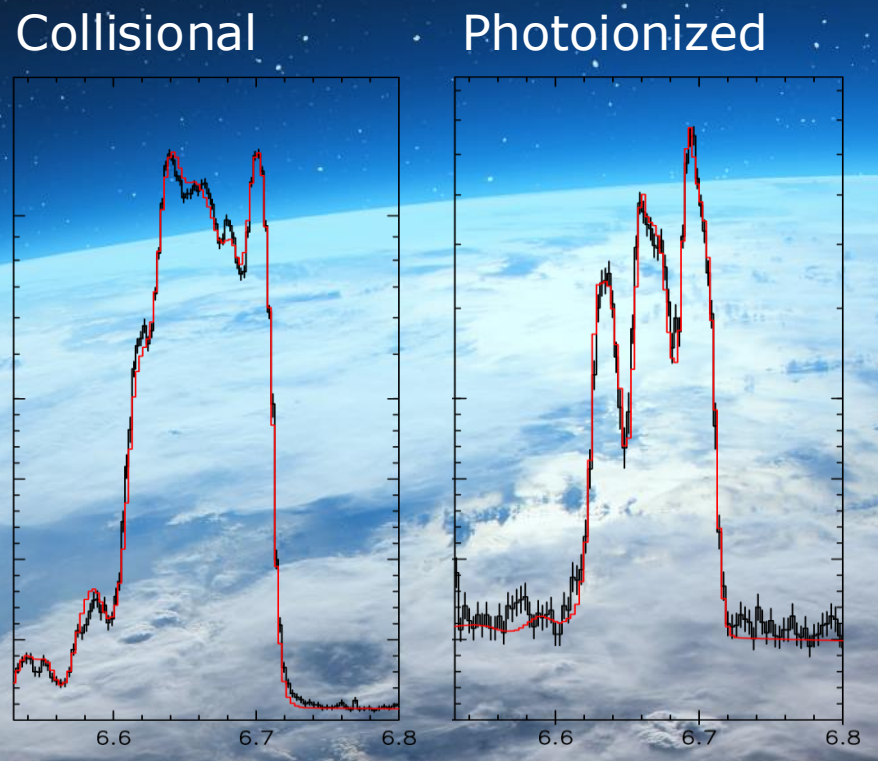
TO BRING ABOUT BREAKTHROUGHS IN INTERNATIONAL SPACE RESEARCH

Lessons from XRISM analysis: spectral models and diagnostics

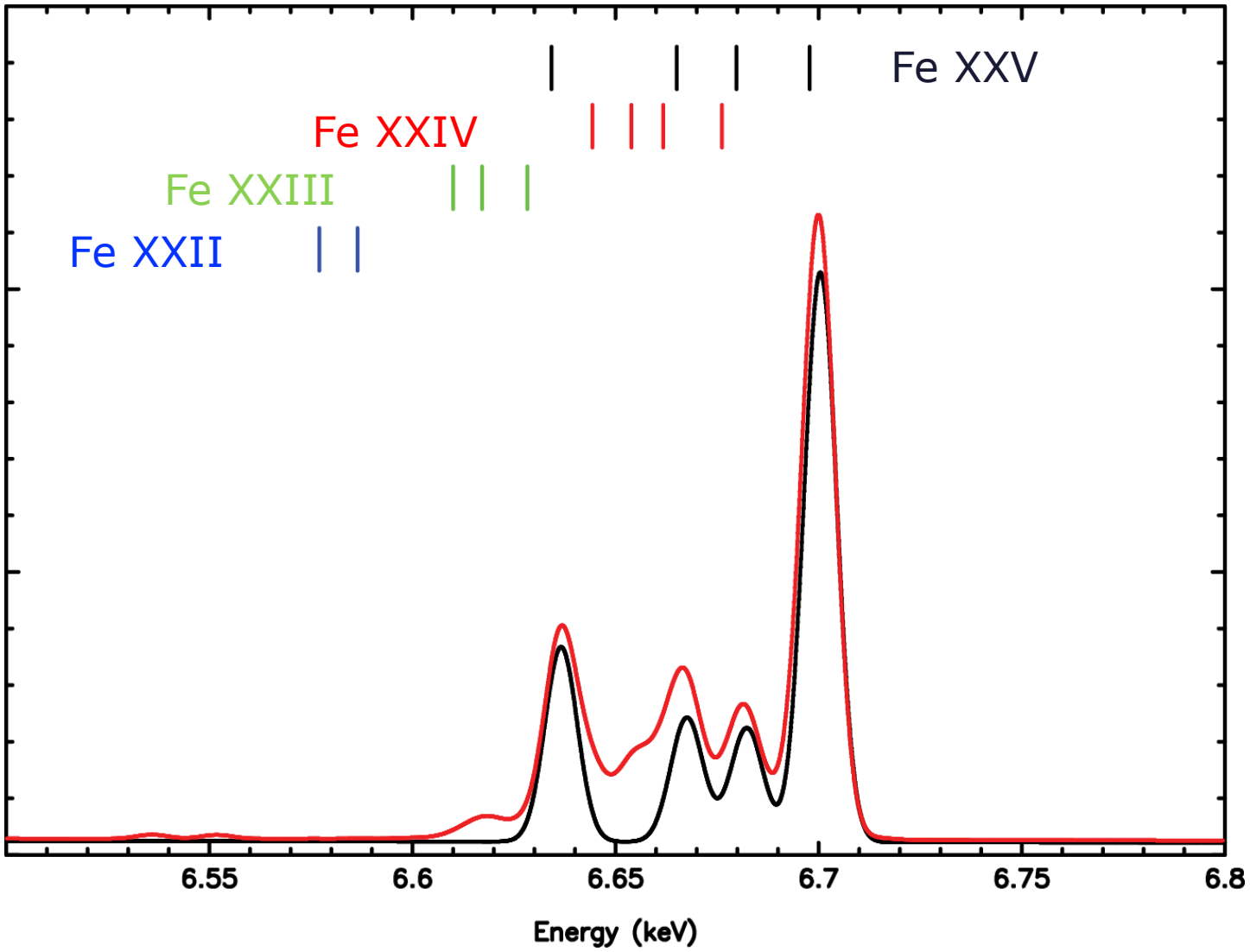
Liyi Gu

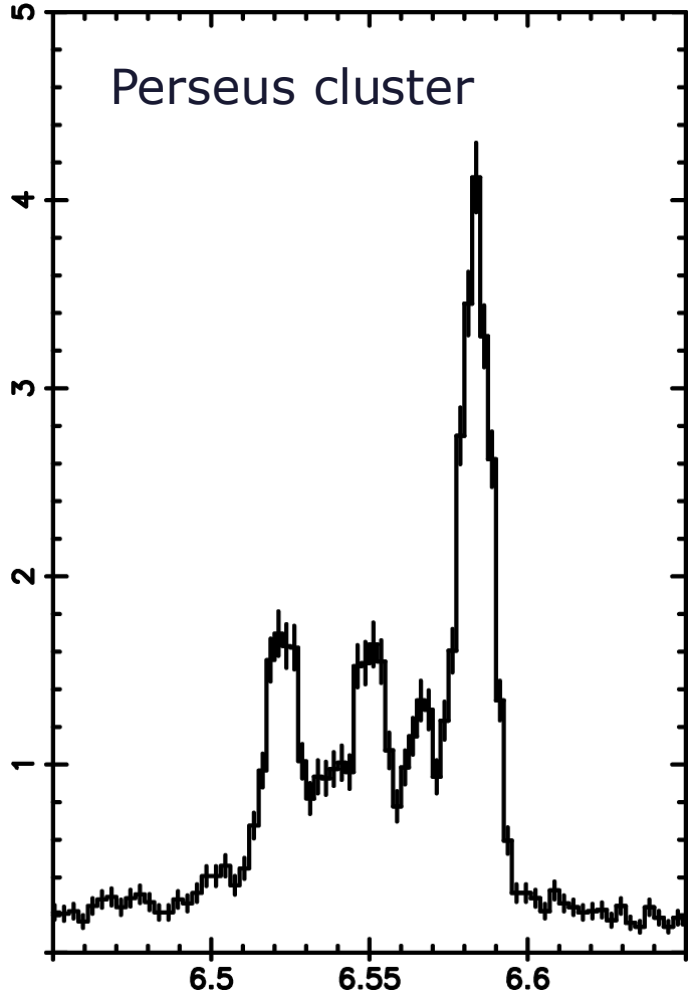
SRON SPACE RESEARCH ORGANISATION NETHERLANDS



Jan 2026 Lumière Paris-Saclay

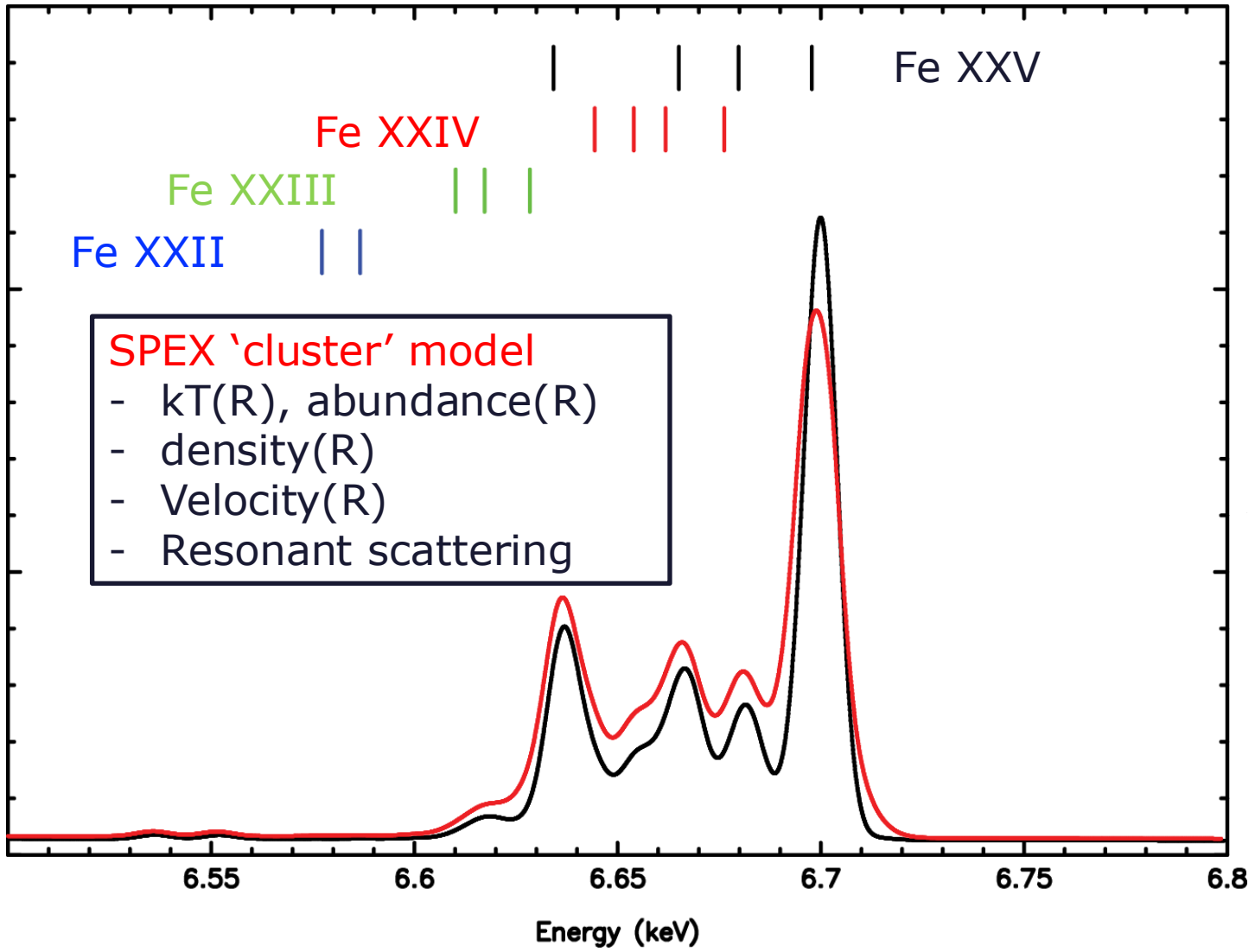
Start with the basic: a CIE model with kT = 4 keV

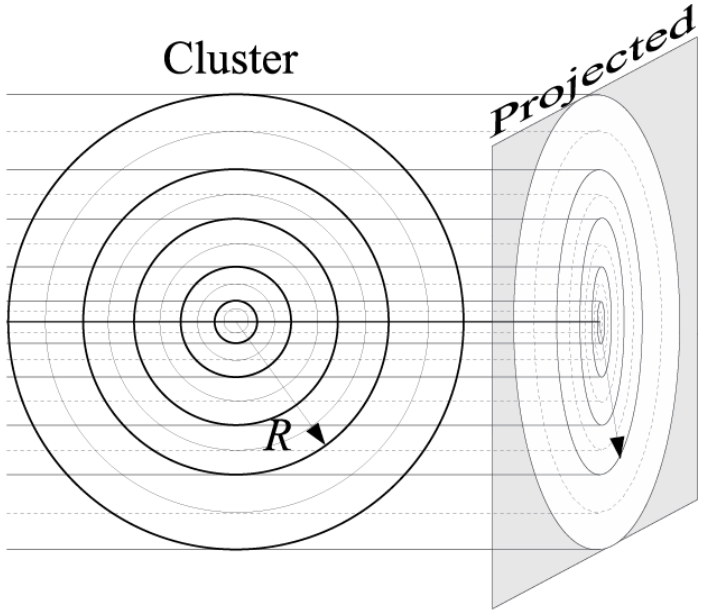


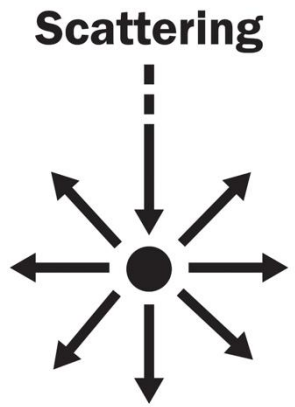


SRON

Adding gradients and photon scattering



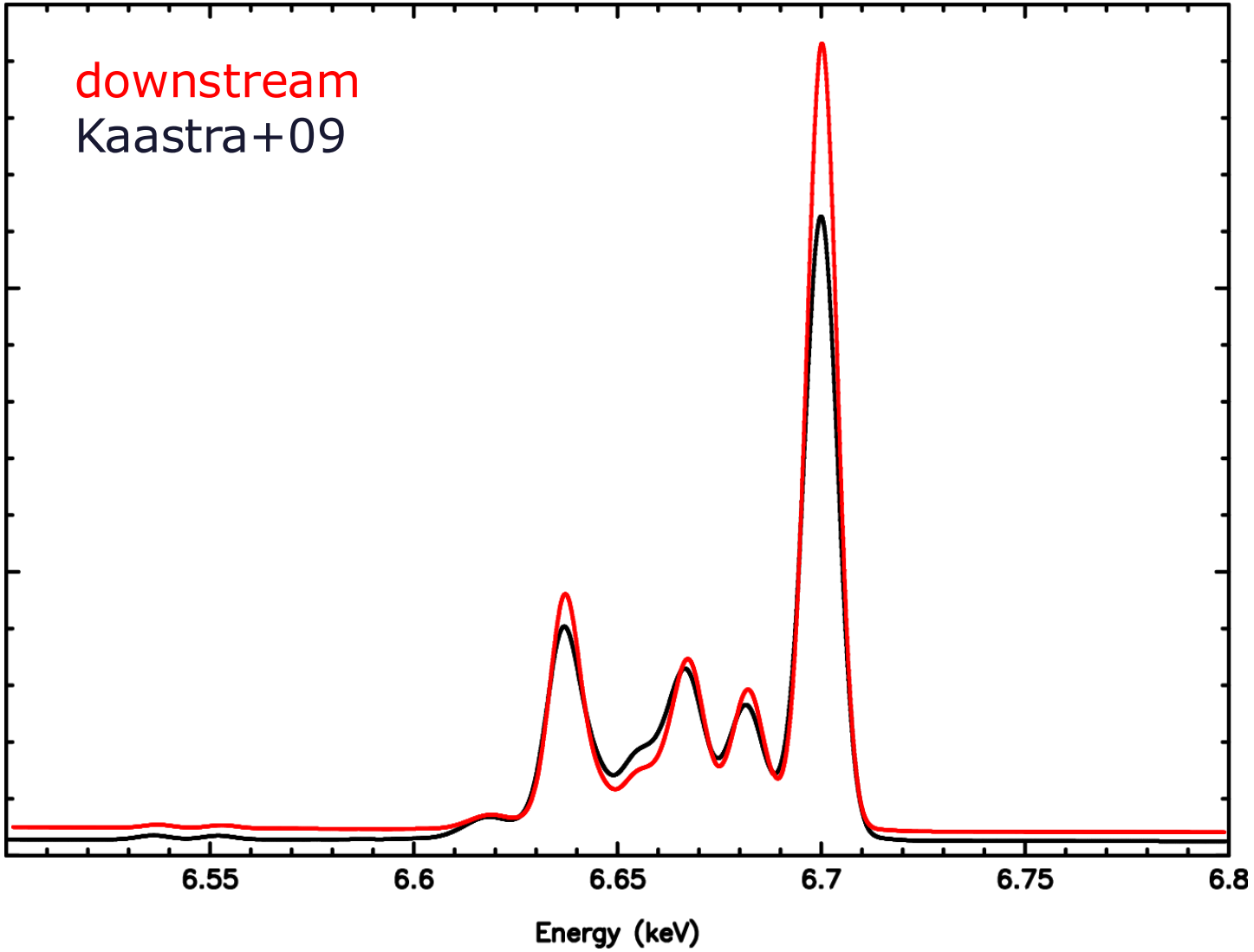


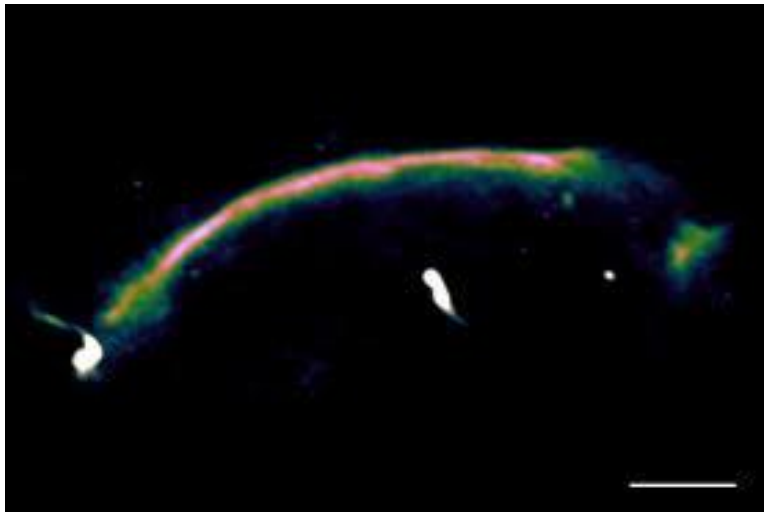


Štofanová+ (2025)

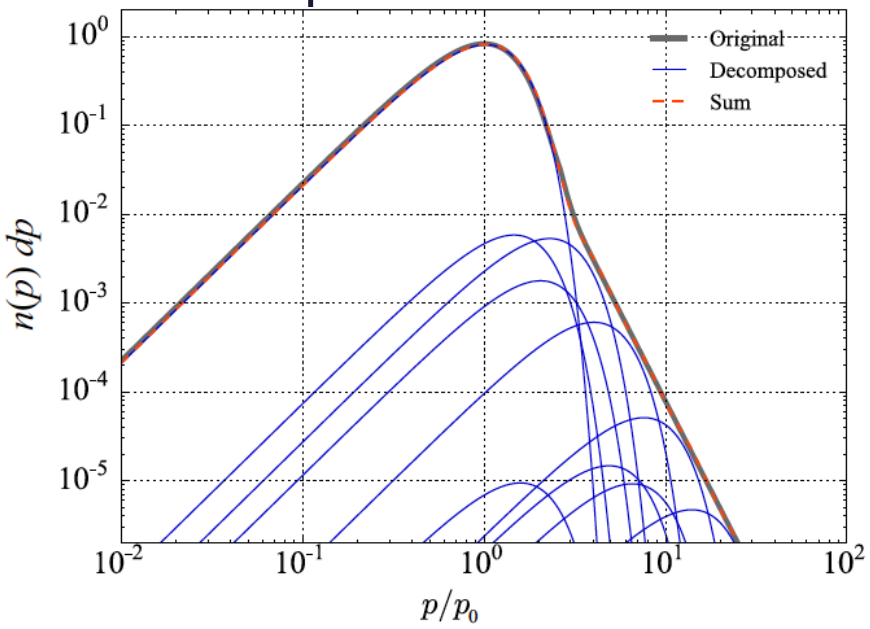
SRON

Adding non-thermal component





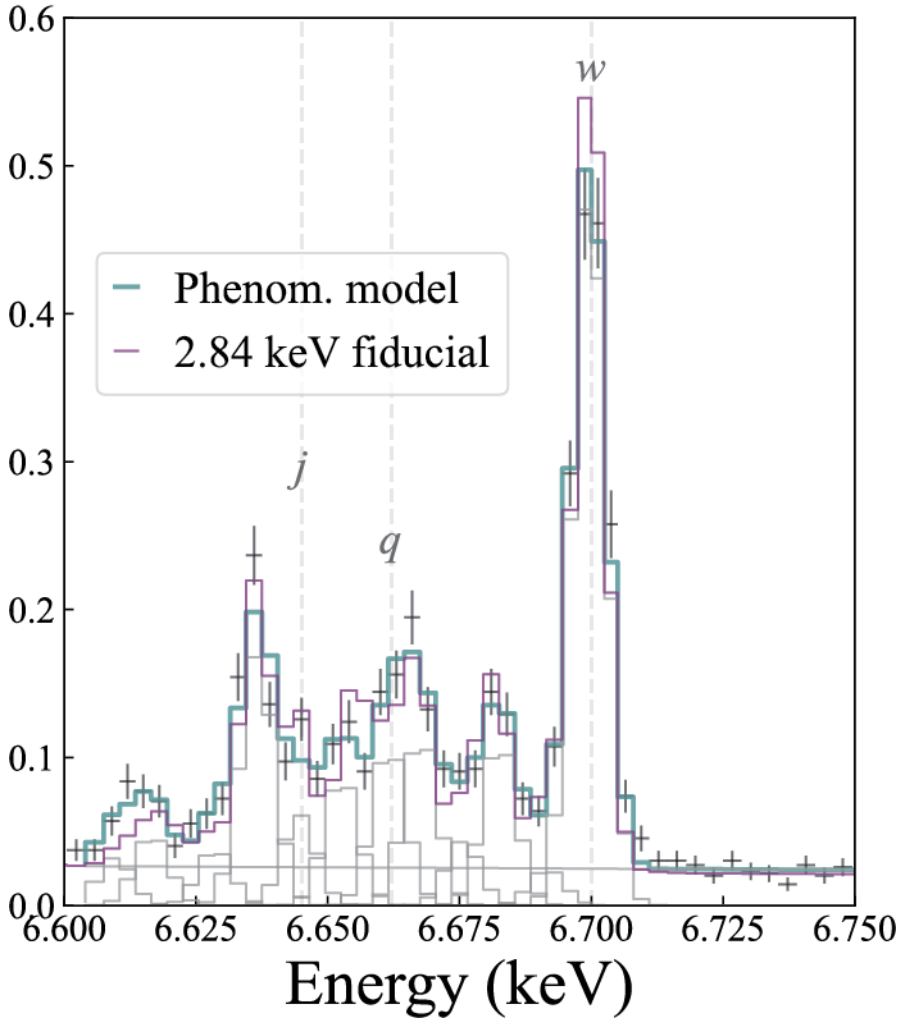
Decomposition



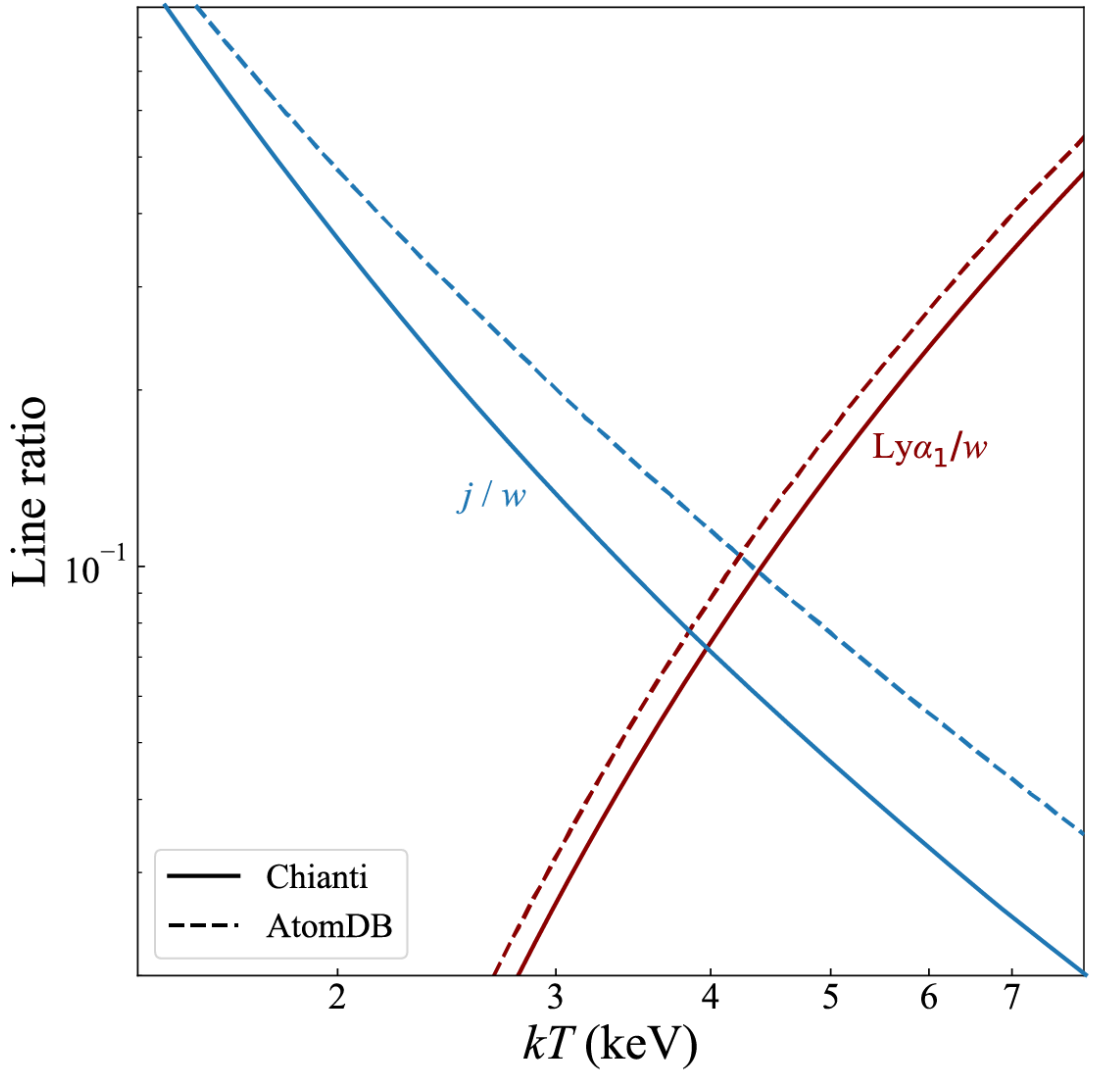
SRON

Line diagnostics

GT Mus (Resolve)
Kurihara+25



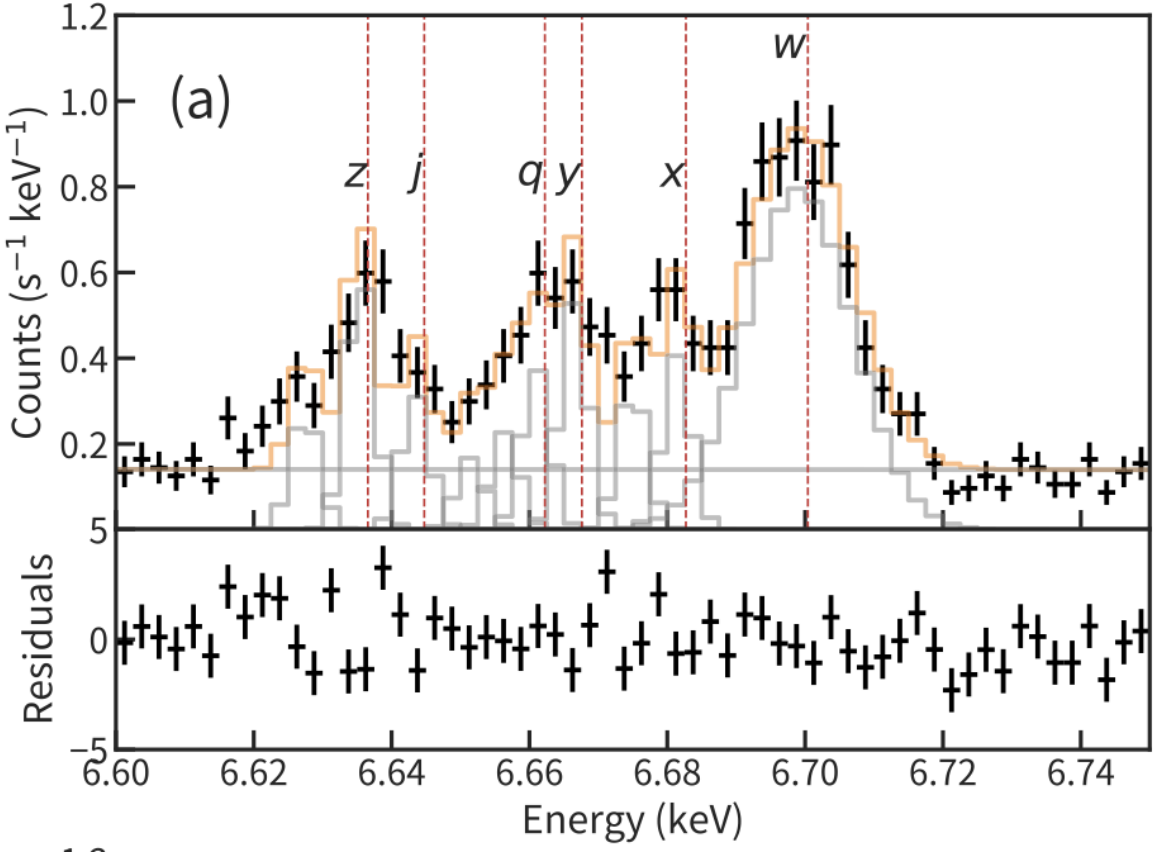
DR lines (such as *j*) will be suppressed at high kT.



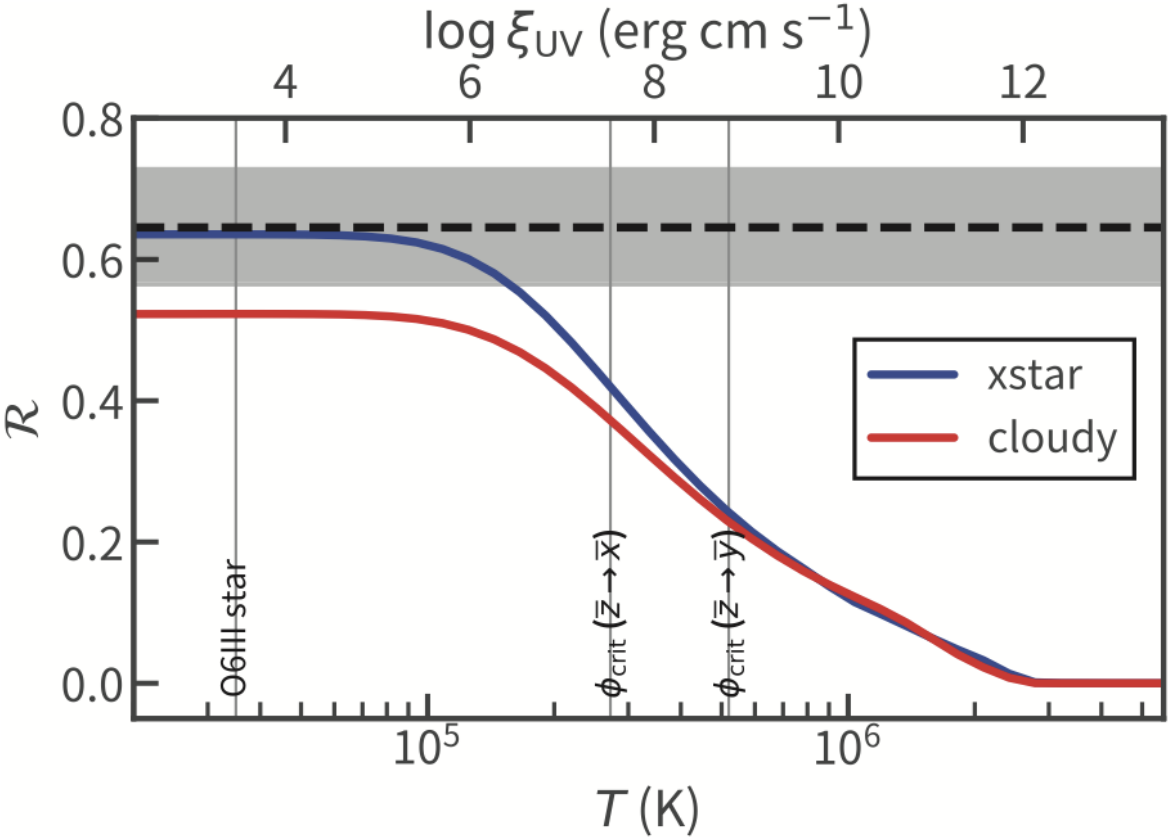
SRON

Line diagnostics

Cen X-3 Mochizuki+25



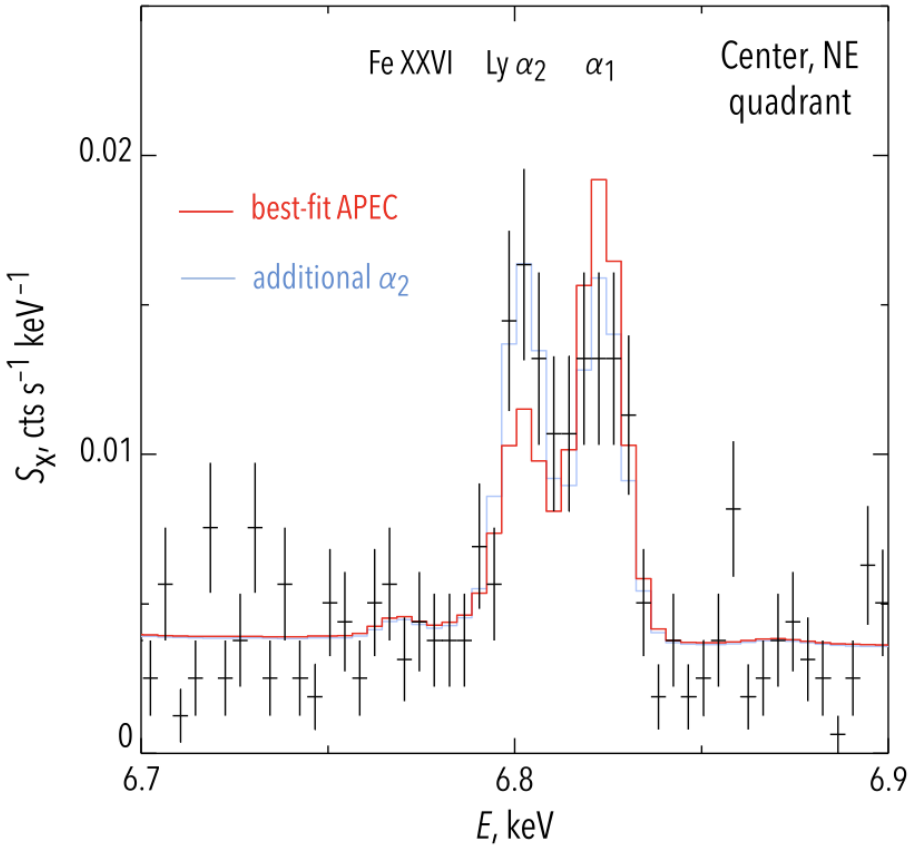
z line is suppressed at high density or high UV flux



Forbidden level can be mixed with upper levels via photon or collision excitation

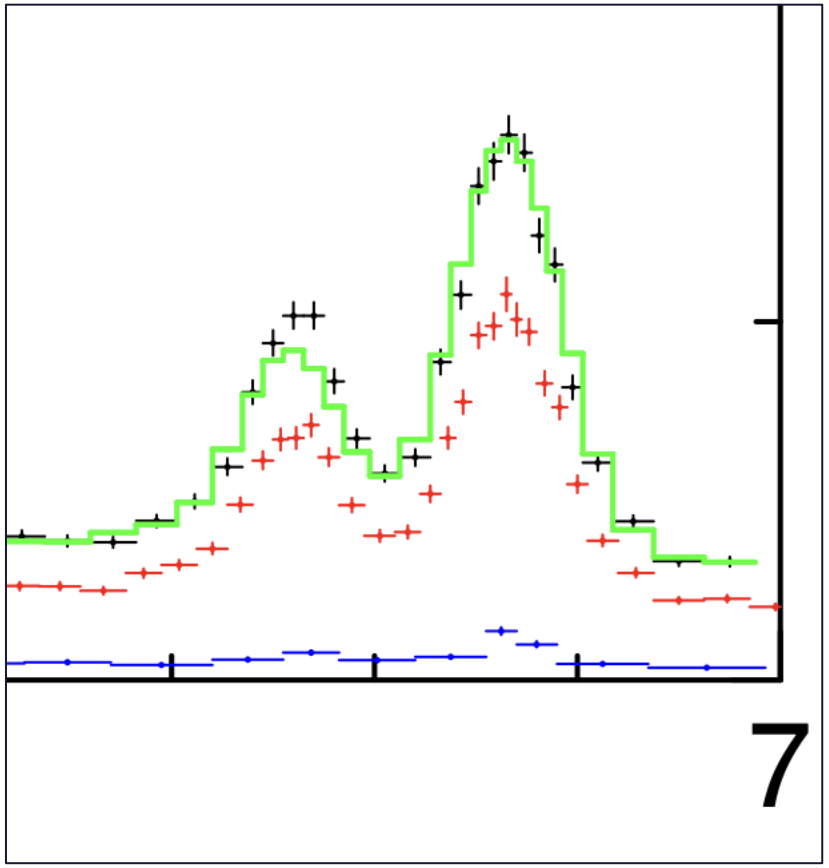
Fe XXVI Lyman α lines

Coma cluster
XRISM+25



By theory, Lya2/Lya1 = 0.5
Several clusters indicate > 0.5

Stacked 10 clusters
XRISM+25

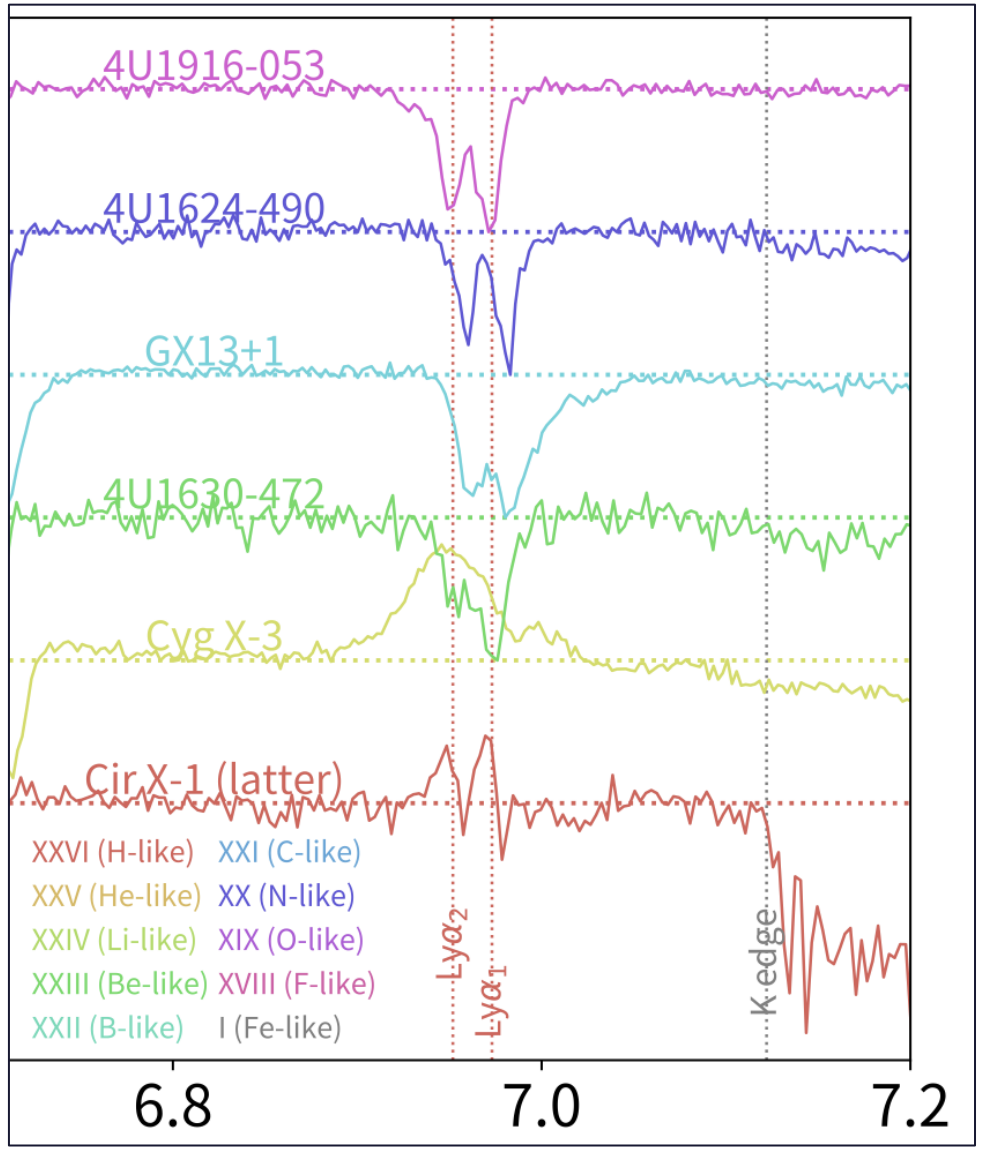


Potential diagnostics: resonant scattering, blending M1 transition, charge exchange...

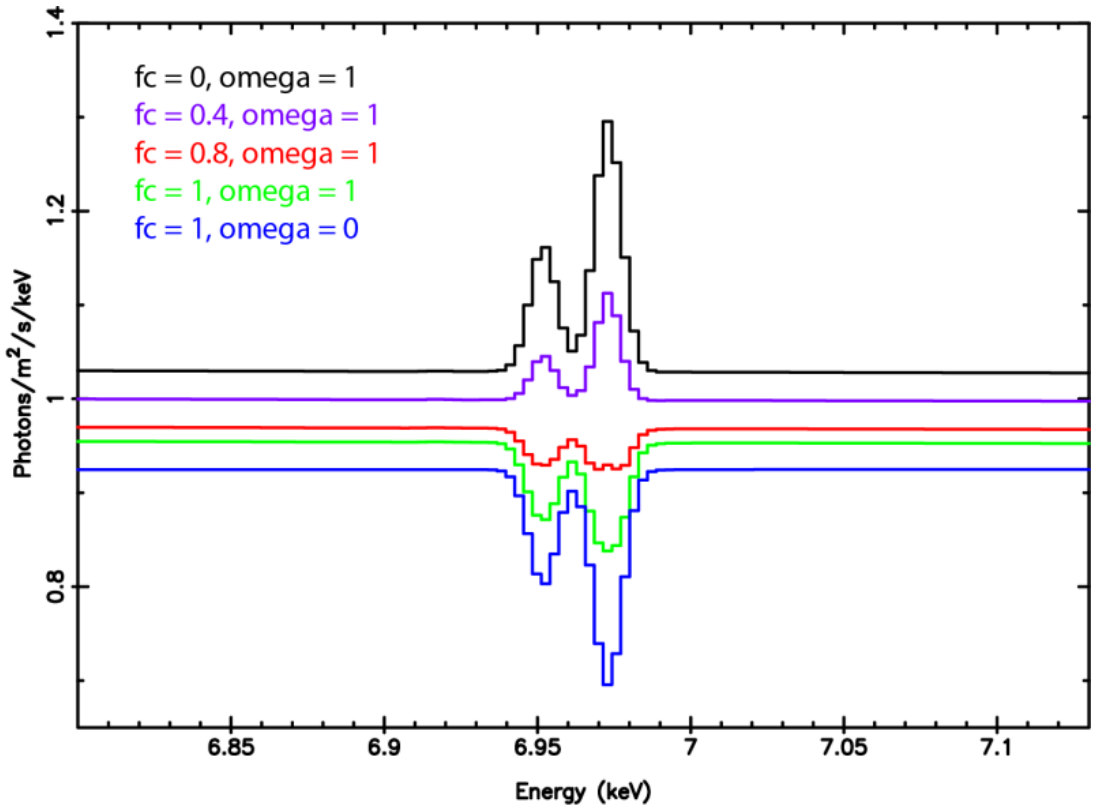
SRON

Fe XXVI Lyman α lines

X-ray binaries Tsujimoto+25



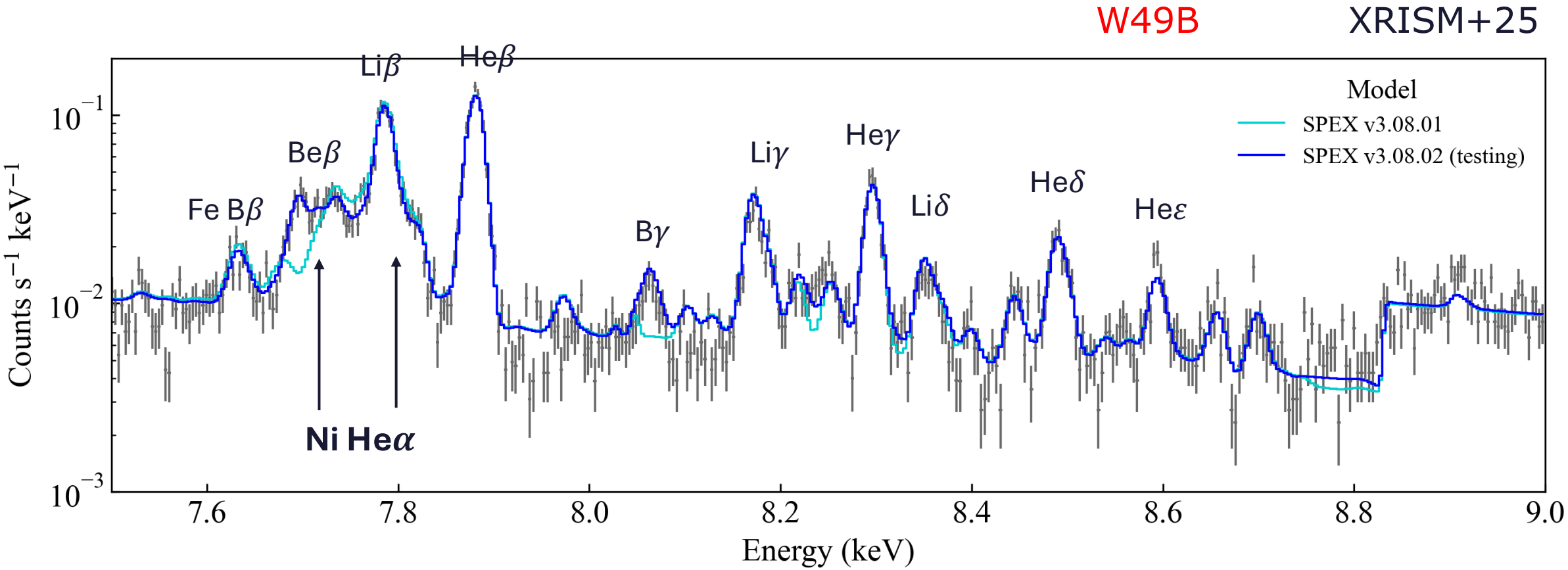
Pion calculation



Potential diagnostics: saturation/partial covering, scattered emission, high density, high UV flux, polarization...

SRON

Fe Kβ lines

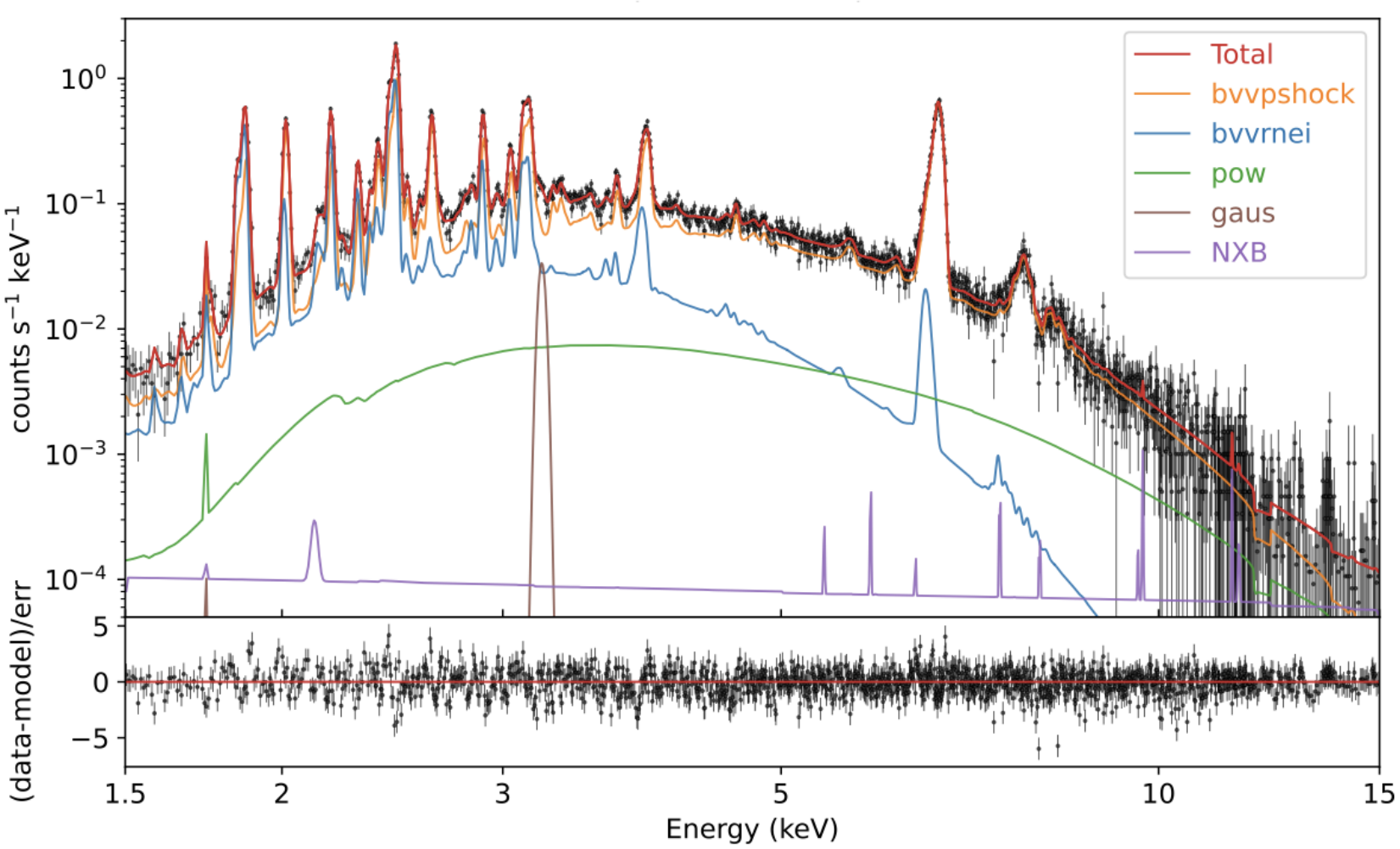


- Improved atomic data: innershell excitation and DR data for C-, B-, Be-, and Li-like ions
- Kβ to >Kε lines are resolved with XRISM
- These data on Si, S, and Fe are more essential for measuring Ni, P, Cl, and K abundances due to line blending

SRON

Fe Kβ and Ni line complex

Cas A Plucinsky+25



Ni/Fe = 1 (AtomDB 3.1.0)

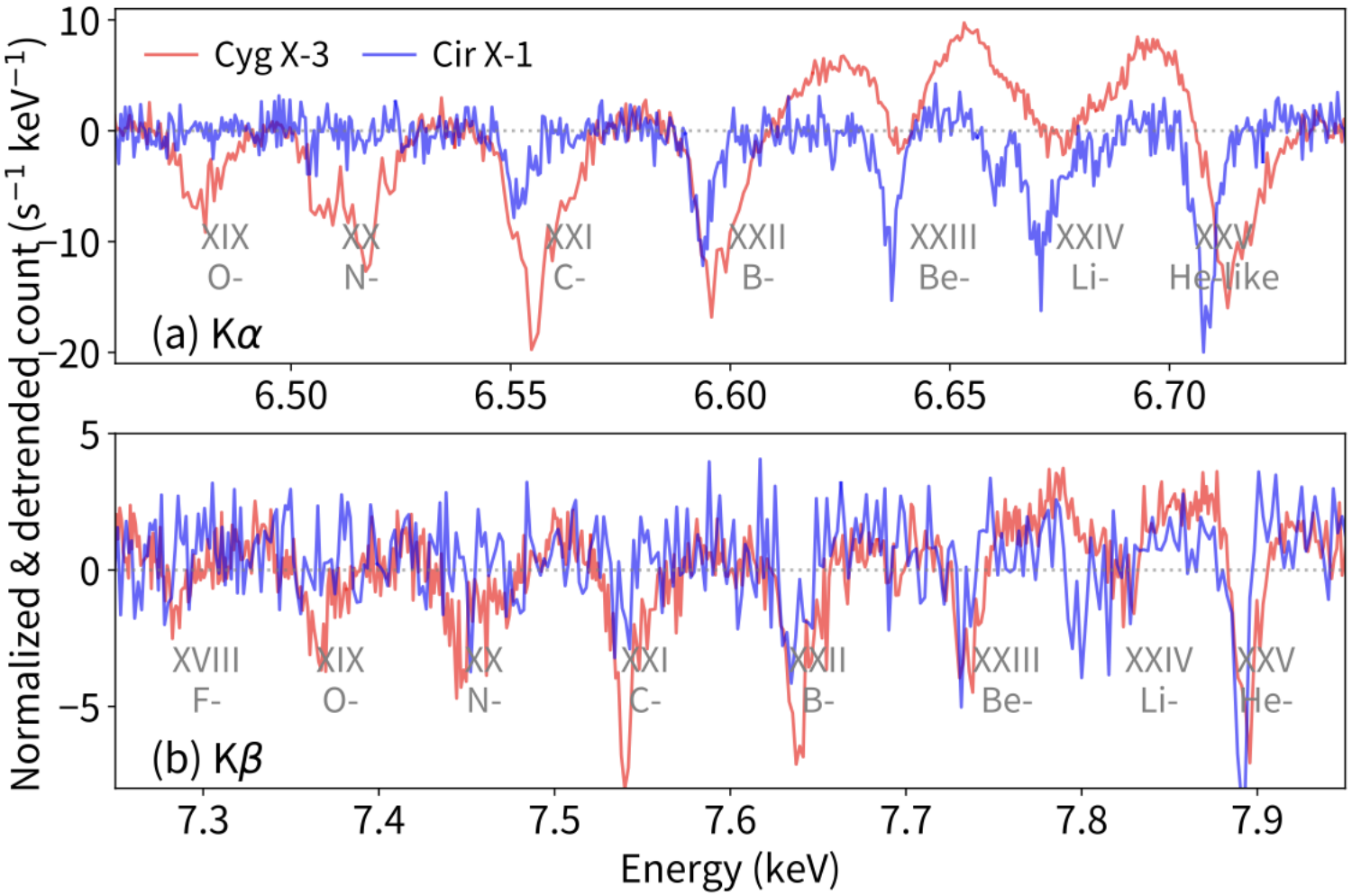
= 0.6 (SPEX 3.08.01)

Both Fe and Ni are in intermediate charge states.

SRON

Fe Kβ lines in X-ray binaries

X-ray binaries Tsujimoto+25

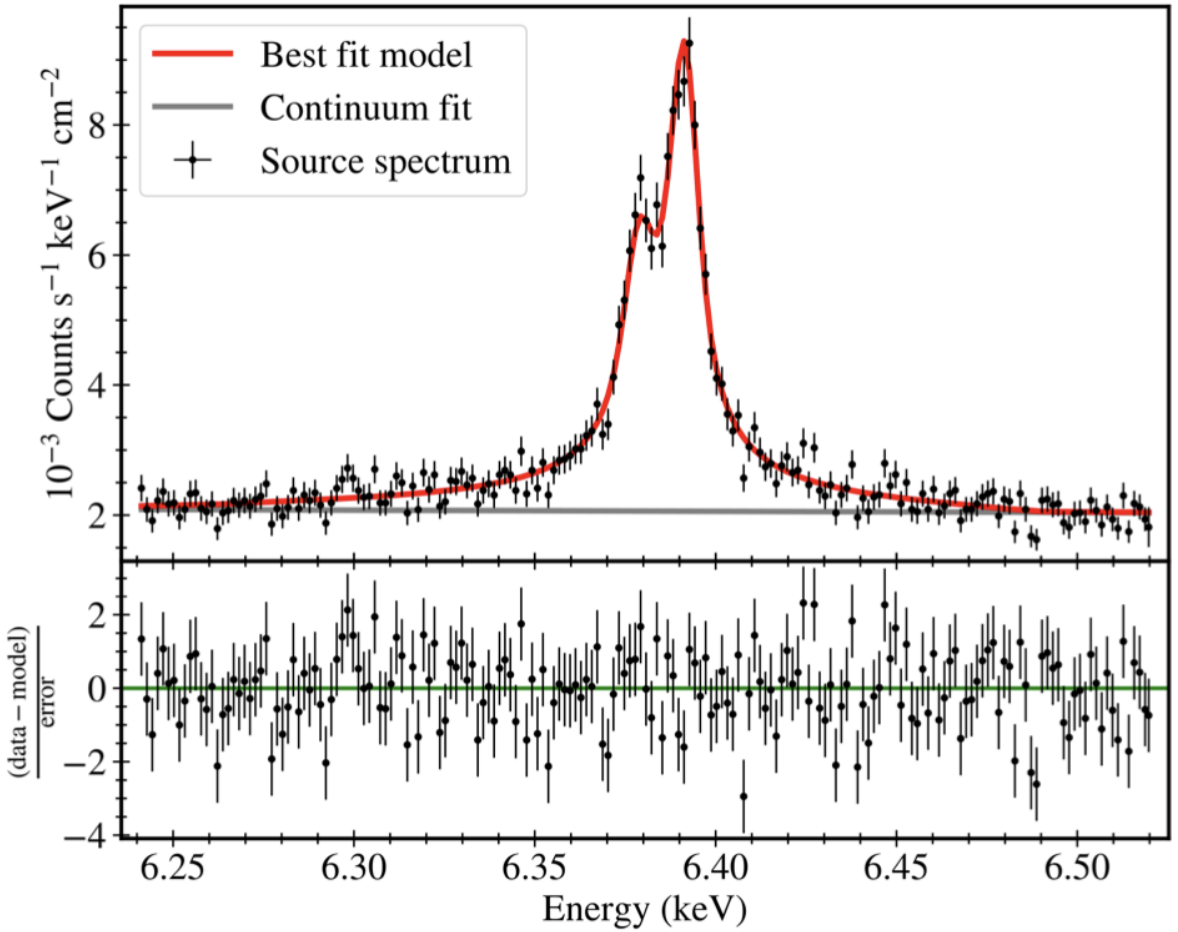


- Fe Kβ lines are better diagnostics of outflow velocity and optical depth, as Kα can be saturated or blended with scatter emission
- Atomic data still need to be improved on Kβ

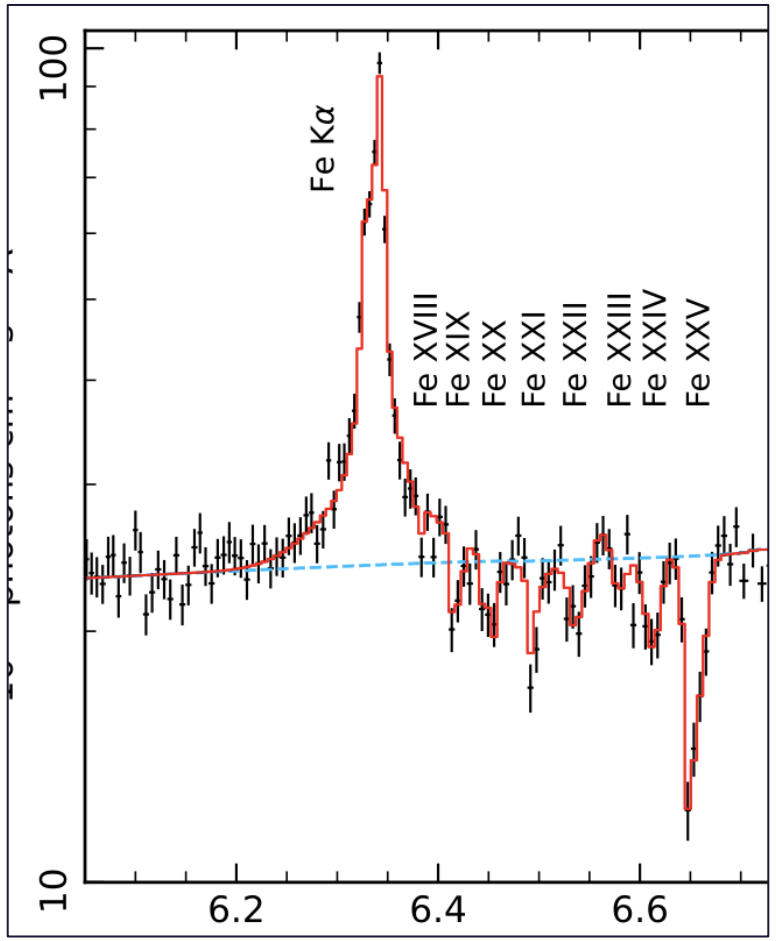
SRON

~Neutral Fe Kα lines

Cen A Bogensberger+25



NGC 3783 Mehdipour+25



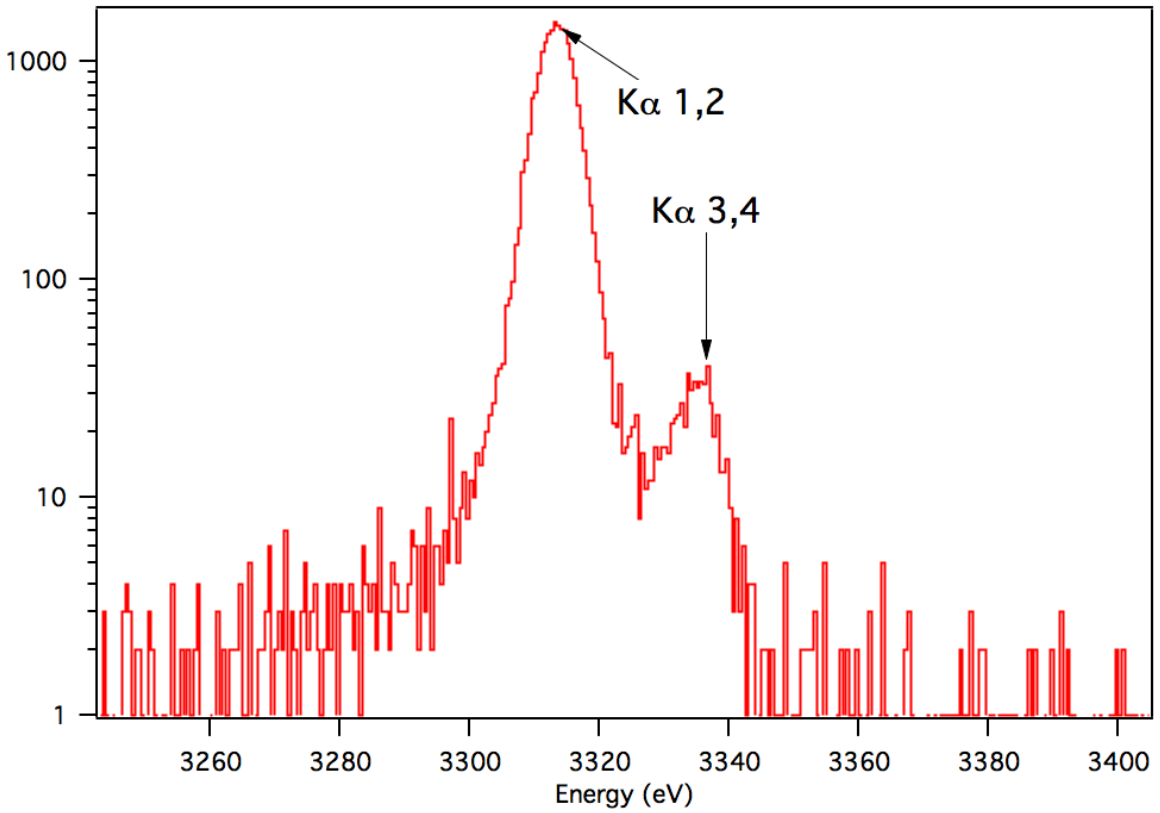
- Fe Kα main lines are complexes of large number transitions forming two main peaks
- No existing atomic model. For now, use Holzer+1997 lab model

SRON

~Neutral Fe Kα lines - satellites

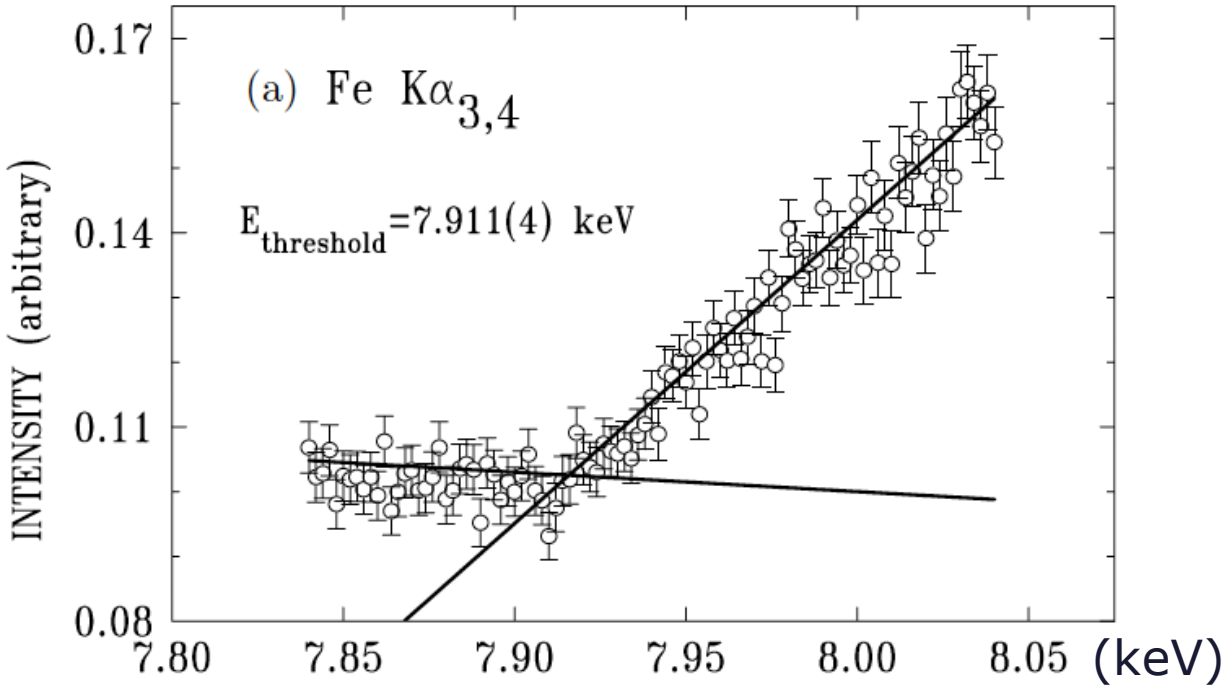
Lab data of K

Porter+



Lab data of Fe

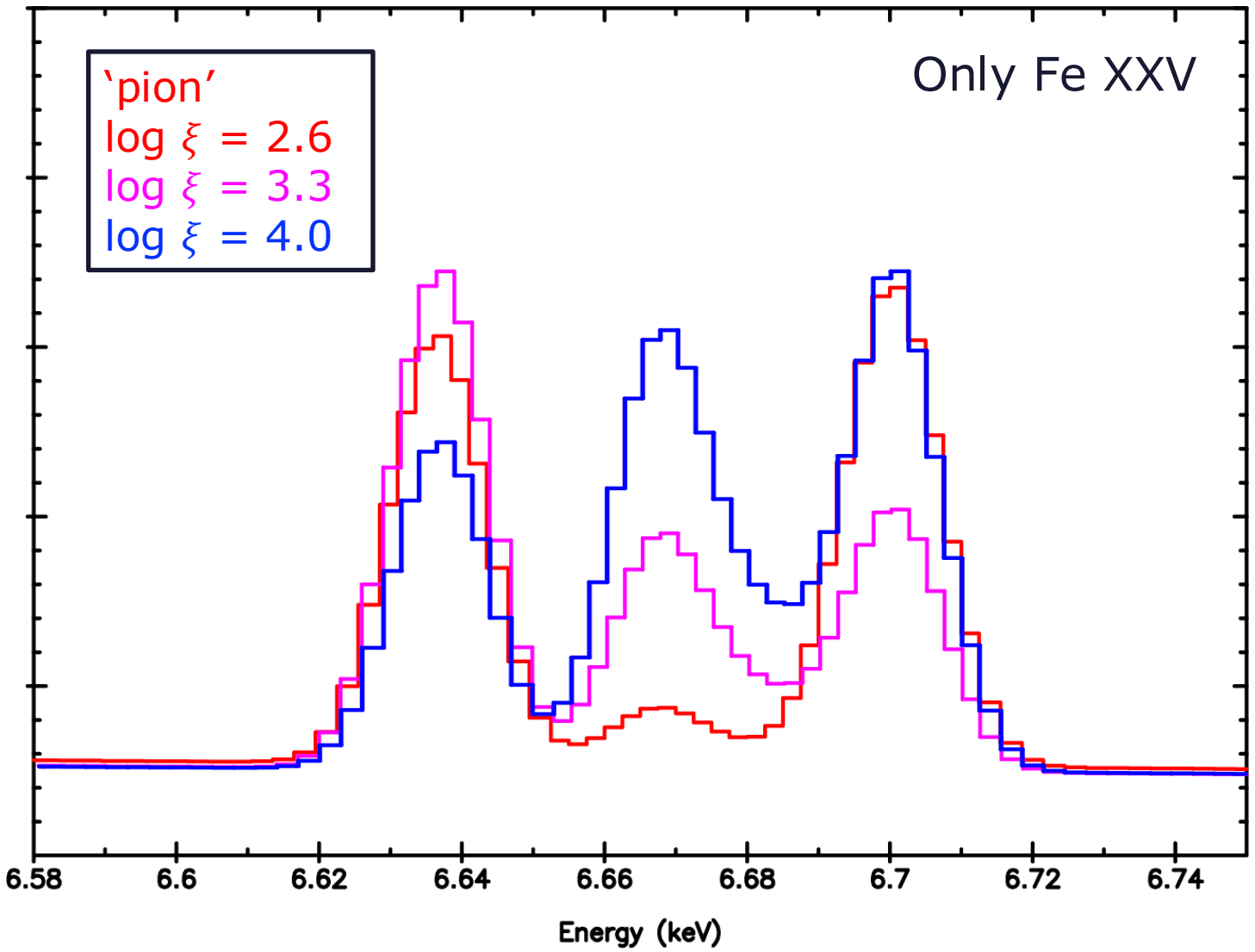
Diamant+05

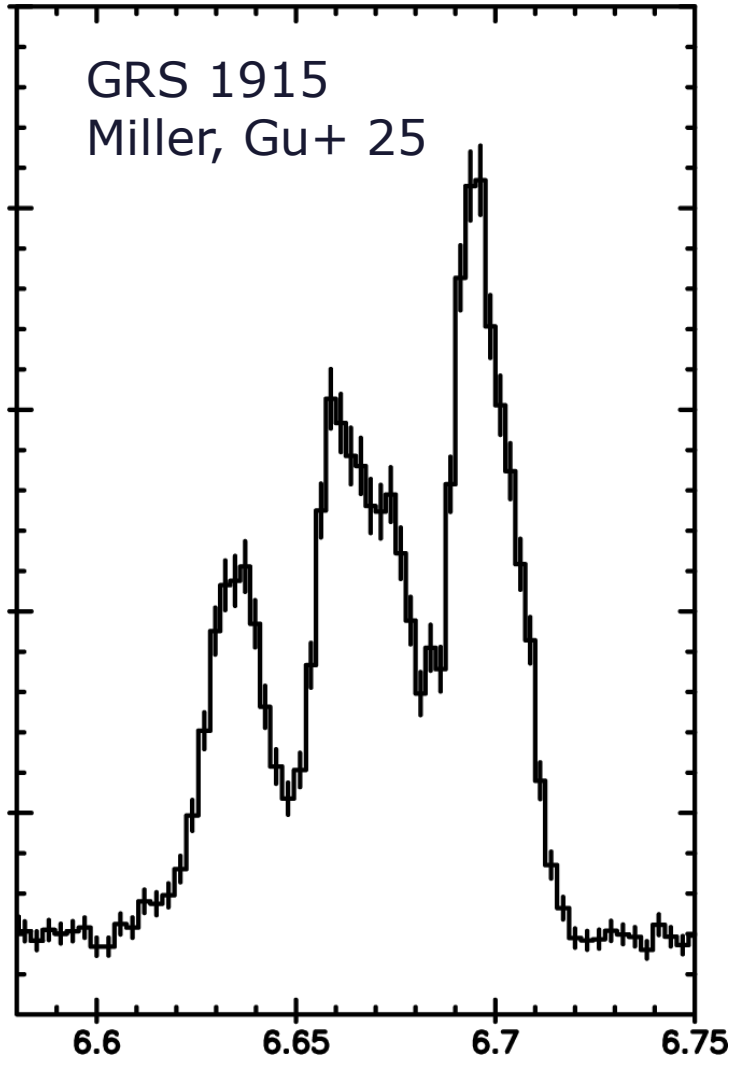


- Satellites are detected in a few objects with Resolve
- Diagnostics of incident photon spectrum on the reflector (Vander Meulen+)

SRON

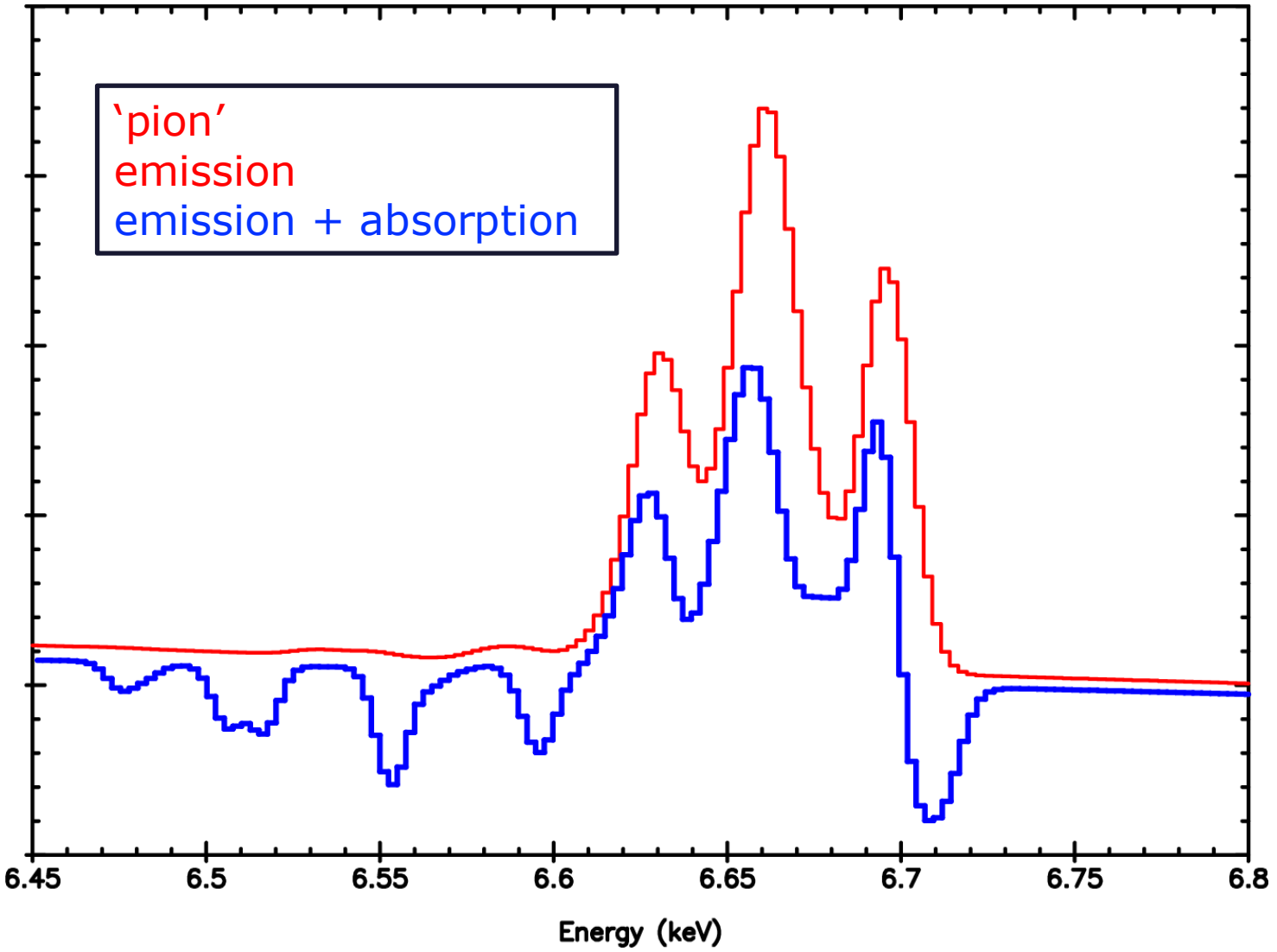
Photonionized emission

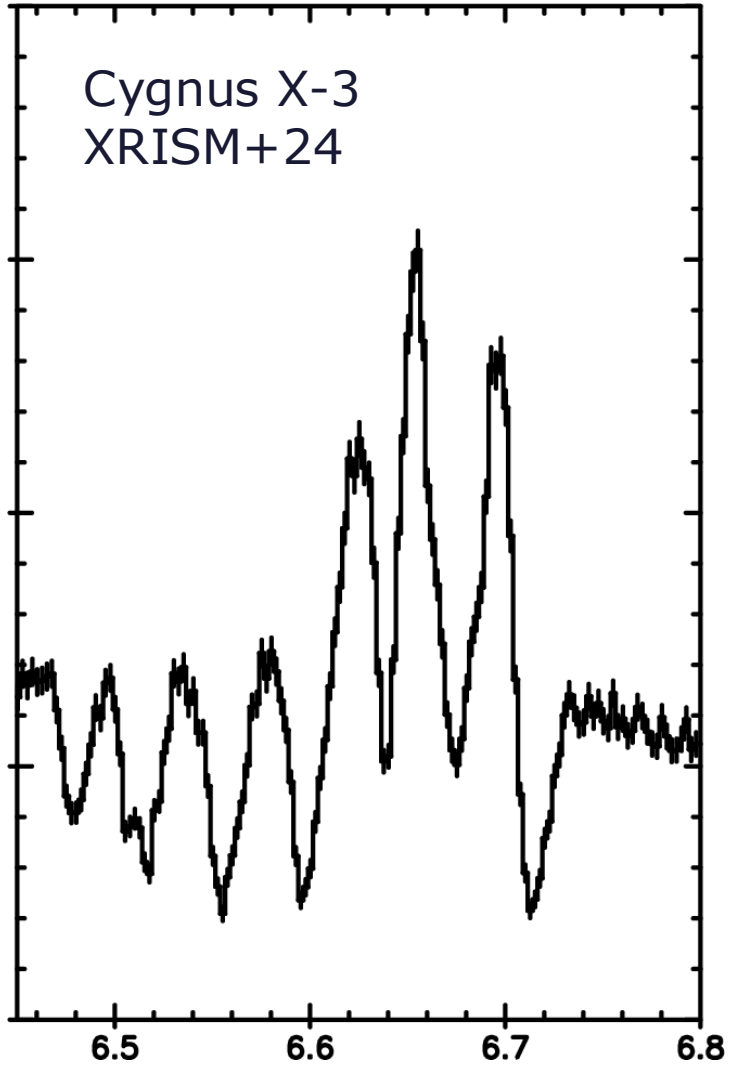




SRON

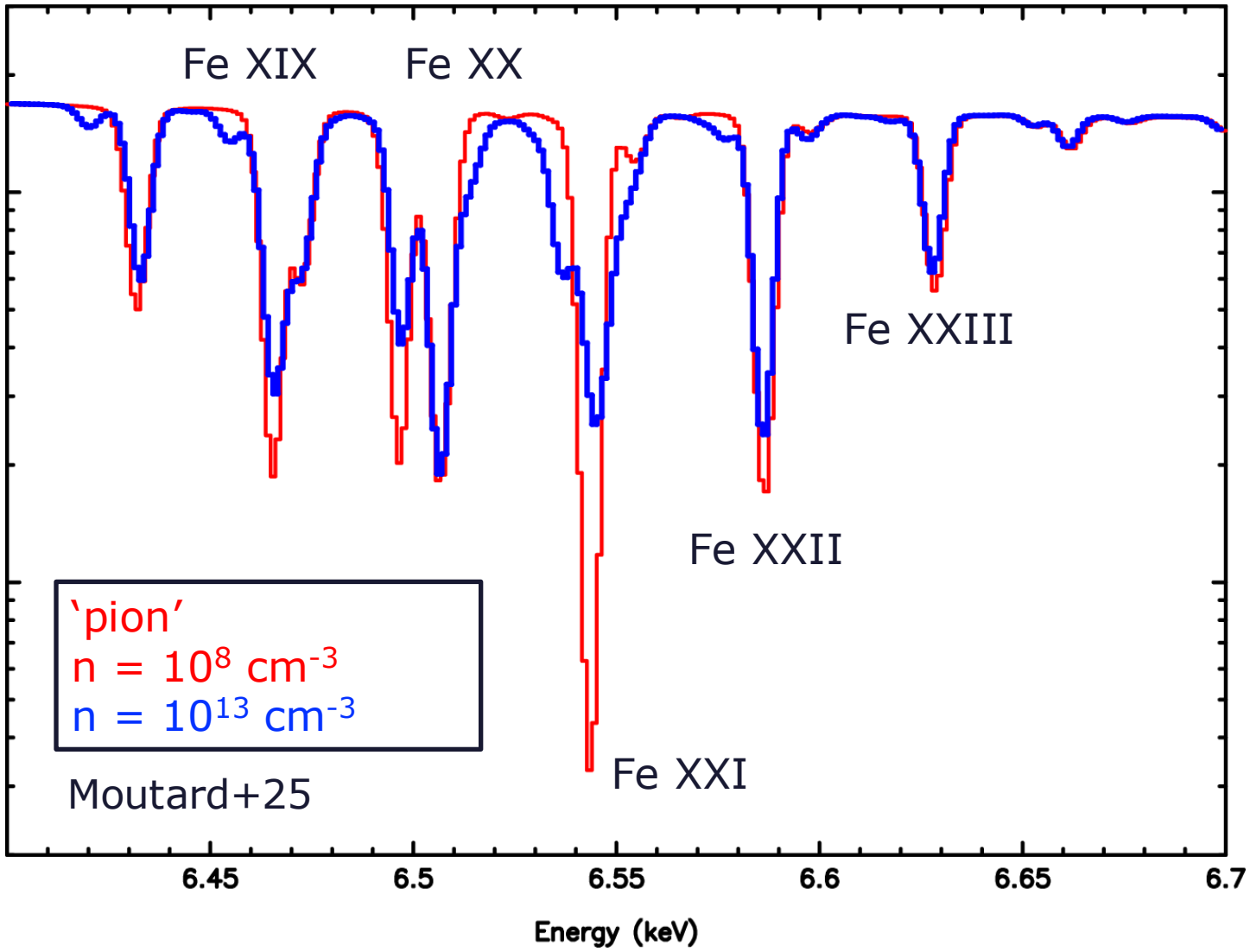
Both emission and absorption present



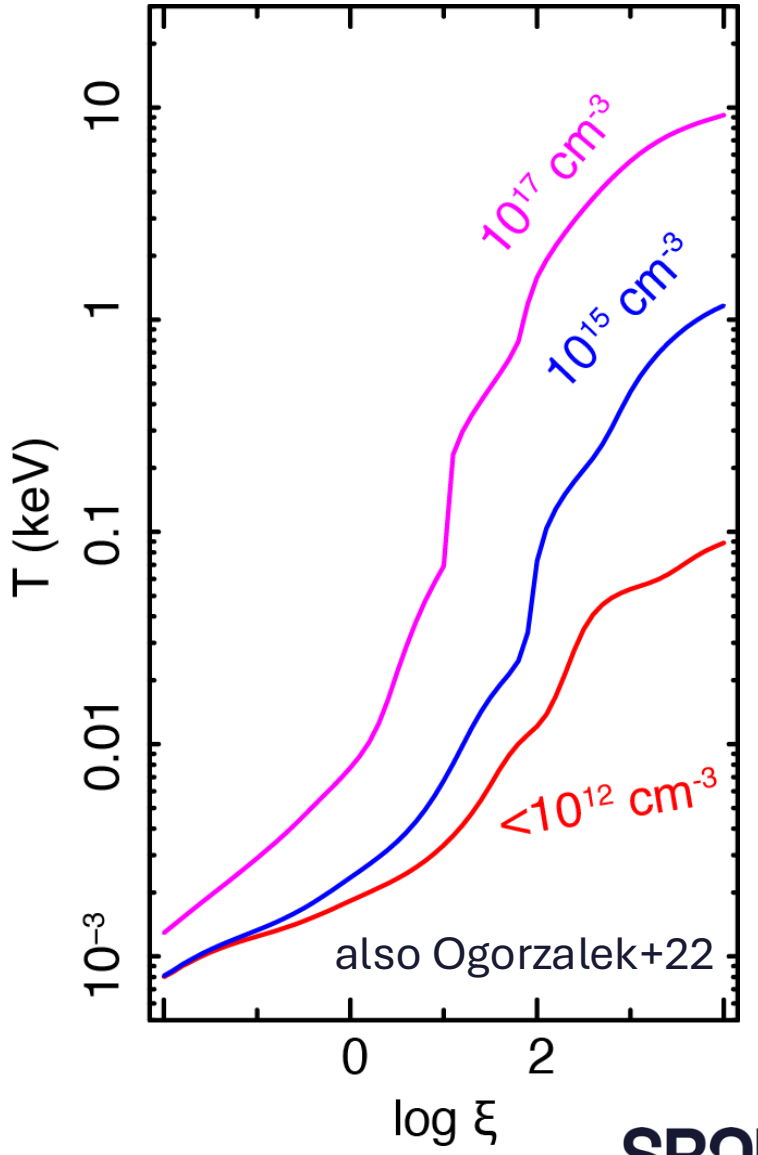


SRON

Effects from high density plasmas

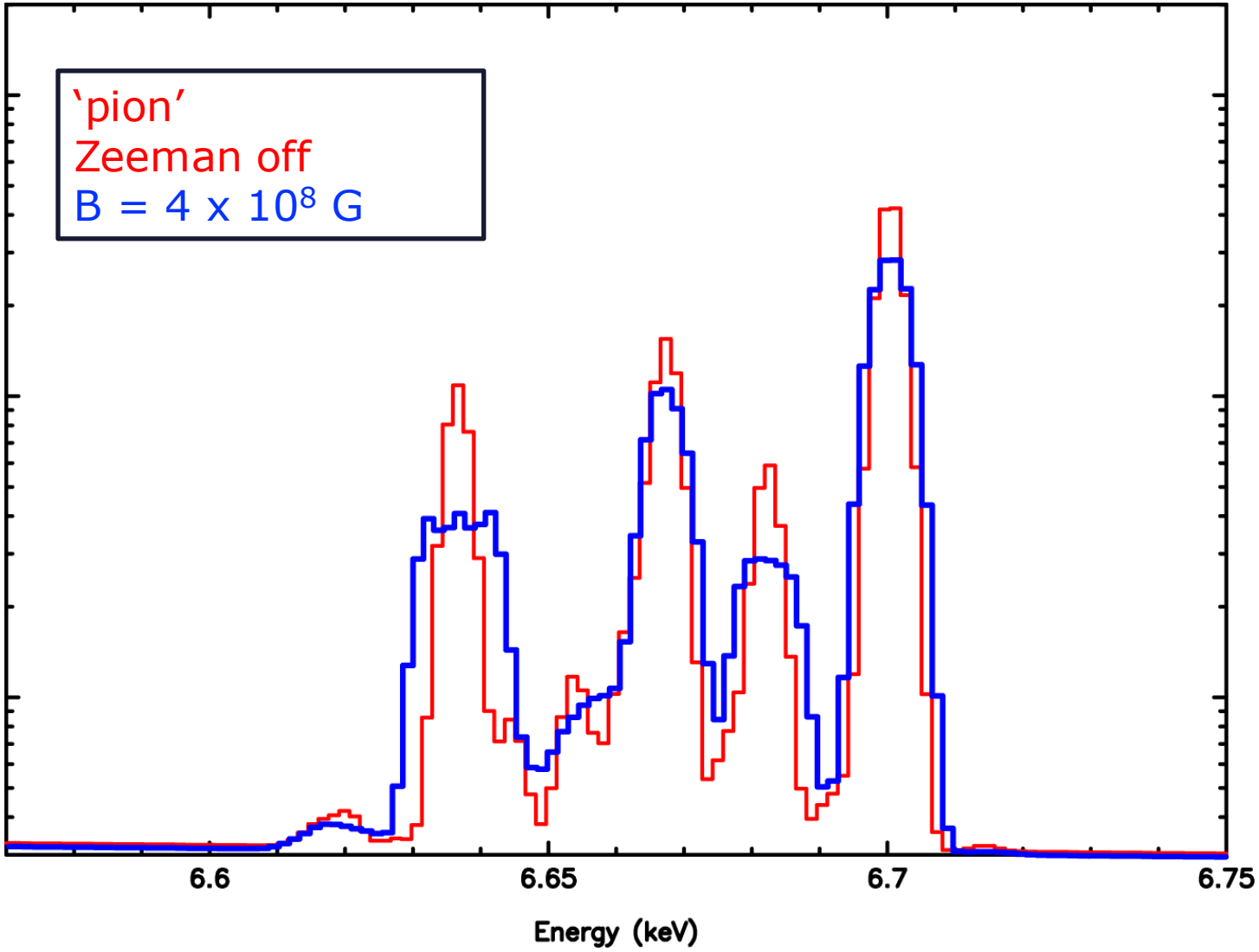


Density effect on Ion fraction



SRON

Effects from strong magnetic field



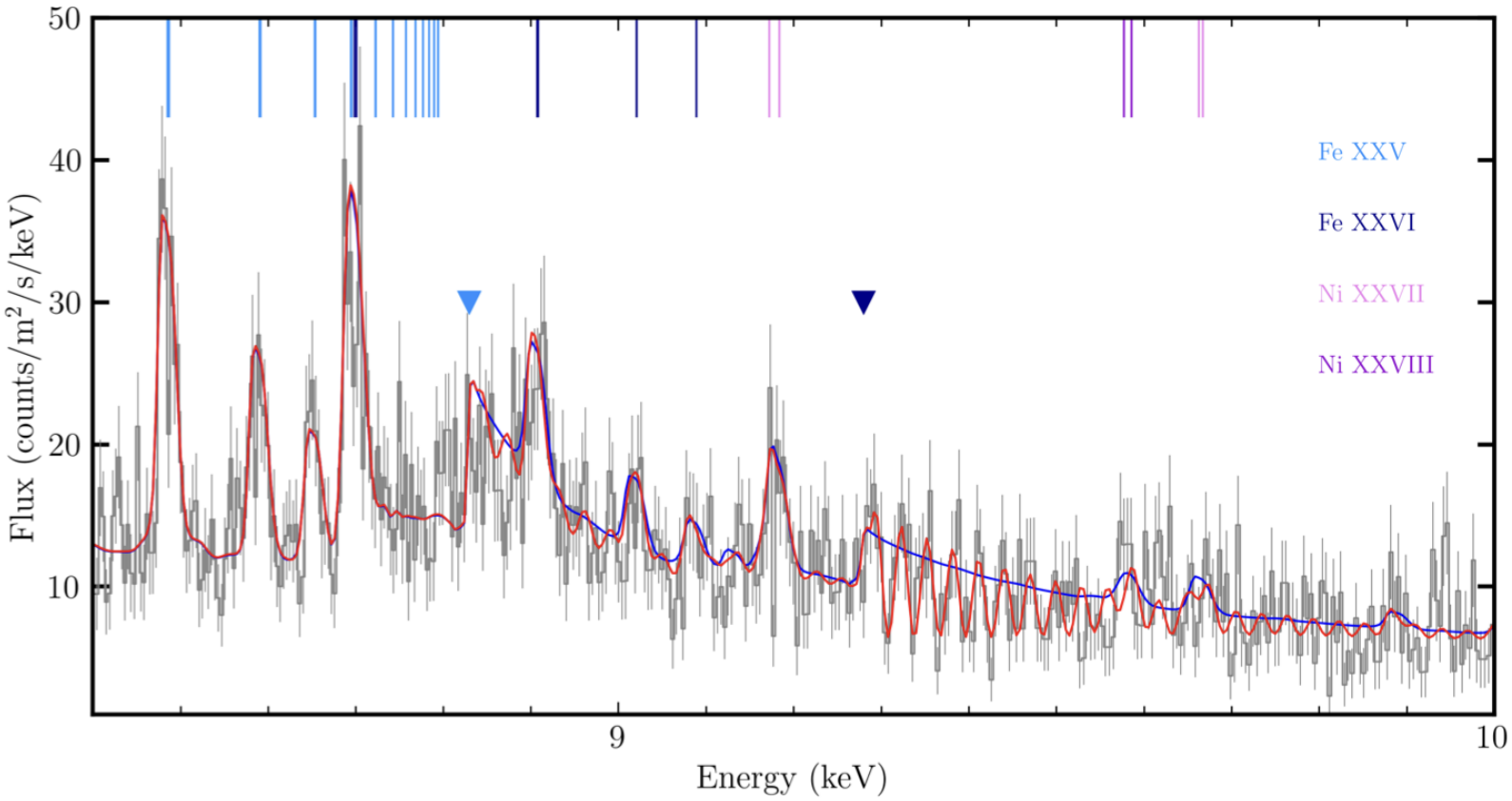
Zeeman effect

SRON

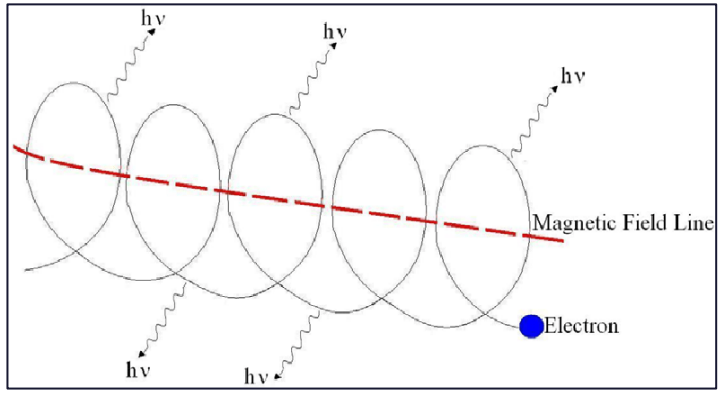
Landau quantum effect

GRS 1915

Miller+25



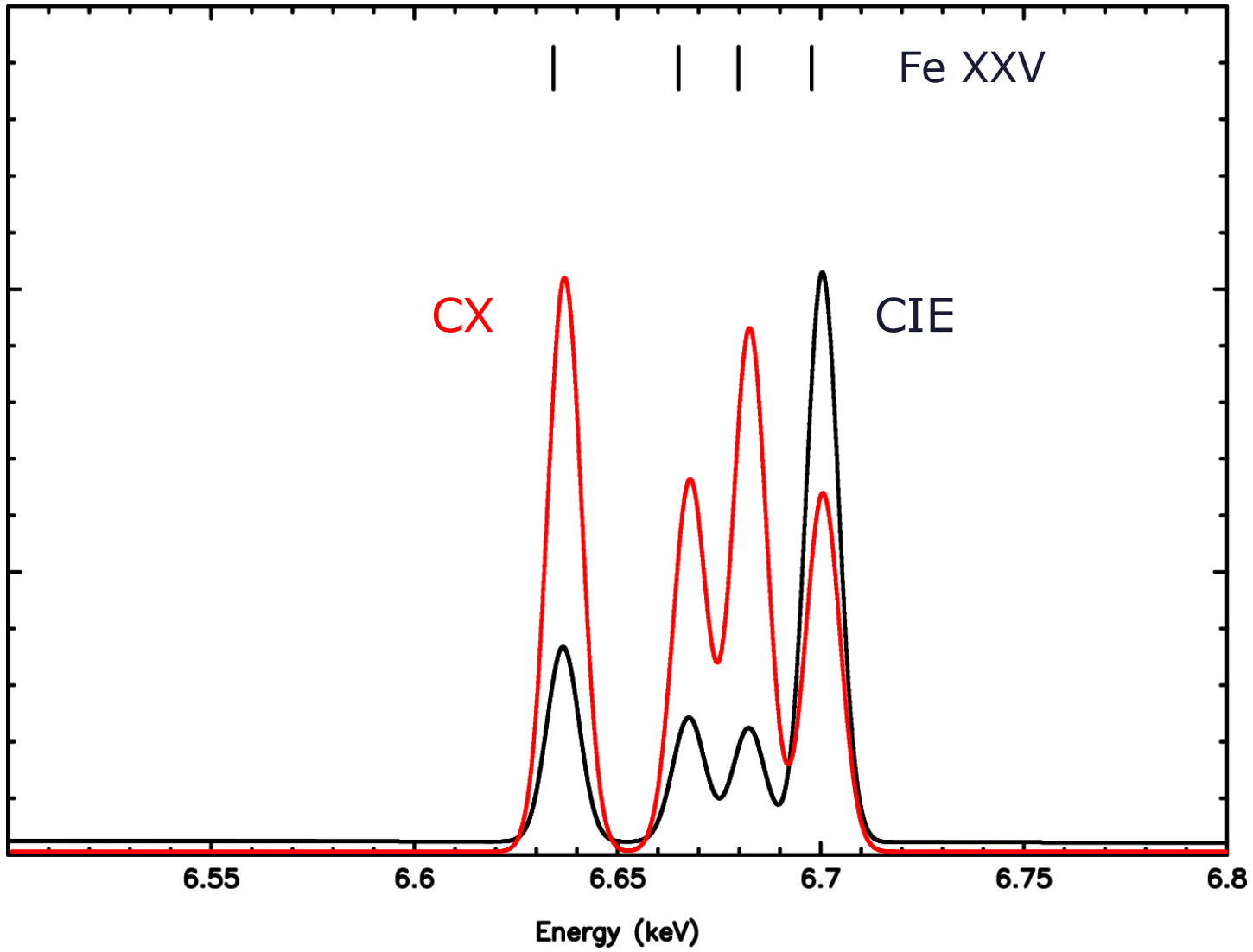
Quantum levels from cyclotron of free electrons

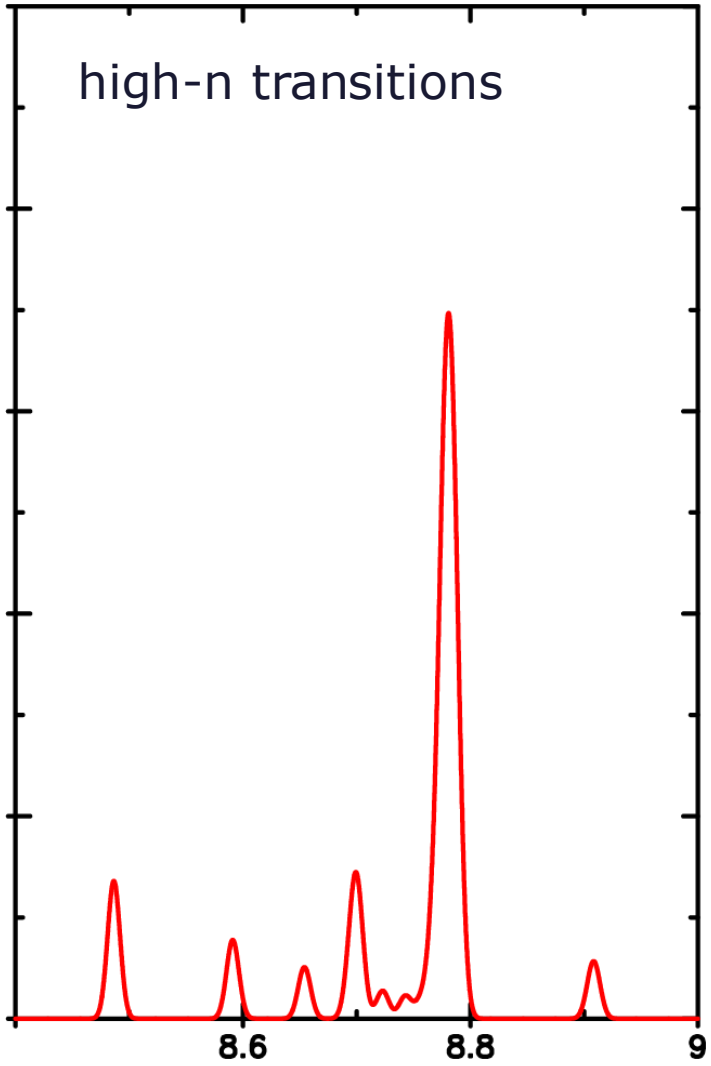


Available in SPEX v3.08.02

Either 2.5 x 10^9 G in the accretion disk
Or
A set of well-structured UFOs

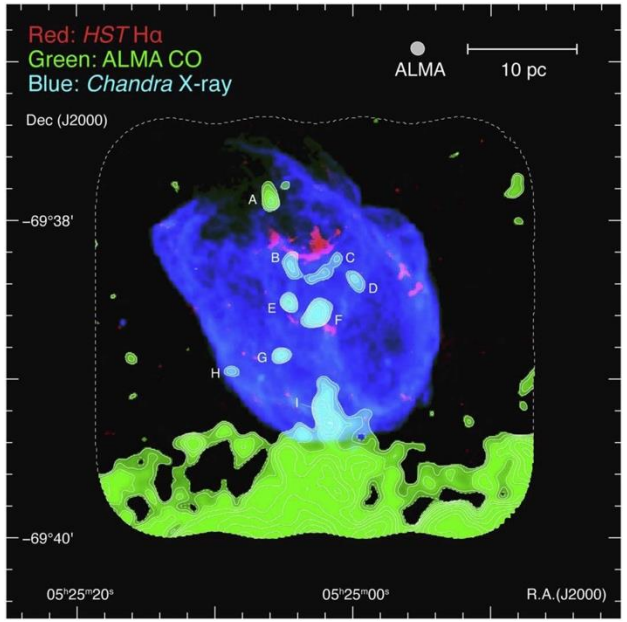
Charge exchange emission





SRON

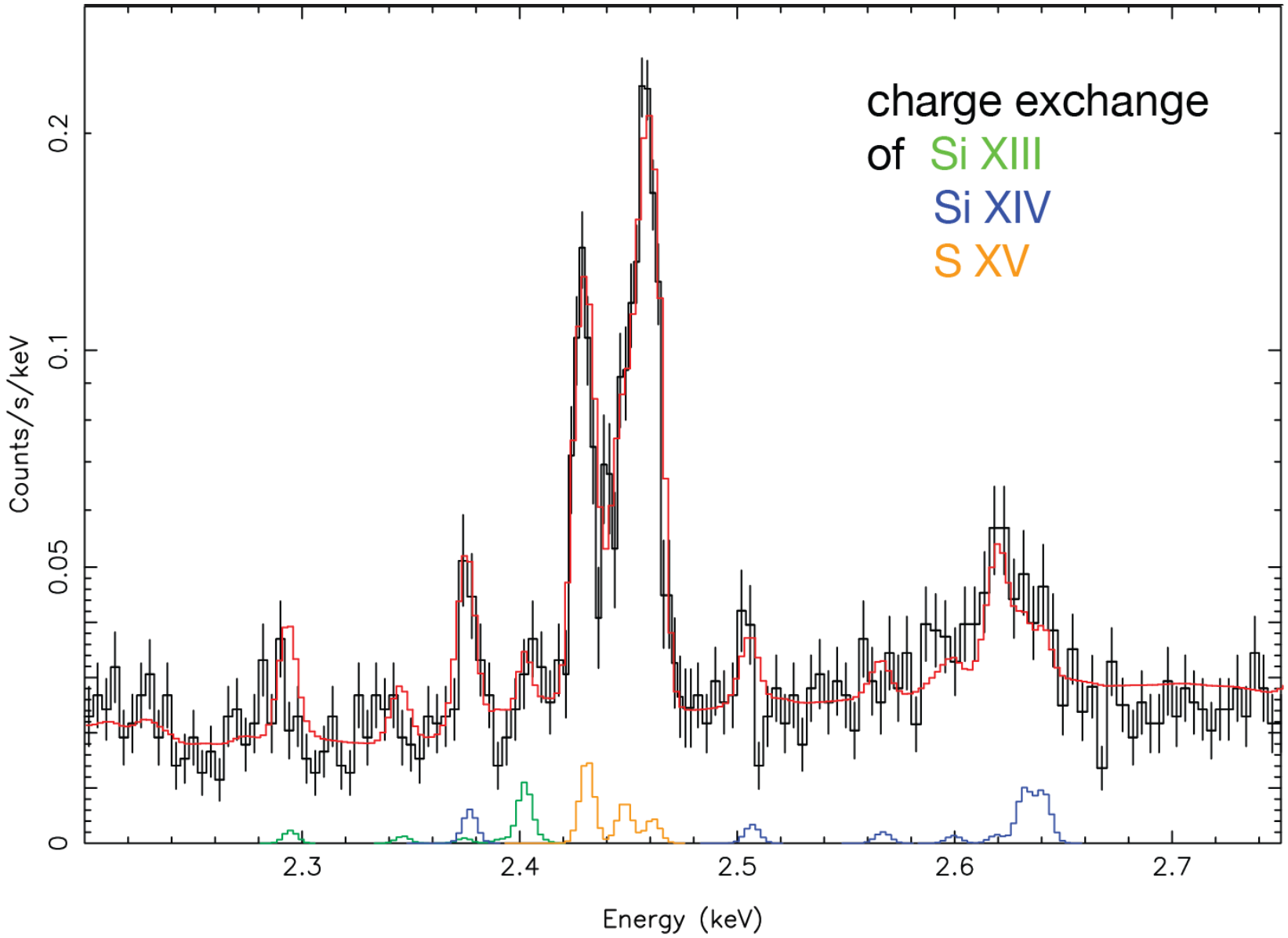
N132D: potential charge exchange



Shock-neutral interaction

Diagnostics of freeze-in temperature

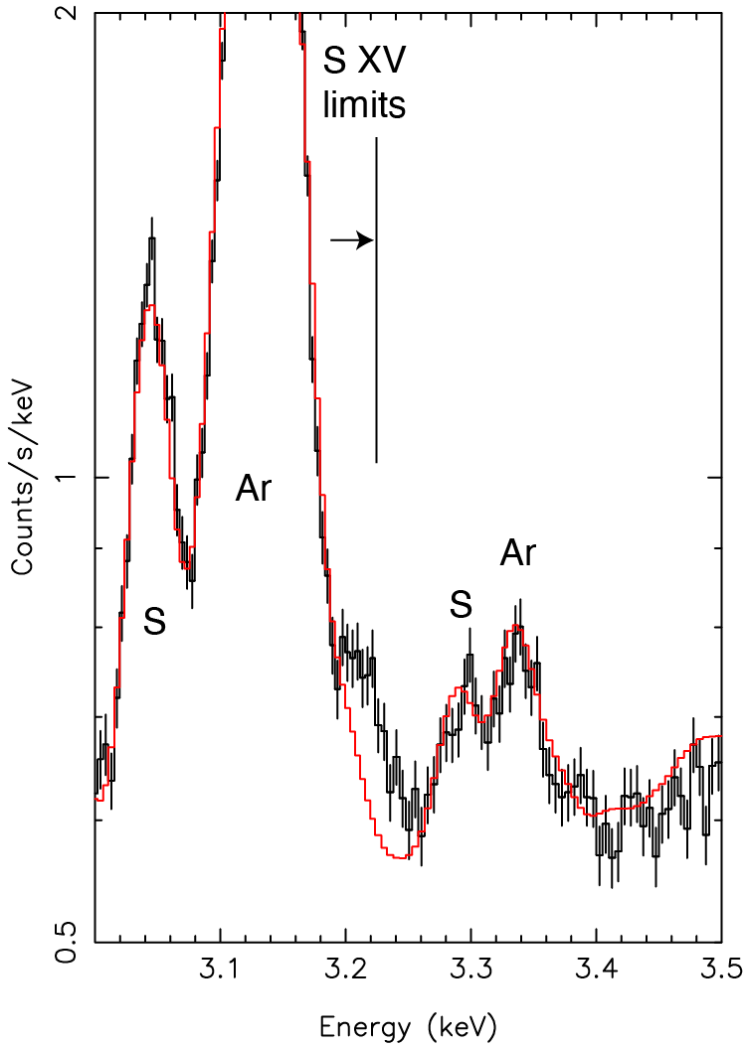
Gu+2025



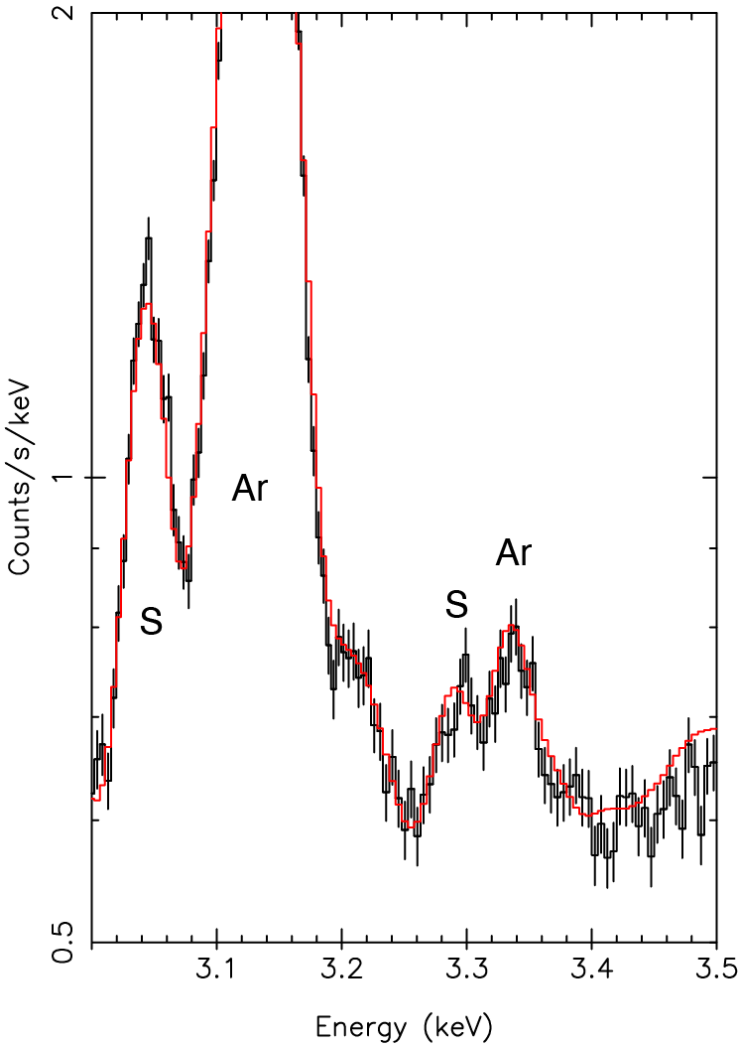
SRON

Rydberg series up to very high n states

Cas A

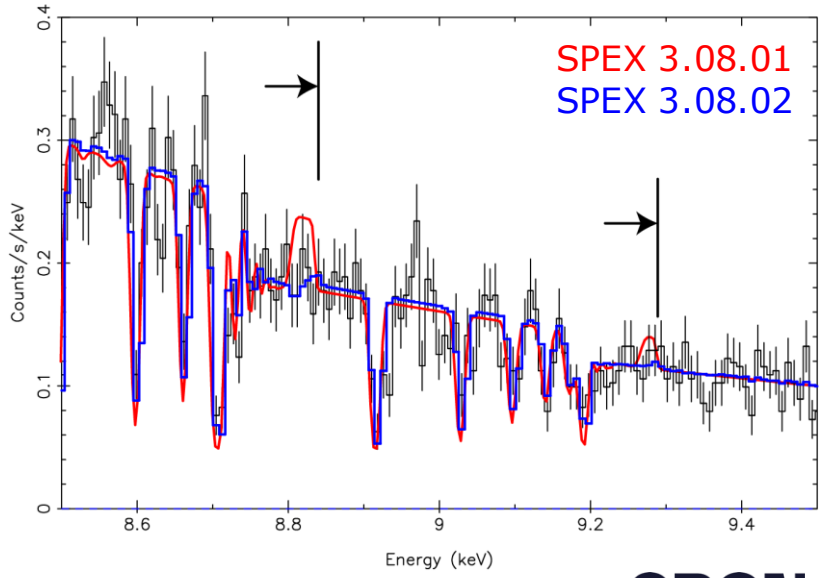


Plucinsky+25



- Data up to **n=52** for Si, S, and Fe by FAC
- Essential for identifying RRC components in supernova remnants, or for measuring density based on Debye screening from ejecta of X-ray binaries

GX 13+1 XRISM+25



SRON

Summary

- Plasma model has demonstrated the power analyzing XRISM data from collisional and photoionized plasmas, both in and out of equilibrium
- New SPEX provides tools for unusual conditions, such as non-thermal, high density, or strong magnetic fields
- XRISM and XIFU are propelling lab astro forward

SRON FDM/TES detector (~2.5 eV) on Heidelberg EBIT since 2024 summer