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

Lyi Gu (SRON)
X-ray Spectrum of Supernova Remnant N132D Measured by XRISM Resolve
- 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 \textit{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.
N132D first light: Si/S band XRISM/Resolve

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

RESOLVE SPECTRUM STILL UNDER EMBARGO
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

- 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

interaction volume \( V = 10^{51} \text{ m}^3 \times \frac{10^3 \text{ cm}^{-3}}{\text{neutral density}} \times \frac{1 \text{ cm}^{-3}}{\text{ion density}} \times \frac{100 \text{ km s}^{-1}}{\text{collision velocity}} \)

- 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: contribute a third possibility
• 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.
The show has begun
3.5 keV in clusters: dark matter or sulfur CX

- $3\sigma$ 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)
Evidence for Si and Fe CX are reported in Hitomi et al. (17, 18)
New data taken by XRISM.
Stacking 21 clusters (Gu+17)

- 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

Charge exchange in cluster: RGS view

Correlation between O and S CX

Colors for different CX velocities
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 $>3\sigma$ excess at 3.5 keV (Bhargava+2024)
NGC 5548 AGN: excess at 18.4 Å

2021 RGS data with PIE modeling (Gu + 2022)

- 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 Ly\(\alpha\) absorbers
Summary

- XRISM can explore CX, together with a number of amusing science, even with the gate-valve closed

- N132D SNR: total of $>4\sigma$ 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