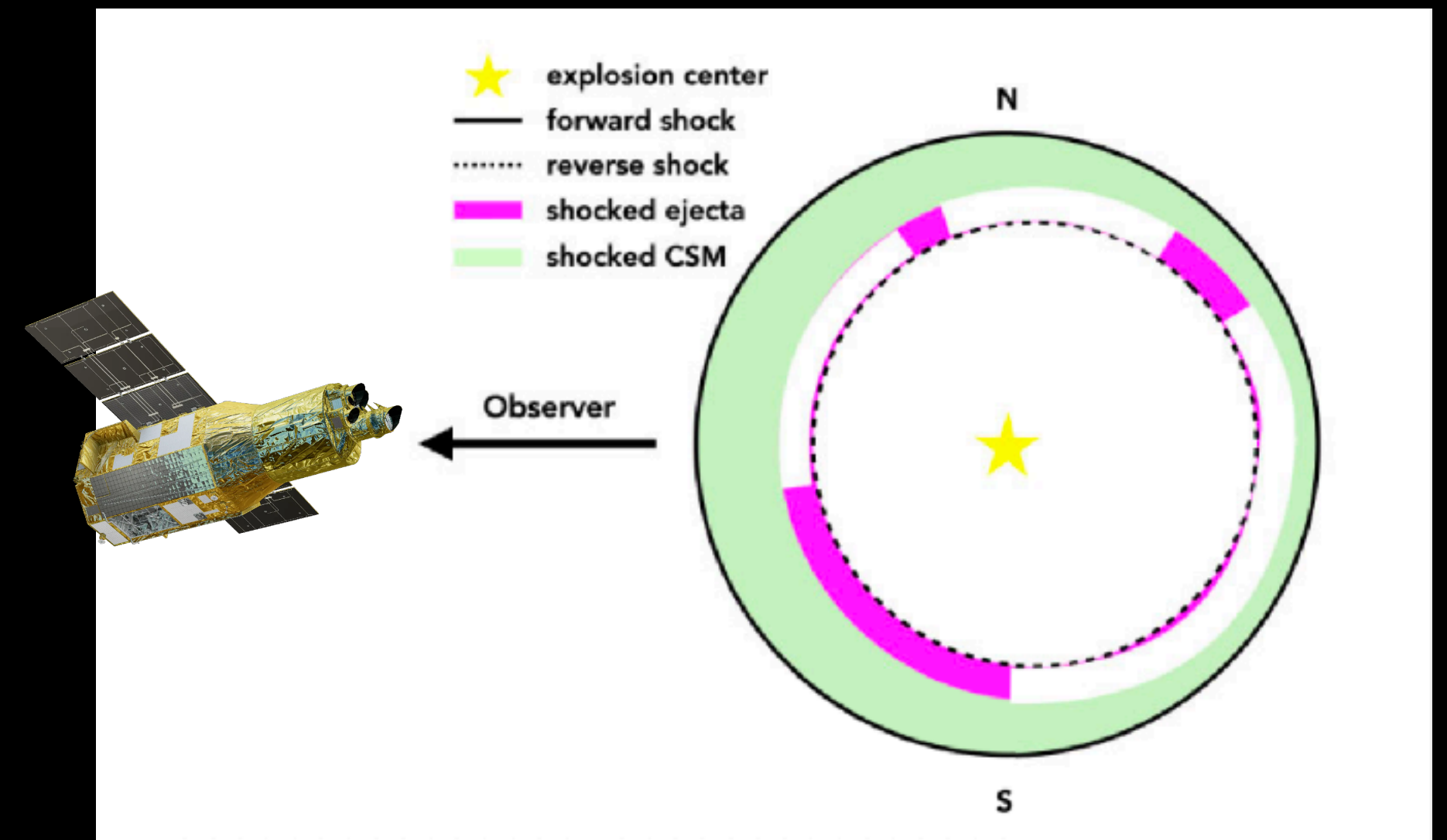
H-like Si/S: broadening, blue component



H-like Si/S: broadening, red component



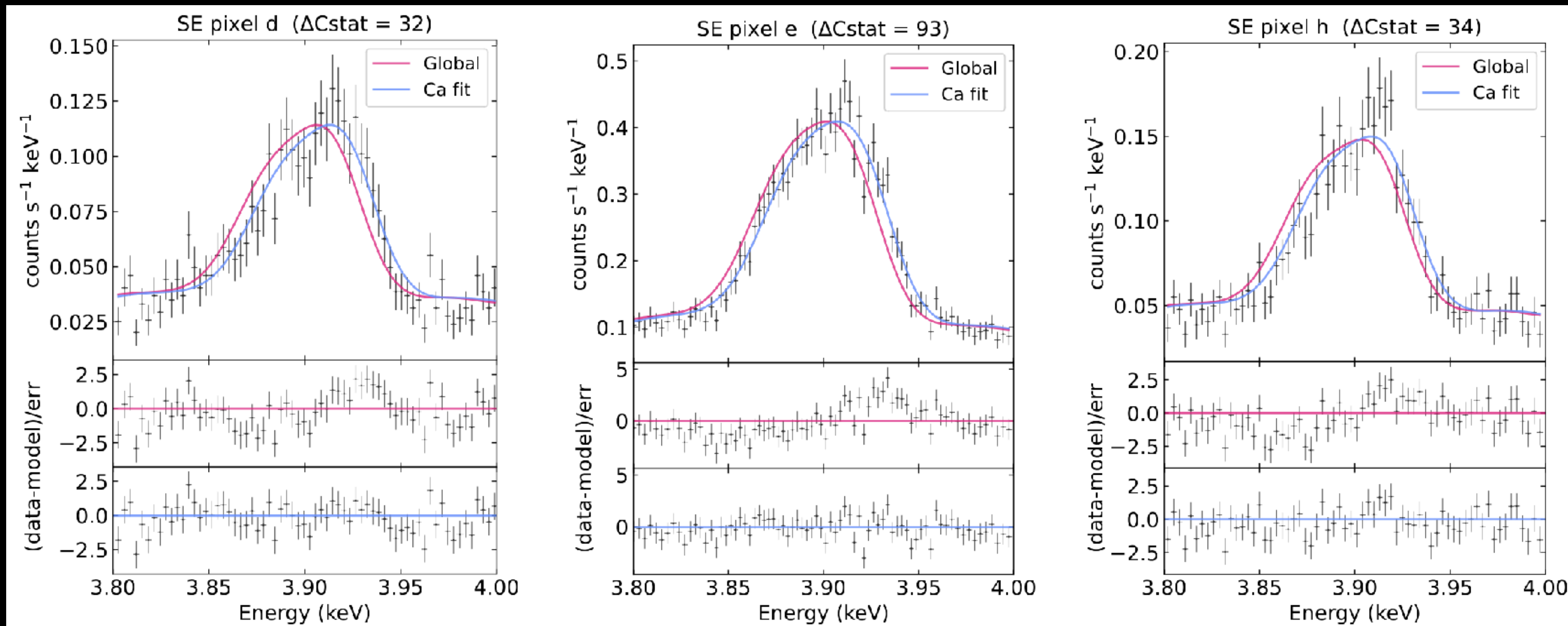
- Both components are either red-shifted (NW) or blue-shifted (SE)
- Except north, distinct red-shifted (1850 km/s) and blue-shifted (-1150 km/s) components
- Narrow, low-velocity components near the center likely originate from shocked CSM, but their exact origin remains ambiguous



# Ca

Ca has higher Doppler velocities than the IMEs, and even Fe, in some SE regions

Ca  $\sim$  -1500 km/s, i.e., more than  $500_{-100}^{+100}$  km/s faster than IMEs



Caution:

# I. Spectral Spatial Mixing

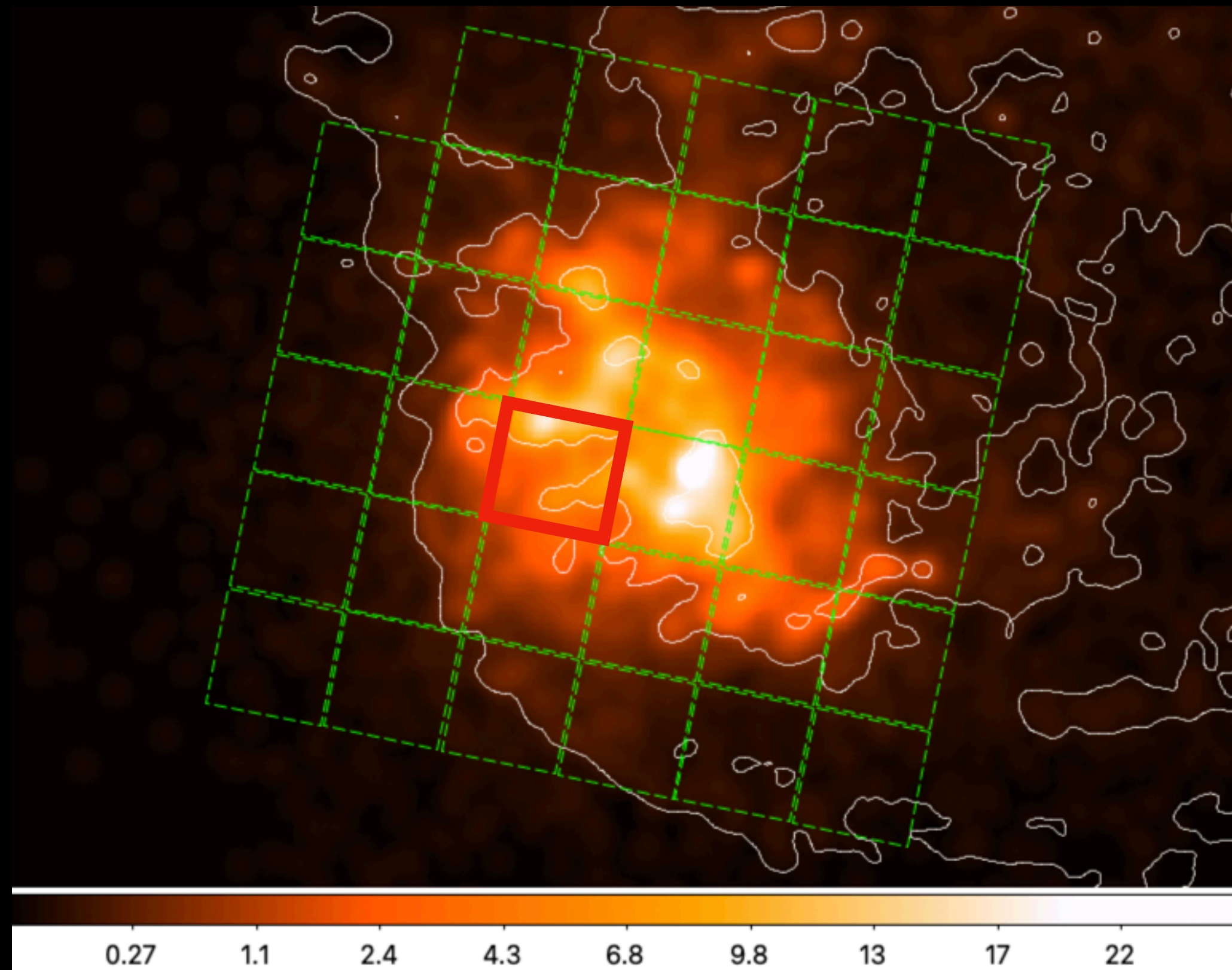
# I. Spatial Spectral Mixing (SSM)

Plucinsky, P., Agarwal, M.,+ 2025

XRISM/Resolve pixel size: **0.5 arcmin**

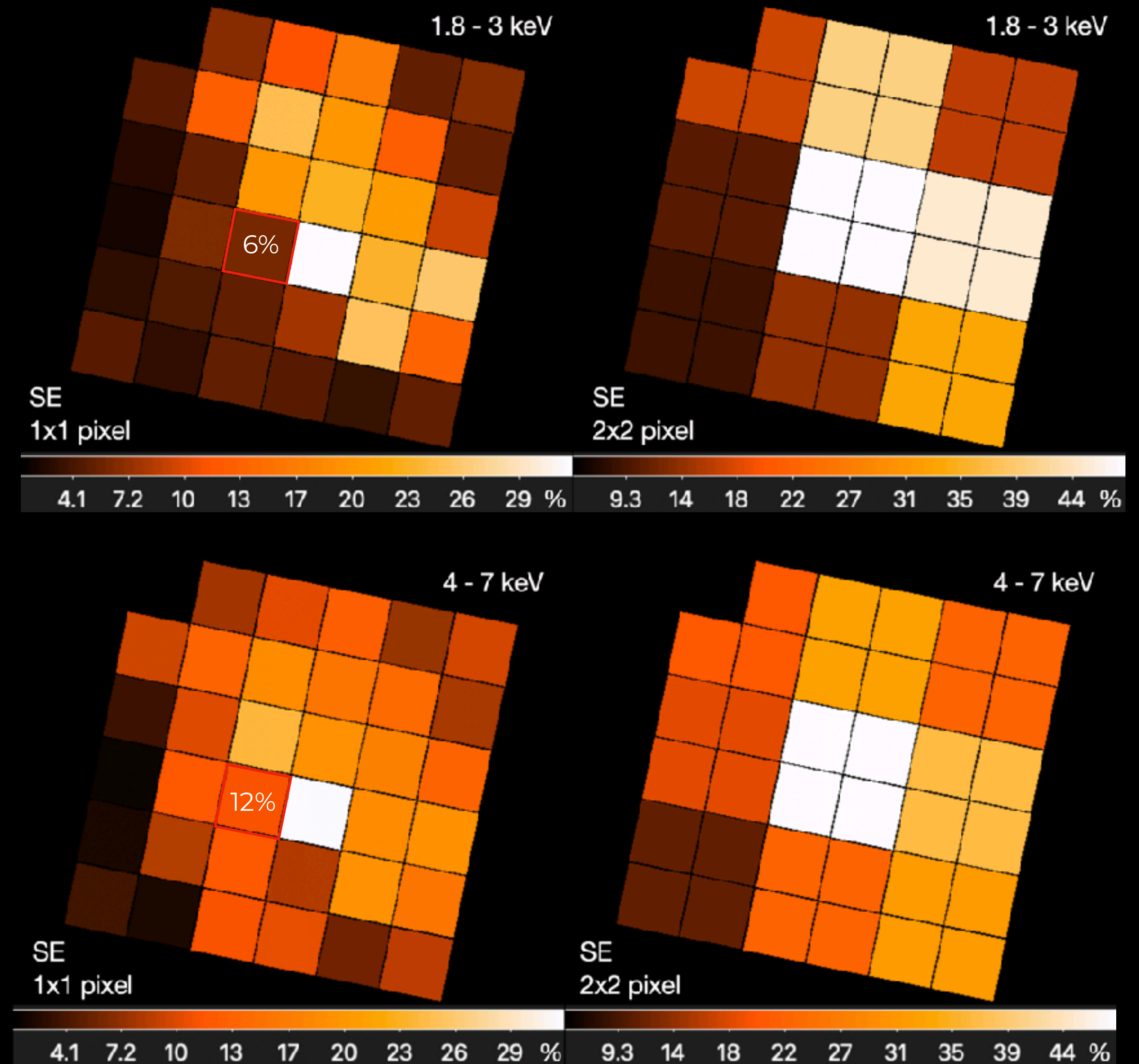
XRISM Point Spread Function (PSF): **1.3 arcmin** HPD

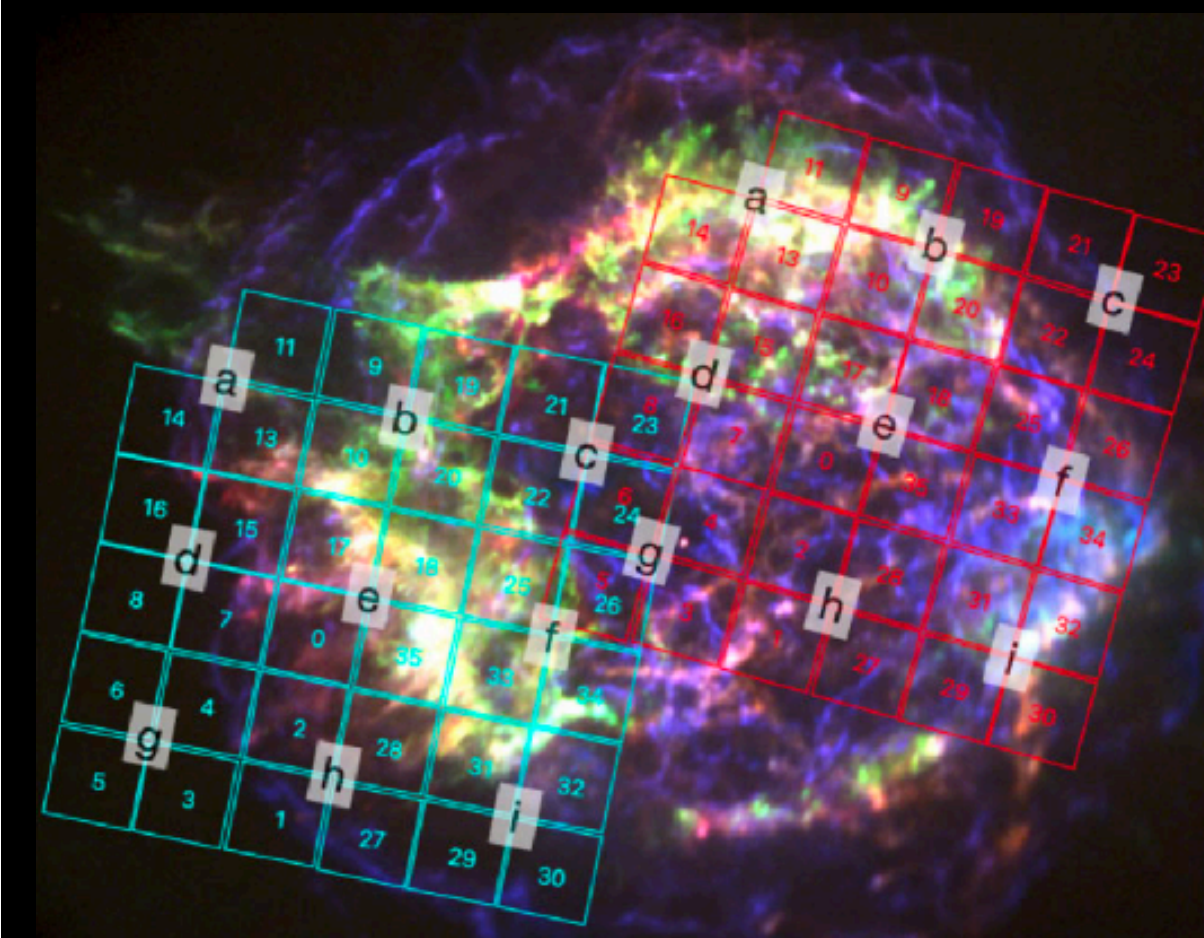
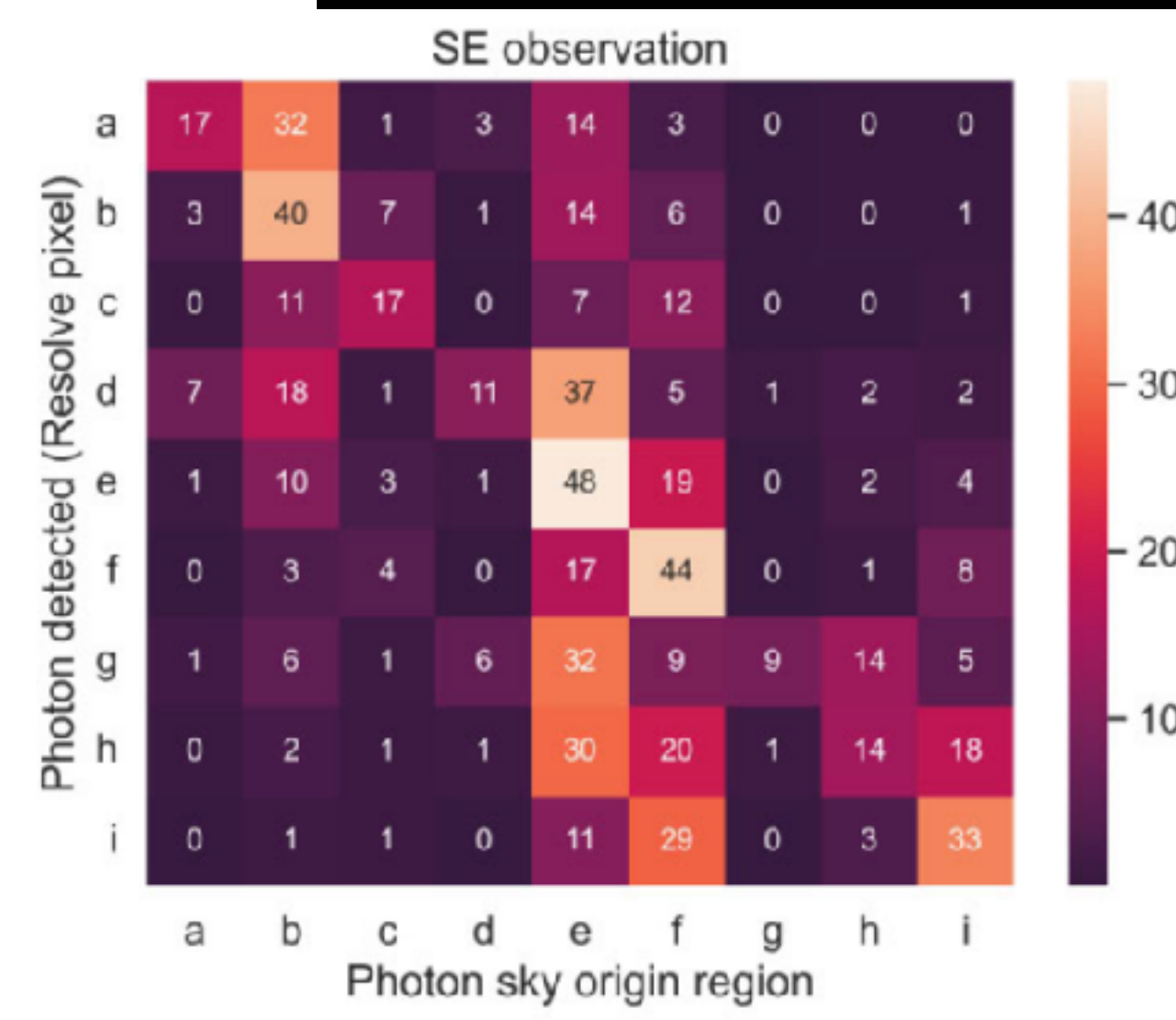
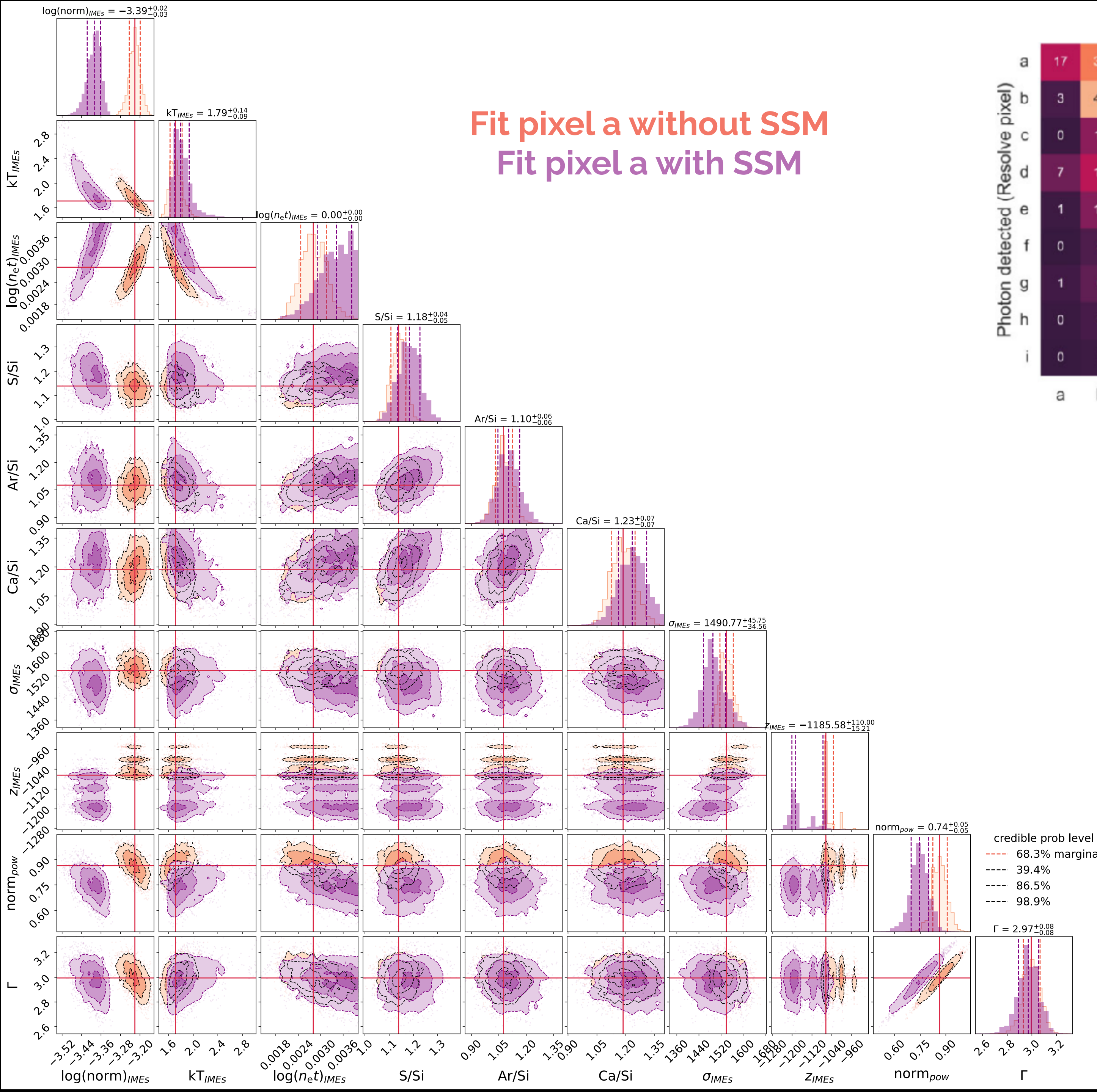
Sky location of the photons detected\* in the Resolve pixel #0 i.e. marked with red border



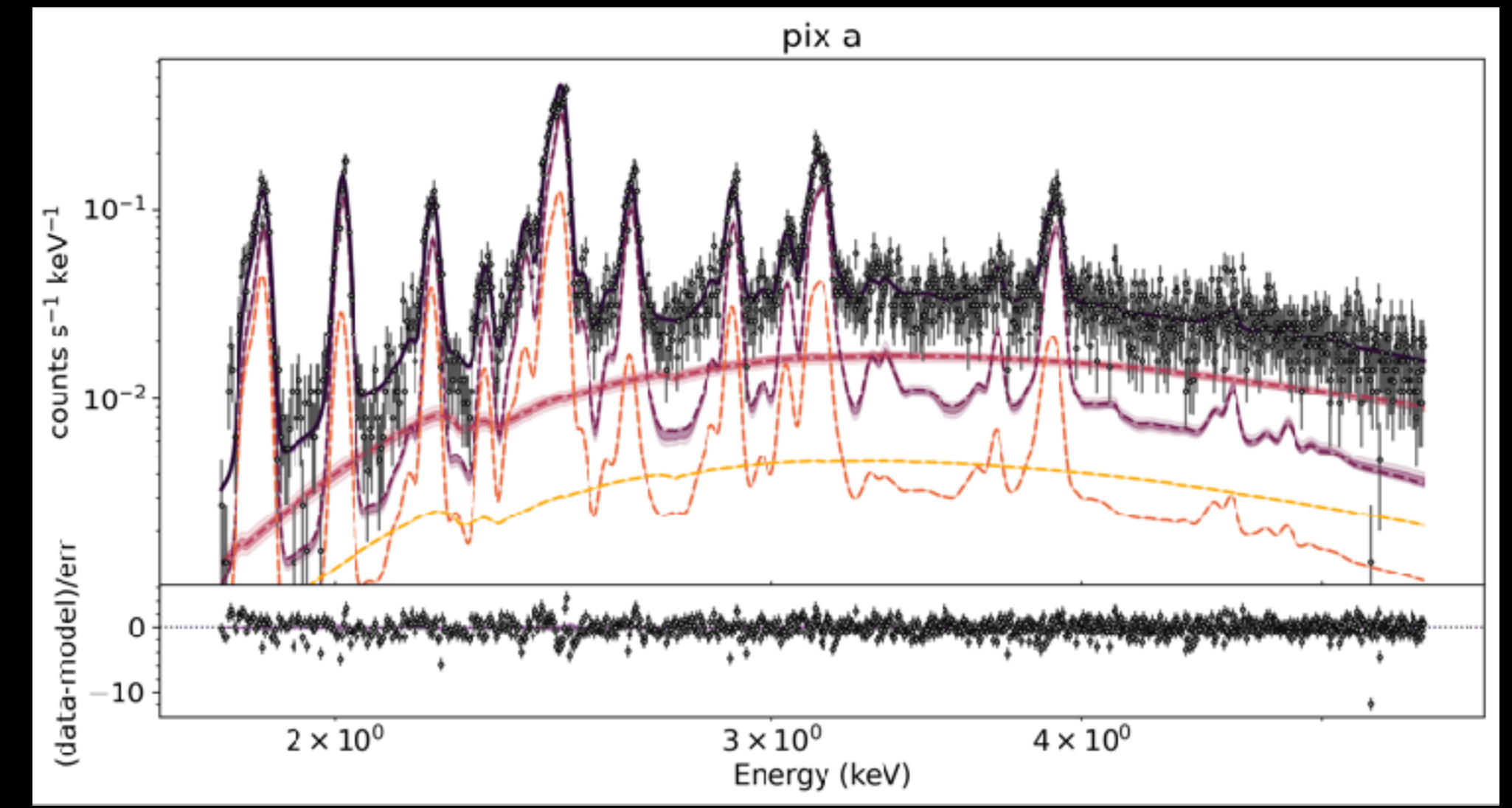
\* Simulated by Monte Carlo redistribution of Chandra events with azimuthally symmetric XRISM PSF

## Estimated 'Purity' Percentage Maps





32% of flux in pixel a comes from sky region pixel b



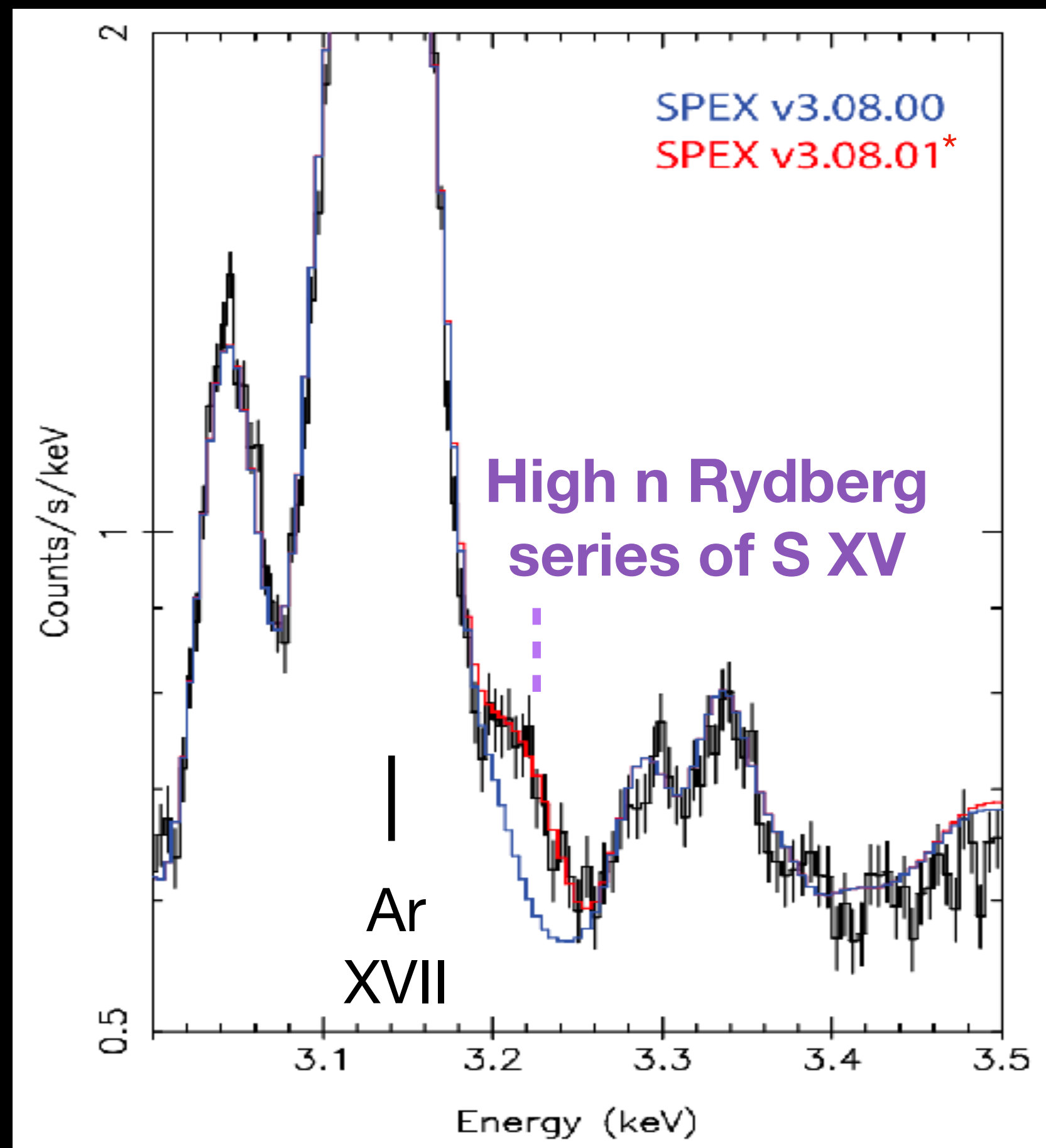
Caution:

## **II. Atomic Database**

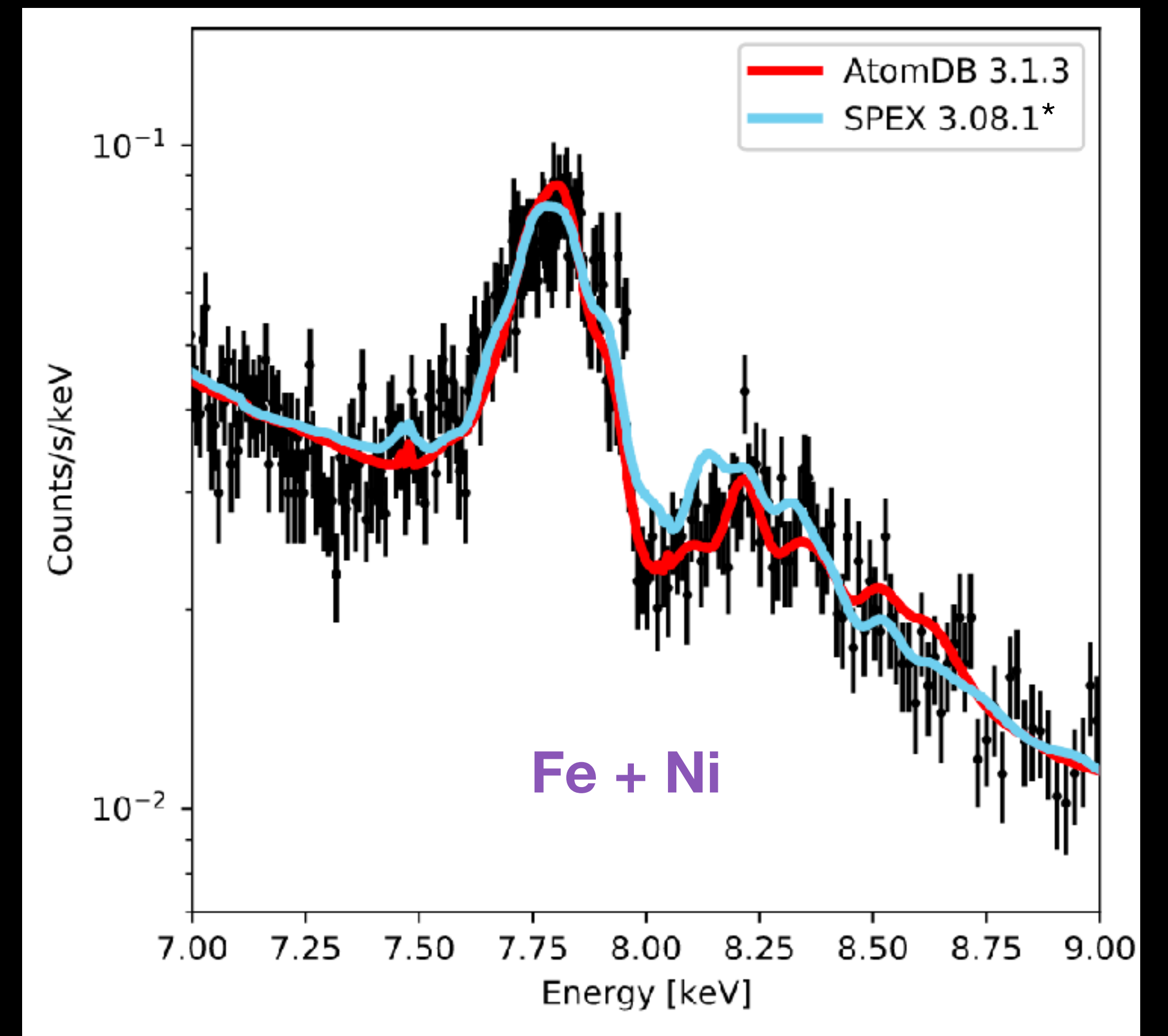
## II. Use latest atomic databases

Plucinsky, P., Agarwal, M.,+ 2025

**Significant updates**  
which can otherwise be confused  
with other features



**Discrepancy in Ni abundance**  
between XSPEC and SPEX  
(SPEX tends to fit lower abundance than XSPEC)



Thanks to Liyi Gu and Adam Foster for updating the atomic databases

# XRISM/Resolve insights on Cas A spectra

- Detection of trace elements: P, Cl, K, Ti, Mn, Cr in the SE region
- Si/S ejecta dynamics — **incomplete shell structure** - Vink J., Agarwal M.,+25
  - Higher ionisation state lines are faster
  - In the **north, both sides of the shocked ejecta shell are visible**
  - **Narrow lines (<500 km/s) in the center**, potentially shocked CSM
- Mapping plasma properties — physical modeling with UltraSPEX - Agarwal M.,+26
  - Fe-group faster and broader than IMEs in most regions (interesting exception with Ca)
  - Evidence for **lower-than-expected shock velocities** in the past and **highly clumpy ejecta**
- **Pshock model** - low-charge state ions
- Latest Atomic database - high-n Rydberg series lines, low-charge state ions (eg., Be-line, B-line, etc.)
- Spatial Spectral Mixing (SSM) is significant in XRISM/Resolve spectra of Cas A