Atomic Physics issues, diagnostics & uncertainties

Ralf Ballhausen

UMCP & NASA-GSFC

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Plasma codes & Databases

Collisional plasma codes

AtomDB / APEC + APED (Foster 2012)

SPEX / CIE (Kaastra et al. 1996, 2013)

CHIANTI (Del Zanna 2021)

Raymond-Smith (Raymond & Smith 1977)

Photoionized plasma codes

XSTAR (Kallman & Bautista 2001)

Cloudy (Ferland et al. 2017)

SPEX / PIE (Kaastra et al. 1996, 2013)

Moccasin (Ercolano et al. 2003)

Titan (Dumont 2000)

Plasma codes & Databases

Relevant processes:

Photo- and collisional excitation

Photo- and collisional ionization

Radiative de-excitation

Radiative and dielectronic recombination

Free-free and Compton scattering

Charge exchange

Plasma codes & Databases

Relevant processes:

Photo- and collisional excitation

Photo- and collisional ionization

Radiative de-excitation

Radiative and dielectronic recombination

Free-free and Compton scattering

Charge exchange

Required atomic data:

Level energies

Photoionization cross sections

Radiative rates

Collision strengths

Recombination coefficients

Auger rates

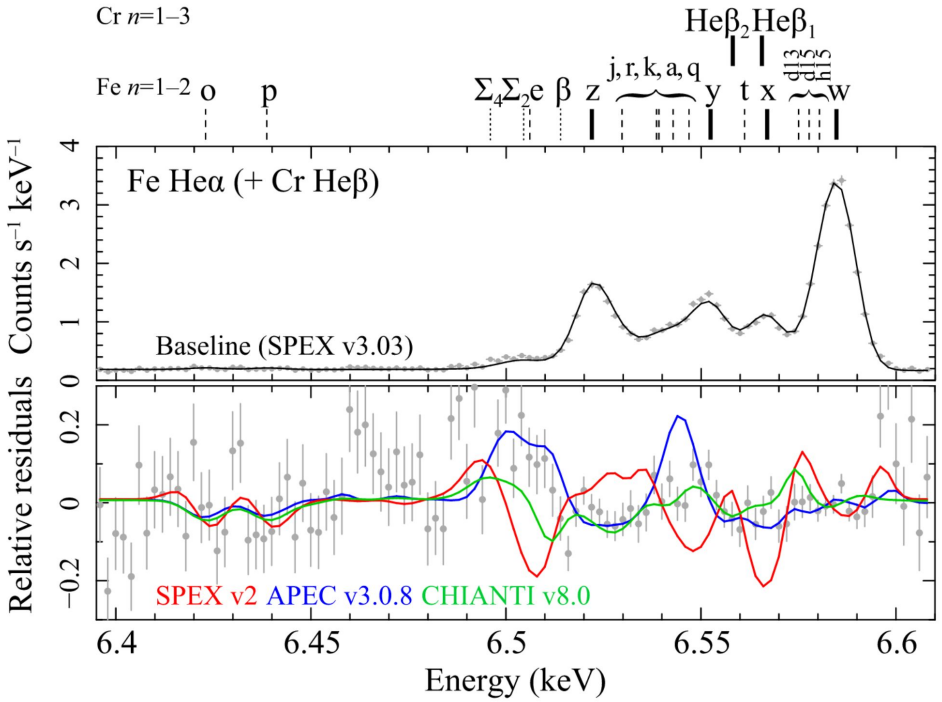
Charge exchange rates

Hitomi view of the Perseus Cluster

Analysis with different plasma codes gives statistically acceptable fits

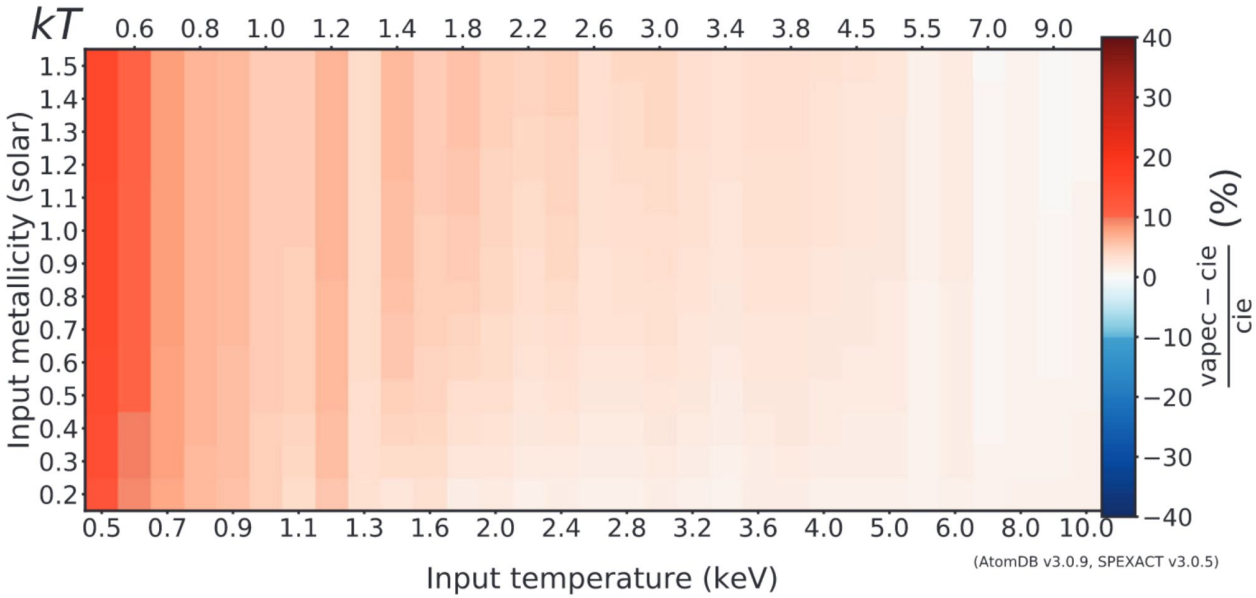
16% difference in Fe abundance between SPEX and APEC

Reason: Different collisional excitation and dielectronic recombination rates



Hitomi Collaboration (2018)

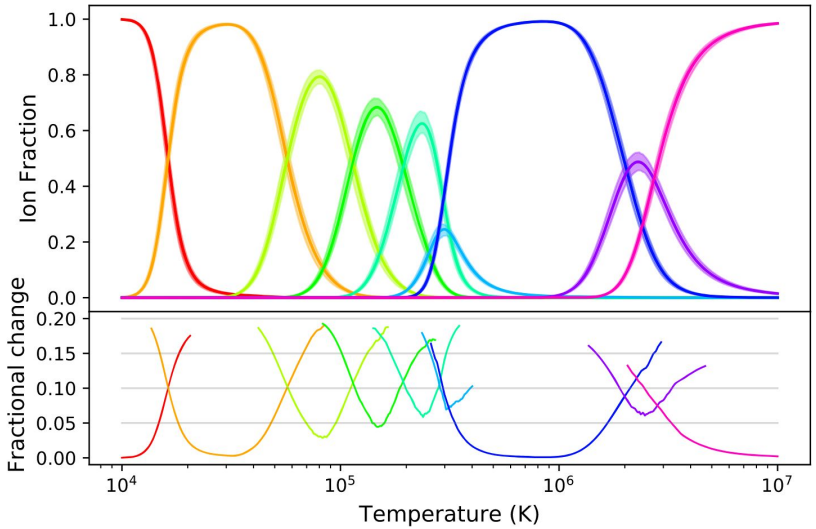
Code comparison: AtomDB & SPEX



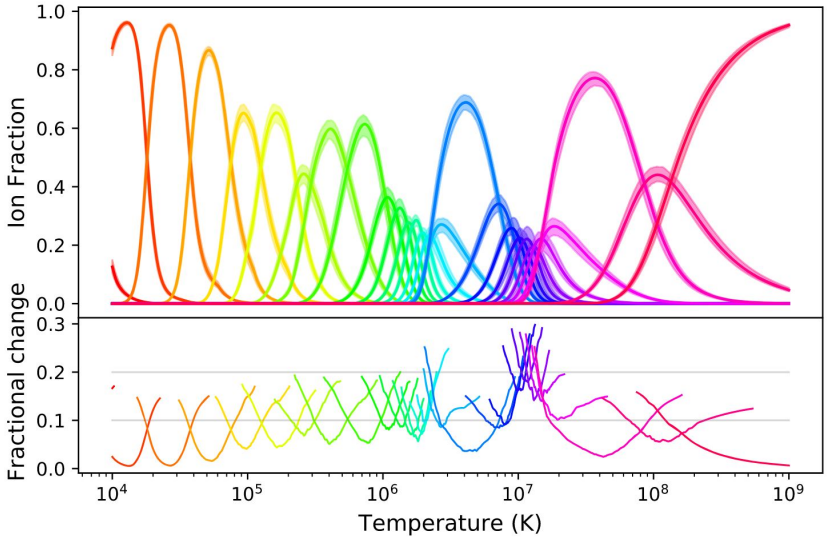
Mernier et al. (2020)

Atomic data uncertainties - Monte Carlo approach

Oxygen



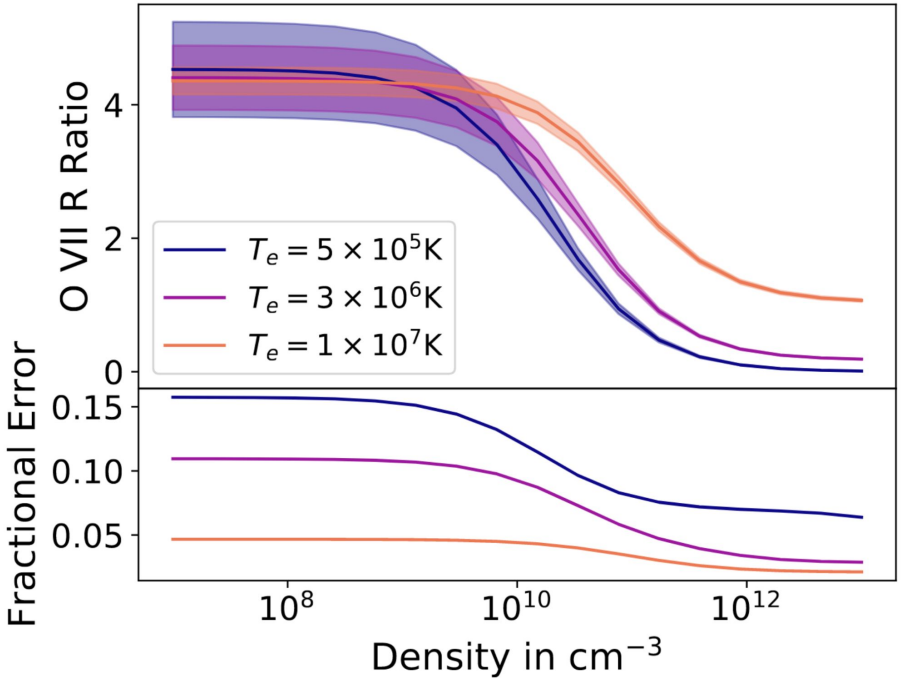
Iron



Heuer, Foster & Smith (2021)

Atomic data uncertainties - Monte Carlo approach

O VII R ratio with a ±15% uncertainty on the DE rates and A-values of the forbidden, resonance, and inter-combination lines

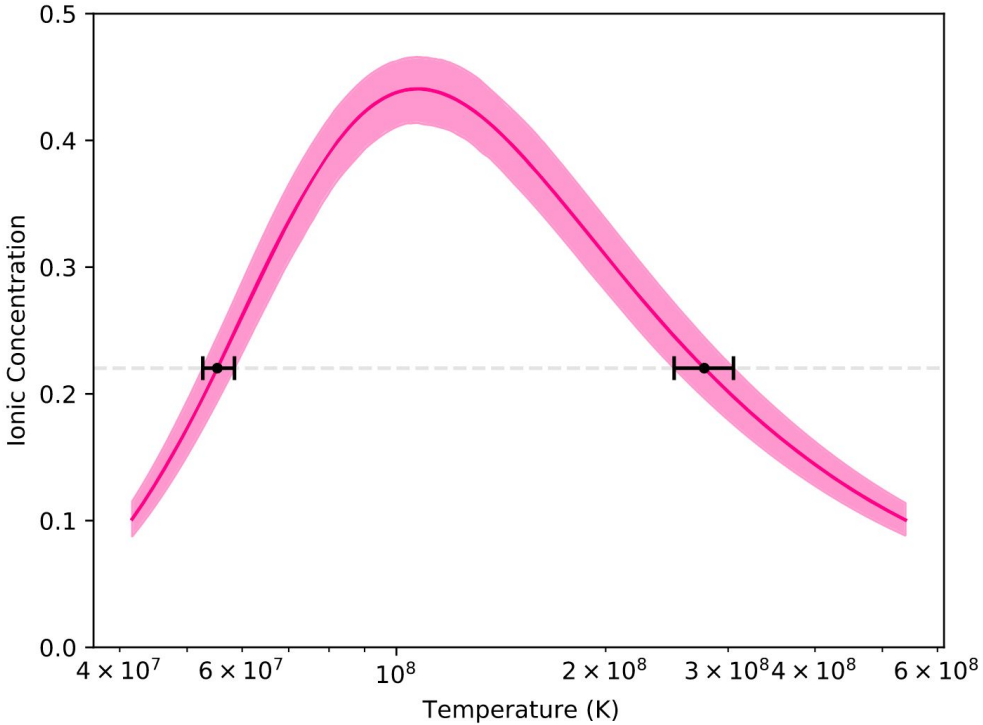


Foster & Heuer (2020)

Atomic data uncertainties - Monte Carlo approach

Good guideline for uncertainty estimates of derived parameters

Limited number of transitions



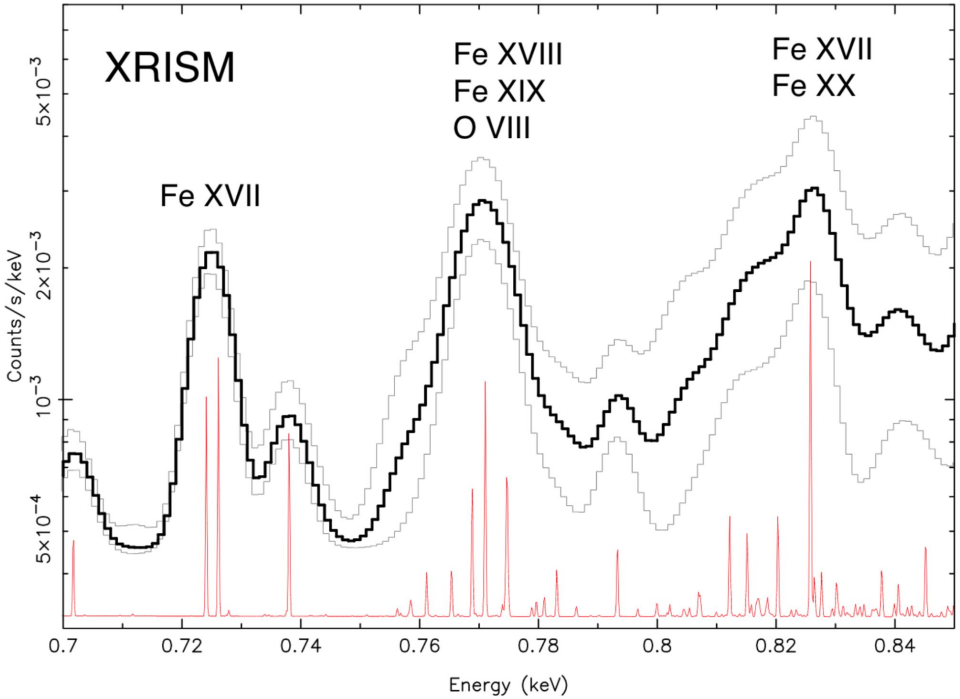
Heuer, Foster & Smith (2021)

Atomic data uncertainties - Data-driven approach

Simulated XRISM spectrum for 1 keV CIE plasma

Derived uncertainties:

- 3-7% on emission measure
- 1-2% on temperature
- 4-7% on O and Fe abundance

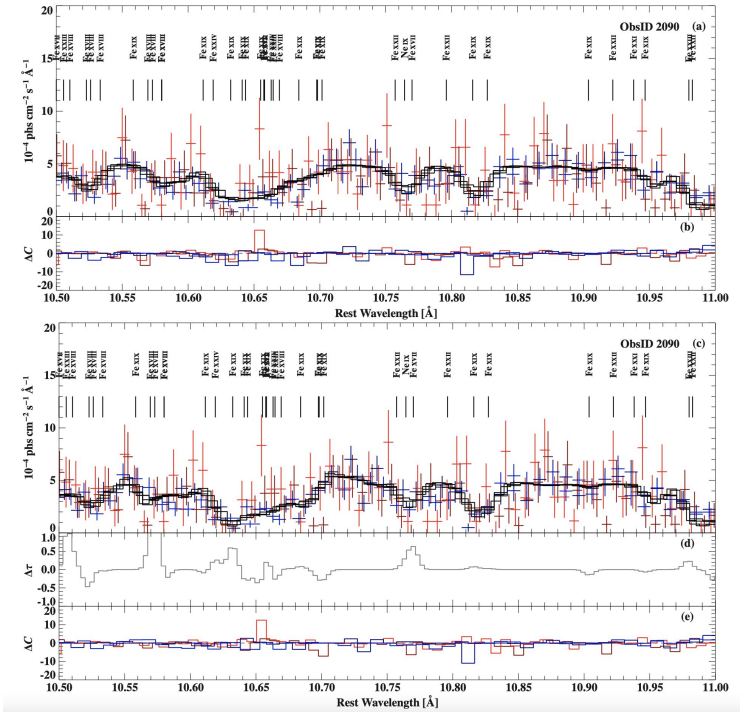


Gu et al. (2022)

Atomic data uncertainties - Data-driven approach

Q: Can uncertainties in atomic data account for statistically unacceptable fit?

A: To some extent, but not entirely!

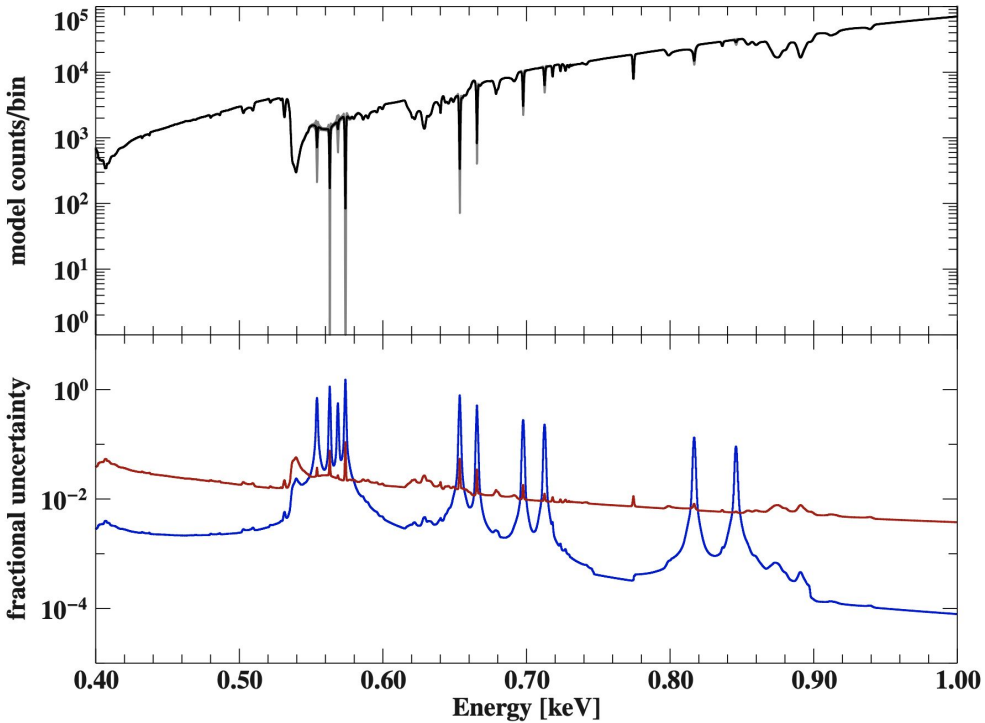


Ballhausen et al. (subm.)

Atomic data uncertainties - Data-driven approach

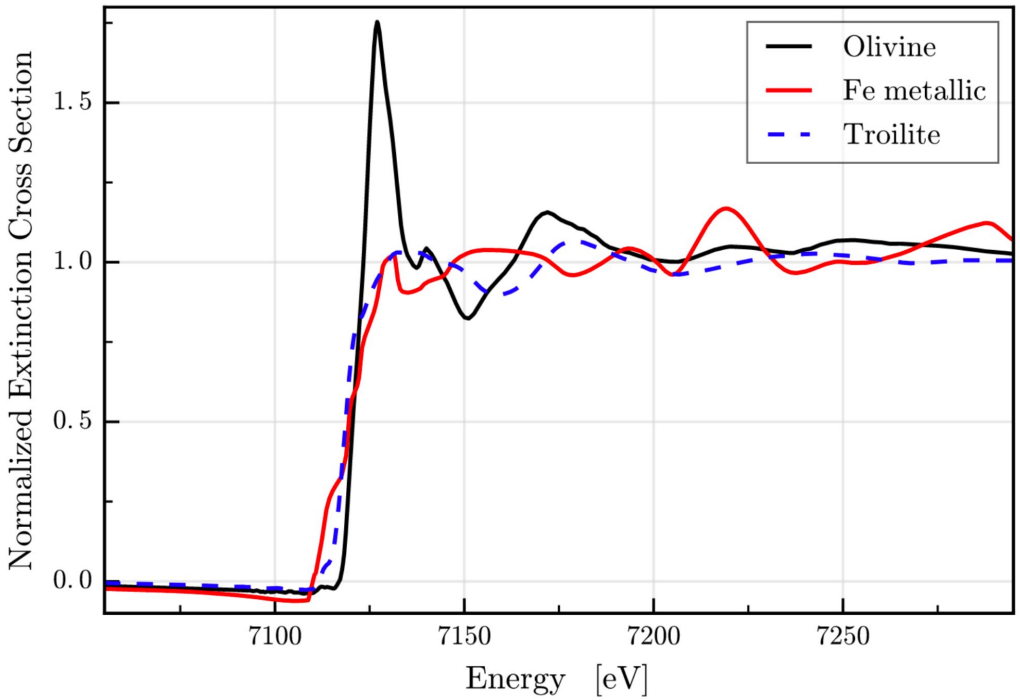
Include model uncertainties in fitting process

Statistical treatment not trivial!



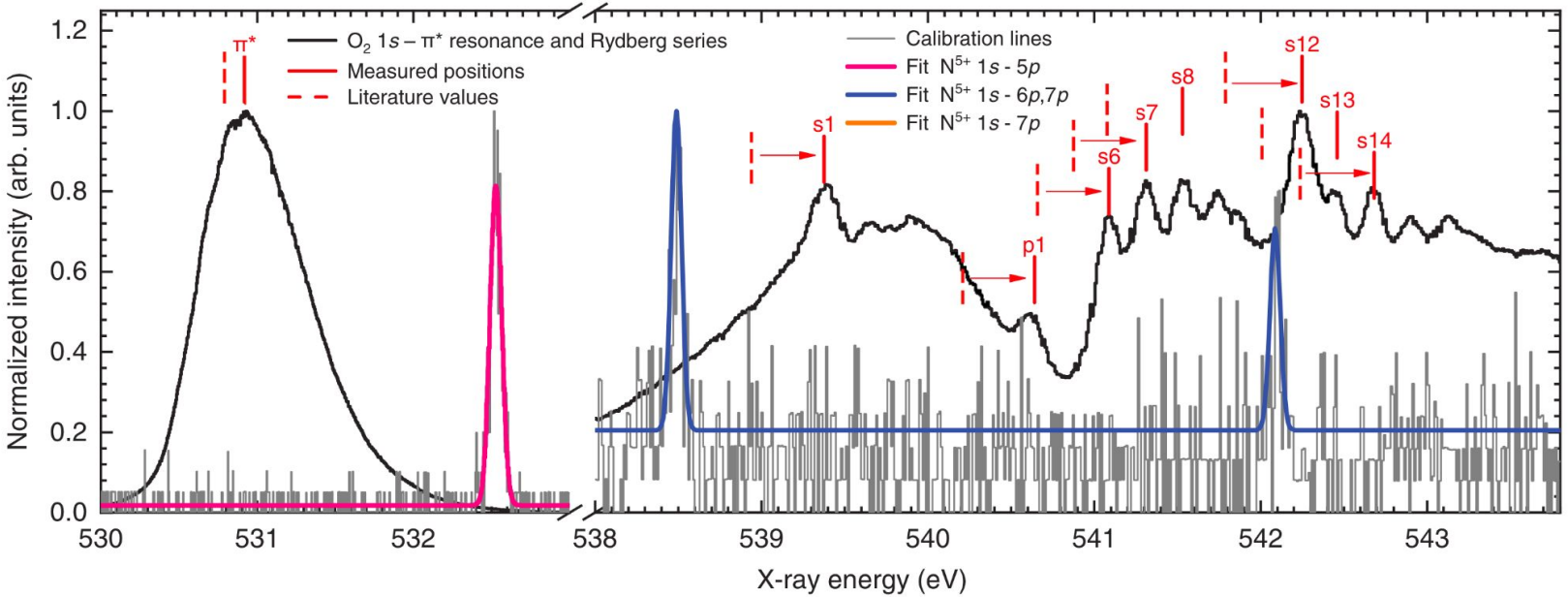
Ballhausen et al. (subm.)

Examples of XRISM-relevant experiments



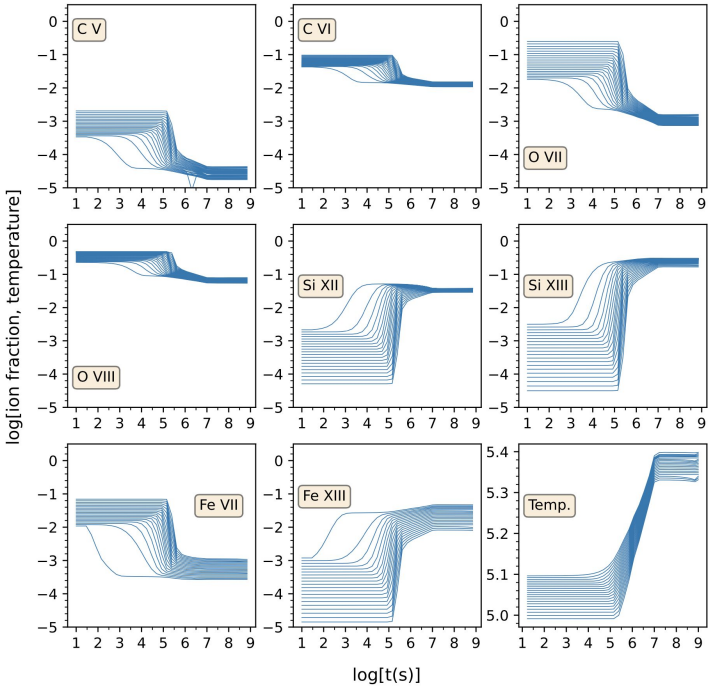
Rogantini et al. (2018)

Examples of XRISM-relevant experiments: O_2 Kα transition energies

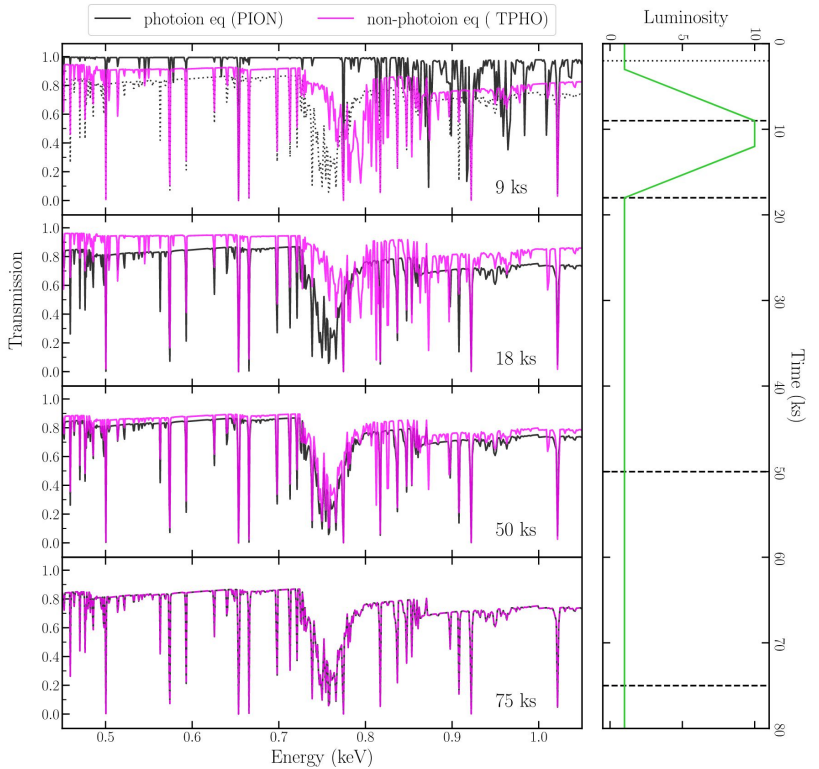


Leutenegger et al. (2020)

Examples of XRISM-relevant code development: Time-dependence



Sadaula et al. (in press)



Rogantini et al. (2022)

Some conclusions

- Rates, emissivities etc. from plasma codes can easily have uncertainties of 10% and more
- Atomic databases are incomplete
- High-quality lab experiments still required for many open astrophysical questions
- More systematic code and database comparisons very important

References

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