

X-ray Spectroscopy in the microcalorimeter era

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Microcalorimeter era in X-ray:

- New generation of microcalorimeter onboard Hitomi makes precision spectroscopy possible in the X-ray.
- Fe XXV K α complex from Perseus core has been resolved into four lines \rightarrow *x*, *y*, *z*, and *w*.
- Detailed modeling required for the future microcalorimeter observations by Athena and XRISM.

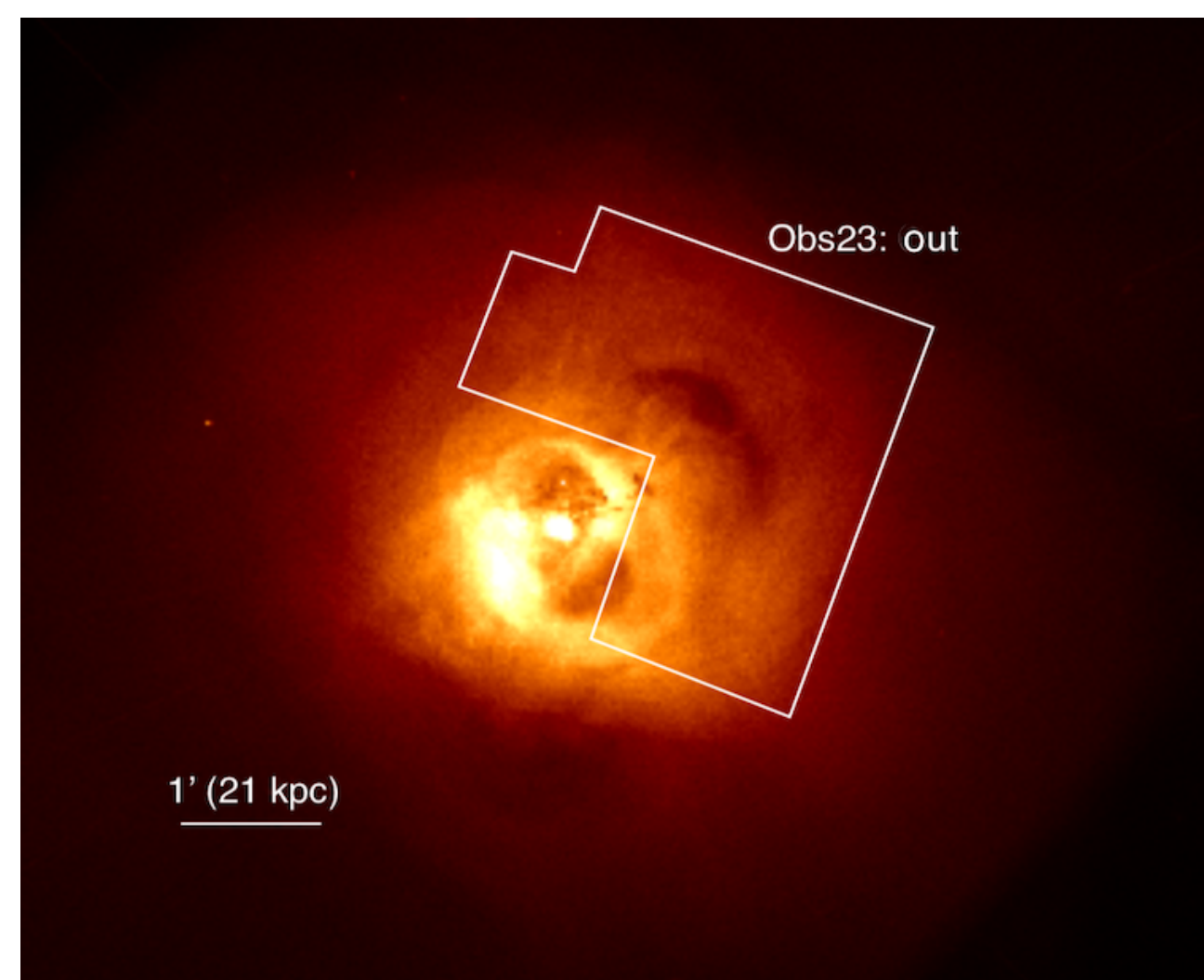


Figure 1: The outer region of Perseus core from Hitomi SXS observation overlaid on a Chandra X-ray image of Perseus.

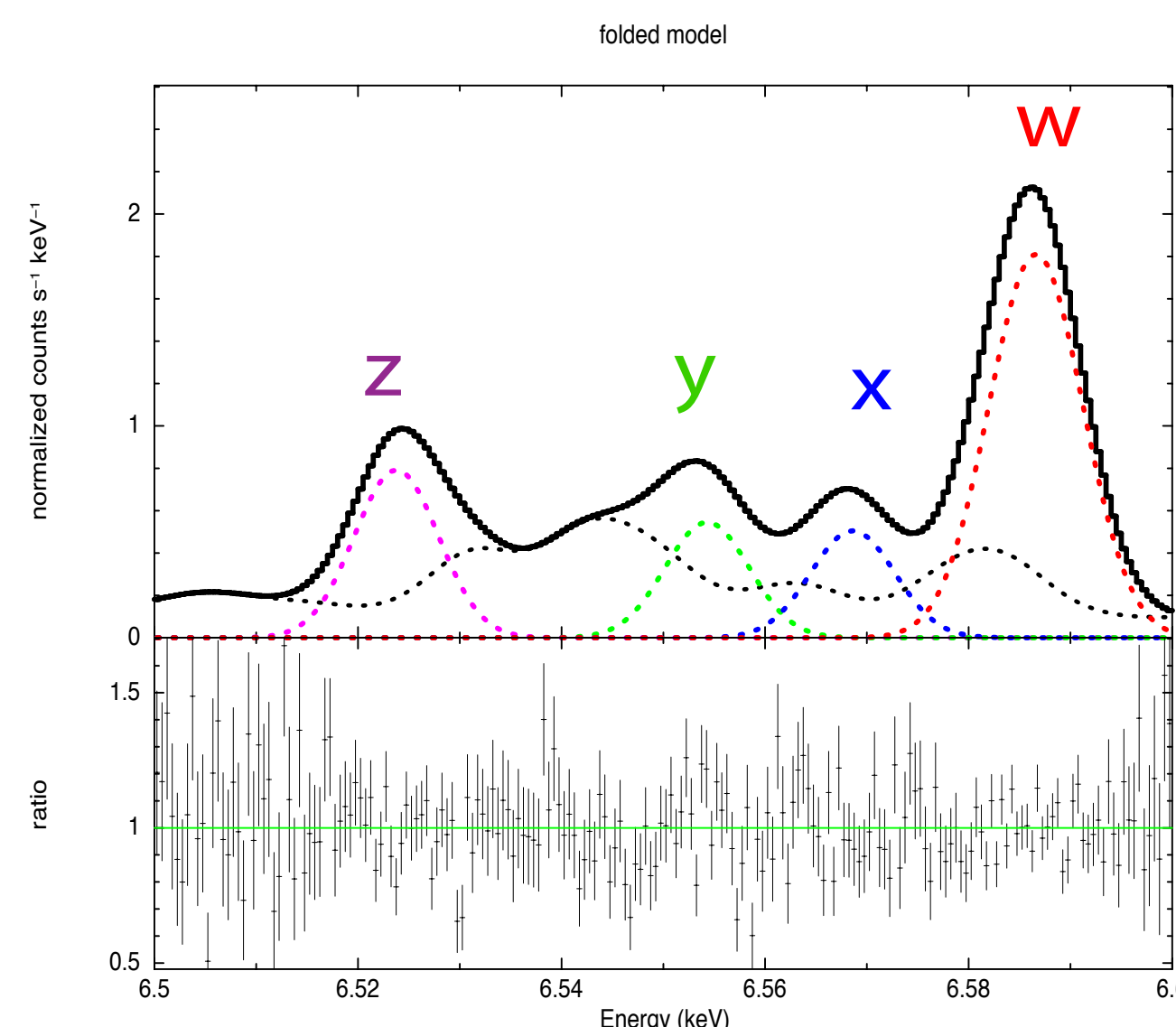
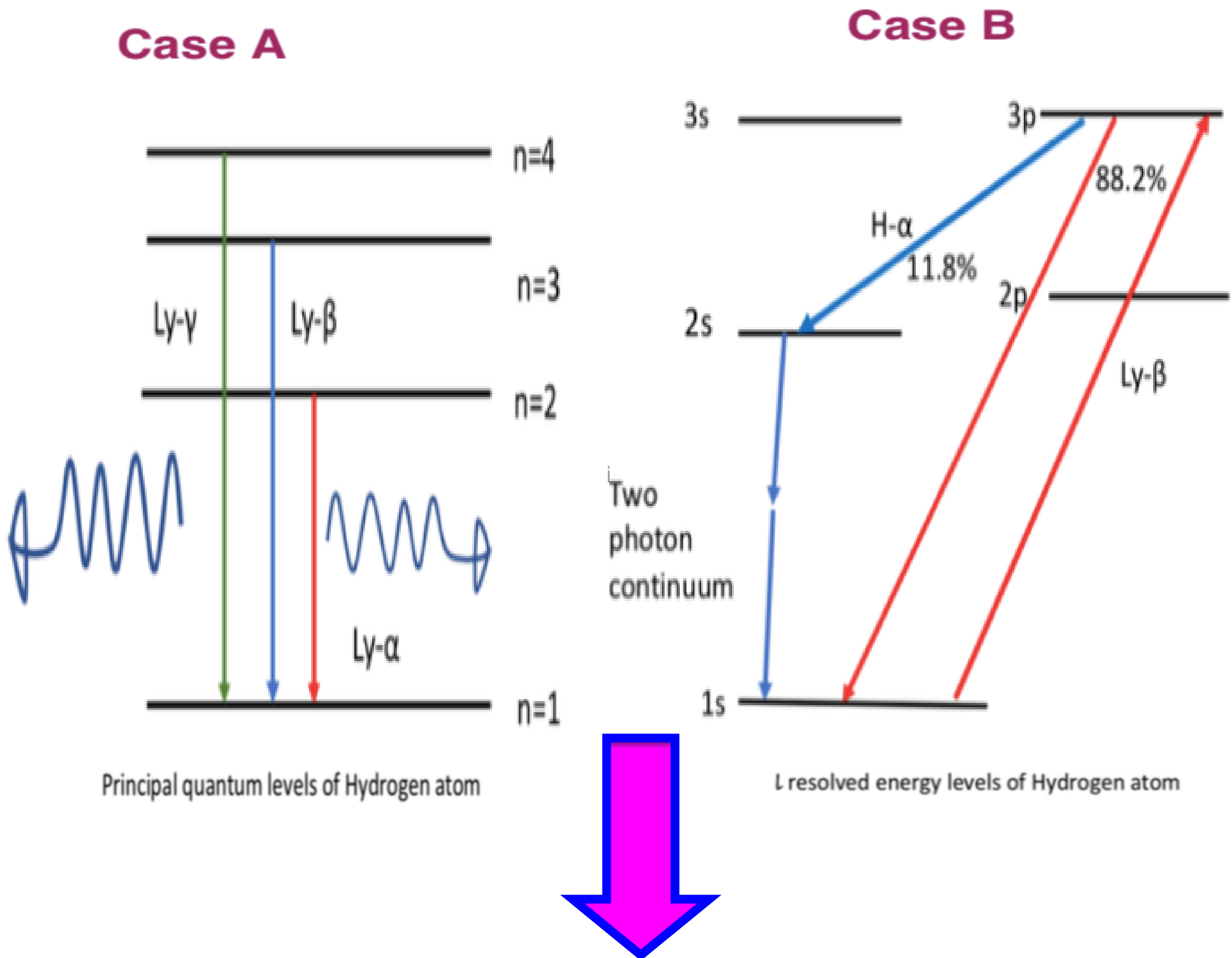


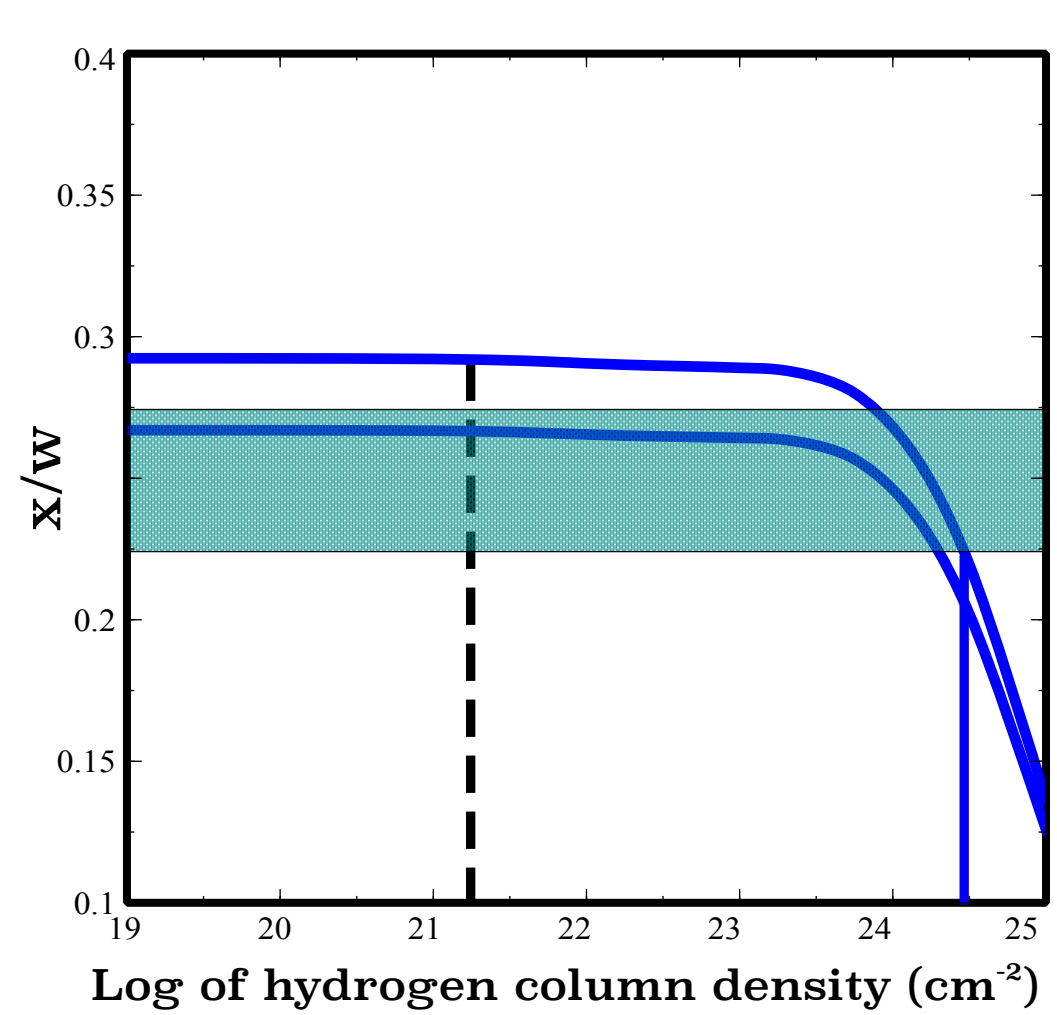
Figure 2: Components of the Fe XXV K α complex fitted with a modified bvapecc model.

Various atomic processes:

Case A to B transition

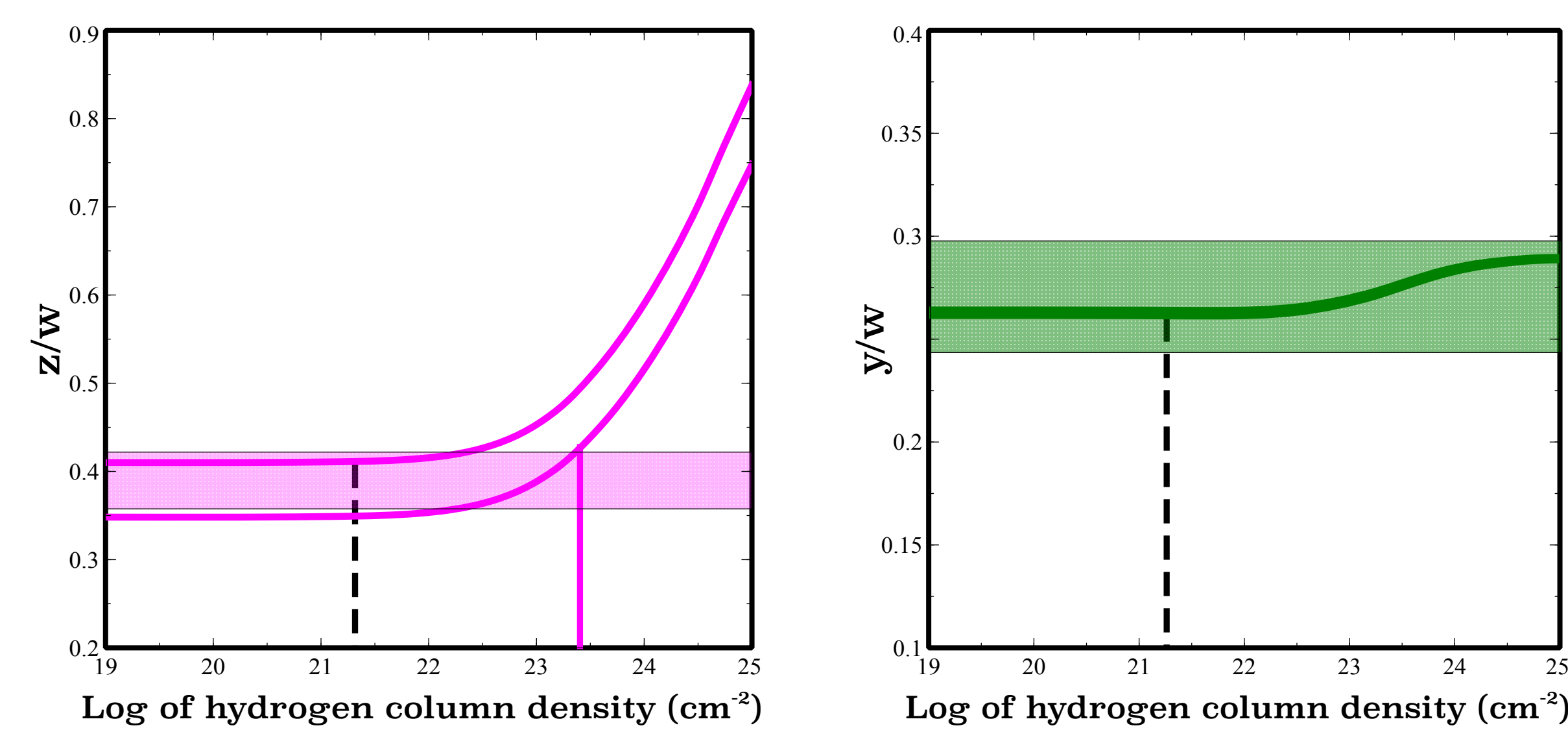


Column density diagnostics from the Case A to B transition in Fe XXV:



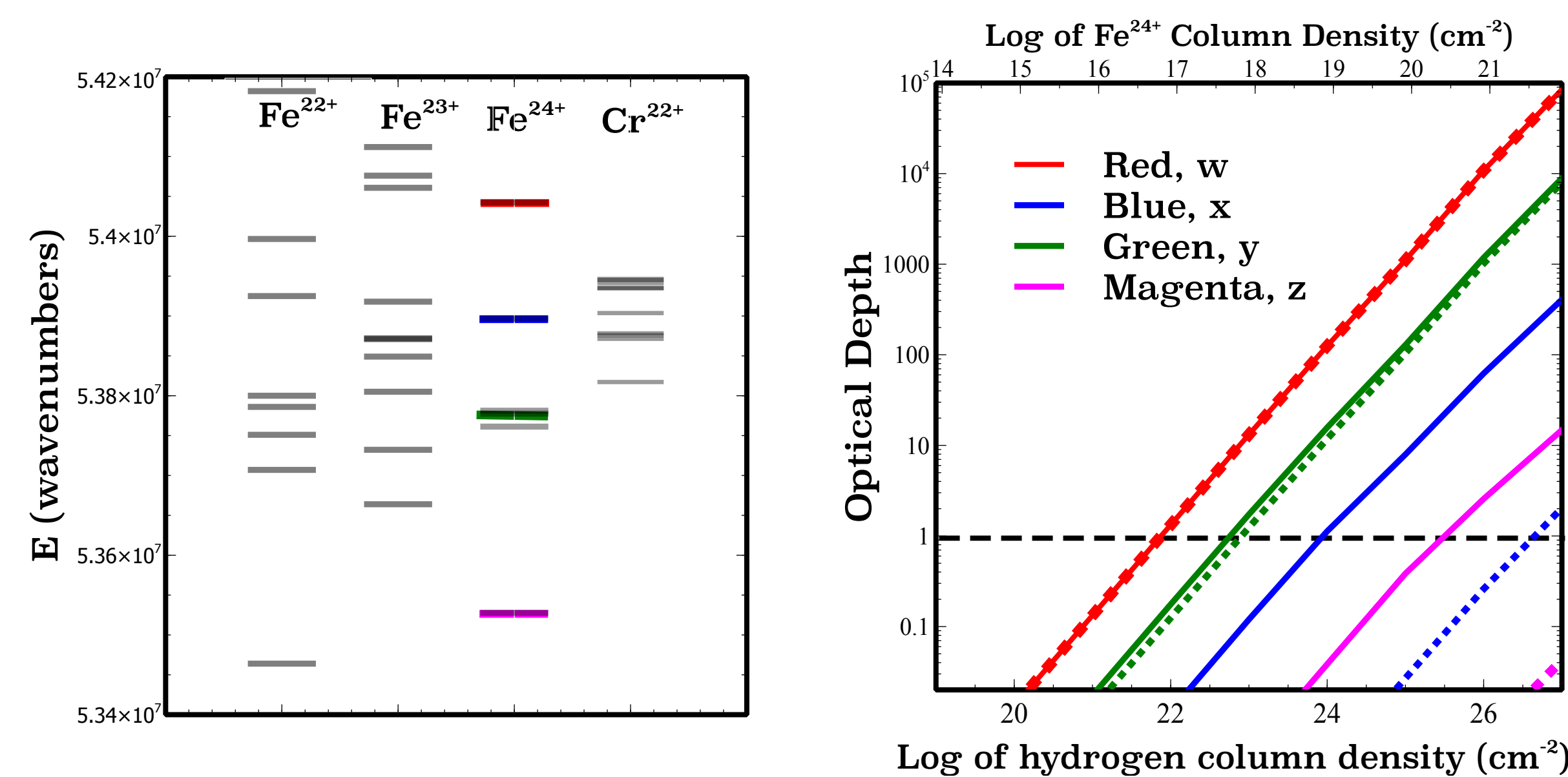
- **Small** hydrogen column density (**Case A**) all line ratios are constant and parallel.
- **Large** hydrogen column density (**Case B**)
 - *x/w* decreases
 - *y/w* slightly increases
 - *z/w* increases

Case A to B transition

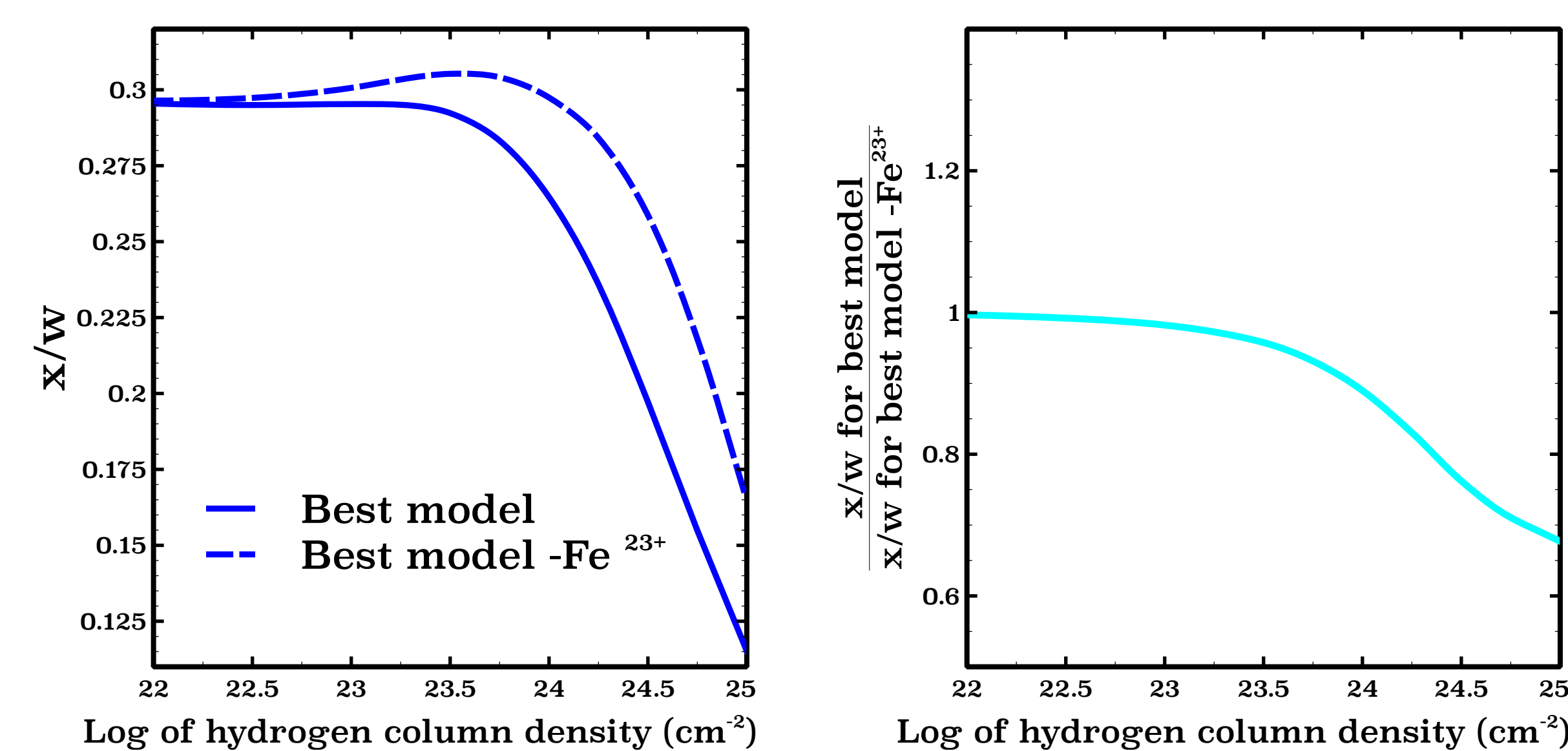


- Case A to B transfer in $n=3,4,5\dots$ to 1 transition Lyman photons causes all 2 to 1 transition line intensities to increase, causing *z/w* to increase, and *y/w* to increase slightly. (*Chakraborty et al. 2020, paper II*)
- The decrease in *x/w* is due to **line interlocking** and Resonance Auger Destruction/RAD (*Liedahl, 2005*) in *x*, and **Electron Scattering escape** (*Chakraborty et al. 2020, paper I*).

Line interlocking and RAD



- Line interlocking with other ions affects *x* the most
- *x* has line interlocking with Fe^{23+} and Cr^{22+}
- *x* photons are absorbed by Fe^{23+} , a fraction of which is autoionized.
- The *x* photon is lost, and *x* line intensity is reduced.
- This process is called Resonance Auger Destruction (RAD), introduced by Liedahl(2005)
RAD starts to become important after $N_H = 10^{23} \text{ cm}^{-2}$.
- **~32% of *x* photons are destroyed at $N_H = 10^{25} \text{ cm}^{-2}$** (Consistent with the analytical theory)



Electron Scattering Escape

- Line photons can become heavily Doppler-shifted from their line-center upon after scattering off fast thermal electrons.
- This leads to one-scattering-escape for a fraction of line photons, a process we call Electron Scattering Escape (ESE). This becomes important after $N_H = 10^{23} \text{ cm}^{-2}$.

- Effective intensity of each line in Fe XXV K complex has two components - *y/w*
 - a) Broad line component (comes from ESE)
 - b) Narrow line component (no ESE)

- High-resolution telescopes like - XRISM, Athena will detect narrow line component

- Low-resolution telescope will detect Narrow + Broad line components
- Different line fluxes will be detected in high- and low-resolution.

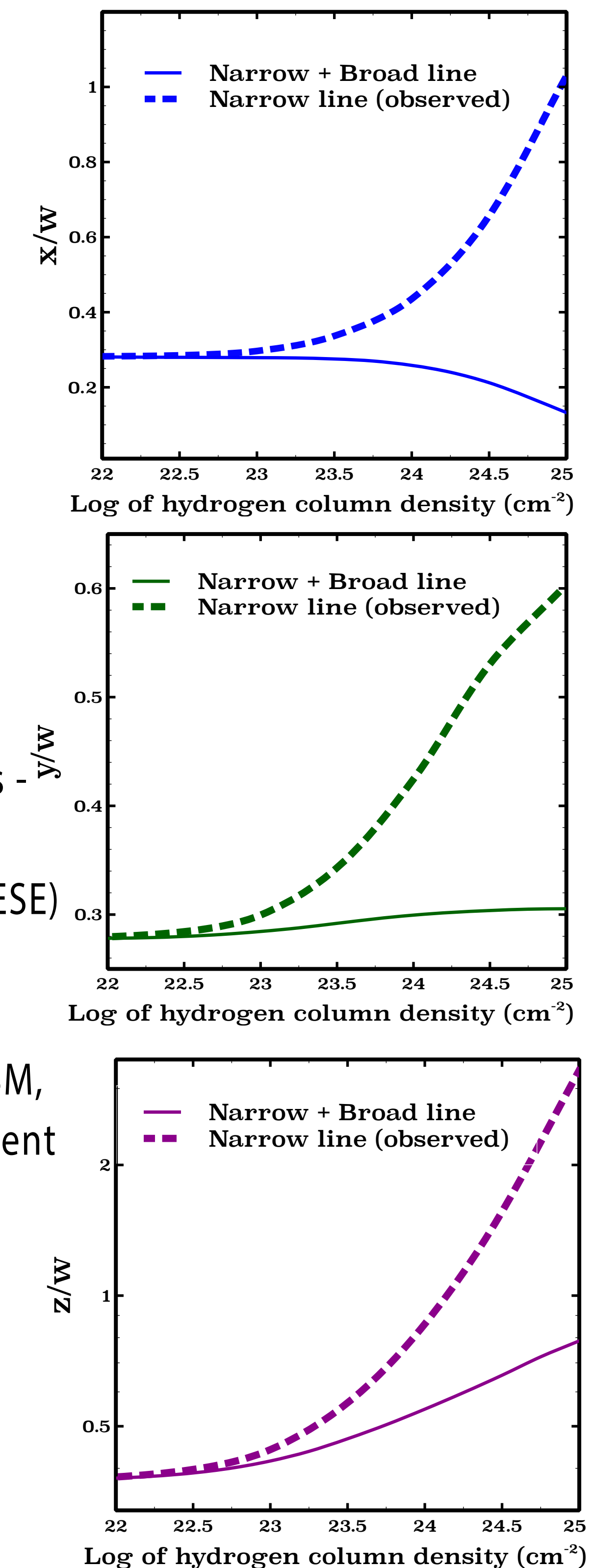


Figure 3: The variation of *x/w*, *y/w*, and *z/w* with respect to the hydrogen column density for narrow + broad line, and narrow line components. The broad line component comes from ESE and has a spread of $\sim 1 \text{ keV}$. The narrow line component does not include electron scattered photons.

Discussion

- Different atomic processes change Fe XXV K α line intensities: Case A to B transition, Line interlocking, Electron Scattering Escape etc.
 - a) Case A to B transfer can be useful to constrain/measure column density from a line ratio diagnostic.
 - b) Line interlocking with Fe^{23+} following RAD decreases *x* line intensity by 32% at $N_H = 10^{25} \text{ cm}^{-2}$.
 - c) Line photons can be heavily doppler shifted and escape the cloudy following a single event of scattering off high-speed electrons. We call this process Electron Scattering Escape (ESE). Due to ESE, high- and low-resolution telescopes will detect different line fluxes.
- Next step: Case C for a photoionized plasma.

References & Acknowledgment

paper I-Chakraborty et al. 2020, 2020arXiv200715565C (accepted in ApJ)
paper II- Chakraborty et al. 2020, available on arxiv from Monday(accepted in ApJ)
Liedahl,D (2005), AIPC, 774, 99L
Hitomi Collaboration et al. 2016, Nature, 535, 117H

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