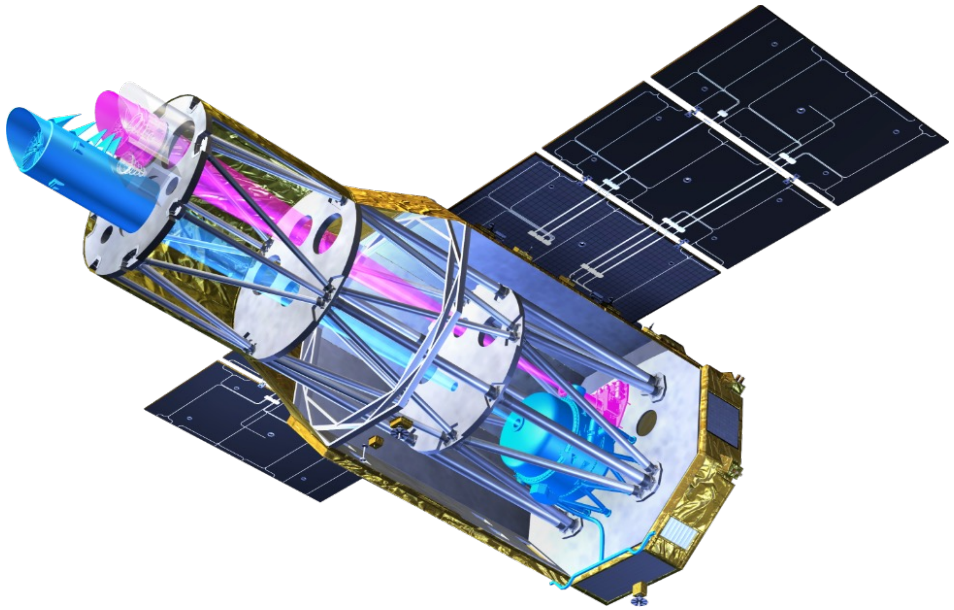
Charge exchange with XRISM/Resolve

N132D and beyond



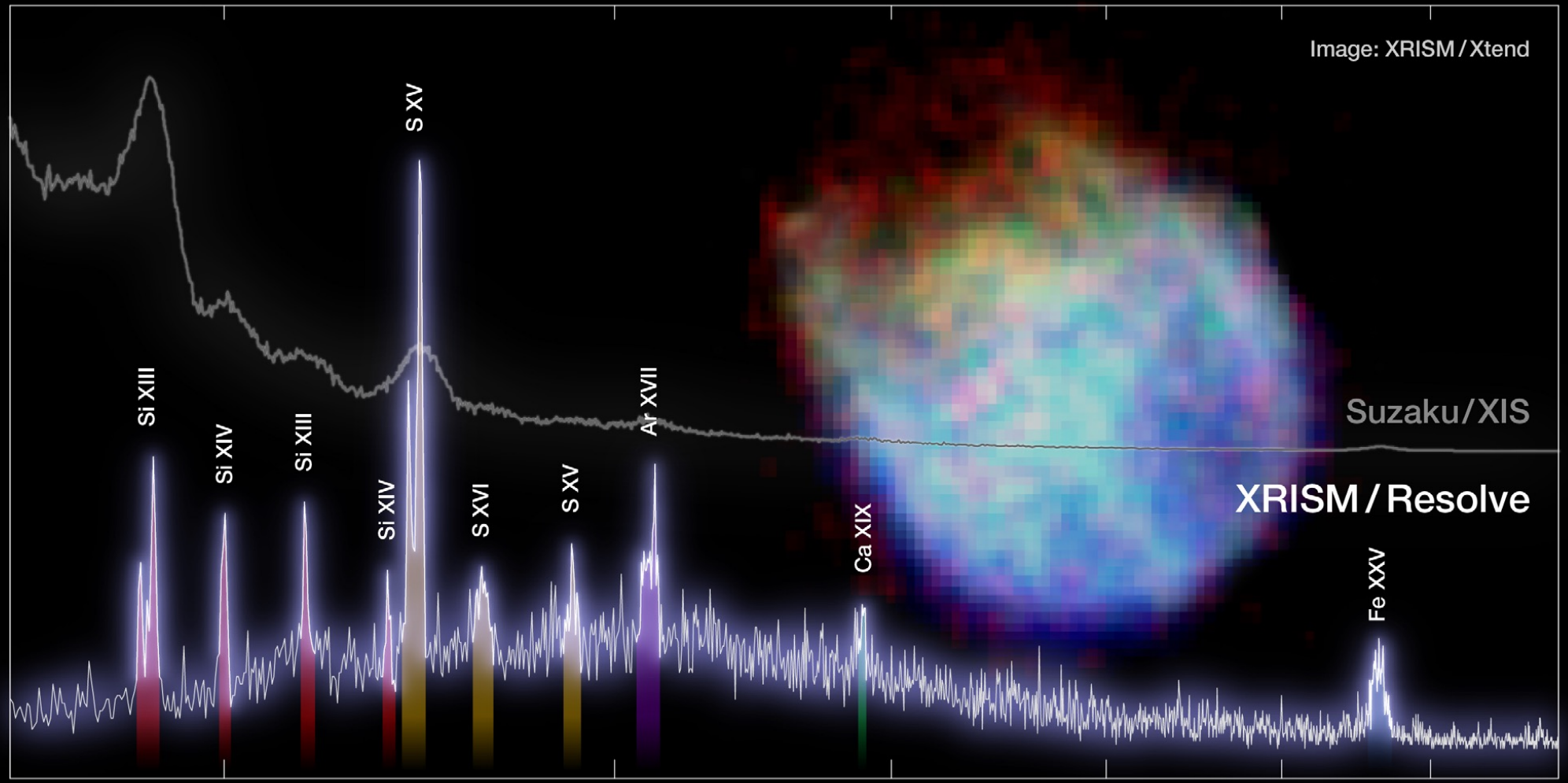
- N132D: X-ray brightest SNR in LMC
- Potential detection of Si charge exchange

(**usual disclaimer applies**)

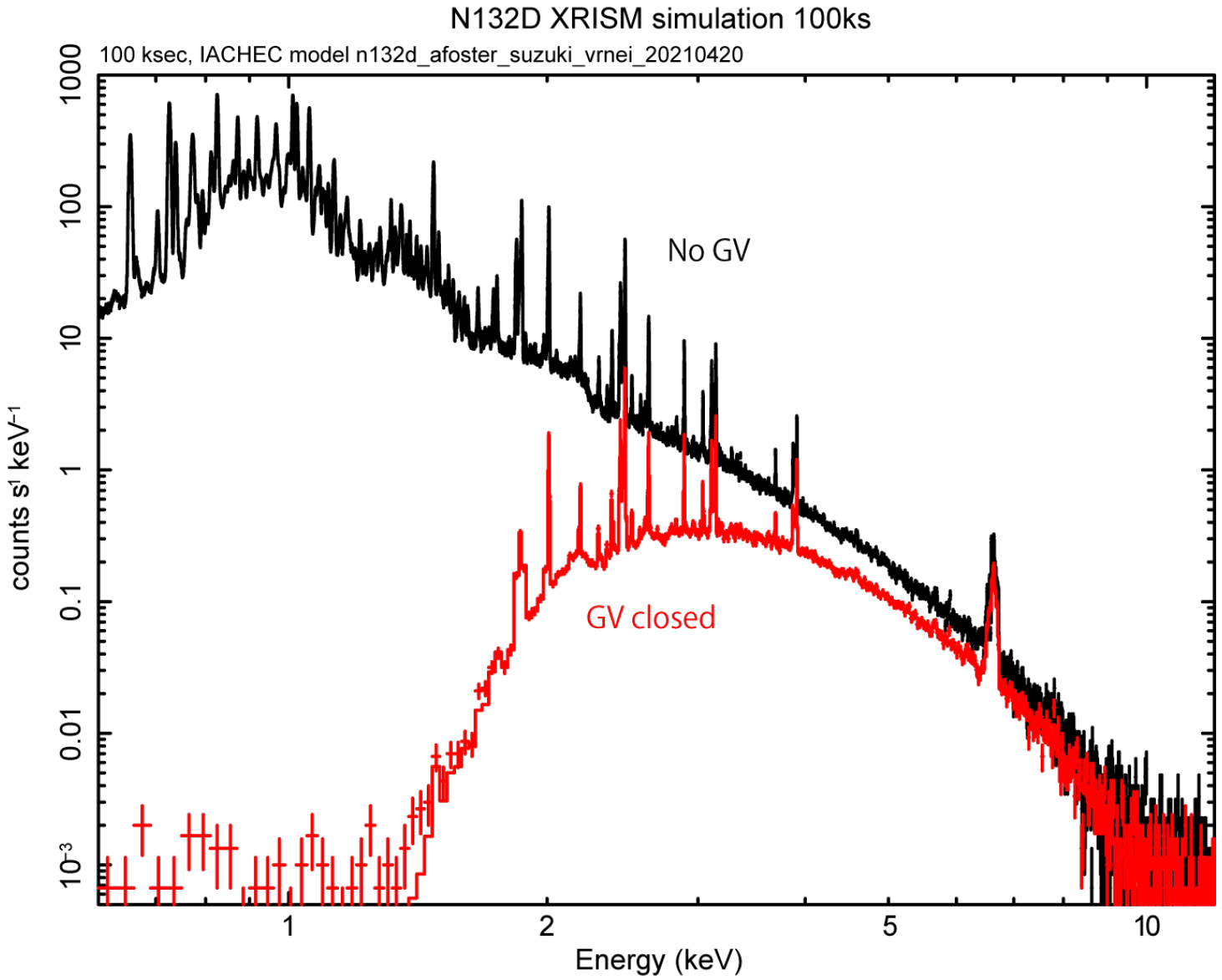
- Other objects

Liyi Gu (SRON)

X-ray Spectrum of Supernova Remnant N132D Measured by XRISM Resolve



Gate valve remains closed



- Bandpass E > 1.7 keV
- C, N, O, Ne, Fe-L lines are not visible, Fe-K remains intact
- Affect CX science

Glitch with the detector window, but the door to awesome science is wide open!

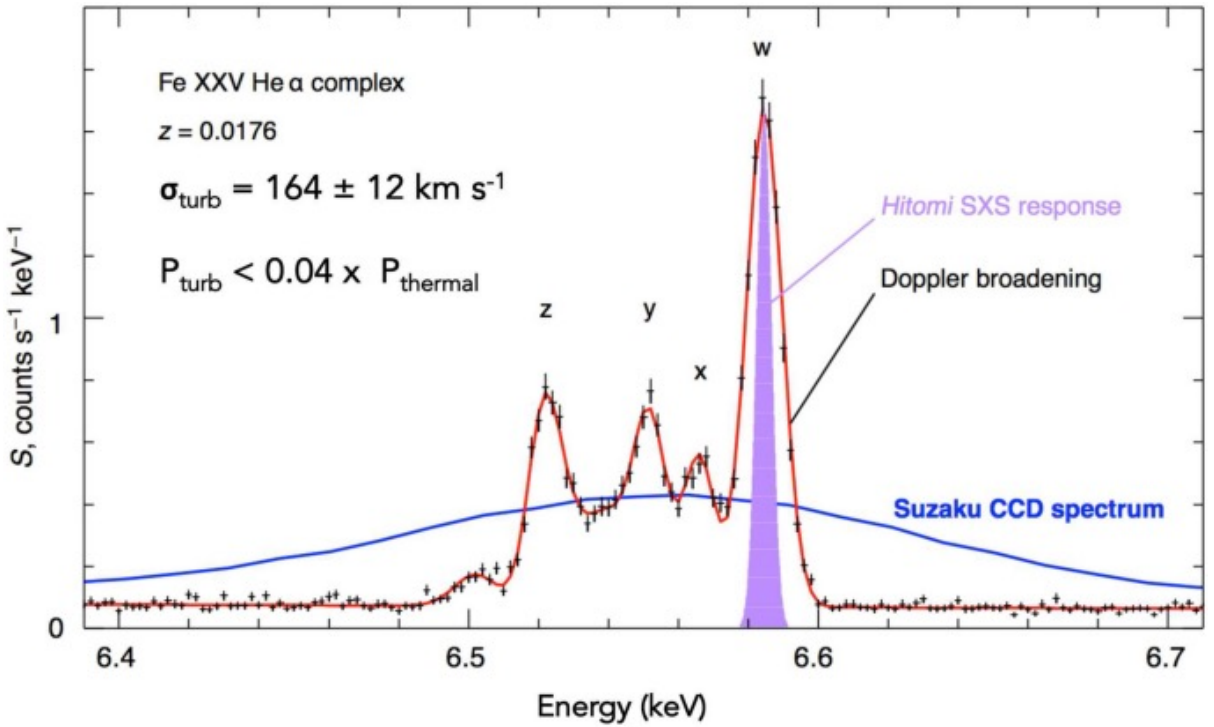
- Traditional X-ray telescopes lack the resolution to distinguish micro- from macro- physics

- XRISM offers revolutionary *optical-spectrum-quality* for X-ray sources

- It serves as a “microscope” resolving atomic structure for the hottest, and the most dynamic parts of the Universe.

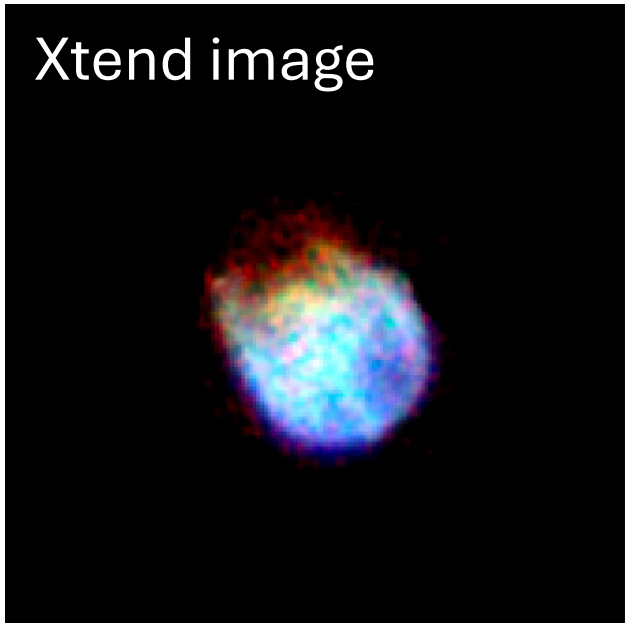
- Unexpected features hold clue to new physics.

Hitomi spectrum of Perseus cluster



Hitomi + 16

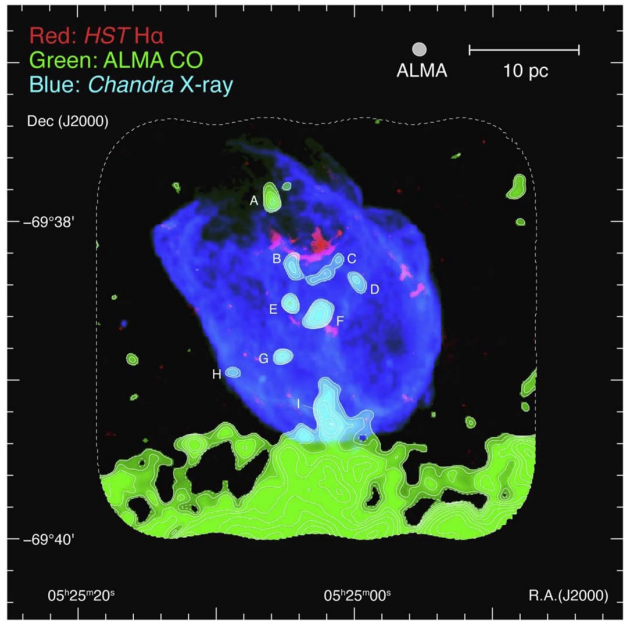
N132D first light: Si/S band XRISM/Resolve



RESOLVE SPECTRUM STILL UNDER EMBARGO

- Core-collapse
- Angular diameter = 2 arcmin
- 2800 yr old, mix of ejecta and ISM
- Expansion at 1700 km/s

First detection of Si charge exchange in astrophysical objects



RESOLVE SPECTRUM STILL UNDER EMBARGO

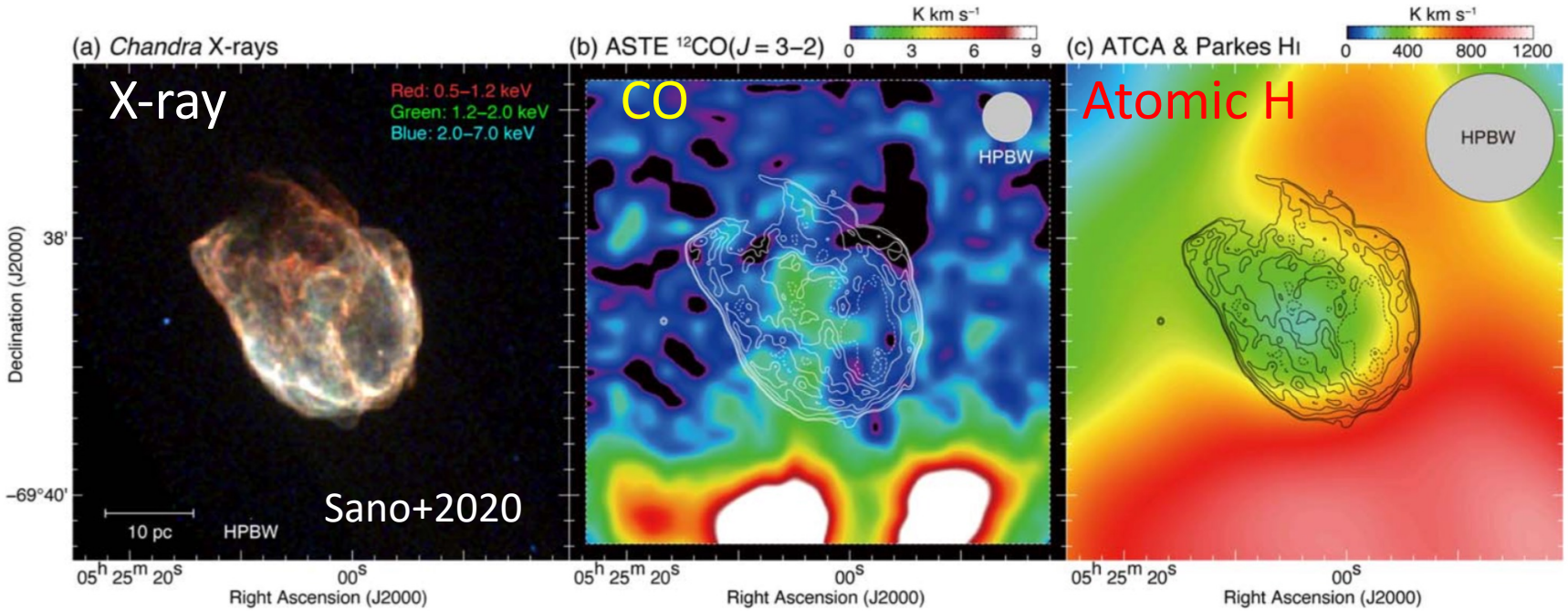
- High Rydberg transitions of Si
- **> 4 sigma in total**
- Charge exchange between shocked ISM and neutral matter

CX the broad band view

RESOLVE SPECTRUM STILL UNDER EMBARGO

- CX contributes 25% of the Si He-alpha forbidden line
- Fits with thermal model overestimates 12% of the Si abundance, 4% of S
- Weaker feature at S band and higher

N132D
Charge exchange interaction volume

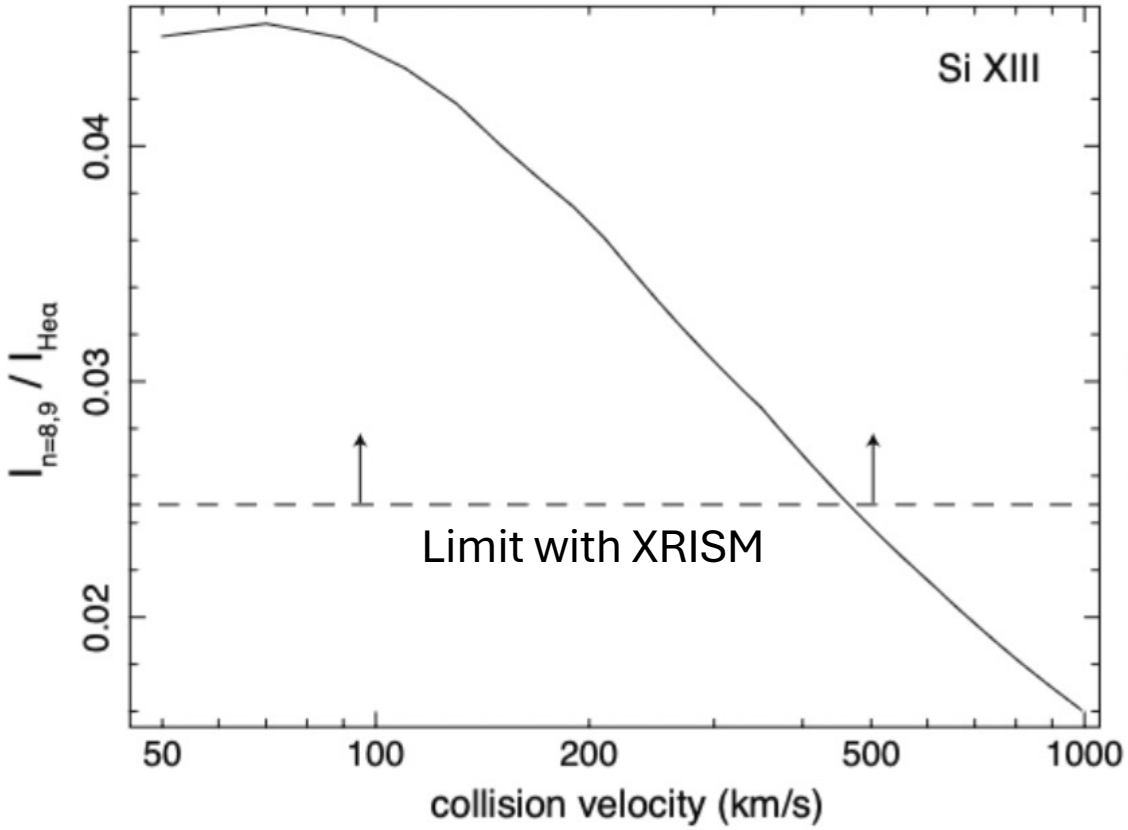


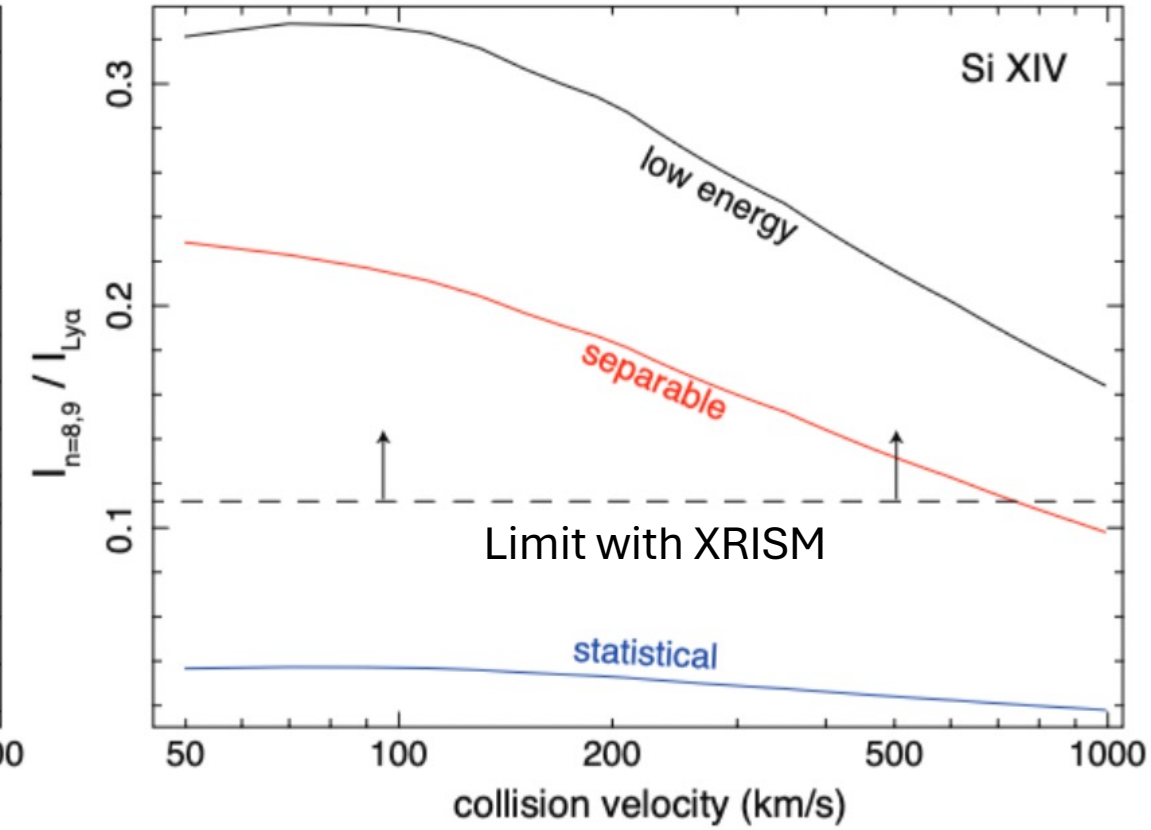
$$\frac{100\ \mathrm{km\ s^{-1}}}{\text{collision velocity}}$$

$$\text{interaction volume } V = 10^{51}\ \mathrm{m^3} \times \frac{10^3\ \mathrm{cm^{-3}}}{\text{neutral density}} \times \frac{1\ \mathrm{cm^{-3}}}{\text{ion density}} \times$$

- For dense CO-emitting cloud: density = 700 cm^{-3} , 40% volume is CX emitting
- For atomic H envelop: density = 30 cm^{-3}, thickness of interface = 0.1 pc
- IR-emitting Dust survives in the shockwave: contribte a third possibility

Constraints on *l*-distribution





- Line ratio n=8,9 / n=2 of He-like Si agrees with low-to-medium impact speed collision.

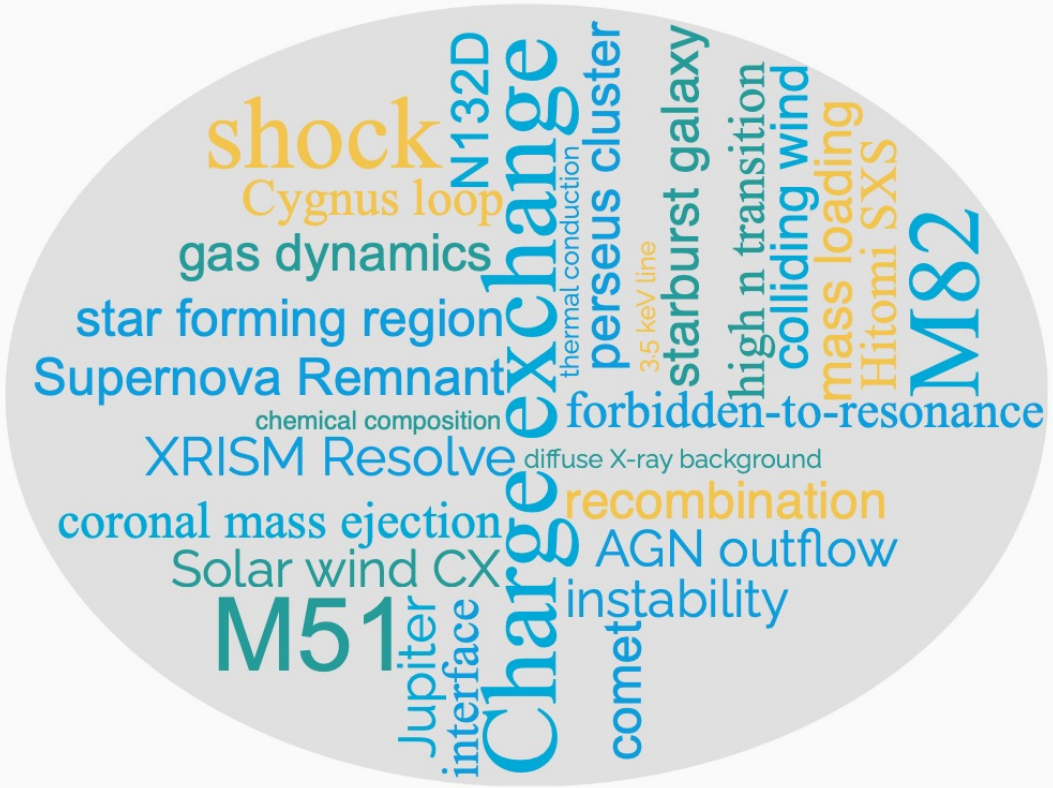
- Line ratio of H-like Si excludes statistical weight distribution.

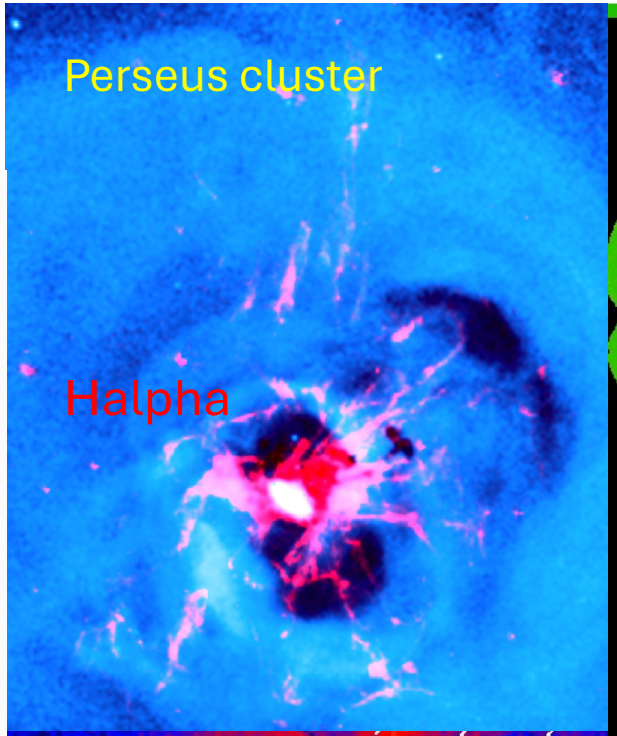
Weaker excesses in the Si band

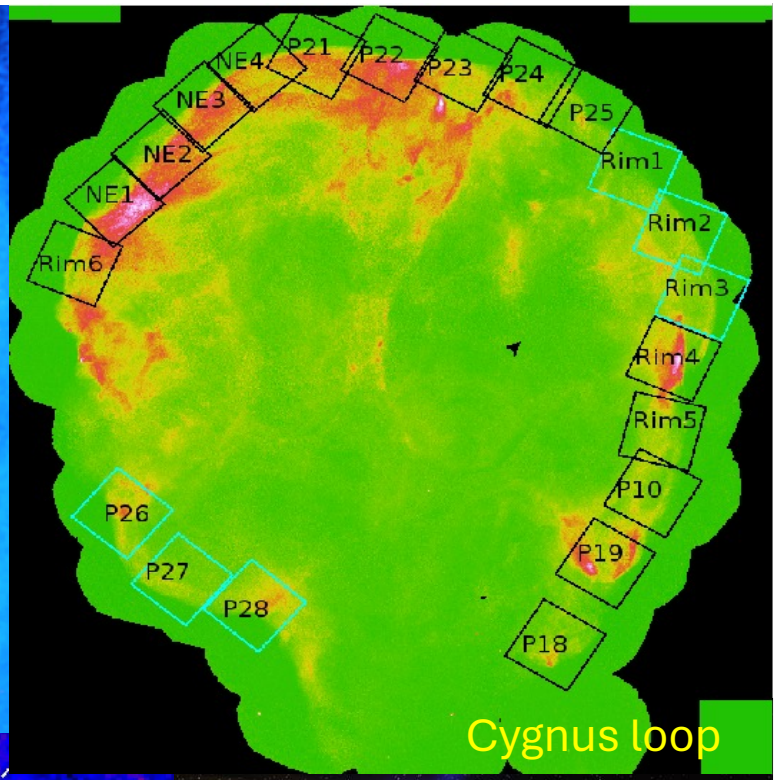
CX with molecule and dust might enhance *double electron capture* into highly excited.

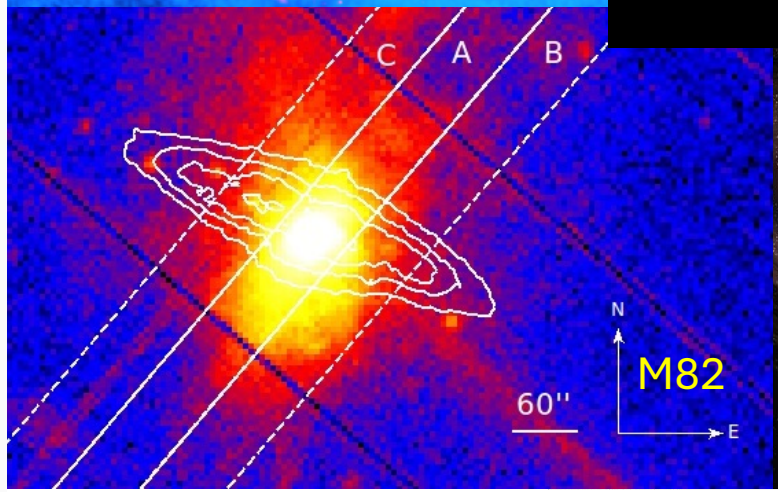
RESOLVE SPECTRUM STILL UNDER EMBARGO

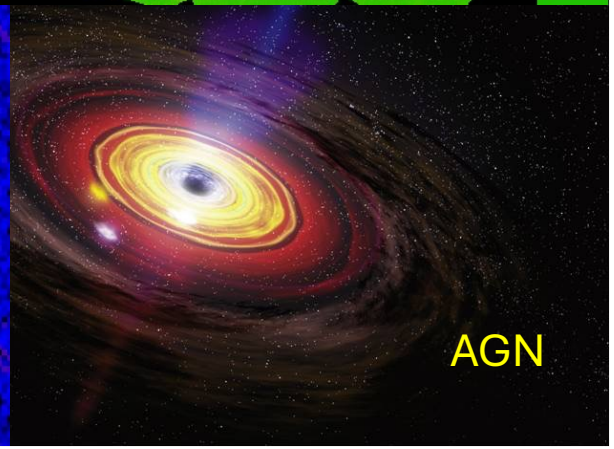
The show has begun



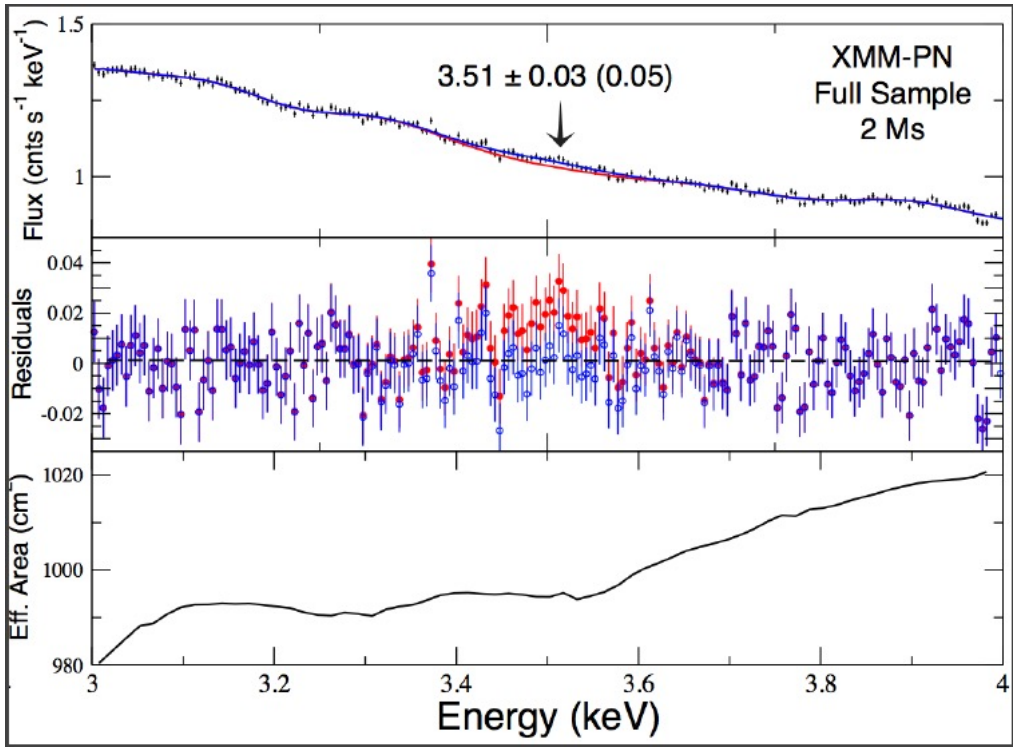


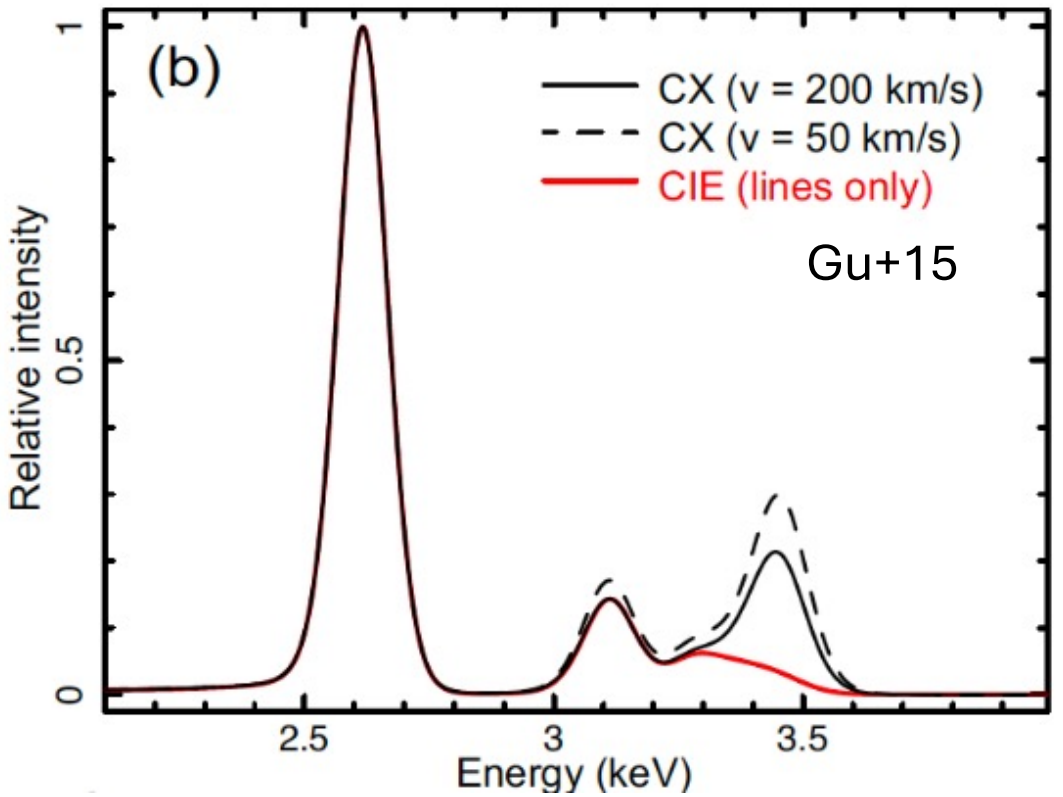






3.5 keV in clusters: dark matter or sulfur CX

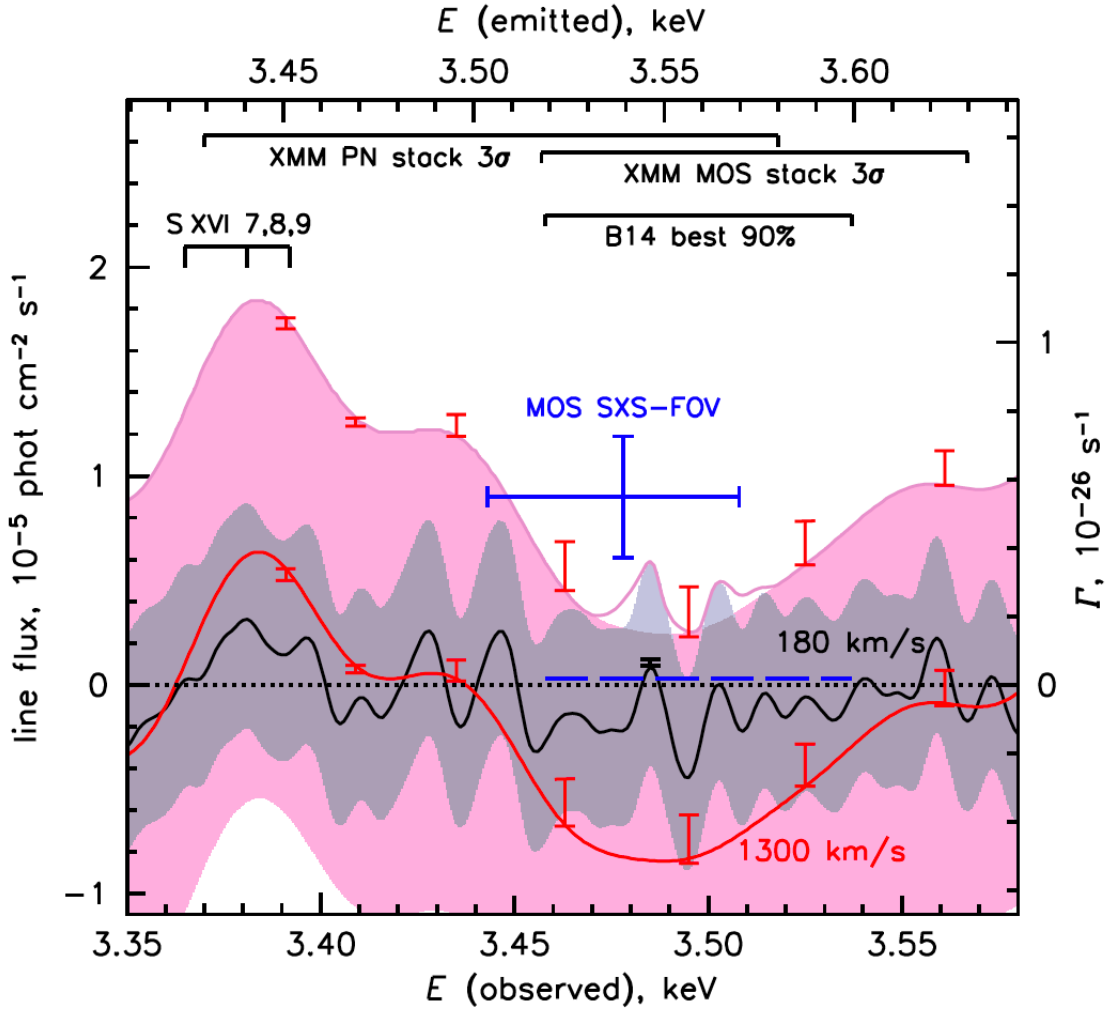


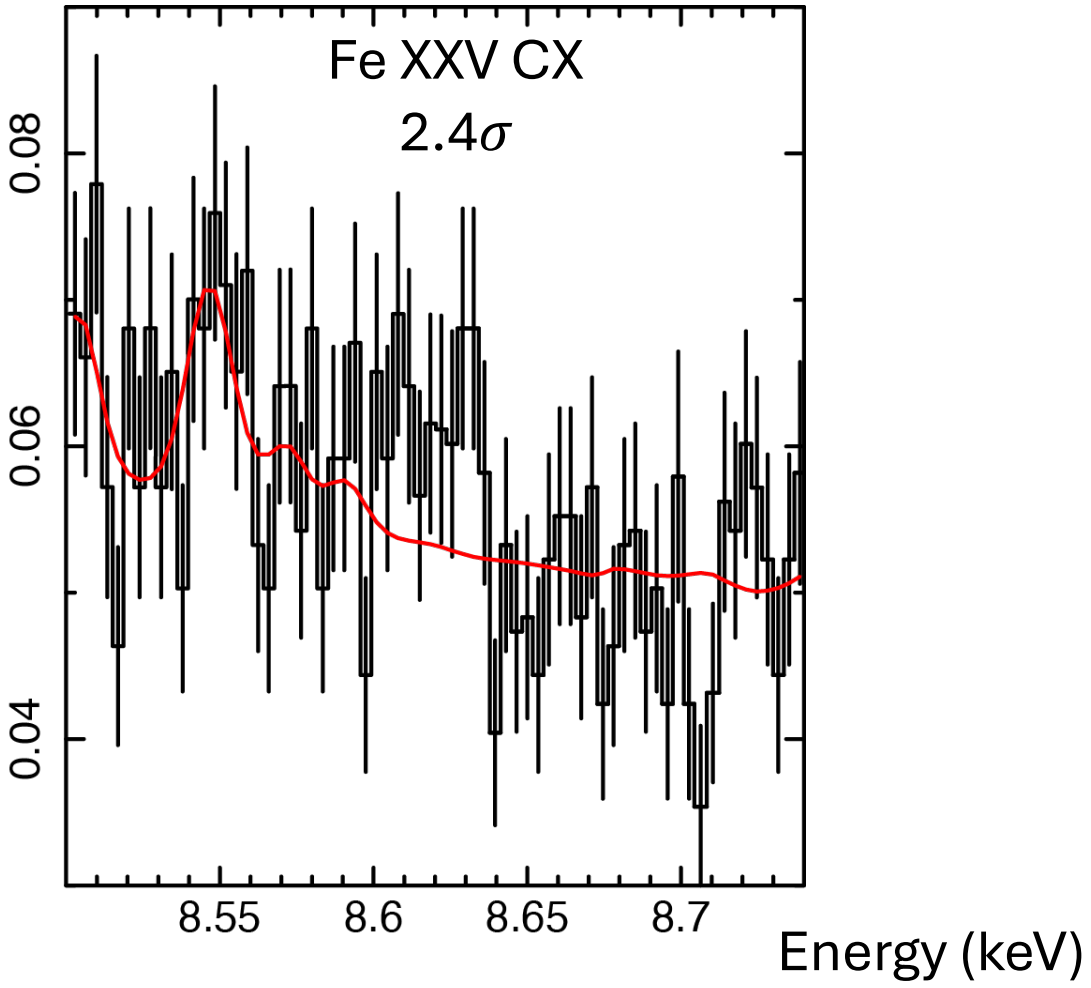


- 3σ detection of unidentified emission line in the stacked X-ray spectrum of galaxy clusters (Bulbul+14, Boyarsky+14)

- Charge exchange of fully ionized sulfur with hydrogen atom produces a peak at 3.46 keV (Gu+15)

Charge exchange in clusters: Hitomi view of Perseus cluster

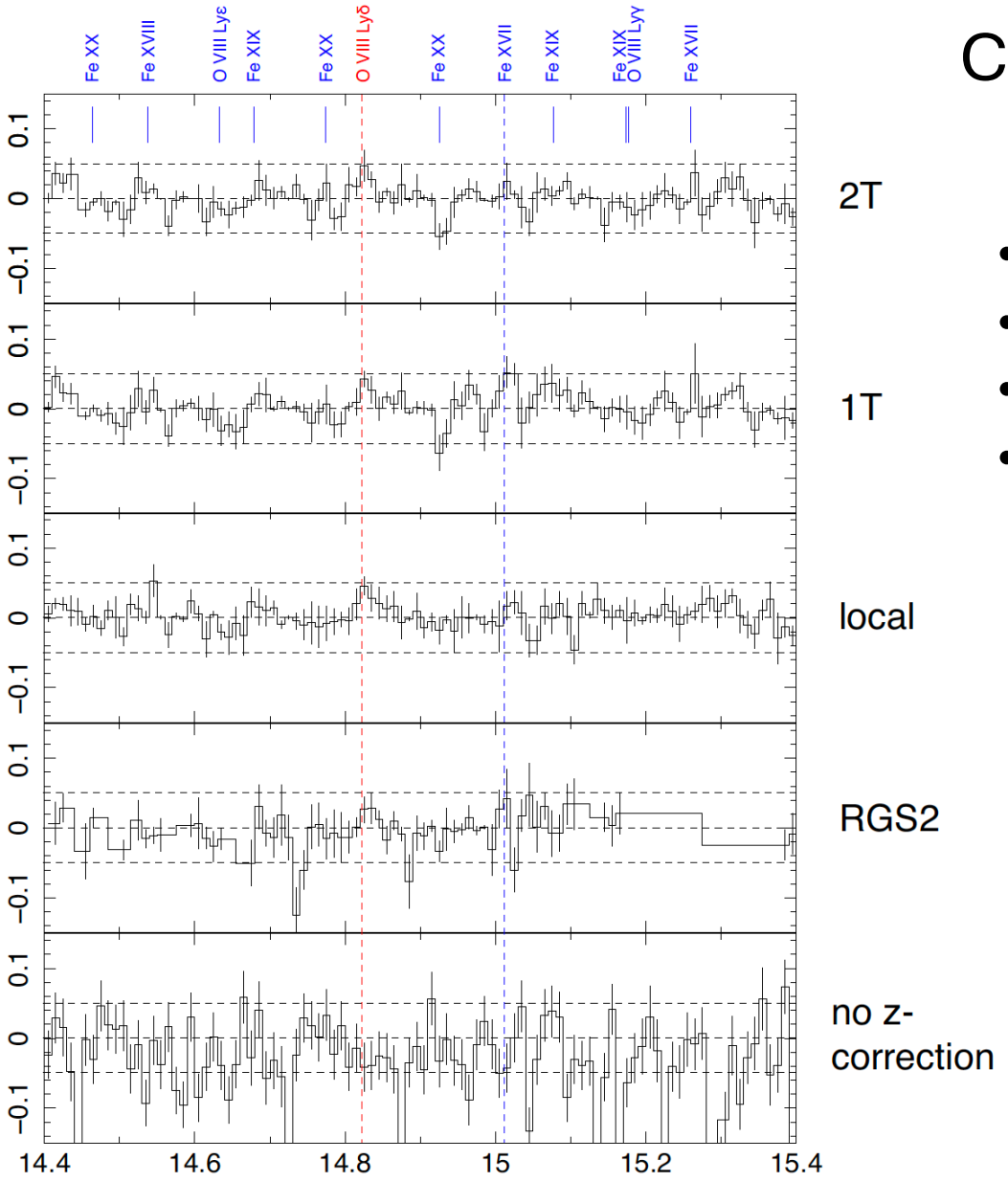




Evidence for Si and Fe CX are reported in Hitomi et al. (17, 18)

New data taken by XRISM.

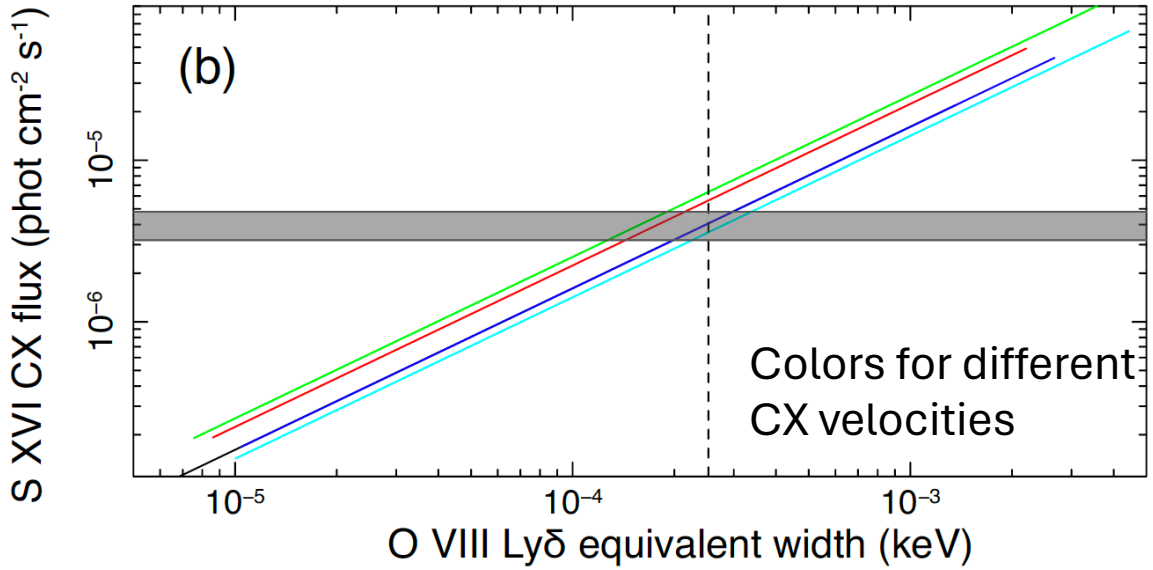
Stacking 21 clusters (Gu+17)



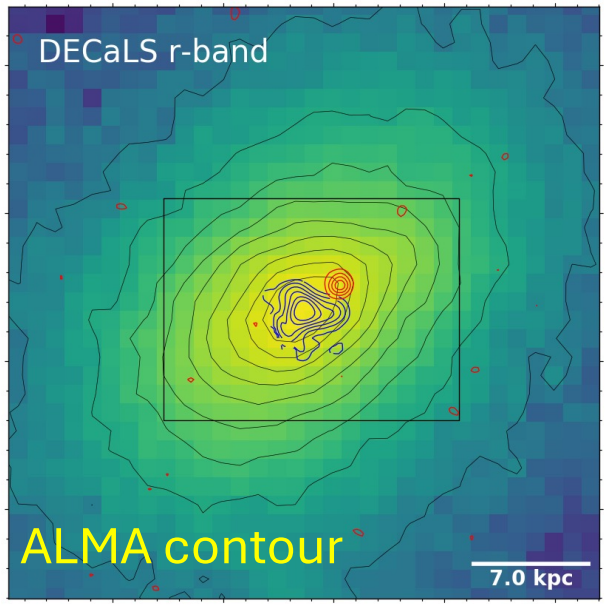
Charge exchange in cluster: RGS view

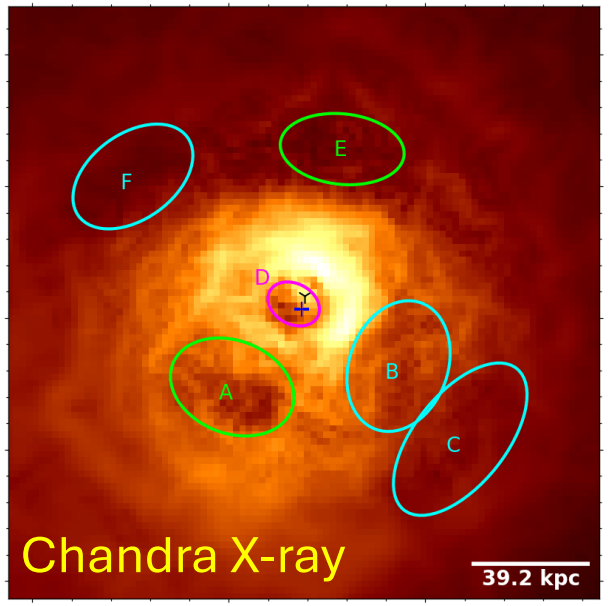
- 2.8σ feature at O VIII *Lyδ*
- Cannot be iron lines
- Cannot be astrophysical effects
- in line with the sulfur model for 3.5 keV

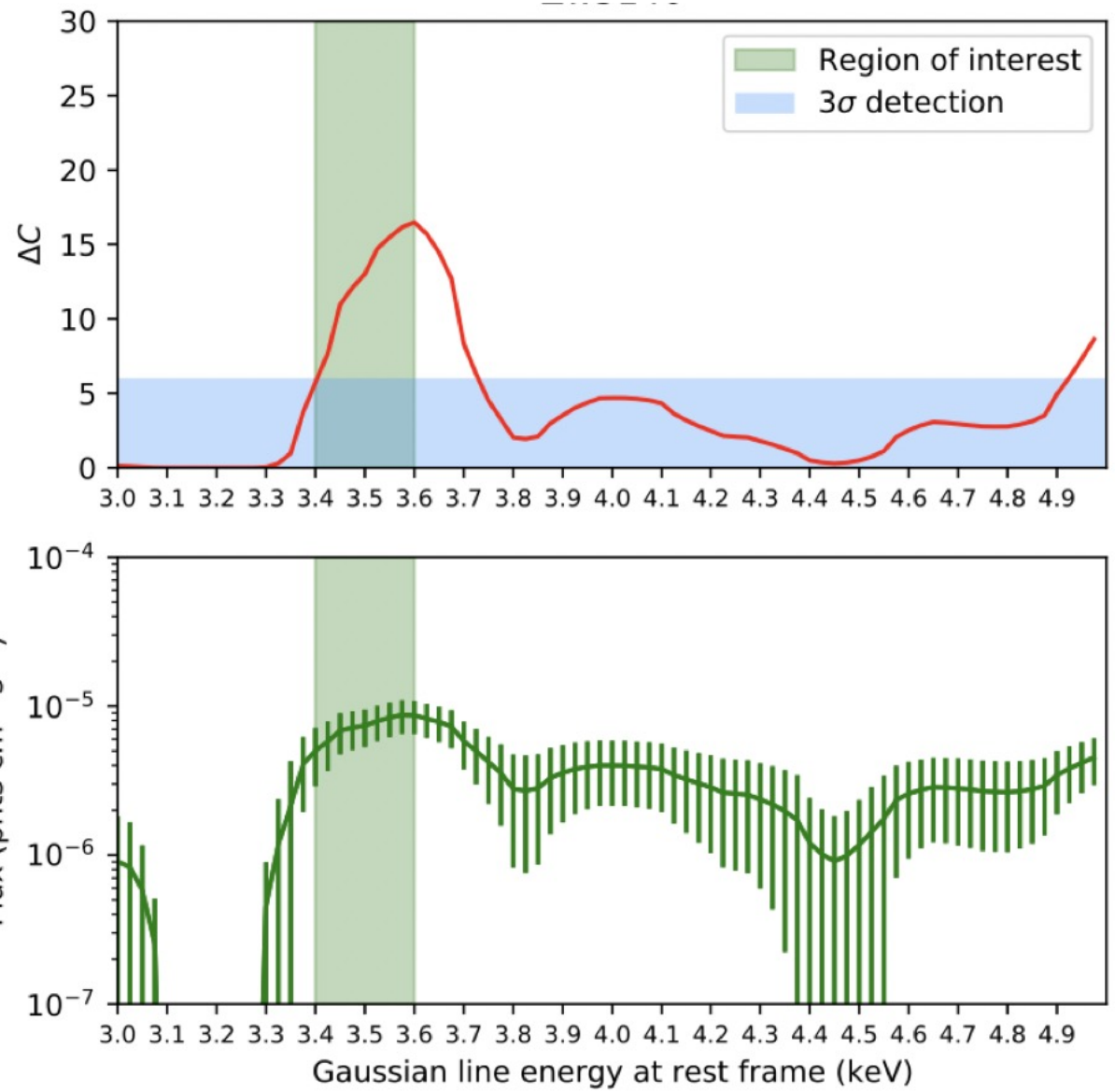
Correlation between O and S CX



ZW3146 cluster of galaxy



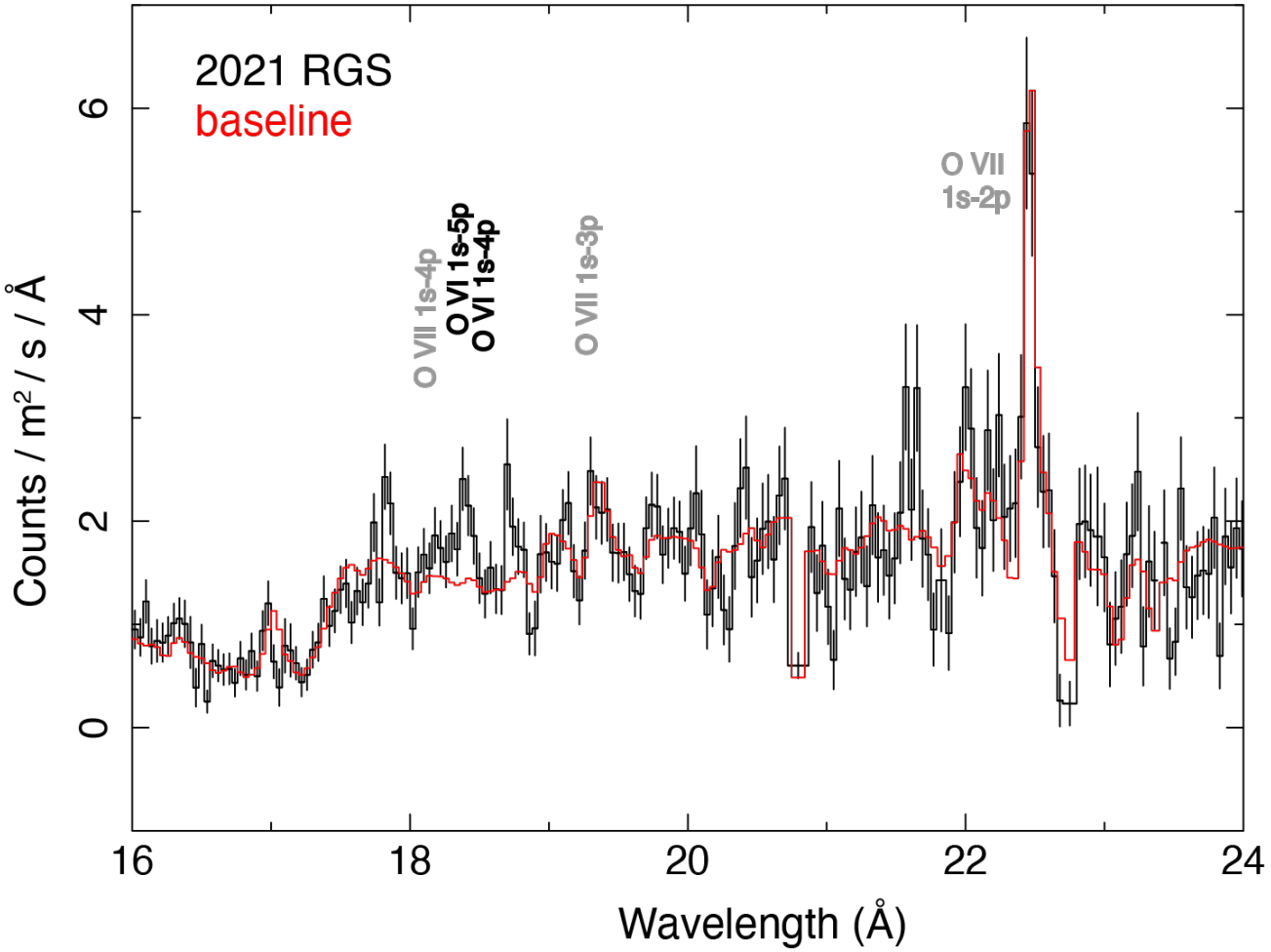




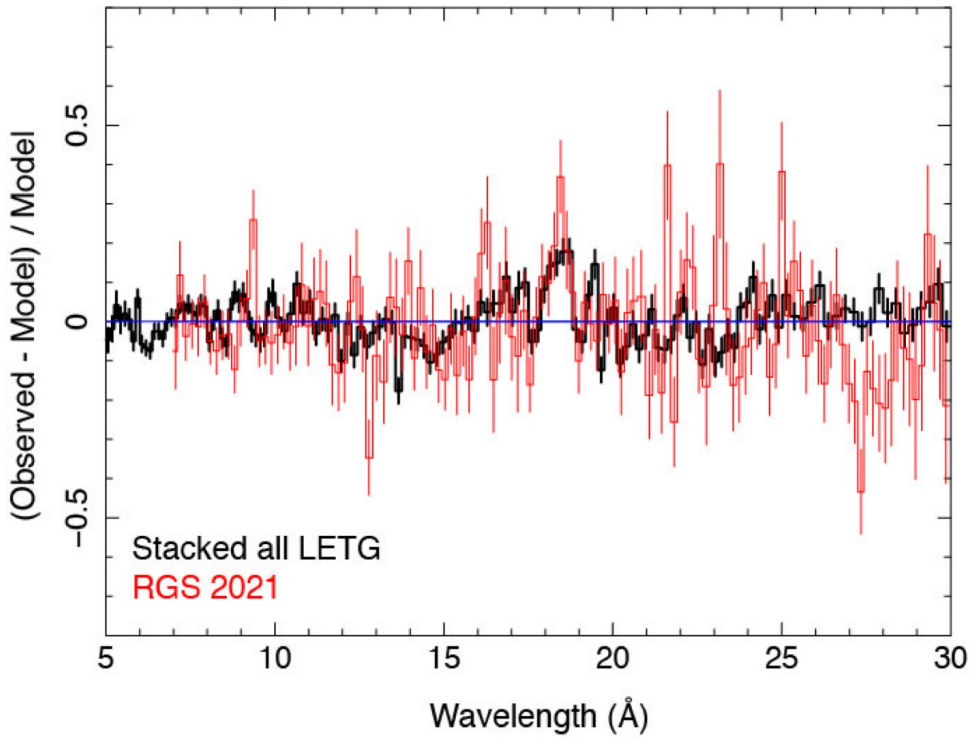
- $5 \times 10^{10}\ M_{\odot}$ molecular hydrogen with ALMA (Perseus cl. = $4 \times 10^{10}\ M_{\odot}$)
- XMM and Chandra spectra detect > 3σ excess at 3.5 keV (Bhargava+2024)

NGC 5548 AGN: excess at 18.4 Å

2021 RGS data with PIE modeling (Gu + 2022)



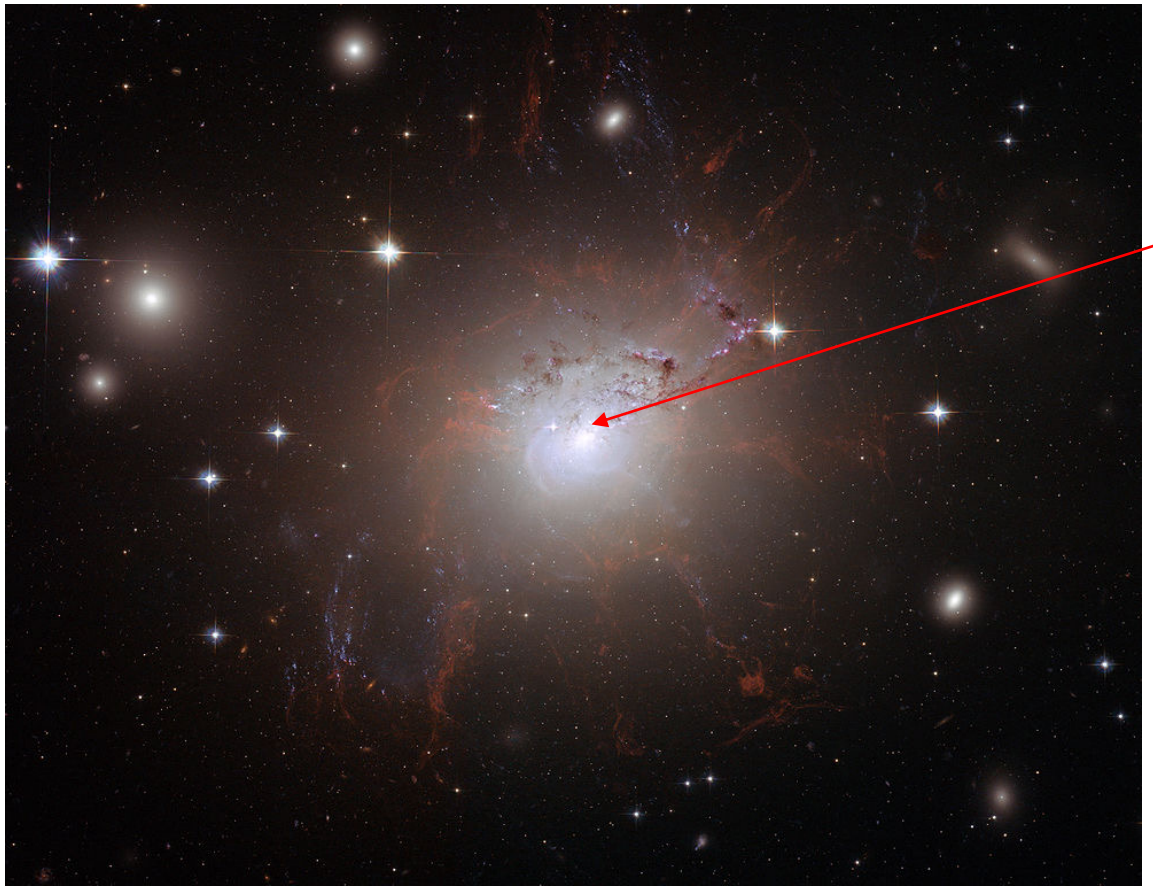
Stacking residuals (1999 - 2021)

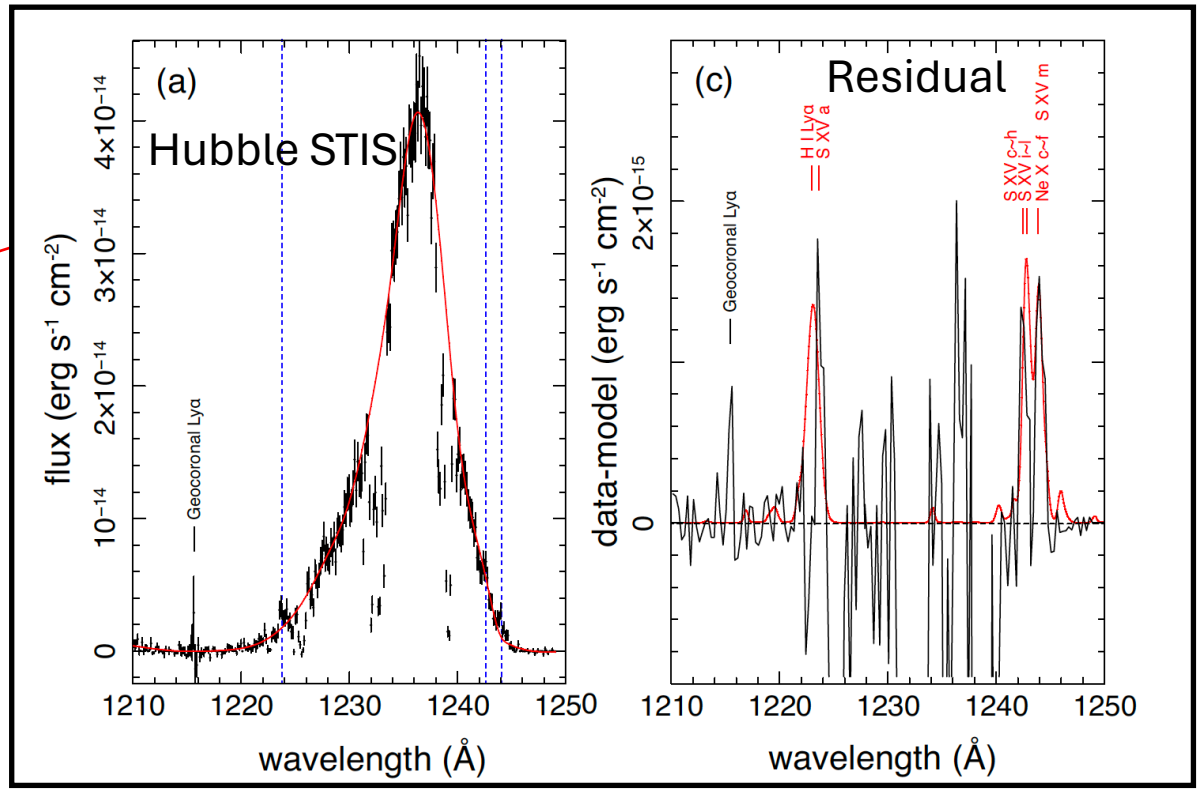


- Excess > 5σ (with looking-elsewhere effect)
- At energies ~ high-*n* of O VI (or O VII)
- Cannot be instrumental, reflection, or (dusty) absorption

NGC 1275 AGN: excess at FUV

optical + Halpha (Gu+2017)





- Excess at S XV charge exchange FUV lines
- Outflow velocity ~ 3000 km/s, agree with *Lya* absorbers

Summary

- XRISM can explore CX, together with a number of amusing science, even with the gate-valve closed
- N132D SNR: total of > 4σ evidence of Si charge exchange, likely due to shock-neutral interaction
- First detection of Si charge exchange beyond the solar system, fully resolved from the thermal lines
- Limited statistics will remain a challenge for most objects before the gate-valve opens
- Apart from SNR, also expect to observe CX from solar events and solar system (Xtend), from diffuse cold clouds in galaxy clusters, and possibly from multiphase outflows in stars, binaries and AGNs