Constraints on new spectral features and atomic modeling from the *Hitomi* spectrum of the Perseus cluster

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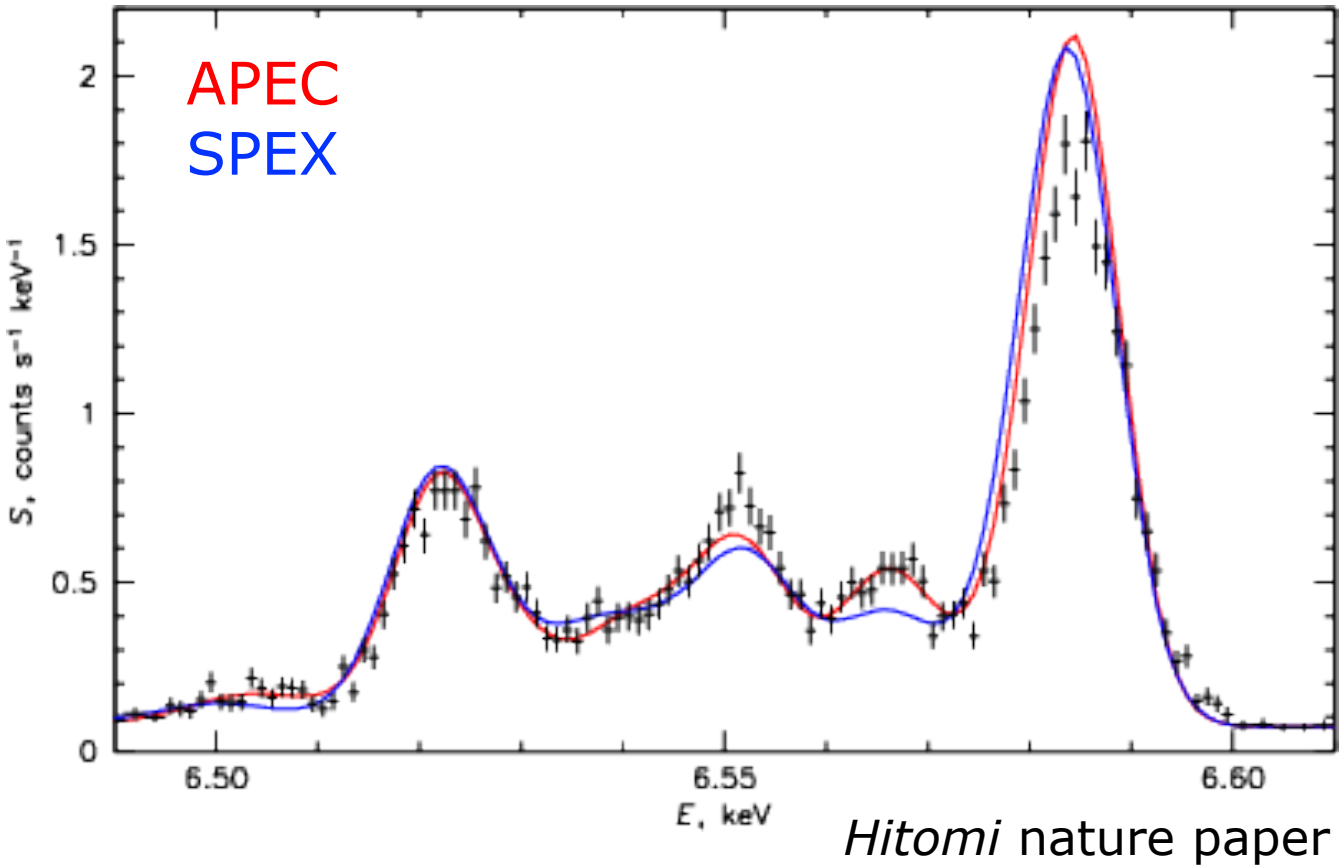
on behalf of the *Hitomi* collaboration

- Atomic physics becomes critical for *Hitomi*-level spectrum
- Review of atomic code updates since pre-launch
- Atomic data needs for the future missions

lesson learned from *Hitomi*

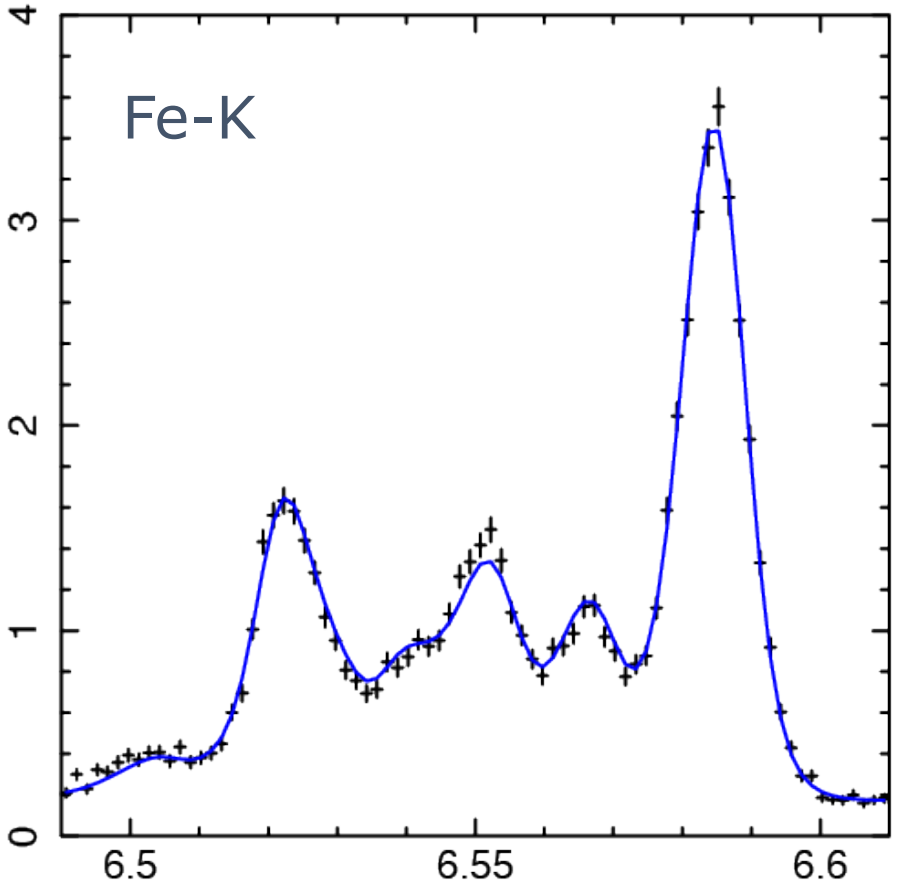
Pre-launch APEC & SPEX



Hitomi nature paper

- match continuum and strong lines
- but formally unacceptable
- only at SXS resolution problems appear

Latest SPEX



- acceptable fits
- two codes agree much better

Updates of APEC and SPEX

Updates were not made to "fit" the data, but triggered by the analysis, as well as by a systematic comparison of two codes.

APEC

(from v3.0.2 to v3.0.8)

- ionization/recombination rates using analytic function
- wavelength correction for H- to Li- like
- Auger rates and branching ratio update
- collisional excitation rates change for H- and He- like

SPEX

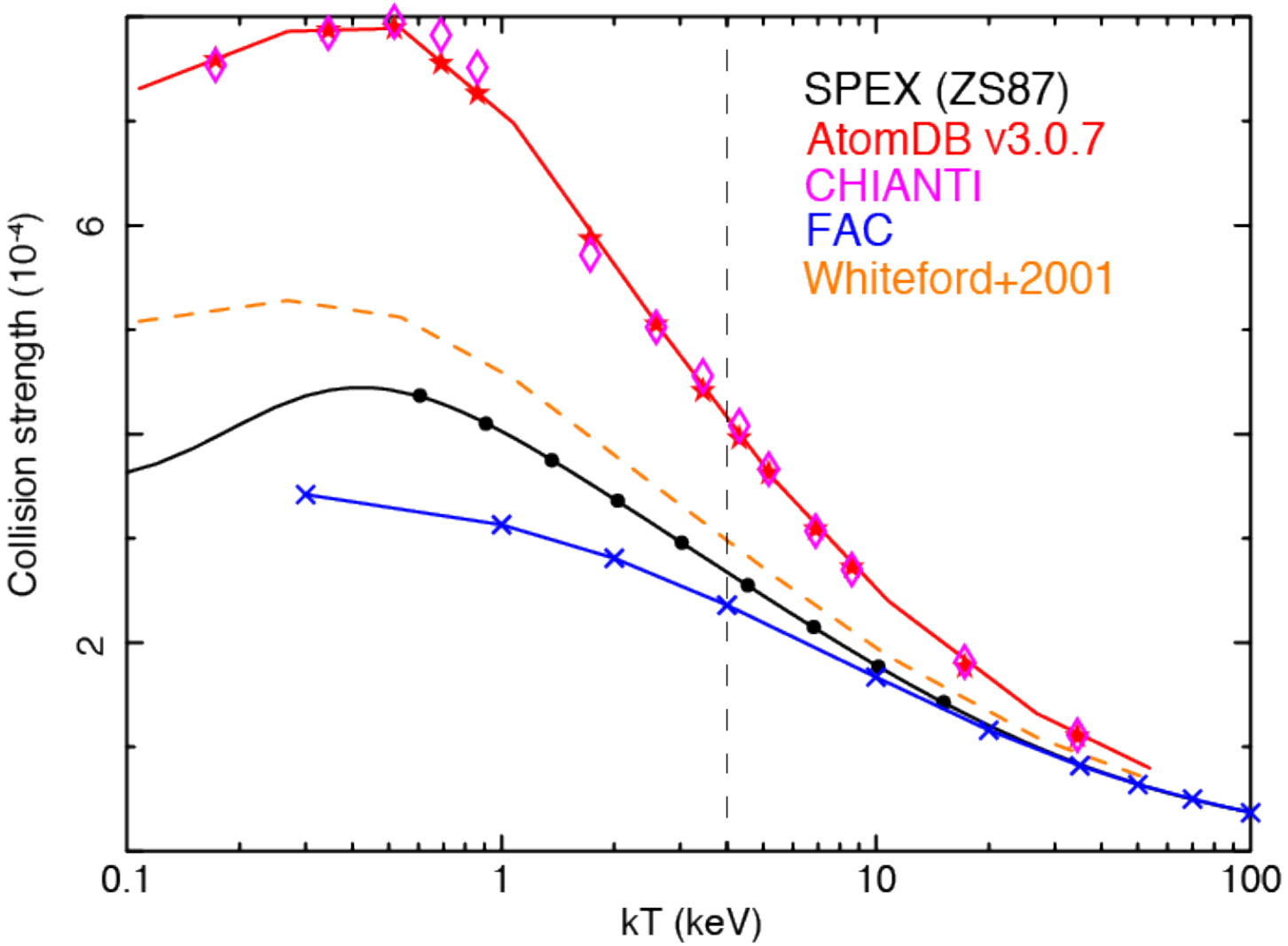
(from v3.00 to v3.03)

- completely on-the-fly calculation (v3.00)
- (bug fix) tri-electronic recombination (v3.01 & 02)
- (bug fix) auto-ionization loss accounted for (v3.03)

X-ray astronomy needs both codes.

Problems to be solved

Fe XXV collision excitation: ground to 2s ($^3S_1$)



- state-of-art calculations can differ by up to 70% @ 4 keV
- Fe XXIV inner-shell radiative/Auger rates and branching ratios differ by up to 50%.
- As a result, Fe abundance differ by 16%.
- Similar difference in a few H-like excitations.

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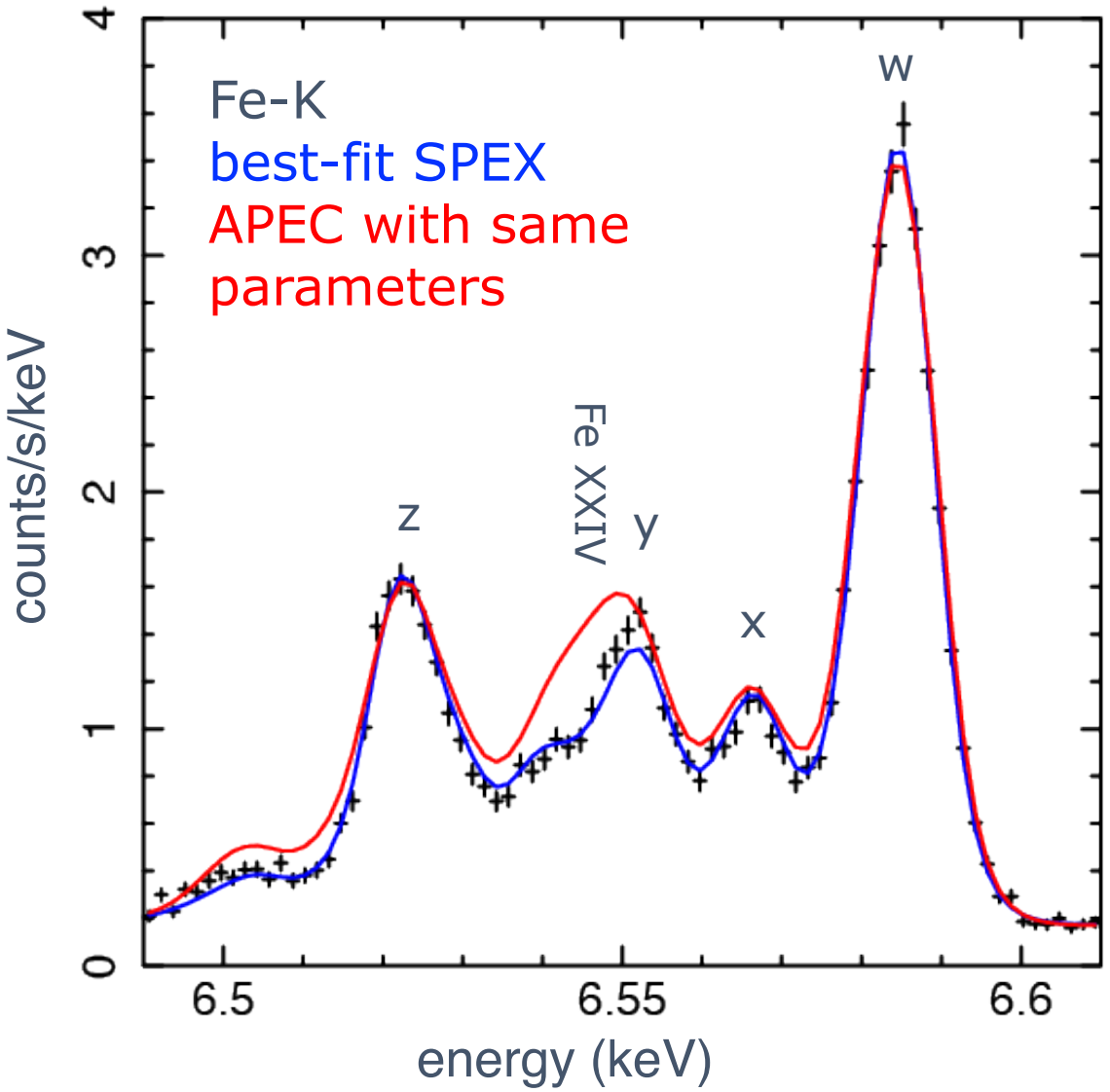

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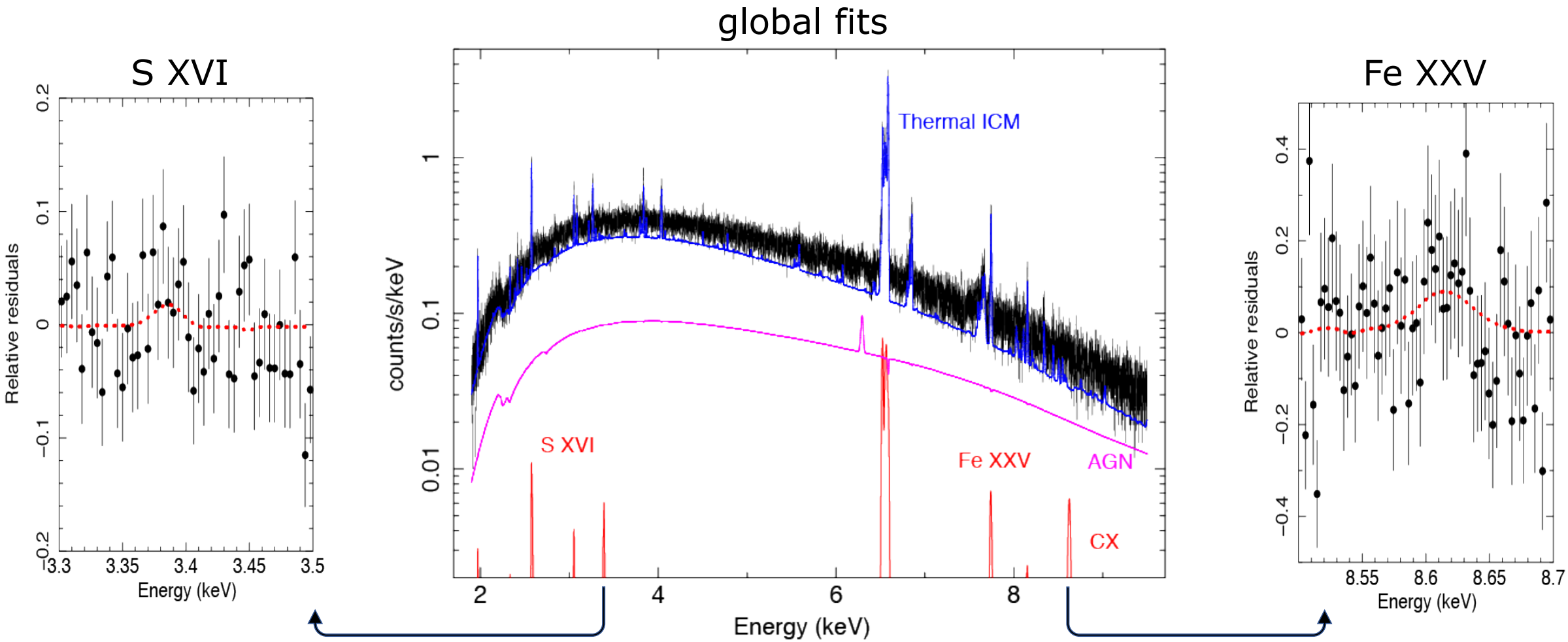
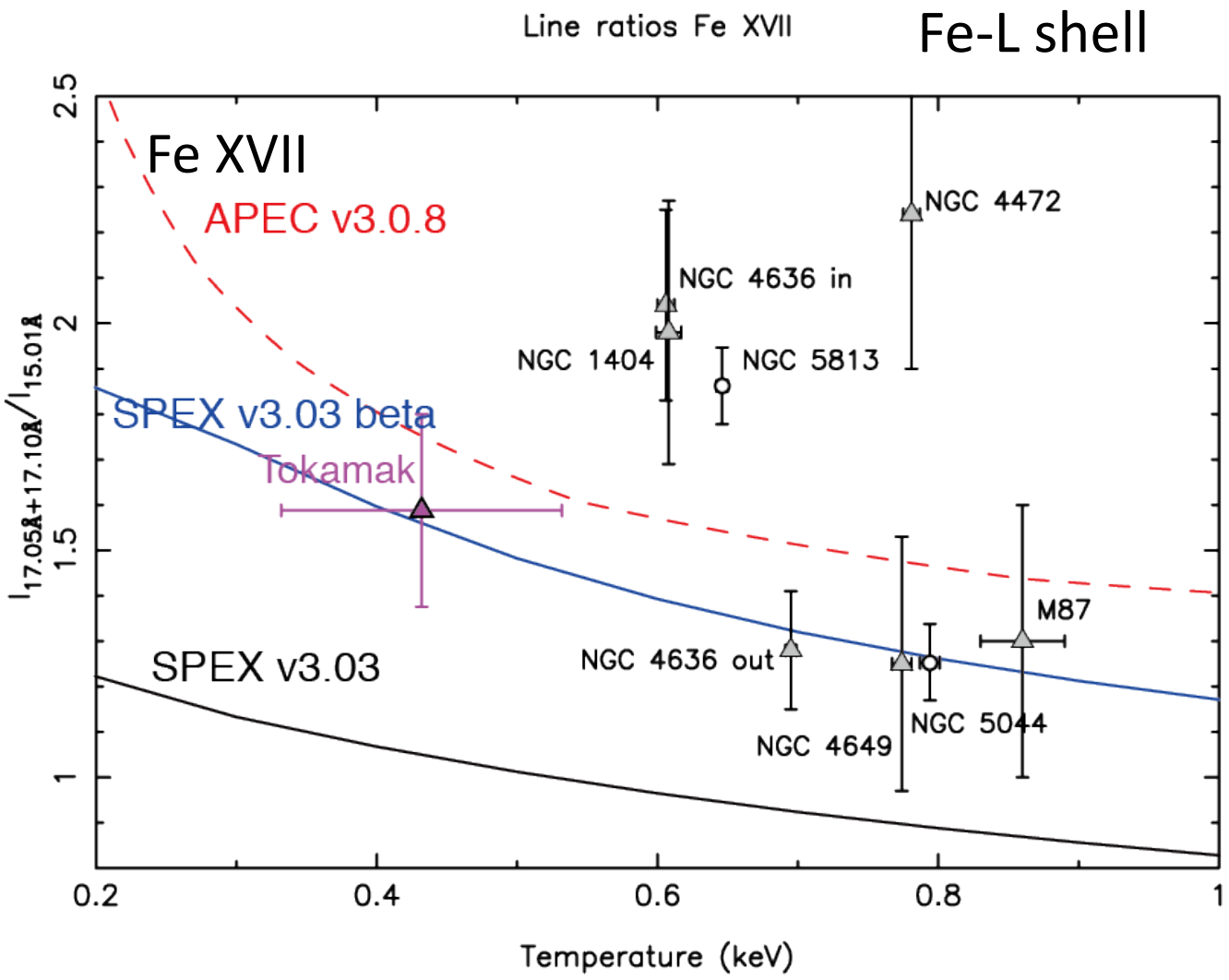
H/He/Li-like are the simplest systems!

Possible charge exchange in Perseus cluster



- significance = 1.6σ and 2.4σ for S and Fe lines
- fluxes agree with the prediction by Gu+2015 (to explain the 3.5 keV line).

Atomic data needs for future missions



- resonance contribution (dielectronic capture followed by auto-ionization) to excitation for L-shell
- test two codes against each other
- compare with laboratory data
- fit deep existing observations (Sun, Capella)

Summary

Hitomi spectrum shows both achievements and challenges

- Both updated APEC and SPEX give plausible fits
- Agree well on temperature and emission measure
- 16% difference on Fe abundances (statistical error=1%)
- large uncertainties on collision rates for simplest H/He-like systems
- lack of laboratory measurement
- tested only for 4 keV CIE
- as a whole, atomic error is as large as calibration error

updating atomic code and database is a key scientific preparation for *XARM* and *Athena*.